CHAPTER FOUR

Results & Discussion

Table.4.1.1: Relative incidence (Mean ± SE) of the four major pests estimated by light trapping and quadrate (0.5 mt.^{2}) method

Months	Fortnight	YSB		BPH		GM		PB	
		Light trap	Quadrate	Light trap	Quadrate	Light trap	Quadrate	Light trap	Quadrate
Jan	A	25.25±2.12	0.79±0.04	82.75±12.11	8.64± 0.98	0.00±0.01	0.00±0.03	0.00±0.01	0.06±0.01
	B	69.45±9.13	3.14±0.11	112.34±11.11	7.82±0.78	0.00±0.04	0.00±0.04	0.22±0.01	0.11±0.01
Feb	A	88.78±12.11	2.39±0.33	122.48±14.23	9.22±1.11	0.00±0.05	0.00±0.03	0.91±0.12	0.42±0.10
	B	55.23±9.56	2.62±0.21	252.48±16.91	18.47±1.23	00.2±0.01	0.07±0.02	1.41±0.23	0.45±0.13
March	A	68.28±11.11	2.17±0.45	392.14±34.11	19.98±0.77	0.22±0.06	0.09 0.02	1.78±0.11	1.47±0.55
	B	47.14±10.12	2.09±0.65	410.19±22.11	12.89±1.23	0.29±0.07	0.31± .08	3.87±0.98	2.62±0.43
April	A	42.42±9.13	2.04±0.44	462.91±30.34	17.24±2.11	0.41±0.10	0.34±0.11	3.73±0.98	3.87±0.23
	B	49.7±6.78	2.09±0.78	698.11±43.11	29.76±0.77	0.51±0.10	0.59±0.23	3.89±0.09	4.91±0.22
May	A	74.29±14.34	2.15±0.55	422.45±45.34	44.14±0.22	0.57±0.11	0.68±0.23	7.89±0.12	4.98±0.78
	B	76.78±6.67	4.38±1.10	406.44±34.34	28.14±0.14	0.54±0.11	0.79±09	8.11±0.31	7.42±0.66
June	A	45.11±6.34	3..92±0.56	152.12±34.56	10.14±0.34	0.59±0.10	0.81±0.77	7.85±0.56	4.21±0.67
	B	42.32±13.11	2.74±0.66	139.47±43.12	15.25±3.11	0.61±0.10	0.97±0.45	5.03±0.45	3.31±0.98

A- First fortnight, B –Second fortnight

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Table.4.1.1: Relative incidence (Mean ± SE) of the four major pests estimated by light trapping and quadrate (0.5 $mt.^2$) method

<table>
<tr><th rowspan="2">Months</th><th rowspan="2">Fortnight</th><th colspan="2">YSB</th><th colspan="2">BPH</th><th colspan="2">GM</th><th colspan="2">PB</th></tr>
<tr><th>Light trap</th><th>Quadrate</th><th>Light trap</th><th>Quadrate</th><th>Light trap</th><th>Quadrate</th><th>Light trap</th><th>Quadrate</th></tr>
<tr><td rowspan="2">July</td><td>A</td><td>100.45±14.11</td><td>5.68± 0.90</td><td>187.23±13.32</td><td>47.12±2.45</td><td>0.63±0.11</td><td>1.02±0.23</td><td>4.72±0.23</td><td>2.77±0.77</td></tr>
<tr><td>B</td><td>31.61±5.23</td><td>4.71±0.99</td><td>87.89±12.45</td><td>45.11±4.34</td><td>1.12±0.13</td><td>1.21±0.12</td><td>4.46±0.33</td><td>1.49±1.11</td></tr>
<tr><td rowspan="2">August</td><td>A</td><td>20.47±3.11</td><td>2.48±0.45</td><td>91.45±18.11</td><td>52.12±6.34</td><td>4.46±0.34</td><td>4.32±0.55</td><td>4.51±0.31</td><td>1.84±0.34</td></tr>
<tr><td>B</td><td>22.37±4.23</td><td>2.92±0.67</td><td>482.72±34.45</td><td>59.29±3.67</td><td>4.21±0.33</td><td>5.41±0.45</td><td>4.32±0.11</td><td>2.29±0.99</td></tr>
<tr><td rowspan="2">Sept</td><td>A</td><td>28.24±6.23</td><td>5.48±0.78</td><td>640.11±50.23</td><td>25.62±7.11</td><td>4.78±1.12</td><td>5.49±0.76</td><td>7.11±0.18</td><td>2.48±0.87</td></tr>
<tr><td>B</td><td>40.19±7.11</td><td>5.63±0.66</td><td>601.23±34.27</td><td>20.78±3.34</td><td>5.22±1.56</td><td>4.57±0.43</td><td>6.98±0.33</td><td>1.89±0.86</td></tr>
<tr><td rowspan="2">Oct</td><td>A</td><td>78.32±9.32</td><td>7.48±1.12</td><td>1382.11±34.23</td><td>56.15±7.56</td><td>12.43±2.11</td><td>3.41±0.34</td><td>7.89±0.34</td><td>8.82±0.67</td></tr>
<tr><td>B</td><td>92.34±9.67</td><td>3.79±1.01</td><td>1287.27±58.45</td><td>49.14±6.11</td><td>18.11±1.98</td><td>1.07±0.32</td><td>6.11±0.98</td><td>9.47±1.02</td></tr>
<tr><td rowspan="2">Nov</td><td>A</td><td>79.23±8.89</td><td>4.02±0.98</td><td>912.02±67.11</td><td>48.27±3.56</td><td>11.23±2.97</td><td>0.53±0.24</td><td>5.56±0.89</td><td>10.68±1.34</td></tr>
<tr><td>B</td><td>77.68±6.77</td><td>4.12±0.26</td><td>789.12±45.23</td><td>16.11±2.45</td><td>3.98±0.34</td><td>0.41±0.13</td><td>2.89±0.91</td><td>5.37±1.11</td></tr>
<tr><td rowspan="2">Dec</td><td>A</td><td>247.45±21.11</td><td>1.12±0.55</td><td>147.19±11.23</td><td>9.23±8.56</td><td>3.21±0.67</td><td>0.32±0.11</td><td>2.44±0.44</td><td>3.98±0.65</td></tr>
<tr><td>B</td><td>28.21±6.24</td><td>1.62±0.68</td><td>72.14±9.11</td><td>7.18±2.11</td><td>0.54±0.091</td><td>0.13±0.12</td><td>1.95±0.44</td><td>1.77±0.56</td></tr>
</table>

A- First fortnight, B –Second fortnight

In relation to Tmin: In all the cases Tmin has a negative correlation with the YSB population.

In relation to Tgr: YSB showed significant positive relation with Tgr in all the years except 2005.

In relation to Tavg: Except in 2005, in all other years, the field populations had a significantly positive correlated with Tavg.

In relation to RHmax: High positive correlation was found with RH max in 2003 and 2004, while in two other remaining years the relation was insignificant.

In relation to RHmin: Effect of RHmin upon the occurrence of the YSB population was insignificant in the year 2003 and 2004 but had a significantly positive relation in other two years.

In relation to RHgr: No significant relation existed between the RHgr and the field populations of YSB in any of the years.

In relation to RHavg: YSB populations exhibited significantly positive relation in all the years with RHavg.

In relation to Shr: Shr exerted a significantly positive effect on the pest except in the year 2006 where the relation was significantly negative.

In relation to Rfall: High rain fall within a short spell of time showed a significantly negative relation with the pest occurrence in the years 2004 and 2006. Intermittent rains with high temperature had insignificantly positive effect on this pest bionomics in 2003. However, the number of rainy days had no significant positive effect on the YSB population.

Discussion: Investigation through light trap catches of YSB by Rai *et al.* (2002) showed no significant correlation with the temperature.Rainfall however, exerted a negative effect on the mean catches of YSB. But RHmax and Shr were found to be positively correlated with the catches. The present findings explaining the effect of temperature corroborates with those of Ramkrishna *et al.* (1994) and Bhatnagar and Saxena (1999). Senapati and Panda (1999) who reported that high Tmax (average 39.4°C) in summer season and low Tmin (average 12.7°C) in winter season were highly associated with low *S.*

incertulas moth population density as also noted in present study. But Mishra *et al.* (2005) observed that collectively, the weather parameters had no direct influence except Tmax and RHmax which had a negative relation to WH formation. Pathak and Pawar (1983) reported that 30-100% RH appeared favourable for YSB infestation. Thus in the present study this range was also proximity to the optimum range during the maximum peak catch periods of YSB. Abraham *et al.* (1972) found that the incidence of DH and WH had a negative correlation with the Tmin but a positively correlation with the Tmax. Such observation matches with the present findings. For survival at pupal stage, the rice microclimate is the most important factor for YSB than the macro climatic conditions (Sahu and Sinha 1990). Contrary to the present findings, Alam *et al.* (1992) reported that the infestation of YSB decreased with an increase in Tmax but increased in Tmin.

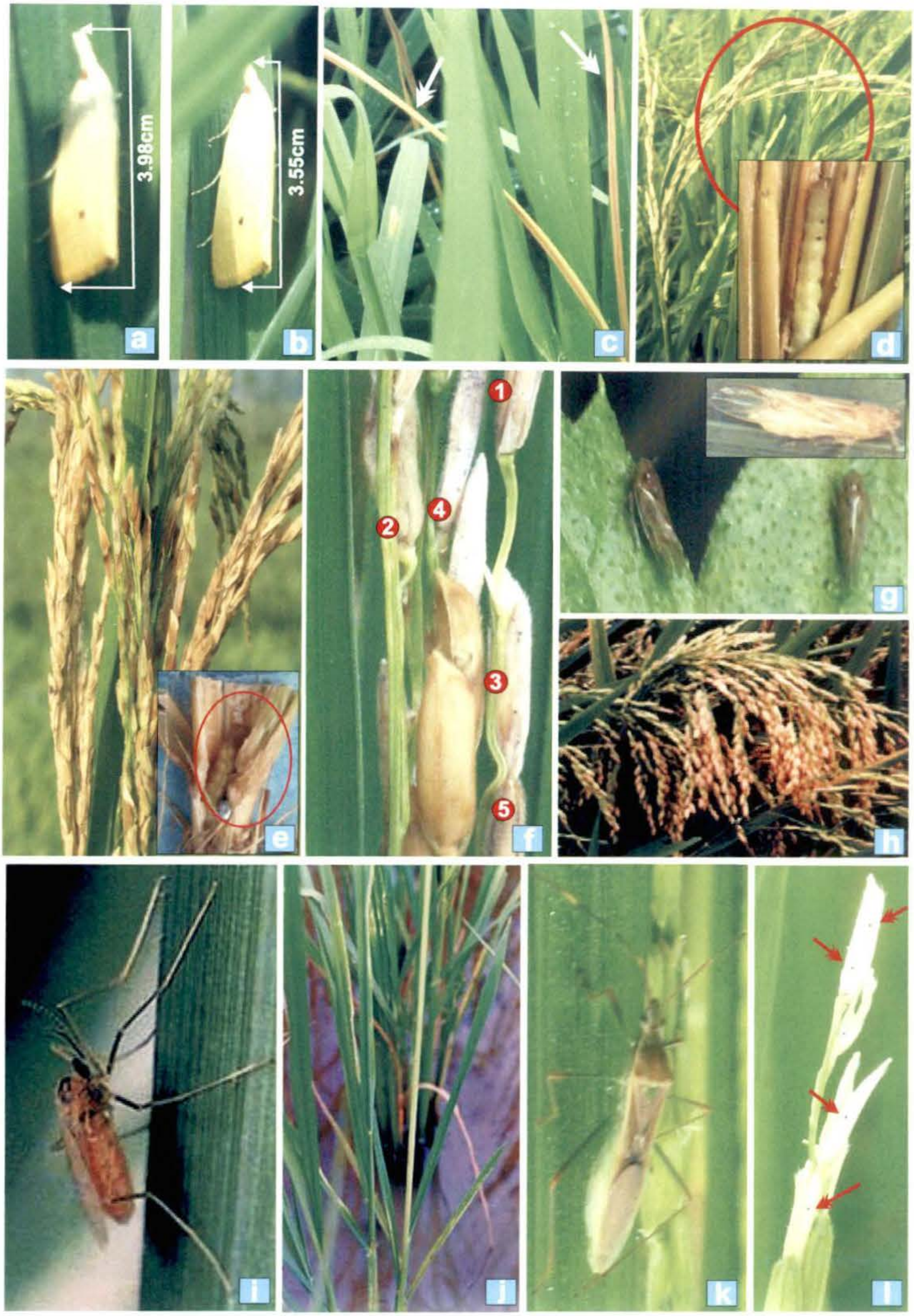
4.1.1.2 Brown plant hopper (BPH)

Population dynamics: The initial low population of BPH from about 2 SMW to 8 SMW was immediately followed by the gradual increase which synchronized with the early growth stages of paddy. The first peak appeared nearly at about 16 to 20 SMW which was followed by a steady decline of the standing population. Very low timing population was noted from about 24 to 28 SMW. The population was extremely narrow from 30 to 32 SMW. Moderate level of population was then observed at about 34-38 SMW and the second highest about peak at about 40-44 SMW, after which the population steadily declined (Fig.4.1.4a).

Correlation analysis of BPH population with climatic factors (Table.4.1.2)

In relation to Tmax: No specific and deductive relation of BPH population with Tmax was apparent though a significantly positive relation in 2004 and a significantly negative relation in 2005 were found.

In relation to Tmin: In all the years, except in 2006, Tmin showed significant positive effect on BPH population. Prolonged winter in 2006 with very low temperature had exerted negative effect on pest survival and accordingly the field population was reduced.



Figs. 4.1.1: Four major pests and their damage symptoms in paddy. a: First brood of YSB, b: Second brood of YSB, c: DH caused by YSB, d: Fifty instar larva of YSB within a stem, e: WH caused by YSB, f: DH with degrees of fungal infestation (1-5), g: BPH, h: Scorching burned pannicles caused by BPH, i: GM, j: Silver shoot caused by GM, k: PB, l: Chaffy grains caused by PB.

In relation to Tgr: Except in 2006, the population of BPH had a positive correlation with Tgr at significant level.

In relation to Tavg: There was significantly high positive correlation between BPH population and Tavg.

In relation to RHmax: High humidity especially in the morning favoured the BPH activity, thus the field level of the pest was accordingly increased and showed significantly positive relation in most of the years.

In relation to RHmin: Except in 2005, the field BPH population was found to have a negatively correlation with RHmin at insignificant level.

In relation to RHgr: Significant positive relation existed between RHgr and the field population in the years 2004 and 2006, while a significantly negative relation existed in the year 2005.

In relation to RHavg: A significantly high positive relation was recorded in 2003, in the other years relation was insignificant.

In relation to Shr: High level of significantly negative relation was noticed only in 2003 and 2004, in other two years the values were also negative but insignificant.

In relation to Rfall: A significantly negative correlation was noted between BPH population and Rfall in 2004 and 2005, while in 2003 and 2006 the relations were insignificantly negative. Heavy shour within a short time minimized BPH out break and thus negative correlation was found. However the effect of interrupted rain fall delivered no relation to the field pest occurrence. The number of rainy days had exerted both significant and moderate level of negative effect on the pest level.

Discussion: Krishnaiah *et al.* (1993) observed that the nymphs of *N. lugens* in Krishna-Godavari zone during *kharif* season constituted more than 80% of the total BPH population. The correlation coefficients between BPH nymphs and BPH brachypterous females were significantly very high (0.9505 to 0.9709). During *rabi* crop, BPH nymph population in the field was low than during *kharif* crop, and showed significantly high correlation with the brachypterous females (0.803 to 0.880). Temperature between 25 and 30°C are considered optimum for egg and nymphal development (Pathak 1968, Ho and Liu 1969).At par with the present study Fukuda (1934) found that high average temperature appeared to be associated with high pest numbers. Present work resembles with the study of Bae 1966 who also found that humid environment was conducive to *N. lugens,* for its development and population increase. In central Java, Sastrowidjoyo (1976) found a significantly positive correlation (r = 0.907) between the total yearly rainfall and the number of infested hectares of rice which does not match to the present observation. Among the weather parameters, Tmin and Shr showed positive correlation with BPH population during *boro* crop. Hence, higher the temperature during *boro* season, greater would be the extent of damage.

At the time of colonization BPH were low up to about 40-50 DAT, a time most suitable for insecticidal control with less quantitative application when more hoppers began to arrive on the plants than in the traps. Otherwise, after 50DAT high input of insecticides would be regarded.

4.1.1.3 Gall midge (GM)

Population dynamics: The activity of the GM was much more restricted to the *kharif* crop than to the *boro* crop. Initial very low population at early months was gradually increased from about 20 to 30 SMW. The moderate number was noted at 32 SMW which was maintained nearly up to 38 SMW. The appearance of peak was restricted to about 40-44 SMW. Persistent low number was noted at about 18-22 SMW and 46-48 SMW. After 48 SMW the midge population was conspicuously declined in field (Fig. 4.1.4b).

Correlation analysis of GM population with climatic factors (Table. 4.1.2)

In relation to Tmax: In all the years except in 2005, the GM population showed an insignificant negative relation with the Tmax.

In relation to Tmin: Tmin had imparted a significant positive effect on the incidence of GM in all the years except in 2005.

In relation to Tgr: Except in 2005, the population size of GM showed significantly negative relation with Tgr.

In relation to Tavg: A significantly positive relation was found with the Tavg in 2005 and 2006, but in 2003 and 2004 relations were insignificantly positive.

In relation to RHmax: Persistent RHmax (80-92%) exerted a significantly positive impact on the activity of GM in all the years, especially at the late tillering stage.

In relation to RHmin: A significantly positive relation between RHmin and the field GM population was found only in 2004 and 2005.

In relation to RHgr: Significant negative relations existed between the RHgr and the field population in all in except 2003 where the relation was non significant but positive.

In relation to RHavg: The population of GM was positively influenced by RHavg almost in all the years. But the values of relation differed among the years, particularly in 2004 and 2006.

In relation to Shr: Bright sunshine hour for an average of 8.20 hrs/day had a significant negative effect on the GM population with the exception of 2006 where the relation though positive, was non significant.

In relation to Rfall: Drizzling Rfall had a significant positive effect on the pest structure. But heavy shour within a short time had negative effect on pest appearance but showed inconsistent relations. Number of rainy days however showed significant positive relation only in 2005.

Discussion: Mohan *et al.* (1982) estimated the dynamics of GM in Tamil Nadu by light trap and found that the population was initiated at the middle of September and maximized at the 1st week of October which is partially supported by the present findings. Early monsoon rains in the months of May or June favoured the multiplication of GM in ratoon crops of the dry season. During normal monsoon periods, GM incidence was found to fluctuate between the ends of September and the end of November (Prakash *et al.* 2005).

Table.4.1.2: Correlation coefficient of incidence of the pests with the climatic factors indicating the level of significance

Pests	Years of observation	Temperature (°C)				Relative humidity (%)				Sunshine hours/ day (Shr)	Rainfall(Rfall)	
		maximum (Tmax)	minimum (Tmin)	gradient (Tgr)	average (Tavg)	maximum (RHmax)	minimum (RHmin)	gradient (RHgr)	average (RHavg)		amount (mm)	rainy days
YSB	2003	0.712*	-0.321	0.622*	0.611*	0.572*	0.321	0.134	0.602*	0.611*	0.144	0.231
	2004	0.664*	-0.421	0.598*	0.712*	0.711*	0.432	0.432	0.511*	0.721*	-0.587*	0.151
	2005	-0.517*	-0.611*	0.453	-0.601*	0.342	0.611*	0.342	0.645*	0.621*	-0.432	0.311
	2006	0.411	-0.422	0.584*	0.598*	0.438	0.675*	0.311	0.543*	-0.645*	-0.675*	0.234
BPH	2003	0.365	0.552*	0.655*	0.632*	0.564*	-0.342	0.432	0.611*	-0.711*	-0.312	-0.448
	2004	0.567*	0.654*	0.712*	0.667*	0.672*	-0.432	0.521*	0.432	-0.654*	-0.541*	-0.564*
	2005	-0.675*	0.711*	0.546*	0.765*	0.543*	-0.541*	-0.564*	-0.342	-0.464	-0.624*	-0.587*
	2006	-0.312	-0.342	-0.123	0.553*	-0.321	-0.421	0.611*	-0.421	-0.211	-0.302	-0.311
GM	2003	-0.281	0.675*	-0.564*	0.306	0.598*	0.491	0.467	0.509*	-0.502*	0.786*	0.321
	2004	-0.465	0.756*	-0.612*	0.411	0.698*	0.589*	-0.712*	0.623*	-0.589*	-0.676*	0.453
	2005	-0.532*	-0.490	-0.234	0.562*	0.723*	0.601*	-0.571*	0.511*	-0.765*	-0.721*	0.553*
	2006	-0.392	0.718*	-0.511*	0.535*	0.551*	0.380	-0.631*	0.497	0.453	-0.641*	0.211
PB	2003	0.626*	0.451	0.587*	0.592*	-0.378	0.831*	0.303	-0.363	0.157	0.207	0.404
	2004	0.425	0.118	-0.213	0.723*	-0.775*	0.765*	-0.850*	-0.290	0.654*	-0.645*	-0.311
	2005	0.567*	0.356	0.648*	0.711*	-0.790*	0.711*	0.329	0.810*	0.534*	-0.711*	0.453
	2006	0.611*	0.439	0.712*	0.812*	-0.675*	0.690*	-0.768*	0.723*	0.354	0.341	0.543*

*Significant at 5% level

However, Bradwaj *et al.* (1988) have reported that, *O. oryzae* starts its activity in traces during the second week of July. As par with the present findings, Hidaka *et al.* (1974) have observed that the seasonal fluctuation of GM population is closely related to the amount of rainfall. Overcast skies and drizzling rains were favourable for rapid build up of the pest population as demonstrated by Sing *et al.* (2001). An outbreak of population has been reported by Devi and Devi (1997) during 1996-1997 and found that the period has been characterized by cloudy sky, high and intermittent rainfall, moderate temperature (26-28°C) and high relative humidity (81.0 to 93.5%). Sain and Kalode (1992) have observed in Andhra Pradesh that the pest appears in the late August, maintains its peak population in October and then declines by December. Such finding partly matches with the present observation. GM is found to attack the crop in Bihar and southern parts of West Bengal from May to September and mid August to October respectively, whereas, its peak was found in between the third week of August to mid September in Southern states of India (Atwal and Dhaliwal 1999). Present observation is further partly supported by Jacob (1999) who has found that there is nil to low infestation up to second week of June in any *kharif* showing in Kerala.

4.1.1.4 Paddy bug (PB)

Population dynamics: The availability of PB was observed almost throughout the year. The first appearance of the population was noted at 4-8 SMW and high range of peaks at about 20-24 and 38-40 SMW respectively. Appearance of medium peak was restricted only to 42-44 SMW. Moderate level of persisting population was found respectively at 14-18 and 26-30 SMW. At 46-48 SMW the population was low. Very low to trace level of population was observed during 10-12 and 50- 52 SMW. The bug was nearly absent from the field at about 1- 4 SMW (Fig.4.1.4b).

Correlation analysis of PB population with climatic factors (Table. 4.1.2)

In relation to Tmax: Significant positive relation was noted between the field population of PB and Tmax except in 2004. Higher the level of the ambient temperature, higher was the availability of PB at the experimental areas.

In relation to Tmin: Tmin had no significant influence on the occurrence of PB, though in all the years relations were positive.

In relation to Tgr: The field population of the PB was positively influenced by Tgr at good significant levels except in 2004 when the relation was non significant and negative.

In relation to Tavg: In all the years the field population exhibited highly significant positive relation with Tavg.

In relation to RHmax: Except in 2003, RHmax had a highly significant negative effect on the pest incidence in most of the years.

In relation to RHmin: RHmin and the field pest level had highly significant positive relation in all the four years under consideration.

In relation to RHgr: Both negative and positive effect on the field population was exhibited by the RHgr. High negative significance relation was observed in 2004 and 2006 for PB populations. But in 2003 and 2005 the relations though positive were non significant.

In relation to RHavg: The noticeable population of the PB was found to be influenced by the prevailing value of the RHavg in both positive and negative manner. The highly significant positive values were observed in the years 2005 and 2006. While in the other two years the relations were negative.

In relation to Shr: Throughout the period of observation, Shr exerted significantly positive influence on PB incidence in 2004 and 2005. But the relations in other two years were positive but non significant.

In relation to Rfall: Rfall exercised both positive and negative effects on the pest numbers. The insignificantly poor levels of positive results were noticed in the years 2003 and 2006. But significant negative relations occurred in the other two years. However, the number of rainy days showed significant positive relation to the pest occurrence only during 2006.

Discussion: Srivastava and Saxena (1967) have opined that intermittent rain favours the population builds up of the bug while a heavy rain has an adverse effect on the pest. Present findings matched with the observation of Israel and Rao (1968) who also reported a severe infestation of rice bug in Orissa when the temperature and relative humidity was lying between 27^0 and 28.2^0c and 80.60 % or above respectively. Garg and Sethi (1980) have found that weekly average of 28.59^0c temperature, 69.55 % relative humidity, 8.18 hrs sunshine hours and 00.0-71.7 mm of rain are favourable for its highest population build up. Rao and Kulshreshtha (1985) have mentioned that high relative humidity, rainfall and insignificant fluctuation in diurnal temperatures during the milky stage encourage higher damage by the pest during the wet season in Orissa. Present observation partly resembles with the findings of Bhatnagar and Saxena (1999) who have found that sunshine hours ($r = 0.662$) had a significantly positive relation on the population build up of rice bug while minimum temperature ($r = -0.868$), evening RH ($r = -0.794$) and rainfall ($r = 0.635$) exhibited negative effect. But Sands (1977) observed that the availability of the alternative host was more important than seasonal weather fluctuation. Sen and Srivastava (1955) reported that in Bihar the bug feeds on *Panicum crus-galli* and millets during June and then migrate to paddy fields.

4.1.2 Seasonal dynamics of the natural enemies

Most of the natural enemies so recorded acted as generalized predators/parasites with few exceptions. For this reason activity of the natural enemy was considered collectively and the guild members were identified.

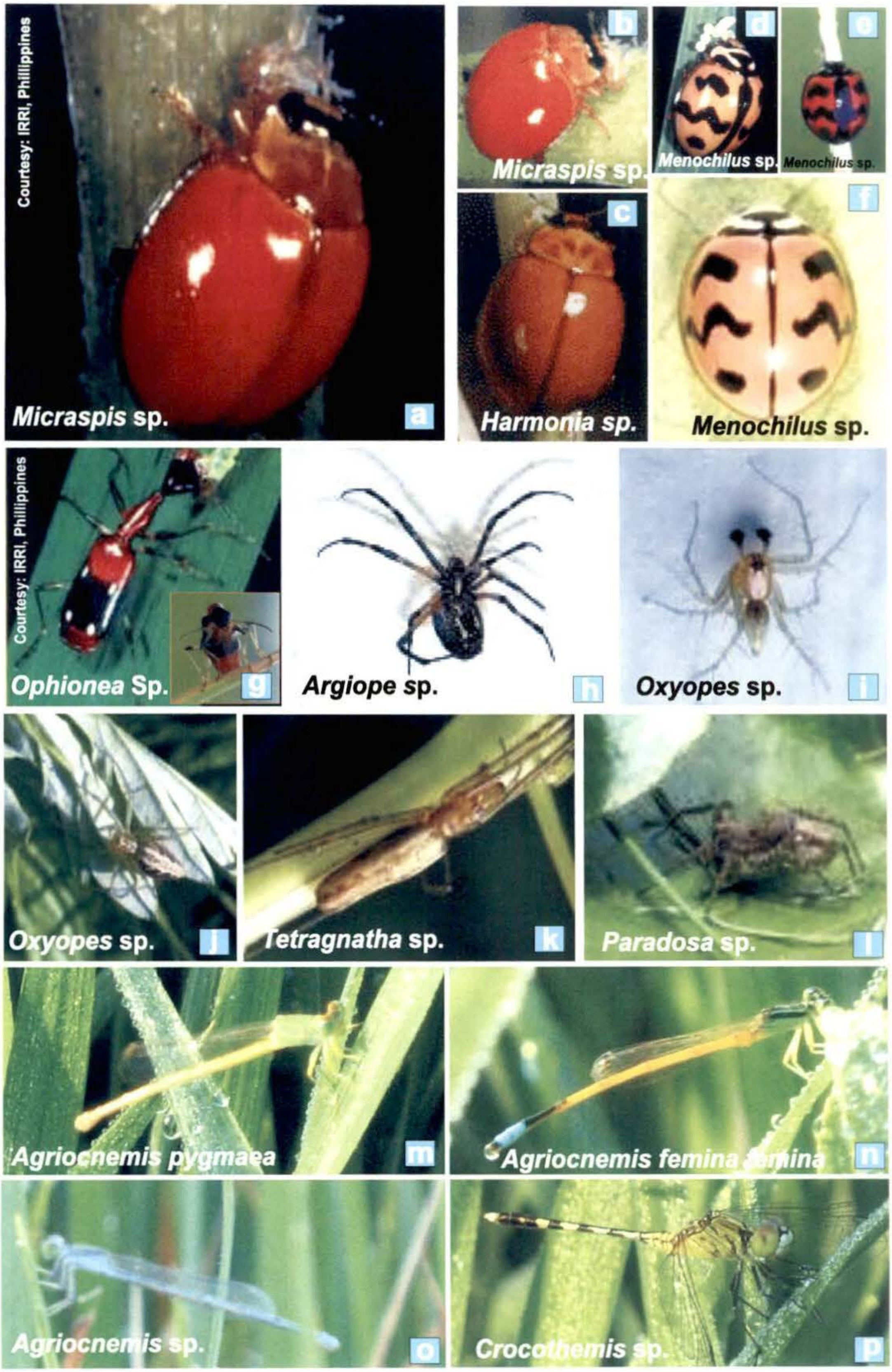
4.1.2.1 Spiders

Guild composition: Relative species composition of the spider communities was found to differ considerably in contemplation of the cultivated paddy field environment. Species richness and diversity were intensified with the progress of the growth stages. Among the identified species *L. pseudoannulata* was the most dominating species followed by *Argiope patenulata* (Doleschall), *A. formosana, Oxyopes javanus* (Thorell), *Tetragnatha maxillosa* (Thorell) and *Paradosa pseudoannulata* (Boesenberg and Strand) respectively.

Gunathilingaraj (1999) reported that in the northern parts of Bihar, the guild was represented by *L.pseudoannulata* (14.5%), *Callitrichia formosa* (16.3%), *Agriope catenulate* (14.5%) and *Clubiona japonica* (8.5%). Thomas *et al.* (1979) has identified seven effective members, *i.e*, *Lycosa* sp., *Pholcys* sp., *Marpissa* sp., *Tetragnatga* sp., *Linyphia* sp., *Oxyopes* sp. and *Agriope* sp. at Kuttanad, Kerala. Survey at Karnataka elaborated 45 genera of spiders from 15 families of which low land, medium land and upland paddy fields respectively shared 34, 17 and 23 species.

Population dynamics: The collective value of spider population was initially low in the months of January which gradually increased to the extremity at 14-18 SMW and then steadily declined at 24-26 SMW. After the 2nd week of July the population gradually increased again and maximized at 36-40 SMW attaining sporadically to the extreme of 80 individuals/15 hills for 2-3 days, thereafter the population rapidly subsumed (Fig.4.1.6a).

The population of *L.pseudonnulata* in rice ecosystem varied from 10 and 34% being the maximum at about 90 and 115 DAT respectively and lowest at 135 DAT irrespective of the seasons. The abundance of *A. formosana* was more during the early growth stages of the crop up to 50 DAT, and then declined by about 80 DAT. Thereafter, it started to increase again with the crop age up to 125 DAT, the maximum being recorded at about 95 DAT and minimum at about 35 DAT sharing about 27 and 6% respectively of the total spider population (individuals/mt^2). *C.japonicola* also maintained a high population at the latter growth stages, the maximum population being observed at 125 and 140 DAT (20% of individuals/mt.^{2}) and the minimum number at 95 and 100 DAT (12% of individuals/mt.^{2}).



Figs. 4.1.2: Natural enemies of paddy pests.

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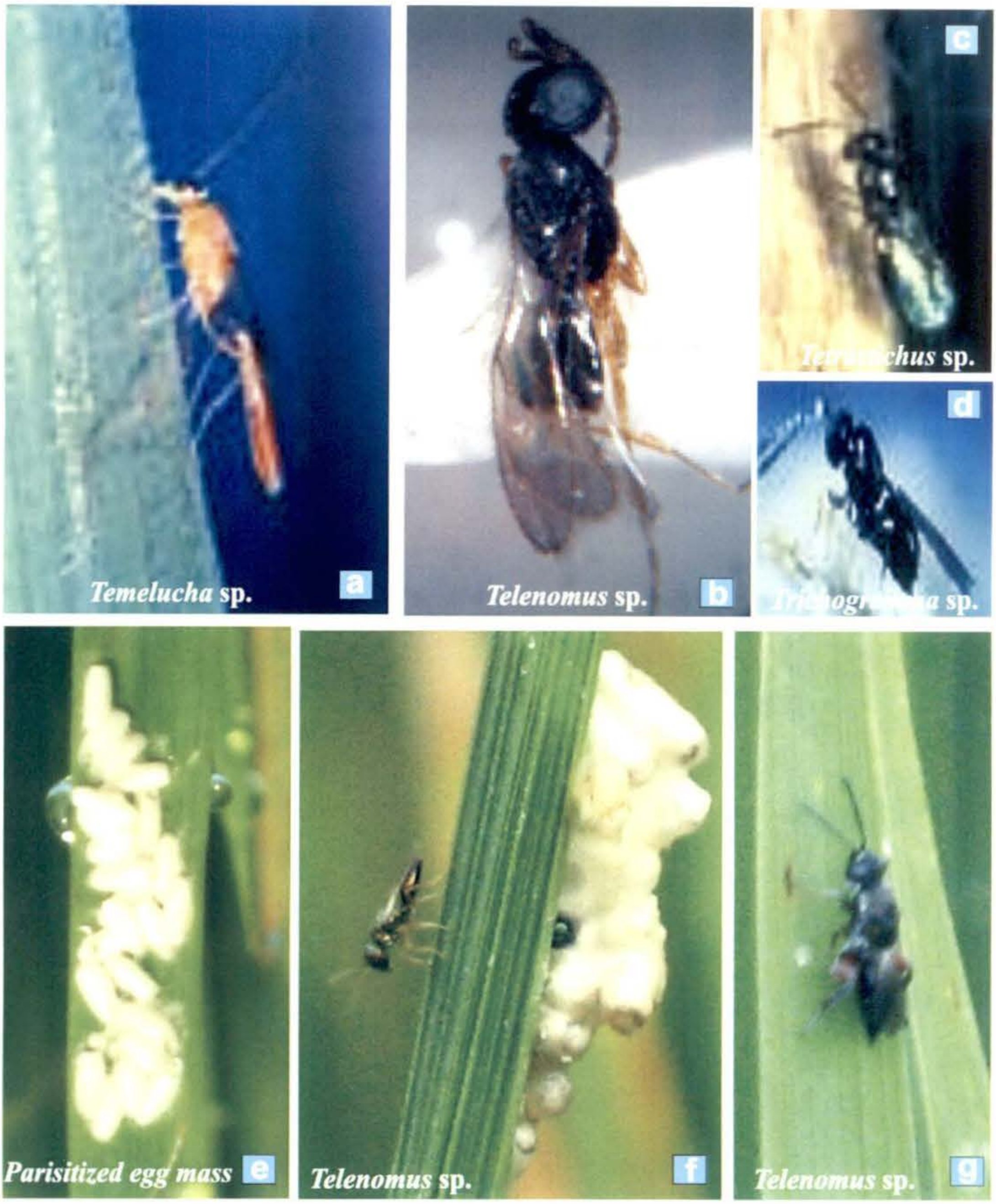
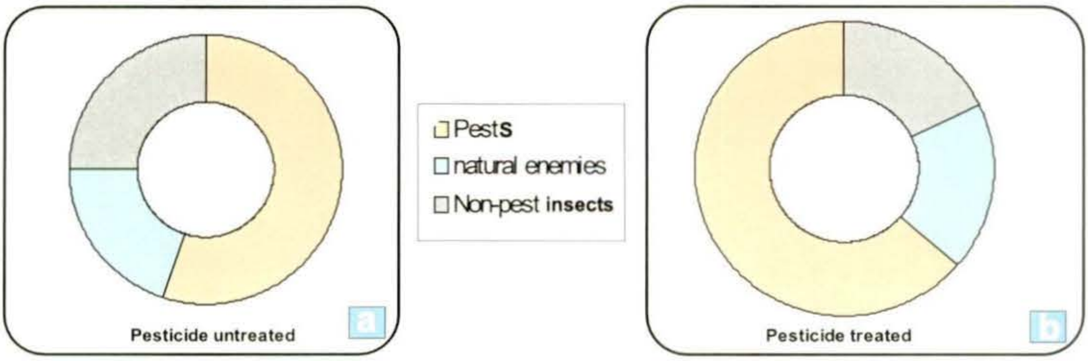


Figs. 4.1.2: Natural enemies of paddy pests.



Figs. 4.1.3: Pie-chart showing relative population of insect pests of paddy, their natural enemies and non-pest insects.

Correlation analysis of spider population with climatic factors (Table.4.1.3)

In relation to Tmax: In all the years the standing spider population had significantly negative correlation with the Tmax.

In relation to Tmin: Here too, significantly negative relation of spider population with the Tmin was noticed.

In relation to Tgr: Except in 2005, the spider population showed significantly negative relation with Tgr. In 2005, the relation though positive was extremely insignificant.

In relation to Tavg: In case of 2004 the relation was insignificantly positive. But during the other three years the relations were significantly negative.

In relation to RHmax: The spider population had highly significant positive relation with RHmax in all the years.

In relation to RHmin: The relations were positive for all the years' population but values were insignificant.

In relation to RHgr: RHgr exerted significant level of negative control on the spider population structure except in 2003.

In relation to RHavg: Except in 2006, high levels of significantly negative relation were recorded. In 2006, the relation was also significant but it was positive.

In relation to Shr: Negative relations were obtained in all the years but the values were significant only in 2004 and 2005. In other two years the relations were marginally insignificant.

In relation to Rfall : During 2003 and 2004 the spider population had significantly high positive relation while during the later years the relations though positive were insignificant. The number of rainy days exhibited insignificant positive relation.

Table.4.1.3: Correlation coefficient of the incidence of the natural enemies with the climatic factors indicating the level of significance

Natural enemies	Years of observation	Temperature (°C)				Relative humidity (%)				Sunshine hours/ day (Shr)	Rainfall (Rfall) (mm)	
		maximum (Tmax)	minimum (Tmin)	gradient (Tgr)	average (Tavg)	maximum (RHmax)	minimum (RHmin)	gradient (RHgr)	average (RHavg)		amount (mm)	rainy days
Spider	2003	-0.836*	-0.878*	-0.872*	-0.883*	0.845*	0.343	-0.380	-0.538*	-0.425	0.658*	0.241
	2004	-0.711*	-0.602*	-0.732*	0.123	0.621*	0.422	-0.541*	-0.611*	-0.522*	0.687*	0.131
	2005	-0.623*	-0.547*	-0.352	-0.523*	0.698*	0.378	-0.617*	-0.644*	-0.534*	0.342	0.341
	2006	-0.581*	-0.612*	-0.602*	-0.567*	0.711*	0.343	-0.712*	0.521*	-0.451	0.123	0.334
Bug	2003	0.654*	0.534*	0.352	0.424	-0.453	0.564*	-0.587*	0.713*	-0.139	0.712*	-0.628*
	2004	0.564*	0.345	0.512*	0.522*	-0.654*	0.543*	0.781*	0.498	-0.352	0.546*	-0.567*
	2005	0.342	0.564*	0.411	0.671*	-0.511*	0.701*	0.654*	0.645*	-0.611*	0.512*	-0.687*
	2006	0.211	0.465	0.651*	0.564*	0.612*	-0.132	0.129	0.467	0.421	0.713*	-0.511*
Beetle	2003	-0.559*	-0.779*	-0.805*	-0.736*	0.065	-0.993*	0.764*	-0.861*	0.342	-0.232	0.321
	2004	-0.380	0.152	0.274	0.225	-0.512*	0.254	0.072	-0.330	0.654*	-0.321	0.453
	2005	-0.401	-0.346	0.202	-0.414	-0.730*	-0.939*	-0.606*	-0.912*	-0.411	-0.511*	0.453
	2006	0.123	0.131	0.312	0.223	-0.611*	-0.412	-0.591*	-0.712*	-0.271	-0.549*	0.211
Fly	2003	0.432	0.453	0.564*	-0.531*	0.711*	0.321	0.542*	0.604*	0.511*	0.542*	0.404
	2004	0.412	-0.311	0.611*	0.587*	0.342	0.412	0.478	-0.329	0.641*	0.632*	-0.311
	2005	0.512*	0.412	0.542*	0.421	0.612*	0.721*	0.538*	0.678*	0.439	-0.571*	0.453
	2006	-0.134	0.512*	0.611*	0.545*	0.671*	0.611*	-0.411	-0.213	0.612*	-0.553*	0.344

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Table.4.1.3: Correlation coefficient of incidence of the parasites with the climatic factors indicating the level of significance

Parasites	Years of observation	Temperature (°C)				Relative humidity (%)				Sunshine hours/ day (Shr)	Rainfall (Rfall) (mm)	
		maximum (Tmax)	minimum (Tmin)	gradient (Tgr)	average (Tavg)	maximum (RHmax)	minimum (RHmin)	gradient (RHgr)	average (RHavg)		amount (mm)	rainy days
Trichogramma	2003	-0.846*	0.878*	-0.872*	-0.883*	0.845*	0.343	-0.380	0.538*	-0.525*	0.358	-0.241
	2004	-0.741*	0.602*	-0.732*	0.523*	0.621*	0.422	-0.341	0.611*	-0.522*	-0.687*	-0.131
	2005	-0.628*	0.547*	-0.352	-0.423	0.698*	-0.578*	-0.417	0.644*	-0.534*	0.242	-0.341
	2006	-0.571*	0.612*	-0.602*	-0.567*	0.711*	-0.643*	-0.312	0.521*	0.651*	-0.723*	-0.334
. *Tetrastichus*	2003	0.654*	0.534*	-0.519*	0.424	-0.453	0.464	0.387	0.713*	-0.639*	0.412	-0.428
	2004	0.564*	0.345	-0.512*	0.522*	-0.654*	0.243	0.481	0.598*	-0.552*	-0.546*	-0.467
	2005	0.542*	0.564*	-0.318	0.671*	-0.511*	-0.701*	0.454	0.645*	-0.611*	0.312	-0.487
	2006	0.211	0.465	-0.651*	0.564*	0.612*	-.0.632*	0.129	0.467*	0.521*	-0.713*	-0.411
Telenomus	2003	-0.559*	0.779*	-0.805*	-0.736*	-0.765*	-0.293	-0.264	0.861*	-0.642*	0.632*	0.321
	2004	-0.607*	0.552*	-0.574*	-0.525*	-0.812*	0.254	0.072	0.530*	-0.654*	-0.521*	0.453
	2005	-0.598*	0.646*	-0.402	-0.414	-0.730*	-0.939*	-0.206	0.912*	-0.711*	0.511*	0.453
	2006	-0.723*	0.531*	-0.512*	-0.623*	-0.611*	-0.512*	-0.391	0.712*	0.571*	0.549*	0.211

*Significant at 5% level

4.1.2.2 Bug

Guild composition: Among all the species only a single species was identified as *Cyrtorhinus lividipennis* (Reuter). However variations occurred regarding the distribution and predatory potentiality of the bug in different agro-ecological conditions.

Population dynamics: Inconsistency of population was noted throughout the year. The low count at the initial months of a year was followed by the gradual increase at 20 SMW which maintained at a steady state up to 40 SMW after which the population gradually declined (Fig. 4.1.6a).

Throughout the entire growth stages of paddy the occurrence of the bug population in general was very low. Up to the late vegetative stage after transplantation, there was very low detectable range of population. The population gradually increased and maximized at about 90 DAT, after which it gradually declined.

Manti (1991) opined that in Philippines the agro-ecological conditions rather than the BPH population was the prime regulatory factor for the bug populations. Subramanium (1981) noted that the rate of predation by bug was badly affected by collection of the pest by light traps. Peter *et al.* (1989) viewed that application of monocrotophos detrimentally affected the predatory behaviour of bug. .

Correlation analysis of bug population with climatic factors (Table. 4.1.3)

In relation to Tmax: A significant positive relation of bug population with Tmax was observed during 2003 and 2004. In the two later years the relations were insignificant but positive.

In relation to Tmin: Significantly positive relations were noted for 2003 and 2005 only.

In relation to Tgr: The population showed a significantly positive relation during 2004 and 2006 only.

In relation to Tavg: Except in the year 2003, the population of the bug showed significant positive relation with Tavg.

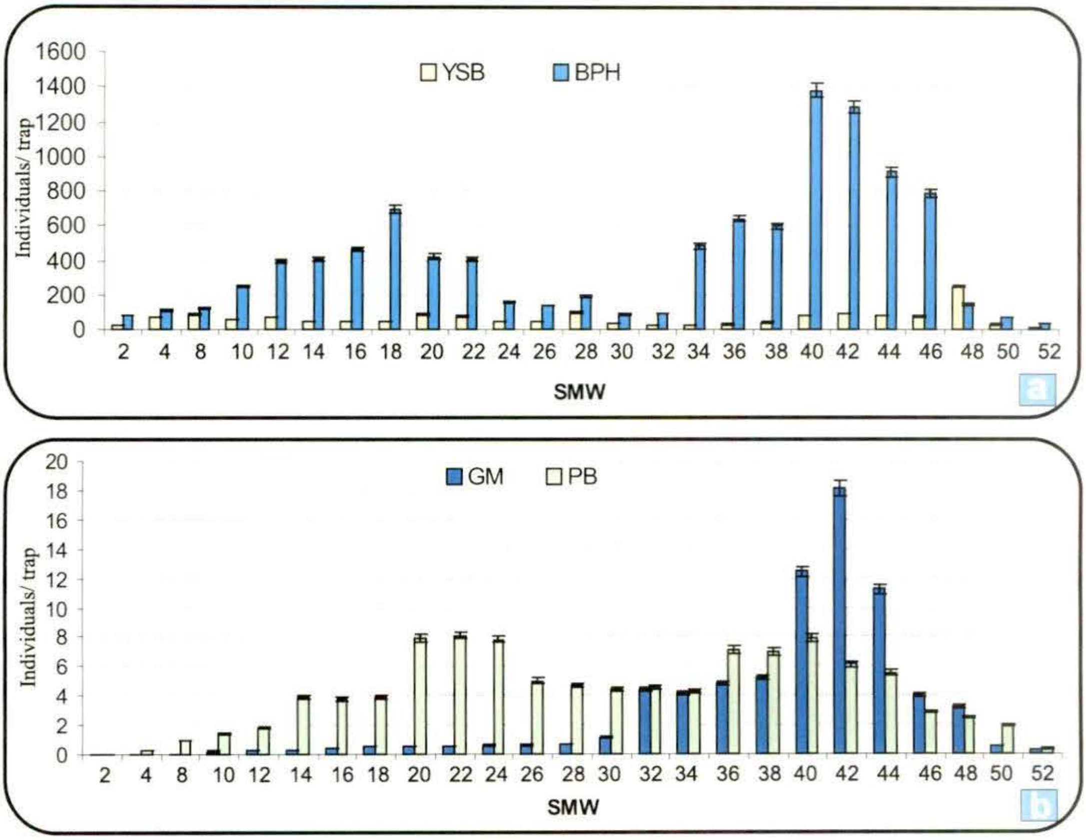


Fig.4.1.4: Population dynamics of four major pests, a: YSB+BPH and b: GM+PB round the year in mono culture fields in terms of SMW.

Fig.4.1.5 : Damage due to YSB larvae a: Larvae inside a mature stem b: Tissue necrosis due to larval growth.

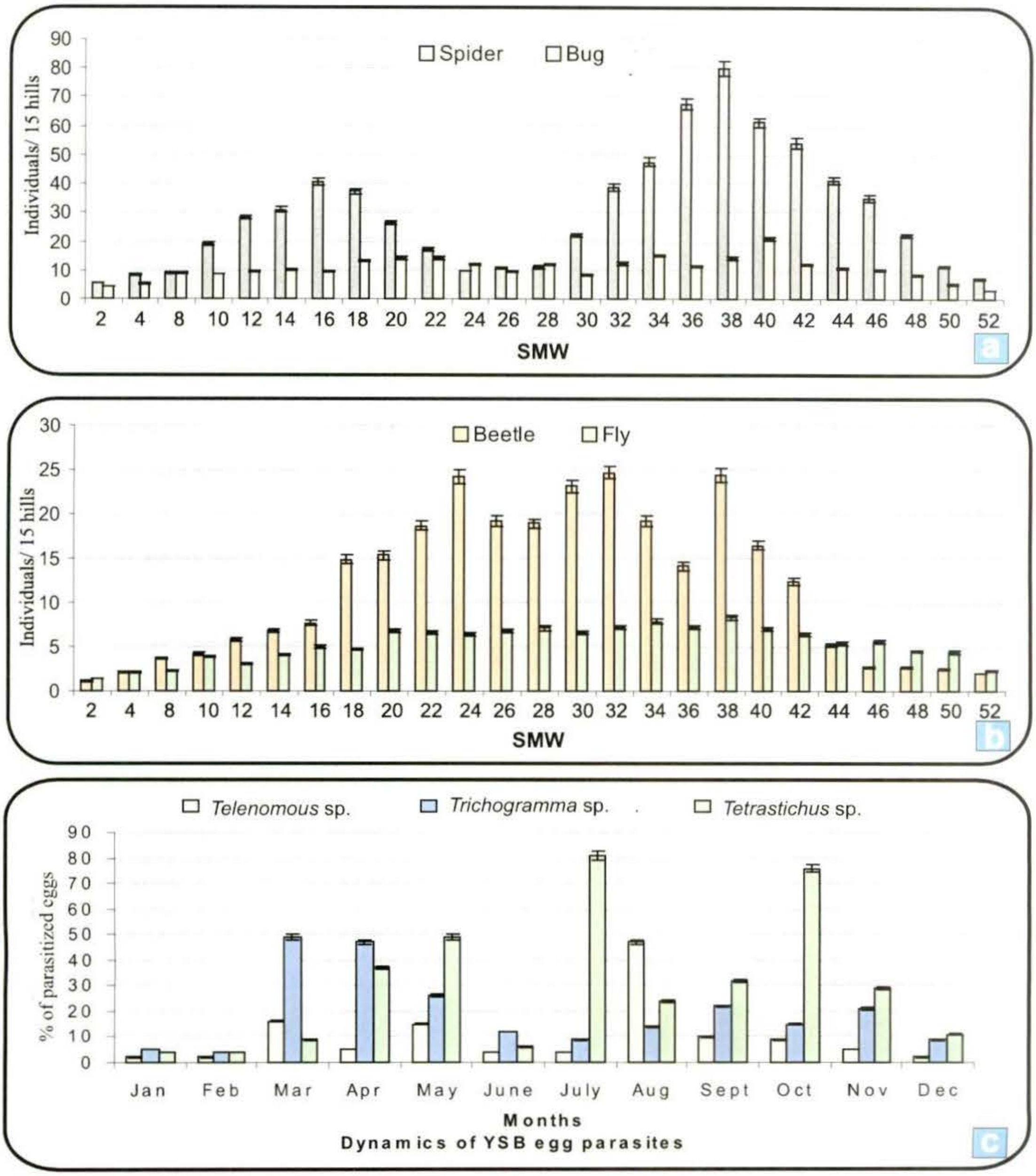


Fig.4.1.6: Population dynamics of paddy field natural enemies a: Spider+Bug, b: Beetle+fly and c: Parasites of YSB eggs round the year in mono culture fields in terms of SMW.

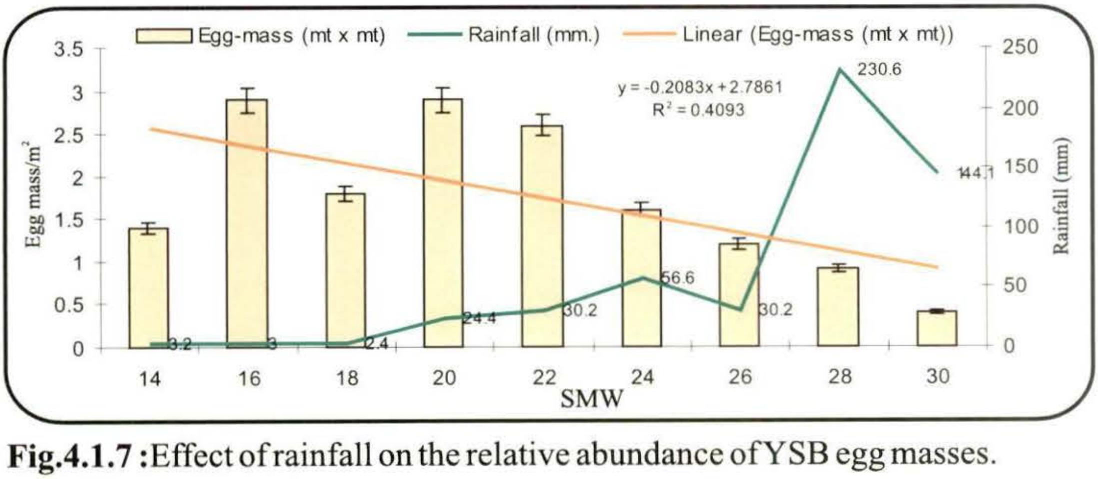


Fig.4.1.7 : Effect of rainfall on the relative abundance of YSB egg masses.

In relation to RHmax: Significant negative relation was found during 2004 and 2005. Significant positive relation was obtained in 2006, during 2003 the relation was insignificant and negative.

In relation to RHmin: Except for the year 2006, the relations of bug population was significantly positive with the RHmin. The relation in 2006 was negative and very insignificant.

In relation to RHgr: Except during the year 2006, the relations were significant, negative during 2003 and positive during 2004 and 2005.The relation though positive, it was highly insignificant in 2006.

In relation to RHavg: In all the years, the relations were positive, highly significant in 2003 and 2005 and insignificant during other two years.

In relation to Shr: Except in the year 2006, the relations were negative, of which good significance was recorded for 2005 only. During 2006, the relation was positive but insignificant.

In relation to Rfall: Significant high grade of positive relation persisted in all the years, but the rainy days showed significant negative effect.

4.1.2.3 Beetle

Guild composition: Variability was noted regarding species composition of the beetle population. The species recorded were *Micraspis crocea* (Mulsant), *Menochilus sexmaculata* (Fab.), *Ophionea nigrofasciata* (Schmidt-Goebel) and *Staphylinus* sp. Relative potentiality of the species was found to be influenced by the location of the land as well as the growth stages of paddy.

Parasuram (1989) reported a variable range of predatory coccinellids from the paddy field of Madurai, India. The prominent species are *Menochilus sexmaculatus* (Fab.) 43%, *Rodolia concolor* (Lewis) 8%, *R.pumila* (Weise.) 8%, *Seymnus* sp. (Kamiya.) 10%, *Micrapsis discolor* (Fab.) 5%, *Hormonia octomaculata* (Fab.) 9%.

Population dynamics: In general no specific pattern of relationship was noted in any of the years. However, the relative availability of the species was more after 18 SMW which was maintained up to 38 SMW (Fig.4.1.6b).

Throughout the entire growth stages of paddy, the beetle population was very low. At early stages of crop establishment very low detectable range of population could be found. The population gradually increased and maximized at about 100 DAT, after which it gradually declined. The periodicity of the population was thus appeared to be more influenced by the growth stage specific alteration of paddy field niche inducing the host pest abundance, rather than by the climatographic factors.

Correlation analysis of beetle population with climatic factors (Table.4.1.3)

In relation to Tmax: The relation in all the years was negative, but significant only during 2003.

In relation to Tmin: The relations were inconsistent in different years, significantly negative during 2003, insignificantly negative during 2005 but insignificantly positive during the remaining two years.

In relation to Tgr: High degree of significantly negative relation in 2003 was followed by insignificant and poor positive relation in the three subsequent years.

In relation to Tavg: The relations were negative during 2003 and 2005, but significant only during 2003.During other two years the values were insignificant but positive.

In relation to RHmax: Significant negative relationship was observed in all the years except 2003, during which very insignificant and negligible positive relation was recorded.

In relation to RHmin: An insignificant positive value was recorded for 2004. During the remaining three years the relations were negative, highly significant during 2003 and 2005, but insignificant during 2006.

In relation to RHgr: High level of significantly negative relationship was obtained in 2005 and 2006 and significantly positive relation during 2003. But for 2004, the relation was very insignificantly positive.

In relation to RHavg: The relationship was always negative, significantly very high in all the years except in 2004.

In relation to Shr: The relations were both positive and negative, but only significantly positive during 2004.

In relation to Rfall: In all the years negative relationship was noted but the values were significant only during 2005 and 2006.The number of rainy days showed insignificant positive relation.

4.1.2.4 Fly

Guild composition: Two species, each of damselfly and the dragonfly constituted the guild of which the former dominated in number of individuals. Of all the species *Agriocnemis pygmaea* appeared as the dominant species representing more than 30% of the collected samples. Other recognized species was *Agriocnemis femina.*

Population dynamics: No specific pattern of abundance of the guild members could be recognized in any of the years. The population was thus inconsistent in respect of the relative abundance of the guild species. The highest population was noticed at the late vegetative stage of paddy. The population thereafter steadily declined. Very low abundance was noted at the time of crop maturity (Fig 4.1.6b).

Correlation analysis of fly population with climatic factors (Table.4.1.3)

In relation to Tmax: During the first three years, the relation was positive, but was significant only during 2005. In 2006, the relation was negative and insignificant.

In relation to Tmin: Insignificant negative relation was recorded during 2004. In all the years the relation was positive but significant only in 2006.

In relation to Tgr: Tgr exerted significantly positive effect upon the dynamics of the fly population in all the years.

In relation to Tavg: Except in 2003, the relationship was positive but was significant in 2004 and 2006. Significantly negative result was obtained in 2003.

In relation to RHmax: In all the years positive relationship was observed and was significant except 2004.

In relation to RHmin : Positive relationship was noted in all the years but was significant only in 2005 and 2006.

In relation to RHgr: Except in 2006, the relation was positive and significant in 2003 and 2006. The relation was negative and insignificant in 2006.

In relation to RHavg: Significantly positive relation was noted during 2003 and 2005. During 2004 and 2006 the relation was negative and insignificant.

In relation to Shr: The correlation values were positive for all the years and were significant except for 2005.

In relation to Rfall: Rfall exhibited both positive during 2003 and 2004 and negative during 2005 and 2006 relationship with the fly population. However in all the years the relation was significant. Number of rainy days exhibited both insignificant positive and negative relation.

Discussion: All the natural predators exhibited diversified relationship. The spider, *Tetragnatha* sp. was positively correlated with Tmax and Tavg. While *Lycosa* sp. exhibited significant positive relation with Shr, Tmin, Tavg. Furthermore, *Araneous* sp. was positively correlated with RH and Rfall (Mishra and Srivastava 1993). Nath and Sarkar (1978) concluded that in the BPH endemic regions of Khanakul (West Bengal), spiders could effectively check the hopper population only from the very date of transplantation in January to the early vegetative stage in March. Bhathal and Dhaliwal (1990) observed that under the agro-climatic condition of Punjub the efficient predatory spiders of

WBPH are *Oxypes pandae* (3.7 prey individuals/day), *Paradosa birmanica* (3.6 prey individuals /day), *Thomisus* sp (3.4 prey individuals / day), *Neoscona nautica* (2.5 prey individuals / day). Heong (1989) noted that collectively spiders can consume 22 individuals of *C.lividipennis* in laboratory condition.

From the recorded data and correlation values between the enemy populations and abiotic factors it appears that the spider population depends negatively with maximum and minimum ambient temperatures and positively with maximum relative humidity. In respect of other climatic factors the abundance of spider population shows disparities to a lesser degree. Hence, spider population does not strictly rely on all the climatic factors.

In general the population abundance of bug, damselfly and dragonflies and beetles is extremely inconsistent and unpredictable with relation to climatic factors. May be that the abundance of enemy population match the increase in the pest population.

4.1.2.5. Nature of YSB egg parasites / parasitoids

Guild composition: Different species of parasites/parasitoids were recorded from the eggs, larvae and pupae of YSB (Table.4.1.4).

Table.4.1.4 Parasites/parasitoid species from different stages of YSB life cycle

Family	Species	Stage of YSB life cycle attacked
Eulophidae	**Tetrastichus* sp.	Eggs
Braconidae	*Stenobracon* sp.	Eggs
	Apanteles sp.	Larva and pupa
	Chelonus sp.	Larva and pupa
Scelionidae	**Telenomus* sp.	Eggs
Ichneumonidae	*Temelucha* sp.	Larva and pupa
	Isotima sp.	Larva
Trichogrammatidae	**Trichogamma* sp.	Eggs

* Most abundant and effective as bio-control agents

Telenomus rowani predominates in Karnataka.At Coimbatore *Tetrastichus* sp.(32%), *Telonomus rowani* (24%) and *Trichogramma japonicum* (2%) are important parasites for paddy fields (Rai and Gowda 1977). Brar *et al.* (1994) have found that the parasitic activity of *T.dignus* is always superior to *T.japonicum*. A study at CRRI, Cuttack it has been found that the contribution of individual parasitoids was 52.8% by *T.dignoides*, 40.5% by *T. schoenobii* and 6.5% by *T.japonicum*. Feijen (1981) has reported that *T. kalkae* is the most important species in Malawi parasitizing on an average of 41% of the eggs of *Diopsis* sp.

Population dynamics: Seasonal dynamics was studied only on the three most abundant and effective species (Table.4.1.4). Activity of *Trichogramma* sp. was recorded maximum in March followed in descending order by April, May, September, November and August. Maximum activity of *Tetrastichus* sp. was noted in July which was followed by October, May, April September and November and December respectively in descending order. Activity of *Telenomus* sp. was recorded highest in August followed by March and May. September and October exhibited sub-moderate level while a low level was noted in January and February (Fig.4.1.6c).

Correlation analysis of YSB egg parasites with climatic factors (Table.4.1.3)

In relation to Tmax: *Trichogramma* sp. and *Telenomus* sp. exhibited significant negative relation with Tmax while *Tetrastichus* elaborated significant positive relation in most of the years. The parasites were found to be more effective when the range of temperature was between 14-30^{0}C. Tmax during March to May and Tmin during February and November exerted no effect on egg laying but the number of the sterilized eggs was quite high.

In relation to Tmin: In all the cases Tmin had a positive relation with the parasites population and significant in most of the years.

In relation to Tgr: All the parasites showed significant negative relation with Tgr in all the years except in 2005 which was insignificantly negative.

In relation to Tavg: Except 2005, in all other years the field populations of *Trichogamma* sp. *and Telonomus* sp. showed significant negative relation with Tavg. While *Tetrastichus* exhibited significant positive relation in most of the years.

In relation to RHmax: *Trichogamma* sp. population was positively correlated with RHmax at significant level in all the years. While *Telonomus* sp. and *Tetrastichus* sp. elaborated significant negative relation in most of the years.

In relation to RHmin: Effect of RHmin upon the occurrence of the parasite population was insignificantly positive in the year 2003 and 2004 but significantly negative in other two years.

In relation to RHgr: Insignificantly negative relation existed between RHgr and the field populations of parasites in all the years, though higher the range of humidity, greater would be the availability of the viable eggs.

In relation to RHavg: Parasite population exhibited significantly positive relation in all the years with RHavg.

In relation to Shr: Shr exerted a significantly negative effect on the observable value of the parasites except in the year 2006 where the relation was significantly positive.

In relation to Rfall: High Rfall within a short spell of time showed a significantly negative relation with the parasite population in the years 2004 and 2006. However *Telenomus* sp. showed significant positive relation in the years 2003 and 2005. Excessive rain dislodged the egg masses resulting in high mortality. Low level of parasitization was recorded in rainy environments. In most of the years number of rainy days narrated insignificant negative relation with the parasites (Fig.4.1.7).

Discussion: The Relative effectiveness of the parasites was more influenced by the prevailing climatic conditions rather than by the density of the eggs. Although the relative dominance of the parasites varied throughout the year, the overall activity of the paddy field parasite species is in the order of

Tetrachius> *Trichogramma*>*Telenomus*. Relative abundance of the major parasites in the present observation is supported by Chandramohan and Chelliah (1990) who also have noted that the dynamics of *Telenomus* sp. is negatively influence by Tmax at significant level. While *Tetrastichus* sp. and *Telenomus* sp. exhibited significant positive and significant negative relation with Tavg respectively. Rao and Ali (1976) found that the average Tmax- 27.9 to 29.4°C and Tmin- 13.8 to 16.4°C are conducive for parasitic multiplication. Growth of the parasite is restricted when Tmax crosses 32°C (Hikim 1979). Nagarkatti *et al.* (1973) found that the extremely cold or hot weather was unfavorable for some natural enemies in field condition. In southern parts of India, *Tetrastichus schoenobii* is most dominant through out the year except from May to August when *Telenomus rowani* governs the fields parasitizing 80-100% of YSB egg masses. But an opposite phenomenon was observed in the present study. High abundance of egg masses during March to April is associated with low level of parasitization. Furthermore, high population of parasites during May to August has been noted while the YSB eggs have been low in number. Hence, in a bio-control component of IPM selective paddy growth stage specific release of the parasites proves helpful when YSB egg is abundant.

4.1.3 Interaction among the non pests, pests and natural enemies: The occupancy pattern of each guild, as appeared from the study was numerically in the order of non-pests > natural enemies > pests, in pesticide untreated fields. The mean density of non-pests was much higher than that of other guilds' representatives and there was little difference between the mean densities of the natural enemies and the pests. But in pesticide treated fields, the pattern appeared in the order of pests > non-pests > natural enemies. Seeding methods adopted at the rice growing season changed the early rice ecosystem. These changes affected the development and the density of arthropod community on rice plants (Figs.4.1.3a and b).

Song *et al.* (2003) also observed that the proportional representation of the members of the guild is in a decreasing order of natural enemies > pests > non-pests. They studied the guilds in an IPM programme. It might be assumed that the heterogeneity in the guild composition could result from the differences of immigration rates of pests, regional characteristics, cultural practices, and sampling methods.

4.1.4 The pest and enemy guilds, and their species dominance: Dominant species among the pests were BPH, followed by YSB and GM. Light trap estimation showed that the relative abundance of BPH constituted over 61% of the total pest species.

In natural enemy guild, spiders were dominant group occupied over 55% which was followed by coleopterans. Variability was noted in the guild composition in relation to the seasons. Collective observations showed that parasitic wasps and heteropterans were two distinctive minor groups in this guild. In non-pest group, chironomids and other flies, and collembolans were dominant groups.

4.1.5 Multiple correlation study to show the variable mutual interactions of pests, natural enemies and ecological factors

4.1.5.1 Interactions of pests: The interaction patterns of the pests with the prominent climatic factors and the natural enemy populations were taken into consideration during the generation of respective equation of multiple correlations. As the occurrence of different pests were found to be influenced by both the biotic and abiotic factors it was rather convenient to consider the effect of some selected major factors. Both spider and beetle population imparted negative effect on the field status of YSB population. While Tmax, Tmin and RH% was viewed as the major positive limiting factors to check the BPH population. RH% and Shr affected the dynamics of GM population in positive and negative way respectively. The prominent limiting factors for the PB population Tmax and RH%, were respectively positive and negative. The interactive role of spider population played a critical negative role on the pest population. The major limiting factors for YSB activity is the field abundance of spider and beetle population (Table 4.1.5).

Table.4.1.5 Multiple correlation study of the pest population with the climatic factors

Pests	Equation of relation	R^2
YSB	Y_N (DH) =-0.43 +8.13 spider + 0.23 beetles.	0.61*
BPH	Y_N (BPH. *kharif* crop.) = -0.83 +0.08 Tmin. + 59.5 Tmax.	0.71*
	Y_N (BPH. *boro* crop.) =-0.83 +0.06 Tmin. + 0.59.T max. + 0.17 RHmax -3.61 Shr.	0.56*
	Y_N(YSB) = 4.503 -0.27 YSB -0.02 BPH + 0.07 GM	0.51*
GM	Y_N (GM) =-7.16+0.26 Tmax.-0.31 T.min. + 0.82 RHmax.- 2.53 Shr.	0.70*
PB	Y_N (PB) = 76.26-2.04 Tmin.- 0.57 T max. + 0.82 RH.	0.68*
	Y_N (PB) = 10.97 +0.38.T.max.- 0.48 Tmin. -0.13 RHmax. + 0.45 GM. – 0.54 spider.	0.59*
	Y_N (PB) = 48.12 – 0.37 RHmax. -3.46 Shr.	0.51*

*Significant at 5% level

Table.4.1.6 Multiple correlations study between the natural enemy populations in reference to the pest intensity

Natural enemies	Equation of relation	R^2
Spider	Y_N (YSB) = -0.04 + 0.02 spider. + 0.1 beetles. -0.04 fly. (*boro* crop)	0.63*
	Y_N (PB) = -24.19 + 0.31 orb spider. +1.28 lynx spider.	0.53*
Bug	Y_N (BPH) =0.97 +0.32. spider. + 0.80. beetles +0.3 bug.	0.76*
Beetle	Y_N(PB) = 0.47+0.03.spider .-0.02.beetles. -0.17 fly.+0.09 YSB egg parasites (*boro* crop).	0.65*
Fly	Y_N (YSB) = 0.48 + 0.21spider.-0.07 beetles. - 0.32 fly. + 0.12 YSB egg parasites.	0.67*

*Significant at 5% level

4.1.5.2 Interactions of natural enemies: As the availability and the potentiality of the natural enemies were governed by multiple factors, it was thus beneficial to correlate the important factors to the dynamics of the natural enemies. Both the spider and the beetle population were intra interactive and acted as effective controlling factors respectively for YSB, BPH and PB population (Table 4.1.6).

4.1.6 Formulation of the forecasting equation for the different pests: Depending on the average value of the field dynamics of the four major paddy pests in four consecutive years (2003-2006) pest forecasting equation was generated.

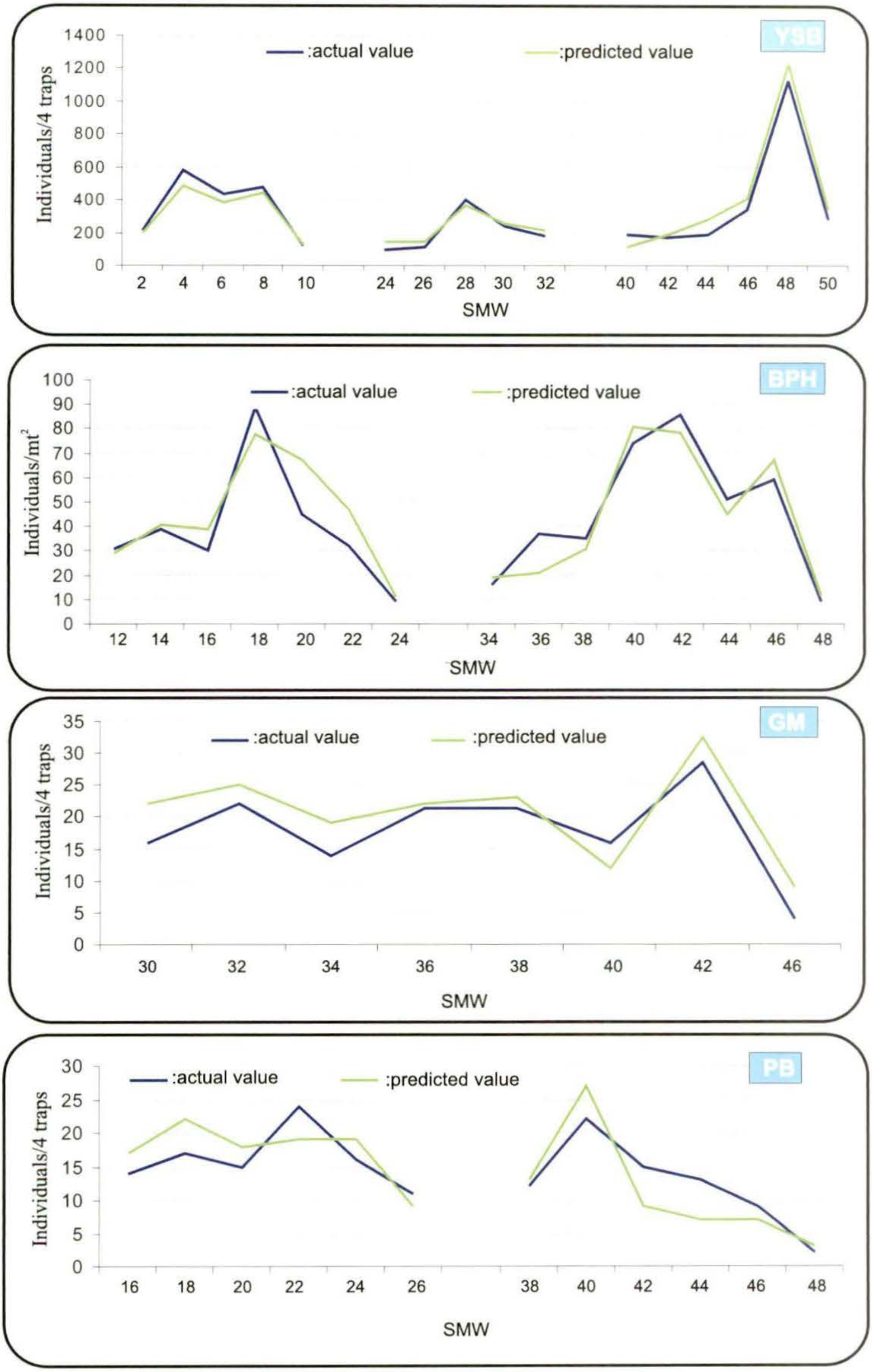


Fig.4.1.8: Determination of validity of the equation generated from the predicted value of pest population with the actual value of field population a: YSB, b: BPH, c: GM and d: PB.

4.1.6.1 Status of the equation: During the formulation of the equation gravity was given more on the climatic factors which imparted comparatively greater effect on the bionomics of the respective pest.

Yellow stem borer

$$YSB_N = 10.6 + 0.78Yc - 0.37Yp - 4.03\ Tmin^{o}.$$
$$r^2 = 0.68^{*} \text{ (significant at 5\% level)}$$

YSB_N = YSB population in next week, Yc = YSB population during the current week, Y_P = YSB population during one week prior to the current week, $Tmin^{o}$ = Minimum temperature two week previous to current week.

Brown plant hopper

$$BPH_N = -87.845 + 0.802\ BPH_{CP} - 1.505\ Tmax^{o} + 2.497\ T\ min^{o}.$$
$$r^2 = 0.62^{*} \text{ (significant at 5\% level)}$$

BPH_N = Square root of BPH population of next week, BPH_{CP} = Average of square root of current week and previous week BPH population, $Tmax^{o}$ = Average of two and three weeks prior to maximum temperature, $Tmin^{o}$ = Average day temperature of two and three weeks prior to minimum temperature.

Gall midge

$$GM_N = -1861.21 + 0.521\ GM_C + 93.689\ Tmin^{o}$$
$$r^2 = 0.55^{*} \text{ (significant at 5\% level)}$$

GM_N = GM population after one week, GM_C = Gall midge population during current week, $Tmin^{o}$ = Minimum temperature during current week.

Paddy bug

$$PB_N = 12.4 + 0.69\ PB_C - 0.42\ PB_P - 3.98\ Tmax^{o}.$$
$$r^2 = 62^{*} \text{ (significant at 5\% level)}$$

PB_N = PB population of next week, PB_C = PB population of current week. PB_P = PB population of previous week, $Tmax^{o}$ = One week prior to current week.

4.1.6.2 Detection of the validity of the equation: The relative validity of the proposed forecasting equation for different pests was assessed in the year 2007-2008. To determine the applicability and the acceptance of the generated equation, the average 'predicted value' obtained from the generated equation for each pest was compared with the 'observed value' from the field data. To get the 'observed value' fortnight light trap (200wt) assessment on the pest population was carried out only in Raiganj and the average value of two consecutive years was considered.

Observed value on the average field dynamics of YSB and BPH were in consonance with the predicted values. But the variations from the 'predicted values' were noted in case of GM and PB populations. Inconsistency of the generated equation for GM and PB was probably due to their unpredictable interaction with the climatic factors and natural enemies (Fig.4.1.8).

4.1.6.3 Preparation of time-tables in relation to pest occurrence: The data on pest incidence for all the tables are obtained from light trap catches using an electric lamp of 200 watt. Depending on the intensity of numbers of individuals of all the four major pests, a comprehensive time table has been constructed for each of the pests. The tables in general focus on the timing of the beginning of pest incidence, passing through different grades of abundance and their disappearance after attainment of the highest numbers. Such tables certainly enable in a holistic way to formulate and hypothesize the seasonal activity of a pest species in an area with contiguous agro-climatic conditions and common schedule of paddy cultivation practices (Table.4.1.7 - 4.1.10).

Table.4.1.7: Relative incidence of YSB in relation to SMW

Grade level of incidence	Number of individuals/trap	SMW
High	201<	48[a]
Medium	151-200	28[a], 42[b]
Moderate	101-150.00	8[a], 20[b]
Low	76.00-100.00	22[b], 40, 44[a], 46
Very low	51.00- 75.00	4[a],10,12,18[b]
Trace	0.00-50.00	2, 14[a] ,16, 24, 26, 30, 32, 34, 36, 38, 50, 52[b]

Most active period ([a]) and least active period ([b]) within level of incidence

Table.4.1.8: Relative incidence of BPH in relation to SMW

Grade level of incidence	Number of individuals/trap	SMW
High	751.00<	40[a], 42, 44, 46[b]
Medium	601.00- 750.00	18[a], 36, 38[b]
Moderate	401.00- 600.00	14, 16, 20, 22[b], 34[a]
Low	151.00-400.00	10, 12[a], 24[b],28
Very low	101.00- 150.00	4[b], 8, 26, 48[a]
Trace	0.00-100.00	2, 30, 32[a], 50, 52[b]

Most active period ([a]) and least active period ([b]) within level of incidence.

Table.4.1.9: Relative incidence of GM in relation to SMW

Grade level of incidence	Number of individuals/trap	SMW
High	15.51<	42[a]
Medium	10.51-15.50	40[a], 44[b]
Moderate	5.51-10.50	36[b], 38[a]
Low	1.51-- 5.50	32[a], 34, 46, 48[b]
Very low	0.51-1.50	18[b], 20, 24, 26, 28, 30[a], 50, 52
Trace	0.00-0.50	2[b], 4, 8, 10, 12, 14, 16[a], 51

Most active period ([a]) and least active period ([b]) within level of incidence

Table.4.1.10: Relative incidence of PB in relation to SMW

Grade level of incidence	Number of Individuals/trap	SMW
High	7.51<	20,22[a],24[b],40,
Medium	5.51-7.50	36[a], 38, 42, 44[b]
Moderate	3.51-5.50	14, 16[b],18, 26[a], 28,30, 32, 34
Low	2.51-3.50	46[b], 48[a]
Very low	1.51- 2.50	12[b], 50[a]
Trace	0.00-1.50	2[b],4, 8,10[a], 52

Most active period ([a]) and least active period ([b]) within level of incidence

Climatic factors have profound effect on the periodicity of the pests than the natural enemies. The overall dynamics of the natural enemies are inconsistent and showed no definite relation with the climatic factors. The population of natural enemies was thus found to be more influenced by the abundance of the pest population. Formulation of the predicted population of both YSB and BPH nearly fitted with the actual field value of the pests. But GM and PB partly satisfy the equation which implies that either the population is more influenced by the macro climate or their rhythmic periodicity requires a longer time.

4.2 Dynamics of the Pests in Relation to the Time of Cultivation

Plantation schedule: Farmers cultivate three paddy crops in a year, *pre-kharif, kharif* and *boro*. Among the three crops, *kharif* and *boro* are mostly practised. The four major pests were assessed for these two cultivation practices round the year at every 7 days interval by hill estimation for the high yielding variety *Swarna Mashuri*. Cultivation periods were categorized into three groups in both *kharif* (KP1, KP2 and KP3) and *boro* (BP1, BP2 and BP3) season for assessing the 4 pest complexes and for determination of suitable cultivation time. For this study the schedule was decided on standard meteorological weeks (SMW) covering one calendar year. During *boro* season the seedlings were retained for longer time in the seed bed. Periodic field observation during *boro* season was carried out discontinuously to satisfy the same times of observation during both the seasons. As there was no hill formation in the seed bed condition, 20 seedlings were considered as the equivalent of one hill.

4.2.1 Yellow stem borer

Population dynamics

***On kharif* crop:** YSB was recorded during the entire crop growing period from 20 SMW to 44 SMW. In KP1, the population was initiated at 20 SMW and increased up to 28 SMW attaining the highest at about 35 SMW, then declined rapidly to traces by 39 SMW. In KP2, YSB attack was initiated at 22 SMW increased up to 29 SMW, reaching a maximum at 29 SMW and then reduced by 41SMW. In case of KP3, the incidence increased gradually from 24 SMW up to 31 SMW and attained the maximum by 44 SMW (Table.4.2.1).

***On boro* crop:** Variable range of YSB was noticed throughout the crop growing season. In BP1, the initiation was noticed from 46 SMW, increased gradually up to 02 SMW, maximized at about 12 SMW; and then declined rapidly. In BP2, the attack was initiated at about 48 SMW, attaining the maximum by 06 SMW and then minimized by 13 SMW, after which the population gradually increased. In BP3, it was initiated at about 49 SMW followed by the gradual ascending up to 13 SMW and then maximized at about 16 SMW (Table.4.2.2).

Table.4.2.1: Incidence and relative abundance of YSB on *kharif* crop of three different cultivation times

Year	Cultivation times	Pest infestation in standard meteorological weeks (SMW)																							
		20	21	22	23	24	25	26	27	28	29	30	31	32	33	35	36	37	38	39	40	41	42	43	44
2003	KP1	2.45 **1.71**	3.12 **1.90**	3.34 **1.95**	2.81 **1.81**	1.21 **1.30**	1.29 **1.33**	2.41 **1.70**	5.12 **2.37**	4.17 **2.16**	2.34 **1.68**	2.61 **1.76**	1.22 **1.31**	1.67 **1.47**	2.31 **1.67**	5.26 **2.41**	3.53 **2.01**	3.91 **2.10**	3.22 **1.92**	2.98 **1.86**	3.09 **1.89**				
	KP2			1.87 **1.53**	2.01 **1.58**	1.01 **1.22**	0.89 **1.17**	2.05 **1.59**	2.47 **1.72**	2.12 **1.61**	2.03 **1.59**	1.78 **1.50**	0.59 **1.04**	0.79 **1.13**	1.14 **1.28**	3.11 **1.90**	1.63 **1.45**	1.87 **1.45**	1.87 **1.53**	1.75 **1.51**	1.91 **1.55**	2.11 **1.61**	2.56 **1.71**		
	KP3					2.41 **1.70**	2.63 **1.76**	2.75 **1.80**	2.81 **1.81**	3.97 **2.11**	3.21 **1.92**	3.45 **1.98**	3.67 **2.04**	2.41 **1.70**	2.47 **1.72**	3.47 **1.99**	2.11 **1.61**	3.21 **1.92**	3.46 **1.98**	3.61 **2.02**	3.75 **2.06**	3.82 **2.07**	4.12 **2.14**	4.79 **2.30**	5.12 **2.37**
2004	KP1	2.15 **1.62**	3.22 **1.92**	3.34 **1.95**	2.71 **1.79**	1.31 **1.34**	1.27 **1.33**	2.52 **1.73**	5.32 **2.41**	4.47 **2.22**	2.34 **1.68**	2.67 **1.78**	1.32 **1.34**	1.68 **1.47**	2.41 **1.70**	5.46 **2.44**	3.63 **2.03**	3.95 **2.10**	3.42 **1.97**	2.67 **1.78**	3.19 **1.98**				
	KP2			1.75 **1.51**	2.42 **1.70**	1.33 **1.35**	0.76 **1.12**	2.23 **1.65**	2.37 **1.69**	2.41 **1.70**	2.63 **1.76**	1.71 **1.48**	0.69 **1.09**	0.83 **1.15**	1.44 **1.39**	3.31 **1.95**	1.73 **1.49**	1.85 **1.53**	1.89 **1.54**	1.69 **1.47**	1.81 **1.51**	2.41 **1.70**	2.76 **1.80**		
	KP3					2.61 **1.76**	2.73 **1.79**	2.77 **1.80**	2.86 **1.83**	3.77 **2.06**	3.25 **1.93**	3.55 **2.01**	3.65 **2.03**	2.61 **1.76**	2.44 **1.71**	3.51 **2.00**	2.41 **1.70**	3.41 **1.97**	3.56 **2.01**	3.71 **2.05**	4.75 **2.29**	4.52 **2.24**	5.02 **2.34**	5.19 **2.38**	5.72 **2.49**
2005	KP1	2.45 **1.71**	3.72 **2.05**	3.44 **1.98**	2.51 **1.73**	1.41 **1.38**	1.26 **1.32**	2.42 **1.70**	5.38 **2.42**	4.57 **2.25**	2.36 **1.69**	2.47 **1.72**	1.52 **1.42**	1.48 **1.40**	2.71 **1.79**	5.86 **2.52**	3.68 **2.04**	3.75 **2.06**	3.48 **1.99**	2.77 **1.80**	3.79 **2.07**				
	KP2			1.55 **1.43**	2.52 **1.73**	1.73 **1.49**	0.66 **1.07**	2.23 **1.65**	2.77 **1.80**	2.91 **1.84**	3.61 **2.02**	1.51 **1.41**	0.57 **1.03**	0.74 **1.11**	1.54 **1.42**	231 **1.52**	1.53 **1.42**	1.83 **1.52**	2.39 **1.70**	1.49 **1.41**	1.71 **1.48**	2.51 **1.73**	2.56 **1.74**		
	KP3					2.31 **1.67**	2.75 **1.80**	2.74 **1.81**	2.81 **1.82**	3.72 **2.05**	3.45 **1.98**	3.67 **2.04**	3.62 **2.02**	2.81 **1.81**	3.04 **1.88**	3.58 **2.01**	2.71 **1.79**	3.61 **2.02**	3.86 **2.08**	3.79 **2.07**	4.85 **2.31**	4.92 **2.32**	5.32 **2.41**	5.39 **2.42**	5.87 **2.52**
2006	KP1	2.25 **1.65**	3.53 **2.00**	3.62 **2.02**	2.49 **1.72**	1.44 **1.39**	1.36 **1.36**	2.22 **1.64**	5.48 **2.44**	4.67 **2.77**	2.56 **1.74**	2.77 **1.80**	1.81 **1.51**	1.88 **1.54**	2.71 **1.79**	5.49 **2.44**	3.68 **2.04**	3.35 **1.96**	3.41 **1.97**	2.65 **1.77**	3.61 **2.02**				
	KP2			1.51 **1.41**	2.62 **1.76**	1.76 **1.50**	0.65 **1.07**	2.33 **1.68**	2.57 **1.75**	2.95 **1.85**	3.65 **2.03**	1.55 **1.43**	0.56 **1.02**	0.54 **1.01**	1.74 **1.49**	2.35 **1.68**	1.56 **1.43**	1.73 **1.49**	2.79 **1.81**	1.79 **1.31**	1.77 **1.50**	2.57 **1.75**	2.86 **1.83**		
	KP3					2.51 **1.68**	2.77 **1.73**	2.78 **1.50**	2.87 **1.81**	3.77 **1.83**	3.75 **2.06**	3.77 **2.06**	3.69 **2.04**	2.89 **1.84**	3.44 **1.98**	3.52 **2.00**	2.73 **1.79**	3.65 **2.03**	3.76 **2.06**	3.73 **2.05**	4.55 **2.24**	4.52 **2.24**	5.32 **2.41**	5.29 **2.40**	5.67 **2.48**

Bold figures are square root transformed value

Table.4.2.2: Incidence and relative abundance of YSB on *boro* crop of three different cultivation times

Year	Cultivation times	Pest infestation in standard meteorological weeks (SMW)																							
		46	47	48	49	50	51	52	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
2003	BP1	0.38 **0.93**	1.32 **1.34**	1.22 **1.31**	1.41 **1.38**	0.59 **1.04**	0.29 **0.88**	0.61 **1.05**	1.22 **1.31**	1.37 **1.36**	1.44 **1.39**	1.21 **1.30**	1.02 **1.23**	1.37 **3.44**	0.81 **1.44**	1.65 **1.46**	1.53 **1.42**	1.31 **1.34**	1.12 **1.27**	0.98 **1.21**	0.39 **0.94**				
	BP2			0.17 **0.81**	0.31 **0.90**	0.11 **0.78**	0.69 **1.09**	0.61 **1.05**	0.67 **1.08**	1.02 **1.23**	1.33 **1.35**	1.18 **1.29**	0.29 **0.88**	0..49 **3.31**	0..54 **1.01**	1.46 **1.40**	0.73 **1.10**	0.87 **1.17**	0..57 **1.03**	0.89 **1.17**	0.86 **1.16**	1.11 **1.26**	1.26 **1.32**		
	BP3					2.11 **1.61**	1.33 **1.35**	1.65 **1.46**	0.71 **1.10**	0..97 **1.21**	1.11 **1.26**	1.25 **1.32**	1.38 **1.37**	1.22 **1.31**	1.27 **1.33**	1.29 **1.33**	0.94 **1.20**	1.21 **1.30**	1.46 **1.40**	2.61 **1.76**	2.75 **1.80**	2.82 **1.82**	1.12 **1.27**	2.56 **1.74**	2.12 **1.61**
2004	BP1	0.15 **0.80**	2.22 **1.64**	2.44 **1.71**	2.41 **1.70**	1.21 **1.30**	0.87 **1.17**	1.62 **1.45**	2.32 **1.67**	3.47 **1.99**	1.34 **1.35**	1.67 **1.47**	1.22 **1.31**	1.28 **1.33**	1.41 **1.38**	2.11 **1.61**	2.13 **1.62**	1.95 **1.56**	1.42 **1.38**	1.64 **1.46**	1.17 **1.29**				
	BP2			0.70 **1.09**	0.42 **0.95**	0.33 **0.91**	0.76 **1.12**	1.23 **1.31**	1.37 **1.36**	1.41 **1.38**	1.13 **1.27**	0.71 **1.10**	0.69 **1.09**	0.83 **1.15**	1.44 **1.39**	2.31 **1.67**	1.79 **1.15**	0.45 **0.97**	1.49 **1.41**	1.19 **1.30**	1.11 **1.26**	2.11 1.61	1.44 **1.39**		
	BP3					2.12 **1.61**	1.13 **1.27**	1.17 **1.29**	1.42 **1.38**	1.27 **1.39**	1.25 **1.32**	1.65 **1.46**	2.69 **1.78**	2.74 **1.80**	2.41 **1.70**	1.41 **1.38**	1.56 **1.43**	1.71 **1.48**	1.85 **1.53**	1.52 **1.42**	2.02 **1.58**	2.19 **1.64**	2.52 **1.73**	2.49 **1.72**	2.51 **1.73**
2005	BP1	1.05 **1.24**	1.42 **1.38**	2.34 **1.68**	2.31 **1.67**	0.71 **1.11**	1.26 **1.32**	0.82 **1.14**	1.38 **1.37**	1.57 **1.43**	2.16 **1.63**	2.17 **1.63**	1.22 **1.31**	1.28 **1.33**	1.32 **1.34**	1.46 **1.40**	2.58 **1.75**	2.75 **1.80**	1.41 **1.38**	1.74 **1.49**	1.79 **1.51**				
	BP2			0.55 1.02	0.59 1.04	0.73 1.09	0.69 1.09	1.23 1.31	1.77 1.50	1.91 1.55	1.61 1.45	1.51 1.41	1.57 1.43	1.74 1.49	1.54 1.42	2.31 1.67	1.53 1.42	1.33 1.35	1.39 1.37	2.19 1.64	2.71 1.79	2.51 1.73	2.56 1.74		
	BP3					1.36 **1.36**	2.75 **1.80**	2.74 **1.81**	2.81 **1.81**	3.71 **2.05**	2.45 **1.71**	1.67 **1.47**	1.64 **1.46**	2.01 **1.58**	2.11 **1.61**	2.06 **1.60**	2.51 **1.73**	2.42 **1.70**	2.59 **1.75**	2.51 **1.73**	2.42 **1.70**	3.32 **1.95**	3.29 **1.94**	3.22 **1.92**	3.31 **1.95**
2006	BP1	1.25 **1.3**	1.53 **1.42**	2.62 **1.76**	2.19 **1.64**	1.14 **1.28**	1.36 **1.36**	2.23 **1.65**	3.48 **1.99**	2.67 **1.78**	2.59 **1.75**	2.78 **1.81**	1.81 **1.51**	1.85 **1.53**	2.70 **1.78**	2.49 **1.72**	2.68 **1.78**	2.35 **1.68**	2.41 **1.70**	1.49 **1.41**	1.61 **1.45**				
	BP2			1.53 **1.42**	1.22 **1.31**	1.06 **1.29**	0.75 **1.11**	2.63 **1.76**	2.17 **1.63**	2.05 **1.59**	2.65 **1.77**	0.85 **1.16**	0.46 **0.97**	0.54 **1.01**	1.54 **1.42**	2.55 **1.74**	0.76 **1.12**	0.98 **1.21**	1.05 **1.24**	1.54 **1.42**	1.59 **1.44**	1.54 **1.42**	1.02 **1.23**		
	BP3					0.98 **1.21**	1.27 **1.33**	1.18 **1.29**	2.51 **1.73**	3.37 **1.96**	2.15 **1.62**	2.17 **1.63**	1.19 **1.30**	1.39 **1.37**	1.54 **1.42**	1.32 **1.34**	1.63 **1.45**	1.85 **1.53**	1.66 **1.46**	1.63 **1.45**	1.85 **1.53**	2.12 **1.61**	1.19 **1.30**	1.31 **1.34**	1.29 **1.33**

Bold figures are square root transformed value

Interaction with crop phenology: As YSB infestation mainly occurred at vegetative and early tillering stages, a growth stage specific positive relation to the three cultivation schedules was recorded. KP3 crop recorded significantly higher mean population followed by in KP1. However in KP2 crop the infestation had been the lowest with the average value of 1.99 individuals / hill.

In *boro* crop the level of the pest attack was the lowest in case of BP2 (1.25 individuals / hill). In case of other two cultivation schedules, BP1 and BP3 accounted 1.63 and 2.01 individuals / hill respectively.

Discussion: The present study reveals that the pest has been least in number in case of the KP2 and BP2 suggesting the best times for the two seasons. Although the pest population was comparatively low in KP1 and BP1 than in KP3 and BP3, the prevailing climatic conditions during these two crops impede the plant growth and hence yield becomes low. Therefore, KP3 and BP3 schedules may be disregarded.

Ganguli *et al.* (2001) have studied *S. incertulas* infestation in two rice cultivars, BD-200 and Kranti, at Raipur, Madhya Pradesh and found that sowing by June 30 and July 15 are most suitable. Delayed sowing increases the level of infestation. Present observation is in consonance with the study of Viajante *et al.* (1988) who have observed that the survivability of YSB larvae improves with increasing plant age up to 34 to 40 days after sowing (DAS), and then declines progressively on plant aged 46 to 52 DAS, suggesting time specific crop cultivation. In China, farmers use a careful selection of sowing dates to prevent damage by the borers.

4.2.2 Brown plant hopper

Population dynamics

***On kharif crop*:** After the crop establishment, the population steadily built up in KP1. The high range of population was observed at 27-31 SMW and was maintained up to 36 SMW which then declined rapidly by 38 SMW. In KP2, maximum and minimum number of BPH was recorded at 32 and 22 SMW respectively. KP3 supported 9.32 individuals/hill at the initial stage of crop establishment. The population increased gradually reaching the maximum at 32 SMW and subsumed afterwards (Table.4.2.3).

On boro crop: In BP1, BPH incidence was initiated at 46 SMW. A moderate level was attained and sustained up to 52 SMW, thereafter; the population reached the peak at 7 SMW. After 15 SMW the population declined steadily. BP2 supported very low number of BPH during crop establishment, increased gradually and peaked at about 7 SMW. In case of BP2, early low population at seed bed was immediately followed by gradual increase which maximized at about 10 SMW. In BP3, the highest number of BPH was noted at 9 SMW while the least was scored at 50 SMW (Table.4.2.4).

Interaction with crop phenology: In *kharif* season, KP3 crop recorded high mean population followed by KP1. On the other hand, KP2 crop supported lowest number of pest with an average 14.11 individuals / hill.

In *boro* crop the lowest count of BPH was registered for BP2 (9.60 individuals / hill). BP1 and BP3 accounted 15.10 and 14.25 individuals / hill respectively. BPH imparted the highest damage to the standing crop from vegetative to early tillering stages.

Discussion: At early vegetative stage maintenance of field water at variable optimum levels disapproves BPH colonization to some extent. A minor adult peak has appeared at about 8 weeks after transplantation (WAT) mostly by the macropterous morph which then multiplies. Immigrant adults together with a few brachypterous adults produce the major peak at about 11 WAT that possibly befits plant age. The pest is most abundant in two periods in a year one in the *kharif* season and the other in the *boro* season. A time bound BPH peak in paddy fields has also been recorded by other authors. Adoption of cultivation schedules KP3 and BP3 synchronizes the pest activity with the late vegetative stage of paddy rendering high level of damage. Observation explains that BPH is most abundant in two periods per year one in the *boro* and the other in the *kharif* season.

Table. 4.2.3: Incidence and relative abundance of BPH on *kharif* crop of three different cultivation times

Year	**Cultivation times**	**Pest infestation in standard meteorological weeks (SMW)**																							
		20	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
2003	KP1	5.21 **2.38**	5.92 **2.53**	6.75 **2.69**	8.11 **2.93**	10.24 **3.27**	14.18 **3.83**	17.11 **4.19**	21.19 **4.65**	26.23 **5.53**	30.12 **5.72**	32.31 **5.49**	29.7 **5.27**	27.3 **5.15**	26.10 **4.98**	24.32 **4.78**	22.44 **4.78**	21.92 **4.73**	20.01 **4.52**	18.21 **4.32**	17.31 **4.22**				
	KP2			4.22 **2.17**	5.37 **2.59**	6.21 **2.93**	8.12 **3.27**	10.21 **3.44**	11.34 **3.76**	13.71 **4.31**	18.11 **4.41**	19.01 **4.53**	20.11 **4.60**	20.71 **4.34**	18.34 **4.30**	18.01 **4.22**	17.34 **4.18**	17.02 **4.18**	16.48 **4.12**	15.28 **3.97**	15.76 **4.03**	12.11 **3.55**	10.31 **3.28**		
	KP3					9.12 **3.10**	10.11 **3.25**	12.13 **3.55**	14.71 **3.90**	16.21 **4.08**	19.01 **4.41**	23.01 **4.84**	24.11 **4.96**	24.17 **4.96**	27.11 **5.25**	25.24 **5.07**	22.01 **4.74**	20.01 **4.52**	20.07 **4.53**	18.47 **4.35**	17.21 **4.20**	16.34 **4.10**	17.01 **4.18**	17.09 **4.19**	17.92 **4.29**
2004	KP1	6.27 **2.60**	6.82 **2.70**	7.11 **2.75**	8.21 **2.95**	10.94 **3.38**	14.31 **3.84**	17.21 **4.20**	21.71 **4.71**	27.21 **5.26**	31.11 **5.62**	32.21 **5.71**	29.21 **5.45**	28.01 **5.33**	27.11 **5.23**	24.31 **4.98**	27.21 **5.26**	20.72 **4.60**	20.47 **4.57**	19.47 **4.46**	19.21 **4.43**				
	KP2			4.98 **2.34**	6.79 **2.70**	6.78 **2.69**	8.72 **3.03**	11.41 **3.45**	11.92 **3.52**	13.74 **3.77**	18.17 **4.32**	19.98 **4.52**	20.41 **4.57**	21.34 **4.67**	18.61 **4.37**	18.34 **4.34**	18.21 **4.32**	17.34 **4.22**	16.61 **4.13**	15.34 **3.97**	15.51 **4.00**	13.09 **3.68**	12.11 **3.55**		
	KP3					10.23 **3.27**	11.71 **3.49**	12.74 **3.63**	13.98 **3.80**	15.11 **3.95**	19.32 **4.45**	20.01 **4.52**	20.51 **4.58**	23.72 **4.92**	26.21 **5.16**	24.10 **4.95**	21.31 **4.67**	20.02 **4.52**	20.12 **4.54**	18.14 **4.31**	18.11 **4.31**	16.34 **4.10**	17.07 **4.19**	17.00 **4.18**	16.32 **4.10**
2005	KP1	5.32 **2.41**	5.87 **2.52**	6.65 **2.67**	8.02 **2.91**	9.31 **3.13**	13.18 **9.69**	16.34 **4.10**	18.21 **4.32**	21.34 **4.67**	23.71 **4.92**	29.12 **5.44**	21.12 **4.64**	26.11 **5.15**	25.17 **5.06**	23.19 **4.86**	22.72 **4.81**	19.84 **4.50**	19.71 **4.49**	19.41 **4.46**	19.11 **4.42**				
	KP2			4.67 **2.27**	5.21 **2.38**	6.12 **2.57**	8.02 **2.91**	11.34 **3.44**	11.21 **3.42**	12.98 **3.67**	16.33 **4.10**	18.72 **4.38**	20.14 **4.54**	20.92 **4.62**	19.11 **4.42**	18.71 **4.38**	18.34 **4.34**	27.27 **5.26**	16.42 **4.11**	14.11 **3.82**	13.24 **3.70**	12.11 **3.55**	11.01 **3.99**		
	KP3					9.02 **3.08**	9.72 **3.19**	11.21 **3.42**	13.37 **3.72**	14.12 **3.82**	18.71 **4.38**	22.34 **4.77**	24.02 **4.95**	24.61 **5.01**	25.81 **5.12**	26.13 **5.16**	22.21 **4.76**	20.11 **4.53**	20.21 **9.55**	18.51 **4.36**	17.31 **4.22**	16.44 **4.11**	17.12 **4.19**	17.17 **4.20**	17.48 **4.24**
2006	KP1	4.96 **2.33**	5.37 **2.42**	6.34 **2.61**	8.78 **3.04**	10.67 **3.34**	12.12 **3.55**	12.98 **3.67**	14.78 **3.90**	16.62 **4.13**	21.12 **4.64**	26.91 **5.23**	21.32 **4.67**	20.18 **4.54**	19.11 **4.42**	18.78 **4.39**	18.21 **4.32**	18.01 **4.30**	17.97 **4.29**	16.31 **4.10**	14.01 **3.81**				
	KP2			4.92 **2.32**	5.71 **2.44**	6.91 **2.72**	8.17 **2.94**	11.11 **3.40**	12.34 **9.58**	12.76 **3.64**	13.72 **3.77**	16.19 **4.08**	20.17 **4.54**	20.42 **4.57**	18.21 **4.32**	18.34 **4.34**	17.11 **4.19**	17.34 **4.22**	16.43 **4.11**	14.11 **3.82**	15.01 **3.93**	13.91 **3.79**	13.87 **3.79**		
	KP3					8.91 **3.06**	10.17 **3.26**	12.31 **3.57**	14.81 **3.91**	16.31 **4.10**	18.34 **4.34**	22.81 **4.82**	23.71 **4.92**	24.11 **4.96**	27.61 **5.30**	23.24 **4.87**	22.12 **4.75**	22.62 **4.80**	20.11 **4.53**	16.14 **4.07**	17.78 **4.27**	16.34 **4.10**	15.19 **3.96**	15.02 **3.93**	14.98 **3.93**

Bold figures are square root transformed value

Table.4.4.4: Incidence and relative abundance of BPH on *boro* crop of three different cultivation times

Year	Cultivation times	Pest infestation in standard meteorological weeks (SMW)																							
		46	**47**	**48**	**49**	**50**	**51**	**52**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
2003	BP1	4.8 **2.30**	4.9 **2.32**	5.7 **2.48**	7.4 **2.81**	9.3 **3.13**	11.8 **3.50**	16.2 **4.08**	20.7 **4.60**	21.7 **4.71**	21.9 **4.73**	24.3 **4.97**	19.7 **4.49**	19.1 **4.42**	18.7 **4.38**	18.2 **4.32**	17.4 **4.23**	17.1 **4.19**	16.7 **4.14**	15.8 **4.03**	12.1 **3.54**				
	BP2			4.2 **2.16**	4.7 **2.28**	5.1 **2.36**	5.7 **2.48**	8.7 **3.03**	8.9 **3.06**	13.7 **3.76**	16.3 **4.09**	18.4 **4.34**	18.1 **4.31**	13.2 **3.70**	13.7 **3.76**	11.2 **3.42**	11.5 **3.46**	10.4 **3.30**	8.2 **2.94**	8.1 **2.93**	5.3 **2.40**	5.1 **2.30**	4.2 **2.16**		
	BP3					5.7 **2.48**	9.7 **3.19**	11.4 **3.44**	14.8 **3.91**	16.5 **4.12**	18.2 **4.32**	18.7 **4.38**	17.4 **4.23**	17.1 **4.19**	16.9 **4.17**	16.3 **4.09**	16.1 **4.07**	15.8 **4.03**	15.3 **3.97**	15.1 **3.94**	14.7 **3.89**	12.7 **3.63**	12.1 **3.54**	11.4 **3.44**	9.8 **3.30**
2004	BP1	4.6 **2.25**	4.7 **2.28**	5.5 **2.44**	7.3 **2.79**	9.1 **3.09**	11.7 **3.49**	16.1 **4.09**	20.2 **4.54**	21.5 **4.69**	20.4 **4.57**	23.2 **4.86**	19.2 **4.43**	18.7 **4.38**	18.1 **4.31**	17.9 **4.28**	17.2 **4.20**	16.8 **4.15**	16.2 **4.08**	15.4 **3.98**	11.9 **3.52**				
	BP2			4.7 **2.28**	5.1 **2.36**	5.3 **2.40**	5.9 **2.52**	7.8 **2.88**	8.4 **2.98**	12.9 **3.66**	16.2 **4.08**	17.4 **4.23**	17.3 **4.21**	12.7 **3.63**	12.8 **3.64**	11.1 **3.40**	11.3 **3.43**	10.2 **3.27**	8.1 **2.93**	6.9 **2.72**	5.1 **2.36**	5.3 **2.40**	4.9 **2.32**		
	BP3					5.4 **2.42**	9.3 **3.13**	11.2 **3.42**	13.7 **3.76**	15.3 **3.97**	15.8 **4.03**	16.8 **4.15**	17.2 **4.20**	17.0 **4.18**	16.4 **4.11**	16.2 **4.08**	15.8 **4.03**	15.4 **3.98**	15.1 **3.94**	14.9 **3.92**	14.4 **3.86**	11.9 **3.52**	11.7 **3.42**	11.4 **3.44**	10.2 **3.27**
2005	BP1	5.2 **2.3**	5.1 **2.36**	5.6 **2.46**	6.9 **2.72**	7.8 **2.88**	9.12 **3.10**	14.21 **3.83**	18.43 **4.35**	19.76 **4.50**	23.21 **4.86**	24.81 **5.03**	19.53 **4.47**	19.86 **4.51**	18.81 **4.39**	18.52 **4.36**	17.61 **4.25**	18.89 **4.40**	16.82 **4.16**	15.91 **4.05**	12.70 **3.63**				
	BP2			4.51 **2.23**	4.78 **2.29**	5.32 **2.41**	5.82 **2.51**	7.91 **2.90**	8.42 **2.98**	12.81 **3.64**	15.0 **3.93**	17.51 **4.24**	18.23 **4.32**	12.73 **3.63**	12.92 **3.66**	11.11 **3.40**	11.31 **3.43**	10.21 **3.27**	8.70 **3.03**	7.41 2.81	5.51 **2.45**	5.57 **2.46**	4.82 **2.30**		
	BP3					5.12 **2.37**	6.72 **2.68**	8.87 **3.06**	11.34 **3.44**	14.52 **3.87**	16.27 **4.09**	18.11 **4.31**	18.96 **4.41**	18.43 **4.35**	17.52 **4.24**	17.32 **4.22**	17.15 **4.20**	16.42 **4.11**	16.23 **4.09**	16.11 **4.07**	15.72 **4.02**	15.22 **3.96**	14.81 **3.91**	14.31 **3.84**	14.10 **3.82**
2006	BP1	4.21 **2.1**	4.72 **2.28**	5.54 **2.45**	6.92 **2.72**	7.73 **2.86**	8.85 **3.05**	12.43 **3.59**	16.23 **4.09**	18.75 **4.38**	20.32 **4.56**	22.41 **4.78**	25.71 **5.11**	28.10 **5.34**	21.72 **4.71**	19.52 **4.47**	19.11 **4.42**	18.41 **4.34**	17.93 **4.29**	17.13 **4.19**	15.27 **3.19**				
	BP2			4.35 **2.20**	4.28 **2.18**	5.57 **2.46**	5.78 **2.50**	8.23 **2.95**	8.78 **3.04**	12.45 **3.59**	15.21 **3.96**	17.42 **4.23**	17.52 **4.24**	12.71 **3.63**	12.80 **3.64**	11.11 **3.40**	11.29 **3.43**	8.91 **3.06**	8.41 **2.98**	7.61 **2.84**	7.41 **2.81**	7.13 **2.76**	6.81 **2.70**		
	BP3					5.81 **2.51**	7.21 **2.77**	9.65 **3.18**	12.11 **3.55**	15.72 **4.02**	17.42 **4.23**	18.21 **4.32**	18.96 **4.11**	21.22 **4.66**	19.23 **4.44**	18.89 **4.40**	16.65 **4.14**	15.96 **4.05**	15.23 **3.96**	14.74 **3.90**	14.19 **3.83**	13.76 **3.77**	12.43 **3.59**	9.98 **3.23**	9.25 **3.12**

Bold figures are square root transformed value

Alam (1971) found in India the largest light-trap catch during the first half of the year. Ho and Liu (1969) stated that the insect density was greater in the first crop in China than in the second. Double or continuous cropping with staggered plantation during late *kharif* season contributes to BPH out break. Early plantation disfavours the generation of suitable alternative hosts. The longer a suitable host plant in the field in a given year, the greater is the chance of the pest population to reach peak densities in the next crop. In case of delayed and asynchronous plantation, the insect may easily disperse from one field to another, and spread infestation from old crop to young. Early plantation will break in between the consecutive crops is one of the possible ways to keep the BPH menace at sub-threshold level. High temperature with optimum RH is associated with high pest number. A range of 70-80% RH is optimum for BPH development (Bhatnagar *et al.* 1999). Adoption of high seedling number / hill at late plantation combined with high density hills results in a dense plant canopy holding high moisture, are regarded be a critical complex factor that indulges the high BPH population build up. Because, egg of BPH have tolerance to high temperature than do the nymphs and adults (Pathak *et al.* 1983). High temperature influences even seasonal abundance. Therefore, the time of planting may be suited in such a way that the greater part of the vegetative stages of paddy pass through the time before the ambient temperature attains the high level congenial to embryonic development of BPH (Srivastava *et al.* 1976).

4.2.3 Gall midge

Population dynamics

On kharif crop: GM population fluctuated considerably throughout the cultivation season. In KP1, GM population initiated at 20 SMW, maintained in low numbers up to 25 SMW, and then maximized at 32 SMW. In KP2, early low population at seed bed immediately was followed by gradual increase in number which was maintained up to 30 SMW. Maximum number of GM was noted at 35 SMW after which the population gradually subsumed. KP3 registered the maximum GM number at 33 SMW (2.32 individuals / hill) and the least at 24 SMW (0.82 individuals / hill) (Table.4.2.5).

On *boro crop:* Though GM was low at seed bed stage, in BP1, it gradually increased from 8 SMW to 10 SMW, maximized at 16 SMW and after which the population declined steadily. The least number of individuals was noted at 46 SMW. In BP2 early low number of population improved gradually attaining the maximum at 17 SMW (0.38 individuals/hill). In BP3 a stable GM number was maintained from 4 to14 SMW after which the population subsumed rapidly (Table.4.2.6).

Interaction with crop phenology: During *kharif* season, KP3 crop recorded significantly the highest mean population of GM followed by KP1. While in case of KP2 least number of pest with an average 0.79 individual / hill was noted. In *boro* crop least number of GM was registered in BP2. While BP1 and BP3 accounted 0.12 and 0.34 individual / hill respectively.

Infestation and damage to the tillers by GM mainly occur at late tillering stage which synchronizes with the peak incidence of the pest at about 60-75 DAT. Irrespective of differences in the seedling number / hills, percentage of damaged tillers varies insignificantly.

Discussion: Maximum damage occurs during the months of October, ranging up to 37.08 % in some provinces of southern parts of India. Present findings is at par with that of Suresh *et al.* (1992) who viewed that GM incidence was significantly higher at vegetative stage during delayed plantation. Present observation also corroborates that of Hussain *et al.* (1996) who have reported from Assam that plantation between 2nd week of July and 1st week of September increase the infestation by 2.85 %. Present observation does not match with the findings of Jacob (1999) who has noted that no infestation occurs up to 2nd week of June in all the *kharif* crop in Kerala. Such variation arises due to the differences in the regional agro-climatic conditions.

Table.4.4.5: Incidence and relative abundance of GM on *kharif* crop of three different cultivation times

Year	Cultivation times	Pest infestation in standard meteorological weeks (SMW)																							
		20	**21**	**22**	**23**	**24**	**25**	**26**	**27**	**28**	**29**	**30**	**31**	**32**	**33**	**35**	**36**	**37**	**38**	**39**	**40**	**41**	**42**	**43**	**44**
2003	KP1	0.47	0.68	0.69	0.71	0.79	0.81	1.21	1.44	1.71	1.76	1.83	1.97	2.12	2.10	2.01	1.23	1.04	0.98	0.95	0.91				
		0.98	**1.08**	**1.09**	**1.10**	**1.13**	**1.14**	**1.30**	**1.39**	**1.48**	**1.50**	**1.52**	**1.57**	**1.61**	**1.61**	**1.58**	**1.31**	**1.24**	**1.21**	**1.20**	**1.87**				
	KP2			0.35	0.41	0.53	0.60	0.73	0.82	0.88	0.94	0.98	1.01	1.00	1.07	1.12	1.13	1.05	0.77	0.55	0.42	0.35	0.38		
				0.92	**0.95**	**1.01**	**1.04**	**1.10**	**1.14**	**1.19**	**1.20**	**1.21**	**1.22**	**1.22**	**1.25**	**1.27**	**1.27**	**1.24**	**1.12**	**1.02**	**0.95**	**0.92**	**0.93**		
	KP3					0.81	0.83	0.91	1.31	1.62	1.84	1.91	1.95	2.31	2.36	2.32	2.07	2.11	2.00	1.67	1.56	1.45	1.32	1.29	1.23
						1.14	**1.15**	**1.18**	**1.34**	**1.45**	**1.52**	**1.55**	**1.56**	**1.67**	**1.69**	**1.67**	**1.60**	**1.61**	**1.58**	**1.47**	**1.43**	**1.39**	**1.34**	**1.33**	**1.31**
2004	KP1	0.49	0.69	0.71	0.79	0.89	0.88	1.41	1.48	1.51	1.86	1.89	1.82	2.52	2.60	2.81	1.13	1.15	0.96	0.93	0.82				
		0.99	**1.09**	**1.10**	**1.13**	**1.17**	**1.17**	**1.38**	**1.40**	**1.41**	**1.53**	**1.54**	**1.52**	**1.73**	**1.76**	**1.81**	**1.27**	**1.28**	**1.20**	**1.19**	**1.14**				
	KP2			0.33	0.51	0.52	0.62	0.74	0.81	0.85	0.92	0.97	1.11	1.06	1.05	1.14	1.21	1.15	0.87	0.75	0.52	0.55	0.47		
				0.91	**1.00**	**1.00**	**1.05**	**1.11**	**1.14**	**1.16**	**1.19**	**1.21**	**1.26**	**1.24**	**1.24**	**1.28**	**1.30**	**1.28**	**1.17**	**1.11**	**1.09**	**1.02**	**0.98**		
	KP3					0.84	0.80	0.89	1.37	1.64	1.87	1.85	1.96	2.34	2.36	2.32	2.09	2.15	2.00	1.66	1.57	1.41	1.30	1.23	1.01
						1.15	1.14	1.17	1.36	1.46	1.53	1.53	1.56	1.68	1.69	1.67	1.60	1.62	1.58	1.46	1.43	1.38	1.34	1.31	1.22
2005	KP1	0.57	0.69	0.79	0.78	0.73	0.85	1.27	1.49	1.75	1.74	1.81	1.94	2.19	2.07	0.98	1.23	1.04	0.91	0.92	0.97				
		1.03	**1.09**	**1.13**	**1.13**	**1.10**	**1.16**	**1.33**	**1.41**	**1.50**	**1.49**	**1.51**	**1.56**	**1.64**	**1.60**	**1.21**	**1.31**	**1.24**	**1.18**	**1.19**	**1.21**				
	KP2			0.41	0.48	0.73	0.61	0.84	0.89	0.86	0.97	0.91	1.31	1.13	1.16	1.19	1.33	1.15	0.89	0.64	0.43	0.33	0.30		
				0.95	**0.98**	**1.10**	**1.05**	**1.1**	**1.17**	**1.16**	**1.21**	**1.18**	**1.34**	**1.29**	**1.28**	**1.30**	**1.35**	**1.28**	**1.17**	**1.06**	**0.96**	**0.91**	**0.89**		
	KP3					0.81	0.78	0.83	1.36	1.61	1.85	1.82	1.91	2.31	2.33	2.31	2.11	2.19	2.02	1.64	1.55	1.45	1.31	1.22	1.11
						1.14	**1.13**	**1.15**	**1.36**	**1.45**	**1.53**	**1.52**	**1.55**	**1.67**	**1.68**	**1.67**	**1.61**	**1.64**	**1.58**	**1.46**	**1.43**	**1.39**	**1.34**	**1.31**	**1.26**
2006	KP1	0.41	0.60	0.61	0.61	0.91	0.84	1.21	1.54	1.81	1.79	1.83	2.17	2.52	2.30	2.03	1.43	1.09	0.98	0.99	0.95				
		0.97	**0.99**	**1.06**	**1.07**	**1.15**	**1.15**	**1.30**	**1.42**	**1.51**	**1.51**	**1.53**	**1.63**	**1.73**	**1.67**	**1.59**	**1.38**	**1.26**	**1.21**	**1.22**	**1.20**				
	KP2			0.45	0.49	0.63	0.65	0.83	0.84	0.87	0.98	0.94	1.21	1.10	1.06	1.12	1.23	1.09	0.87	0.65	0.49	0.39	0.31		
				0.97	**0.99**	**1.06**	**1.07**	**1.15**	**1.15**	**1.17**	**1.21**	**1.20**	**1.30**	**1.26**	**1.24**	**1.27**	**1.31**	**1.26**	**1.17**	**1.07**	**0.99**	**0.94**	**0.90**		
	KP3					0.83	0.79	0.84	1.39	1.65	1.89	1.89	1.90	2.21	2.23	2.30	2.10	2.13	2.06	1.61	1.58	1.48	1.35	1.25	1.18
						1.15	**1.13**	**1.15**	**1.37**	**1.46**	**1.54**	**1.54**	**1.54**	**1.64**	**1.64**	**1.65**	**1.67**	**1.61**	**1.60**	**1.45**	**1.44**	**1.40**	**1.36**	**1.32**	**1.29**

Bold figures are square root transformed value

Table.4.4.6: Incidence and relative abundance of GM on *boro* crop of three different cultivation times

Year	Cultivation times	Pest infestation in standard meteorological weeks (SMW)																							
		46	47	48	49	50	51	52	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
2003	BP1	0.09 **0.76**	0.04 **0.73**	0.03 **0.72**	0.03 **0.72**	0.01 **0.71**	0.02 **0.72**	0.02 **0.72**	0.05 **0.74**	0.05 **0.74**	0.01 **0.71**	0.07 **0.75**	0.12 **0.78**	0.15 **0.80**	0.15 **0.80**	0.19 **0.83**	0.16 **0.81**	0.09 **0.76**	0.17 **0.81**	0.23 **0.85**	0.34 **0.91**				
	BP2			0.09 **0.76**	0.12 **0.78**	0.09 **0.76**	0.08 **0.76**	0.13 **0.79**	0.17 **0.81**	0.17 **0.81**	0.19 **0.83**	0.16 **0.81**	0.17 **0.81**	0.21 **0.84**	0.26 **0.87**	0.31 **0.90**	0.32 **0.90**	0.29 **0.88**	0.33 **0.91**	0.36 **0.92**	0.35 **0.92**	0.38 **0.93**	0.38 **0.93**		
	BP3					0.17 **0.81**	0.21 **0.84**	0.26 **0.87**	0.31 **0.91**	0.32 **0.90**	0.29 **0.88**	0.33 **0.91**	0.36 **0.92**	0.35 **0.92**	0.38 **0.93**	0.38 **0.93**	0.41 **0.95**	0.43 **0.96**	0.47 **0.98**	0.32 **0.90**	0.37 **0.93**	0.33 **0.91**	0.35 **0.92**	0.39 **0.94**	0.41 **0.95**
2004	BP1	0.04 **0.73**	0.03 **0.72**	0.03 **0.72**	0.01 **0.71**	0.02 **0.72**	0.02 **0.72**	0.05 **0.74**	0.05 **0.74**	0.01 **0.71**	0.07 **0.75**	0.12 **0.78**	0.15 **0.80**	0.15 **0.80**	0.19 **0.83**	0.16 **0.81**	0.09 **0.76**	0.17 **0.81**	0.23 **0.85**	0.34 **0.85**	0.37 **0.91**				
	BP2			0.09 **0.76**	0.08 **0.76**	0.13 **0.79**	0.17 **0.81**	0.17 **0.81**	0.19 **0.83**	0.16 **0.81**	0.17 **0.81**	0.21 **0.84**	0.26 **0.87**	0.31 **0.90**	0.32 **0.90**	0.29 **0.91**	0.33 **0.92**	0.36 **0.92**	0.35 **0.93**	0.38 **0.93**	0.38 **0.93**	0.39 **0.94**	0.36 **0.92**		
	BP3					0.33 **0.91**	0.36 **0.92**	0.35 **0.93**	0.38 **0.93**	0.38 **0.87**	0.26 **0.90**	0.31 **0.90**	0.32 **0.88**	0.29 **0.91**	0.33 **0.92**	0.36 **0.92**	0.35 **0.93**	0.38 **0.90**	0.32 **0.88**	0.29 **0.91**	0.33 **0.92**	0.36 **0.94**	0.39 **0.99**	0.39 **0.95**	0.41 **0.99**
2005	BP1	0.03 **0.72**	0.01 **0.71**	0.02 **0.72**	0.02 **0.72**	0.05 **0.74**	0.05 **0.74**	0.01 **0.71**	0.07 **0.75**	0.12 **0.78**	0.15 **0.80**	0.15 **0.80**	0.19 **0.83**	0.16 **0.81**	0.09 **0.76**	0.17 **0.81**	0.23 **0.85**	0.34 **0.91**	0.25 **0.86**	0.24 **0.86**	0.31 **0.90**				
	BP2			0.08 **0.76**	0.13 **0.79**	0.17 **0.81**	0.17 **0.81**	0.19 **0.83**	0.16 **0.81**	0.17 **0.81**	0.21 **0.84**	0.26 **0.87**	0.31 **0.90**	0.32 **0.90**	0.29 **0.88**	0.33 **0.91**	0.36 **0.92**	0.35 **0.92**	0.38 **0.93**	0.38 **0.93**	0.35 **0.92**	0.39 **0.94**	0.41 **0.95**		
	BP3					0.26 **0.87**	0.31 **0.90**	0.32 **0.90**	0.29 **0.88**	0.33 **0.91**	0.36 **0.92**	0.35 **0.92**	0.38 **0.93**	0.38 **0.93**	0.35 **0.92**	0.39 **0.94**	0.41 **0.95**	0.37 **0.93**	0.33 **0.91**	0.35 **0.92**	0.39 **0.94**	0.41 **0.95**	0.33 **0.91**	0.34 **0.91**	0.39 **0.94**
2006	BP1	0.01 **0.71**	0.02 **0.72**	0.02 **0.72**	0.05 **0.72**	0.05 **0.72**	0.01 **0.71**	0.07 **0.71**	0.12 **0.77**	0.15 **0.80**	0.15 **0.80**	0.19 **0.80**	0.16 **0.83**	0.09 **0.81**	0.17 **0.76**	0.23 **0.81**	0.34 **0.85**	0.36 **0.91**	0.39 **0.92**	0.27 **0.87**	0.26 **0.87**				
	BP2				0.09 **0.76**	0.08 **0.76**	0.13 **0.79**	0.17 **0.81**	0.17 **0.81**	0.19 **0.83**	0.16 **0.81**	0.17 **0.81**	0.21 **0.84**	0.26 **0.87**	0.31 **0.91**	0.32 **0.90**	0.29 **0.88**	0.33 **0.91**	0.36 **0.92**	0.35 **0.92**	0.38 **0.93**	0.36 **0.92**	0.40 **0.94**		
	BP3					0.29 **0.88**	0.33 **0.91**	0.36 **0.92**	0.35 **0.92**	0.38 **0.93**	0.38 **0.93**	0.35 **0.92**	0.39 **0.94**	0.41 **0.95**	0.37 **0.93**	0.33 **0.91**	0.35 **0.91**	0.39 **0.94**	0.41 **0.95**	0.33 **0.91**	0.34 **0.91**	0.39 **0.94**	0.37 **0.93**	0.41 **0.95**	0.47 **0.98**

Bold figures are square root transformed value

Rao (1981) has also found that *O. oryzae* is a major pest of late planted rice during wet season (May-November) in Krishna-Godavari delta of Andhra Pradesh. Srivastava *et al.* (1976) have commented that in Madhya Pradesh the incidence of GM continues from 36th to 43rd SMW, covering the months from September to October. The first peak has been found when the climatic parameters were about Tmax - 31^{0}C, Tmin - 24.2^{0}C and RH - 92.9 %. The conditions during the second peak were Tmax - 30.1^{0}C, Tmin - 20^{0}C and RH-90.4 %. Such abiotic factor dependence partly supports the present findings. The present findings partly supports Katanyukul *et al.* (1980) who have also reported from Sri Lanka that GM infestation is positively influenced by south west Monsoon (April-July). Israel *et al.* (1961) reported earlier those coastal and monsoonal states of India endemic to the pest after a heavy shower suggesting an early transplantation of paddy. The suggestive cultivation protocol in the present study is to follow an early transplantation, which is also supported by Kudagamage *et al.* (1981) who also have noted that an early transplantation minimizes GM attack.

4.2.4 Paddy bug

Population dynamics

On kharif crop: In KP1, attack by PB initiated at 20 SMW, maintained up to 24 SMW, and then maximized at 30 SMW. After 32 SMW the PB population declined steadily. In KP2, the initial low population increased gradually reaching the extreme at 32 SMW after which the population subsumed rapidly. In KP3, PB was active throughout the growth stages; maximum number was noted at 36 SMW (2.10 individuals / hill) while the minimum at 22 SMW (0.92 individuals / hill) (Table.4.2.7).

On boro crop: In BP1, the GM incidence was started at 46 SMW, maintained up to 49 SMW attaining the maximum at 9 SMW, then by 16 SMW it steadily declined. In BP2, PB number was low throughout the entire crop growth stages. The maximum and minimum number was recorded at 18 and 48 SMW respectively. In BP3, PB built up steadily attaining the maximum at 16 SMW. The least number was noted at 50 SMW (Table.4.2.8).

Table.4.4.7: Incidence and relative abundance of PB on *kharif* crop of three different cultivation times

Year	Cultivation times	Pest infestation in standard meteorological weeks (SMW)																							
		20	21	22	23	24	25	26	27	28	29	30	31	32	33	35	36	37	38	39	40	41	42	43	44
2003	KP1	0.98 **1.21**	1.21 **1.30**	1.54 **1.42**	1.53 **1.42**	1.72 **1.48**	1.88 **1.54**	2.23 **1.65**	2.44 **1.71**	2.83 **1.82**	2.76 **1.80**	2.61 **1.76**	2.55 **1.74**	2.43 **1.71**	2.12 **1.61**	1.90 **1.54**	1.78 **1.50**	1.75 **1.50**	1.56 **1.43**	1.43 **1.38**	1.27 **1.33**				
	KP2			0.92 **1.19**	0.97 **1.21**	1.23 **1.31**	1.28 **1.33**	1.71 **1.48**	1.54 **1.42**	1.73 **1.49**	1.88 **1.54**	1.91 **1.55**	1.97 **1.57**	2.12 **1.61**	2.01 **1.58**	2.08 **1.60**	1.91 **1.55**	1.45 **1.39**	1.12 **1.27**	1.07 **1.25**	0.98 **1.21**	0.97 **1.21**	0.95 **1.20**		
	KP3					1.24 **1.31**	1.42 **1.38**	1.61 **1.45**	1.63 **1.45**	1.71 **1.48**	1.81 **1.51**	1.88 **1.54**	1.92 **1.55**	2.38 **1.69**	2.87 **1.83**	3.21 **1.92**	3.50 **2.00**	2.41 **1.70**	2.21 **1.64**	2.12 **1.61**	2.08 **1.60**	1.97 **1.57**	1.81 **1.57**	1.72 **1.48**	1.75 **1.50**
2004	KP1	0.97 **1.21**	0.98 **1.21**	1.21 **1.30**	1.51 **1.41**	1.62 **1.45**	1.92 **1.55**	2.12 **1.61**	2.31 **1.67**	2.73 **1.79**	2.91 **1.84**	2.66 **1.77**	2.42 **1.70**	2.33 **1.68**	2.21 **1.64**	2.02 **1.58**	1.82 **1.52**	1.83 **1.52**	1.64 **1.46**	1.57 **1.43**	1.38 **1.37**				
	KP2			0.95 **1.20**	0.97 **1.21**	1.23 **1.31**	1.34 **1.35**	1.67 **1.47**	1.41 **1.38**	1.62 **1.45**	1.71 **1.48**	1.82 **1.52**	1.83 **1.52**	1.03 **1.23**	1.91 **1.55**	1.94 **1.56**	1.87 **1.53**	1.32 **1.34**	1.31 **1.34**	1.11 **1.26**	0.95 **1.20**	0.98 **1.21**	0.94 **1.20**		
	KP3					1.42 **1.38**	1.51 **1.41**	1.62 **1.45**	1.71 **1.48**	1.81 **1.51**	1.93 **1.55**	1.91 **1.55**	2.40 **1.70**	2.71 **1.79**	3.21 **1.92**	3.50 **2.00**	2.88 **1.83**	2.27 **1.66**	2.34 **1.68**	2.25 **1.65**	2.19 **1.64**	1.88 **1.54**	1.78 **1.50**	1.56 **1.43**	1.54 **1.42**
2005	KP1	1.12 **1.27**	1.31 **1.34**	1.56 **1.43**	1.66 **1.46**	1.76 **1.50**	1.77 **1.50**	1.91 **1.55**	2.21 **1.64**	2.60 **1.78**	2.81 **1.81**	2.71 **1.79**	2.51 **1.73**	2.44 **1.71**	2.20 **1.64**	2.12 **1.61**	1.90 **1.54**	1.80 **1.51**	1.71 **1.48**	1.61 **1.48**	1.43 **1.38**				
	KP2			0.91 **1.18**	0.97 **1.21**	1.23 **1.31**	1.33 1.35	1.83 **1.52**	1.61 **1.45**	1.81 **1.51**	2.11 **1.61**	2.15 **1.62**	2.19 **1.64**	2.21 **1.64**	2.16 **1.63**	2.00 **1.52**	2.17 **1.63**	1.51 **1.41**	1.23 **1.31**	1.15 **1.28**	1.23 **1.31**	1.12 **1.27**	0.98 **1.21**		
	KP3					1.31 **1.38**	1.42 **1.41**	1.51 **1.42**	1.52 **1.45**	1.63 **1.48**	1.71 **1.52**	1.82 **1.55**	1.93 **1.61**	2.11 **1.63**	2.17 **1.70**	2.42 **1.81**	2.81 **1.90**	3.11 **1.97**	3.42 **1.76**	2.61 **1.61**	2.11 **1.54**	1.90 **1.52**	1.82 **1.53**	1.54 **1.42**	1.44 **1.37**
2006	KP1	0.95 **1.20**	0.98 **1.21**	1.21 **1.30**	1.43 **1.38**	1.54 **1.42**	1.78 **1.50**	1.82 **1.52**	2.11 **1.61**	2.22 **1.64**	2.83 **1.82**	2.63 **1.76**	2.90 **1.84**	2.65 **1.77**	2.15 **1.62**	2.45 **1.71**	2.33 **1.68**	2.19 **1.64**	1.84 **1.52**	1.33 **1.35**	1.41 **1.38**				
	KP2			0.92 **1.19**	0.95 **1.20**	1.11 **1.26**	1.21 **1.30**	1.41 **1.38**	1.54 **1.42**	1.74 **1.49**	1.85 **1.53**	1.13 **1.27**	2.23 **1.65**	2.32 **1.67**	2.45 **1.71**	1.91 **1.55**	1.83 **1.52**	1.79 **1.51**	1.59 **1.44**	1.47 **1.40**	1.28 **1.33**	0.98 **1.21**	0.92 **1.19**		
	KP3					1.21 **1.30**	1.31 **1.34**	1.54 **1.42**	1.63 **1.45**	1.76 **1.50**	1.78 **1.50**	1.82 **1.52**	1.91 **1.55**	2.14 **1.62**	2.11 **1.61**	2.25 **1.65**	2.43 **1.71**	2.26 **1.66**	2.18 **1.63**	1.95 **1.56**	1.88 **1.54**	1.78 **1.50**	1.71 **1.48**	1.55 **1.43**	2.60 **1.70**

Bold figures are square root transformed value

Table.4.4.8: Incidence and relative abundance of PB on *boro*crop of three different cultivation times

Year	Cultivation times	Pest infestation in standard meteorological weeks (SMW)																							
		46	**47**	**48**	**49**	**50**	**51**	**52**	**04**	**05**	**06**	**07**	**08**	**09**	**10**	**11**	**12**	**13**	**14**	**15**	**16**	**17**	**18**	**19**	**20**
2003	BP1	0.24 **0.86**	0.38 **0.93**	0.72 **1.10**	0.92 **1.19**	1.01 **1.12**	1.07 **1.25**	1.31 **1.34**	1.20 **1.70**	1.20 **1.30**	1.41 **1.38**	1.71 **1.48**	1.91 **1.55**	2.42 **1.70**	2.31 **1.67**	2.11 **1.61**	2.22 **1.64**	1.90 **1.54**	1.71 **1.48**	1.51 **1.41**	1.56 **1.43**				
	BP2			0.31 **0.90**	0.41 **0.95**	0.53 **1.61**	0.62 **1.05**	0.84 **1.15**	0.92 **1.19**	0.93 **1.19**	0.97 **1.21**	0.96 **1.20**	1.14 **1.28**	1.26 **1.32**	1.42 **1.38**	1.71 **1.48**	1.53 **1.42**	1.55 **1.43**	1.67 **1.47**	0.97 **1.21**	0.93 **1.19**	0.97 **1.21**	0.91 **1.18**		
	BP3					0.62 **1.05**	0.75 **1.11**	0.81 **1.14**	1.11 **1.26**	1.21 **1.30**	1.30 **1.34**	1.32 **1.34**	1.51 **1.41**	1.61 **1.45**	1.64 **1.46**	1.69 **1.47**	1.75 **1.50**	2.11 **1.61**	2.33 **1.68**	2.21 **1.64**	2.71 **1.79**	2.13 **1.62**	1.61 **1.45**	1.52 **1.42**	1.41 **1.38**
2004	BP1	0.29 **0.88**	0.41 **0.95**	0.77 **1.12**	0.96 **1.20**	0.97 **1.21**	1.03 **1.23**	1.08 **1.25**	1.21 **1.30**	1.27 **1.33**	1.32 **1.34**	1.37 **1.36**	1.39 **1.37**	1.42 **1.38**	1.49 **1.41**	1.51 **1.41**	1.57 **1.43**	1.63 **1.45**	1.65 **1.46**	1.61 **1.45**	1.51 **1.41**				
	BP2			0.34 **0.91**	0.42 **0.95**	0.56 **1.02**	0.71 **1.10**	0.82 **1.14**	0.87 **1.17**	0.91 **1.18**	0.92 **1.19**	0.99 **1.22**	1.10 **1.26**	1.18 **1.79**	1.21 **1.30**	1.25 **1.32**	1.41 **1.38**	1.45 **1.39**	0.78 **1.13**	0.92 **1.19**	0.69 **1.09**	0.62 **1.05**	0.61 **1.05**		
	BP3					0.59 **1.04**	0.71 **1.10**	0.79 **1.13**	1.21 **1.30**	2.23 **1.65**	1.35 **1.36**	1.37 **1.36**	1.52 **1.42**	1.67 **1.47**	1.71 **1.48**	1.75 **1.30**	1.79 **1.39**	2.13 **1.62**	2.37 **1.69**	2.28 **1.66**	2.74 **1.80**	2.15 **1.62**	1.67 **1.47**	1.58 **1.44**	1.52 **1.42**
2005	BP1	0.32 **0.90**	0.39 **0.94**	0.81 **1.14**	0.93 **1.19**	1.12 **1.27**	1.16 **1.28**	1.32 **1.34**	1.14 **1.28**	1.21 **1.30**	1.41 **1.38**	1.68 **1.47**	1.82 **1.52**	2.31 **1.67**	2.24 **1.65**	2.12 **1.61**	2.15 **1.62**	1.81 **1.51**	1.62 **1.45**	1.42 **1.38**	1.39 **1.37**				
	BP2			0.22 **0.84**	0.41 **0.95**	0.62 **1.05**	0.78 **1.13**	0.92 **1.19**	0.98 **1.21**	1.01 **1.22**	1.03 **1.23**	1.12 **1.27**	1.21 **1.30**	1.24 **1.31**	1.29 **1.33**	1.31 **1.34**	1.34 **1.35**	1.36 **1.36**	1.41 **1.38**	1.28 **1.33**	1.12 **1.27**	0.98 **1.21**	0.77 **1.12**		
	BP3					0.71 **1.10**	0.82 **1.14**	0.89 **1.17**	0.93 **1.19**	1.21 **1.30**	1.27 **1.33**	1.31 **1.34**	1.39 **1.37**	1.41 **1.38**	1.47 **1.40**	1.51 **1.41**	1.62 **1.45**	1.71 **1.48**	1.79 **1.51**	1.82 **1.52**	1.32 **1.34**	2.12 **1.61**	1.12 **1.27**	0.98 **1.21**	0.95 **1.20**
2006	BP1	0.28 **0.88**	0.37 **0.93**	0.78 **1.13**	0.79 **1.13**	0.97 **1.21**	0.98 **1.21**	0.72 **1.10**	0.18 **0.82**	0.21 **0.84**	0.28 **0.88**	0.31 **0.90**	0.47 **0.98**	0.89 **1.17**	1.12 **1.27**	1.21 **1.30**	1.38 **1.37**	1.41 **1.38**	1.42 **1.38**	1.47 **1.40**	0.98 **1.21**				
	BP2			0.37 **0.93**	0.31 **0.90**	0.55 **1.02**	0.69 **1.09**	0.87 **1.17**	0.91 **1.18**	0.93 **1.19**	0.98 **1.21**	1.22 **1.31**	1.29 **1.33**	1.37 **1.36**	1.42 **1.38**	1.69 **1.47**	1.71 **1.48**	1.82 **1.52**	1.88 **1.54**	2.10 **1.61**	2.31 **1.67**	2.22 **1.64**	2.37 **1.69**		
	BP3					0.69 **1.09**	0.71 **1.10**	0.89 **1.17**	0.92 **1.19**	1.13 **1.27**	1.17 **1.29**	1.27 **1.33**	1.31 **1.34**	1.37 **1.36**	1.49 **1.41**	1.62 **1.45**	1.69 **1.47**	2.11 **1.61**	2.32 **1.67**	2.61 **1.76**	2.69 **1.78**	2.41 **1.70**	2.32 **1.67**	1.81 **1.51**	1.61 **1.45**

Bold figures are square root transformed value

Table.4.4.9: Average incidence and relative abundance of four pests on *kharif* crop of three different cultivation times

Year	Cultivation times	Pest infestation in standard meteorological weeks (SMW)																							
		20	21	22	23	24	25	26	27	28	29	30	31	32	33	35	36	37	38	39	40	41	42	43	44
YSB	KP1	2.32 **1.67**	3.39 **1.97**	3.41 **1.98**	2.63 **1.76**	1.34 **1.35**	1.29 **1.33**	2.39 **1.70**	3.32 **2.41**	4.47 **2.22**	2.40 **1.70**	2.63 **1.76**	1.46 **1.40**	1.67 **1.47**	2.53 **1.74**	5.51 **2.45**	3.63 **2.03**	3.74 **2.05**	3.38 **1.96**	2.76 **1.80**	3.42 **1.97**				
	KP2			1.67 **1.47**	2.39 **1.71**	1.45 **1.39**	0.74 **1.11**	2.23 **1.64**	2.54 **1.74**	2.59 **1.75**	2.98 **1.86**	1.63 **1.45**	0.60 **1.04**	0.72 **1.10**	1.46 **0.97**	2.77 **1.80**	1.61 **1.45**	1.82 **1.52**	2.23 **1.65**	1.68 **1.47**	1.80 **1.51**	2.40 **1.70**	2.68 **1.78**		
	KP3					2.46 **172**	2.72 **1.79**	2.76 **1.80**	2.83 **1.82**	3.80 **2.07**	3.41 **1.97**	3.61 **2.02**	3.65 **2.03**	2.68 **1.78**	2.84 **1.82**	3.52 **2.00**	2.49 **1.72**	3.47 **1.99**	3.66 **2.03**	3.71 **2.05**	4.77 **2.22**	4.44 **2.22**	4.94 **2.33**	5.16 **2.37**	5.59 **2.46**
BPH	KP1	5.41 **2.43**	5.19 **2.54**	6.71 **2.68**	8.28 **2.89**	10.29 **3.28**	13.44 **3.73**	15.91 **4.05**	18.97 **4.41**	22.28 **4.83**	27.01 **5.19**	30.13 **5.53**	27.83 **5.08**	25.40 **5.08**	24.37 **4.98**	22.33 **4.81**	21.39 **4.81**	20.12 **4.54**	19.54 **4.47**	18.33 **4.34**	17.91 **4.43**				
	KP2			4.69 **2.27**	5.52 **2.50**	6.50 **2.64**	8.85 **2.95**	11.01 **3.34**	11.70 **3.49**	13.29 **3.71**	16.58 **4.13**	18.47 **4.35**	20.20 **4.54**	20.89 **4.61**	18.56 **4.36**	12.57 **4.34**	17.75 **4.27**	17.24 **4.49**	16.48 **4.12**	14.71 **3.90**	14.88 **3.92**	12.80 **3.64**	11.82 **3.50**		
	KP3					4.32 **3.13**	10.31 **3.30**	12.09 **3.54**	14.21 **3.83**	15.43 **3.99**	18.84 **4.34**	22.04 **4.74**	23.08 **4.85**	24.45 **4.96**	26.68 **5.21**	25.17 **5.01**	21.91 **4.73**	20.70 **4.60**	20.11 **4.54**	17.81 **4.27**	17.60 **4.25**	16.36 **4.10**	16.59 **4.13**	16.57 **4.13**	16.80 **4.14**
GM	KP1	0.48 **0.98**	0.66 **1.07**	0.70 **1.09**	0.72 **1.10**	0.83 **1.15**	0.84 **1.15**	1.27 **1.33**	1.48 **1.40**	1.69 **1.47**	1.78 **1.50**	1.84 **1.52**	1.37 **1.57**	2.33 **1.68**	2.26 **1.66**	1.35 **1.56**	1.25 **1.32**	1.08 **1.25**	0.95 **1.20**	0.99 **1.20**	0.31 **1.18**				
	KP2			0.38 **0.93**	0.47 **0.98**	0.60 **1.04**	0.62 **1.05**	0.76 **1.13**	0.84 **1.15**	0.86 **1.16**	0.35 **1.20**	0.35 **1.20**	1.16 **1.28**	1.07 **1.25**	1.08 **1.25**	1.14 **1.28**	1.22 **1.31**	1.11 **1.26**	0.85 **1.16**	0.64 **1.06**	0.46 **0.97**	0.40 **0.94**	0.36 **0.92**		
	KP3					0.82 **1.14**	0.80 **1.14**	0.86 **1.16**	1.49 **1.41**	1.63 **1.45**	1.80 **1.53**	1.86 **1.53**	1.93 **1.55**	2.29 **1.67**	2.32 **1.67**	2.31 **1.67**	2.09 **1.60**	2.14 **1.62**	2.02 **1.58**	1.64 **1.46**	1.56 **1.43**	1.44 **1.39**	1.32 **1.34**	1.24 **1.31**	1.13 **1.27**
PB	KP1	1.00 **1.22**	1.11 **1.27**	1.35 **1.37**	1.51 **1.42**	1.63 **1.46**	1.77 **1.52**	1.47 **1.58**	2.25 **1.66**	2.57 **1.75**	2.80 **1.82**	2.62 **1.77**	2.57 **1.75**	2.42 **1.72**	2.25 **1.65**	2.10 **1.61**	1.92 **1.56**	1.85 **1.54**	1.65 **1.47**	1.45 **1.40**	1.32 **1.36**				
	KP2			0.92 **1.19**	0.96 **1.20**	1.17 **1.30**	1.25 **1.33**	1.62 **1.46**	1.50 **1.42**	1.70 **1.48**	1.85 **1.54**	1.97 **1.50**	2.00 **1.59**	2.15 **1.55**	2.10 **1.62**	1.95 **1.57**	1.90 **1.56**	1.47 **1.41**	1.25 **1.34**	1.15 **1.30**	1.58 **1.26**	1.00 **1.22**	0.94 **1.20**		
	KP3					1.27 **1.33**	1.40 **1.38**	1.55 **1.43**	1.60 **1.45**	1.70 **1.48**	1.77 **1.51**	1.82 **1.53**	2.02 **1.59**	2.25 **1.68**	2.55 **1.75**	2.82 **1.82**	2.87 **1.84**	2.47 **1.73**	2.50 **1.74**	2.20 **1.68**	2.00 **1.60**	1.82 **1.54**	1.75 **1.50**	1.55 **1.44**	1.55 **1.52**

Bold figures are square root transformed value

Table.4.4.10: Average incidence and relative abundance of four pests on *boro* crop of three different cultivation times

Year	Cultivation times	Pest infestation in standard meteorological weeks (SMW)																							
		46	47	48	49	50	51	52	04	05	06	07	08	09	10	11	12	13	14	15	16	17	18	19	20
YSB	BP1	0.70 **1.09**	1.62 **1.95**	2.15 **1.62**	2.08 **1.60**	0.31 **1.18**	0.34 **1.20**	1.32 **1.34**	2.10 **1.61**	2.27 **1.66**	1.88 **1.54**	1.35 **1.56**	1.31 **1.34**	1.44 **1.39**	1.56 **1.43**	1.32 **1.55**	2.33 **1.68**	2.09 **1.60**	1.59 **1.44**	1.46 **1.40**	1.24 **1.31**				
	BP2			0.73 **1.10**	0.63 **1.10**	0.55 **1.06**	0.72 **1.02**	1.90 **1.10**	1.49 **1.54**	1.59 **1.41**	1.68 **1.44**	1.06 **1.47**	0.75 **1.24**	0.90 **1.11**	1.26 **1.18**	2.15 **1.32**	1.20 **1.62**	0.90 **1.30**	1.12 **1.18**	1.45 **1.27**	1.56 **1.39**	1.81 **1.43**	1.57 **1.51**		
	BP3					1.61 **1.45**	1.64 **1.46**	1.62 **1.45**	1.68 **1.47**	1.86 **1.53**	2.33 **1.68**	1.74 **1.49**	1.68 **1.47**	1.72 **1.48**	1.84 **1.52**	1.83 **1.52**	1.52 **1.42**	1.66 **1.46**	1.79 **1.51**	1.89 **1.54**	2.06 **1.60**	2.26 **1.66**	2.61 **1.76**	2.03 **1.59**	2.39 **1.70**
BPH	BP1	4.70 **2.28**	4.85 **2.31**	5.57 **2.46**	7.12 **2.76**	8.87 **2.99**	10.35 **3.29**	14.72 **3.90**	18.87 **4.40**	20.4 **4.57**	21.45 **4.68**	23.67 **4.91**	21.02 **4.64**	21.42 **4.68**	19.32 **4.45**	18.52 **4.36**	17.82 **4.28**	17.82 **4.27**	16.90 **4.17**	16.05 **4.06**	12.93 **3.67**				
	BP2			4.42 **2.22**	4.67 **2.28**	5.30 **2.41**	5.77 **2.50**	8.15 **2.94**	8.60 **3.01**	12.95 **3.66**	15.77 **4.02**	17.67 **4.26**	17.77 **4.27**	12.82 **3.65**	13.05 **3.68**	11.12 **3.41**	11.32 **3.44**	9.95 **3.22**	2.35 **2.97**	7.25 **2.82**	5.82 **2.51**	5.75 **2.50**	5.17 **2.38**		
	BP3					5.50 **2.44**	8.22 **2.95**	10.25 **3.28**	12.97 **3.67**	15.50 **4.00**	16.90 **4.17**	17.95 **4.29**	18.10 **4.31**	18.42 **4.35**	17.50 **4.24**	17.15 **4.20**	16.35 **4.11**	15.87 **4.04**	15.45 **3.99**	15.20 **3.96**	14.72 **3.90**	13.37 **3.72**	12.75 **3.64**	11.75 **3.50**	10.82 **3.36**
GM	BP1	0.04 **0.73**	0.02 **0.72**	0.02 **0.72**	0.85 **0.74**	0.03 **0.72**	0.02 **0.72**	0.03 **0.72**	0.07 **0.75**	0.08 **0.76**	0.09 **0.76**	0.13 **0.79**	0.05 **0.80**	0.13 **0.79**	0.15 **0.80**	0.18 **0.82**	0.82 **0.83**	0.24 **0.86**	0.26 **0.87**	0.27 **0.87**	0.32 **0.90**				
	BP2			0.08 **0.76**	0.11 **0.78**	0.11 **0.78**	0.13 **0.79**	0.16 **0.81**	0.17 **0.81**	0.17 **0.81**	0.16 **0.82**	0.20 **0.83**	0.23 **0.85**	0.27 **0.87**	0.29 **0.88**	0.31 **0.90**	0.32 **0.90**	0.33 **0.91**	0.35 **0.92**	0.36 **0.92**	0.36 **0.92**	0.35 **0.92**	0.20 **0.83**		
	BP3					0.26 **0.87**	0.30 **0.89**	0.32 **0.90**	0.33 **0.91**	0.35 **0.92**	0.32 **0.90**	0.33 **0.91**	0.36 **0.92**	0.35 **0.92**	0.35 **0.92**	0.36 **0.92**	0.38 **0.93**	0.39 **0.94**	0.38 **0.93**	0.32 **0.90**	0.35 **0.92**	0.37 **0.94**	0.36 **0.92**	0.38 **0.93**	0.42 **0.95**
PB	BP1	0.28 **0.88**	0.38 **0.93**	0.77 **1.12**	0.91 **1.18**	1.01 **1.22**	1.06 **1.24**	0.95 **1.26**	0.93 **1.19**	0.97 **1.21**	1.10 **1.26**	1.26 **1.32**	1.39 **1.37**	1.75 **1.50**	1.78 **1.51**	1.73 **1.49**	1.82 **1.52**	1.68 **1.47**	1.59 **1.44**	1.50 **1.41**	1.34 **1.36**				
	BP2			0.31 **0.90**	0.43 **0.93**	0.56 **1.02**	0.70 **1.09**	0.86 **1.16**	0.92 **1.19**	0.94 **1.20**	0.97 **1.21**	1.07 **1.25**	1.17 **1.29**	1.24 **1.32**	1.33 **1.35**	1.48 **1.41**	1.49 **1.41**	1.53 **1.42**	1.41 **1.38**	1.26 **1.61**	1.27 **1.32**	1.19 **1.30**	2.66 **1.36**		
	BP3					0.65 **1.07**	0.74 **1.11**	0.84 **1.15**	1.04 **1.24**	1.44 **1.39**	1.27 **1.33**	1.31 **1.34**	1.43 **1.38**	1.51 **1.41**	1.57 **1.43**	1.64 **1.46**	1.71 **1.48**	2.01 **1.58**	2.19 **1.64**	2.22 **1.65**	2.51 **1.69**	2.19 **1.64**	1.68 **1.47**	1.46 **1.40**	1.37 **1.36**

Bold figures are square root transformed value

Interaction with crop phenology: Infestation of PB mainly occurs at panicle initiation stage. KP1 crop records significantly higher mean population (1.29 individuals / hill) followed closely by KP3 (1.63 individuals / hill) However KP2 crop supports a lower number of PB with and average 1.10 individuals / hill.

Multi location trials at three blocks have shown that ripening stages support comparatively higher number of PB. Larger bold grain size of *Swarna Mashuri* provides enough opportunity for PB to get ample diet by single sucking. KP3 and BP3 allow the PB to interact positively with the milky stage of the growing panicles rendering high range of damage.

Asynchronization of the interactive growth stages of paddy with PB attack can effectively be done by an early transplantation (Saroja *et al.* 1985, Atwal 1993). In southern parts of West Bengal, Banerjee *et al.* (1965) has recommended for an early transplantation, because the active period of PB is between May to November. Srivastava and Saxena (1964) have observed that in Uttar Pradesh early rains in May-June encourages prolific weed growth which is conducive for PB multiplication.

4.2.5 Quantitative relative yield of paddy in reference to different time of plantation: Mean value of four consecutive years in relation to the SMW showed that the abundance of all the pests were least under KP2 and BP2 (Tables.4.2.9 and 4.2.10). As the collective average value of the pest differs considerably, variation has also been noted regarding the quantum of yield for three different cultivation protocols. The total yield loss is contributed by a pest complex rather than by a single pest. During *kharif* season the maximum yield (29.67 q / ha) was achieved under KP2 while in *boro* season, BP2 registered the highest yield (34.89 q / ha) (Tables.4.2.11 and 4.2.12).

Table.4.2.11: Relative average abundance of different pests (individuals / hill) in relation to the different times of *kharif* cultivation

Time of cultivation	Relative abundance of the pests				Yield q / ha
	YSB	BPH	GM	PB	
KP1	2.98±0.16	18.01±0.98	1.29±0.56	1.29±0.34	26.12
KP2	1.99±0.09	14.11±0.33	0.79±0.11	0.79±0.11	29.67
KP3	3.77±0.61	18.26±0.12	1.69±0.51	1.63±0.67	25.79

Table.4.2.12: Relative abundance of different pests (individuals / hill) in relation to the different times of *boro* cultivation

Time of cultivation	Relative abundance of the pests				Yield q / ha
	YSB	BPH	GM	PB	
BP1	1.63±0.88	15.10±0.98	0.12±0.09	1.22±0.11	31.18
BP2	1.25±0.48	9.60±0.21	0.25±0.07	1.10±0.09	34.89
BP3	2.01±0.23	14.25±0.33	0.34±0.07	1.53±0.07	32.49

Asynchronous plantation when the pests are least abundant can maximize the yield. Plantation for early time at about 22 SMW during *kharif* season and 48 SMW during *boro* season scored least pest activity. Initiation of cultivation before and after this time scale was found non economic and thus can be avoided. Less favourable climatic conditions at early plantation restricted grain generation. At late plantation high pest activity renders maximum loss.

4.3 Analysis of the Prevailing Cultivation Practices

4.3.1 Nature of cropping practices

4.3.1.1 Cropping time: Paddy is cultivated throughout the year in three consecutive periods of cultivation- *prekharif, kharif* and *boro* seasons. The adoption of high yielding varieties got its prominence over the local ones. In all the villages under experimentation; cultivation of *kharif* (Aman) was more prevalent. Restricted cultivation in *pre kharif* (Aus) season was due to the unavailability of required water and improper conditions for water stress management. However *boro* cultivation gained the momentum in the recent years (Fig.4.3.3).

4.3.1.2 Nature of rice varieties: Farmer of all the blocks relied mostly on High Yielding Varieties (HYV's), but their choice was restricted only to 3 to 4 varieties. Adoption of local varieties was mainly limited to winter season. During the selection of the varieties, the pest performance of the locality was given least attention. While selecting a variety, its production, productivity and the maturation time were regarded as the prime consideration.

4.3.1.3 Source of seed: Majority of the farmers relied on the seeds available from the local markets (63%), a few trusted on the previous stocks maintained at home (22%) and very few purchased seed from the registered shop (9%). For this reason gradual decrease in the hybrid vigour was noted (District Agricultural Hand Book 2000, Uttar Dinajpur). Very few farmers showed their confidence on the pure line maintained and propagated at the regional block agricultural farms (2%).

4.3.1.4 Nature of seed: Less than 5% farmer relied on certified seed and only 4% trusted on registered seed. However, seeds of local varieties were mainly stored by the farmers at home.

4.3.1.5 Seed rate: Inconsistency was noted regarding the seed rate. Depending on the availability and the pattern of the cultivating land, farmers commonly used 20-60 kg seeds for one hectare land.

4.3.1.6 Seed treatment: 22-25 kg seeds were generally wetted for 6-11 hours in 15 liter water containing pesticide formulation of methoxy ethyl murcuric chloride.

4.3.1.7 Seed sorting: Seeds with poor germination quality were sorted out depending on the concentration gradient of salt water. Those seeds floated on surface of the water with low gravity were discarded.

4.3.1.8 Germination procedure: Seeds were wetted overnight and then spread over the moist jute matrix of 2.5 cm thickness and allowed for 32-48 hours for germination.

4.3.1.9 Seed bed preparation: On most of the occasions, seed bed preparation was not in accordance to the size of the mainland. Farmers' usually prepared 750-1225 mt^2 seed bed for one hectare land. The dimension of the adopted seed bed was variable and ranged between 18-26 ft.(length) x and 3-9 ft.(breath). Seed beds with 'internal alley' were rarely adopted by the farmers of all the three blocks. Arrangement for water stress management was given least attention.

Table.4.3.1: The recommended protocols prevailing in three blocks and percentage of the farmers responded to this

Nutrient management				**Farmers (%) responded in the three blocks**		
Nature of nutrients applied (Kg/1000 mt x mt)	Time of application					
	During seed bed preparation	5-10 days before sowing (DBS)	5-15 days after sowing (DAT)	Raiganj	Hemtabad	Itahar
Cow dung/ compost	1200-2000	RN	RN	15	19	21
Inorganic N	2.5-5.0	0.00-3.00	0.00-3.00	27	41	32
Phosphate	2.5-5.0	0.00-3.00	0.50-4.50	18	12	37
Potassium	2.5-5.0	RN	RN	17	13	24

RN- Recommended none

4.3.1.10 Seed bed nutrient management: Adoptability of the suggested nutrient management protocols given by the District Agricultural office was tested on 200 farmers in consideration of the practices commonly followed by them. The result given in the table.4.3.1 which indicated that overall 50-55% trusted on the recommended protocols with befitting modifications while the remaining showed no specific pattern of nutrient management.

4.3.1.11 Water stress and weed management: No specific seed bed management practice was followed. Water stress management and weeding practices were partially adopted. Alley irrigation was not strictly maintained. Both the water and the weed stress management were countered mainly by the necessity rather than the scheduled protocols.

4.3.1.12 Pesticide application: Both solid and liquid formulations of pesticides were frequently applied to avoid pest infestations. No major discrepancy was noted regarding the pattern of adoption of the pesticides by the farmers in all the blocks. Applications recommended by the local Block Agricultural Farms were often disregarded. On an average 80-90% farmers apply pesticides at random.

Table.4.3.2: Some mostly used insecticides and their relative adoption by the farmers in the three blocks

Formulation	**Name of the insecticide**	**Applied dose (1000 mt ^{2})**	**Proportion of farmers adopted this practice (%)**		
			Raiganj	Hemtabad	Itahar
Solid/dust	Carbofuran(3G)	2.5-5kg	22	16	12
	Phorate(10G)	1000-1500 gm	18	25	24
Liquid	Phosphamidon (85%)	2.5-4 ml/liter	22	26	39
	Monocrotophos(36%)	0.50-1.5 ml/liter	37	31	11

4.3.1.13 Age of seedlings at transplantation: The age of the transplanted seedlings differed considerably among the farmers depending on the season. At *kharif* crop farmers' generally transplanted 35-45 days old seedlings. While in *boro* season, 15-25 days old seedlings were retained through out the winter season in the seed bed for 60-75 days until the advent of the favourable climatic conditions.

4.3.1.14 Number of seedlings/ hill: Normally 2-3 seedlings/hill were considered for *boro* crop. Some farmers found it more economic with higher seedling numbers especially in the Raiganj block which was known as BPH and GM prone areas. During the selection of the seedlings very little attention was paid to the quality of the seedlings. Leaf number, leaf and the root conditions were not properly maintained. Trimming of the terminal part of the leaves of the seedling, necessarily to avoid the subsequent occurrence of stem borer incidence was nearly conspicuous.

4.3.1.15 Hill number and hill distances: No specific hill distance was followed. However 15x15, 15x20, 10x15 and 15x20 cm distances were maintained depending on the variety. To stabilize the yield, more seedlings per hill were adopted by the farmers when delayed plantation was followed.

4.3.1.16 Main land treatment: Summer plowing was not strictly followed as only 10-13% farmers followed the procedure within 1-2 weeks after harvesting the previous crop. For majority of the farmers the time was generally extended up to 6-8 weeks. Only 4-6% farmers who cultivate paddy in one season permitted the fields unplowed (Table.4.3.3). Intensive plowing with the help of mechanical assistance was comparatively increased (59%) among the farmers than bullock plowing (36%). Farmers were found to prefer different plowing and harrowing combinations rather than simply plowing as shown in the (Table.4.3.4).

Table.4.3.3: Time span in between two consecutive crops when the lands are left to open air either after inadequate plowing or unplowed

% of farmers adopted	Weeks after crop harvesting				Unplowed
	1-2	3-5	6-8	8-10	
Raiganj	10	39	42	03	06
Hemtabad	14	27	45	10	04
Itahar	13	27	49	06	05

4.3.1.17 Water stress management after transplantation: Poor attention was given to the water stress management. Growth stage specific management of the water level was followed only by 19% farmers. Variability of preference was noted regarding the maintenance of the standing water during vegetative stage.

Table.4.3.4: Pattern of initial land preparation techniques commonly followed by the farmers before transplantation

Blocks	Land preparation techniques							
	1P	2P	2Pl +1H	1P +1H	2P +1H	1P+ 1H+1R	2P+ 1H+1R	Not specified
Raiganj	12	24	13	07	05	04	03	32
Hemtabad	14	27	10	09	04	03	03	30
Itahar	11	22	17	09	07	05	05	24

P- plowing, H- harrowing, R-roto-tilling ; 1- once, 2- twice

.**4.3.1.18 Nutrient management:** Without the proper detection of the actual requirements, application of NPK fertilizer rather than simply application of N as the nutrient source was more profound among the farmers (72%). Dose combinations were mainly selected depending on the paddy variety. Variety-dependent alternation of the NPK application was noted among farmers.

Application of inorganic N fertilizer was given priority while the adoption of organic fertilizer was followed by few farmers (2-13%) (Table.4.3.5). 69-74% followed the split application procedure. Farmers differed considerably in their view regarding the applied split combinations (Table.4.3.6). Split proportions were generally selected depending on the variety and particularly the standing growth stages of paddy. Majority of the farmers (69-74%) relied on the double splits while a few (1-4%) trusted on the triple split (Table.4.3.7). Nature of split proportions and their relative pattern of adoption in relation to the growth stages of paddy are given in the table 4.3.8.

Table.4.3.5: Proportional use of inorganic and organic sources of N fertilizers by the farmers in the three blocks

Blocks	Sources of N fertilizer (%)		
	Inorganic	Organic	Inorganic + Organic
Raiganj	61	13	26
Hemtabad	69	02	29
Itahar	72	03	25

Table.4.3.6: Paddy variety dependent NPK input commonly practised by the farmers

Duration of the paddy varieties	Quantity (kg / ha)		
	Nitrogen	Phosphate	Potash
Short duration	80-110	30-60	40-50
Medium duration	90-150	40-70	45-60
High duration	100-180	45-70	45-65

Table.4.3.7: Split proportion of fertilizer and their adoption by the farmers (%) in the three blocks

Pattern of application	Percentage of farmers follow split application		
	Raiganj	Hemtabad	Itahar
No split	27	22	25
Double	69	72	74
Triple	04	06	01

Table.4.3.8: Patterns of split quantities and the nature of their growth stage dependent application among the farmers in the three Blocks

Split combinations and growth stages of paddy	Farmers followed the operation (%)		
	Raiganj	Hemtabad	Itahar
50% basal+50% maximum tillering stage	15	22	30
50% basal +50% early flowering stage	17	19	13
60% basal+ 40% maximum tillering stage	19	14	25
Other alternative combinations	49	45	32

4.3.1.19 Weeding operation: No specific time schedule was followed regarding weeding operations. Weeding for two times was common, but inconsistency was noted regarding the time specificity. However, weeding practices at 30 and 60 DAT (days after transplantation) were comparatively higher among the farmers (Table.4.3.9).

Table.4.3.9: Timings of weeding and their practice among the farmers (%) in three Blocks

Time of adoption of weeding operation(s) (DAT)	**Percentage of farmers (%)**		
	Raiganj	**Hemtabad**	**Itahar**
21 and 45	26	34	30
35	16	22	27
30 and 60	45	41	40
Not specific	13	03	03

4.3.1.20 Pesticide treatments: differences existed regarding the nature and dose of insecticides applied in the three blocks. Carbofuran and phorate were mostly used. Malathion was the least selected pesticide. However, variability was noted regarding dose of application (Table.4.3.10).

Table.4.3.10: Insecticides and their pattern of use by the farmers in the three blocks

Trade name	**Generic name**	**Dose applied**	**Percentage of farmers use**		
			Raiganj	Hemtabad	Itahar
Thymade, Phoradox	Phorate-10G	7-9kg / acre	20	22	27
Furadon-3	Carbofuran-3G	13-16kg /acre	29	26	22
Dimecron	Phosphomidon 85%	1-5 ml / ltr	05	07	04
Coroban, Dasbarn	Chloropyriphos	3-7gm / ltr	03	06	05
Ekalax	Endosulfan	1.5-4.5 ml /ltr	09	12	07
Endosel	Methyl parathion	2 - 5ml / ltr	03	02	04
Metasid-50	Monocrotophos	1-3ml / ltr	12	09	15
Nuvacron	Malathion	1-3ml / ltr	07	07	09
Others			12	09	07

Table. 4.3.11: Frequency of application of insecticides in the three blocks

Blocks	**Percentage of farmers practise**			
	Once	**Twice**	**Thrice**	**Not specific**
Raiganj	10	36	47	07
Hemtabad	08	29	59	04
Itahar	11	24	61	04

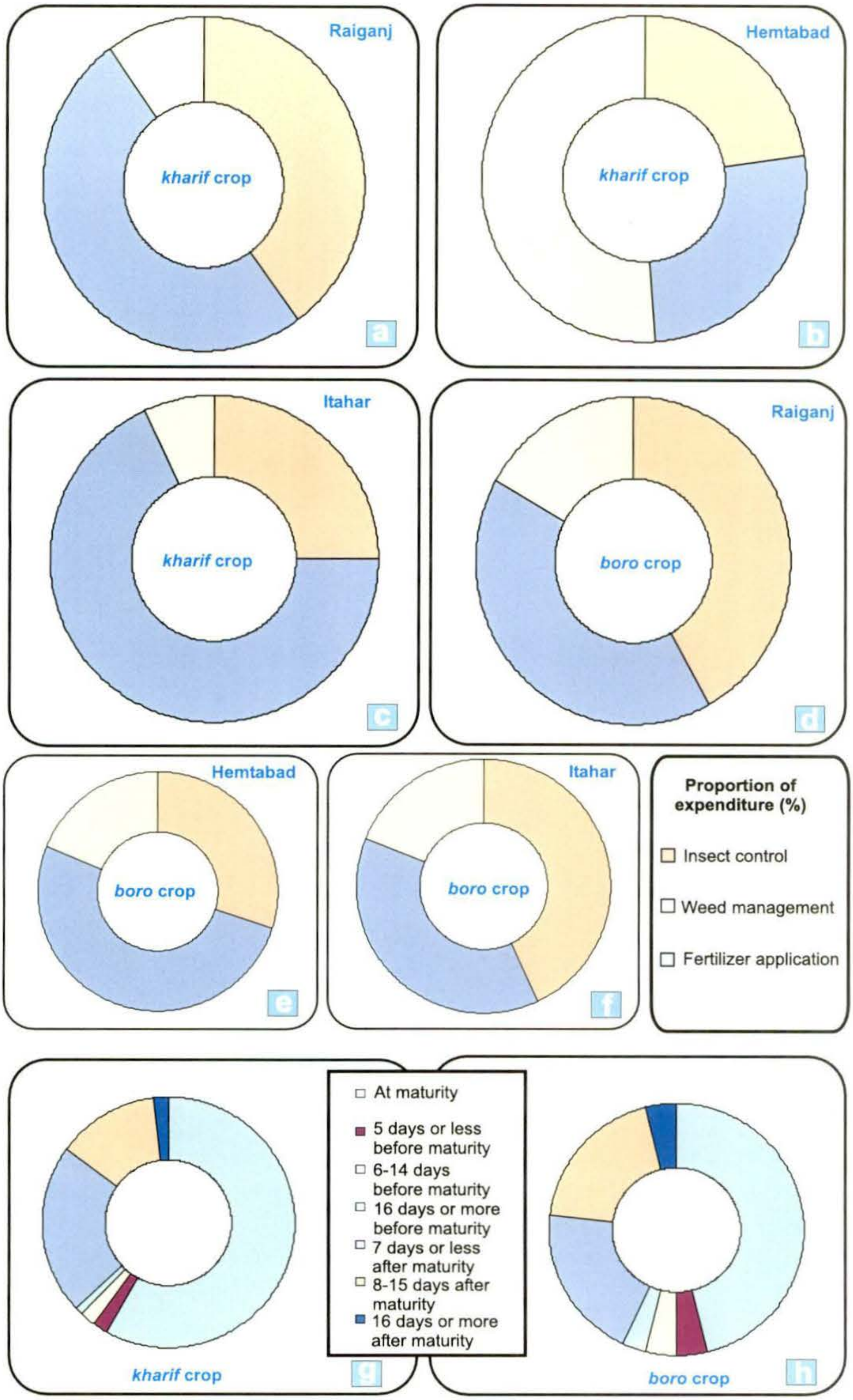


Fig. 4.3.1: Pie chart showing the proportion of expenditure of farmers of the three blocks in relation to the seasons (a-f) and the average date of harvest (g and h).

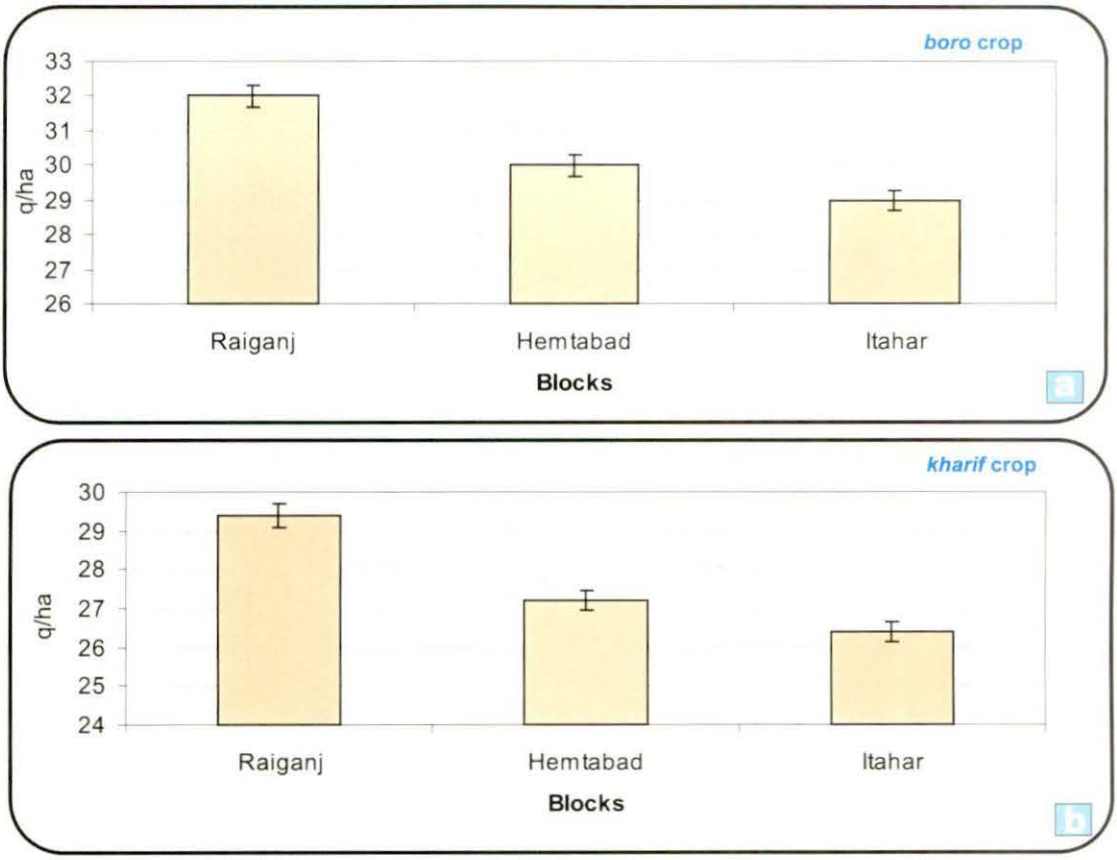


Fig. 4.3.2: Comparative bar diagram showing the yield in three blocks (a and b).

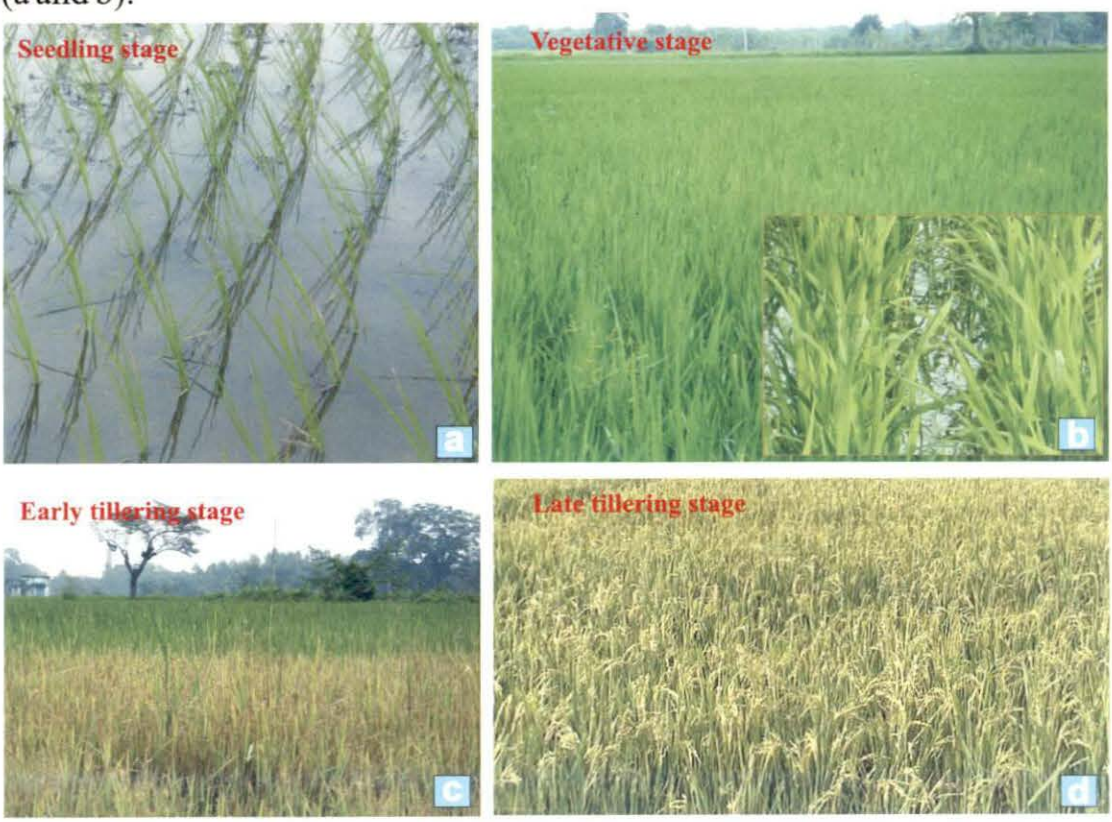


Fig. 4.3.3: Stretches of land showing the cultivation of paddy of different growth stages (a-d).

4.3.1.21 Times of pesticide application: Majority of the farmers (47-61%) applied pesticides three times. Time specific application was generally underscored. During application poor attention was given to the standing growth stages of paddy and the pest status of the fields. Choice was mainly guided by market availability (72%) and the price (18%). Dose dependent application at specific time intervals was followed by very few farmers (4%) (Table. 4.3.11).

4.3.2 Proportional field management expenditure: The expenditure differed considerably in relation to the seasons. Expenditure of 100 farmers from each block was assessed and was plotted as pie diagrams.

During *kharif* season: Farmers of Raiganj and Itahar block spend more in fertilizer. Insect control application was given second preference in both the blocks. Least attention was paid to weeding operations except in Hemtabad where it was give priority (Figs.4.3.1a, b and c).

During *boro* season: Insect pest control was given the first priority in Raiganj and Itahar while in Hemtabad more focus was given to fertilizer application. Least expenditure was incurred on weed control and Hemtabad and Itahar ranked nearly same in terms of percentage of expenditure (Figs.4.3.1d, e and f).

4.3.3 Date of harvest: During *kharif* season variable dates of harvest was observed. About 5 and 37% farmers harvested crop before and after maturity respectively. About 58% harvested the crop at maturity. About 2% of the farmers preferred to procure the crop 5 days before the scheduled date of harvesting but only about 22% preferred 16 days before the suggested date. After crop maturity, grains were collected by 7 days by about 22% farmers, 8-15 days by about 13% and 16 days by about 2% respectively (Fig.4.3.1g).

During *boro* season about 4% of the farmers preferred to procure the crop 5 days or less before the scheduled date of harvesting but only about 3% preferred 16 days before the suggested date. After crop maturity, grains were collected by 7 days or less by about 20% farmers, 8-15 days by about 19% and 16 days or more by about 4% farmers (Fig.4.3.1h).

4.3.4 Yield generation: Yield was comparatively higher during *boro* season than *kharif.* In both the seasons' maximum yield was obtained in Raiganj block while the least in Itahar block. In Hemtatabad block, the yield was intermediate between the two. Pedological variation together with the differences in the pest complexity was responsible for the variation of the yield in the three blocks (Fig.4.3.2a and 4.3.2b). Reduced yield is due to the inconsistent cultivation strategy which encompasses uneven hill distances, asynchronous plantation and improper nutritional management.

Discussion: Assessment on the proportional expenditure of cultivation practices was required for safer crop production. Application of high dosage of fertilizer may catapult the yield increase but renders alteration of microclimatic environment that induces pest survival and multiplication. However, in all the cases there was substantial increase in yield in dry season than in wet season.

Time of harvesting was crucial to suppress the multiplication and subsequent carry over of the pest population to the next generation. Suggestion of the by Directorate of Agriculture, Government of West Bengal for early harvesting when 80 % of the crop matured was hardly followed except for only 2% farmers .

In West Bengal, the respective value of pesticide treatment in consideration of per 1000 distribution is 616 and 541 during *kharif* and *boro* season respectively which is far above the national level (National sample survey organization, Department of statistics and Programme Implementation. Govt. of India.1999.report no.451.54/31/3). Time of transplantation and cultural practices differ considerably throughout the state. In the southern districts of West Bengal especially in Birbhum and Bankura summer plowing has been followed by 60 and 40 % farmers respectively. Both transplantation and direct seeding practice has been practiced in Bankura while only seedling transplantation gained the priority in Birbhum. Cropping intensity is medium and low in Birbhum and Bakura respectively. However, proportional application of organic and inorganic fertilizers was noted in both the districts. BPH, GLH, SBs are the major insect pest in both the districts. While the weeds

Cyperus iria and *Cynodon* are the prime alternative hosts. Insect control gains the priority at both the places. However in the northern parts of Bengal especially in Jalpaiguri frequency of all the paddy pests is low.

Cultivation practices observed among the farmers were grossly irregular and inconsistent. Least attention was given to the IPM practices. Poor management skills generated less production. Knowledge, attitude and perception of the farmers to the improved management skills were underscored.

4.4 Paddy Growth Stage Related Judicious and Minimum Input of Pesticides

In order to determine the proper growth stages of paddy at which the chemical protection should be taken, experiments were carried out with four commonly used pesticides in different schedules of variable combinations (Table.3.8.1 in materials and methods). So that a particular combination will be most efficacious against one or more pests at a particular growth stage. Selection of pesticide was done in due consideration of spectrum toxicity and targeted to a particular pest as recommended by the manufacturers.

Efficacy of pesticide(s) was assessed after evaluating both the field pests status and their respective damaging profile. YSB and GM were counted by quadrate (0.5x0.5 mt) while BPH, PB and natural enemies were recorded by hill estimation. Both intra and inter stage comparison in relation to the growth stages were drawn. As the two extreme stages, all stage protection (ASP) and no stage protection (NSP) had no combinational stages, comparison with these stages was made in consideration of the rest of the growth stages.

4.4.1 Numerical occurrence of pests and consequent extent of damage

4.4.1.1. In case of yellow stem borer (YSB) infestation

Numerical abundance

Single stage protection (SSP): From quadrate estimation it was revealed that there was no major difference of YSB population in all the stages of SSP except in case of seed bed protection where a high incidence of pest abundance was observed after pesticide application (Fig.4.4.1a).

Double stage protection (DSP): No significant differences in pest status were noted except in case of DSP(6) out of six DSP combinations. A lowest count of 4.52 individuals / quadrate was recorded in case of DSP(6) while the highest incidence of 5.42 individuals/quadrate was noted in case of DSP(3) (Fig.4.4.1b).

Triple stage protection (TSP): The incidence of YSB did not differ between TSP(1) and TSP(3), the other two differed significantly between them as well as with TSP(1) and TSP (3) (Fig.4.4.1c).

All stage protection (ASP): Least number of YSB was noted.

No stage protection (NSP): The incidence of YSB was maximum with 7.4 individuals / quadrate.

Extent of damage in different protection protocols

Single stage protection (SSP)

Dead heart (DH): A high profile of DH of 5.70/quadrate were recorded in case of SSP(4) protection though the field pest number was low (6.21 individuals / quadrate). The lowest level of DH of 4.4 / quadrate in case of SSP(2) though the number of YSB was 6.24 / quadrate(Fig.4.4.1d).

White head (WH): WH increased when SSP(1) protection was adopted. But the infestation was least in case of SSP(3).The observable pest status of SSP(2) and SSP(4) was of intermediate status recording 3.48 and 3.58 DH / quadrate respectively (Fig.4.4.1e).

Double stage protection (DSP)

Dead heart (DH): Comparatively high magnitude of DH was noted in case of DSP(6) while the least was counted in DSP(2).The field values of DSP(1), DSP(4) and DSP(5) were of intermediate nature (Fig.4.4.1f).

White head (WH): The quantum of WH was highest in DSP(6). Out of all the stages, DSP(1), DSP(2) and DSP(3) did not differ significantly with regard to WH incidence. DSP(4) and DSP(5) ranked second and third respectively (Fig.4.4.1g).

Triple stage protection (TSP)

Dead heart (DH): TSP (4) and TSP (3) did not differ significantly in extent of damage. In TSP(1) the number of DH was lowest. DH was significantly higher in case of TSP (2) than TSP (1) protection(Fig.4.4.1h).

White head (WH): The highest level of WH was scored in TSP (4) while the least was observed in TSP (1) (Fig.4.4.1i).

All stage protection (ASP): Least number of DH and WH was noted.

No stage protection NSP): The incidence of DH and WH was maximum with 7.16 and 3.18 symptoms/quadrate respectively (Fig 4.4.1j).

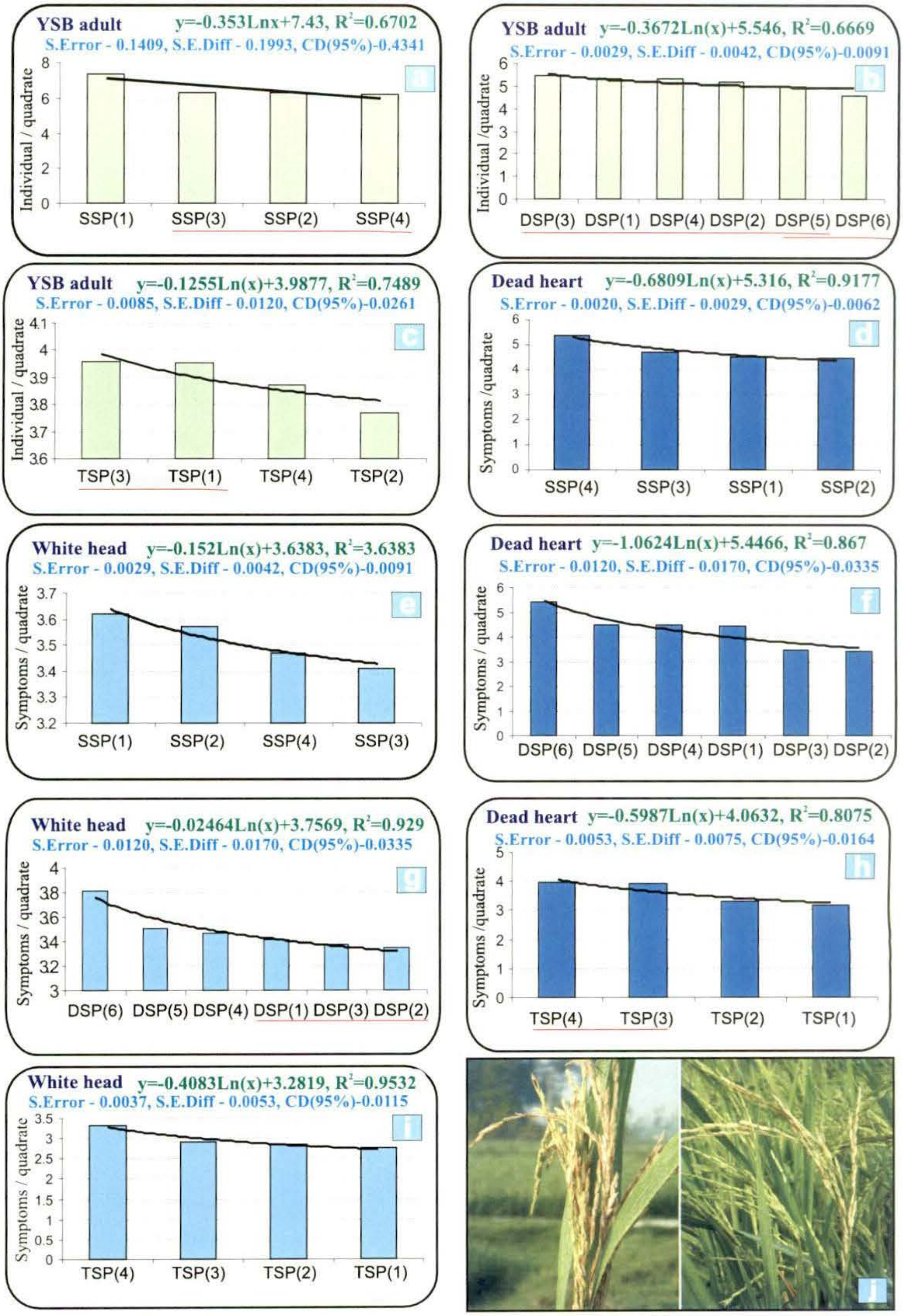


Fig. 4.4.1: Numerical occurrence of YSB and consequent DH and WH in different paddy growth stage specific insecticidal protections. SSP(1-4): single stage protections, DSP (1-6): double stage protections, TSP (1-4): triple stage protections. j: Symptoms of DH and WH. — : No significant

Discussion: In view of the protection schedules, all the growth stages except the seed bed stage are vulnerable to the YSB attack. Early infestation at vegetative stage causes DH and the late infestation at reproductive stage and early ripening stage results WH. Early arrival of the pest in the total absence of pesticidal protection from seed bed to reproductive stage results in the two successive generations of YSB in the same field. The long duration of 140 days of *Swarna Masuri* (MTU 7029) can easily support two broods, the first brood completes the life cycle at about the end of vegetative stage and the next brood emerges at the starting of ripening stage. The dimension and the extent of the damage to the plant and its relative consequences of yield loss depend on the specific stage of YSB life cycle occurring in the field and the respective growth stages of paddy.

As the growth stages of paddy progress, the early arrival indulges to generate high population with two consecutive broods of YSB moth at late reproductive stage. SSP(2) and SSP(3) application if implemented separately, the pest population is reduced. As a result, the average pest incidences after these two categories of protection remain below the ETL. The high magnitude of DH in case of SSP(4) with relatively low level of pest has been due to the consequence of successful boring of tillers by the early brood of YSB larvae ensuring their high survival value. The SSP(1) renders the crop a partial protection at vegetative stage as the effect of the pesticide is continued to the early vegetative stage only. SSP(2) and SSP(3) impart instantaneous effect on early larval brood, causing their death and hence, minimize DH.

SSP(1) has provided no protection to the reproductive growth stage, so the crop is vulnerable to a cumulative attack of two subsequent broods of YSB, so the extent of WH has increased significantly. SSP(2) can protect the plants from the larvae of first generation directly, therefore, can restrict the magnitude of the second generation so the cumulative damage by the pest can be impeded. A steady significant level of decrease of WH has been observed at SSP(3) in comparison to the SSP(1). Such a decrease may be due to the deposition of excess silica in plants that imposes a stress on the larvae. In addition, the

SSP (3) causes direct mortality to the second larval brood and also drive away the adult.

Analogous to the SSP(4), highest level of DH has been observed in case of DSP(6) with a low pest population size since the unprotected vegetative and the reproductive stages are accessible to YSB larvae. Least damage has been noticed in case of DSP(2) with moderate pest level in the fields. Least population in case of DSP(6) has accounted highest level of WH probably due to the successful attack by the second generation larvae to the tillers of both late vegetative stage and early reproductive stages. In spite of highest population of YSB at DSP(3), the number of WH has been significantly low, as both reproductive and ripening stages have received direct protection and thus prevented larval attack.

TSP(3) and TSP(4) do not differ significantly and the level of DH remains below ETL. TSP(3) at the seed bed stage renders no effective security to the vegetative growth stage which is vulnerable to YSB attack, hence results in extensive damage. Pesticide free vegetative stage of nearly 45-60 days can support the YSB and the first larval brood generation is encouraged. At TSP (4) the cumulative effect of the applied doses of pesticide at the seed bed and vegetative stage remains low in the reproductive stage as the applied quantity of the lethal doses of pesticides can hardly protect the subsequent foliage growth. So, the tillers are prone to the larval attack. Consequently, the apparently moderate field level of YSB can induce a significant level of WH. TSP(2) lowers the pest at lowest number hence a low count of WH is obtained. The Lowest number of WH has been observed in case TSP(1) although the field population remains high.

Observable field population of YSB and the recorded symptoms of DH and WH are not in parity in all the protection stages. Frequencies of the observable symptoms are not always in accordance with the intensity of the field pest level as the field with low pest intensity can induce higher range of damage and vice versa. Discrepancies relating to the generated value of the damaging symptoms arise due to the relative change in the physiology structural conditions of the paddy plant at different growth stages to combat or recover the distresses.

4.4.1.2 In case of brown plant hopper (BPH)

Numerical occurrence

Single stage protection (SSP): Hill estimation revealed that the pest population recorded from different SSP protocols differed significantly. The highest level of BPH was observed in SSP(1) with 13.82 individuals / hill while the least was recorded at SSP(4) with a count of 12.29 (Fig.4.4.2a).

Double stage protection (DSP): Significant level of difference with high range of population was estimated in DSP(1) with an average value 9.69 and the least was noted at DSP(2) with 7.59. DSP(4) and DSP(6) showed no significant level of difference. Similarity DSP(6) and DSP(5), DSP(5) and DSP(3) evicted no significant level of difference when the different protection pairs were considered separately (Fig.4.4.2b).

Triple stage protection (TSP): The pest status showed significant level of differences among all the TSP's. In case of TSP(1) highest pest number was recorded while the least number occurred at TSP(4). TSP(3) and TSP(2) ranked second and third respectively (Fig.4.4.2c).

All stage protection (ASP): Least number of BPH was noted under such practice.

No stage protection (NSP): The incidence of BPH was maximum with 14.41 individuals / hill.

Extent of damage in different protection protocols

Single stage protection (SSP): High profile of damaged flag leaf area (DAL%) was recorded at SSP(1) due to the persistent high level of pest. The lowest level of DAL% was observed in SSP(2) in spite of the fact that the pest level of the field remained comparatively high than in case of other protection strategies such as SSP(3) and SSP(4). Although least pest performance was recorded at SSP(4), in terms of damage it ranked third after SSP(1) (Fig.4.4.2d).

Double stage protection (DSP): High level of DAL% was observed in DSP (6) though the number of pest individuals was moderate. The least level of DAL (%) was recorded at DSP(2) with lowest pest incidence. DSP(5) and DSP(3) did not differ significantly in regard to damage. Significant difference of DAL(%) was observed in between (DSP(4) and DSP(6)) and (DSP(5) and DSP(6)). Nevertheless in both the cases pest status of the field did not vary significantly (Fig.4.4.2e).

Triple stage protection (TSP): TSP(1),TSP(2) and TSP(4) protections differed insignificantly in respect of damage and the extent of damage was highest in case of TSP(3) with the value 20.1% DAL (Fig.4.4.2f).

All stage protection (ASP): The damage was minimum with 10.14% DAL.

No stage protection (NSP): Maximum range of damage was registered.

Discussion: Assessment on the flag leaf area damage (DAL%) forecasts the level of pest occurrence and the probability of yield loss by the hopper species. The damage is mainly contributed by the direct feeding activity of the nymphs and adults to the vascular tissue of growing leaves which eventually manifest to the formation of 'hopper burn'.

The extent of damage to the paddy plant depends mainly on the standing growth stages of paddy, the available population status and the interactive stages of the life cycle occurring in the field. Prevailing abiotic conditions, adopted agronomic practices and stage specific application of pesticides are found to dictate the range of damage.

In the variety *Swarna Mashuri*, no single stage protection appears to be suitable to check the BPH population below ETL. The high magnitude of BPH at SSP(1) has been due to the rapid colonization of the macropterous forms and their subsequent growth and multiplication which render the generation of a larger population. In case of SSP(1), absence of pesticide protection in three consecutive growth stages after seed bed allows the pest to colonize rapidly without any hindrance. Seed bed treatment thus is found ineffective in providing the proper protective function at early vegetative stage and after wards.

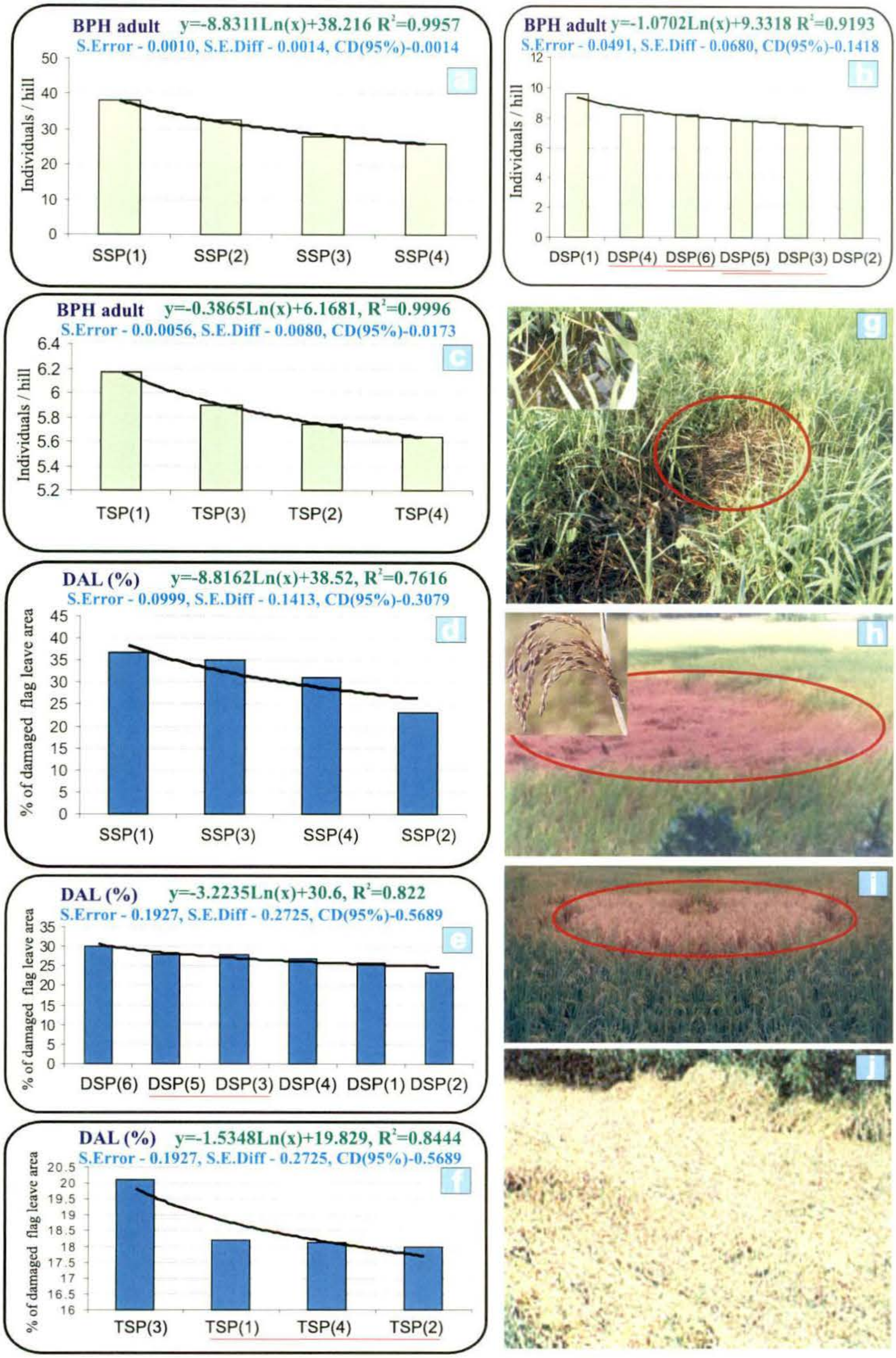


Fig. 4.4.2: Numerical occurrence of BPH in different paddy growth stage specific insecticidal protections and consequent quantum of hopper burns. SSP (1-4), DSP (1-6) and TSP (1-4): single, double and triple stage protections. —: No significant differences.

As asynchronous cultivation with small land sizes are mainly practiced by the farmers, colonization occurs mainly in two ways, long winged macropterous forms migrate from the adjacent fields where the growth of paddy is at advanced stages. And secondly, by the emigration of the short winged brachyptrous forms which hops from the contiguous fields of other crops or barren land, acting as reservour niches.

Adoption of any single stage specific protection give spectacular results for a very short time, as in the immediate vicinity the population thrives well. The pest recolonizes within 10-15 days after pesticides application.

Among the double stage protection measures, highest level of DAL% at DSP(6) was noted with a low average pest population. The alternative vegetative and ripening stage protection in case of DSP(5) accounts for a steady dispersion of the BPH from the field. Protection free reproductive stage encourages to recolonize the population with utmost rapidity resulting in a high magnitude of damage. In case of DSP(3), the completely protection free early growth stages allows the nymphs to multiply devouring on the green foliage of vegetative stage. In spite of a low pest count at DSP(4) the value of DAL% has been moderate. Because, the luxurious foliage of vegetative stage attracts BPH nymphs the most. Protection in the first two growth stages of paddy in case of DSP(1), saves the plants from early damage. However, the pest colonizes at late growth stage prior to reaching the reproductive stage and the population builds up rapidly due to the availability of suitable microclimatic zone near the base of the paddy plant formed by the reciprocal shading of the adjacent canopies that hinders light penetration. Furthermore, translocation of sugars to the grains is slowed down nearing the ripening stage. BPH is poorly attracted to such low sugar diets, and pest emigrates, population declines, hence damage is minimized.

Comparatively a low pest infestation occurs at TSP(1). Protection during the first three consecutive stages obviously reduces the effect of damage. The trivial damage accounted at TSP(1) is due to immigration of the population after a few days of pesticide applications. Spraying is normally done at the upper canopy. The adults hide themselves at the lower level of paddy stalks. They survive better in the paddy bushes. Though the pest status in TSP(1), TSP(4) and TSP(2) differs significantly, on the contrary, the damaging profile varies insignificantly. No protection at the vegetative stage renders high magnitude of direct damage as has been found in TSP(3). Because the pest can multiply vigorously at this stage.

Efficiency and success of pesticide protection to BPH population largely depends on the plant architecture, standing growth stages of paddy, tillering capacity of the plant, appropriate selection of the pesticides, mode of application and other cultivation strategies.

As the adult BPH feeds at the base of the plant and is mostly sedentary, it seldom comes in contact with the insecticide applied after vegetative stage. Application of pesticides at higher growth stages with different combinational strategy offer different grades of protective advantage and accordingly give disproportionate level of damage. Alternatively, application of high volume of spray is found drudgery and involves high cost. Therefore farmers spray the pesticide far below the requirement, resulting in poor coverage. Farmers do not have effective and handy equipment which can disperse the insecticides at the base of the plant. So BPH can only be controlled by the use of high volume sprayers. Growth stage specific application of pesticide denotes the exact stage at which special care should be taken to check the pest induced damage.

Laboratory evaluation has shown that methyl parathion is less effective in controlling the hoppers. Adoption of methyl parathion at seed bed at 2% @ of 6kg / ha by foliar application has restricted the early arrival of the pest with minimum residual toxicity (Natarajan *et al.* 1975). Green house evaluation of available marketable pesticides like carbofuran, chlopyrifos, diazinon, decamethrin and carbaril killed at least 80% of the hopper series (Basilio 1981). Application of such pesticides is discouraged due to longer residual toxicity (Senapati 1988). Methyl parathion is found effective to drive the hoppers, and due to its ovicidal activity protects the field from producing next generation. Application of carbofuran granules checks the population due to strong ovicidal activity but is also disregarded due to its persistent toxicity, disruption of soil microbes, and phyto-toxicity in the late growth stage of the paddy (Heinrichs *et al*.1984).

4.4.1.3 In case of gall midge (GM)

Single stage protection (SSP): Least number of GM occurred in case of SSP (3) while the highest was noted in SSP(1), the numbers were being 2.22 and 2.68 individuals / quadrate respectively. The other two, SSP(2) and SSP(4), did not differ considerably (Fig.4.4.3a).

Double stage protection (DSP): Except in case of DSP(6), the other 5 combinations of protections did not differ significantly in number of GM infestation (Fig.4.4.3b).

Triple stage protection (TSP): All the four protection stages differed considerably in respect of pest number.The highest of 0.30 individual / quadrate was observed at TSP(3) and least of 0.19 individual/quadrate was scored in case of TSP(1). At other two categories of protection the infestation was in between. (Fig.4.4.3c).

All stage protection (ASP): Least number of GM was noted.

No stage protection (NSP): The incidence of GM was maximum under such protection.

Extent of damage in different protection protocols

Single stage protection (SSP)

Silver shoot (SS%): High level of GM at SSP(1) and SSP(2) caused the higher level of SS% but showed significant difference. The SS% at SSP(2) and SSP(3) was 32.10 and 27.41 respectively. The observable values of SS% differed significantly in all the SSPs(Fig.4.4.3d).

Parasitized gall (PG%): High level of SS% in case of SSP(1) was coupled with high level of parasitization (PG%). PG% was high in case of SSP(2) than in SSP(4). Least level (%) of parasitization was observed in case of SSP (3) (Fig.4.4.3e).

Double stages protection (DSP)

Silver shoot (SS%): Higher value of SS% was observed in DSP(6) while the least in DSP(1). Effects of other protections were of intermediate conditions. SS% was directly correlated with field GM level in some stages (Fig.4.4.3f).

Parasitized gall (PG%): PG% in the galls was comparatively higher in DSP(6), while in DSP(2), it was least. Other protectional types showed varied level of parasitization. DSP(5) resulted in moderate parasitization with 17.58 SS (%). All the DSP patterns showed significant differences in the occurrence of PG(%) (Fig.4.4.3g).

Triple stage protection (TSP)

Silver shoot (%): Higher SS% was scored in case of TSP(3) followed by TSP(4), the values were 14.2% and 13.6 % showing no significant level of difference. TSP(2) and TSP(1) differed insignificantly in respect of SS(%) appearance (Fig.4.4.3h).

Parasitized gall (PG%): The PG% was comparatively high (11.3%) in case of TSP(4), while the least was observed in TSP(1). At other two protocols, the value of PG(%) differed significantly (Fig.4.4.3i).

All stage protection (ASP): The value of SS% and PG% were respectively 5.01 and 6.14.

No stage protection (NSP): Maximum level (%) of GM infestation and parasitization was noted.

Discussion: High level of GM in SSP(1) is due to the lack of protection at late growth stages. SSP(2) and SSP(3) result comparatively low level of GM population, though of significant differences. This has been possible from the direct interference of pesticides to the mid growth stages. As GM incidence is more to the late tillering stage, SSP(3) has offered consistent protection to the mid growth stage rendering the lowest level of GM.

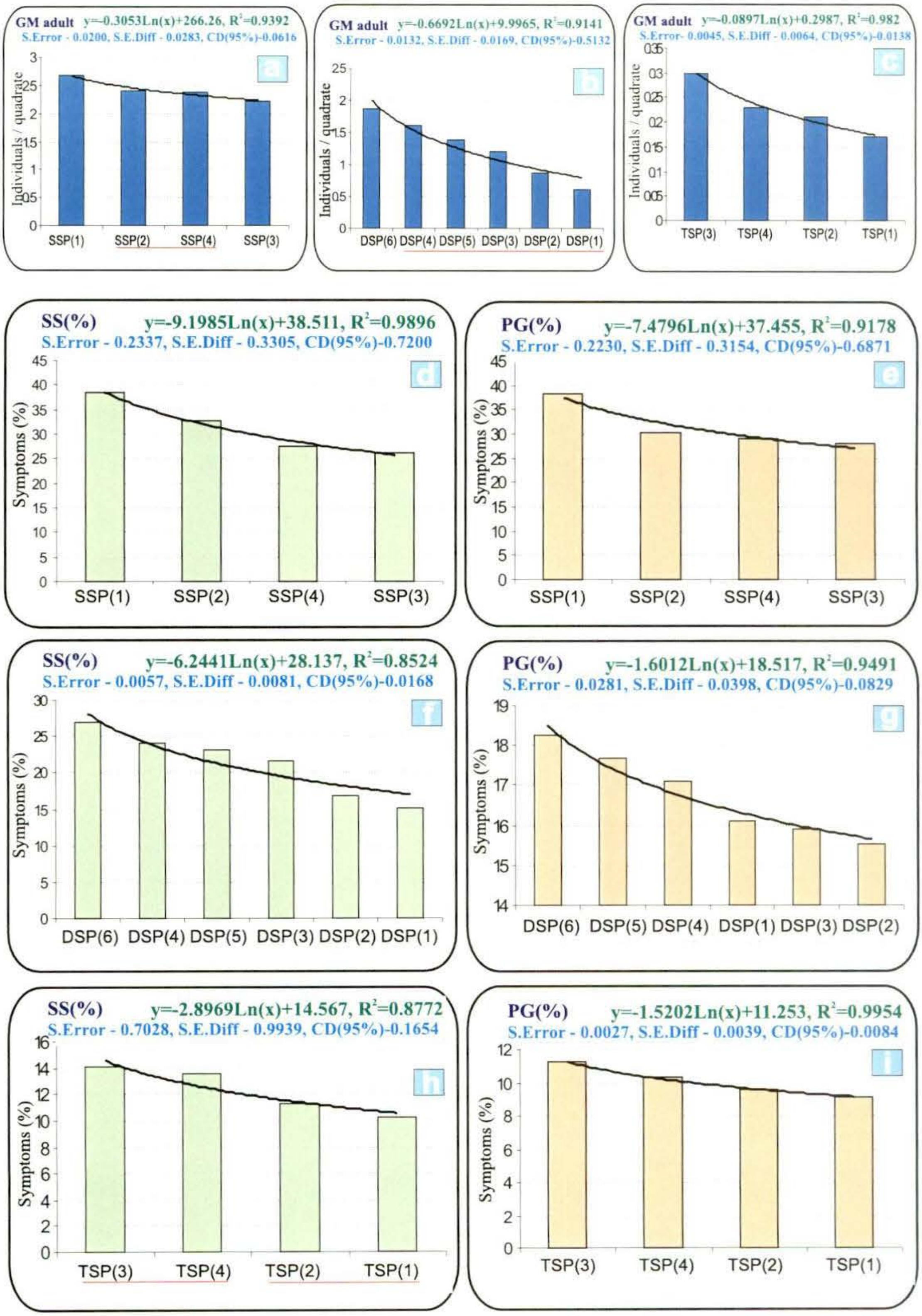


Fig. 4.4.3: Numerical occurrence of GM and consequent silver shoot and parasitized galls in different paddy growth stage specific insecticidal protections. SSP (1-4), DSP(1-6) and TSP (1-4): single, double and triple stage protections. —: No significant differences.

SS% has been definitely related to the field GM level indicating that the prevailing field pest level is the prime factor for SS formation. However, the rate of parasitization, has not been in proportion to the field GM level. High parasitization at SSP(1) can be accounted for the relatively pesticide free late growth stages. The least level of PG% at SSP(3) has resulted due to the arrested parasitic development at the late growth stages.

In all the stages of DSP except the DSP(6), the level of GM differed insignificantly, High level of GM at DSP(6) has been largely due to the presence of relatively pesticide free vegetative and reproductive stages. Appearance of SS(%) has a positive correlation to the field pest population. Higher the GM incidence, greater will be the extent of SS.

In TSP, the relation between SS and field GM level has been nearly equivalent. Rate of parasitization has been found to be density dependent. As parasitization occurs mainly at the late growth stages, profuse tillering at this time provides a positive effect allowing the parasite to multiply. Application of pesticides at higher growth stages confers the rapid reduction of the parasite thus reduces the rate of parasitization.

As GM is more prone to damage to the late growth stages, TSP(2) is suitable for controlling the population effectively. In case of TSP(3) there is no vegetative stage protection. This coupled together with prevailing climatic conditions induces GM settlement and their multiplication. Least population of GM at TSP(1) can be accounted for the extended protection up to the late reproductive stages. TSP(4) leaves the crop a pesticide free reproductive stage for multiplication.

With some rare exceptions significant positive relation has been found between the field GM level and the appearance of SS(%). No specific relation of field GM or SS(%) with the rate of parasitization(%) has been obtained. Thus it appears that the rate of parasitization is density independent at higher doses of insecticide application. Low level of PG at higher application stages was due to the poor accessibility of the parasite to the fewer available galls. Thus the

Extent of damage in different protection protocols

Single stage protection (SSP): Persistent high level of PB at SSP(4) caused pesticide application exerted direct effect on PG formation. Rate of gall parasitization was thus found to be application independent.

4.4.1.4 In case of paddy bug (PB)

Numerical occurrence

Single stage protection (SSP): High level of PB (1.95 individuals / hill) was observed in SSP(4). Significant differences occurred in the PB populations of other three SSPs. Least level of pest infestation was noted in SSP(3) (1.62 individuals/hill) (Fig.4.4.4a).

Double stage protection (DSP): DSP(6) showed the highest incidence of PB (1.80 individuals / hill) while the least was observed in DSP(5).In case of other four protections PB was in between (Fig.4.4.4b).

Triple stage protection (TSP): No significant level of differences in the population occurred with the exception of TSP(2), suggesting that all the protection stages were equally effective to control the pests. In case of TSP(2) the average value of the population was 0.34 individuals / hill(Fig.4.4.4c).

All stage protection (ASP): Least number of PB was noted.

No stage protection (NSP): Maximum number of PB with 1.8 individuals / hill occurred.

Extent of damage in different protection protocols

Single stage protection (SSP): Persistent high level of PB at SSP(4) caused unfilled grain (UG%).. The dimension of damage did not differ significantly between SSP(1) and SSP(4) in spite of the fact that the field populations differed significantly. No significant range of difference in UG% was noted in SSP(2) and SSP(3) though the average pest population was higher in SSP(2) (Fig.4.4.4d).

Double stage protection (DSP): Higher level of UG% occurred in DSP(6) followed by DSP(4) but without significant difference. Difference in the extent of damage did not differ between DSP(5) and DSP(4). Moderate level of grain damage was observed in DSP(3) while the least was noted in DSP(1) (Fig.4.4.4e).

Triple stage protection (TSP): Highest level of UG% occurred in case of TSP (3). Least level of damage was registered in TSP(1) though the pest population remained high. Relatively higher damage was recorded in TSP(4) with only 0.87 individual / hill(Fig.4.4.4f).

All stage protection (ASP): Least frequency (%) of grain damage was noted.

No stage protection (NSP): The extent of grain damage was maximum with 28.14% unfilled grains.

Discussion: Nearly all the growth stages of paddy except seed bed are vulnerable to the attack by PB. In the pesticide free field (NSP), PB has been found to complete nearly three generations successfully. Early arrival and settlement yielded the first batch of nymphs at the very beginning of vegetative stage which start to propagate with the available foliage as food source. *Swarna Masuri* (MTU 7029) with about 50-55 days duration of vegetative stage promotes rapid increase in nymph's population by completing its second life cycle in late vegetative stage. Reproductive stage supports another generation to complete. However the intensity of PB population has increased during advanced growth stages of paddy with multiple overlapping generations.

SSP(1) has offered protection to the plant from early colonization. Late assemblage at early vegetative stage requires adequate time for the population to buildup. SSP(4) allows early settlement and propagation up to reproductive stages without any hindrance causing an out break. Least level of population at SSP(3) has been due to the efficacious control and to inhibit the production of second batch of population under pesticide stress.

DSP(6) has protected the crop from early settlement of PB. But the subsequent pesticide free two consecutive growth stages has invited the pest and encouraged rapid multiplication causing a high level of damage. The magnitude of damage has far more intensified when the neighboring paddy fields were at later growth stages.

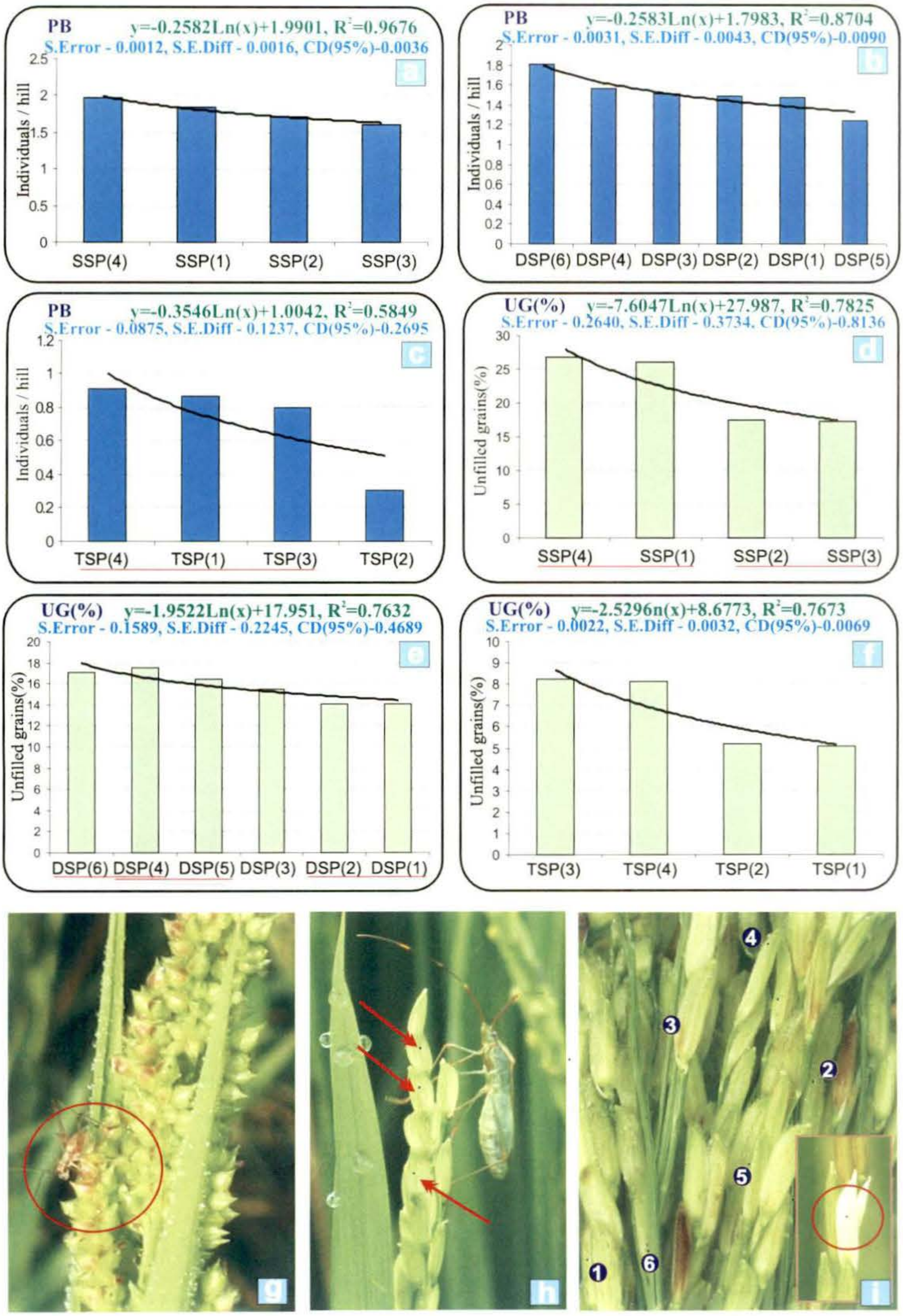


Fig. 4.4.4: Numerical occurrence (a-c) of PB and consequent unfilled grains (d-f). SSP (1-4), DSP(1-6) and TSP (1-4): Single, double and triple paddy growth stage specific insecticidal protections. (g-i): Consequent damage, (g): on the alternate host, *Echinochloa crus-galli*, (h and i): on paddy causing puncture spots (1-6). —: No significant differences.

When episodic and discontinued pesticide protection have been adopted as in DSP(4), it interrupted the life cycle of both first and second batches of nymphs, hence the magnitude of the damage has been reduced. Though in DSP(1) and DSP(2) the early life cycle of PB is halted, the low level of damage occurs due to migration of the pest from the nearby fields.

TSP(1) has concealed the plant from the early settlement of the PB. TSP (2) interferes with the nymph's activity of all the batches and TSP(3) hinders the activity of the adults. But the damage has been high in TSP(3) as the early generation nymphs has got adequate time to survive and mature. In TSP(4), application of pesticide at reproductive stage of paddy becomes less accessible to the nymph due to the presence of luxuriant foliage offering greater survival value and thus results in higher grain damage. But the persistent presence of protection in combination of two contiguous growth stages, vegetative and reproductive stage, in TSP (2) easily has caused nymph mortality and hence low unfilled grains.

Majority of the works relating to the assessment on the efficacy of the pesticides are largely based upon the single pesticide formulation in which more stress was given on the additive / subtractive methods which includes / excludes all the major growth stages one by one and the extent of damage is determined collectively for all the pests in consideration of a single growth stage (Banerjee 1982, Heinrichs 1984). Furthermore, such studies are mainly concerned with the final yield losses but the relative damaging potentiality of a particular pest or pest complexes in relation to the growth stage of paddy is underscored. As all the pests are not equally harmful to any of the growth stages, specification of relative range of damage by a particular pest under different protection protocols has been given priority in the present investigation. Moreover, as the efficacy of pesticides to control all the pests at a standing growth stage of paddy is not equally potent it is more appropriate to study the field pest level under different pesticide combinations as a prerequisite measure at a particular locality before the recommendation and execution of a protection schedule.

4.4.2 Numerical occurrence of natural enemies and consequent of protection

4.4.2.1 In case of spider

Single stage protection (SSP): High level of spider population with 0.97individual / hill was observed in SSP(1). When SSP(2) and SSP(4) were applied, significant changes were noted in the population structure. The least level of population was noted at SSP(3) (Fig.4.4.5a).

Double stage protection (DSP): Persistent high level of spider population was noted in all the growth stages of paddy when DSP(4) was in practice. Population in case of other modes differed significantly. A hierarchical spider populations in the ascending sequence of DSP(3), DSP(2), DSP(1), DSP(5) DSP(6) and DSP(4) were noted in all double stage protections (Fig.4.4.5b).

Triple stage protection (TSP): Significant level of differences occurred in spider populations in all the triple stage protections. The highest number was observed in TSP(1) while the least was scored in case of TSP(4) (Fig.4.4.5c).

All stage protection (ASP): Least number of spider population was noted.

No stage protection (NSP): The incidence of spider population was maximum.

Discussion: All the growth stages of paddy except seed bed support the spider population. Application of insecticides at different growth stages, except in the seed bed has offered varied level of protection of the crop. As the growth stage advances, the crop canopy becomes denser offering higher survival value to the spiders. Seed bed stage supports the early colonization while the vegetative and reproductive stages provide support to the web decoration and subsequent population multiplication.

Pesticide free seed bed stage is thus found indispensable for early colonization of spiders. Application of pesticides in SSP(2) and SSP(4) has imparted no significant level of difference in the spider population. The population after colonization at seed bed could easily retrieve from the insecticidal application at SSP(2) or SSP(4). But when SSP(3) has been adopted, the population could rarely withstand resulting in steady population crash. Such 'turn down' of the population has been due to the less adaptability of the spiders in the field for food and shelter and to recolonize after being subsided due to pesticide.

Interrupted alternative growth stage specific pesticide application at DSP (4) has promoted comparatively higher level of spider with 0.92 individual / hill than in case of continuous applications. Separate episodic application in the two consecutive stages of DSP(3) and DSP(2) has disapproved the ready colonization thus restricted the population rebuild. DSP(6) has a higher population nearly to that in DSP(4) due to pesticide free vegetative and reproductive stages. DSP(6) has allowed the population to multiply, but the presence of protection at ripening stages has rendered the population to hide within the canopy. Further, as the growth stage of the paddy is in progress from reproductive stage to ripening stage, a steady decline of the population has been observed due to the depletion of food source. Alternative stage specific application at DSP(5) has provided the spider enough time to with stand the effect of pesticide application.

Least level of spider population in TSP(4) has been accounted due to the successive application of pesticides in the early two growth stages and their extended effect to the next growth stage. Although in TSP(1), protection is given to the early growth stage but differences arises in the late growth stages. Absence of protection at ripening stage in TSP(1) permits the spiders to reappear at higher numbers.

Spiders are found on leaves around paddy fields after the crop is established, they occasionally may leave the place to inhabit the nearby newly cultivated fields. In an untreated field, growth stage dependent activity of the spider community is evident from their gradual increase as the crop grew older. Among all the species the wolf spider *L. pseudoannulata* has been abundant. Although spider abundance generally fluctuated little within a short time, spider density has increased with crop age, peaking near crop maturity (Satpathi 2004). They have been occasionally found to reach a density of 8 individuals / hill in the present study but usually inconsistently as a few on a hill.

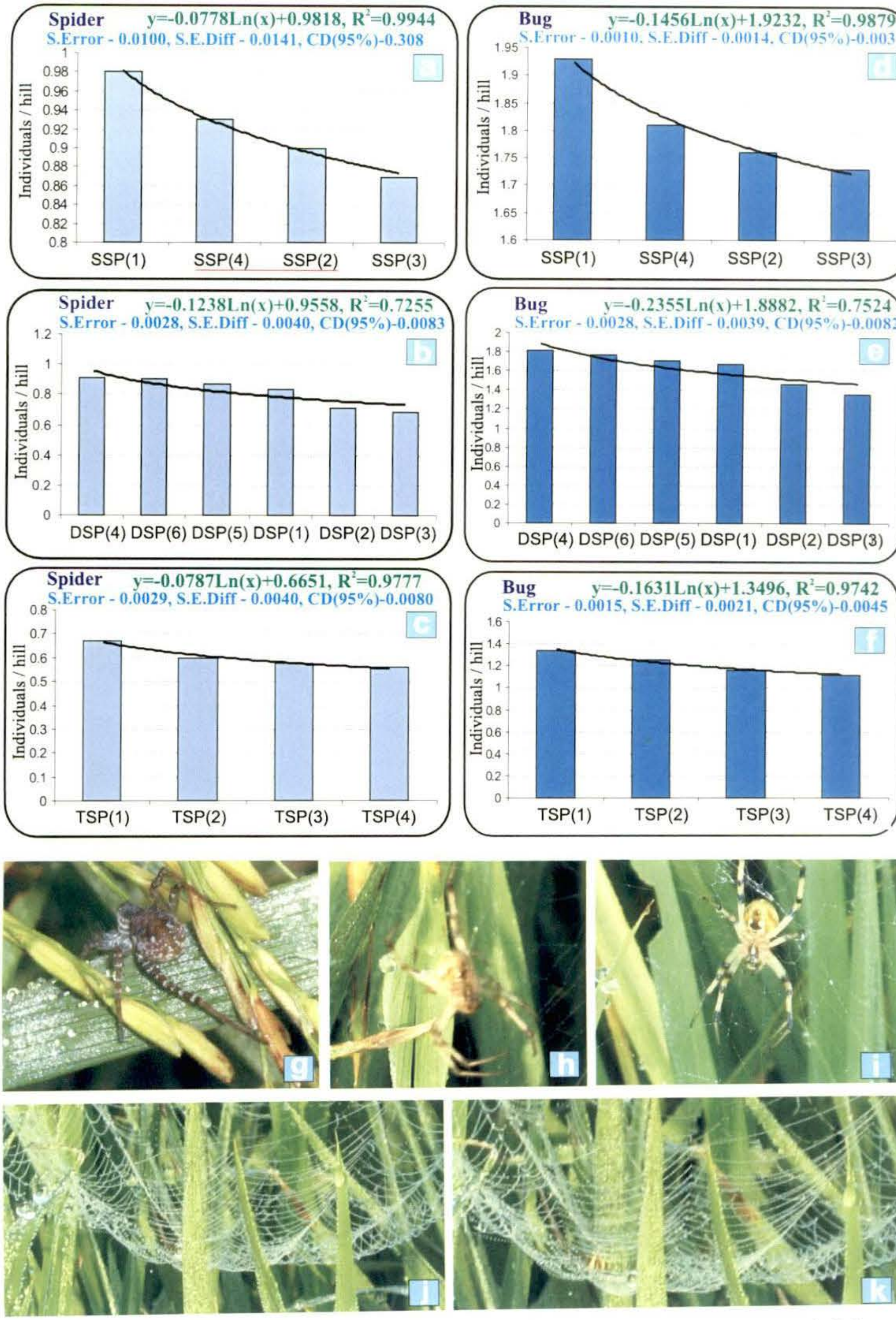


Fig. 4.4.5: Numerical occurrence of natural enemies: a-c: spider, d-f: bug. SSP(1-4), DSP(1-6) and TSP (1-4): single, double and triple paddy growth stage specific insecticidal protections g. Pesticidal deposition on leaves, h and i: Flimsy web decoration due to all growth stage protection of paddy with insecticide. j and k: Healthy web decoration in fields without insecticidal protection. — : No significant differences.

4.4.2.2 In case of bug

Single stage protection (SSP): Comparatively high level of bug population with 1.94 individuals / hill was registered in SSP(1). The population varied significantly when SSP(4) and SSP(2) were considered. The least level of population was scored at SSP(3) (Fig.4.4.5d).

Double stage protection (DSP): Consistently high level of bug population was encountered throughout the growth stages when DSP(4) was adopted. All other stages of DSP differed considerably. Least level of bug population was estimated in DSP (3) with 1.35 individuals / hill (Fig.4.4.5e)

Triple stage protection (TSP): Significant level of variations in the incidence of bug population was noted among all the stages of triple protections. The highest level was observed in TSP(1) with 1.35 individuals / hill while the least number in case of TSP(4) with 1.17 individuals / hill (Fig.4.4.5f).

All stage protection (ASP): Least number of bugs was counted.

No stage protection (NSP): The incidence of bug population was highest.

Discussion: All the growth stages of paddy except the seed bed have been found to support the bugs. Application of insecticides at different growth stages, excluding the seed bed, has offered different level of protective advantage. Higher the growth stages, greater the generation of crop canopy better is the survival value to the bug. Seed bed stage supports the early colonization while the vegetative and reproductive stages help in multiplication.

Insecticide free seed bed stage is thus the prime necessity for early colonization of the bug. The population after early colonization at seed bed can easily retrieve the insecticide application at SSP(2) or SSP(4). But when pesticide is adopted in SSP(3), the bug population can rarely over come the action of insecticide resulting in 'out break' of pest population. Decline of population has been noted due to the less adaptability of the bugs in the field for food and shelter.

Discontinued episodic application at DSP(4) has resulted in a higher level of bug than the continuous applications as in DSP(1), DSP(2) and DSP

(3). DSP(3) and DSP(2) have permitted ready colonization and population build up. At DSP(6) population was quite high nearly to that at DSP(4), both have pesticide free vegetative stage. DSP(6) has permitted the population to increase, but the protection at ripening stage in DSP(3) hardly has allowed the population to escape. Further, as the growth of the paddy is in progress from reproductive to ripening stage, a steady decline of the bug population has been observed due to the depletion of food sources. Alternative application at DSP(5) has provided the bug enough time to withstand the stress and to colonize.

Least level of bug population in TSP(4) can be accounted for the successive protections in early two growth stages and their extended residual effect to the next growth stage. Absence of protection at ripening stage in TSP(1) has allowed the bug to reappear in the field at low level.

Cyrtorhinus lividipennis has been the prime predator primarily of hopper eggs in the agro-ecological region of Raiganj. The bug, has also been reported from other blocks of the District Uttar Dinajpur during the period of study. This study reveals that the rate of predation of BPH eggs by *C. lividipennis* is on an average 20% in wetlands and 43% in dry land paddy. Predation accounts for the damage of 50% of eggs available in an untreated field.

4.4.2.3 In case of beetle

Single stage protection (SSP): Comparatively high level of beetle population with the average value 3.14 individuals / hill was observed in SSP(1). Significant differences in the beetle population were noted in other operations. The least number of beetles (2.96 individuals / hill) was noted in SSP (3) (Fig.4.4.6a).

Double stage protection (DSP): Highest level of beetle population was noted in DSP (6) while the least number was counted in case of DSP(3). The population did not differ significantly in DSP(4), DSP(2) and DSP(1) (Fig.4.4.6b).

Triple stage protection (TSP): Beetle population remained high in both TSP (3) and TSP (4) without significant difference. TSP(2) offered a least average population level of 1.67 individuals / hill (Fig.4.4.6c).

All stage protection (ASP): Such type of protection supported least number of beetle population.

No stage protection (NSP): The incidence of beetle population was maximum under this protection.

Discussion: SSP(1) has supported and maintained higher number of beetle. The population has colonized rapidly from the nearby field and maintains a steady level up to the ripening stage. Availability of green foliage at both vegetative and reproductive stages accelerates the rate of colonization. Adoption of SSP(2) and SSP(3) confer protection to the vegetative and reproductive stages respectively and interferes with the activity of the bug resulting in a steady fall in population. Such reduction of population size has been mainly attributed to the direct mortality following application of pesticides. SSP(4) has exerted very little effect on early colonization, hence the population has heightened.

DSP(6) has permitted high beetle level due to the availability of the pesticide free foliage. Early growth stage protection in DSP(1), consecutive protection in DSP(2) or interrupted episodic protection in DSP(4) differ insignificantly but with low population status. This indicates that a considerable time is required for the beetle to establish in higher numbers.

Absence of protection at vegetative stage in TSP(3) and reproductive stage in TSP(4) has allowed the predator to aggregate and multiply. Low beetle population at TSP(2) was due to the arrest of population growth at prime growth stage of paddy.

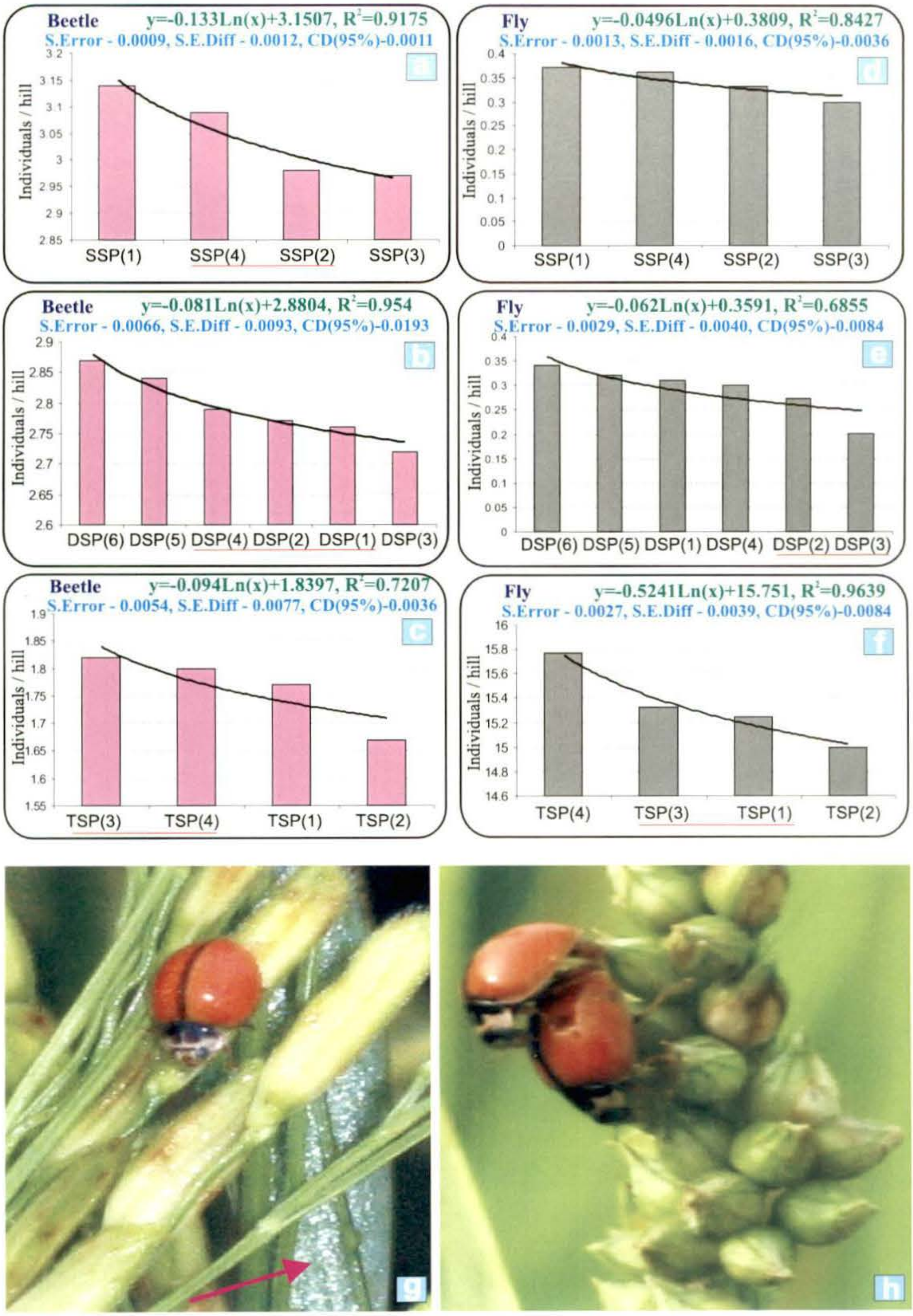


Fig. 4.4.6: Numerical occurrence of natural enemies: a-c: beetle, d-f: fly. SSP(1-4), DSP(1-6) and TSP(1-4): Single, double and triple paddy growth stage specific insecticidal protections. g: Beetle in all stage protected field(ASP). h: Beetle in field without insecticidal exposure (NSP). —: No significant differences.

4.4.2.4 In case of fly

Single stage protection (SSP): 0.38 individual / hill fly was recorded in SSP (1). The other three protection protocols showed significant differences in fly population, particularly between SSP(4) and SSP(2). The lowest level of population was noted at SSP(3) with 0.30 individuals / hill (Fig.4.4.6d).

Double stage protection (DSP): Very low count of fly population with insignificant level of difference was noted between DSP(2) and DSP(3). A relatively high population was noted in DSP(6). Interrupted episodic application as in DSP(4) had resulted in low fly population than DSP(5) and DSP(1). It was therefore, implied that fly could hardly colonize in a short period of time to build up the population (Fig.4.4.6e).

Triple stage protection (TSP): No significant difference of fly population was observed between TSP (3) and TSP (1).TSP (4) supported higher number of fly population while in TSP (2) the number was least (0.22 individuals / hill) (Fig.4.4.6f).

All stage protection (ASP): The fly number was least with 0.28 individuals / hill.

No stage protection (NSP): Maximum number of fly individuals was noted.

Discussion: SSP(1) has maintained comparatively higher number of fly. The population settles speedily from the nearby field attaining a steady level up to the ripening stage. Adoption of SSP(2) and SSP(3) confer protection to the vegetative and reproductive stages respectively and interferes with the activity of the fly causing the steady reduction of the population. Such attenuation of population size has been mainly credited either by the direct mortality or rapid migration following pesticides application. SSP(4) has exerted very little effect on early colonization, hence the population has heightened.

Pesticide free DSP(6) has allowed high fly level due to the availability of food. Early growth stage protection in DSP(1), consecutive protection in DSP (2) or interrupted episodic protection in DSP(4) differ significantly but exhibiting low population status. This designates that a substantial time is required for the fly to establish in higher numbers.

Unprotected vegetative stage in TSP(3) and reproductive stage in TSP (4) vary significantly allowing the fly to aggregate and multiply. Low fly population at TSP(2) was due to the detained population growth at major growth periods.

Kumar *et al.* (2000) has carried out a study during 1994-95 at paddy breeding station in Coimbatore, Tamil Nadu, India for assessing the influence of commonly used insecticides on predators of leaf and planthoppers of rice. Acephate, chlorpyrifos and monocrotophos were found to be safe to *Lycosa pseudoannulata*, *Tetragnatha javana* and *Paederus fuscipes* . Acephate was also found safe to *Microvelia atrolineata* and *Cyrtorhinus lividipennis*. Phorate and carbofuran were more toxic to both *M. atrolineata* and *C. lividipennis*. He suggested growth stage specific selective application of pesticides.

Assessment on the field dynamics of the predatory complex under different protection protocols appears to be the prime requisite to understand their relative efficacy of alternative pesticide applications. As the application of different pesticides influences the structure of natural enemy population, consequently the potentiality of predation by enemies was changed.

4.4.3 Growth stage specific application of pesticides on yield attributes

Plant height

Single stage protection (SSP): Relatively longer plant height was obtained in SSP(1) and the shortest height in SSP(4). In case of other two protections the height were intermediate (Fig.4.4.7a).

Double stage protection (DSP): The maximum height was attained in case of DSP(6) with an average value 128.5 cm. The height did not differ significantly in DSP(4), DSP(5) and DSP(3).The heights in other two protections were intermediate (Fig.4.4.7b).

Triple stage protection (TSP): The highest plant height was noted in TSP(2). In TSP(1) and TSP(3) the heights differ insignificantly. Shortest plant height was in TSP(4) (Fig.4.4.7c).

All stage protection (ASP): Maximum plant height was obtained.

No stage protection (NSP): Minimum plant height was noted.

Effective tillers

Single stage protection (SSP): The number of effective tillers was maximum in SSP(1) and minimum in SSP(3). SSP(4) and SSP(2) ranked 2nd and 3rd with the individual average value of 19.11 and 18.97 / hill respectively (Fig.4.4.7d).

Double stage protection (DSP): The maximum number of effective tillers was found in DSP(6). DSP(2), DSP(5) and DSP(1) did not differ significantly. The number of effective tillers were nearly the same in DSP(5), DSP(1) and DSP(3).Insignificant difference was noted between DSP(3) and DSP(4) (Fig.4.4.7e).

Triple stage protection (TSP): TSP(3) had registered the highest number of tillers while the lowest number was noted in TSP(1).TSP(4) and TSP(1) did not vary significantly. The number of tillers was relatively low in TSP(2) than in case of TSP(3) (Fig.4.4.7f).

All stage protection (ASP): Maximum number of effective tillers was obtained.

No stage protection (NSP): The tiller number was minimum under such application.

Panicle length

Single stage protection (SSP): Under SSP(3) the maximum panicle length was obtained with an average of 249 cm. While it was minimum in case of SSP(2) having an average value of 247.0 cm. In SSP(4) and SSP(1) nearly the same length was obtained (Fig.4.4.8a).

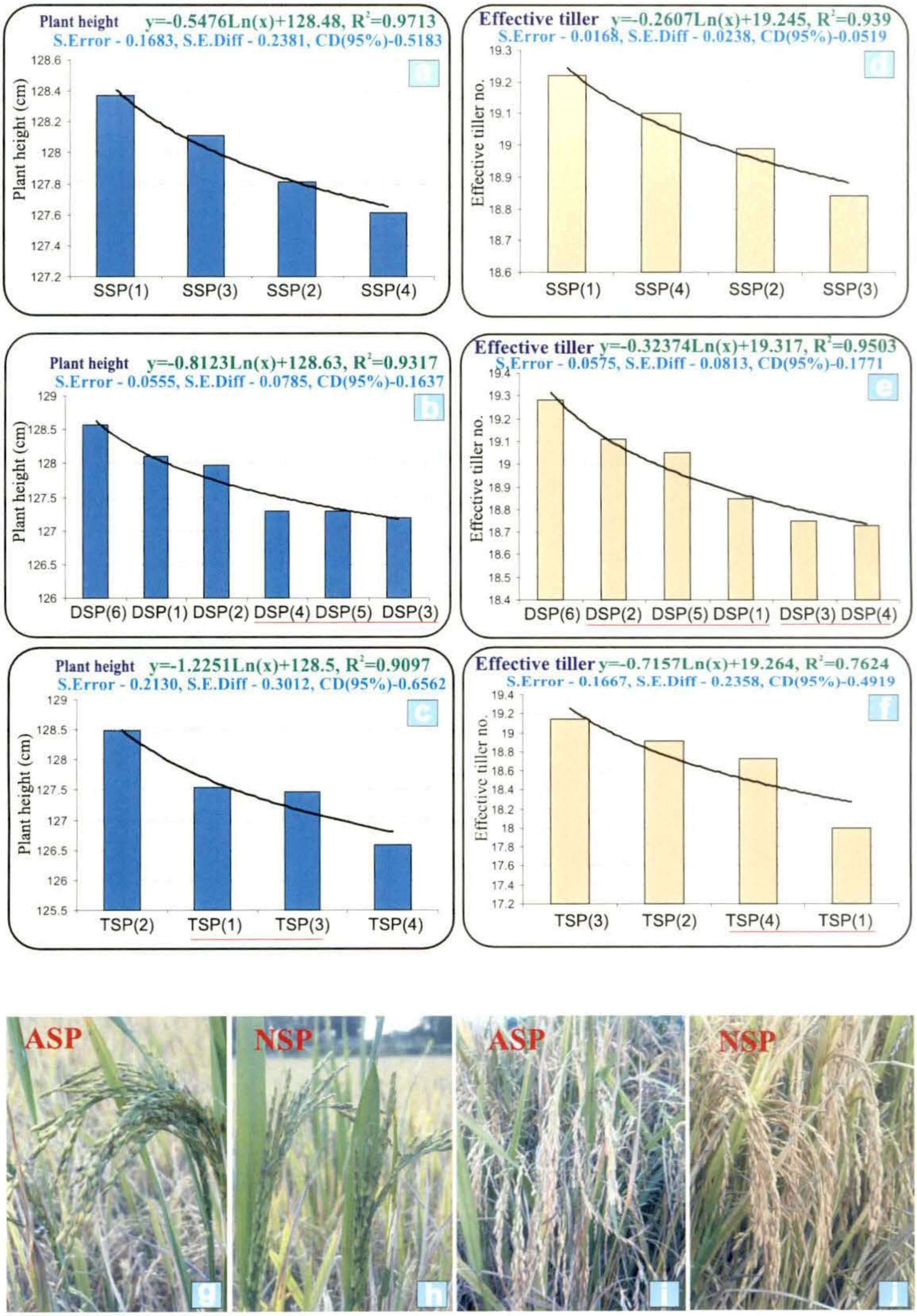


Fig. 4.4.7: Effect of pesticide on paddy plant height (a-c), g: ASP, h: NSP and on effective tiller number (d-f), i: ASP, j: NSP. SSP (1-4), DSP (1-6) and TSP (1-4): single, double and triple paddy growth stage specific insecticidal protections. —: No significant differences.

Double stage protection (DSP): Insignificant difference was observed among the treatments except in DSP(6) (Fig.4.4.8b).

Triple stage protection (TSP): No significant difference in panicle length was noted among TSP(2), TSP(1) and TSP(3) treatments. Further TSP(1), TSP(3) and TSP(4) differed insignificantly (Fig.4.4.8c).

All stage protection (ASP): Maximum panicle length was obtained

No stage protection NSP): The panicle length was minimum.

Number of grains /panicle

Single stage protection (SSP): The highest grain number / panicle was observed in SSP(4) while the lowest in SSP(1). No significant difference was noted between SSP(3) and SSP(2) (Fig.4.4.8d) .

Double stage protection (DSP): DSP(4), DSP(6), DSP(3), DSP(1) did not vary significantly with regard to grain number / panicle. Further DSP(6),DSP(3),DSP(1),DSP(5) and DSP(2) had nearly the same number of grains / panicle (Fig.4.4.8e) .

Triple stage protection (TSP): The highest number of grains /panicle was obtained in TSP(1). No significant difference was found between TSP (3) and TSP(4) .In TSP(2), the number of grain / panicle was significantly low with an average of 234 grains / panicle (Fig.4.4.8f).

All stage protection (ASP): Highest grain number / panicle was obtained.

No stage protection NSP): The grain number was least.

Grain yield

Single stage protection (SSP): Maximum grain yield was observed in SSP(2) with an average value 23.4 q / ha and the minimum was in SSP(1). SSP(3) and SSP(4) differed significantly regarding the yield potential, the average value was being 22.6 and 22.1 q / ha respectively(Fig.4.4.9a).

Double stage protection (DSP): The highest production occurred in DSP(2) which was immediately followed by DSP(3). DSP(4), DSP(5), DSP(1) and DSP(6) ranked afterwards in descending order with significant level of difference (Fig.4.4.9b).

Triple stage protection (TSP): The highest yield was noted in TSP(2). TSP(1), TSP(3) and TSP(4), ranked afterwards and shoed significant differences (Fig.4.4.9c).

All stage protection (ASP): Highest grain yield was noted.

No stage protection (NSP): Very poor grain generation was registered.

Discussion: Though plant height and effective tiller generation have been maximum in SSP(1) but the yield has been minimum due to lowest grains / panicle. Maximum yield in case of SSP(2) is due to the protection of vegetative stage for a longer time and proper grain filling. Comparatively low yield in SSP(3) with maximum panicle length and moderate grain number/panicle has been due the continuous damage by YSB in the absence of pesticide protection at late vegetative stage. This was again followed by PB attack.

In DSP(6) the highest plant height with minimum panicle length has been obtained. This has happened due to the absence of pesticidal protection at two consecutive vegetative and reproductive stages, which has favoured a high magnitude of GM infestation. The infestation induces greater tiller generation. DSP(2) has offered pesticide protection at vegetative and reproductive stages and thus has escaped damage by YSB and GM, resulting in the maximum grain yield. The panicle length is nearly the same in all the treatments, except in DSP (6) indicating the steady interactions between the plant phenology and pest complex.

Although in TSP(1) the grain number / panicle has been highest, low yield occurs only due to the damage by PB at ripening stage in the absence of protection. TSP(2) with moderate grain number/panicle has ranked first in terms of yield. This happens because of continuous protection in all the stages except in the seed bed.

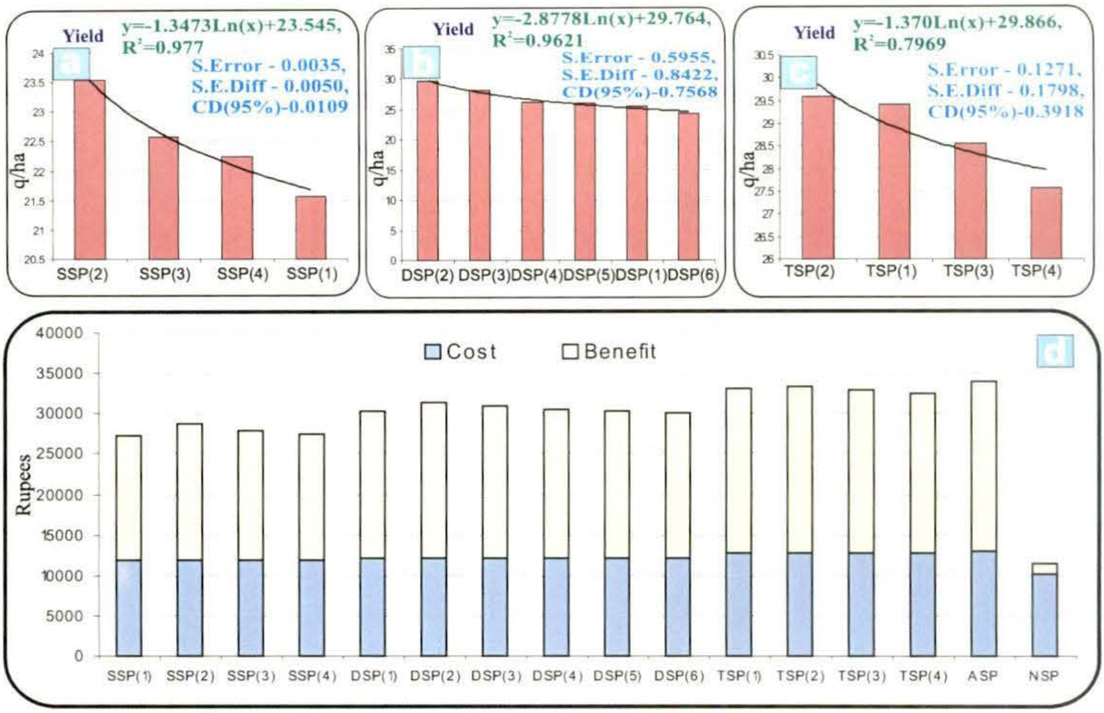


Fig. 4.4.9: Impact of insecticides (a-c): on grain yields and (d): on C:B values (d): SSP(1-4), DSP(1-6) and TSP (1-4): single, double and triple paddy growth stage specific insecticidal protections.

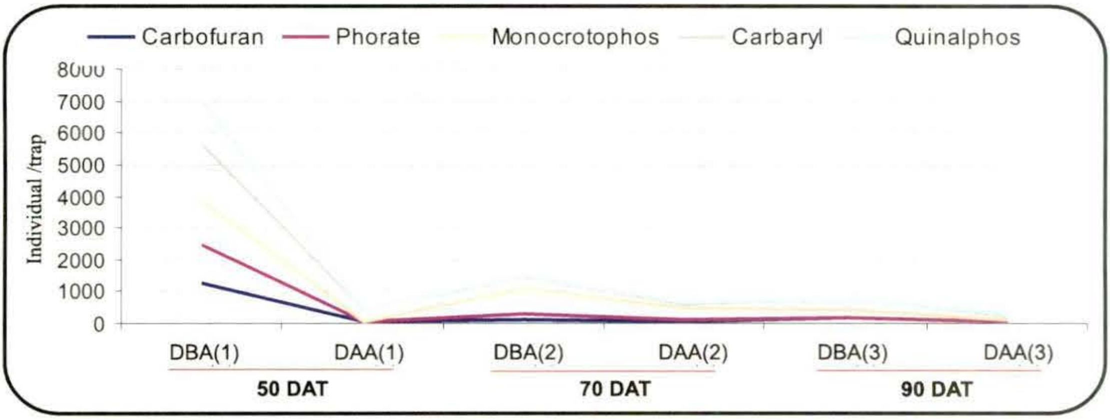


Fig. 4.4.10: Impact of different insecticides on numerical occurrence of BPH. DBA(1-3): days before insecticide applications. DAA(1-3): dates after insecticide applications.

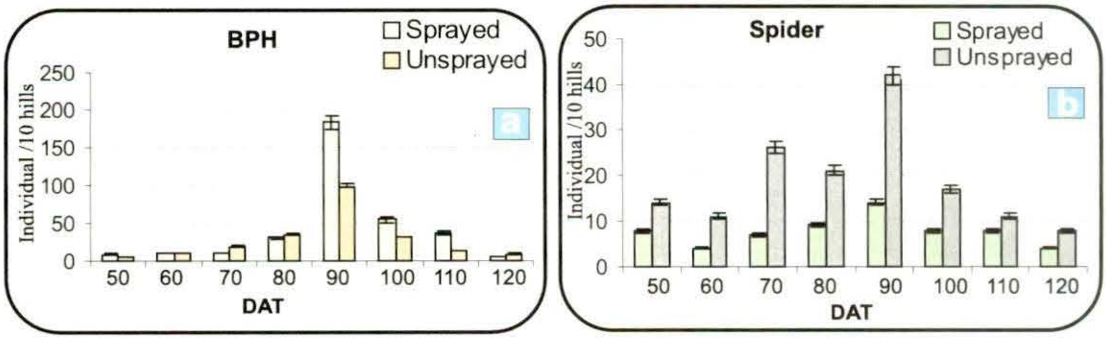


Fig. 4.4.11: Effect of carbofuran on the occurance of BPH(a) and spider(b).

Absence of protection in vegetative stage in case of DSP(4) results in lower number of effective tillers, reduced panicle length bearing low grain number / panicle hence, results in poor yield.

Lowest number of tillers in TSP(1) with highest grain number / panicle has been due to interaction between pesticidal activity and crop phenology. Apart from protective function, pesticides act as phytotonic agents inducing plant growth and offer positive effect on yield attributes. Greater the yield attributing characters, higher will be the pest infestation. But the relative variability in the nature of pest infestation is due to the preference of the pest(s) to the particular growth stage(s).

Previous studies regarding the phytotonic effect of the pesticides has been restricted to a single formulation. But the farmers rely upon varieties of pesticide compositions; their collective role on the plant physiology has so far been disregarded.

Rao *et al.* (1983) have recorded an increased vegetative growth of rice plants due to soil application of carbofuran @ 1 kg a.i / ha in addition to the effective stem borer control.

Present study is in consonance with the previous observation by Balasubramaniyan *et al.* (1981) although the nature of pesticides used in their experiment differs. Observation shows that the phytotonic effect of carbofuran applied @ 0.5 kg a.i / ha in low land rice has manifested through increased leaf area index, number of productive tillers, grains / panicle and 1000 grain weight. The grain yield increased to 41.8 - 46.8 q / ha as against 35.7-39.3 q / ha in untreated control.

Venugopal *et al.*(1983) found that the stimulatory effect of carbofuran induced greater root development, enhanced plant height, more number of total and productive tillers, rapid maturation of the grain leading to high yields. Contrary to this, Sing *et al.* (1990) found that the carbofuran did not influence the yield or yield attributes. Sontakke *et al.*(1998) made an comparative assay on the phytotonic effect of carbofuran and found that the influence was more profound in the variety '*Jajati*' than in '*Jaya*' and concluded that the activity of carbofuran was variety specific.

Present investigation encompasses the growth stage dependent application of different pesticides in a collective manner. Phytotonic effect of each of the pesticides in succession has essentially induced physiological change which in turn has caused positive impact on both grain yield attributes and pest number. The extent of 'boosting effect' is dose dependent and growth stage specific. Accordingly, the stage-specific selection of the pesticides is to be made with proper consideration of the standing growth stage.

Yield economics

Growth stage specific protection experiment implies highest grain yield in All Stage Protection (ASP) with a cost:benefit =1:1.61. DSP has been economically more justified and profitable than SSP with an average C : B ratio = 1:1.52. Among all the stages of SSP, SSP(1) and SSP(3) have generated 64.70 and 68.23% of the yield obtained in ASP respectively. In other treatments with SSP, yield gain has been relatively low. In comparison to the yield from ASP, all the stages of TSP collectively have resulted in slightly higher (81.58%) than in DSP (74.68%), among all the treatments of DSP; the DSP(2) has given better result (Fig.4.4.9d).

Discussion: Works, so far undertaken to evaluate the relative efficacy of the newly evolved pesticide application protocols have aimed at to determine the highest return under maximum protection. Works carried out so far concern mainly with input of pesticides, very little attention was paid upon the yield generation under different growth stage specific protection protocols.

Though a partial study to evaluate the comparative damaging potentiality of pests has been undertaken by the RRI, Chinchura, West Bengal and the relative comparison has been drawn between the 'crop protected' and the 'crop unprotected', but the importance of the different growth stages had not been considered.

Present study depicts a changeable range of yield benefit under the adoption of different protection protocols. Initial survey in the three blocks reveals that only 12% farmers can avail of the opportunity of maximum protection (ASP). Due to the lack of proper knowledge farmers use the pesticides randomly disregarding the 'actually effective' growth stage(s). The result encourages the farmers, after proper adoption of such protectional protocol, will be able to evaluate readily the yield benefit under different growth stage specific protection.

4.4.4 Study on the effect of a particular pesticide on a particular pest

4.4.4.1 Evaluation of the pesticides for controlling YSB

Effect of chain application of five pesticides commonly used by the farmers in all the blocks on the activity of YSB was assessed by counting DH(%) and WH(%) on 50, 70 and 90 DAT respectively in *kharif* crops against the fields with no pesticide application, considered as control. Pesticides were applied twice, at 35 and 75 DAT correspondingly. Experiments were conducted in four consecutive years and the average was considered (Tables.4.4.1 and 4.4.2).

Quinalphos was the least toxic pesticide to bring about the YSB mortality accordingly the number of DH(%) was highest at 50 DAT. Carbofuran showed the highest efficiency at 50 DAT limiting the available DH to 0.80%. But the activity of carbofuran was not extended as the number of DH was considerably increased in the subsequent observation at 70 DAT. Highest efficiency at 70 DAT was noted for phorate while the least for carbaryl.

The other pesticides showed the activity in the descending order of carbofuran, monocrotophos and quinalphos during 70 DAT observations. Estimation of WH at 90 DAT showed that phorate was the most effective while quinalphos was the least. Carbaryl, carbofuran and monocrotophos exhibited the efficiency in ascending order to check WH.

Final yield generation was greatly influenced by the pesticide treatments. Minimum grain yield was noted for control against the maximum under carbofuran application. Phorate, monocrotophos and carbaryl yielded 32.42 , 31.04 and 28.67q / ha respectively.

Table.4.4.1: Extent of damage by YSB on different growth stages of paddy after the application of different insecticides

Insecticide applied	DH(%)										WH(%)				
	50 DAT					70 DAT					90 DAT				
	2003	2004	2005	2006	Avg.	2003	2004	2005	2006	Avg.	2003	2004	2005	2006	Avg.
Carbofuran	0.74a	0.89a	0.81a	0.77a	0.80	7.11bc	6.51b	7.45bc	6.21a	6.82	1.58a	1.78ab	1.98c	2.05a	1.84
Phorate	1.98ab	1.72a	1.61ab	1.85ab	1.79	3.87ab	3.65ab	3.91ab	3.78ab	3.80	1.45cd	1.54ef	1.63ef	1.75ef	1.23
Monocrotophos	2.08bc	2.43bc	3.11ef	2.54ab	2.54	8.21bc	7.43ef	7.54ef	6.98a	7.54	1.67bc	1.78bc	1.77ef	2.04cd	1.81
Carbaryl	2.54ab	2.06bc	2.22bc	3.01bc	3.01	6.88cd	6.59cd	7.12cd	7.67cd	7.06	3.22ef	3.41ef	3.58ef	4.01ef	3.55
Quinalphos	4.66cd	4.32cd	4.55cd	4.98bc	4.98	7.89ef	8.31ef	7.56cd	7.79cd	7.88	3.67ef	3.78ef	3.91cd	4.03cd	3.84
Control	12.22g	10.31g	12.64g	12.72g	12.70	13.22g	12.21g	10.87g	12.55g	12.21	11.21g	10.87g	11.65g	11.21g	1.23

Figures marked with the same letter are not significantly different at 5% level

Table.4.4.2: Paddy yield generation under different pesticide treatments

Insecticide applied	Yileld (q / ha)
Carbofuran	39.87
Phorate	32.42
Monocrotophos	31.04
Carbaryl	28.67
Quinalphos	34.11
Control (without insecticide)	27.23

Discussion: It appears that none of the pesticides when used at randomly can control YSB completely for all the growth stages of paddy. Selection and application of a particular pesticide should be suited to the objective to maximize the larval death. Carbofuran is most effective during the early brood of the larvae. Carbaryl and quinalphos have lower effect on YSB at 50 DAT. Phorate has been found relatively more effective to the second batch of larvae than carbofuran. Application of monocrotophos can hardly manage the YSB population at 70 DAT. However through out the growth stages, phorate can moderately check the causation of DH and WH in comparison to the other insecticides. Variability of the pesticide lethality in relation to the plant growth stage is related to the half life of the particular brand and to their access within the crop canopy. Further all the pesticides are differentially potent to all the developmental stages of pests.

Therefore, farmers may adopt carbofuran at early stage of plant growth but selection of phorate is more economically viable as it helps to reduce the pest population throughout the paddy ages.

4.4.4.2 Evaluation of pesticides for controlling BPH

4.4.4.2.1 Study on the relative efficacy of different pesticides

Small field (100x100mt.): Relative efficiency of five pesticides commonly used by the farmers to check BPH population was assessed. Pesticides were applied at 70 DAT, there were 3 replications and the BPH individuals(both adult + nymphs) / hill was counted at 75 DAT. The average value was then statistically analyzed.

Carbofuran showed the maximum lethality while for qunalphos it was minimum. Phorate, monocrotophos and carbaryl expressed the lethality in the descending order (Table.4.4.3).

Table.4.4.3: Field evaluation of the relative efficacy of five granular pesticides for controlling BPH at 75 days after the transplantation (DAT) of the seedlings.

Insecticides applied		**Individuals/15 hills (adult + nymphs)**					**Grain yield (q/ ha)**				
Generic name	Dose	Years of observation				Avg.	Years of observation				Avg.
		2003	2004	2005	2006		2003	2004	2005	2006	
Carbofuran	1.00	17.1 (4.18)	13.3 (3.67)	9.2 (3.08)	14.1 (3.80)	13.25 (3.70)	34.21 (5.89)	33.87 (5.86)	34.68 (5.93)	34.39 (5.90)	34.28 (5.89)
Phorate	1.00	23.2 (4.84)	18.1 (4.30)	13.2 (3.67)	11.1 (3.39)	16.25 (4.09)	32.69 (5.76)	32.88 (5.77)	32.46 (5.74)	32.55 (5.74)	32.64 (5.75)
Mono-crotophos	0.50	28.1 (5.33)	24.2 (4.94)	31.1 (5.61)	34.0 (5.87)	29.25 (5.45)	30.11 (5.53)	31.31 (5.64)	30.43 (5.56)	30.69 (5.58)	30.63 (5.57)
Carbaryl	0.75	26.0 (5.14)	19.1 (4.41)	29.0 (5.43)	39.1 (6.28)	28.25 (5.36)	28.82 (5.41)	28.91 (5.42)	30.21 (5.54)	27.11 (5.25)	28.76 (5.40)
Quinalphos	1.25	38.1 (6.16)	45.1 (6.74)	37.0 (6.12)	42.0 (6.51)	40.50 (6.40)	26.65 (5.21)	27.33 (5.27)	27.69 (5.30)	27.01 (5.24)	27.17 (5.26)
Control	x	47.0 (6.20)	52.0 (7.24)	45.0 (6.74)	39.0 (6.28)	43.25 (6.61)	22.25 (4.76)	23.67 (4.91)	22.11 (4.75)	21.45 (4.68)	22.37 (4.78)
SE of mean		2.11	1.16	2.31	2.22		2.51	1.48	2.12	1.37	
LSD (p <0.05)		6.22	4.12	2.39	3.41		6.11	2.14	N.S	2.41	

(x)- No pesticide applied

All the value except control is the mean of three treatments in each year. Figure in the parenthesis are the transformed value and the standard error (S.E) and LSDs referred to this.

Wide field (1000x1000mt.): The efficacy of the selected pesticides was also tested in the larger fields. BPH was counted by light trapping(400 watt.) on the day immediately before (DBA) and after (DAA) the pesticide application. As the farmers use pesticides mostly in a chain, each type of pesticide was applied against the BPH every 20 days interval. The average pooled data of light trapping in relation to the five insecticides were graphically plotted (Fig.4.4.10).

In each application BPH population declined steadily due to mortality and immediate steady migration. The population again recolonized, settled and attained peak .But the magnitude of colonization was gradually decreased as the times of application was increased progressively with the application schedules on 50, 70 and 90 DAT. Pattern of colonization directly related by the efficacy of the pesticides. In this regard monocrotophos stood first and carbofuran and phrorate second and third respectively. However the shortcoming with carbofuran at late growth stages was due to its inability to penetrate to higher plant canopy.

Experiment indicates that the efficacy is field size independent as smaller and larger field expresses same range of efficiency in consideration of a particular pesticide.

4.4.4.2.2 Dynamics of BPH population in relation to the growth stage of paddy

Dynamics of BPH was noted under two different modes of application each with two different brands. Both the granular and sprayable formulation was applied at 45-50 and 65-70 DAT respectively and BPH number was counted fortnightly staring from 10 DAT up to 80 DAT.

4.4.4.2.2.1 Fixed date application: Pesticides irrespective in variable doses and in two different modes of applications, to the immediate vicinity drived out the BPH. Efficacy was studied in consideration of the population change(%) after pesticidal input against the field without pesticide application, considered as control. Grannular formulation of carbofuran @ 2 kg a.i/ha proved more effective than the other pesticides. With the increase of doses the incidence of BPH was minimized. Formulation of phorate had the lowest efficiency in respect of the granular application. Among the spray application, phoxim and cypermethrin gave intermediate results (Table.4.4.4).

Table. 4.4.4: Incidence of BPH in relation to the growth stages of paddy after the application of different types of pesticide at 10 x10 spacings

Types	Trade name	Application rate (kg .a.i/ha)	BPH individuals/5hills									Change (%)
			10 DAT	20 DAT	30 DAT	40 DAT	50 DAT	60 DAT	70 DAT	80 DAT	Mean	
Granular application.	Carbofuran	1.00	13.56±1.14	8.24±1.11	20.1±4.11	29.11±4.11	18.34±2.11	28.11±2.12	64.22±3.11	34.11±1.11	26.75	-68
		1.50	16.11±2.12	5.76±1.12	4.21±1.31	5.34±1.11	8.11±1.11	04.21±2.43	02.34±3.56	43.21±3.23	10.87	-87
		2.00	6.12±2.34	01.45±1.45	1.00±0.91	1.02±0.98	1.21±1.77	01.21±0.98	01.45±3.67	01.32±0.12	01.63	-98
	Photate	1.00	10.34±3.11	17.67±2.34	88.01±5.32	10.21±1.67	63.16±3.21	110.98±9.67	79.55±2.78	126.11±8.23	73.05	-12
		1.50	10.56±2.45	11.65±4.11	56.13±4.21	77.22±4.22	67.33±1.21	91.23±9.88	81.31±2.90	133.44±9.21	66.00	-21
		2.00	11.67±3.11	12.34±3.24	36.31±5.56	52.22±2.11	21.23±1.01	30.13±4.45	26.03±4.11	32.11±2.34	27.50	-67
Spray able application.	Cypermethrin	1.00	17.11±2.31	3.22±1.02	19.88±3.34	52.34±4.11	19.01±2.11	32.01±3.67	27.33±5.01	29.09±3.34	24.75	-70
		1.50	12.45±2.32	5.11±1.21	11.90±1.45	19.23±2.12	8.23±1.23	22.00±4.33	13.21±1.49	27.67±3.23	14.62	-82
		2.00	18.67±3.11	7.24±1.31	5.78±2.21	29.34±3.32	11.21±0.99	43.32±4.11	18.11±2.27	57.77±4.34	23.50	-71
	Phoxim	0.025 %	19.81±4.12	44.89±1.21	53.56±6.33	69.45±4.34	60.33±6.89	87.32±5.23	69.34±7.11	105.55±9.56	64.10	- 19
		.05 %	13.45±4.21	21.11±1.11	24.22±5.32	40.31±4.23	40.33±4.78	59.34±5.98	52.43±5.11	85.34±5.49	41.75	-50
		0.1 %	15.67±3.12	37.00±1.41	33.11±4.11	31.11±2.11	43.22±3.22	31.21±2.67	61.32±9.31	68.24±4.45	39.87	-52
Control		NA	12.11±2.25	47.11±1.22	74.45±5.67	87.47±4.34	92.55±9.34	147.11±9.78	132.78±10.99	78.21±4.22	83.62	x

NA: No application, (x): Not applicable

Treatment was made on 45-50 and 65-70 DAT respectively. Treatments are significant at 1 % level (CD.=1.73)

extent of more than 98%. However, with the progress of paddy growth the

4.4.4.2.2.2. Alternative date applications: The farmers follow optimum cultural practice of pesticide applications in different times schedules which were grossly irregular. In order to get the best result, application of pesticides at suitable time schedules, a study was undertaken. The data were then match with those obtained by the farmers in such practices so that an optimum application frequency and time schedule can generate.

Carbofuran and monocrotophos were noted as the most effective pesticide in application among the batches in the previous experiments. For this, to evaluate the relative efficacy of alternative date application only these two pesticides were considered. The pesticides were sprayed either in single, double or triple applications. Different combinations of these three timings were given at 45-50, 65-70 and 85-90 DAT respectively, designated as 1st, 2nd and 3rd application. The population was then assessed by light trapping immediately day before (DBA) and day after application (DAA) and the yield generation was noted at post harvest condition.

Carbofuran (Table.4.4.5)

Single dose (SD1, SD2 and SD3): In each category of application carbofuran was found effective to drive away the BPH population to the extent of more than 98%. However, with the progress of paddy growth the efficacy gradually decreased because of canopy compactness.SD2 scored maximum yield.

Double dose (DD1, DD2 and DD3): The best result was obtained at DD1. DD3 and DD2 ranked next in descending degree. In spite of high efficacy obtained at DD1, yield loss was high due to the damage of paddy at late growth stage. But collectively DD1 yielded maximum.

Triple dose (TD): BPH infestation was always low in triple dose application and paddy yield was maximum.

Table.4.4.5: Effectiveness of different modes of application of carbofuran @ 300-400l (2 kg a.i)/ha (usually used by the farmers) on the incidence of the BPH and its their consequences on paddy yield.

Times of application	Sub category	% of farmers adopted	Schedule of pesticide chain application and the time of population assessment						Yield q / ha
			1st (45-50 DAT)		1st (65-70 DAT)		1st (85-90 DAT)		
			1 DBA	1 DAA	1 DBA	1 DAA	1 DBA	1 DAA	
Single	SD1	09	1,699 a	11 b	x	x	x	x	27.84
	SD2	14	x	x	1,120 a	161 a	x	x	29.80
	SD3	07	x	x	x	x	1321 a	151 a	28.01
Double	DD1	13	1,351 a	22 b	83 abc	13 b	x	x	33.34
	DD2	18	1432 a	32 b		x	503 ab	87 a	31.51
	DD3	12	x	x	1457 a	35 abc	419 ab	43 b	33.21
Triple	TD	27	1272 a	12 b	75 abc	09 b	52 ab	3 c	33.92

(x): Population assessment was not done
DBA: One day before application, DAA: One day after application
Figures marked with the same letter are not significantly different at 5% level

Monocrotophos (Table.4.4.6)

Single dose (SD1, SD2 and SD3): Of all the single dose applications, SD2 was found effective and yielded 29.79 q / ha.

Double dose (DD1, DD2 and DD3): In this case of DD, DD1 was found more effective and higher paddy yield was obtained with 32.24 q / ha.

Triple dose (TD): Highest level of yield benefit was obtained from triple dose application due to significantly low pest occurrence.

Discussion: In comparison of all the treatment categories, SD2 and DD1 have provided best result. However the efficacy of carbofuran has been higher than that of monocrotophos. Each category of application timing caused a steady decline of BPH population due to both death and migration. But the population again recolonized, settled and attained the maximum level.

The farmers in the district of Uttar Dinajpur have experienced of periodic attack by BPH almost every year causing severe crop failure. It is thus more economic for the farmers to adopt SD2 or DD1 protection. Although triple stage protection is relatively profitable, but it has the short coming of higher residual toxicity.

4.4.4.2.3 Study on the relative impact of the pesticides both on BPH and spider population: Farmers frequently applied sub-lethal dose of carbofuran at 30-35 DAT, at early growth stages of paddy.The impact of such early application of carbofuran to the relative dynamics of BPH population and its natural spider enemy (*L. pseudoannulata*) was assessed from their relative incidence by comparing the values obtained from pesticide free fields. The BPH attack started from the very day of transplantation and maximized at about 90 DAT after which the population gradually declined. But in case of single spray of monocrotophos although the initial population was low a sudden explosion of population was noted at 90 DAT, after which there was a steady fall in the population. Monocrotophos probably acted as an instigating factor for oviposition leading to high population structure. Standing spider population could not manage such enormous abundance resulting high field crop damage (Figs.4.4.11a and b).

Table.4.4.6: Effectiveness of different modes of application of monocrotophos@ 300-400l (2 kg a.i)/ha (usually used by the farmers) on the incidence of the BPH and its their consequences on paddy yield.

Times of application	Sub category	% of farmers adopted	Schedule of pesticide chain application and the time of population assessment						Yield q/ ha
			1st (45-50 DAT)		2nd (65-70 DAT)		3rd (85-90 DAT)		
			DBA	DAA	DBA	DAA	DBA	DAA	
Single	SD1	04	1,279 d	19 a	x	x	x	x	27.64
	SD2	13	x	x	1,421 d	219 a	x	x	29.79
	SD3	12	x	x	x	x	1621 d	290 c	28.01
Double	DD1	13	1,351 d	32 bc	153 abc	23 abc	x	x	32.24
	DD2	17	1432 d	48 bc		x	713 cd	127 a	31.11
	DD3	16	x	x	1457 d	35 a	419 a	43 a	31.91
Triple	TD	25	1272 d	15 a	155 c	19 a	132 ab	3 a	33.72

(x): Population assessment was not done
DBA: One day before application, DAA: One day after application
Figures marked with the same letter are not significantly different at 5% level

Spider dynamics showed an agreement with the field abundance of BPH population. Although the spider incidence was initiated from the early day of transplantation, it increased gradually, peaked at about 90 DAT after which the population progressively diminished. Although the population dynamics of spider was nearly the same under both pesticide treated and untreated fields, but the intensity of population was much higher in unsprayed fields.

The population of the spider showed a density dependent variation with the BPH population. Pesticide application has almost equal impact on the pattern of dynamics on both BPH and spider populations.

Discussion: Pesticide induced resurgence of BPH population due to suppression of a mirid predator has been recorded earlier by Dyck and Orlido (1977). But very few have been done on the relative activity of natural enemies and pest status under different pesticide application protocols.

Reduction in the population of natural enemies following the injudicious and rampant insecticide application has been suggested as an important factor for BPH resurgence (Kiritani *et al.* 1971, Kiritani 1972). But present findings is contradicted by Reissig *et al.*(1986) who have found that the increase in population of different spiders, *Cyrtorhinus lividipennis* and *Microvelia atrolineata* under field conditions is not proportional to the reduction of BPH population. These workers have concluded that insecticide induced resurgence of BPH population is independent of natural enemy density. That the natural enemy destruction is a minor factor in pest resurgence has also been corroborated by Chelliah (1979) and Heihrichs *et al.* (1981). It may be the fact that instigation for oviposition together with the depleted spider population is collectively responsible for pest out break.

From the present results it appear that stage specific selection of pesticides is important to control the BPH problem. In areas where BPH activity is found endemic, judicious application of carbofuran in consideration of the dynamics of the spider population is understandable. But indiscriminate application will result in BPH resurgence.

4.4.4.3 Effect of insecticide on the activity of gall midge

4.4.3.1 Study on the relative efficacy of different pesticides: Relative efficacies of five commonly used pesticides to control the GM incidence were tested after single dose pesticide treatment at 70 DAT. The average data on the number of silver shoot (%) at 95 DAT obtained from each pesticidal protection were statistically analyzed (Table.4.4.7).

Table.4.4.7: Field evaluation of the relative efficacy of five granular pesticides on the GM population at 90 days after the transplantation (DAT) of the seedlings.

Insecticides applied		Silver Shoot (SS%)					Percentage of parasitized gall (PG%)				
Generic name	Dose (a.i/ha)	Years of observations				Avg.	Years of observations				Avg.
		2003	2004	2005	2006		2003	2004	2005	2006	
Carbofuran	1.00	13.9 (3.79)	15.7 (4.02)	14.6 (3.88)	17.1 (4.19)	15.10 (3.94)	19.21 (4.43)	21.78 (4.72)	25.15 (5.06)	22.98 (4.840	22.28 (4.77)
Phorate	1.00	26.55 (5.20)	19.82 (4.50)	21.77 (4.71)	24.21 (4.97)	23.08 (4.85)	7.98 (2.91)	28.73 (5.40)	17.98 (4.29)	22.11 (4.75)	19.20 (4.43)
Monocrotophos	0.50	12.34 (3.58)	16.21 (4.08)	09.85 (3.21)	13.11 (3.68)	12.87 (3.65)	19.13 (4.43)	11.04 (3.39)	12.21 (3.56)	16.11 (4.07)	14.62 (3.88)
Carbaryl	0.75	18.41 (4.34)	13.47 (3.73)	09.67 (3.18)	11.01 (3.39)	13.14 (3.69)	13.12 (3.69)	9.02 (3.08)	12.61 (3.62)	08.62 (3.01)	10.84 (3.36)
Quinalphos	1.25	41.22 (6.45)	28.79 (5.41)	38.65 (6.25)	39.54 (6.32)	37.05 (6.12)	12.32 (3.58)	14.36 (3.85)	09.01 (3.08)	27.11 5.25)	15.72 (4.02)
Control	x	62.12 (7.41)	54.12 (7.39)	49.31 (7.05)	52.61 (7.28)	54.54 (7.14)	34.44 (5.91)	36.67 (6.09)	27.18 (5.26)	31.11 (5.62)	32.35 (5.73)
SE of mean		2.31	1.26	2.11	2.32		2.41	1.88	2.32	1.97	
LSD (p <0.05)		6.62	5.32	3.39	4.42		7.11	3.14	N.S	3.41	

(x)- No pesticide applied

Figure in the parenthesis are the transformed value and the standard error (S.E) and LSDs referred to this. Figure in the parenthesis are the root mean square transformed value.

Monocrotophos was highly effective against GM with least number of SS(%) while quinalphos was least toxic. Phorate, carbofuran and carbaryl treatment expressed 23.08, 15.32 and 13.14 SS% respectively. However, the percentage of parasitized galls (PG%) was highest and lowest in case of carbofuran and monocrotophos treatments respectively.

Monocrotophos and carbaryl were found most effective, the former was being superior to the latter in respect of SS%. Quinalphos was the least effective pesticide to control GM. Action of phorate was less potent than carbofuranThe value except control is the mean of three treatments in each year.

Application of pesticide hampers parasite development. So, selection of pesticide should be done judiciously in due consideration of the parasite activity. Though SS% formation was comparatively higher under carbofuran, it preserves parasitic activity.

Dash *et al.* (2003) have evaluated the effect of the insecticide chlorphos in granular formation against early pests infestation on *Jaya* variety. They have found that the insecticide is promising in reducing the silver shoot incidence during the first year, but not in the next year. Such finding reflects that the activity of the pesticide is season specific.

For this, carbofuran is best suitable pesticide for prophylactic control at late application. But for GM endemic areas application monocrotophos for a short duration is economically compatible than others. As inconsistency was noted regarding the efficacy of pesticides which necessities periodic assessment before admitting in the schedule.

4.4.4.3.2 Impact of different mode of applications of different pesticides on GM and enemy: Selective role of 5 insecticides against rice GM was tested for need based management practices with minimum use of insecticides. Carbofuran, phorate, monocrotophs, carbaryl, quinalphos were broadcasted at a rate 1 kg a.i. / ha on 50 DAT in a split plot design at seedling stage. Root dip treatment of seedlings was carried out with chlopyrifos (Dursban 20) and Isophenphos (Oftalon 50) for the main plot and the granular insecticide for the subplots, each one in three different replications (Table.4.4.8).

Table.4.4.8 Study on the variable mode of application of different types of pesticides

Types of treatments	Growth stages at which pesticides applied		Incidence(%) of gall midge induced damage symptoms and parasitic activity	
	Root dip	Main land	Silver shoot	Parasite
Root dip application	Chlopyriphos	x	39.12 (6.29)	39.81 (6.34)
	Isophenphos	x	24.2 (4.96)	41.81 (6.50)
Root dip supplemented by field application	Chlopyriphos	Carbofuran.	13.10 (3.68)	22.26 (4.77)
		Phorate.	21.08 (4.64)	19.20 (4.43)
		Monocrotophs.	10.87 (3.37)	15.62 (4.07)
		Carbaryl.	12.14 (3.35)	11.84 (3.51)
		Quinalphos	34.05 (5.87)	14.72 (3.90)
	Isophenphos	Carbofuran.	12.10 (3.28)	22.18 (4.76)
		Phorate.	19.08 (4.14)	19.22 (4.44)
		Monocrotophs.	10.17 (3.17)	14.52 (3.87)
		Carbaryl.	11.14 (3.15)	10.74 (3.35)
		Quinalphos	30.05 (5.52)	12.42 (3.59)
Control(without treatment)			54.54 (7.41)	42.95 (6.59)

(x)- No pesticide application

Figure in parenthesis indicated square root transformed value

Root dip treatment: Seedling root dipping in both the insecticides were effective against the subsequent GM incidence, chlopyriphos was inferior to isophenphos. Pesticidal protection, 40 days after root-deep treatment, when the plant was at late vegetative stage failed almost completely resulting in free access to GM. Root-dip treatment in general gave excellent protection to the productive tillers to early vegetative stage. But without any conceivable impact on the activity natural enemies, particularly on *Platygaster* oryzae, a hymenopteran parasite of GM.

Root-dip treatment supplemented by granular pesticides: In both *kharif* and *boro* seasons the incidence of SS(%) was comparatively high in the control plots. Root dip treatment supplemented by the granular application of monocrotophos restricted the SS% . Carbaryl appeared second best insecticide, followed by carbofuran and phorate respectively in descending order. On the other hand, quilalphos was least effective.

A marginal reduction in SS(%) was recorded in case of only root-dip treatment of the seedlings, the effect of which remained effective for 30-35 days.

Granular application reduced the activity of the gall parasite to some extent. Carbaryl (11.84-10.74%) followed by monocrotophos(15.62-14.52%) and quinalphos (14.72-12.42%) expressed lethality in descending order to the parasite. However, carbofuran was the least effective pesticide (22.18-22.26%) on parasite.

Discussion: Single root-dip treatment had particularly no effect on the parasite which started building after transplantation and maximized at 80 DAT.SS(%) was nearly at par with the plots receiving the supplemented doses of treatment. On the contrary, root-dip treatment was ineffective against pest incidence. If pesticide was applied at early growth stages the activity of the parasite was restored.

Tripathy *et al.*(1999) have evaluated the effectiveness of several insecticides in Orissa for the control of YSB and GM. They used the insecticides in a chain of 10, 58 and 74 DAT. The study indicated that 1.0 kg carbofuran / ha (Furadon 3G) has given best result in controlling YSB (1.53% DH) 15 days after treatment. and that 0.6 kg isazofos / ha (Miral 3G) has been the best for controlling GM (2.28% SS) on the same time gap of 15 days. But the authors have used the pesticides to the higher growth stages of paddy disregarding the necessity of protection at early stages.

So in the areas of high gall midge infestation it is suggested to adopt the granular application rather than the root dip protocol. As a routine prophylactic measure root dip treatment can be adopted. Further it will be prudent to select monocrotophos among the five pesticides trialed during early growth stage application.

4.4.4.4 Effect of application of pesticides on the dynamics of paddy bug: Comparative efficacy of different pesticides was tested for controlling PB population. During this experiment need based management practices were followed.Relative activity of PB was assessed by counting the number of the unfilled grains (UG%). Of all the pesticides tested carbofuran was found least effective against the bug population while phorate was noted as the most excellent. Monocrotophos followed by carbaryl protection exhibited 15.87 and 15.17% UG. While quinalphos provided moderate range of protection with 18.27% UG. The average value of UG% of four consecutive years of control fields was up to 38.30 %(Table.4.4.9).

PB induces maximum damage after panicle initiarion. Maximum damage under the application of carbofuran is due to its least lethality to the PB population. Application of phorate renders toxicity to the PB thus the population is considerably reduced.

Table.4.4.9: Field evaluation on the relative efficacy of five granular pesticides on the activity of paddy bug at the time of harvesting

Insecticides applied		Percentage of unfilled grains (%)				
Generic name	Dose	Years of observations				
		2003	2004	2005	2006	Avg.
Carbofuran	1.00	23.3 (4.87)	.28.3 (5.36)	25.4 (5.08)	29.2 (5.44)	26.55 (5.20)
Phorate	1.00	14.2 (3.83)	12.4 (3.59)	13.7 (3.76)	16.1 (4.07)	14.07 (3.81)
Monocrotophos	0.50	16.3 (4.09)	15.1 (3.94)	14.2 (3.83)	17.9 (4.28)	15.87 (4.04)
Carbaryl	0.75	15.4 (3.98)	14.8 (3.91)	17.2 (4.20)	13.3 (3.71)	15.17 (3.95)
Quinalphos	1.25	17.9 (4.28)	19.2 (4.43)	19.8 (4.50)	16.2 (4.08)	18.27 (4.33)
Control	x	32.2 (5.71)	40.4 (6.39)	41.1 (6.44)	33.5 (5.83)	38.30 (6.22)
SE of mean		2.31	1.32	2.51	2.56	
LSD ($p <0.05$)		6.61	3.40	7.14	5.21	

(x)- No pesticide applied

All the value except control is the mean of three treatments in each year. Figure in the parenthesis are the transformed value and the standard error (S.E) and LSDs referred to this. Figure in parenthesis indicated square root transformed value

4.3.5 Effect of pesticide on YSB in different season: The relative seasonal performance of the 5 commonly used pesticides against YSB attack was evaluated in two seasons in *Swarna Mashuri* (MTU 7029) fields.

Pesticides were applied in a chain on 30, 50, 70 and 90 DAT in both the seasons. The damage symptoms were counted by quadrate estimation (5mt x 5mt). The average results of the four consecutive years are tabulated in terms of the number of DH at 75 DAT and WH at harvest (Table.4.4.10).

Table.4.4.10 Effect of pesticide on YSB induced damage symptoms in different seasons (5mt x 5mt)

Name of the pesticide with application rate		***kharif* crop**		***boro* crop**	
Generic name	**Applied dose (kg/ha)**	**DH**	**WH**	**DH**	**WH**
Carbofuran	1.00	8.7 c (3.03)	389.2 f (19.74)	5.1 d (2.36)	260.6 d (16.15)
Phorate	1.00	10.4 c (3.30)	372.2 f (19.30)	6.2 bc (2.58)	234.1 e (15.31)
Monocrotophos	0.50	6.0 bc (2.54)	391.2 f (19.79)	5.3 b (2.40)	297.4 d (16.96)
Carbaryl	0.75	9.5 bc (3.14)	357.3 f (18.91)	5.5 b (2.44)	276.2 d (16.26)
Quinalphos	1.25	9.7 bc (3.19)	344.1 f (18.56)	6.7 bc (2.68)	284.4 d (16.87)
Control	x	13.1 a (3.68)	397.2 f (19.94)	9.4 bc (3.14)	310.2 f (17.62)

(x)-pesticide not applied

Figure followed by the same letters are not significantly different at 5% level

Figure in parenthesis indicated square root transformed value

kharif season

Dead heart: The appearance of DH was relatively low in case of of monocrotophos, followed by carbofuran application in ascending order. Carbaryl application restricted the formation of DH at moderate level (9.4-5.5 damaged tillers / quadrate). The result with quinalphos was in almost the same degree with carbaryl where DH occurred up to 9.7 damaged tillers / quadrate. Phorate was found least effective against YSB.

White head: Least number of WH was found in fields treated with quinalphos followed by carbaryl. Phorate ranked next. The efficacy of carbofuran to protect WH was relatively lower than that of Phorate. Monocrotophos was found least effective producing maximum number of WH.

***boro* season**

Dead heart: The protective function of carbofuran, carbaryl and monocrotophos remained almost the same during *boro* season. Quinalphos and phorate were found equally effective.

White head*:* Least number of WH was found under phorate application. WH comparatively increased under carbofuran treatment. Carbaryl and quinalphos ranked second and third respectively afterwards in consideration of the numerical abundance of WH showing no significant difference. Of all the pesticides, monocrotophos was found least effective to control WH.

Discussion: The efficacy of pesticides to control the DH and WH are season dependent. In *kharif* season monocrotophos was best effective in early growth stages of paddy, but quinalphos was effective during late growth stages. A reverse result was found with carbofuran and carbaryl in *kharif* season, carbofuran was effective in early growth stage while carbaryl in the late growth stage. In areas where borer incidence was endemic, it is reasonable to apply monocrotophos at early growth stage followed by carbofuran and carbaryl. While in the late growth stage quinalphos is to be followed by carbaryl for effective control of YSB than carbofuran or monocrotophos.

Monocrotophos was found effective in both early and late growth stages of paddy during *boro* season. Further, the activity of carbaryl and carbofuran was higher in early growth stages. Protective function of phorate was relatively better in late growth stages during *boro* crop. Quinalphos was least effective in both the stages. During *boro* season phorate proved better at late growth stage in respect of the number of WH. Again in consideration of DH carbofuran was more effective at early growth stage. However, in *kharif* season protectional activity of carbofuran and quinalphos were efficacious in the early growth stages. Activity of phorate was better in the *boro* season.

The rainfall and temperature had profound influence on the action of the pesticides. As the same pesticide showed different degree of effectiveness in different seasons, the selection of the pesticides should be done in due consideration of the time of cultivation and the prevailing agro ecological conditions.

4.5 Growth Stage Specific Application of Fertilizers

Nitrogen is one of the foremost nutrients which are required in proportionate amounts at mid-tillering and panicle initiation stages of the paddy. Significant increase in grain yield was observed by Rao *et al.* (1962) using split application of nitrogen. An integrated N management practices for sustained high yield and to suppress the pest population is thus inevitable.

With this objective, three doses of urea (40, 80,120 kg / ha) and three modes of applications (mud ball, band placement and split applications) were trialed and corresponding level of incidence and damage by YSB and BPH was assessed. Side by side the effect of application of three organic sources (decomposed cow dung, paddy straw and *dhaincha*) upon the pest bionomics in relation to yield attributes is also separately noted aiming to suggest a more suitable integrated application of organic and inorganic fertilizer, thus the pest infestation will be the least without compromising the yield generation. When considering each treatment, in relation to the main land, seed bed also received the same type and proportionate dose of fertilizer.

4.5.1 Effect of inorganic fertilizers

4.5.1.1 On Yield attributes: Yield of paddy was assessed in three replications under three alternative modes of different doses of fertilizer (Fig.4.5.1a).

By urea mud ball application: Urea mud balls (r = 4 cm) of three different dosages (40, 80, 120 kg / ha) when applied to the paddy fields (100 x 100 mt.) equidistantly (2.5mt.) at early vegetative stage, remarkable increase in grain production was noted against control. Higher the doses of fertilizer higher were the yield. The highest yield (34.71q / ha) was obtained after application of 120 kg/ha while the least was scored in case of 40kg / ha.

By band placement: Consequences of using of granular urea by 'bands' in three different dose specific applications were studied. Application of 120 kg/ha caused a substantial increase in yield (31.97q / ha) over control. The other two doses 80 kg/ha and 40kg / ha recorded 30.12 and 24.37 q / ha respectively.

By split application: Effect of split application on the over all final yield was recorded in three phases:

70% basal (BSL) + 30% at panicle initiation stage (PIS): The highest yield of 31.67 q/ha was obtained when urea was applied at 120 kg / ha, which was a marginal increase over the band application with the same dosage.

35% basal (BSL) + 35% at 10 DAT + 30% at panicle initiation stage (PIS): As the dosage of fertilizer was increased, the quantum of production was enhanced accordingly with a maximum production of 32.20 q / ha with an input of 120 kg / ha urea.

60% 10 DAT + 25% at maximum tillering stage (MTS) + 15% at panicle initiation (PIS): A substantial increase in yield over the other two split applications was recorded. The highest grain yield (35.12q / ha) was obtained at 120 kg N / ha.

Table.4.5.1: Relative cost: benefit ratios due to 120 kg inorganic N application by different modes

Mode of fertilizer applications		C:B benefit
Urea mud ball placement		1:1.60
Band placement		1:1.57
Split application	70% basal(BSL)+30% at panicle initiation stage (PIS)	1:1.60
	35% basal(BSL) +35% at 10 days after transplantation (10 DAT) +30% at panicle initiation stage (PIS)	1:1.62
	60% basal(BSL)+25% at maximum tillering stage (MTS) +15% panicle initiation stage (PIS)	1:1.65

Amongst treatments, maximum benefit was obtained from the three split application while the least was obtained in urea mud ball placement (Table.4.5.1).

Dose dependent applications of fertilizer in relation to the growth stages of paddy yielded variably. In all the cases, as the dose of fertilizer was increased, there was considerable yield gain over the control.

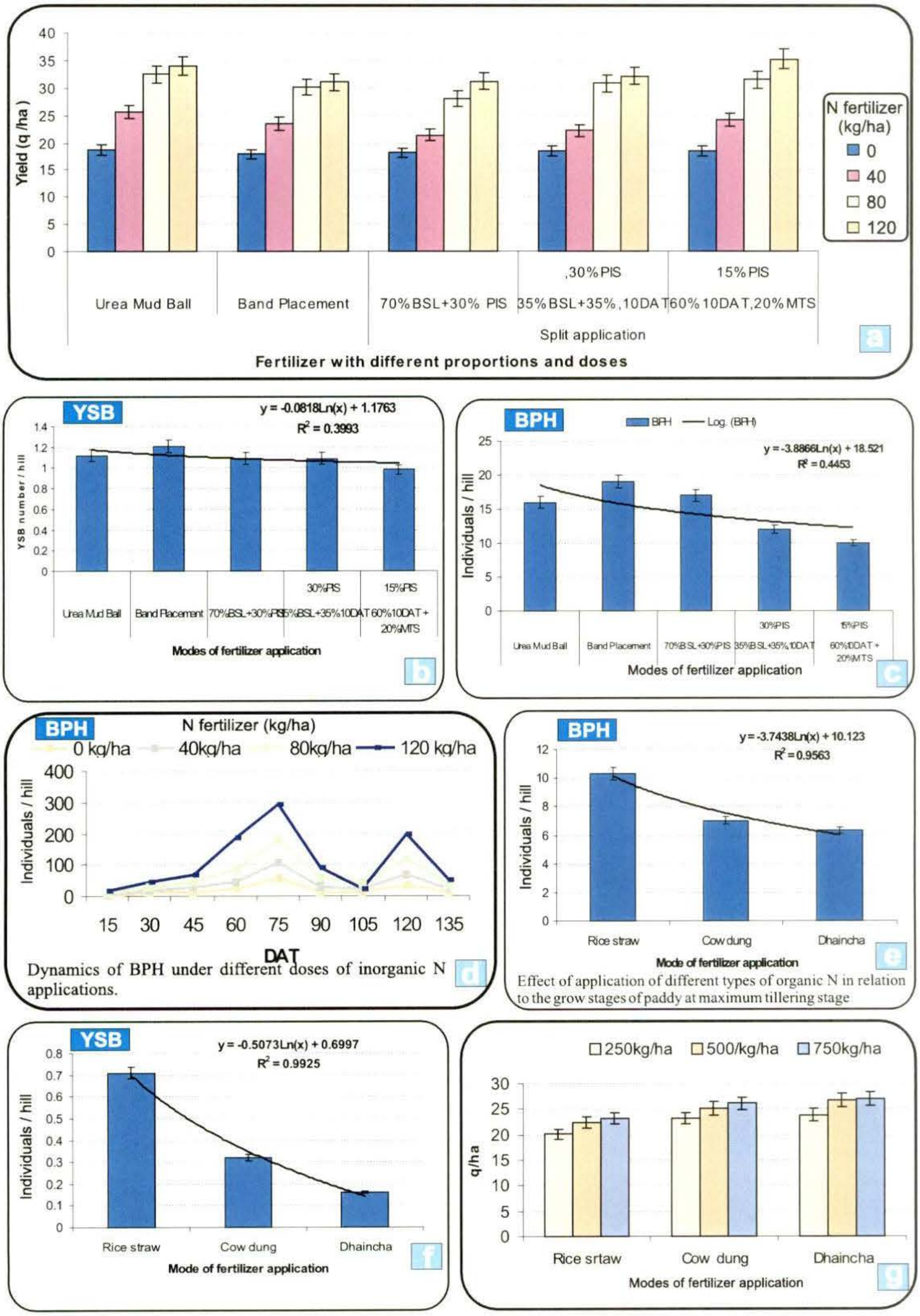


Fig. 4.5.1: Effect of inorganic N fertilizer on the paddy yield (a), occurrence of YSB and BPH at maximum tillering stage (b and c) and dynamics of BPH (d). Effect of organic N on BPH number (e) and YSB number (f) at maximum tillering stage and on paddy yield (g).

In all the modes of application, urea mud ball placement was found more effective than the 'band placement'. The mud in balls of urea acts as regulator, controlling the N availability. Band placement faced the unavoidable run off of the field during irrigation at late vegetative stage.

Both the 'three step spilt' applications were found economic. But, as the number of splits increased, labour cost became high. But three stage split application was proved more economic with better cost effectivity by high yield generation.

The result of present study has been in consonance with the observation by Dikshit *et al.* (1982) who also have obtained the proportional increase of yield with three step split applications. But Pillai (1979) and De Datta (1981) have reported that deep placement of nitrogen was superior to all other methods.

Split applications of 120 and 80kg / ha nitrogen have resulted 97% and 61 % more yield respectively over no urea input as experienced by Mohapatra *et al.* (1982) and Verma *et al.*(1988). Maximum N use efficiency (45%) of low land rice has been recorded with 2 splits (50% basal + 50% at panicle initiation) application of 30kg N / ha. On the contrary, Paul (1994) has suggested that the application of urea in three equal splits at basal, maximum tillering and panicle initiation stages maximizes the yield. Englested *et al.* (1975) have also observed that the mode of application and the applied doses of fertilizer are directly related to the agro-ecological conditions as prevailed in the tropics. A study by Islam *et al.* (1990) has shown that time specific application of fertilizer in consideration of the cultivar and the growth stages of paddy have a positive impact on the grain protein content. To economize the benefit Khilael *et al.* (2004) has suggested to rely on the different required doses and fertilizer application devices depending on the agro-ecological conditions of the locality. Reddy *et al.*(1986) have found that balanced application of N and P is necessary in optimizing the rice yield. Ghosh (1984) has noticed that the rice variety *Pankaj* in West Bengal, has responded well to the high dosages of nutrients up to certain limit. Rao and Raju (1987) have stated that improved grain yield is possible with every increase in N level up to 120 kg / ha.

Hussain *et al.* (1991) have shown that the tissue responsiveness is variety dependent and that *IR 36* and *Mashuri* may yield to the extent of 4.59 and 4.38 ton / ha respectively with the same dose of 80 kg. N / ha. Dhal *et al.* (1994) have established that higher the doses of fertilizer, higher will be the production and the maximum quantity grain can be produced from the application of 120 kg urea / ha. Dahiya *et al.* (2004) have found that application of inorganic fertilizer in supports of organic matrix enhances the utilization of N.

From the earlier and present results it is apparent that the average yield attributes and grain yields differ significantly in relation to the time of application of nitrogen fertilizer. The N use efficiency of rice is comparatively high in split applications in comparison to other application strategies due to the reduced N losses and better utilization by paddy plant of the phase wise added N. But, in split application, the N use efficiency was decreased with increasing N levels from 80 to 120 kg N / ha.

4.5.1.2 On pest incidence: As the consequences of high doses of fertilizer are more profound on the activity of YSB and BPH, a holistic approach of study was undertaken to understand the dose dependent change of population structure, if any, of these two pests at *kharif* season.

Dynamics of YSB: A persistent high level of YSB population was observed from early vegetative to tillering stages irrespective of the dose and mode of applications in consideration of control of no fertilizer application. However, low pest incidence was recorded in the split applications. The frequency was nearly the same when urea applied either by mud ball or two splits (70% basal + 30% panicle initiation). As the growth stages of paddy progressed, intensity of YSB population gradually increased. Appearance of DH and WH was initiated at about 35 and 75 DAT respectively, irrespective of the mode of applications. The highest occurrence of YSB was observed when 120kg N /ha was applied to the field (Fig.4.5.1b).

Fig. 4.5.2: Integrated inorganic and organic N fertilizer applications and consequent occurrence of WH. a-e: Layout for all the 14 fertilizer combinations, f-i: consequent extent of WH at 90 DAT; f: FT1, g: FT9, h: FT4, i: FT13 (Table 3.11).

The overall average value of DH and WH varied from 20.1 to 28.2 / 200 hills and 13.7 to 19.8 / 200 hills respectively. The frequency of DH was intensified with the increase of the dose of nitrogen between 40 and 80 kg N / ha. Similarly, WH was also intensified with the rise in the dose of nitrogen to the extent of 15.5-19.8 / 200 hills with the input of 120 kg N/ha. In untreated control plots the incidence of WH was about 13.7% against the treated fields (Table.4.5.2).

Table.4.5.2: Effect of different doses and modes of fertilizer application on the occurrence of DH and WH

Dose of fertilizer (kg/ha)	**Mode of application**	**Symptoms of stem borer / 200 hills**	
		Dead heart(DH)	**White head(WH)**
0	NR	20.1±2.4	13.7±2.1
40	Mud ball placement	21.1±3.2	14.6±2.3
	Band application	22.1±2.4	15.8±3.5
	Split application	20.3±4.1	13.9±3.1
80	Mud ball placement	24.7±2.1	15.5±2.7
	Band application	25.6±2.5	17.8±2.5
	Split application	23.9±2.8	16.4±2.3
120	Mud ball placement	27.1±1.9	17.2±2.1
	Band application	28.2±2.1	19.8±2.7
	Split application	25.1±2.3	16.8±2.2

NR- no recommendation

Discussion: Result of the present study is in consonance with the observation by Duerden (1953) who has demonstrated that the application of N fertilizer exerted profound effect on stem borer complexities. The influence of chemical fertilizers on the incidence of stem borer has also been reported by Ishii and Hirano (1959), Israel and Vedamoorthy (1963), Saha and Saharia (1970), Hirano (1971), Prakasa Rao (1972), Raj and Morachan (1973), Kisimoto (1977), Nath and Sen (1978), Palachamy and Nagarajan (1978) and Saroja and Raju (1981). All these findings corroborate the positive impact of high doses of inorganic N on the incidence of YSB. Prasad *et al.* (2004) have recorded a significant level of DH at 200 kg N / ha (6.2%) followed by 120 kg N / ha (5.4%) and lowest at no N/ha application (4.8%). In case of 200 kg N / ha, WH

% has been significantly more (11.7%) than in case of 120 kg N / ha (9.5%) as against no N input (8.0%).

Application of higher doses of fertilizer induces metabolic activity of plants, thereby promotes growth which in turn encourages the pest incidence and damage. A higher dose increases the girth and internodal length of the stem making it more spacious for larval boring and subsequent accommodation and hence imparts greater survival value to the larvae. Ghosh (1962) extrapolated the relationship between nitrogen applications and stem borer incidences and found that the variable water content in stem and leaves of plants in relation to the applied N facilitated stem borer to prefer for oviposition and the subsequent easy penetration of the neonates. Nishida (1975) suggested that nitrogenous fertilizers encouraged the thickness of the rice canopy which created humid and shaded microenvironment conducive for the insects to multiply.

Abro *et al.* (2003) have suggested an adoption of resistant variety rather than fertilizer management in due consideration of the agro-ecological conditions to combat YSB activities. After studying the regular occurrence of *Sesamia cretica* Evaristo (2000) of Portugal has concluded that the incidence is dose dependent. Jiang *et al.* (2003) in China have found a positive interaction between the *C. suppressalis* larvae and paddy plants in response to N application. Khan *et al.* (1991) have suggested a growth stage specific effective application of inorganic fertilizer to minimize YSB damage.

Dynamics of BPH: Irrespective of the mode of application, in all the cases higher the dose of fertilizer higher was the BPH abundance. Rapid colonization followed by speedy multiplication of the pest was noted.

The impact of different doses of urea on the dynamics of BPH population from early vegetative stage was studied. Comparatively high level of pest incidence was recorded in case of band placement followed by in 'two step split' application. The least incidence was noted in 'three split' applications (Fig.4.5.1c).

Estimation (individuals/mt^2) under three split application denotes two definite peaks, one major at about 60-70 DAT following a minor at about 120

DAT. The height of the peak was proportional to the fertilizer doses. The highest peak was noted when 120 kg N/ha was applied and the least was recorded in fields without urea input. Both the peaks were preceded and followed by decline of population due to the quick migration of BPH to the nearby field (Fig.4.5.1d).

Discussion: In a trial at IRRI (1963, 1998), three consecutive peaks have been noticed. Each peak has followed by a rapid fall. Contrary to this, in the present study of two peaks the nature of the depletion of the population after the peak formation differs suggesting the persistent occurrence. Kulshrestha (1974) and Abaraham *et al.* (1975) have observed that high doses of inorganic fertilizer in some plots in Kerala have directly induced BPH out break. Baskaran *et al.* (1983) have found a similar result from South Arcot district, Tami Nadu. BPH has been found to attain the major pest status resulting in hopper burn in some areas of Kerala following fertilizer application (Das *et al.* 1972). A high level of BPH of 150 individuals/hill has been found proportional to the N fertilizer input (Uthamasamy *et al.* 1983). Feng *et al.* (2001) have found that migration of BPH is directly related to the cultural practices including fertilizer applications.

The farmers who used high doses of N/ha fertilizer suffered from losses from hopper burn. Therefore, the present result and similar earlier observations suggest that a high input of N fertilizer should not be given particularly in those areas where BPH frequently causes menace, rather a moderate dose may be recommended.

Present findings show that about 80 kg N/ha though increases the pest density significantly above that of the control, but the effect lasts for only a short period in the first pest generation. However, the density of BPH/mt^2 attains peak when the plants are treated with 120kg N/ha and the high BPH population continues for a prolonged period.

Direct application of urea granules immediately causes the flourishing of foliage which provides adequate nutrients to the BPH. Applications of urea in different split proportions allow availability of nitrogen to plants slowly. This may be the cause for low level of BPH occurrence but for a relatively longer time. Dose dependent physiological alterations in the paddy plant have been noted, which in turn induce the pest abundance. Application of higher doses of fertilizer at early stage causes luxurious growth and foliage development alters the microclimate environment which provides suitable niche for BPH multiplication. Split applications of fertilizer at three growth stages of paddy have been found to maintain the pest level within the limit of management.

4.5.1.3 On the incidence of natural enemies

The population of natural enemies were periodically assessed by hill estimation after 120kg urea/ha input from the very beginning of the vegetative stage to tillering stage fortnightly. The pooled average value obtained from four years count on population was considered (Table.4.5.3).

Table.4.5.3: Effect of inorganic fertilizer on natural enemies (Individuals / hill)

Natural enemy	Dynamics of population in relation to DAT								
	15	30	45	60	75	90	105	120	135
Spider	0.12 (0.79)	0.27 (0.88)	0.32 (0.91)	0.48 (0.99)	0.57 (1.03)	0.72 (1.10)	0.62 (1.06)	0.58 (1.04)	0.41 (0.95)
Bug	0.09 (0.77)	0.12 (0.79)	0.42 (0.96)	0.57 (1.03)	0.68 (1.09)	0.98 (1.22)	0.84 (1.16)	0.66 (1.08)	0.40 (0.95)
Beetle	0.21 (0.84)	0.33 (0.91)	0.39 (0.94)	0.74 (1.11)	0.82 (1.15)	0.97 (1.21)	0.61 (1.05)	0.53 (1.01)	0.36 (0.93)
Fly	0.02 (0.72)	0.18 (0.82)	0.34 (0.92)	0.53 (1.01)	0.61 (1.05)	0.80 (1.14)	0.55 (1.02)	0.39 (0.94)	0.10 (0.77)

Figure in parenthesis are square root transformed value

Spider: From the period of early vegetative stage, the level of spider population was very low. From the late vegetative stage the population increased rapidly with an average level 0.27 individual/hill .Comparatively a high range of 0.57 to 0.72 individuals / hill was observed in the reproductive stage. Population remained nearly unchanged throughout the ripening stage. However, at the end of the ripening stage the population decreased rapidly.

Bug: In the early vegetative stage, the population of bug was in traces. Very low population with an average 0.09 individual/hill was noted at the mid vegetative stage. But the level gradually elevated and maximized at late vegetative stage. Through out the reproductive stage a steady level of bug population was maintained with an average value 0.57-0.98 individual / hill. The population declined steadily from the middle of the ripening stage.

Beetle: Very low population was recorded in the early vegetative stage with the average value 0.21bug / hill. An average population of 0.33 individuals / hill at mid vegetative stage increased up to 0.97 individuals / hill in the late stage. No noticeable variation of beetle number occurred at the reproductive and ripening stages. The average number ranged from 0.53 to 0.63 individual / hill.

Fly: The early level of fly population was very low with 0.02 Individual / hill. Moderate level of population was scored at the late vegetative stage. No major alteration in the mean population of fly was found in the next growth stage with a value ranging from 0.88 to 0.69 individual / hill. A change of fly population at early ripening stage was observed. However at late ripening stage the population decreased steadily with an average value 0.29 individual / hill.

Discussion: In general with the highest dose of urea all the natural enemies remain at a higher number at early growth stages. With the advancement of the growth the populations built up rapidly reaches to the highest level at the mid growth stage (tillering stage) after which it declined rapidly.

4.5.2 Effect of organic fertilizers

4.5.2.1 On yield attributes

Relative efficacies of organic fertilizers prepared from three different sources were tested in different proportions during *kharif* season only and accordingly the yield potentiality was analyzed. The control plots did not receive any fertilizer. Organics were always added at the time of land preparation (Fig.4.5.1g).

Rice straw: Decomposed rice straw of 60 days old when applied at the rate of 750 kg / ha, there was a substantial increase in yield.

Cow dung: Three different dosages of decomposed cow dung were used. The highest yield generation was obtained with 750 kg / ha.

Dynamics of YSB: Noteworthy differences in YSB population were noted in comparison to that obtained with inorganic fertilizer. Least number of YSB was noted in case of *Dhaincha*. But the use of decomposed rice straw comparatively accounted high. Such enhanced activity was due to the presence of hibernating larvae in the stubbles because of improper and incomplete decomposition (Fig.4.5.1f).

Dynamics of BPH: Except the decomposed rice straw, cultivation using cow dung or *Dhaincha* has resulted in nearly same range of BPH occurrence at maximum tillering stage. Application of rice straw causes a fibrous matrix in soil, a condition retains water and hence maintain high humid microclimatic niche congenial for BPH accommodation (Fig.4.5.1e).

Table.4.5.4: Correlation between the applied fertilizer doses and the incidence paddy pests in the variety *Swarna Mashuri*

Applied dose of fertilizer (kg/ha)	Source	Values of correlation in relation to pest incidence	
		YSB	BPH
0	-	0.236	0.344
250	Organic	0.211	0.242
40	Inorganic	0.513*	0.473
500	Organic	0.321	0.276
80	Inorganic	0.743*	0.699*
750	Organic	0.432	0.511*
120	Inorganic	0.856*	0.911*

(-): not applicable
*Significant at 5% level

YSB showed significant positive relation when the applied doses of inorganic fertilizer was incrementally increased from 40 to 120 kg / ha. While in case of BPH irrespective to the source, both organic and inorganic fertilizer narrated significant positive relation at the higher doses (Table.5.4.4).

4.5.2.3 On natural enemies

Spider: After applying organic fertilizer, throughout the early vegetative stage the population was very low, improved rapidly from the late vegetative stage with an average 1.10 individuals / hill. A high range of population of 1.69-2.10 individuals / hill was observed at the reproductive stage especially at the end of tillering stage. At the end of the ripening stage the number declined steadily. At maturation stage the population was relatively low (Table.4.5.5).

Table.4.5.5: Effect of organic fertilizer on natural enemies (Individuals/hill)

Natural enemy	Dynamics of population in relation to DAT								
	15	30	45	60	75	90	105	120	135
Spider	0.78 (1.13)	1.10 (1.26)	1.29 (1.34)	1.44 (1.39)	1.69 (1.48)	2.10 (1.61)	1.82 (1.52)	1.63 (1.46)	0.94 (1.20)
Bug	0.22 (0.85)	0.35 (0.92)	0.49 (0.99)	0.58 (1.04)	0.79 (1.14)	1.40 (1.38)	1.00 (1.22)	0.81 (1.14)	0.61 (1.05)
Beetle	0.19 (0.83)	0.28 (0.88)	0.41 (0.95)	0.69 (1.09)	0.88 (1.17)	1.90 (1.55)	1.10 (1.26)	0.76 (1.12)	0.32 (0.91)
Fly	0.06 (0.75)	0.14 (0.80)	0.41 (0.95)	0.53 (1.01)	0.64 (1.07)	0.90 (1.18)	0.55 (1.02)	0.39 (0.94)	0.10 (0.77)

Figure in parenthesis are square root transformed value

Bug: Throughout the early vegetative stage the population was relatively low. Very low population of 0.49 individuals / hill was noted at the late vegetative stage, attained a high of 0.58 individuals / hill at reproductive stage. Tillering stage maintained an average of 1.20 individuals / hill. The population steadily decreased from the mid ripening stage.

Beetle: Very low population was recorded throughout the early vegetative stage with 0.22 individuals / hill. The average population of 0.49 / hill at late vegetative stage was increased to 0.58 individual / hill in the late vegetative to early reproductive stage. The incidence was further heightened up to 1.10-1.90 individual/hill throughout the reproductive to ripening stage of paddy.

Fly: The initial low population of 0.06 individual / hill increased to 0.64 individual / hill in the late vegetative stage and 0.90 individual / hill at reproductive stage (tillering stage). At the late ripening stage the population declined steadily.

Discussion: In case of all the enemies, the appearance and increase of number remained limited up to early growth stages. With the advancement of growth stages the populations grew rapidly reaching the maximum at the mid growth stage after which the population declined rapidly.

Spider and bug population increased following the application of the organics while the number of beetle and fly remained unaltered. Low canopy compactness due to the application of the organics generates available spaces for the foraging behaviour of the natural enemies. Low canopy is further suitable for the decoration of the webs for the webers. As the activity of the beetle and fly was much more restricted to the upper part of the canopy the effect of fertilization had very little effect.

4.5.3 Growth stage specific application of both organic and inorganic fertilizers in an integrated manner: Efficacy of the inorganic fertilizer to boost very high yield is very encouraging in comparison to the yield potentiality with organic fertilizers of the doses that ensure same quantity of N availability. For this reason adoption and application of the inorganic N were profound among the farmers. But the intensity of the pests is amplified with the higher doses of inorganic N input and destroys soil health. Therefore, an integration between the two sources of fertilizers with proportionate and growth stage specific applications can offer a better alternative solution with marginal conciliation to the yield, retaining quality of the produce, health of both soil and ecosystem. With this objective a study was undertaken to find out suitable proportions of both inorganic and organic sources of N and to find out the consequent pest and enemy population status (Table.3.8.2.2 in materials and methods).

9 combinations of inorganic and organic fertilizer (FT3 to FT 11) were used. 5 controls were maintained, two exclusively with urea of different proportional applications (FT1 and FT2), two exclusively with organics of different proportional applications (FT12 and FT13) and the remaining one without fertilizers (FT14). So collectively 14 fertilizer treatments were considered. Urea and decomposed *Dhaincha* was considered as the prime source of inorganic and organic fertilizer respectively. Organic, if applied, was added during land preparation while inorganic was offered in relation to the growth stages of paddy (Fig.4.5.2).

4.5.3.1 Yield attributes resulted from split application: Yield attributes and pest bionomics were evaluated against 14 different fertilizer treatments.

Plant height (cm): The highest average plant height of 128.5 cm was observed in FT1 and FT11 but with no significant difference. The lowest plant height was noticed in FT14. The other FTs produced plant heights variably intermediate (Fig.4.5.3a).

Effective tiller number: No significant difference was observed when FT1, FT2 and FT11 separately were in practice. Further FT2, FT5 and FT11 resulted same number of effective tillers. FT5, FT6 and FT9 differed insignificantly in respect of result. FT8 and FT7 gave similar output. Further, the results varied insignificantly when FT7, FT10 and FT12 were separately in practice. Although the least number of effective tillers were scored in FT14, but it also differed insignificantly from FT12, FT4, FT13, FT3 (Fig.4.5.3b).

Panicle length (cm): Highest length of panicle was observed in FT1 followed by FT2 with the respective value 25.4 and 25.1 cm. FT5 and FT11 did not vary significantly. The value of FT6 and FT13 were nearly same. FT3, FT4, FT9 and FT10, showed insignificant difference.FT7,FT8 and FT12 showed a hierarchical representation with a varied level of panicle length. The least level of plant height was scored in FT14 (Fig.4.5.3c and 4.5.6).

Grain number / panicle: Nearly all stages of fertilizer application differed significantly in consideration of the generation of the grains per panicle. The highest grain number was obtained in FT1 followed by FT11.While the least level of grain number was scored in FT14. FT3 and FT9 did not vary significantly. FT7 and FT10 had nearly same impact on the grain number. The result was insignificant in case of FT4 and FT13.The remaining application stages showed varied level of plant height (Fig.4.5.3d).

Grain yield: The highest level of yield generation was obtained in FT1 followed by FT11, FT2, FT5, FT6, FT8, FT9, FT7, FT10, FT12 and FT13 in descending order. FT3 and FT4 insignificantly differed in consideration of the grain production. The least level was observed in FT14. The other application stages showed variable ranges of effect on yield formation (Fig.4.5.3e).

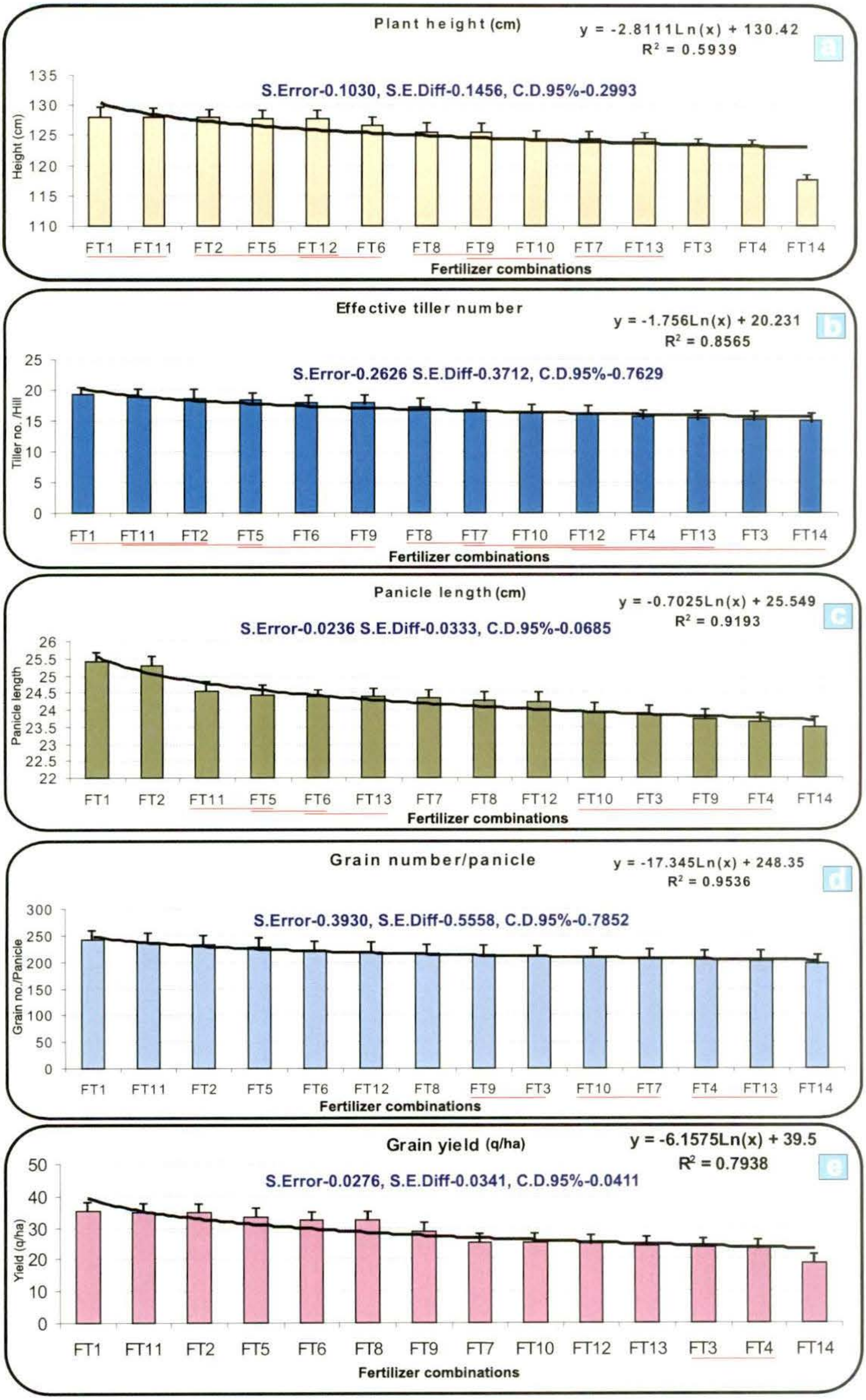


Fig. 4.5.3: Effect of different integrated combinations of inorganic and organic N fertilizers on the yield attributes of paddy.

Discussion: FT11 treatment (inorganic 50: organic 50) showed nearly the same functional efficacy like FT1 (inorganic 100: organic 00) application. FT1 and FT2 did not differ in overall split share but varied regarding the time of application. Proportional decrease of the amount of inorganic fertilizer at early vegetative stage in FT2 in comparison to FT1 caused the nutrient deficiency which resulted a steady decrease of the yield. Although same doses of fertilizer were employed in FT3, FT5 and FT4 (inorganic 75: organic 25) but the pattern of yield generation considerably differed. Proportionately low doses of inorganic fertilizer input at 10 days after transplanting reduced the yield generation in FT4. Restricted N availability at vegetative stage in FT7 had lowered yield attributes than FT8. Proportionately equal doses(inorganic 50: organic 50) of split application was adopted in FT9, FT10 and FT11 in which FT11 showed more functional efficacy followed by FT9 with variable yield attributing characteristics. The adoption of FT12, FT13 stages with only organic sources could not meet the proper N requirements resulting the reduction of the yield. Least yield was generated under FT14.

Sarder *et al.* (1988) have claimed that combined (inorganic + organic) high N input promotes panicle length and total number of grain / panicle and thus generated high yield. Sekhar and Prasad (1989) have also obtained a similar result. Contrary to the present findings, Srivastava *et al.* (1984) observed that rice straw and grass could sufficiently act as manure for the transplanted rice.

Basically organic sources of N acts as 'bio-regulator' and thus functions as a slow N releaser avoiding N loss. It thus supports plant growth in early vegetative stage. But an instant supply of inorganic N is required at tillering stage and early reproductive stage (panicle initiation stage). The efficacy of plants to utilize inorganic N is also increased at this stage due to augmentation of N loss by volatization and reciprocal shading of plant canopy.

Growth stage specific application of fertilizer has also been suggested by various authors (Pillai 1979, Dikshit *et al.* 1982, Mohapatra *et al.* 1982). However, they rely on only inorganic N, as is the practice among the farmers, and their split applications do not match with the 'fertilizer use protocol' of the present study.

Yield economics: The yield attributes and the cost: benefit (C: B) ratio differed significantly among the different combinations of inorganic and organic fertilizers. FT11 was superior to the other split applications. Greater the proportion of inorganic fertilizer higher was the yield attributes. But in collective consideration, not all the organic proportions are equally economic. Of all the treatments the highest economic value was obtained in FT1 with a C: B of 1: 1.68. FT2 and FT11 had similar cost competence with a ratio 1: 1.66 although the nature of split proportion varied. The lowest C:B value of 1:1.49 was obtained from FT14 treatment (Table.4.5.6).

Table.4.5.6: C:B ratio obtained after 14 different combinations of integrated inorganic and organic N

Fertilizer combinations with C:B value													
FT1	FT2	FT3	FT4	FT5	FT6	FT7	FT8	FT9	FT10	FT11	FT12	FT13	FT14
1.68	1.66	1.60	1.59	1.57	1.58	1.57	1.59	1.60	1.62	1.66	1.65	1.65	1.49

In FT11, the crop is fertilized with both inorganic and organic fertilizer in equal proportion. 50% of the total application is organic and applied at land preparation. Inorganic proportions are applied at 20% in the 1st split (10 DAT) + 20% in the 2nd split (Maximum tillering stage) + 10% in the 3rd split (panicle initiation stage) which has resulted in the highest number of panicles signifying a greater accumulation of dry matter. FT11 achieved nearly C: B value, similar to that of FT1 with only inorganic input.

4.5.3.2 On the occurrence of insect pests

Yellow stem borer (Fig.4.5.4a)

Adult moths: Highest incidence of YSB was noted in FT1 (7.5 individuals / 5 hills) while the least was in FT11 (2.3 individuals/5hills). No noteworthy difference was observed between FT13 and FT14. Though the number of the moths was low there were differences between the control and FT2, FT5 and FT6.

Symptoms

Dead heart (DH): High DH number was observed in FT1 (7.0 DH / 50 hills) while the least was scored in case of FT11 (2.4 / 50hills).

White head (WH): Highest number of WH was noted in FT6 (3.5 WH / 50 hills) while the least was scored in FT11 (2.2 WH / 50 hills).

Application of only inorganic fertilizer as a chief N source causes greater luxuriant foliage, higher internodal space with greater lumen dimension and deep green nutritious foliage all of which provide suitable environment for YSB attraction, colonization and subsequent multiplication. Application of the organic and inorganic fertilizer in equal proportion as in case of FT11 or organic fertilizer alone lowers the available field N resulting in impairment of all the attributes congenial for YSB attack, hence the paddy suffers less from YSB damage.

Brown plant hopper (Fig.4.5.4b)

Adult: Of all the treatments, FT1 supported highest number of BPH (21 individuals / hill) against the control, FT14 (13.40 BPH / hill). The lowest number (6.11 / hill) was observed in FT11.

Symptoms

Damaged leaf area (DAL %): Relative damage profile (%) of flag leaf was considered as the activity of the BPH. The Highest DAL% was observed in FT1 (41.01%) and the lowest (9.47%) in FT11.

Proportional application of organic and inorganic fertilizer in combinations had resulted different level of damage by BPH. In case of inorganic fertilizer alone (FT1) about 75% DAL was recorded out of more than 40% of the flag leaves. In case of only organic fertilizer (FT13) the extent of damage was some what reduced. Application of organic and inorganic fertilizer in equal proportion (FT9) had resulted in the occurrence of low magnitude of damage, 18% leaves having 75% DAL was noted.

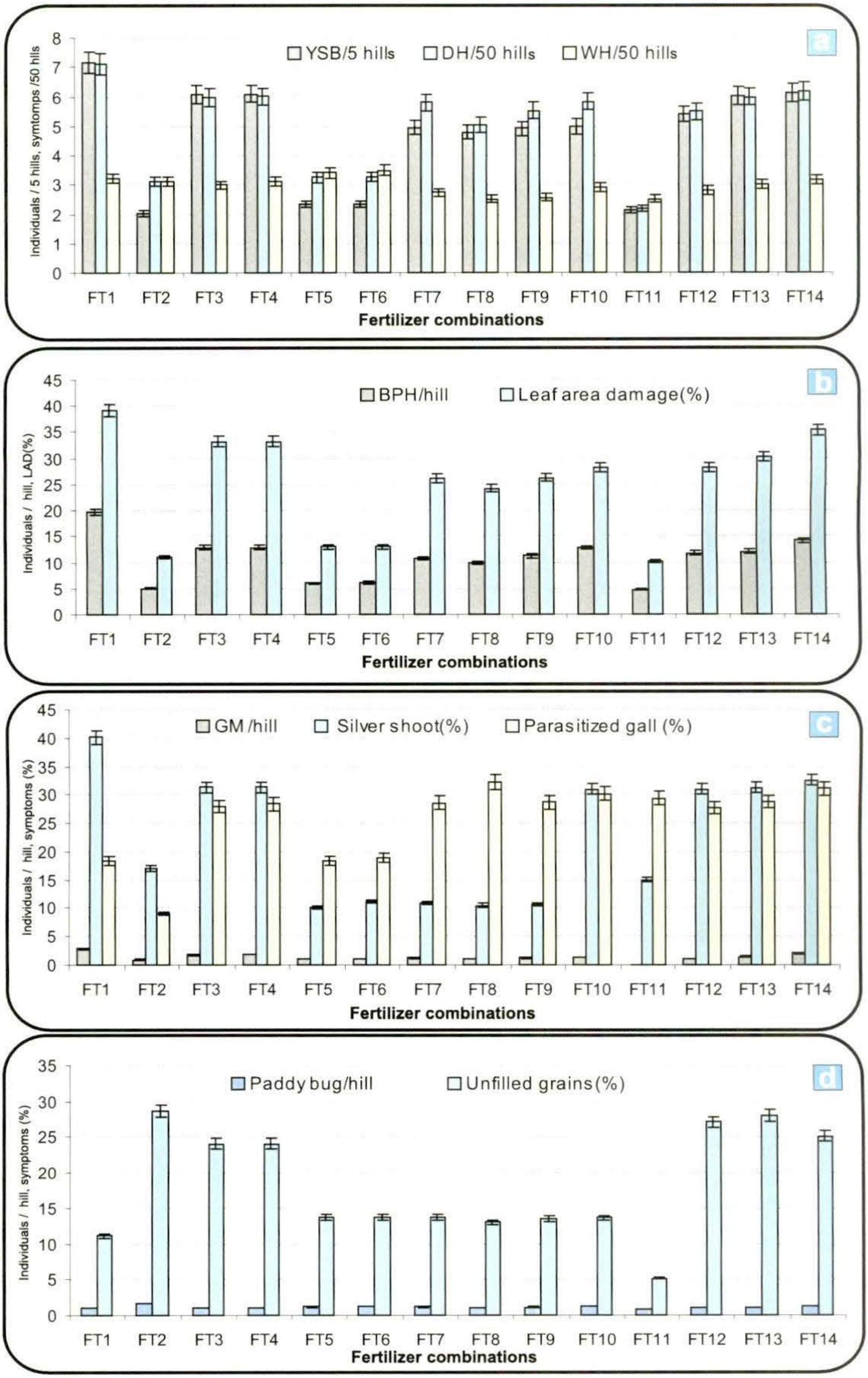


Fig. 4.5.4: Effect of different integrated combinations of inorganic and organic N on the incidence of four major paddy pests and their consequent.

Gall midge (Fig.4.5.4c)

Adult: FT1 enhanced GM population (4.11 individuals / hill). Here too, the lowest number was recorded in case of FT11 (0.12 GM / hill).

Symptoms

Silver shoot (SS%): SS(%) scored maximum in case of FT1(40.2%) and the lowest value was counted under FT 11 application (15.61%).

Parasitized gall (PG %): The highest level of PG (%) was registered in FT8 (33.21%) treatment followed by FT11 (30.01%). The lowest was noted in FT2 (8.17%).

Level of GM population has been found to be influenced by the split proportions. Generally higher doses of inorganic fertilizer attracted high level of GM. Again the magnitude of population has directly been related to the stage specific application of fertilizer. Same doses of fertilizer with different combinations of inorganic and organic have exerted differential effects on midge appearance as observed in FT1 and FT2 applications. Higher the doses of organic fertilizer, lesser will be the abundance of the pest and accordingly the extent of damage will be minimized. The parasitization of the galls increases with organic fertilizer inputs and reached the extreme in case of FT8. Further FT5 and FT6 supported nearly same frequency of galls.

Paddy bug (Fig.4.5.4d)

Adult + nymphs: Highest level of PB with an average value 2.31 individuals / hill was observed in FT1 while least number (0.59 / hill) was scored in FT11.

Symptoms

Unfilled grains (UG %): High percentage of unfilled grains was found in FT2 (29.21%) and the lowest was scored in FT11 (5.21%).

Growth stage dependent proportionate application of fertilizer has been found crucial for PB performance and the extent of damage. Same dose of fertilizer with different split proportions have variable effect on PB as found in FT1 and FT2. As the damage to the grain by the PB is attained at panicle initiation stage, a high proportional dose of inorganic fertilizer in case of FT2 causes high magnitude of damage. Least level of damaged at FT11 can be explained that proportion of inorganic and organic fertilizer and the growth stage of the paddy at which the fertilizers have been applied are better cultural practice. Increase in the proportion of organic fertilizer acts as slow N releaser leading to slow and gradual grain filling and thus protects the grain from PB damage.

Emty grain formation is related to the grain sucking at the late growth stages. A single puncture in *Swarna Mashuri* has provided enough scope to the PB for ample diet. Hence, the magnitude of unfilled grain is increased even at low pest incidence, Higher the doses of organic fertilizer slower will be the N assimilation resulting in low rate of grain filling, which restricted the deteriorations by the bug. But, formation of unfilled grain in case of FT11 with inorganic and organic levels of equal proportion is due to the poor grain filling than the attempt to attack the grains by the pest.

4.5.3.3 On the occurrence of natural enemies

Spider: FT14 supported relatively high (1.78 individuals / hill) and the FT1 (1.63 individuals / hill), the least number of spider population (Fig.4.5.5a).

.**Bug:** FT13 (2.68 individuals / hill) followed by FT12 (2.61 individuals / hill) and FT 14(2.21 individuals / hill) harboured relatively higher number of bug population while the least number was scored under FT10 (0.78individual / hill) (Fig.4.5.5a).

Beetle: Variability of beetle population was noted under different proportion of fertilizers and split applications. The highest of 3.52 individuals / hill in case of FT3 followed by FT13 (3.55 individuals /hill) FT12 (3.48 individuals / hill) and FT 14(3.31 individuals / hill) while the least number of 1.21 individuals / hill was noted under FT11(Fig.4.5.5a).

Fly: The highest number of fly was obtained under FT1 (0.41 individuals / hill) treatment while the least number was noted under FT11 (0.22 individuals /hill).The other combinational stages of fertilizer application showed variable intermediate number of the fly population (Fig.4.5.5b).

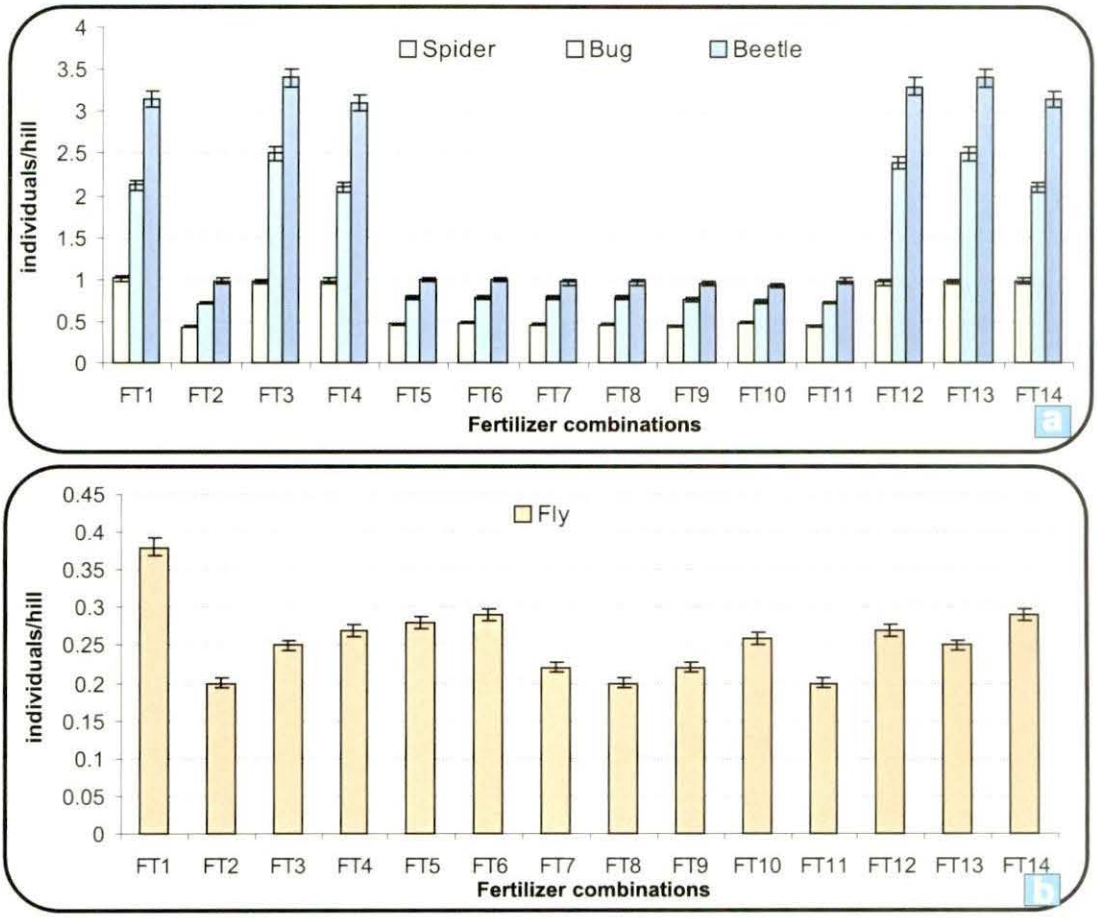


Fig. 4.5.5: Effect of different integrated combinations of inorganic N on the incidence of natural enemies.

Fig. 4.5.6: Fertilizer treatment a: Heap of organic fertilizes being processed for the subsequent application b: Panicle from the field with only organic fertilizer application (FT14) c: Panicle from the field with only inorganic fertilizer application (FT1).

Extent and dimension of damage by the pest was found to be directly related to the variable proportional growth stage specific N fertilizer applications. In all the cases of observations, higher the proportion of the inorganic greater has been the intensity of the pest. In all the cases under consideration, proportionate increase of the inorganic fertilizer had imparted a positive effect on the pest bionomics. Adoption of FT11 treatment was found comparatively more economic and could minimize the pest attack with unaltered grain production. But It was suggested to take FT5 treatment (inorganic 25: organic 75) in areas where GM are epidemic. However, except fly population, application of different fertilizer combinations had conveyed major influence on the standing natural enemy population.

4.6 Assessment of Bionomics of the Major Phototropic Pests

4.6.1 Light trap estimation of yellow stem borer

4.6.1.1 Dynamics of different species of SBs in relation to YSB abundance

Species composition in relation to seasonal variation: YSB predominated throughout the season. The relative abundance of YSB was found to increase with the progress of the months and maximized in November with no major variations in the three blocks. Highest range (%) of white stem borer (WSB) and pink stem borer (PSB) was recorded in March and April respectively (Figs.4.6.1a, b and c).

Species composition in relation to the growth stages of paddy: Among all the SBs, YSB predominated at all the growth stages. Relative activity of the YSB was recorded highest at ripening stage followed by the reproductive and vegetative stage in descending order. While both WSB and PSB were more active at vegetative stage (Fig.s 4.6.2 a and b).

Early arrival of PSB at vegetative stage allowed the species settlement and multiplication resulting in relatively high population size. During the subsequent growth stages moths of the new generation hiked the population size. Higher frequency (%) of YSB from the very beginning of the vegetative stage and their subsequent multiplication under favourable agro-ecological situation excluded other SBs. Gradual decrease in the population size of WSB and PSB in consideration of the growth stages can be viewed as a case of 'species exclusion'. WSB and PSB can hardly manage the 'species pressure' of YSB resulting in steady population reduction .Male YSB shared the maximum part of capture at early night. While in the late night female YSB predominated. However as the night advanced the proportion of total catch improved gradually (Fig.4.6.4 d). Monthly mean catches of YSB showed that the maximum log value was noted in March and October followed by April and February and the minimum in January and December (Fig.4.6.4 c).

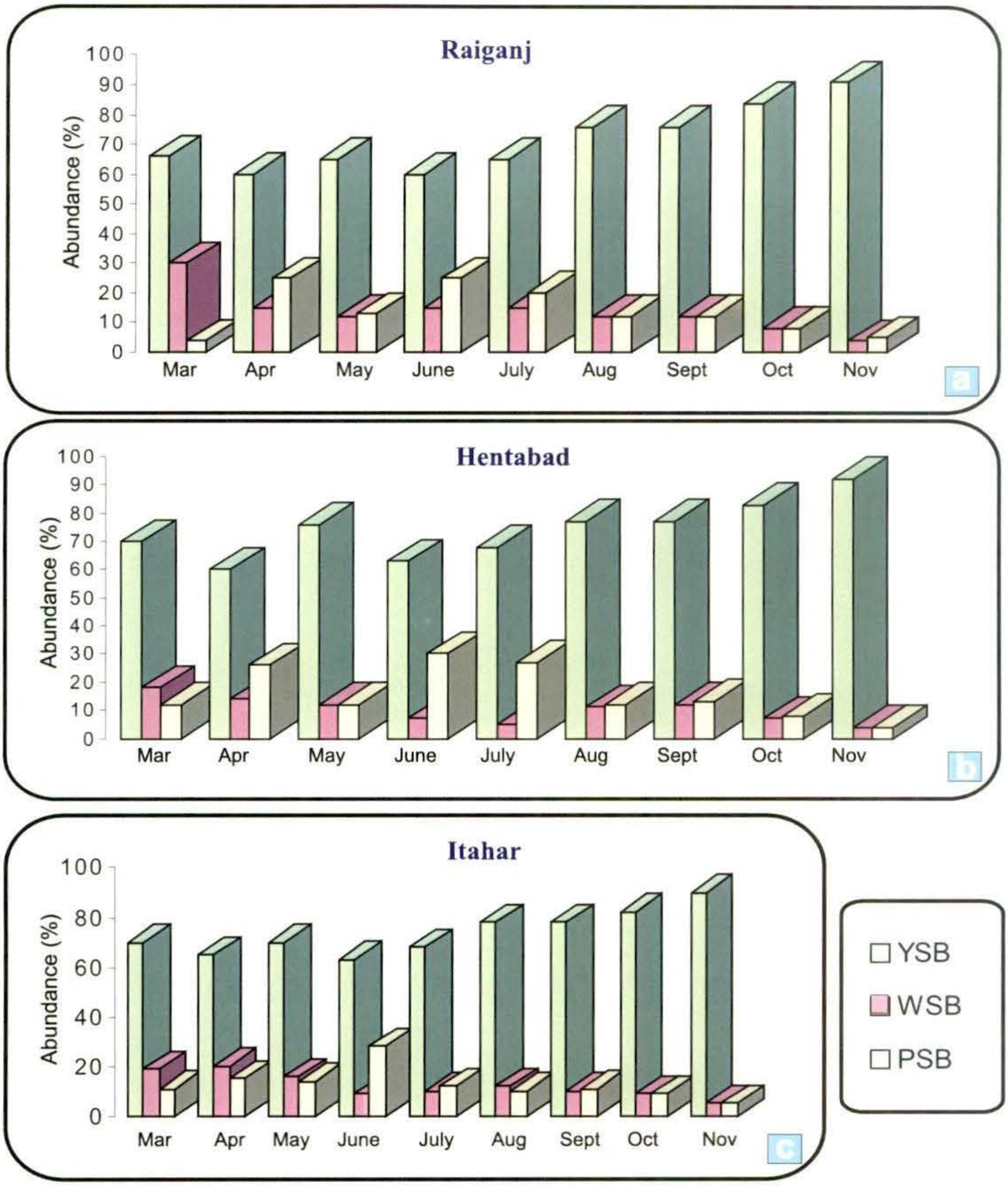


Fig. 4.6.1: Seasonal abundance of different species of paddy stem borers in the three blocks. a: Raiganj, b: Hemtabad, c: Itahar.

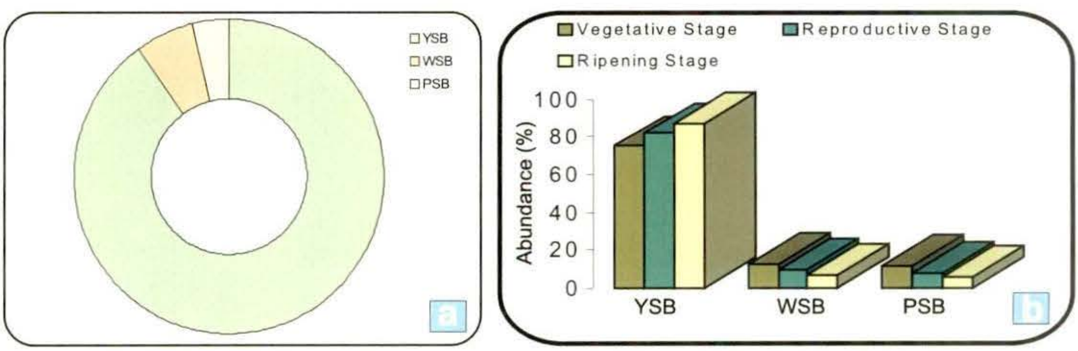


Fig.4.6.2: Abundance of stem borer species a: Combined abundance of the borers in the three blocks. b: Paddy growth stage specific relative abundance of the three species of stem borer.

Discussion: SBs showed marked variation in their abundance. High number of YSB moths at the ripening stage was due to the additive effect of the previous two generations. Ragini *et al.* (2001) also reported from Killikulam, Tamil Nadu, India, that YSB was the most predominant species during both *kar* (June-September) and *pishanum* (October-January) seasons with the frequency of 60.0 and 48.43% respectively. PSB was the second most abundant, 35.21% during *kar* and 48.43% during *pishanum* season. Catling *et al.* (1987) noted that YSB accounted 77% of the SBs in the agro-ecological condition of Bangladesh. YSB dominated nearly entire northern parts of Philippines in the early 60's. While WSB was abundant in southern parts of Philippines and Java (Cendana and Calora 1967). Prolonged EL Nino droughts in the mid 1980s in Indonesia and southern Philippines led to a shift from the non aestivating YSB to aestivating WSB (Glanz 1996). In general, YSB is prevalent in the monsoonal tropics while WSB dominates the intertropical zone. The cultivar *O. sativa japonica* comparatively supported more SBs than *O. sativa indica*. Mixed population of SBs in the present study is probably due to heterogeneity of climate, moist irrigation regimes, higher cropping intensity (>169%) and the practice of monoculture. Previous documentation of the relative proportional variation of SBs covering the *Tarai-Teesta* agro ecological zone of the northern parts of West Bengal disregards the standing growth stages of paddy (Status report, UBKV 2004). In the Southern parts of India covering districts Tirunelveli, Kanyakumari, Madurai, Thanjavur, Coimbatore, Dharmapuri and Vellore, YSB was recorded as the most dominating species Ragini *et al.* (2000).

4.6.1.2 Seasonality of YSB broods and consequent damages on paddy crop: Four Light traps (400 watt) were installed equidistantly in monoculture paddy fields (100 x 100 mt) throughout the year fortnightly covering all the three crops (pre-*kharif*, *kharif* and *boro*) (3.6.1.2.2 in materials and methods). Dynamics of YSB was assessed in consideration of the total collection of four traps in each date. The average pooled data of the four years showed, one major, two moderate and one minor peak. The two consecutive moderate peaks occurred one during the 4th week of January to early February (4-6 SMW) and the next one during late May (20-22 SMW). The latter one was followed by a minor peak at mid July (26-28 SMW). All the major and moderate peaks were preceded and followed by the ultra peaks. The only major peak was observed during early to middle of November (46 - 48 SMW) after which the population steadily declined (Figs.4.6.3 and 4.6.4. a and b).

Fortnightly catches of YSB were correlated with the average climatic components. Catch pattern showed that brood emergence mostly has an insignificant positive but significant negative agreement with Tmax and Tavg. However, Tgr and Tmin elaborated respectively positive and negative relation of variable degrees. The effects of RHmin and Rfall are respectively positive and negative, both were mostly significant. RHavg and RHgr showed positive relation mostly at insignificant level. Throughout the year no specific role of RHmax was noted for all the brood emergence. However sizable population at 43-48 SMW was positively influenced by RHmin. No definite role of Shr was evident in relation to YSB brood emergence. YSB brood emergence was more influenced by Tmax, Tgr and Rfall. RHmax only effected the last brood while the other factors had inconsistent role (Table.4.6.1, Figs. 4.6.4. c and d).

Discussion: The pest was most destructive to the standing crops about two weeks after the emergence of 'winter generation' and a month before the '*kharif* generation'. Appearance of the moths at late May with 'moderate peak' might be viewed as 'desperate emergence', as the standing crop growth stages can not support such large progenies. 'Self destructive' major peak was noted only at the end of a year during early to middle November due to the absence of paddy crop. Furthermore, absence of crop after the harvest could hardly support this massive generation causing 'population crash'. Peak formation even in the absence of suitable growth stages of paddy plant reflects that the environmental factors rather than the standing crop govern the YSB dynamics. Only a small fractional population immigrates and survives in the alternative host in absence of crop by virtue of their rapid physiological adaptability.

In contrary to the present findings, Manjunath (1982) reported from Mandya (1976-1979), Karnataka three annual peaks: low in February (winter generation), moderate in May (summer generation) and high in November (*kharif* generation).

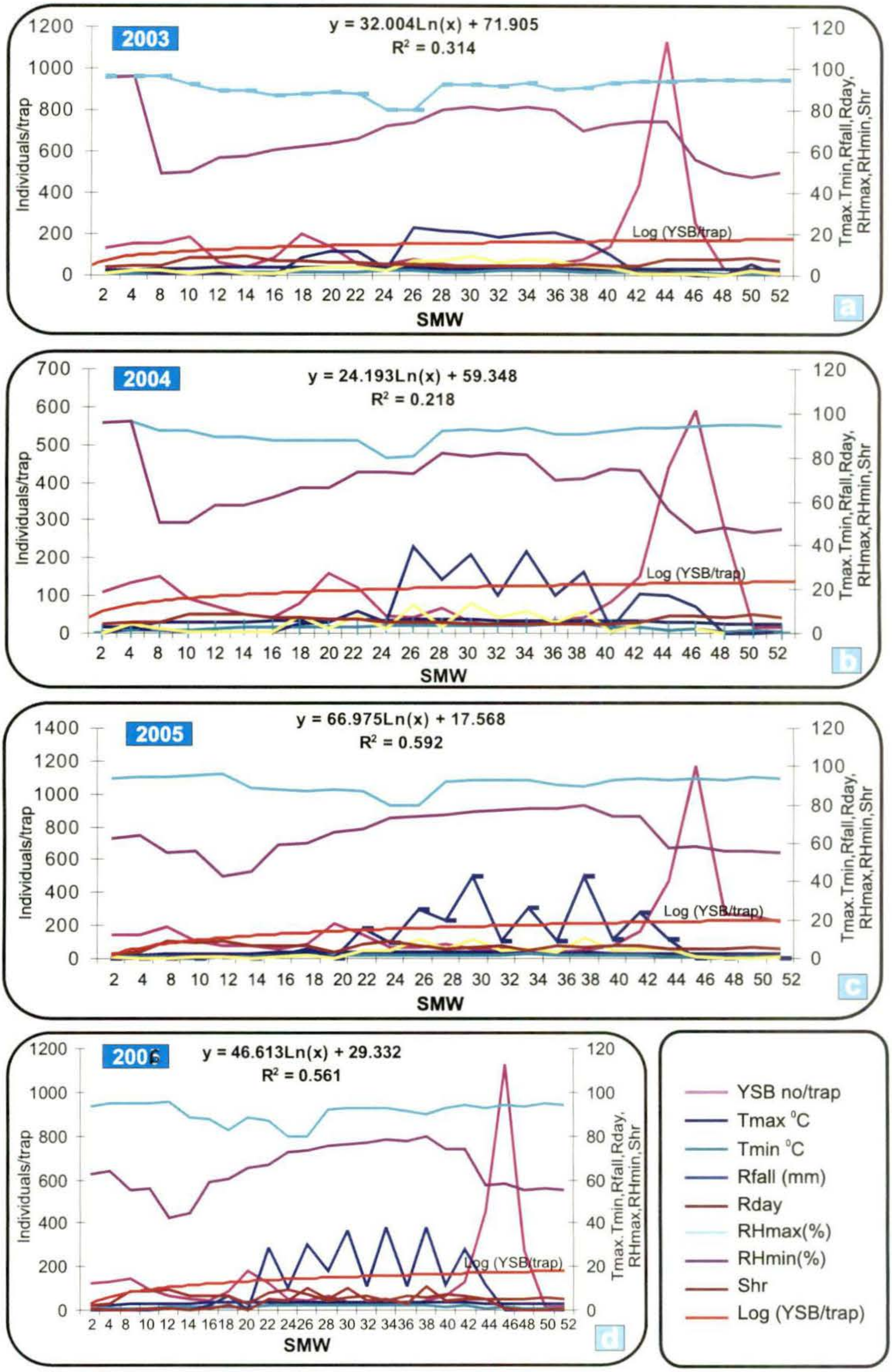


Fig. 4.6.3: Dynamics of YSB population in relation to climatic factors in each of the four years.

Presence of additional ultra peaks in the present observation reflects that the moths are active round the year due to their tolerance to a wide range of agro-climatic variations. While Nandihalli *et al.* (1990) noted two peaks, one at March-May and another at Oct-Dec with the respective catch value of 4 to 82 and 9 to 1150 individuals / trap. Contrary to the 4 peaks in the present observation, study at RRI, Chinsura (22°52'N, 88°24'E,8.62 msl.), West Bengal has recorded six peaks: one major (Oct. 16±6) three moderate (April 15±6, July 07±6, August 27± 6) and two minor peaks (February 15±6 and May 19±6). Primary responsible factors for such activity is high average Tmax (35.8°-24.5°C), Tmin (26.5°-14.5°C) and Shr (7.8-4.2 hr). Paddy cultivar, soil pedology and cultural practices marginally influence the peak attainment. Malhi *et al.* (1998) noted that the average life span of male and female adult YSB has been 2.50 and 2.78 days respectively during August, while it was 2.50 and 2.85 days in September. The average span of life cycle was 46.35 and 52.79 days during July-August and August-September respectively which was in agreement with the attainment of peak status. 50 % of the total yearly adult emergence occurred around February 22, April 11, May 23, August 18 and October 2. The first larval brood causes DH in *boro* during July (summer rice), the second brood causes WH in *boro* and also in *aus* (autum rice), the third and the fourth broods affects *amon* crop (winter Rice). Present observation is also supported by that of Chhabra *et al.* (1976) who have reported from Kapurthala, Punjab that peaks are highly correlated with the environmental conditions. Qadeer *et al.* (1990) have also reported from Karnal District, Haryana that the peak intensity is environment specific, especially the moisture regimes of the canal system.

Observation by Rai *et al.*(2002) from 1970 to 1995 reveals that peak formation and Tmax show poor positive relation except in the years 1970 and 1971. Larval mortality increased when the field water temperature exceeded beyond 35^{0}C for any 5 days in July. Sunwongwan and Catling (1987) have observed that the survivability of larvae has a negative relation with Tmax (>33^{0}C) at moderate RH level (<70%). Peak catches are influenced by the availability of food, cultivar and land condition.

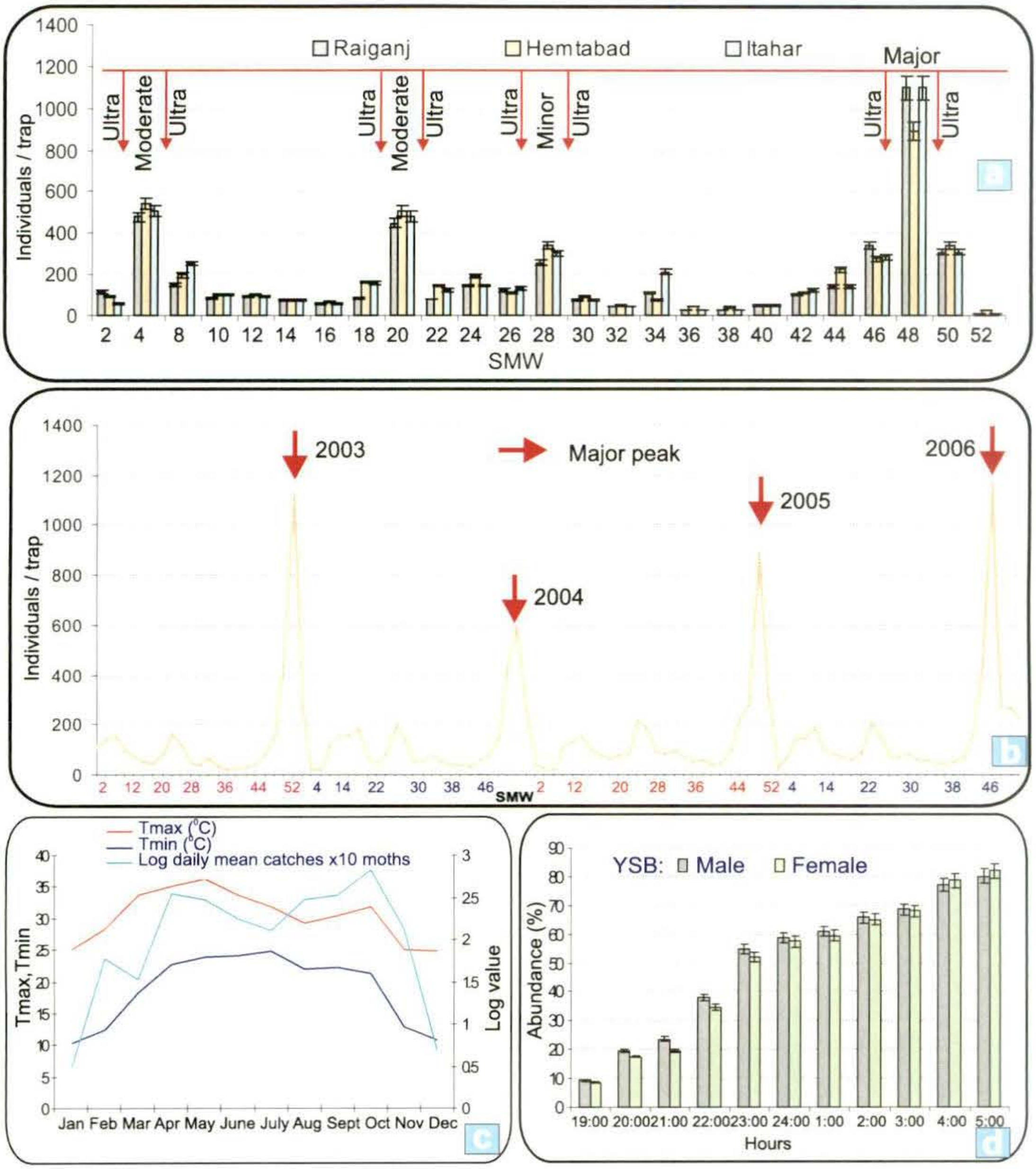


Fig. 4.6.4: (a) Relative abundance of YSB in the three blocks throughout the year (average of the four years). (b)Abundance of YSB throughout the year (combined values of the three blocks and average values of the four years). (c) Daily mean catches of YSB throughout the year.(d) Nature of hourly catches of YSB.

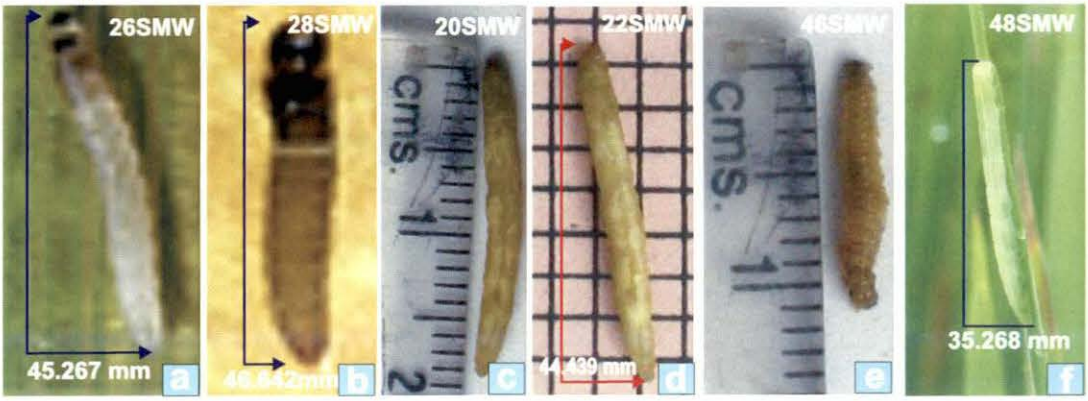


Fig. 4.6.5: Relative size of the fifth instar YSB larva of different broods at different SMWs.

Table.4.6.1: Correlation coefficient of incidence of the YSB brood emergence with the climatic factors indicating the level of significance

Fort night	Temperature(°C)				Relative humidity (%)				Sunshine hours/ day (Shr)	Rainfall (Rfall)	
	maximum (Tmax)	minimum (Tmin)	gradient (Tgr)	average (Tavg)	maximum (RHmax)	minimum (RHmin)	gradient (RHgr)	average (RHavg)		amount (mm)	rainy days
1	0.211	-0.422	0.484	0.498	0.238	0.455	0.201	0.453	-0.605*	-0.632*	0.207
2	0.664*	-0.461	0.508*	0.612*	0.721*	0.532	0.542*	0.521*	0.731*	-0.567*	0.141
3	0.597*	-0.711*	0.478	-0.651*	0.344	0.651*	0.332	0.645*	0.628*	-0.462	0.399
4	0.411	-0.422	0.584*	0.598*	0.438	0.675*	0.311	0.543*	-0.645*	-0.675*	0.234
5	-0.607*	-0.601*	0.443	-0.651*	0.351	0.631*	0.302	0.605*	0.635*	-0.471	0.317
6	-0.577*	-0.621*	0.477	-0.637*	0.351	0.617*	0.347	0.648*	0.661*	-0.473	0.356
7	-0.507*	-0.671*	0.453	-0.598*	0.353	0.661*	0.352	0.600*	0.634*	-0.431	0.345
8	-0.827*	-0.600*	0.493	-0.602*	0.421	0.643*	0.361	0.615*	0.627*	-0.430	0.333
9	0.411	-0.422	0.584*	0.598*	0.438	0.675*	0.311	0.543*	-0.645*	-0.675*	0.234
10	0.664*	-0.421	0.598*	0.712*	0.711*	0.432	0.432	0.511*	0.721*	-0.587*	0.151
11	-0.417	-0.598*	0.363	-0.631*	0.392	0.651*	0.367	0.567*	0.643*	-0.437	0.341
12	-0.527*	-0.631*	0.472	-0.671*	0.339	0.641*	0.366	0.600*	0.553*	-0.439	0.381
14	-0.555*	-0.627*	0.461	-0.590*	0.342	0.651*	0.371	0.621*	0.571*	-0.481	0.375
15	0.411	-0.422	0.584*	0.598*	0.438	0.675*	0.311	0.543*	-0.645*	-0.675*	0.234
16	-0.547*	-0.601*	0.480	-0.588*	0.341	0.605*	0.344	0.645*	0.661*	-0.443	0.371
17	0.311	-0.442	0.574*	0.558*	0.338	0.685*	0.331	0.603*	-0.625*	-0.605*	0.254
18	0.411	-0.422	0.584*	0.598*	0.438	0.675*	0.311	0.543*	-0.645*	-0.675*	0.234
19	0.417	-0.425	0.588*	0.528*	0.478	0.605*	0.371	0.553*	-0.665*	-0.632*	0.244
20	0.441	-0.462	0.594*	0.508*	0.439	0.611*	0.319	0.573*	-0.600*	-0.641*	0.254
21	0.314	-0.429	0.564*	0.498*	0.438	0.775*	0.388	0.653*	-0.621*	-0.651*	0.260
22	-0.501*	-0.619*	0.473	-0.603*	0.344	0.671*	0.355	0.632*	0.451*	-0.491	0.381
23	0.604*	-0.427	0.508*	0.722*	0.751*	0.436	0.462	0.551*	0.621*	-0.687*	0.251
24	0.654*	-0.423	0.598*	0.709*	0.711*	0.432	0.432	0.511*	0.721*	-0.587*	0.151
25	0.712*	-0.321	0.622*	0.611*	0.572*	0.321	0.134	0.602*	0.611*	0.144	0.231
26	0.664*	-0.471	0.598*	0.712*	0.711*	0.432	0.432	0.511*	0.721*	-0.587*	0.151

(*) :Significant at 5% level.

Pathak and Pawar (1993) have noted that the population after the harvest is low during the summer months due to non availability of 'choice food' together with the high temperature. Padhi (1994) also has observed that weather parameters influence the peak incidence of *S. incertulus*. Brood emergence of YSB is thus more influenced by the regional environmental conditions rather than by the standing growth stages of paddy.

4.6.1.3 Morphometric observation on the prominent neonatal forms of YSB

Morphometric observation on YSB broods was done after splitting the infested stems (3.5 in materials and methods). The prominent moderate and major broods comprised of the following characters.

Minor brood (26-28 SMW): The larvae were milky-white, 46.26 – 46.47 mm in length with district prothoracic shield, reduced abdominal pro-legs having short crochets. The pupa was soft bodied, pale in colour with the free terminal appendages. Adults were crimish-white with 18-23 mm wing under fully stretched condition (Figs.4.6.5 a and b).

Moderate broods (4-6 and 20-22 SMW): The 2^{nd}, 3^{rd} and 4^{th} instar larvae were dirty in colour while the pre-pupal forms were greenish-yellow and about 44.43 mm in length. Head capsule was orange in colour and relatively smaller than the body width. The crochets of the pro-legs were biordinal. They pupated into yellowish white cocoons. The adult moths were straw-coloured and measured 14-17 mm in length and 22-30 mm in wing span. Females had a single dark spot at the center of fore wing as the sexual dimorphic symbol (Figs.4.6.5 c and d).

Major brood (46-48 SMW): The larvae were purple pinkish dorsally and whitish ventrally with orange-red head capsule, and about 25.26 mm in length The pupa was dark brown with purplish tinge on the head region. The moths were brownish, with the hairy thorax and head and comparatively shorter than the other two broods (Figs.4.6.5 e and f).

YSB dynamics in the present study partly corroborates the findings of Malhi *et al.* (1998). Differences in respect of the peak emergence have been probably due to the differences of agro-ecological condition and the paddy variety.

Fig. 4.6.6: Lay out light trap catches of YSB in relation to paddy growth stages and light intensity zonations. A: Vegetive stage, b: Panicle initiation stage, c: Light intensity zonations.

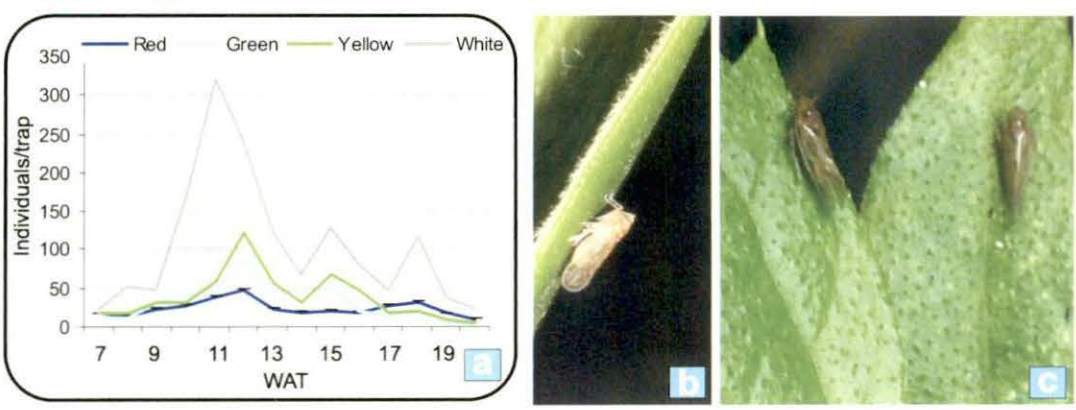


Fig. 4.6.7: a: Relative response of BPH to different coloured light traps, b and c: Consequent minimum settlement of BPH in case of white light traps.

4.6.1.4 Comparative dynamics of YSB of two fields by light trap

Relative variation of YSB catch was studied in two fields under three variable combinations of inorganic and organic fertilizers (0:100, 50:50 and 100:0) (3.6.1.2.2.3 in materials and methods). The highest catch was noted under inorganic fertilizer application while the least was counted under the organics. Application of organic and inorganic fertilizers of equal proportion resulted in moderate catch size. In all the applications, the population has initiated after 30 DAT. Peak was recorded between 60-90 DAT in both the varieties irrespective to the nature of the fertilizer combinations. Low catch number was noted under organic fertilizer application. Thus the nature of fertilizers influences the magnitude of the relative catch but the overall dynamics remain same in all the applications. The occurrence of YSB was comparatively low in *Tulaipanji* (LYV) than in *Swarna Mashuri* (HYV)

Table.4.6.2: Correlation between the YSB larval abundance and internal diameter of the stem of the paddy variety *Swarna Mashuri*

N Fertilizer combinations Inorganic: organic	r value
100:0	0.778*
50:50	0.518*
0:100	0.421

* Significant at 5% level

Under favourable conditions the eggs of YSB hatch within 9-10 days and the larvae penetrates into the stem. Increase in the quantity of inorganic fertilizer causes phenological alternation of paddy plants. Inorganic fertilizer increases tiller number, leaf area and stem width with greater lumen diameter in HYV provide greater survival value for the larvae. Higher the dose of inorganic fertilizer the higher is the internodal diameter. Greater the lumen diameter higher would be the available space for larval accommodation (Table 4.6.2). The lowest number of YSB in light trap catches has been recorded by Ragini *et al.* (2001) after manuring with only organics.

4.6.1.5 Light trap collection and moth settlement

White light traps were periodically installed from early vegetative stage for mass collection and subsequent destruction of YSB moths (3.6.1.2.2.5.1 in materials and methods). Farmers either do the trapping practice continuously throughout the night or discontinuously according to at their convenience disregarding the growth stages of paddy. Relatively high level of WH and DH was noticed at the vicinity of the 'light trap zones' (16%) in comparison to the rest of the fields (4%) which necessitates the judicious time specific settlement and monitoring of the light traps (Figs.4.6.6 a,b and c).

4.6.1.5.1 In relation to the growth stages of paddy (Tables4.6.3 and 4.6.4)
Collection for uninterrupted time scale: Comparatively higher number of moths settled near the trap zones. Greater the distances the lesser was the number of moths. Moths settled at the distances of 2 and 6 mt from the trap had shown very significant positive relation with the trap light intensity. DH increased significantly at 2 mt (14%) and 6 (9%) mt distances circles of the traps. However the incidence of WH differed marginally in all the zones.

Collection for interrupted time scale: Light traps were discontinuously used for 5 days either during vegetative or tillering stage. Setting at vegetative stage showed significant positive relation (0.789) with the number of DH and WH. But late setting at tillering stage exhibited insignificant positive effect (0.364) on the subsequent WH formation. The number of moths settled was comparatively higher at vegetative stage than at tillering stage (Tables.4.6.3 and 4.6.4).

4.6.1.5.2 In relation to the trap setting time at night: Traps were either established at early night (18:00-24:00) or at late night (24:00-6:00). Irrespective of the time of trap setting, At all the distances except at 18 mt, the number of moths captured showed significant positive relation with light intensity. Higher levels of WH were counted at 2 mt (12.1%) and 6mt (8.4%) distances where trapping was practiced in early night. The incidence of WH progressively decreased as the distances increased. However, at late night, the collection comparatively scored high at all distances (1.21-2.14 individuals /

hill) than the early night. Accordingly the intensity of DH and WH were magnified in comparison to the early night collection.

Discussion: Moths attracted to the light traps, settle on the paddy plant at the vicinity of trap areas. The number of individuals multiplies through egg laying and consequently results in the appearance of higher number of DH in comparison to the area away from the trap. DH number was higher when trapping was done at vegetative stage for a continuous time period. The settled moth, mostly females, lay eggs and multiplies, resulting in higher degree of pest appearance (Prakasa Rao *et al.*1988). But the frequency of WH in the trap zone has been more when trapping was done at tillering stage. Discontinuous trapping covering two growth stages of paddy intensifies WH due to the steady multiplication of the earlier batch of moths. Discontinuous collection is thus discouraging for this reason. As the appearance of both WH and DH was more intensified at 2 and 6mt. circles, judicious field scouting in the light trap areas is required.

Late night operation of the light trap enhances a higher degree of infestation. When a comparison is made between the incidence of DH/WH at distances 2, 6, 10, 14 and18 mt from the trap and in the light shadow zone, significant difference have been found among them. Infestation at 2 and 6 mt. were the highest with nearly same level of damage. It differed significantly from the other distances. The extent of infestation in the light shadow zone, *i.e*, immediately below the light, was least. The lower the nearness of the zone to the light trap the greater is the damage. In case of late trap setting time however, the magnitude of damage is comparatively high at late night implying that the moths are more active at late night. As higher portion of collection happens at late night, and accordingly the damage is profound by late moth settlement. It is thus more economic to install the light trap at late night with simultaneous field scouting on the next dates.

Table.4.6.3: Impact of light trapping on YSB moth settlement at different distances from the light trap and the formation of DH and WH at different zones

Types of trap operations			Relative distances from the light trap. (mt)									
			2		6		10		14		18	
			Adult	DH+WH	Adult	DH+WH	Adult	DH+WH	Adult	DH+WH	Adult	DH+WH
Mode of trap period operation	. Continuous	Vg	7.11 (2.78)	8.70 (3.03)	4.87 (2.31)	6.91 (2.72)	3.54 (2.00)	4.71 (2.28)	1.65 (1.46)	3.51 (2.00)	1.54 (1.42)	2.13 (1.62)
		Tr	5.31 (2.41)	6.90 (2.72)	3.81 (2.07)	5.11 (2.36)	2.21 (1.64)	3.91 (2.10)	1.02 (1.23)	3.34 (1.95)	1.15 (!.28)	1.72 (1.48)
	Discontinuous	Vg	4.62 (2.26)	10.40 (3.30)	3.61 (2.02)	8.23 (2.95)	2.98 (1.86)	7.31 (2.79)	1.56 (1.43)	5.42 (2.43)	1.31 (1.34)	4.73 (2.28)
		Tr	2.78 (1.81)	7.70 (2.86)	2.97 (1.86)	6.73 (2.68)	1.67 (1.47)	5.42 (2.43)	1.09 (1.26)	4.91 (2.32)	1.11 (1.26)	3.45 (1.98)
Time of trap operation	Early night	Vg	4.29 (2.18)	14.60 (3.88)	3.23 (1.93)	8.12 (2.93)	2.43 (1.71)	6.11 (2.57)	1.48 (1.40)	3.45 (1.98)	1.23 (1.31)	2.13 (1.62)
		Tr	3.08 (1.89)	10.10 (3.25)	2.57 (1.75)	6.81 (2.70)	1.34 (1.35)	5.32 (2.41)	1.22 (1.31)	2.11 (1.61)	1.12 (1.27)	1.22 (1.31)
	Late night	Vg	6.02 (2.55)	15.90 (4.04)	4.87 (2.31)	14.80 (3.91)	3.63 (2.03)	8.91 (3.06)	2.39 (1.70)	6.23 (2.59)	1.59 (1.44)	4.71 (2.28)
		Tr	5.71 (2.49)	8.40 (2.98)	3.45 (1.98)	5.32 (2.41)	3.27 (1.94)	4.77 (2.29)	2.68 (1.78)	3.81 (2.07)	1.11 (1.26)	2.51 (1.73)

Vg – Vegetative; Tr – Tillering growth stage of paddy.
Figures in the parenthesis are root mean square transformed value

Establishment of light trap from early vegetative stage maximizes the catch number and can effectively control YSB population. Trapping should be followed by field scouting for the settled YSB on the next date especially at the vicinity of the light trap zones. Continuous light trapping is found more effective than the discontinuous procedure.

4.6.1.6 Influence of physical and climatic conditions on the moths settlement at different distances of light trap zones

In relation to the distance from the light sources: At all the distances the number of moths settled showed positive relation with the available radiant energy. The degree of phototropism was directly dictated by the distances from the trap. Greater the distances, lesser would be the available radiant energy, accordingly the relation would be poor. Significant positive relation was noted only at the distances of 2 and 6 mt irrespective of the growth stages and the nature of light trap. The settlement at the remaining distances of 10, 14 and 18 mt was positive but insignificant.

Table.4.6.4: Correlation between the available light intensity (lux) moth settlement at different distances in the paddy field from the trap light sources

Types of trap operations		**Growth stages**	**Relative distances from the light trap (mt)**				
			2	**6**	**10**	**14**	**18**
Growth stage related	Continuous	Vg	0.712*	0.584*	0.498	0.432	0.342
		Tr	0.645*	0.511*	0.342	0.262	0.234
	Discontinuous	Vg	0.698*	0.544*	0.477	0.462	0.421
		Tr	0.429	0.511*	0.354	0.278	0.211
Time related	Early night	Vg	0.622*	0.493	0.396	0.386	0.326
		Tr	0.567*	0.311	0.278	0.289	0.211
	Late night	Vg	0.559*	0.531*	0.468	0.498	0.287
		Tr	0.352	0.234	0.251	0.311	0.217

* Significant at 5% level. Vg – Vegetative and Tr – Tillering stage of paddy

Climatic factors and moths settlement: Climatic factors exerted profound influence on the pattern of catches (Tables 4.6.5 and 4.6.6).

In relation to Temperature: Tmax induced significant positive effect on the moth settlement while Tmin exhibited mostly insignificant positive effect. Moths settled during discontinuous collection exhibited significant positive relation with Tmin. Furthermore, Moths settled at late night in vegetative stage showed significant positive relation with Tmax and Tmin.

In relation to relative humidity: RHmax mostly had significant positive effect irrespective of the growth stages of paddy and the mode of operation. RHmin, however, influenced the settlement insignificantly at negative level.

In relation to wind velocity: Wind velocity exercised significant to moderate negative effect in all conditions.

Table.4.6.5: Influence of climatic parameters on moths settlement under different types of trap collection

Types of trap operations			Temperature (°C)		RH %		Wind velocity (km./h)
			Tmax	Tmin	RHmax	RHmin	
Growth stage related	Continuous	Vg	0.632*	0.345	0.564*	-0.321	-0.576*
		Tr	0.567*	0.267	0.511*	-0.256	-0.523
	Discontinuous	Vg	0.612*	0.543*	0.677*	-0.121	-0.642*
		Tr	0.511*	0.521*	0.577*	-0.100	-0.587
Time related	Early night	Vg	0.582*	0.411	0.563*	-0.414	-0.543*
		Tr	0.552*	0.342	0.452	-0.371	-0.500*
	Late night	Vg	0.621*	0.531*	0.653*	-0.212	-0.348
		Tr	0.599*	0.474	0.487	-0.231	-0.216

* Significant at 5% level. Vg – Vegetative and Tr – Tillering stage of paddy

Table.4.6.6: Effect of climatic parameters on the yearly average YSB number

Weather parameters	B value	Standard error	T value	Beta
Tmax	0.153	7.562	1.823 ns	0.048
Tmin	-7.437	8.600	-1.029ns	0.312
RHmax	4.923	3.411	0.152 ns	0.762
RHmin	3.482	3.445	0.157 ns	0.756
Rainfall(%)	-2.761	1.251	-2.311 ns	0.057
Shr	3.423	6.533	0.461 ns	0.589
Wind velocity(km/hr)	-1.356	6.921	-0.159 ns	0.879

ns –non significant

Present observation is at par with the study of Pathak and Pawar (1993), Pandya *et al.* (1989), Nandihalli *et al.* (1990) and Rai *et al.* (2000). In contrary to the present findings negative effect of Tmax on moth settlement was confirmed by Sankar and Gayen (1992) and Ramakrishanan *et al.* (1994). Present finding also supports the earlier observation by Pandya *et al.* (1989) that the effect of Tmin has limitations. Present observation corroborates the findings by Sarkar and Gayen (1992), Ramakrishanan *et al.* (1994) and Bhatnagar and Saxena (1999) who also have documented the positive effect of the RH(%). But observations by Sunwongwan and Catling (1987) and Bhatnagar and Saxena (1999) are contrary to the present findings, who have found a negative effect of RH(%). The observation is in concurrence with the finding of Prakasa Rao *et al.* (1988) and Bhatnagar *et al.* (1999). Ramakrishanan *et al.* (1994) . Bhatnagar *et al.* (1999) have noted a negative effect of Rfall. But no authors have observed the effect of wind velocity on moth settlement.

4.6.2 Light trap estimation of BPH

Light trapping is the effective device for rapid collection of phototropic insects. Periodic collection followed by rapid destruction of BPH by light trap is an effective economic tool to check the population (Figs.4.6.7a, b and c).

4.6.2.1 Light trap estimation partitioned by time: Relative fluctuation of BPH catches (%) on different dates and times of collection was noted. Maximum collection in relation to the total catch was obtained at 19:00-20:00 hours (14.62%) followed by 20:00 - 21:00 (14.41%), 21:00 - 22:00 (11.87%) and 18:00 - 19:00 (11.33%) in descending order. The least was counted at the time 05:00 - 6:00 hours (1.92%) In the remaining hours the catches were low to moderate in number (Table 4.6.7).

BPH abundance differed with the paddy growth stages. Furthermore abiotic factors and standing crop phenology influenced the number of the moth catch. At 36 SMW when the crop was at tillering stage during *kharif* season, the catch was low which then increased at 38 SMW and subsumed by 40 SMW. Higher number of catches at 38 SMW was due to the reciprocal shading by leafy foliage together with the favourable microclimate which is conducive to

BPH multiplication. The collected Macropterous form of BPH showed significant positive correlation with the paddy field BPH number / mt.^{2} with a regression value of $Y_{catch\ number} = 5781 + 9.00x$ ($r = 0.521$), x- individual / mt^2 at field level. For every unit (50 nos.) increase in the catches, field count increased up to 4-5 individuals / hill on the next dates.

The foremost objective of this study is to understand the relative effectiveness of hourly catches and to specify the time at which the maximum collection occurs. Such understanding will help to recommend for the farmers to set up the trap at the most effective time and thereby may avoid the unnecessary trap monitoring cost. As 52.53 % of the total trap collection occurred within 18:00 - 22:00, it is further recommended to operate the light traps within the time frame to maximize the collection.

4.6.2.2 Coloured light traps for BPH collection (Fig. 4.6.7)

The use of *kerosene light traps* (62%) followed by the household light sources (23%) was found to be the common practice among the farmers. Relative efficacies of emitted light from different sources, *i.e,* red, green yellow and white were evaluated with the help of number of BPH collections at *kharif* season (3.6.1.2.2.4 in materials and methods).

The highest catch of 341 individuals/trap was noted for white light which was respectively followed by yellow and green colours. This signifies that BPH is more attracted to the white beams. The peak collection was recorded at 11 WAT followed respectively by subordinate peaks at 15 DAT and 19 DAT. The nature of the peak is thus found to be influenced by the colours of light of a trap. The high peak was noted for white light, moderate for yellow and subordinate for green and poor for red colours.

Table.4.6.7: Nature of average hourly catches of BPH (individuals ± SE) population in three specific weeks during *kharif* season

Hour	Raiganj					Hemtabad					Itahar				
	SMW of collection			Mean	% of catch	SMW of collection			Mean	% of catch	SMW of collection			Mean	% of catch
	36	38	40			36	38	40			36	38	40		
18:00-19:00	216±12	412±18	312±13	313.34±14.33	17.33	282±11	445±5	315±11	347.34±9.66	15.62	319±13	370±21	251±21	313.34±18.33	11.33
19:00-20:00	313±15	382±11	291±12	328.66±12.66	18.77	354±9	491±5	461±12	435.36±8.66	19.59	472±18	398±19	343±21	404.34±19.33	14.62
20:00-21:00	136±16	271±5	254±11	220.34±10.6	12.18	243±7	401±6	478±11	374.00±8.01	16.82	454±21	373±17	369±23	398.67±20.33	14.41
21:00-22:00	119±13	218±3	232±13	189.67±9.66	10.49	211±13	248±11	211±16	223.34±13.33	10.04	398±11	276±14	311±19	328.34±14.66	11.87
22:00-23:00	174±9	189±13	177±8	180.00±10.1	09.95	196±12	213±12	167±15	192.00±13.01	08.63	342±23	265±11	287±20	298.00±18.01	10.77
23:00-24:00	141±11	172±11	164±7	159.00±9.66	08.79	167±16	167±6	179±14	171.00±12.04	07.69	312±11	247±21	247±22	268.67±12.40	09.71
24:00-01:00	91±7	116±14	139± 5	115.34±8.66	03.39	95±5	121±9	142±11	119.34±8.33	05.37	105±10	142±13	152±13	132.35±15.33	05.95
01:00 02:00	97±4	98±4	98±6	97.00±4.66	05.40	127±12	112±7	87±9	108.67±9.33	04.88	278±11	232±21	189±14	233.00±11.33	04.31
02:00-03:00	79±9	81±5	87±4	82.34±6.01	04.55	112±9	95±5	78±6	95.00±6.66	04.27	112±9	185±13	121±12	139.34±9.01	05.03
03:00-04:00	48±11	58±4	51±7	52.34±7.33	02.89	98±9	58±7	62±7	72.67±7.11	03.26	87±9	98±9	89±9	91.34±7.01	03.30
04:00-05:00	29±12	37±6	43±4	34.34±7.33	01.90	65±7	35±5	43±5	47.68±.66	02.14	74±8	62±7	77±6	71.00±7.01	02.56
05:00-06:00	18±4	27±4	37±5	27.35±4.33	01.51	32±12	37±6	39±4	36.00±7.33	01.62	54±7	47±6	59±7	53.34±6.66	01.92
Total	1443±10.25	2096±8.16	1885±8.25	1808±12.04	100	1982±10.16	2423±7.01	2262±10.08	2222±9.47	100	3007±11.16	2695±15.58	2595±15.68	2765±14.20	100
CD at 5% level										5.21					

The objective of this experiment is to suggest the best trap light colour for maximizing the collection. Poor yellow light emitted from *kerosene light* sources gave repelling result and hence was discouraged.

4.6.2.3 Seasonal variations of average pooled population and the reports of hopper burn

Average annual catches of BPH showed seasonal variation and accordingly status of hopper burn differed. Low BPH population in January and February was immediately followed by the gradual increase which was synchronized with the early growth stages of *boro* paddy. The first peak in early May declined steadily. Very low population was noted in July and August due to the non availability of the suitable growth stages of the supportive standing crop. Moderate population was observed in September after which the population steadily declined.

Severity of hopper burn showed positive agreement with the field pest level. Roughly, a catch of more than 500 BPH / trap during the immigration period results in a severe outbreak before panicle initiation and that a catch of 100 to 500/trap results in hopper burn of the entire field after heading especially during the months September-October, light hopper burn occurs in October, when the catch number is around 100 / trap. Roughly, a catch of 50 was found to be the threshold value for next hopper burn.

Hopper burn occurred almost every year in the three blocks unless insecticides were applied. Present findings is at per with that of Bhatnagar *et al.* (1999) who have opined that prevailing abiotic factors and *catch number* influence the extent of hopper burn.

4.6.2.4 Climatic factors and the consequences of hopper burn: Evaluation of different climatic factors in relation to the consequences of hopper burn (symptoms / mt.^{2}) showed a diversified gradient relationship with the trap proportions. Multiple regression analysis showed the key factors explaining the causes of hopper burn among a set of cropping intensity variables (Tables.4.6.8 and 4.6.9).

Table.4.6.9: Effect of weather parameters on the yearly average BPH number in trap collection

In relation to temperature: Tmax exhibited negative influence while Tmin had a high range of positive influence on hopper burn.

In relation to relative humidity: The effect of both RHmax and RHmin were significantly positive.

In relation to rainfall: Rfall exhibited significant to moderate negative effects on the trap collection. For every unit increase in the rainfall, there was a population reduction of 2 individuals/ 10 hill.

In relation to sunshine hour: Shr had no influence on the generation of the hopper burn symptoms.

In relation to wind velocity: The overall impact of wind velocity was significantly negative on the hopper burn formation, *i.e*, high velocity decreased the number of BPH.

Table.4.6.8: Correlation between the incidence of hopper and the climatic factors

Tmax	Tmin	Tgr	RHmax	RHmin	RHgr	Rfall	Shr	Wvl
-553*	0.675*	0.453	0.677*	0.623*	0.345	-0543*	0.341	-0.621*

*Significant at 5% level

Table.4.6.9: Effect of weather parameters on the yearly average BPH number in trap collection

Weather parameters	B value	Standard error	T value	Beta
Tmax	0.143	8.566	-1.854 ns	0.078
Tmin	7.456	8.698	1.026 ns	0.342
RHmax	4.932	3.132	0.172 ns	0.866
RHmin	3.444	3.453	0.167 ns	0.786
Rainfall(%)	-2.576	1.212	-2.321 ns	0.067
Shr	3.454	6.543	0.465 ns	0.569
Wind velocity(km/hr)	-1.398	6.989	-0.189 ns	0.808

ns –non significant

Present study corroborates that of Mohan (1982) who found that Rfall exhibited significant negative relation in early September due to the nymphs mortality. Absence of multiple correlations between catches and weather factors probably due to the macropterous nature of the insect and the asynchronous nature of plantation. Hinckley (1963) and Grist (1999) also have suggested that excessive rains destroy eggs and thereby the population is substantially reduced. Furthermore, adult BPH might have been washed away from the field by heavy rains. Loevinsohn (1984) and Loevinsohn *et al.* (1982) have reported from Philippines that field heterogeneity influences abundance of BPH and accordingly the extent of hopper burn.

As Installation of the light trap is not economically justifiable throughout the year, it is suggested to set the trap for YSB in consideration of the 'peak' pest intensity and thus, to maximize the collection. Further as the effectiveness of trap collection is directly influenced by climatic conditions it is more appropriate to monitor the trap in relation to the climatic conditions, in due consideration of the growth stage of the standing paddy crops and the land location which determine the functional efficacy of the light trap. Maximum collection of BPH occurred at the early night and was noted for white light.

4.7 Performance of the Weed Communities Under Integrated Weed Management

Weed vegetations provide alternative resources for both beneficial organisms and the pests (Dennis and Fry 1992). Rampant weeding in the paddy fields was prominently viewed under the activity of high cropping intensity (>189%) through out the blocks. Majority of the paddy field weed species serve as alternative hosts of the pests. This is why judicious weeding practices and land preparation techniques are necessary for better pest suppression. Proper management of weeds modifies the paddy field ecosystem which in turn exerts positive influence on the natural enemy and negative on the pest.

4.7.1 Diversity of the field weed communities

Weed flora at 60 days after sowing (DAS) consisted of 22% grasses, 40% sedges and 32% broad-leaf weeds. The Collected weed species that are reported to act as alternative host are given in the table 4.7.1.

Table.4.7.1: Different species of paddy field weeds in the three blocks

Category of weeds	Species recorded
Grasses	*Echinochloa colona* , *Paspulum* sp., *E* . *crus-galli, Cynodon dactylon,Saccharum* sp., *Sphenocloa* sp., *Leptochloa, Panicium repens, Panicium conjngatum.*
Sedges	*Cyperus iria, C. rotundus, Fimbristysis* sp., *Scirpus maritinus.*
Broad leaf weeds	*Cleome viscosa, Eclipta prostrate, Marsilea minuta, Sphenochlea zeylanica, Burgia ammanioides, Aeschynomene indica, Scirpus articulatus, Ipomea aquatica,Elytrophus arteculata, Eragrostis interrupta, Marsilea minuta, Ludwigia* sp.

The extent of infestation calculated to be up to 54.4%, 21.4% and 22.2% in case of grasses, sedges and broad-leaf weeds respectively. Among these species *E. colona* , *E* . *crusgalli*, *C. iria* and *I. aquatica* were relatively more important as alternative host (Figs.4.7.1 and 4.7.2).

Joy (1991) showed that the survivability of the paddy field pests varied in relation to the weed status in different agro-ecological zones.

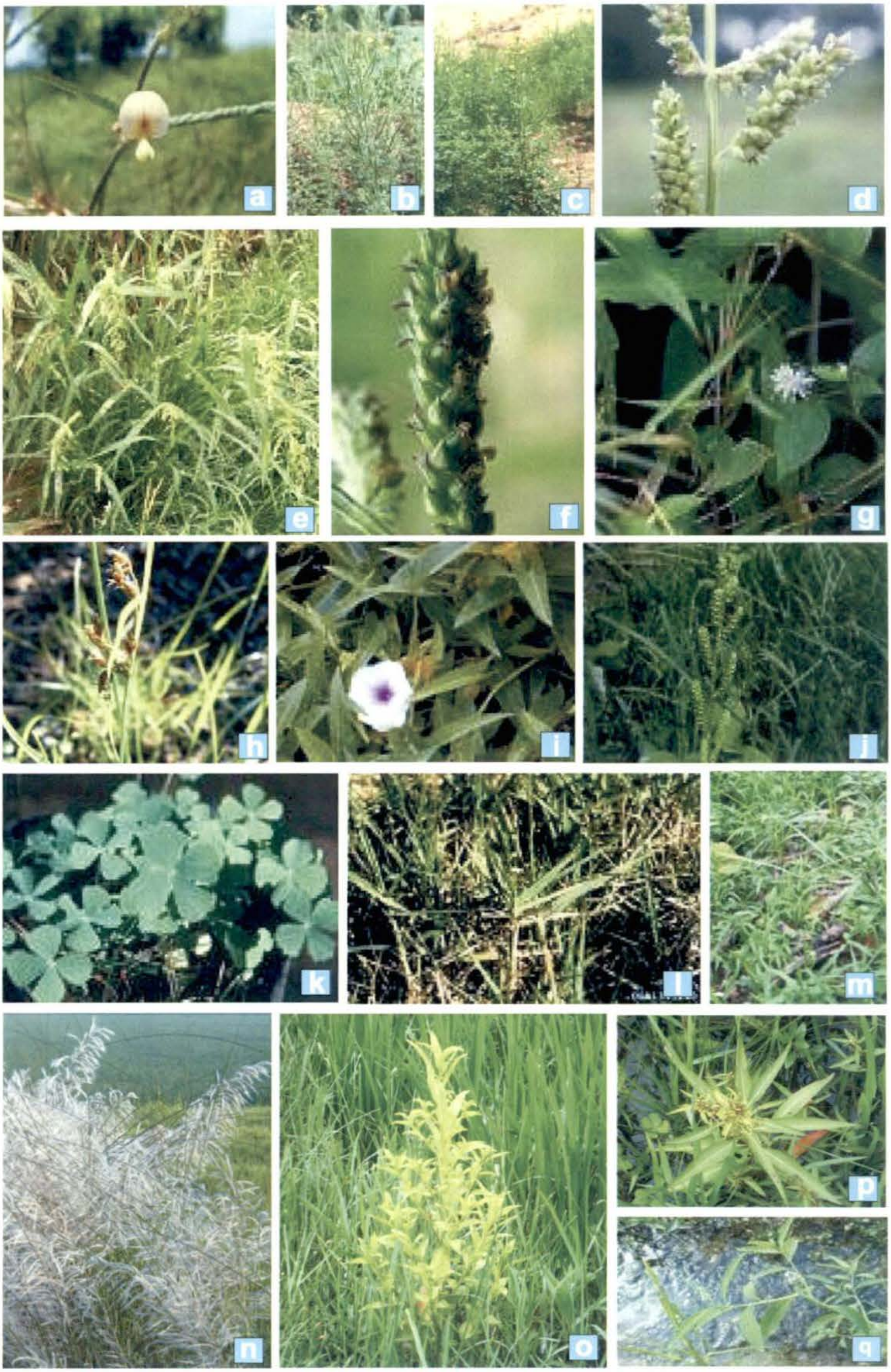


Fig. 4.7.1: Important paddy field weeds. a: *Aeschynomere indica*. b+c: Cleome viscosa, d: *Echinochloa crus-galli*. g: *Leptochloa* sp. h: *Fimbristysis* sp. k: *Marsilea minuta,* n: *Saccharum spontanearum*, o+p:*Ludwigia sp*. e,f,i,j,l,m and q are not identified.

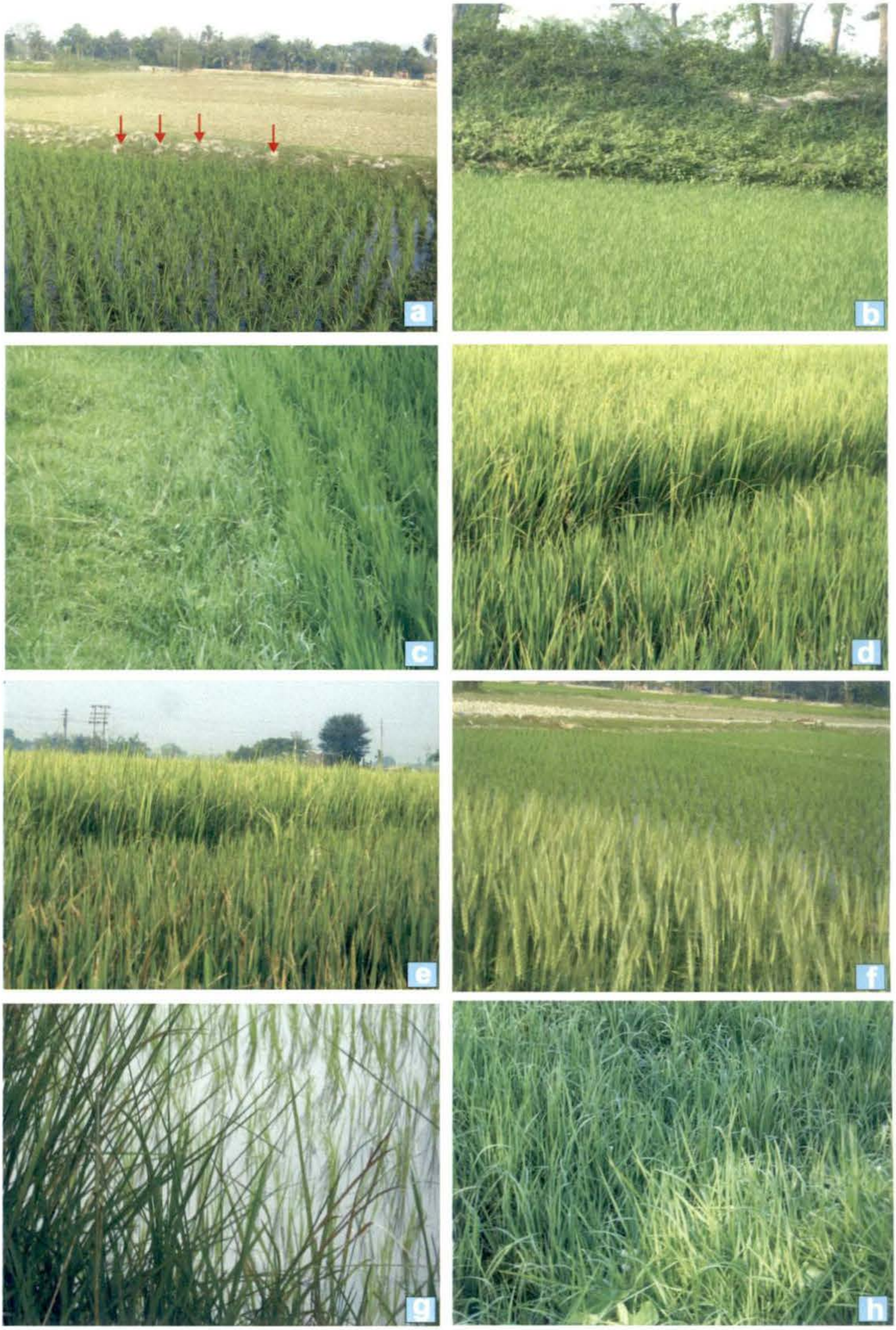


Fig. 4.7.2: Different types of faulty plantation related to weed management a: Improper completely weeded bund management, b: Adjoining wild vegetation that harbours PB & GM, c: Adjoining weed field that nourishes GM, d&e: Asynchronous cultivation of paddy that promotes pest carry over, f: Adjoining completely weeded field that drives pests to paddy, g and h: Paddy planted along side the taller grasses, this also drives pests to paddy.

In the plains of Indo-gangetic alluvial region covering the southern parts of West Bengal, the predominating species were *E. crusgalli*, *E.colonum*, *C.iria*, *C.difformis*, *Fimbristylis tenera*, *Eragrostis japonica*, *Paspalum dicticum* and *Staria glauca*. Kim (1990) reported. 92 host weed species belonging to 27 families from Korean paddy fields of which 30 were common weeds. In Australia, the main species competeting with the rice crops were *E. crus-galli* and related genera, *C. difformis*, *Damasonium minus* and *Elatine gratioloides* (Jahromi *et al.* 2001). Ghosh (1980) documented the positive role of weed flora on natural enemies. Kandibane (2008) has observed that floristic composition governs the pest guild structure and their seasonality. Schoenly *et al.* (1998) noted significant positive influence of the weed vegetation on some natural enemy population. Cruzdela and Litsinger (1986) documented high population of mirid bugs in the rice field adjacent to the grassy fallow.

4.7.2 Tillage intensity and weed generation

Tillage practices alter the physical characters of the soil which in turn influence the weed generation (3.8.4 in materials and methods). Performance of selected major weed species in relation to the yield attributes were studied under 9 different land preparation techniques, P1 (single plowing), P2 (double plowing), P3 (triple plowing), P1H1 (single plowing + one harrowing), P2H1 (double plowing + single harrowing) P1H2 (single plowing + double harrowing), P2H2 (double plowing + double harrowing) P3H3 (triple plowing + triple harrowing) and P1H1R1(single plowing + one harrowing + one roto tilling) (Tables. 4.7.2 and 4.7.3).

Paddy yield: Except in case of P2H2, there was no significant increase in the paddy yield.

Weed weight: Except in case of P3 and P2H1, weed weight under all treatments differed insignificantly during the first time of weeding operation (25 DAT). The weed biomass was nearly same under all treatments. During the second weeding (50 DAT), weed weights in the tillage practices P2, P3, P3H3 and P3H3 did not vary. The collected weed mass under the second operation in P1, P1H1, P2H1 and P1H2 remained nearly the same. Significant variation was noted during third weeding (75 DAT); P1, P1H1, P2H1 and P1H2 varied insignificantly. Minor variation was noted under P2, P3 and P1H1R1 treatments at the time required for the third weeding. Weed masses were nearly the same under P2H2 and P3H3 practices.

Table.4.7.2: Effect of land preparation techniques on the subsequent weed mass generation, time required for weeding practices, yield production and cost effectivity

Tilling operation	Average weed weight at the time of weeding			Weeding labour (h /ha)			Grain yield Q/ha	C:B
	1st	2nd	3rd	1st	2nd	3rd		
P1	442a (21.9)	391b (19.7)	292b (17.10)	106a (10.31)	178c (13.3)	406a (20.16)	30.89a (5.60)	1:1.52b
P2	416a (20.40)	391b (19.78)	290c (17.04)	100a (10.02)	182c (13.50)	401a (20.03)	30.80a (5.59)	1:1.52b
P3	395b (19.88)	397b (19.93)	280c (16.74)	102a (10.12)	300a (17.33)	416a (20.40)	30.21a (5.54)	1:1.51b
P1H1	409a (20.23)	400a (20.01)	307a (17.53)	95b (9.77)	194c (13.94)	393a (19.83)	30.81a (5.59)	1:1.52b
P2H1	398b (19.96)	368b (19.19)	334a (18.28)	97b (9.87)	298b (17.27)	418a (20.45)	30.29a (5.54)	1:1.51b
P1H2	440a (20.98)	412b (20.31)	319a (17.87)	102a (10.12)	181c (13.47)	272a (16.50)	31.01a (5.61)	1:1.53b
P2H2	401a (20.03)	412a (20.31)	320a (17.90)	95b (9.77)	170c (13.05)	270b (16.44)	33.55b (5.83)	1:1.58a
P3H3	415a (20.38)	450a (21.22)	305a (17.19)	115a (10.74)	310a (17.62)	421a (20.53)	30.76a (5.59)	1:1.52b
P1H1R1	405a (20.13)	380b (19.50)	284c (16.86)	104a (10.22)	234b (15.31)	360a (18.98)	29.98a (5.52)	1:1.50b
Control	467d (21.62)	452a (21.67)	357d (18.90)	100a (10.02)	182c (13.50)	416a (20.40)	28.24a (5.36)	1:1.43c

Figure followed by the same letter are insignificant at 5% level

Figure in the parenthesis are square root transformed value

Table.4.7.3: Relative proportional requirement of the promising land preparation techniques and the respective value of the labour utilized

Land preparation techniques	Labor requirements (h/ha)			Fuel consumed (lit / ha)
	Man	Animal (bullock)	Machine (Tiller)	
P1H1	116	117	-	-
P1	102	98	-	-
P1H1R1	129	117	7	14.00

(-): Not required

Weeding hour/ labour: Except under P2H2 and P1H1, in all other practices the times required for the first weeding at 25 DAT differed insignificantly. But during the second weeding at 50 DAT, significant differences were noted. P2H2, P1, P2, P1H1 and P1H2 required nearly same times. Time required for weeding under P2H1 and P1H1R1 differed insignificantly. During the third weeding at 75 DAT except P1, all the practices differed insignificantly.

Cost:Benefit value: Weed biomass and paddy yield under different land preparation practices have shown significant to poor levels of relation and with different cost: benefit ratios. Except for P2H2, under all the treatments C:B ratio remained same. The minor difference was due to the relative efficacy of the farmers regarding weeding practices.

Discussion: The required man power increased with the tillage intensity with no major change in the field weed population and the paddy grain production. Except under P2H2, the weeding labour requirement (hour / ha) remains same. Intensive plowing significantly alters the physical prosperities of the soil without any positive influence on production. The frequency of the YSB larvae was reduced under P1H1R1. So, the subsequent pest attack is checked. But the paddy production remains unaltered. The unaltered yield was probably due to the elimination of the natural enemies following intensive weeding. In addition to this, physiological alteration of the soil under intensive plowing indulges other soil inhabiting pests. Though YSB larval activity was lowered under PIHIRI, high expenditure during land preparation could not be economic for adoption. Plowing at higher grades does no provide any additional nutritional benefit to the crop. However, periodic weeding minimizes the nutritional competition of the weed communities with the paddy plants. In case of P2H2 yield was the highest.

4.7.3 Land preparation techniques and species composition

Land preparation techniques influence the relative species composition of the weed flora which in turn encourages the field pest. Dynamics of four weed species was recorded under 9 land preparation techniques with the ultimate objective to suppress the pest activity.

Weed number / mt.^{2} of paddy field was recorded highest under check which was followed in decreasing order by P1H2, P1, P1H3, P2H1, P1H1 respectively. P2 and P3 generated nearly the same weed population. The relative availability (%) of *Scirpus articilatus* was recorded least under P2H1 and highest under P1H3. While *Paspalum* sp. was counted least under P1H3 and highest under P2. Under P1, P3, P1H1 and P2H2 the population differed marginally. *Echinocloa* sp. and *Cyperus* spp. collectively were least abundant under P3 which was followed by P2 and P1 in ascending order. Nearly same frequency of both the species was noticed in case of PIHI and P2H2. But, in P1H2 and P1H3 there was comparatively higher abundance of both the species (Figs.4.7.3a and b).

Table.4.7.4: Correlation between the weed biomass and the abundance of the pests at maximum tillering stage

Preparation techniques	Pests			
	YSB	BPH	GM	PB
P1	0.123	0.231	0.342	0.121
P2	0.342	0.312	0.211	0.232
P3	0.311	0.311	0.342	0.132
P1H1	0.412	0.265	0.452	0.141
P2H1	0.211	0.456	0.332	0.321
P1H2	0.435	0.331	0.212	0.453
P2H2	0.355	0.421	0.342	0.234
P1H3	0.567*	0.411	0.435	0.543*
P1H1R1	0.589*	0.566*	0.576*	0.456*
No tillage	0.511*	0.543*	0.514*	0.543*

*Significant at 5% level

Weed biomass under P1H1, P2H2, and P1H1R1 had little or no significant effect on the pest population generation indicating an pest independency of the weed biomass production irrespective of tillage practices. Significant positive relation between the weed biomass and the YSB as well as weed biomass and PB were observed under P1H3. Furthermore, all the pests expressed significant positive relation with the weed biomass under P1H1R1 (Table.4.7.4).

The critical period of crop of weed competition has been observed between 30 to 60 days after sowing (Moorthy and Saha 2002). Moorty (1992) has noted that repeated plowing immediately after harvest is advantageous for next crop.

Most of the weed species encountered was found to be the alternative hosts of the four major pests under consideration, YSB, BPH, GM and PB. Variation in the weed species composition and changes in population size in turn, dictated the pest population structure in the field. It is thus suggested to adopt P2H2 treatment during land preparation.

4.7.4 Tillage practices, occurrence of the alternative host and the incidence of YSB

4.7.4.1 Effect of different tillage practices on the incidence of YSB in relation to the growth stages of paddy: All the tillage techniques were found to influence the YSB incidence. The growth stage related dynamics of YSB suppression showed that under all the treatments, the combination of one plowing + one harrowing + one rototilling (PIHIRI) was found more effective. The effect was least when the field was prepared by one plowing (P1). Activity of one plowing one harrowing (P1H1) was intermediate (Tables4.7.5 and 4.7.6).

Table.4.7.5: Effect of prominent land preparation techniques on the physical parameters the soil.

Condition of the land	Land preparation techniques	Specific volume (cm^3/g)	Bulk density (gm/cm^3)	Total porosity (%)	Void ratio
Before plowing		0.89±0.03	1.02±0.03	60.4±1.7	1.54±05
After plowing	PIH1	0.85	1.07	59.3	1.45
	P2H2	0.83	1.13	57.7	1.30
	PIHIR1	0.96	1.05	56.8	1.54

Table.4.7.6: Correlation study between the availability of the YSB larvae and the physical parameters of the soil

Specific volume	Bulk density	Total porosity	Void ratio
-0.567*	-0.572*	0.712*	0.532*

Irrespective of tillage practices, P1H1 and P2H2 the total porosity (%) and the void ratio of the soil remains unaltered after plowing (Table.4.7.6). Diapausing YSB larvae showed significant negative relation with the bulk density while total porosity and void ratio revealed a significant positive relation, indicating that the survivability of the larvae was dependent on the physical properties of soil. Land preparation techniques especially the P1H1R1 brought about the change of specific volume of soil causing the higher mortality of the larvae.

Except P1H1R1, adopted land preparation techniques were found to exert profound influence on the viability of the YSB larvae at significant level which in turn dictated the pest structure of the field in the next crop. Among the tillage combinations, PIHIRI rendered highest level of specific volume of the soil; it was thus proved that such treatment was superior to others.

Adopted land preparation techniques by tilling procedure hardly exercise any role on the subsequent weed mass generation. Relative variations observed at yield level are insignificant with few exceptions. However, alteration in the physical properties of the soil following combinations of tillage techniques increases air permeability and thus exerts significant positive impact on the biology of YSB with better survival value.

4.7.4.2 Specification of the proper time of tillage practices

Adoption of proper tillage practices successfully suppressed the subsequent generation of YSB population. As the field was kept unplowed for a longer time after a harvesting of the *kharif* crop the chances of YSB intensity in the subsequent *boro* season was heightened (Figs. 4.7.4a, b and c).

Observations in three consecutive years indicated that retention of the stubbles for a longer period in an open field allowed the hibernating pupae to complete its life cycle. The YSB pupae in the stubbles gradually increased from 46 SMW to the maximum at about 2 SMW of the next year, after which the frequency gradually decreased. Persistent high level of larva from 1-2 SMW had a direct correlation to the subsequent first brood at early February (Fig. 4.7.4d).

Discussion: No definite works were carried out regarding the collective field situation after post tillage operation in India. Works so far undertaken elsewhere were principally restricted either to the productivity or pest occurrence separately without any time and method specification of tillage.

Tillage reduces borer populations through mechanical damage either by burying them deeply into the soil or by breaking the stems and exposing the larval to adverse weather conditions (Harris 1962, Ajayi 1990) as well as to the predatory complex (Kfir 1993). Cheshire and Griffin (1985) have indicated that predators of lesser corn stalk borer larvae were more abundant in no-tillage than in conventional tillage cropping systems. Cividanes (2002) have shown that no-tillage favours predators.

Presence of stubble residue after harvest acts as the reservoir of YSB pupa for the subsequent outbreak and thus requires immediate time specific eradication of stubbles before 1-2 SMW during the next transplantation.

Proper management of the stubbles is found to be a prime need to check the *kharif* crop from subsequent YSB population. Early destruction of the stubbles 2-4 weeks after harvesting and before the emergence of next seed generation is thus suggested to avoid the pest out break.

4.7.5 Land preparation techniques and paddy yield generation

The highest yield was achieved under P2H2 followed by P1H1R1.The least was scored under control under P2 and P3, almost the same yield was obtained. Further, P1H1and P2H1 differed marginally.P1H2 produced slightly lower quantity of grain than P1H1.P2H2 yielded slightly higher than P1H1R1 (Fig.4.7.3a).

Increase in seed rate from 70 to 110 kg / ha can effectively reduce the weed biomass (Tosh *et al.*1981). Moorty (1990) noted finger weeders /wheel hoes supplemented with one hand weeding gave efficiently control the weeds thus the chances of pest infestation was curtailed.

Weed masses were found to influence the grain production in two ways. Primarily, weed species at the early growth stages of paddy competed with the paddy plant for both food and shelter which in turn influenced the final yield. Secondly, some weed species were selectively advantageous to specific pests. As the pest abundance was nearly unaltered under different land preparation techniques; it was rather phenological interaction of the weed canopy which dictated the yield generation. So, the species abundance rather than the species composition acted as an ultimatum for the final yield production.

Variability of cost effectiveness was noted under different cultivation practices. As P2H2 ensured greater returns, it is thus suggested to adopt such land preparatory techniques.

4.7.6 Weeding practices and weed generation

Hand weeding was carried out by about 79% farmers at different times. Application of herbicides was adopted only by about 11% while the remaining showed no specific weed-control practices. Experiments were carried out with three different time combinations (25, 50 and 75 DAT) during *kharif* crop and their relative impact on the final yield was analyzed. Efficiency of each of the three weeding practices was considered in relation to the weed weight generation (gm/mt.^{2}) at reproductive stage and the time of harvesting respectively. Yield was assessed after harvesting (Table.4.7.7).

Table.4.7.7: Effect of weeding practices on weed generation (gm/0.5 mt^2)

Treatments	Weeding combinations			Weed weight (gm)		Total Weight (gm)	Yield q/ha
	25	50	75	Reproductive stage	Harvesting		
HW1	+	-	-	17.4ab (4.23)	88.6 ab (9.43)	106.0a (10.31)	29.6c (10.31)
HW2	-	+	-	18.4 ab (4.34)	92.3ab (9.63)	110.7a (10.54)	28.9c (10.54)
HW3	-	-	+	42.2 a (6.53)	102.3 b (10.13)	121.4bc (11.04)	30.7d (11.04)
HW4	+	+	-	6.5 c (2.64)	14.1c (3.82)	56.3c (7.53)	32.8ab (7.53)
Control						181.9b (13.50)	27.1e (13.50)
CV (%)						9.2	

Data suffixed by the same letters are non significant

Figure in the parenthesis are square root transformed value

Highly significant negative relation (- 0.789) between weed biomass and grain yield was observed. High level of weed mass generation was noted under HW3 followed by HDW2 and HDW1 practices. Weeding operations carried out individually at 25DAT, 50DAT and 75DAT had allowed enough time for weed generation. Longer the interval of weeding the greater was the weed biomass generation. Cost: benefit value showed exponential relationship with the collected weed mass.

Hand weeding is laborious, tedious drudgery and expensive. It may require 60-70 persons day / ha (Moorthy 1990). But it effectively controls the weed between the rice hills and near the base of the rice plants. Chandrakar *et al.* (1992) have recommended that chemical control supplemented by hand weeding maximize the yield.

4.7.7 Crop establishment method, crop rotation and weed generation

Crop establishment method and weed generation: Methods adopted for paddy crop establishment influence the weed generation. When crop was directly seeded in comparison to transplantation, annual grasses were dominant than perennial and annual weeds. Annual grasses support all the pests relatively at higher levels. Direct sowing permits weeds multiplication without any hindrance and to compete with the paddy plant canopy from the very beginning of the vegetative stage, the yield was thus reduced. While under transplantation techniques the interference of the weed canopies was minimum (Table.4.7.8).

Table.4.7.8: Effect of paddy crop establishment methods on the weed mass generation (gm / 0.5 mt^2)

Types of crop establishment	Growth stages of paddy		Total weight	Yield q/ha
	Vegetative	Reproductive		
Direct sowing	27.2 (5.26)	119.4 (10.94)	146.6 (12.12)	25.2 (5.06)
Transplanting	19.7 (4.49)	98.4 (9.94)	118.1 (10.89)	30.5 (5.56)

Figures in the parenthesis are square root transformed value

Crop rotation and weed mass generation: Crop rotation noticeably influenced the weed mass generation which was studied under three major crop rotation practices taking paddy as one of the major crop components against the monoculture field of paddy fields. In each occasion hand weeding was carried out at 25 and 50 DAT. Weed generation (mt^2) was evaluated collectively at maximum tillering and reproductive stages. Maximum weed was collected in paddy-paddy rotation followed by paddy-maize, paddy-pulses and paddy-vegetables in descending order. Fewer weeds were counted from double-copping fields where rice was followed by winter crops. Monoculture supported greater weeds (132.7 weed mass / 0.5 mt^2) while paddy-vegetable rotation maintained comparatively low weed level (87.6 weed mass / 0.5 mt^2) (Table.4.7.9).

Rotational practices directly regulate the weed generation which is also related to the niche condition. Monoculture fields due to unaltered microclimatic components support the maximum weeds. The resultant niche for maize field is supposed to be similar to that of paddy field. Cultivation of pulses makes the solar radiation available to the ground altering the microclimatic components that impedes weed growth.

As weeds are alternative hosts their growth is to be restricted for living the pest numbers. From the stated point paddy-pulses rotation regulates considerably prevents weed generation.

Table.4.7.9: Effect of crop rotation practice on the weed mass generation and the final yield

Crop rotation pattern	Weed mass (gm)	Yield(q/ha)
Paddy-paddy	132.7 (11.54)	27.7 (5.31)
Paddy-vegetable	87.6 (9.38)	34.7 (5.93)
Paddy-pulses	91.4 (9.58)	32.1 (5.70)
Paddy-maize	104.2 (10.23)	29.5 (5.47)

Aerial sowing suppressed *E. crus-galli*. In contrast, sod and combine sowing favoured *E. crus-galli*. Higher intensity of cropping favoured all the major species as well as some more minor weeds, such as *Chara* spp. and *Diplachne fusca* in Australia (Mc Intyre *et al.* 1991).

As transplanted plantation supports less number of weed, it is thus suggestive to adopt the technique rather than the direct seed sowing.

4.7.8 Effect of field weeds status on the pest and natural enemy population

Under conventional paddy cultivation practices weedy vegetations were removed during the crop establishment which in turn destroys the habitat of natural enemies. Such complete elimination indulges the pest activity and thus requires regulated management of weed flora.

4.7.8.1 On the pest population

The effect of different time specific conventional weeding practices were evaluated against the weed mass generation (1 mt.^{2}), yield (q/ha) and the field pest level. Weeding was done following four different time schedules and the collected weed biomass was correlated with the field average pest level of the following dates to suggest the proper time of weeding.

4.7.8.1.1 Numerical abundance

Yellow stem borer

Effect of collective weed coverage in consideration of farmers practice: Farmers adopt weeding of different combinations. Weed masses (gm / mt.^{2}), YSB egg masses / hill, DH (%) and WH (%) were assessed periodically from 8 to 19 WAT from the natural bio-control fields .The weed population had a positive influence on YSB egg masses. Higher weed cover ensures better available surface area, so the survivability of the available eggs (effective egg mass) was increased. So, Greater the weed mass generation the higher was the frequency of WH (%). Paddy yield was also negatively influenced by the weed cover. From the late vegetative stage, the weed canopy competed with the plant canopy both for the space and nutrients resulting in reduced yield. Two control was manifested, one without weeding and the another by the periodic weeding at 50 + 75 DAT with least number of YSB eggs and WH. Weeding practice at only 75 DAT (HW3) was least effective with highest weeding coverage / mt.^{2}.YSB egg masses was maximum side by side yield was minimum (Fig.4.7.3c).

Effect of weeding practices: Relative efficacy of different weeding practices was evaluated in respect of the DH (%) and WH (%). Except in the case of weeding at 75 DAT (HW3), in all the operations there was a steady decrease in the weed mass population. The frequency of DH and WH was decreased under all the operations, except in HW3 (Fig.4.7.3d).

Brown plant hopper: Most of the weeds act as alternative hosts for the BPH population. The BPH population decreased under all the management practices with the exception of HW3 where pest population increased marginally due to the presence of high weed coverage. BPH dynamics was positively influenced by field weed biomass. Frequent weeding halted the pest life cycle (Fig.4.7.5b).

Gall midge: All the weeding practices effectively suppressed the SS formation. Among all the weeding operations HW4 was found to be the most suitable. The treatment HW1 and HW3 generated moderate amount of weeds (Fig.4.7.5d).

Paddy bug: Paddy bug sucking causes incomplete and chaffy grains. PB is aerial feeder and the activity is restricted only to the late tillering stage thus weed cover did not influence the pest dynamics. So, the different weeding practices could not influence PB population at all (Fig.4.7.5a).

Of all the combinations considered, HW4 generated comparatively low weed biomass and the percentage of DH and WH was relatively low. The treatment HW1 and HW3 generated moderate amount of weeds. No direct influence of the weed cover upon the activity of the PB at the early growth stages was noted. HW4 reduced the uneven nutritional competition of the paddy plant with the weed canopy.

4.7.8.1.2 Correlation study analysis of pest abundance with weed biomass: Weed mass collected at vegetative stage following high tillage practice (P1H1R1) showed significant positive relation with the field population of BPH and GM. While YSB and PB expressed insignificant positive relation. All the pests showed moderate to high range of significant positive relation with the weed biomass at reproductive stage (Table.4.7.10).

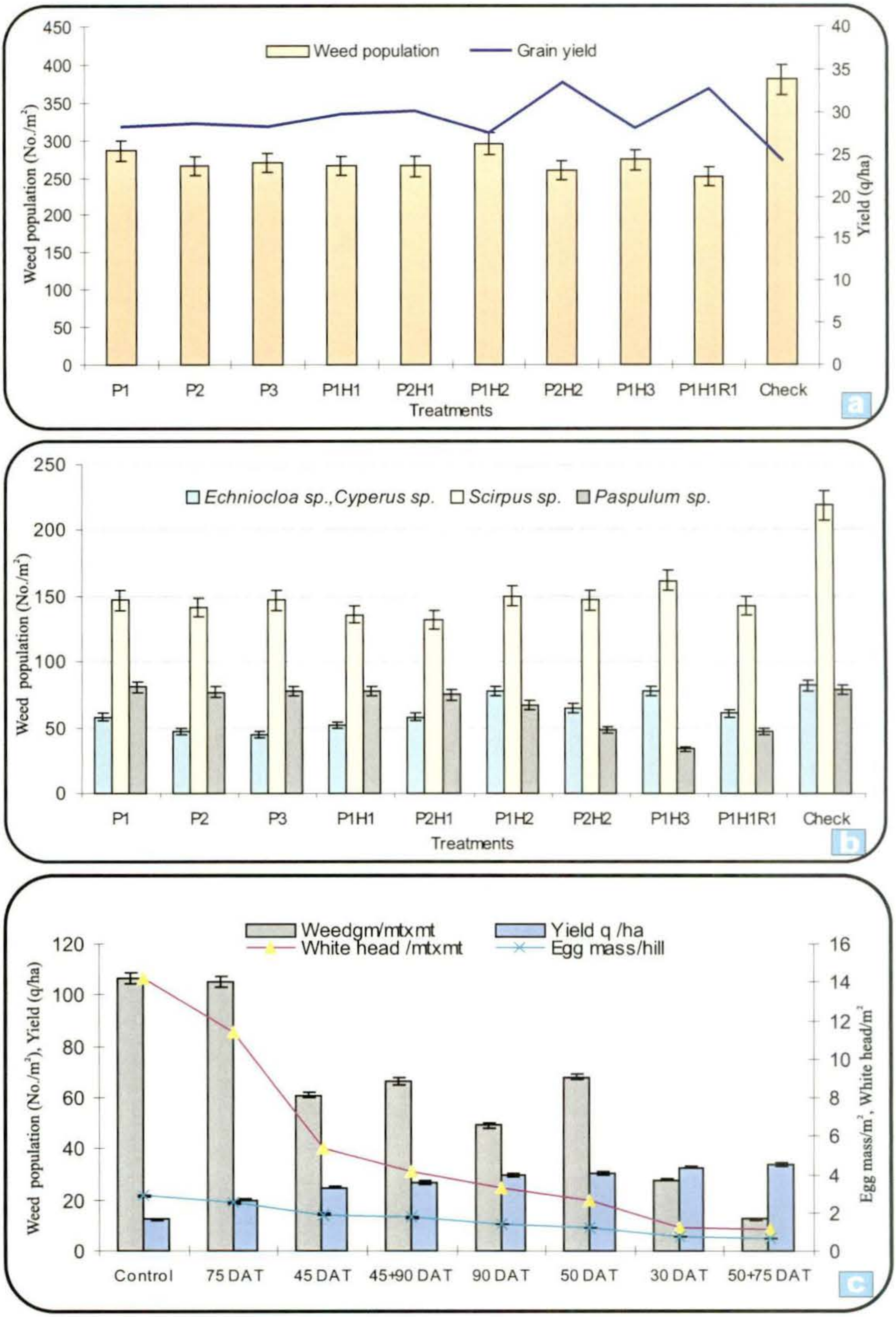


Fig. 4.7.3: a: Weed density and paddy yield under different field preparation practices, b: Weed species composition under different field preparation practices, c: Influence of weed biomass on the number of YSB egg masses and WH and consequent paddy yield.

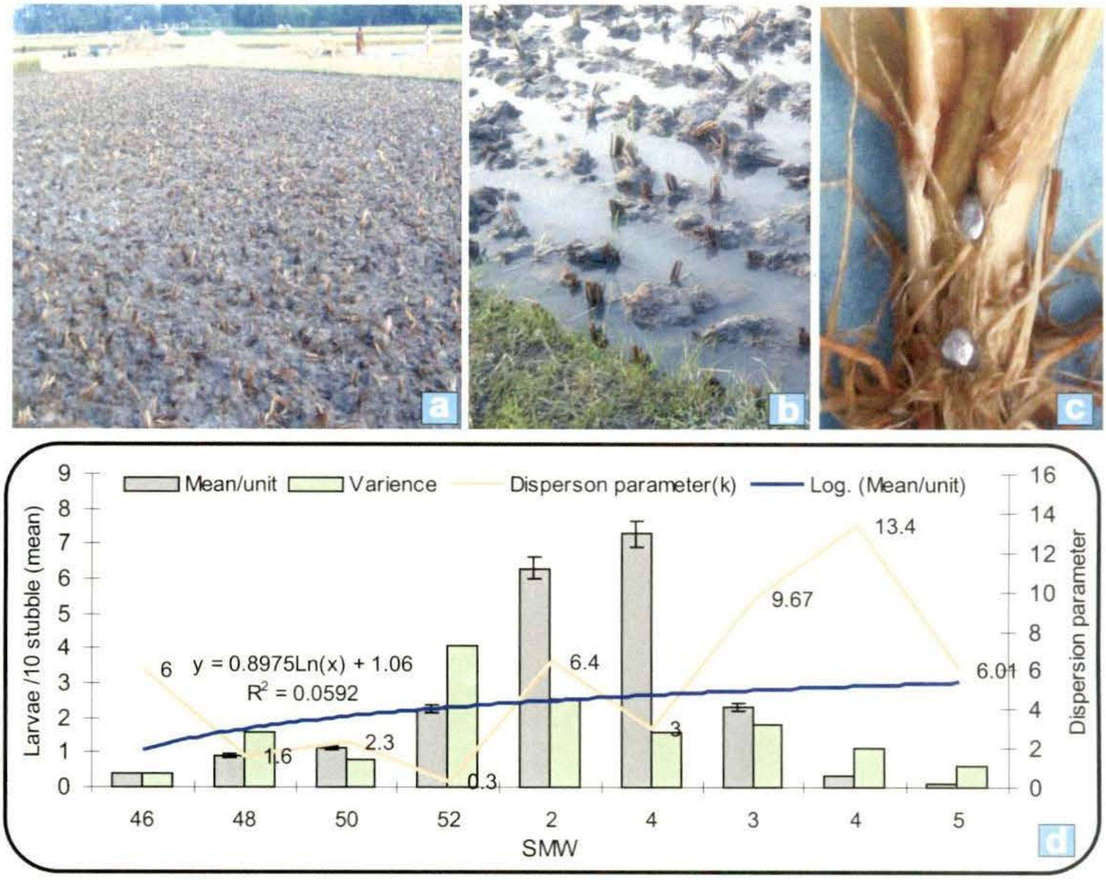


Fig. 4.7.4: Consequences of stubbles on the subsequent YSB population. a and b: Improper tillage with retained field water which help to survived YSB larvae, c : YSB larvae in stubble, d: Distributional characteristics of YSB larvae in the paddy stubble at farmer's agricultural fields.

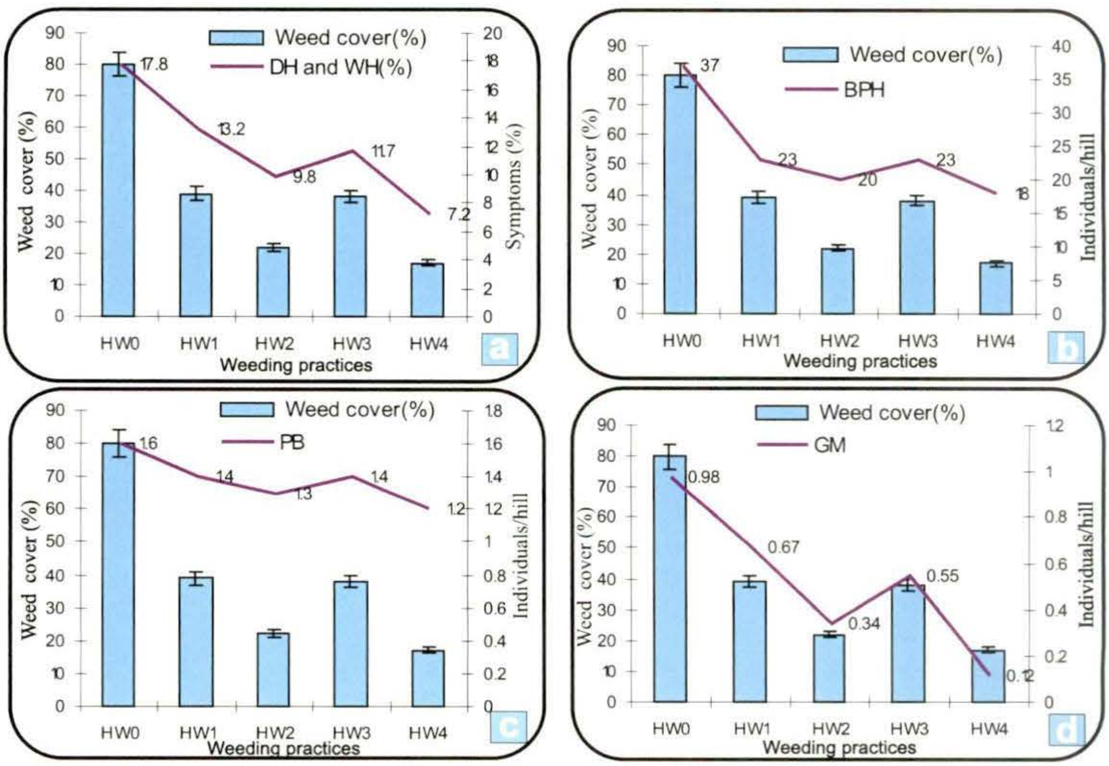


Fig. 4.7.5: Effect of hand weeding on the incidence of four major paddy pests. a: DH and WH, b: BPH, c: GM, d: PB.

Table.4.7.10: Correlation between the stage specific weed biomass and the pest abundance

Growth stages of paddy	YSB	BPH	GM	PB
Vegetative	0.442	0.572*	0.571*	0.141
Reproductive	0.711*	0.678*	0.546*	0.489

(*) significant at 5% level

Growth stage specific phenological alteration of both paddy plant and weed population was observed. As the paddy growth stage advanced, higher weed mass together with the higher foliage of paddy plant supported higher pest numbers. However, GM and PB are more responsive to the late growth stages. Such paddy growth stage related changes in pest population structure continued till the establishment of the pest on paddy.

4.7.8.1.3 Selection of proper weeding practice

Weed mass collected under different weeding practices was correlated with the field dynamics of the pest at tillering stage. The amount of the weed mass under no weeding practices was assessed after the end of the tillering stage. YSB and BPH abundance in HW1 and HW2 were significantly and negatively related with the weed mass. While in case of GM and PB both insignificant and significant negative relation was mostly found.HW3 and HW4 offered a high level of significant negative relation with the YSB and BPH and insignificant negative relation with PB and GM (Table.4.7.11).

Table.4.7.11: Correlation between pest abundance and weed biomass under different hand weeding practices

Weed biomass	YSB	BPH	GM	PB
HW0	0.862*	0.968*	0.567*	0.461
HW1	-0.548*	-0.624*	0.342	-0.445
HW2	-0.791*	-0.598*	-0.611*	-0.378
HW3	-0.522*	-0.648*	-0.403	-0.431
HW4	-0.572*	-0.767*	-0.321	-0.411

(*) significant at 5% level

Irrespective of the methods and times the hand weeding restricted the pest abundance Weed biomass (gm / mt^2) generated in each of the four weeding practices was correlated with the pest occurrence at the tillering stage.

All the weeding practices showed a significantly negative effect on all the pests. The only exception was noted for HW1 method which had insignificant positive relation with GM. Weeding restricted alternative food resources, multiplication and survival of the pests. However early weeding at 25 DAT in HW1 imparted very little effect on GM population and hence there was no change in pest numbers. HW0 showed both positively insignificant (for PB) and significant (for YSB,BPH and GM) relation.

As weed masses at vegetative stage was found to influence the population of YSB and BPH in the high yielding variety, HW4 practices imparted positive role to control these pests. However weeding practices at reproductive stage had been found crucial to check all the pests. Weeding practices was found to be the decisive factor as all the pests except PB was found to be influence by the weed biomass.

Discussion: No references relating to the intensity of weed biomass and the field pest level in relation to their extent of damage are available in India. Works so far undertaken elsewhere were mainly concerned to trace the relative influence of the weed biomass on the collective yields with superficial observation on the paddy field pest intensity. Correlation study indicates that the weed flora as alternative food sources positively influence the pest multiplication. Pruning of the weeds in lieu of clean cultivation together with the field scouting at specific time in relation to the growth stage of paddy is essentially required. So, the available surface area for oviposition is restricted resulting in comparatively low egg masses/mt^2.

Afun *et al.* (1999) studied the effects of five weed management practices on weed abundance, insect pests, and generalist predators, damage caused by the pests and yield in upland rice ecosystem in Cote d'Ivoire over two years. In both the years there were highly significant negative correlations between the weed biomass and grain yield in all the treatments. However, abundance of the pest was positively influenced by the presence of weed biomass. Selective destruction of the weeds at proper time would enable to minimize the subsequent pest incidence. Ombir and Chouhan (1989) found that in northern parts of India selective destruction of *Vicia sativa* could minimize the incidence of *Helicoverpa* in chickpea fields.

Weeding practices reduces the abundance of YSB and BPH. Restricted insignificant and significant effect of weeding was noted for GM while very little influence has been found on PB at early growth stages. In HW2 significant negative relation has been obtained with all the pests except PB, implying a positive role of the generated weeds on the pests' dynamics. Thus, in consideration of all the weeding practices it is suggestive to adopt the HW2 method.

4.7.8.2 On the natural enemy population

Effect of hand weeding practices on the dynamics of each of the four natural enemies at two growth stages was evaluated separately for four weeding practices against control. In general, all the practices restricted the size of the natural enemy's population. However, the effect is profound at reproductive stage.

4.7.8.2.1 Numerical abundance

Natural enemy dynamics and weeding practices

Spider: Spider population varied considerably under different weeding practices. Higher number of spiders' population was noted under HW0. Followed by HW1 in descending order. HW3 ranked next. The least was noted in case of HW4. Reproductive stage of paddy supported comparatively higher number of spider population than the vegetative stage (Table 4.7.12).

Bug: In HW0 and HW1 treatments the bug population remained at the same level. Least number was noted under HW2 while HW4 supported moderate range of bug population.

Beetle: Highest number of beetle population was noticed in HW0 and the least in HW2.

Fly: Throughout the entire growth stages of paddy, the level of fly population was very low. No major alternation of the fly population was noticed for different weeding practices.

Table.4.7.12: Effect of hand weeding status on natural enemies (individuals / hill)

Natural enemies	Weeding practices in relation to two growth stages of paddy									
	HW0		HW1		HW2		HW3		HW4	
	Vg	Rp	Vg	Rp	Vg	Rp	Vg	Rp	Vg	Rp
Spider	2.11 (1.61)	2.32 (1.67)	1.92 (1.55)	1.03 (1.23)	1.11 (1.26)	1.21 (1.30)	1.73 (1.49)	1.87 (1.53)	0.84 91.15)	0.89 (1.17)
Bug	1.42 (1.38)	1.38 (1.37)	1.23 (1.31)	1.28 (1.33)	0.92 (1.19)	0.69 (1.09)	1.22 (1.31)	1.34 (1.35)	0.95 (1.20)	0.81 (1.14)
Beetle	1.93 (1.55)	2.01 (1.58)	1.64 (1.46)	1.78 (1.50)	0.93 (1.19)	0.99 (1.22)	1.51 (1.41)	1.57 91.43)	1.66 (1.46)	1.71 (1.48)
Fly	0.91 (1.18)	1.01 (1.22)	0.71 (1.10)	0.87 (1.17)	0.51 (1.00)	0.65 (1.07)	0.73 (1.10)	0.88 (1.17)	0.52 (1.17)	0.61 (1.05)

Vg: vegetative, Rp: Reproductive stage

Figure in the parenthesis are square root transformed value

4.7.8.2.2 Correlation analysis of natural enemy abundance with weed biomass: The relative impact of the weed biomass was assessed in respect of two respective growth stages of paddy, the vegetative and reproductive stages. At the vegetative stage, the field weed biomass showed a significant positive relation with the bug and beetle population. However spider and fly population showed very low insignificant positive relation. But at reproductive stage, all the natural enemies showed significant positive relation (Table.4.7.13).

At vegetative stage weed biomass had significant positive relation with all the natural enemies except the spiders and fly. Spider generally invades the paddy field at late vegetative stages; therefore, early weeding had little influence on spider population. However at reproductive stage of paddy weed biomass exhibited significant positive relation with all the natural enemies. Results indicated that weeding, in general, hampers naturally colonization, but the effect is more prominent at late growth stages.

Table.4.7.13: Correlation between the weed biomass and the number of natural enemies

Growth stages of paddy	Spider	Bug	Beetle	Fly
Vegetative	0.324	0.553*	0.514*	0.327
Reproductive	0.711*	0.678*	0.666*	0.711*

(*) Significant at 5% level

Both the pests and natural enemies were found to be positively influenced by the standing weed biomass. Adoption of improper weeding practices may thus impart detrimental effect to the natural enemy density. Retention of weed biomass in patches at specific sites may prove alternative solution to restore the natural enemy at field level.

4.7.8.2.3 Selection of proper weeding practice: In order to evaluate the impact of weeding practices on the status of natural enemy populations, the collective weed biomass was correlated with them. HW1 showed a significant positive relation with bug, insignificantly positive with spider and beetle, and finally insignificantly negative relation with fly population. HW2 showed significant negative effect on all the natural enemies. Similarly, HW3 imparted significant negative effect on all the natural enemies except the bug where the relation was negative but insignificant. However HW4 exhibited insignificant negative relation with all the natural enemies. On the whole, in HW2, HW3 and HW4 the degree of negativity in respect of different species of natural enemies differed. Rampant hand weeding restricted the activity of the natural enemies, justifying the need of judicious management (Table.4.7.14).

Table.4.7.14: Correlation between pest abundance and weed biomass under different weeding practices

Weed biomass	Spider	Bug	Beetle	Fly
HW0	-0.762*	0.868*	-0.507*	0.431
HW1	0.448	0.504*	0.311	-0.411
HW2	-0.701*	-0.871*	-0.600*	-0.543*
HW3	-0.512*	-0.408	-0.513*	-0.563*
HW4	-0.471	-0.441	-0.311	-0.422

(*) significant at 5% level

Selection of HW4 could minimize the pest attack. All the weeding practices except HW4 less detrimental to the natural enemies. Adoption of HW4 practice together with the retention of the weed communities near the border vegetation by 'bund management' could act as the alternative protective source for the natural enemies.

Discussion: Weeds around crop fields act as alternate hosts for natural enemies, providing seasonal resources to bridge the gaps in the life cycles. Present finding corroborates with the work of Settle *et al.* (1996) who have found that manipulation of weed flora conserves the natural enemy population. Similarly Altieri (1995) had advocated that proper manipulation of weed communities enhances natural enemy population. Competition of rice canopy with weedy vegetation above the critical level steadily reduces the yields. However weeds provide protection and resources for other generalist predators. Thus clean weeding is conducive to pest damage (Altieri and Gliessman 1983, Altieri and Whitcomb 1988, Ezueh and Amusan 1988). Nalini *et al.* (2001) have found that unwedded rice field serves as reservoirs for pests, WBPH (1.82 individuals / tillers) and the natural enemies *C. lividipennis* (26.75 individuals / tiller) spider (8.30 individuals / tiller). Rapparini (2001) also has recommended scientific weed removal for pest control.

Proper manipulation of weed vegetation adjacent to crop fields promotes biological control, since the survival and activity of natural enemies often depend upon the resources provided by the vegetation around crop fields. It is thus suggested to adopt the HW4 procedure with the retention of some weedy vegetation to the nearby fields in patches. Such vegetation will act as over wintering sites for enemies and provide increased resources such as pollen and nectar for predators from flowering plants.

4.7.8.3 Water depth, weed management and pest abundance: Periodic submergence of paddy fields inhibits weed generation. Farmers commonly maintain different water depth during the growth stage of paddy. Such water level favours weed germination and growth. Proper management of the water stress was thus found crucial to minimize the host plant generation and to boost up the yield.

Correlation analysis of weed biomass with water depth: Influence of the different field water depth on the generation of the weed biomass was assessed. In all the cases, negative but insignificant relation was noticed between the water level and the weed biomass at vegetative stage. At reproductive and early ripening stage, water level imparted significant negative effect on the weed biomass. However, in control plots of no water weed mass showed significant positive relation in both the growth stages of paddy (Table.4.7.15).

Table.4.7.15: Correlation between the water depth and the weed biomass two growth stages of paddy

Water depth(cm)	Vegetative	Reproductive
0.0	0.511*	0.654*
2.5	-0.323	-0.543*
5.0	-0.435	-0.675*

(*)- Significant at 5% level

4.7.9 Field pest dynamics of transplanted paddy as affected by the adopted water stress management practices: In order to asses the relative efficacy of the water regimes, variable ranges of standing water level as normally maintained by the farmers were maintained in the paddy field with respect to the growth stages of paddy and compared with the control of fixed water depth (Tables.4.7.16a and b).

4.7.9.1 Numerical abundance: Relatively low profile of some pests (YSB, BPH) was observed after water stress management while the levels of other pests were marginally increased. Although the incidence of all the pests were noticed from the very beginning of transplantation, with the advent of higher growth stages the relative population remained unaltered. Alternative flooding offered mechanical rigidity to the paddy plant, thus rendered the YSB larvae incompatible for boring. Periodic flooding and draining altered the microclimatic environment at the base of the plant canopy, unsuitable for BPH accommodation. However, retention of water caused canopy wetness which in turn attracted the GM population.

Table.4.7.16: Abundance of four major pests at different depths of field water

A. At different depths as recorded from the conventional practices by the farmers

Growth stages	Stage(s)	Sub stages	Weeks	Water level (cm.)	Abundance of the pests (individuals /hill)			
					YSB	BPH	GM	PB
Vg	Seedling			1-2	0.68 (1.08)	1.21 (0.98)	0.21 (0.84)	0.47 (1.25)
	Transplanting			1-2	0.79 (1.13)	2.34 (1.00)	0.24 (0.86)	0.52 (1.27)
	Tillering	Early	1 - 2	2-3	0.98 (1.21)	6.25 (1.11)	0.47 (0.98)	0.74 (1.31)
		Middle	3 - 5	3-4	1.31 (1.34)	7.11 (1.14)	0.81 (1.14)	0.82 (1.35)
		Late	6 - 7	3-4***	2.12 (1.61)	7.25 (1.28)	0.91 (1.18)	1.14 (1.45)
Rp	Booting stage		8 - 9	4-5	2.41 (1.70)	7.81 (1.40)	1.34 (1.35)	1.48 (1.48)
	Panicle initiation stage	Heading	10 – 11	4-6	1.21 (1.30)	8.21 (1.44)	1.42 (1.38)	1.58 (1.34)
		Flowering	12 - 13	5-7*	0.98 (1.21)	8.45 (1.47)	1.51 (1.41)	1.67 (1.31)
Mt	Milk stage		13	5	0.92 (1.19)	8.69 (1.52)	1.62 (1.45)	1.84 (1.30)
	Dough stage		13 – 14	5-7	0.62 (1.05)	9.04 (1.45)	0.82 (1.14)	1.61 (1.24)
	Maturation		14 - 15	4-5**	0.51 (1.00)	9.21 (1.20)	0.41 (0.95)	0.94 (1.22)

(*) Constant water level was maintained, (**) drained water level before 10-12 days of harvest, (***) alternatively drained

Vg - Vegetative stage, Rp – Reproductive stage, Mt – Maturation stage

Figures in the parenthesis are square root transformed value

B: At fixed water depth (regarded as control)

Growth stages	Stage(s)	Sub stages	Weeks	Water level (cm.)	Abundance of the pests (individuals /hill)			
					YSB	**BPH**	**GM**	**PB**
Vg	Seedling			1-2	0.91 (1.18)	4.31 (2.19)	0.18 (0.82)	0.22 (0.84)
	Transplanting			1-2	1.19 (1.30)	5.37 (2.42)	0.19 (0.83)	0.39 (0.94)
	Tillering	Early	1 - 2	1-2	1.28 (1.33)	7.55 (2.83)	0.35 (0.92)	0.65 (1.07)
		Middle	3 - 5	1-2	1.81 (1.51)	9.15 (3.10)	0.67 (1.08)	0.67 (1.08)
		Late	6 - 7	1-2	2.74 (1.80)	13.85 (3.78)	0.81 (1.14)	1.09 (1.26)
Rp	Booting stage		8 - 9	1-2	2.81 (1.81)	16.41 (4.11)	1.07 (1.25)	1.27 (1.33)
	Panicle initiation stage	Heading	10 -11	1-2	1.47 (1.40)	18.11 (4.31)	1.42 (1.38)	1.32 (1.34)
		Flowering	12 - 13	1-2	1.34 (1.35)	15.15 (3.95)	1.31 (1.34)	1.41 (1.38)
Mt	Milk stage		13	1-2	1.22 (1.31)	10.19 (3.26)	1.41 (1.38)	1.54 (1.42)
	Dough stage		13 -14	1-2	1.21 (1.30)	7.24 (2.78)	0.67 91.08)	1.41 (1.38)
	Maturation		14 - 15	1-2	1.02 (1.23)	5.21 (2.38)	0.22 (0.84)	0.32 (0.90)

(*) Constant water level was maintained, (**) drained water level before 10-12 days of harvest, (***) alternatively drained

Vg - Vegetative stage, Rp - Reproductive stage, Mt - Maturation stage

Figures in the parenthesis are square root transformed value

4.7.9.2 Correlation between the water depth and the pest performance: Standing water of variable depths at late vegetative stage (2.5 or 5.0 cm) showed significant negative effect on YSB moth incidence. BPH population also was negatively influenced at significant level in comparison to control fields without standing water. The dynamics of GM population was positively dependent of water stresses. Water depth showed insignificant positive effect on paddy bug population. Thus the effect of standing water is significantly pronounced on YSB moths and BPH at negative level, almost positive on GM, low or nil on PB.

So, except PB, all other pest frequencies were significantly influenced by the field water regimes. (Table.4.7.17).

Table.4.7.17: Correlation between the water depth and the pest incidence

Water depth (cm)	YSB	BPH	GM	PB
0.0	0.423	0.543*	0.466	0.511*
2.5	-0.556*	-0.511*	0.541*	0.097
5.0	-0.571*	-0.675*	0.545*	0.067

(*)- Significant at 5% level

Discussion: Moisture regimes disapprove the generation of suitable microclimatic zones conducive for pest multiplication. Further retained water displaces BPH in search of favourable niche, to the upper canopy of paddy is again, which invaded by the lady bird beetle and thus enhances higher degree of predation. Activity of PB is restricted to the upper part of the canopy thus escaping from the effect of water regimes. However negative hydrotropic behaviour of neonates of YSB restricts it from stem penetration to some extent. Field water regimes are thus found to influence the dynamics of the pests in two ways. Primarily, at the early vegetative stage stagnant water inhibits the weed germination thereby discouraging the generation of alternative hosts of the pests generation. Secondly, alteration of microclimatic environment due to alternative draining disfavours pest multiplication.

Study at the CRRI, Cuttack has revealed that grain losses due to pre-submergence and post-submergence was 25 and 17% respectively in low land. Deep plowing and sub soiling restrict weed emergence (Nyarko and De Datta 1991). References relating to the impact of water management on the paddy pest bionomics are very much restricted. Mehto *et al.* (1987) observed that irrigation significantly reduced the incidence of major pests in chickpea in India. Rivany (1967) reported from Israel that injudicious irrigation has been conducive for *Chilo agamemnon* developement. Deol (1964) observed that the intensity of *C. infuscatellus* had a relation to the frequency of irrigation. Chowdry and Sharma (1960) similarly found that incidence of *Sesamia. inferens* could be controlled by proper water stress management. Water management reduces rice water weevil, *Lissorhoptrus oryzophilus* in Louisiana, USA (Quisenberry *et al.* 1992).

Suppression of the weed vegetation by periodic water stress management can effectively check the pest population. But retention of more than 2.5 cm deep field water was found uneconomic as no major change in the field pest population was noticed in the subsequent stages.

4.7.10 Collective effect of the water stress and the weeding operation on the yield generation: Collective impact of both water stress management and weeding performance in relation to the grain production was assessed. Hand weeding was performed at 25 and 50 DAT (HW4) under three variable water stress conditions at late vegetative stage against the field without weed control which was considered as control. Yield increased substantially when the water depth was increased from 2.5 to 5.0 cm. No further improvement of the productivity was noted when the depth was increased from 2.5 to 7.5 cm. At 2.5 cm water treatment comparatively higher yields were obtained than the other treatments. Retention of 7.5 cm water hiked management expenditure and reduced the production; the net result was being low cost benefit ratio. The 'control' fields showed comparatively lower benefit than the fields under weeding operation (Table.4.7.18).

Table.4.7.18: Mean grain yield (q / ha) and cost effectivity of transplanted paddy in relation to different depths (cm) of water weeding

Weed control					No weed control					
Field water level (cm)										
2.5	5.0		7.5		2.5		5.0		7.5	
Yield	C:B	Yield	C:B	Yield	C:B	Yield	C:B	Yield	C:B	Yield
32.45	1:1.51	33.27	1:1.62	30.12	1:1.48	28.11	1:1.34	29.12	1:1.47	27.08

Standing water suppresses the weed germination and growth, reduces the competition of the plant canopy with the weedy vegetation for nutrition. But higher depth of water hindered the utilization of the applied N to the plant. The extent of yield loss ranged up to 17% in *Swarna Mashuri.*

In India, weed-induced loss is around 33% of the total losses ranging from 12.8% to 24.4% after herbicide applications over manual weeding. Study at ICRISAT (International Crop Research Institute for Semi Arid Tropics), Hyderabad indicates that the per cent yield reduction ranges up to 70 due to the phenological interaction and by the of the pest multiplication. Study by AICRP indicates that the losses may range up to 16.9% in unwedded and transplanted paddy

Synchronized time specific water management and weeding practices can effectively increase the yield. Collective management of two practices comparatively attributes more yield than a single management. Management of water depth at of 5.0 cm has been found more economic in consideration of the cost of production.

4.8 Impact of Selected Cultural Practices on the Pest Incidence

Cultural control of insect pests involves appropriate cultivation practices for a given locality. This requires a thorough knowledge of life history, behaviour and ecology of a particular pest species as well as of its host(s) (Fagan 2002). The most vulnerable growth stage(s) in the life cycle must be determined and accordingly befitting management practices should be developed. Farmers in the area of study follow a variety of cultivation practices. Chapter elaborated the relative consequences of some of the cultivation practices on the incidence of all the pests. Simultaneously the effect of some practices which interfere with the biology of a particular pest were considered individually.

4.8.1 Comparative dynamics of pests in some major crop rotation practices

A total of 32 types of crop rotation practices with reference to paddy as the major crop were observed among the villages. Out of these six types of rotation were mostly practised by the farmers.

Cultivation of three paddy crops in a year headed the list. Rotational cultivation of paddy with maize / lentil or jute or wheat ranked next. Paddy in rotation with pulses and vegetables contributed about 16% and 10% respectively. Relative dynamics of all the pests had been assessed at late vegetative stage and on the basis of symptoms at late tillering stage by hill estimation separately to quantify the comparative impact of a particular rotational practice.

Yellow stem borer: Rotational cultivation of paddy with green manure (*Sesbania* sp.) registered least number of YSB with 1.45 individuals / 5 hills while the highest was noted in case of rotation with paddy-paddy (Fig.4.8.1a).

The intensity of DH and WH has a positive relation with the pest intensity. The highest level of DH and WH was noted in case of three consecutive paddy crops while the least was scored in paddy-green manure rotation.

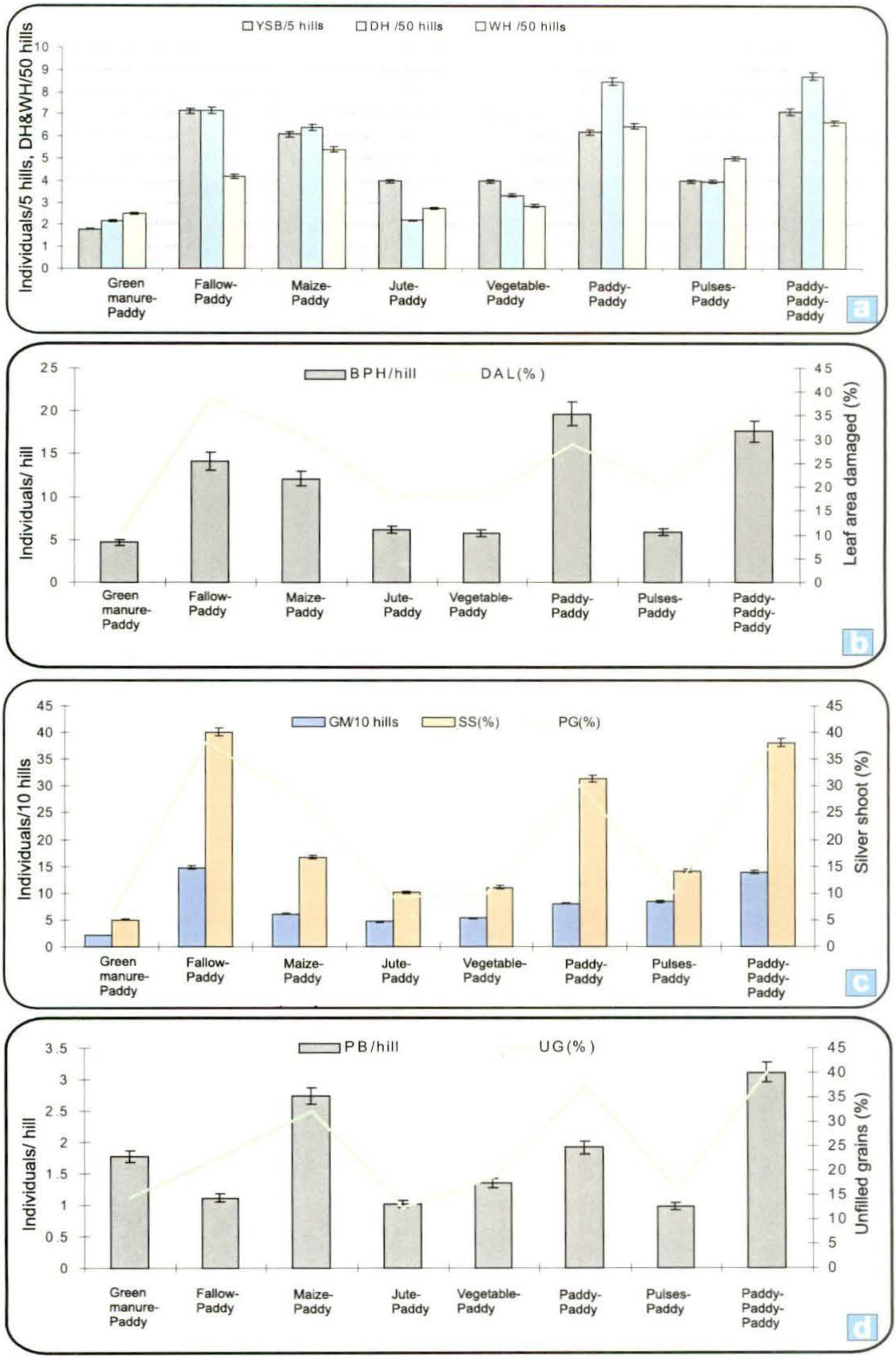


Fig. 4.8.1: Effect of different types of crop rotations on the incidence of the four major pests and their consequent damages. a: YSB, WH and DH, b: BPH and leaf area damage, c: GM, silver shoot and parasitized gall, d: PB and unfilled grains.

Brown plant hopper: The least number of BPH was recorded in case of paddy-green manure rotation. Only three paddy crop a year registered highest number of BPH population with 21.5 individuals / hill. The least level of damaged leaf area (DAL%) was noted in paddy-green manure rotation while the highest was observed in case of three consecutive paddy cultivation with any rotation with other crop (Fig.4.8.1b).

Gall midge: The numerically GM and SS% was highest in fields when only one rice crop is cultivated in a year. The least number of GM and SS% was noted in rice-green manure rotation.

Rate of gall parasitization appeared density dependency on the available field galls. Paddy-fallow cultivation showed the PG% was the highest in the former case while the least was in case of later (Fig.4.8.1c).

Paddy bug: Comparatively high level of PB was observed under paddy-paddy-paddy cultivations followed by paddy-maize cultivation. However paddy-green manure fields also suffered from PB attack by high numbers(Fig.4.8.1d).

. Highest level of PB induced damage was noted in paddy-paddy-paddy rotation followed maize-paddy cultivation. Least number of unfilled grain (UG%) was found in paddy-jute rotation which was followed in ascending order by paddy-pulses and paddy-vegetable rotation.

The least level of pest occurrence was observed in paddy-pulses followed by in ascending order by jute-paddy and fallow- paddy rotation.

Discussion: The intensity of the different pests is directly related to the amount of available field nitrogen. Cultivation of green manure acts as a chief N source for the subsequent paddy cultivation. Decomposed leaf litter has an additional benefit on the following cultivation for providing N as a matrix of slow releaser. In the absence of food YSB could survive up to a period of six months with an extended larval period in the field stubbles (Heinrichs1984). Interruption due to cultivation of paddy altered with other crops especially the green manure or jute with proper plowing helps to check the subsequent out break of the stem borer.

Intercropping of rice with cow pea and green gram effectively controls the weeds (Moorty 1992) which may be the alternative host of the paddy pests. Crop rotation interferes with the life cycle of major pests and thus lowers the range of their of the survival. Under integrated cereal development programme (ICDP) and accelerated maize development programme (AMDP) cultivation of maize along with pulses have been suggested in the district of Uttar Dinajpur to economize the benefit. But Maize is known as be the alternative host of YSB and BPH resulting in the appearance of a larger population in the subsequent paddy cultivation. Effect of maize cultivation in rotation with paddy has very little positive effect upon the subsequent GM and PB population. But the intensity of all the pests has been relatively low in the paddy field where the cultivation of paddy is rotated with pulses. Because the life cycle of pests is distracted due to the absence of host plant. Paddy cultivation followed by the fallowing the land has resulted in high pest level in comparison to that of paddy- paddy cropping. Because, the ratoon crops of the open paddy fields provide enough opportunity to carry over the pests after harvest.

Very little references are available regarding the effect of crop rotation on the dynamics of paddy field pests. Panwar (2002) observed in Haryana a high incidence of the stem borer *P. perpusila* in paddy fields adjacent to the sugar canes. The impact of the crop rotation on the pest population has been studied by different authors. Tomar *et al.* (2003) have advocated that paddy-wheat rotation system in western U.P has been an effective way to suppress paddy pest population and side by side to increase the yields.

Thus, it is evident that the incidence of paddy pests has been the lowest in case of green manure-paddy cultivation followed by jute-paddy rotations in ascending order. However, in general the effect of the crop rotation has been considerable. Hence, suitable crop rotation practice may be adopted by the farmers depending on the relative opportunity and befitting the local conditions.

4.8.2 Relation between different paddy varieties commonly cultivated by the farmers and the extent of YSB incidence

A total of 12 commonly cultivated high-yielding varieties were evaluated for their susceptibility to YSB attack so that the suitable variety/varieties for an area may be recommended. The mean observations of 4 consecutive years were considered for the standard evaluation system (SES). The percentage of the farmers selecting particular variety/varieties was also taken in consideration after taking in percentage. The superiority of a variety was evaluated in due consideration of its relative rank.

The occurrence of YSB induced damage was maximum in *Sabita* and *Lalat*. The least level of pest damage was observed in *IR64*. The varieties, *Ratna, Nagarjuna, Vijeta, IR72* and *Gobinda* were almost free from YSB damage with a scoring value 01 and were placed under resistant(R) category. *Swarna* appeared susceptible variety with a scoring value 7, where *Lalat* was considered as moderately susceptible variety as it scored 5. IR64 and IR36 scored 0 and were regarded as highly resistant (HR) (Table.4.8.1).

The ascending order of the high yielding varieties in respect of the degree of YSB damage is as follows:

Swarna > Sabita > Lalat > Vijeta > Nagarjuna >

Mashuri > IR72 = Gobinda > IR50 > Ratna > IR36 = IR64

Discussion: In most of the studies by different authors the screening of the paddy germplasm for YSB susceptibility was restricted to the high yielding varieties. Pandey (2003) has noted variable range of resistance on some selected high yielding varieties and recorded the minimum WH in *Rajshree* and the maximum in *Radha*.

Screening of commercial rice cultivars (ASD 19, ADT 39 and IR 20) by Ragini *et al.*(2001) has revealed that these cultivars are more susceptible to the infestation by YSB and pink stem borer (PSB) than by the dark headed borer (DHB).

Table.4.8.1: Resistance status of paddy varieties to YSB attack

Cultivar	farmers cultivate (%)	Incidence of YSB (appearance of WH+DH in percentage)					SES score	Resistance status
		2003	2004	2005	2006	Mean		
Sabita	06	9.8 (3.20)	15.7 (4.02)	12.6 (3.61)	13.9 (3.79)	13.00 (3.67)	5	MS
Mashuri	11	3.4 (1.97)	2.3 (1.67)	2.8 (1.81)	2.5 (1.73)	02.75 (1.80)	1	R
Swarna	25	21.7 (4.71)	20.4 (4.57)	30.1 (5.53)	32.6 (5.75)	26.20 (5.16)	7	S
IR 50	10	2.4 (1.70)	2.5 (1.73)	2.5 (1.73)	2.9 (1.84)	02.57 (1.75)	1	R
IR 64	07	0.0 (0.70)	0.5 (1.00)	0.4 (0.94)	0.7 (1.09)	00.40 (0.94)	0	HR
Ratna	09	1.2 (1.30)	0.0 0.70	0.7 (1.09)	0.4 (0.94)	00.57 (1.03)	1	R
IR 36	08	0.2 (0.83)	0.4 (0.94)	0.4 (0.94)	0.6 (1.04)	00.40 (0.94)	0	HR
Nagarjun	05	4.2 (2.16)	1.8 (1.51)	3.0 (1.87)	4.6 (2.25)	03.40 (1.97)	1	R
Vijeta	03	5.1 (2.36)	2.5 (1.73)	4.9 (2.32)	2.7 (1.78)	03.80 (2.07)	0	R
Lalat	06	13.5 (3.74)	9.3 (3.13)	12.8 (3.64)	13.4 (3.72)	12.25 (3.57)	5	MS
IR 72	07	2.7 (1.78)	2.4 (1.70)	2.6 (1.76)	2.7 (1.78)	02.60 (1.76)	1	R
Govinda	03	3.5 (2.00)	1.9 (1.54)	2.7 (1.78)	2.3 (1.67)	02.60 (1.76)	1	R
SE (±)		0.93						
CD(p=0.05)		2.82						

R-resistant, HR- highly resistant, S- Susceptible, MS- moderately susceptible, MR- moderately resistant, HS- highly susceptible

Figure in the parenthesis are square root transformed value

Rubia-Sanchez *et al.* (2001) have observed that the mortality of first and second instar larvae of YSB in *indica* rice cultivars IR36, IR40, IR62 and IR72 during the vegetative stage and found that the larval mortality inside leaf sheaths has been highest in IR40. The most susceptible cultivar, IR62, has an average of 6.2 larvae / tiller; with 92% live larvae / hill (consisting of 2 rice seedlings). IR40 showed only 1.6 larvae / tiller, with only 7% live larvae / hill.

Selection of variety/varieties among the commonly cultivated cultivars appears to be difficult for an area where YSB is endemic. As *Swarna, Sabita* and *Lalat* are more susceptible, their cultivation is required

to be restricted. Relative variation in the damage of the pest on different varieties is due to their different phenology and physiology.

4.8.3 Specification of dose of N fertilizer and hill distance in relation to pest incidence

Effect of N fertilizer and spacing on BPH: Maximum number of BPH was found under 120 kg / ha applications while the least was scored at 0 kg/ha. As the doses of fertilizer were increased the intensity of the pest was intensified proportionately. Closer spacing at 15 x 10 cm harboured BPH population to a greater intensity. As the spacing was increased the intensity decreased steadily in all the experiments.

CD value for N level was found 6.21 and for spacing 5.91. CD for interaction was 10.84 signifying that closer the spacing higher will be the BPH abundance. In areas where BPH is epidemic, 15x20 spacing with moderate N application 80 kg / ha is suggested for the farmer (Table.4.8.2).

Table.4.8.2: Effect of different doses of inorganic N fertilizer and spacing on the abundance of BPH at panicle initiation stage

N level (kg/ha)	Gap distance (cm.)					
	15x10	**15x15**	**15x20**	**25x25**	**30x30**	**Avg**
0	13.67	12.21	11.24	10.03	9.11	11.25
40	18.98	17.11	16.87	15.67	14.08	16.54
80	23.34	21.54	19.67	18.21	16.56	19.86
120	28.21	23.32	22.45	21.33	19.87	23.03
Avg	21.05	18.54	19.55	16.31	14.90	NA
		CD for N level		6.21		
		CD for spacing		5.91		
		CD for interaction		10.84		

NA-Not applicable

Effect of N fertilizer and spacing on GM: Maximum range of damage was accounted under 80kg / ha N application. Although a steady decrease in infestation with the increment of supplemented dose was noted in Hemtabad.

The least level of infestation was found at 30 x 30 cm spacing in all the three blocks. Higher the range of spacing the lesser was the GM induced damage. Damage by GM has been quite high and increased significantly when a high dose of N was added. CD for N level was 2.38 while CD for spacing was 2.08. The interactions between the two factors were 4.52 and significant.

Average values of infestation at closer spacing of 15 x 10 cm and 15 x 15cm were relatively high. With some exceptions, grossly the infestation by GM has a positive association with the applied N doses while it has a negative relation to the hill distances (Table.4.8.3).

Table.4.8.3: Effect of different doses of inorganic N fertilizer and spacing on the abundance of GM at panicle initiation stage

N level (kg/ha)	Hill distance (cm.)					
	15x10	15x15	15x20	25x25	30x30	Avg
0	10.12	9.01	9.78	8.56	6.90	8.87
40	11.72	11.12	10.37	9.45	7.97	10.12
80	14.12	12.76	11.71	10.11	10.91	11.92
120	15.71	13.78	12.92	11.37	11.69	13.09
Average	12.91	11.66	12.26	9.87	9.36	NA
CD for N level 2.38						
CD for spacing 2.08						
CD for interaction 4.52						

NA-Not applicable

Discussion: Very few references are available relating to the pest intensity and the hill distances. Chandrakar and Khan (1981) have reported a higher grain yield at a closer spacing of 10 x 10 cm than some wider spacing in some early varieties in GM prone area. Verma *et al.* (1988) have found that 44 plants / m^2 has recorded significantly higher yield than 27 plants / m^2 in the rice variety *Jaya* in GM infested area. Present observation is in consonance with the previous study by Prakasa Rao (1975) who found that closer spacing in transplanted rice resulted in a greater number of midge attack.

Extent of infestation by GM is known to be region specific and fertilizer dose dependent. In endemic areas, farmers can adopt a cultivation practice of 15 x 20 cm or 25 x 25 cm with high doses of 120 kg / ha N application. Further increase in spacing has been found non-economic, because it reduces hill number, thus reduces the yield. Such practice is economically justifiable in block Itahar where GM is recurrently epidemic. In the block, Hemtabad 15 x 15 cm spacing with 120kg N / ha is compatible to give higher yields.

Ghosh *et al.* (1975) have reported that high dose of fertilizer with low hill distance encourage the high level of weed generation which provides shelter for the BPH. Chandra *et al.* (1986) have observed that grain protein content is significantly influenced under different light intensity. Pillai *et al.* (1979) have also noticed that abundance of BPH differed significantly under different spacing and row orientations. Application of inorganic N of higher dose singly could modify the microclimatic conditions as observed by Prasad *et al.* (2004).

Extent of infestation by BPH and GM has been found to be region specific. The degree of occurrence is influenced by both the doses of N fertilizer and the hill distances. Low hill distance with high doses fertilizer and high hill distance with low fertilizer may cause the same result. In endemic areas, farmers can adopt a spacing of 15 x 20 cm or 25 x 25 cm with high doses of 120kg / ha N. Further increase in spacing has been found non-economic for reducing the hill number, hence a reduction in yield.

4.8.4 Cultivation practices and the level of parasitization of YSB eggs

4.8.4.1 Effect of plantation techniques: Directly seeded fields had comparatively low level of parasitization than in the transplanted fields. The percentage of the parasitized eggs in transplanted fields had shown uniform variation with that of directly seeded fields. The level of parasitization was initially low but increased at 30 DAT in both the fields. A steadily increased of parasitic activity was recorded up to 45 DAT after which it declined steadily (Figs.4.8.2a and b).

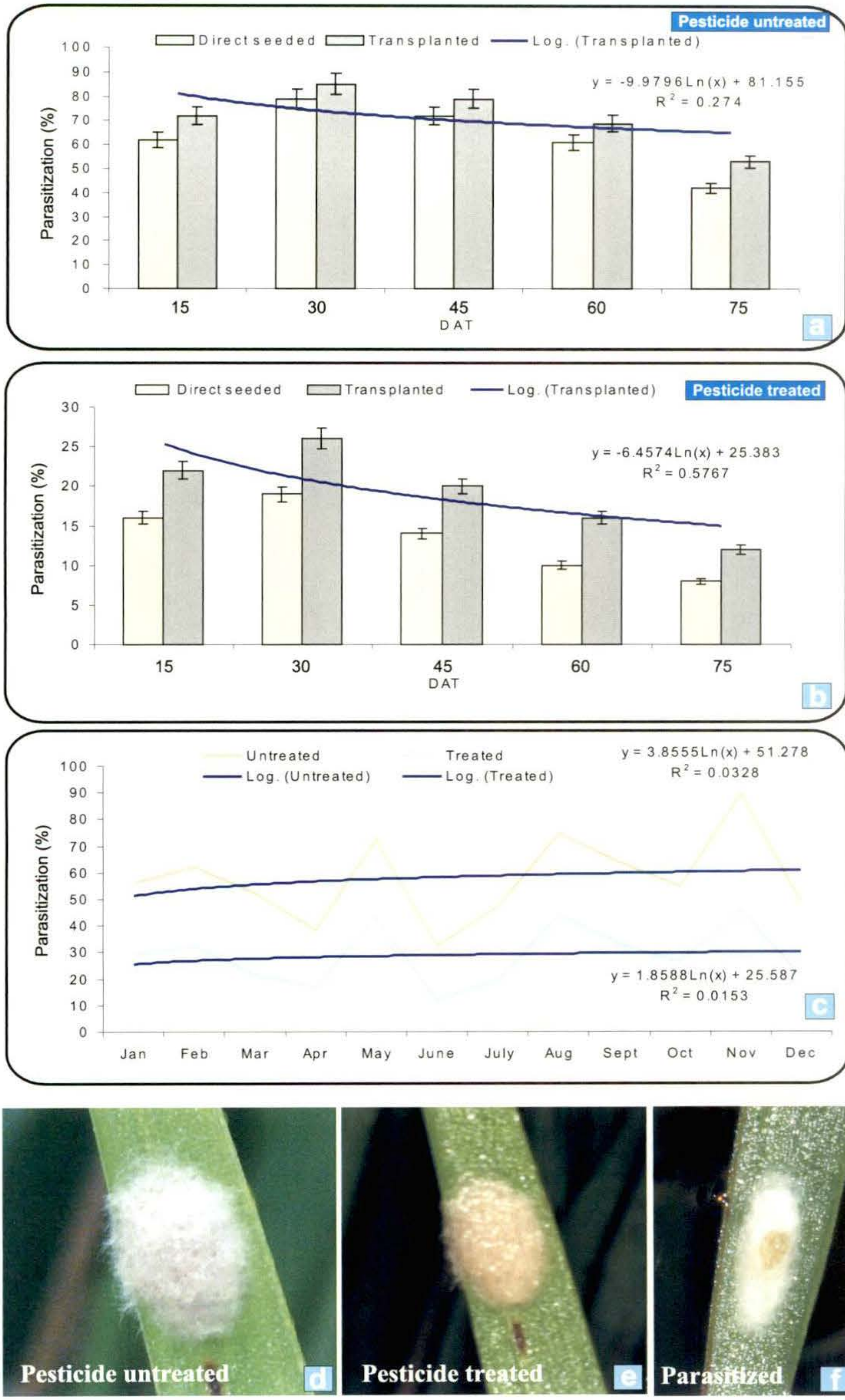


Fig. 4.8.2: Effect of mode of planting and insecticidal protection on the parasitization of YSB eggs. a: No pesticidal protection, b: with pesticidal protection, c: Annual dynamics, d, e & f: YSB eggs.

The relative high range of parasitic activity in transplanted fields was probably due to the cultural hygiene's adopted in the seed bed before the transplantation of the seedlings. Rejection of the unhealthy seedlings and the proper tillage operation in the main land was supposed to influence the rate of parasitization.

4.8.4.2 Effect of pesticides: Application of pesticide was found to reduce the rate of parasitization in both the plantation practices, direct seeded or transplanted. The effect was positive and comparatively greater in case of transplanted variety with a significant R value (0.576). Pesticide application reduced the rate of parasitization up to 55% in both the cases collectively. Although the overall dynamics did not differ (Figs.4.8.2d,e and f).

Dynamics of YSB's egg parasitization through out the year was influenced by the application of pesticides. The untreated plots showed the parasitic activity with the maximum peak in November followed by about August and May irrespective of plantations. Of course, the extent of parasitic activity was comparatively higher in untreated fields. The average range of parasitization varied up to 60% in untreated fields in comparison to 20-25% in treated fields (Fig.4.8.2c).

The present investigation appears to be in consonance with the findings by Arida and Shepard (1987) who observed in Philippines that the rate of parasitization and predation of YSB eggs was comparatively higher in unsprayed fields. Raman *et al.* (1991) have reported that the population dynamics of *Micraspis discolor* (Coleoptera: Coccinellidae) was lower after application of insecticides. The level of attack by the pests was paddy growth stage dependent and season specific. Rajendran *et al.* (1988) have reported from unsprayed paddy fields of Tamil Nadu, 5-26 adult / mt^2 of *P.fuscipes*, a predator of leaf folder.

4.8.4.3 Land conditions and rate of parasitization of YSB eggs: In case of sandy soils comparatively higher rate of parasitization was noted than in case of sandy loam soil. Eggs collected from the lowland exhibited relatively low level of parasitization. However, sandy loam area of the low land showed the lowest percentage of parasitization which was far below than in case of the sandy area of lowland (Table 4.8.4).

Table.4.8.4: Quality, soil condition and rate of parasitization of YSB eggs

Land quality	Soil condition	Egg parasitization (%)
Upland	Sandy	46.21±3.42
	Sandy loam	43.22±4.34
Low land	Sandy	38.89±2.39
	Sandy loam	30.33±4.65

On the whole it has been found that YSB egg parasitization is highly dynamic in all the sites and even within the same site. However, the parasitization has been high in uplands that in irrigated wetlands. The effectivity of YSB egg parasites in low lands paddy differ from those of uplands. Such parasites appear more effective in upland having more alternative hosts. *Tetraratichus* sp. is specific only YSB eggs and occurs mainly in irrigated lowlands.

Discussion: Plant characteristics, the presence of specific weeds in the habitat, favourable cropping systems, and even the soil types are known to attract some parasites. For instance, *Trichogramma chilonis ishii*, an important egg-parasitoid of *Heliothis armigera* (Hb.) in India, is not attracted to its host's eggs laid on chickpea (*Cicer arietinum*), while it heavily parasitized eggs (up to 98%) on various other crops such as cotton, cowpea, groundnut, Lucerne, maize, potato, safflower and tomato.

Observation of the relative parasitization is the prime requisite in the modern IPM practices. Innundative release of parasite / parasitoid can be adopted as a supplemental conditioning agent to control the activity of the YSB population. Depending on the generation pattern of parasitoids, the specific months at which a particular parasite / parasitoid is abundant can be used for YSB suppression.

4.8.5 Water depth, irrigation management and BPH intensity

Seasonality of the water availability: The rainfall can meet the required quantity of water only in the month of September. Except in the months of July and August, when surplus rainwater is available, in other months the required quantity of water is to be supplied by irrigation.

Cultural practices, water use efficiency and brown plant hopper abundance: Occurrence of BPH at *kharif* season was noted by hill estimation after applying NPK fertilizer (F1= 80:40:40, F2=120:60:60), in three modes of plantation (T1 = sowing the seeds in dry field conditions, T2=spouted seeds in puddle condition,T3=Transplantation) and two different depths of water (S1 = submergence only at tillering and flowering stages, S2 = submergence throughout the crop growing period).The average value of three consecutive years were considered (Figs.4.8.3a and 4.8.3b).

The water use efficiency of the crop was found to be directly related to the final yield and the BPH numbers. The highest number of BPH was attained in case of F2T1S1 and the least was secured in F1T1S2. Higher utilization of water caused low stagnation that impedes the generation of the microclimate congenial to BPH. Higher water use efficacy in F1T2S1 with a low BPH level and comparatively higher yield was possible due to the absence of suitable microclimatic zone for BPH. However in F2T1S1, as the dose of fertilizer was increased the BPH population increased simultaneously, indicating that higher doses of fertilizer influenced BPH colonization.

The water use efficiency to the plant is found to be directly related to the final yield and the BPH population. Higher water use efficacy in F1T2S1 with a low BPH level and comparatively higher yield is possible due to the absence of suitable microclimatic zone for BPH

4.8.6 Hill frequency and pest abundance

Brown plant hopper: The BPH population was found to be directly influenced by the hill number/ mt^2 and the doses of fertilizer. Higher the hill number greater was be the pest abundance. Fertilization however dictated the BPH population positively .When fertilizer application was increased from 0 to 120kg/ha, the number of BPH population increased up to 40% (Figs.4.8.4a, b, c and d).

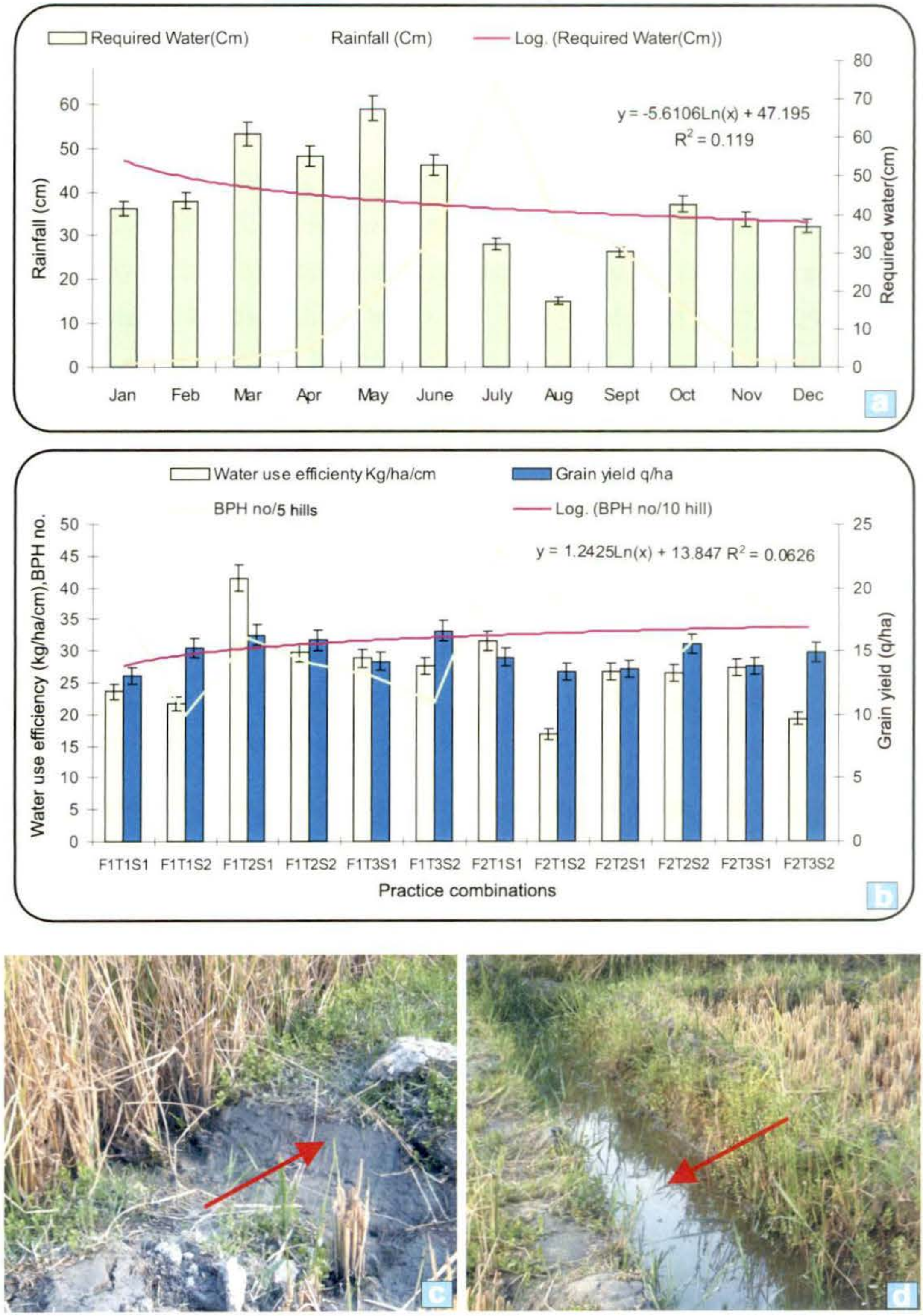


Fig. 4.8.3: a: Seasonal rainfall and required water in the paddy field and their correlations, b: Water use efficiency, BPH incidence and paddy yield influence by planting methods, fertilizer doses and water management practices, c & d: Pattern of water used management during the period of experimentation, (→) indicated the canal to drain out the surplus water.

Increased hill number causes reciprocal shading, generating the microclimatic environment suitable for BPH generation. Application of fertilizer boosts up further foliage and panicle growth. Foliage provides suitable shelter for BPH. Low fertilizer input with increased hill number should preferably be used as a compensatory mechanism by the farmers to attain the higher yields. Fields with 45 hills / mt.^{2} have yielded 25.2, 27.6, 29.4, 32.5 respectively under 0, 40, 80,120 kg / ha inorganic N application. While the 90 hills/mt.^{2} yielded 26.7, 29.2, 30.4, 34.8 q / ha respectively. Finally 90 hills/ mt.^{2} generated 27.1, 28.4, 29.5 and 32.8 q / ha respectively. The intensity of the BPH population has been positively influenced both by the doses of fertilizer and the gradual increment in hill number. With higher number of hill / mt^2 together with the higher fertilizer input has resulted higher cost: benefit (C:B) value. The C:B value has been high in case of 120 kg N/ha application while the least was noted under 0 kg / ha application. The other schedules of 80 kg and 120 kg / ha have shown an intermediate value (Fig.4.8.5).

A gradual increase in C:B value has been noted when hill number was increased from 15 hills / mt^2 to 90 hill / mt^2. Higher doses of fertilizer application registered extra cost instead of the effective return, the C:B has been thus reduced.

Gall midge: Guided by their common belief, farmers have a tendency to increase the number of seedlings / hill to compensate the losses occurred due to GM infestation (Table.4.8.5).

Table.4.8.5: Gall midge infestation, yield components and grain yields of paddy cultivar *Swarna Mashuri* at different seedling per hill at *kharif* season

Seedlings/hill	% of damaged tillers (pre harvest condition)	Tiller no / hill	Panicle no / hill	Grain no / panicle	Yield q / ha
3	14.8	7.4	5.5	216	31.9
5	13.6	8.5	5.8	228	32.1
7	15.8	10.4	6.1	232	33.8

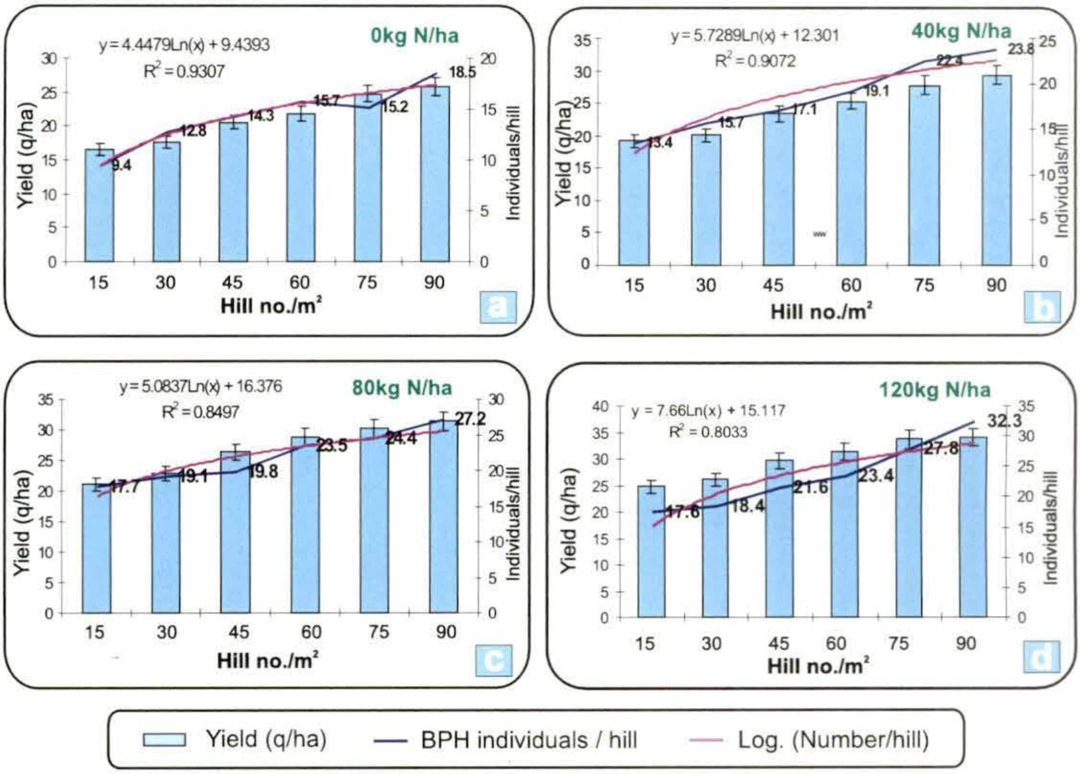


Fig. 4.8.4: a: Dynamics of BPH incidence in relation to number of hill/ m² and dose of N fertilizer. a: Without fertilizer, with fertilizer of b: 40 kg N/ha, c: 80 kg N/ha, d: 120 kg N /ha.

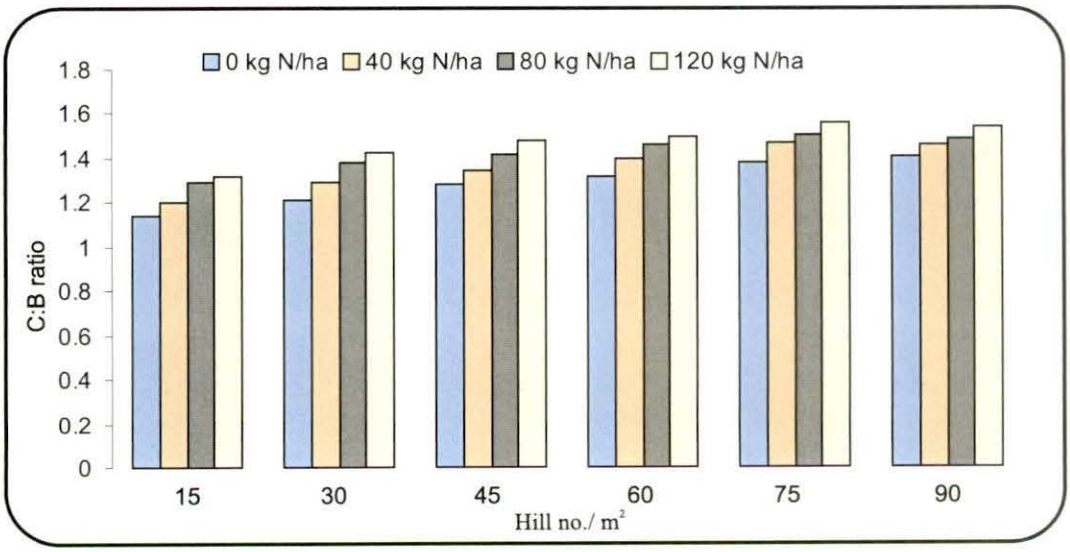


Fig. 4.8.5: Cost effectivity in case of different hill number/m² and different doses of fertilizer.

The appearance of the damaged tillers was observed at about 25-35 DAT with the attainment of peak at about 75-90 DAT when the crop is at late reproductive stage. Higher the seedling number, higher would be the generation of the tiller. Hill with 7 and 9 seedlings / hill produce more tillers and panicles than 3 and 5 seedlings / hill. Overall mean infestation did not vary significantly, probably due to restricted entry of the GM to the crop canopy and accordingly the percentage of damaged tillers did not vary.

Adoption of higher number of seedlings per hill is thus found profitable at the time of delayed plantation with the supplementary nutrient management.

4.8.7 Age of seedling and pest abundance (Figs.4.8.6a and b)

The status of YSB and BPH and the yield generation were found to be directly influenced by the age of the transplanted seedlings. Experiments were undertaken during *kharif* season in two types of plantation schedules with different ages of seedlings. Transplantation was done on the same date. Normal plantation was done with 30 days old seedlings while the delayed plantation with 45 days, 80-85 days old or by double plantation (plantation in two alternative rows) with 4 seedlings per hill.

Highest number of YSB and BPH were noted under double plantation while the least was scored in 45 days old seedlings. 30 and 80-85 days seedlings respectively supported 1.72 and 1.34 individuals / hill.

Transplantation at higher ages restricted the early plant growth due to the physiological distress. Such distress was conducive for pest infestation. So the adoption of 45 days old seedling could aptly reduce the incidence of both the pests at higher proportions.

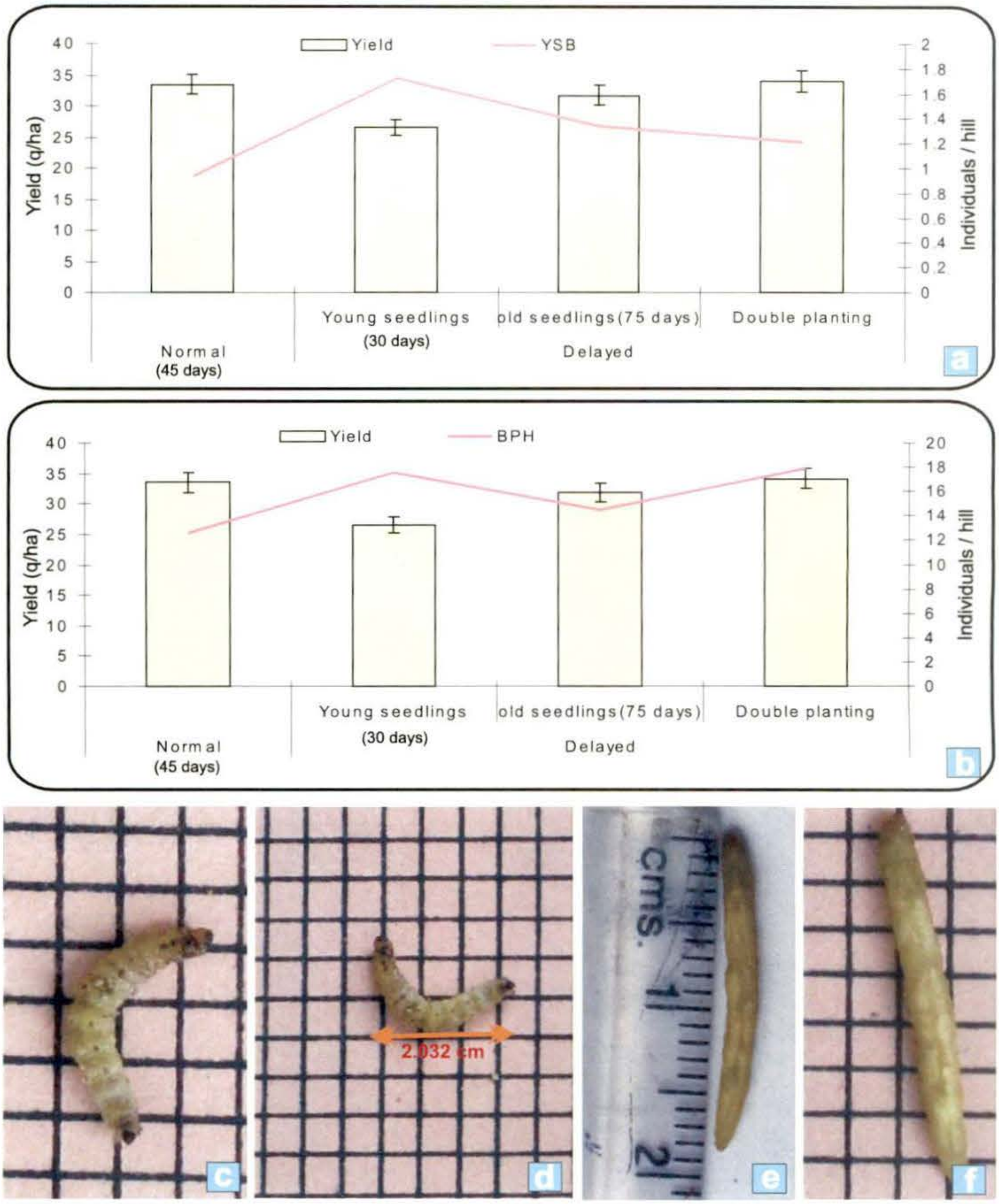


Fig. 4.8.6: a & b: Effect of age of seedling at transplantation on the incidence of YSB, BPH and paddy yield, c: YSB larval size at early age transplantation with young seedlings, d: Larval size at normal age (45 days) transplantation, e: Larval size at late age transplantation and f: With higher number of seedlings hill in double plantation.

4.8.7. a: Healthy paddy plants with healthy panicles, b & c: Paddy field with hopper burn due to late age transplantation and consequent separate colour of panicles.

4.9 Study on the Influence of Some Selected Cultural Practices on the Life Cycle and Behaviour of the Major Phototropic Pests

4.9.1 Detection of the proper time of field scouting in relation to the YSB brood emergence

4.9.1.1 Seasonal variation of YSB egg laying: YSB eggs were periodically assessed from randomly collected 100 hills from 10 plots. Collected egg masses broadly represent two categories, active and inactive. Eggs were inactivated either by parasitization or by season induced sterilization. The active egg masses hence influence the subsequent pest intensity. Available egg masses and the quantum of their viability also differ in different seasons (Fig 4.9.1a). The highest number of egg masses was obtained in the month of November followed in descending order by February, October, April and March. The number of egg masses was nearly the same in August and December. The frequency of inactive eggs was season specific. Maximum number (%) of inactive egg masses were found in the month of January (50.1%) followed in descending order by May (46.6%), August (45.45%), December (44.89%), September (40.32%) and July (32.70%) respectively. The percentage of sterile eggs was the highest in the month of January (33.3%) followed by May (30.1%), December (24.48%), April (17.8%), June (16.41%) and February (10.48%). Low temperature in the months of December and January promoted the sterility while high temperature in April and June reduced sterility. In general least number of active eggs was noted in January and the highest in November.

4.9.1.2 Field scouting in relation to the selection of cultivar: Yield attributing characters of paddy are cultivar dependent. The activity of adult YSB can be previewed by the estimation of active egg masses. Periodic field scouting and ready destruction of YSB egg masses are essentially required to check the subsequent pest outbreak. In order to evaluate the relative importance of some selected yield generating characters on the egg laying behaviour of YSB fields of 10 widely cultivated varieties, 5 high yielding (HYV) and 5 local low yielding ones (LYV) were periodically inspected four times (25, 50, 70 and 90 DAT) to record YSB brood emergence. Average value of egg masses (number / hill) so collected in four observations were correlated with the average value of the yield attributes. An average value was considered out of three years data (Table.4.9.1).

Table.4.9.1: Number of YSB egg masses deposited on different paddy varieties cultivated in the three blocks and correlation values between the egg mass number and physiological characters of the paddy varieties

Paddy yielding category	Name of the variety	Plant height (cm)	Tiller no. / hill	Leaf blade width (mm)	Leaf no / hill	Egg masses (no / 5 hill)
High yielding	*Ranjit*	0.521*	0.312	0.472	0.512*	4.6±0.32
	Swarna Mashuri	0.301	0.213	0.543*	0.562*	5.7±0.76
	Lalat	0.126	-0.121	0.321	0.611*	4.8±0.34
	Ratna	0.321	0.232	0.211	0.523*	4.5±0.44
	Mashuri	0.423	0.421	0.312	0.518*	5.1±0.67
Local low yielding	*Tulaipanji*	0.102	0.321	0.432	0.222	2.2±0.45
	Changa	0.212	0.211	0.545*	0.523*	4.2±0.49
	Parijat	0.102	-0.087	0.255	0.312	4.1±0.71
	Dudhkalam	0.325	0.122	0.531*	0.511*	4.9±0.34
	Jinghasal	0.123	0.131	0.412	0.502*	4.4±0.41

*Significant at 5% level

No significant relation of YSB egg masses with the tiller number, leaf blade width and plant height was noted. But, leaf number / hill had shown significant positive relation with the egg masses in most of the varieties. Egg mass deposition was thus in general variety independent. All the selected high yielding and local cultivars, scented and non scented varieties and finally the resistant and susceptible varieties supported nearly the same number of egg masses (Table.4.9.1).

Discussion: The elicited sensory cues from paddy plants probably play important role in the egg laying by YSB moths. The study shows that crop phenology and yield attributing characteristics have no definite effect on the egg mass density. Same number of egg masses is found in both susceptible and resistant varieties. Leaf colour is not a prime factor for egg laying contrary to the belief that application of higher doses of inorganic N fertilizer brings up deep greenness of leafy canopy that indulges vigorous egg laying. However egg laying is positively influenced by leaf number. Thus higher number of seedlings / hill generating more leaves pampers energetic egg laying. However, the size of a clutch is comparatively larger in case of HYVs. Siliceous leaf of the HYV's renders rigidity providing vascular strength and thus capable to bear bigger egg clutches. Low vascular mechanical support in the local varieties imposes limitation to bear the bigger egg masses for longer time.

As the frequency of egg laying is cultivar independent, it is the clutch size and not the clutch numbers, which regulates the pest dynamics. Furthermore, as the density of egg clutches remain same, the required manpower for field scouting would be invariably constant.

4.9.1.3 Specification of time for first field scouting in relation to YSB egg masses: Time specific field scouting is essentially required to maximize the destruction of YSB egg masses. The time should befit the availability of the maximum number of eggs and destruction. This study was conducted in case of *Swarna Mashuri*. To select the proper time for the first field scouting, fields were periodically inspected for egg masses every 7 days intervals from 5 to 140 DAT. At the same time number of DH (%) and WH(%) (symptoms / hill) were assessed after counting the fresh damage symptoms. Female YSB moth number was counted by light trapping using electric bulb (200 watt).

In each occasion the peak abundance of female moths in the light trap was preceded by huge number of active eggs. Female moths peaked at 70-75 and 105-120 DAT respectively. The first egg masses were noted at 7 DAT in trace quantity. After which the number increased steadily. The two consecutive peaks of egg masses appeared at 25-28 and 77-80 DAT respectively after which the availability of egg masses gradually decreased. DH was first observed at 25 DAT and maximized at about 40 DAT.WH was first observed at about 49 DAT, then steadily increased to the maximum at about 91-98 DAT, subsumed gradually and maintained a low steady level up to about 130 DAT.

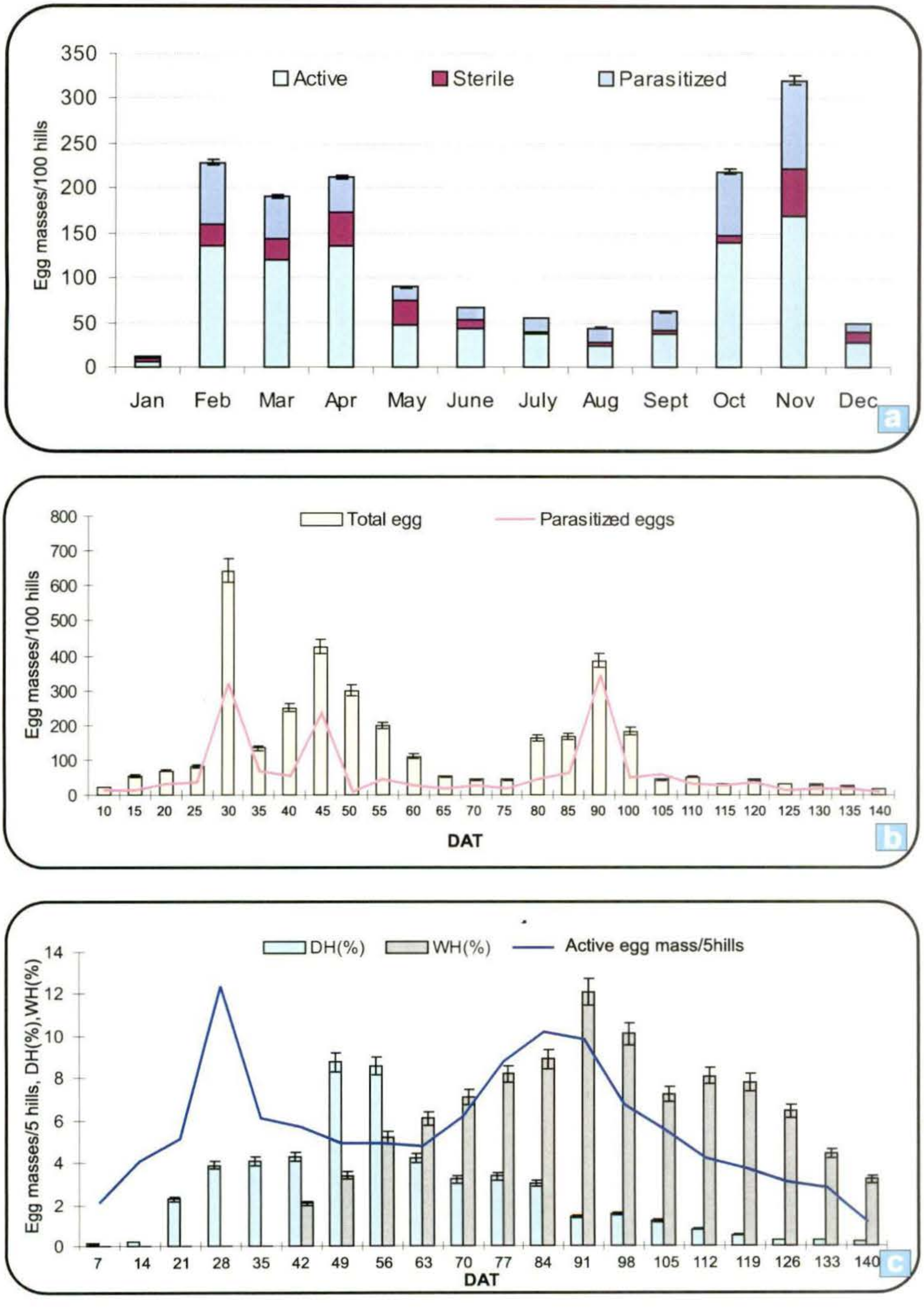


Fig. 4.9.1: Seasonal variations of YSB masses, their viability, consequent moth, DH and WH incidences in pesticide free *kharif* paddy fields. a: Egg mass abundance and viability, b: Egg mass parasitization and YSB moth status, c: Egg mass numbers and consequent DH and WH.

Inactiveness of egg masses was found to be density independent during the first brood but density dependent during the second brood. Numbers of inactive eggs were initially low, increased gradually and attained the highest at about 26-30 DAT when the number of egg masses is also abundant. Thereafter, the number gradually declined and again peaked at 77-85 after which a steady low level was maintained up to 125 DAT. As the active eggs shared about 65-76% in the first brood, the loss incurred, is correspondingly high. So the first brood larvae caused the maximum damage. Hence, scouting relating to the second brood is comparatively less crucial (Fig.4.9.1b and 4.9.1c).

Discussion: *Swarna Mashuri* (MTU7029) of 140 days can easily support two broods of YSB. The immigrants settle down and start eggs laying. After an incubation period of 5-8 days, the larvae hatch out and feed on the soft tissue, tunneled in the stem, severing the conducting tissue of plant causing DH. The first brood completes the life cycle within about 50-55 days and the adults emerge at the end of the vegetative growth stage. Newly emerged adults start laying egg at early reproductive growth stage and the next brood appears at the middle of the ripening stage at about 105-110 DAT. So, grossly YSB successfully completed two broods in *Swarna Mashuri* crop.

So, first field scouting for egg mass collection thus should be carried out either at about 25 or 35 DAT. Though the available egg masses were comparatively higher in the second brood but the role of parasitization was comparatively higher thus reducing the adult population size. Scouting if performed at 75-80 DAT, special attention should be given as the plant was at advanced growth stage.

4.9.2 Cultural practices, consequent leaf areas and BPH incidence

BPH showed multiple overlapping generations in relation to the growth stages of paddy. At each periodic inspection, fields represented heterogeneity of an admixture of different nymphal stages. As the growth stage of paddy advanced nymphs of higher order dominated. Nymphs feed voraciously as the development progressed. Cultural practices especially the input of fertilizer indulged the generation of yield attributing characters, such as greater leaf area which in turn accelerated the nymphal growth and BPH multiplication. Depending on the field heterogeneity, the time fitted application of fertilizer can may minimize the pest intensity.

4.9.2.1 Temporal nymphal dynamics of BPH (Fig.4.9.2a)

First instar: The 1^{st} Instar nymphs at 15 DAT was due to immigration. A definite low peak of this instar occurred at about 30 DAT followed by moderate peak at 45 DAT and high peak at about 90 DAT.

Second instar: The initial low count of second instars nymph at 15 DAT reached maximum at about 90 DAT, preceded by a moderate peak at 40 DAT.

Third instar: This instar attained peak at about 90 DAT, maintained a steady level up to 105 DAT. The numerical abundance of 3^{rd} instar nymph was about 72% that of the 1^{st} instar during the highest abundance.

Fourth instar: The peak of this stage was allained by 90 DAT, after which the population declined steadily and maintained a persistently low number up to 105 DAT, thereafter the population suddenly subsumed.

Fifth instar: A low count of fifth instar was available from 15 DAT up to 80 DAT. After reaching the maximum level at about 85 DAT, the population subsumed rapidly with very low marginal population up to the crop maturation.

Discussion: Standing growth stages of paddy abounds the developmental stages of BPH. The first adult peak at 30 DAT is minor and is due to the macropterous forms which lay huge number of eggs after settlement. Another wave of immigrant adults, together with a few brachypterous adults creates a second peak at about 45 DAT which is major. The population size of the short-winged brachypterous form regulates the size of the second generation. Females are numerically three times more abundant than the males. The nymphs hatched out the second batch of egg and have higher survivability than the previous generation.

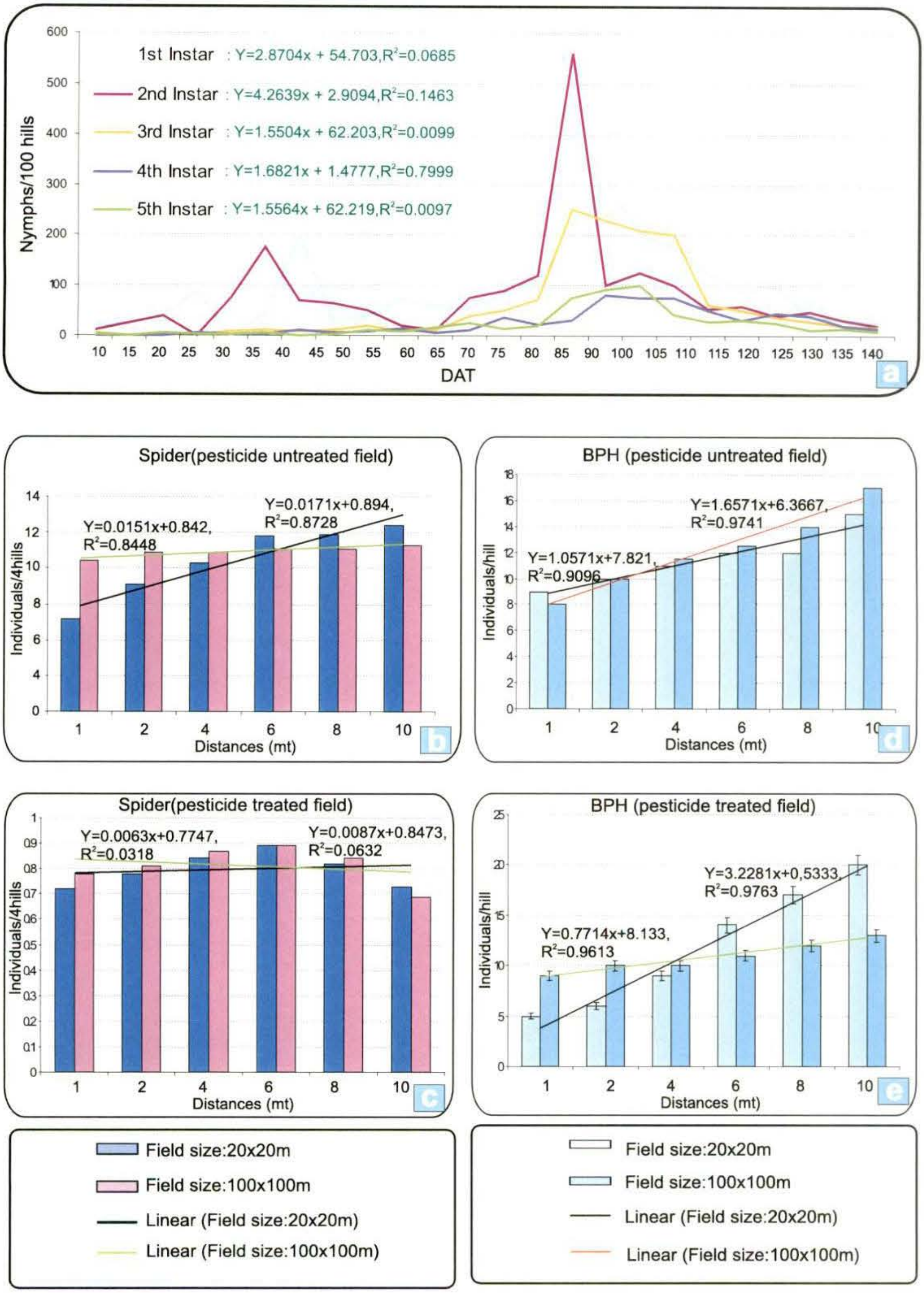


Fig. 4.9.2: a: Dynamics of different nymphal instars of BPH in relation to the growth stage of paddy in pesticide free field. Distribution of spiders and BPH across horizontal transect from the border of paddy fields of two different sizes, b&c: Spiders in 20x20m and 100x100m fields respectively, and d & e: BPH in20x20m and 100x100m fields respectively.

The appropriate plant age at that time is probably a determining factor. Nymph mortality is apparently high in between the transition of second and third, and third and fourth instars. The final adult peak consists mostly of brachypterous form at about 85 DAT. Nymph development befits the plant growth stage related phenological alteration especially the foliage size. Higher the LAI higher is the pest intensity.

At a standing growth stage of paddy an admixture of all the developmental form of BPH population was noted. But their relative occurrence depends on the growth stage related phenological alteration of the crop canopy.

4.9.2.2 BPH dynamics in relation to hill spacing, fertilizer application and leaf area generation

Foliage generation and development are governed primarily by the applied doses of N fertilizer. Fertility positively induces larger leaf area that influences the paddy bush configuration. Further, hill distances and seedling population / mt^2 determine the plant size and the foraging area for BPH. The effects of three doses dependent application of fertilizer (F1-0, F2-40, F3-80, F4-120 kg/ha) in three different hill spacings (S1-10 x 10, S2-10 x 20 and S3-20 x 20 cm) on the LAI and its relation to the BPH abundance was studied (3.8.3.4 in materials and methods). Fields were fortnightly inspected starting from 15 DAT up to 60 DAT. At each occasion value of LAI and BPH abundance were noted in relation to the treatment combinations. Experiment was replicated thrice and the average values of both LAI and BPH count were considered to study their interactive role (Table.4.9.2).

LAI was low at early transplantation, increased gradually with the crop age and finally decreased towards crop maturity due to senescence of the leaves. The maximum LAI was obtained in high fertilizer input (F4) at 60 DAT. F4 was significantly superior to F1 and F2. But F3 and F4 were statistically at par, in almost equal at all the stages of the crop growth.

Closer the spacing higher the LAI generation at maximum vegetative stage and the highest was obtained in S1 at 60 DAT which was significantly higher than S3. Generation of new tillers gradually impeded after vegetative stage, accordingly LAI declined. But S3 and S2 were statistically important from 30 DAT onwards till maximum vegetative growth stage (60 DAT).

Table.4.9.2: Effect of different doses of fertilizer and hill spacings on leaf area index and resultant BPH incidence

Treatments	Leaf area index (LAI) at different time of growth stages.							
	15 DAT		30 DAT		45 DAT		60 DAT	
Fertilizer level	**LAI**	**BPH/ hill**	**LAI**	**BPH/ hill**	**LAI**	**BPH/ hill**	**LAI**	**BPH/ hill**
F1	1.08	8.10	2.58	12.31	2.96	17.11	3.51	19.72
F2	1.38	12.20	2.71	16.71	3.31	22.30	3.71	26.21
F3	1.39	16.30	2.81	19.42	3.16	26.01	3.81	29.11
F4	1.54	20.20	2.84	23.21	3.48	28.12	4.31	32.32
SEm (±)	0.003	0.011	0.011	0.013	0.15	0.046	0.11	0.042
CD (P =0.05)	0.012	.0290	0.039	0.021	0.17	0.033	0.03	0.091
Spacing (cm)								
S1	1.26	18.10	2.31	20.21	3.01	22.10	4.41	26.11
S2	1.35	15.20	2.48	18.11	3.12	19.21	4.92	24.22
S3	1.43	12.10	3.41	14.30	3.38	16.33	4.11	20.10
SEm (±)	0.0038	0.016	0.006	0.022	0.007	0.012	0.02	0.091
CD (P= 0.05)	0.012	0.011	0.02	0.032	0.022	0.014	0.06	0.072
Interaction								
F1 S1	0.92	14.30	2.15	9.71	2.92	10.11	3.52	10.41
F1 S2	1.11	12.40	2.27	10.31	3.06	10.15	3.61	10.91
F1 S3	1.21	10.20	3.31	15.32	2.97	15.82	3.41	16.42
F2 S1	1.28	16.40	2.25	16.22	3.13	16.71	3.62	17.11
F2 S2	1.34	14.20	2.43	16.81	3.21	18.20	3.92	22.71
F2 S3	1.47	12.71	3.45	17.61	3.02	18.47	4.11	19.49
F3 S1	1.37	16.91	2.38	18.20	3.12	22.91	4.22	29.01
F3 S2	1.38	15.22	2.56	16.89	3.35	19.41	4.33	23.09
F3 S3	1.48	14.13	3.47	15.41	3.13	28.71	3.87	19.22
F4 S1	1.52	20.72	2.43	24.21	3.25	26.39	4.29	34.21
F4 S2	1.58	18.23	2.59	21.61	3.92	22.10	4.61	28.11
F4 S3	1.56	16.27	3.51	19.40	0.018	0.019	0.008	26.51
SEm (±)	0.0038	0.0012	0.018	0.017	0.014	0.022	0.006	0.021
a) M x S b) S x M	0.0047	1.0032	0.013	0.013	0.059	0.032	0.023	0.016
CD (P= 0.05)	0.012	0.016	0.057	0.041	0.041	0.021	0.018	0.021
a) M x S b) S x M	0.015	0.021	0.038	0.031	0.048	0.039	0.054	0.026

M x S = Main plot x sub plot. S x M= Sub plot x main plot. N.S = Not significant
F1 – 0 (control), F2 – 40, F3 – 80 and F4 – 120 kg / ha
S1 – 10 x10 cm, S2 – 10 x 20 cm , S3 – 20 x 20 cm

The relative dynamics of BPH population varied in accordance with the LAI generation. High LAI value at closer hill spacing (10 x 10cm) generated suitable microclimatic condition for maximizing BPH population. The population gradually increased as the doses of fertilizer were increased. BPH was more abundant as the plants growing to mature. Number of BPH was more in closer spacing than distant one.

Table.4.9.3: Correlation between the climatic factors with some yield attributing characters

Climatic factors	Yield attributes		
	Tiller/hill	**Leaf area**	**Dry matter/mt2**
Tmax	0.612*	0.611*	0.722*
Tmin	0.123	0.211	0.111
Tavg	0.562*	0.664*	0.765*
Tgr	0.321	0.324	0.365
Shr	0.444	0.432	0.510*
Rfall	- 0.321	- 0.221	0.021

Table.4.9.4: Correlation between the important yield attributing characters and field BPH number

Yield attributes	**BPH number / hill**
Tiller no / hill	0.768*
Leaf area	0.647*
Dry matter / mt^2	0.811*

*Significant at 5% level

Tmax and Tavg positively influenced tiller generation, leaf area formation and dry matter accumulation. Except Rfall, the effect of other climatic factors though mostly positive but insignificant All the yield attributing characters in turn positively influenced the BPH abundance (Table.4.9.3 and 4.9.4).

Higher the doses of fertilizer higher would be the LAI generation. Abundance of BPH population is positively influenced by yield attributing characters. Maintenance of either 20 x 20 cm hill distances with 120 kg N application or 10 x 10 cm hill distance with 80 kg N application can minimize BPH abundance.

4.9.2.3 Field size, border distance, and effect of pesticide on BPH (pest) and spider (natural enemy) distribution

Field sizes govern the distribution and dispersion of both the pest and natural enemies. Dynamics of BPH and spider population was periodically studied in the fields (20 and 100 mt.^{2}) treated with carbofuran (1kg / ha) at 60 DAT. Field of the same sizes received no pesticide, considered as control. Hills were inspected for BPH and spider along a hypothetical equidistant (2mt.) transects totally covering 10 mt. from the border to the interior of the field and the value of both the population was graphically plotted.

In the untreated field BPH population was unevenly distributed throughout the field, higher the distance from the border higher would be the abundance. However, larger field size supported comparatively high number of BPH. The population gradually increased attaining the maximum at 10mt from the border to the interior of the field. However the range of migration was marginally higher for larger field (Figs 4.9.2b and 4.9.2c).

Irrespective of the field size, in a perpendicular transects from the border, the spider population was evenly distributed in larger field. In smaller fields the number gradually improved from the border to the interior, maximized at 10mt after which it decreases slowly (Figs.4.9.2d and 4.9.2c).

The pesticide immediately after application drove both the spider and BPH to the interior of the field. The effect was profound in a small paddy field. Such short range of migration suddenly increased the population density of both the species at the interior. Larger field size supported comparatively higher spider number than the small field size up to the distance 6mt after which the phenomenon was reversed.

Pesticide application caused the congregation of the spider population to the interior of the field. Higher the distances from the border greater would be the availability of the spider in case of both the field sizes up to the distance of 6 mt after which the numerical abundance of spider population decreases. However the migratory impact was more profound in smaller fields. Following pesticide application, BPH moved to the interior of the field. Higher the distance from the border the abundance of BPH was high. The impact was more profound in larger lands.

Spider is less migratory species while BPH could cross a wide distance. Following pesticide application spider migrate to short distance. The shifted spider population to the interior of the field acted as the reservoir. Spider took the advantage and reestablished the territory when the effect of pesticide no longer persisted. Contrary to this, larger fields disallowed the higher aggregation, dispersed the population which can hardy resettle. Pesticide applications immediately drove the BPH population. But BPH resettled immediately as the action of pesticide was over but the spider could not.

Paddy was cultivated in stretches of continuity. Entrance to the interior of the field was generally restricted. Farmers commonly apply pesticides with handy tools from the border of the fields resulting a 'push back' of BPH and spider population to the interior of the field .Canopy within the field provide enough space for survival of BPH. Loss of land due to small size can be compensated by the use of additional seedling / hill with proper care.

Larger field size has negative impact on the resettlement of the spider population when the action of the pesticide is over. Further congregation of BPH population was higher in larger fields. Smaller field size restored the spider population allowing for the subsequent resettlement. So it is thus suggested to fragment the wider paddy field into smaller areas for better management.

4.9.3 Dynamics of gall midge parasites and stubble management

GM attack is particularly restricted more to the *kharif* crop. Generation of gall is suppressed in the presence of parasite (Fig.4.9.4a). The frequency of gall parasitization is guided by agro-ecological conditions. Dynamics of healthy and parasitized galls varied considerably in relation to the growth specific phenological alterations of the tillers. Gall formation is initiated from about 26 SMW, gradually increased, maximized at 39 SMW, maintained a steady stage up to 42 SMW after which it steadily declined. The rate (%) of parasitization was initially low up to 30 SMW, improved gradually and attaining the peak at about 43 SMW. The rate of parasitization was found to be density dependent at early growth stages up to 40 SMW. But at late growth stages it was density independent (Fig.4.9.3a).

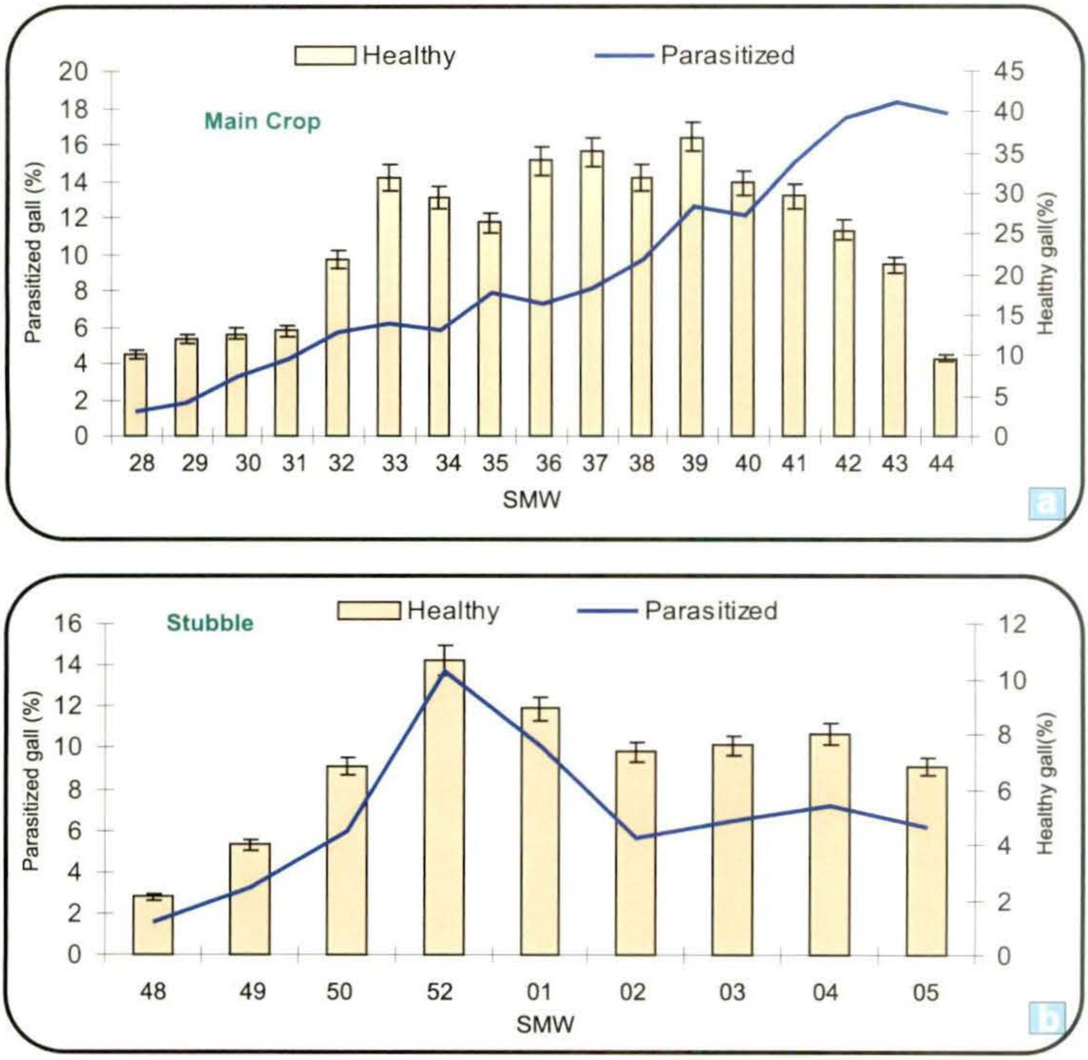


Fig. 4.9.3: Relative incidence of healthy and parasitized galls caused by GM, in pesticide free fields. a: In the standing paddy crop, b: In the stubbles.

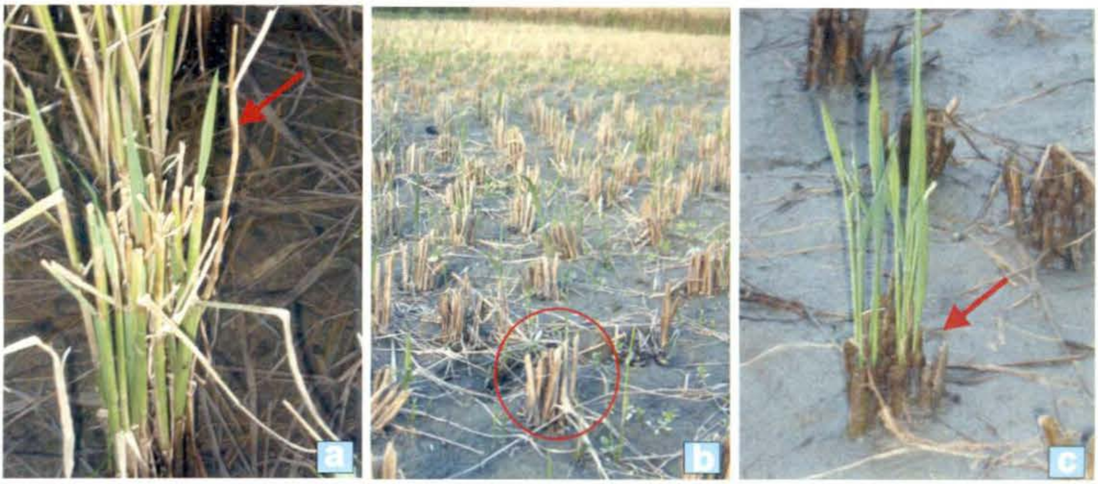


Fig. 4.9.4: Figures showing the occurrences of healthy and parasitized galls caused by GM, in pesticide free fields. a: In the standing paddy crop, b: In the stubbles, c: In the ratoon crop.

After harvesting the stubbles acts as reservoir for the gall parasites (Figs.4.9.4b and 4.9.4c). The number of parasitized gall in the stubble gradually increased from 48 SMW to 50 SMW attained the maximum at about 52 SMW after which the population declined and maintained a steady state up to 05 SMW (Fig 4.9.3b). Maintenance of the stubble acted as reservoir for the parasite and subsequent infestation to the new galls from the early vegetative stage of new cultivation thus effectively suppresses the GM activity.

Plantation at proper time can maximize the GM parasite. Retention of some residual stubble after harvest helps for the immediate inoculation of the parasite to the next crop. Such practice may be adopted in the places where YSB infestation is less. Other wise there will be every possibility for the survival of the YSB larvae in the residue stubbles.

As the stubbles acted as reservour of gall parasite it is judicious to retain some stubble in undisturbed condition at the corner of a field for their subsequent inoculation.

4.9.4 Detection of the proper hill spacing in relation to niche specification for the lady bird beetle (LBB) and brown plant hopper (BPH)

Successful predation of BPH by the LBB, *Menochilus* sp. requires effective contact between them by niche overlapping. Cultural practices markedly influenced microclimatic conditions of fields resulting in niche displacement (Fig.4.9.6c). Farmers adopt different hill spacings and directions of plantation. To evaluate the relative role of the predatory potentiality of LBB for different hill distances, experiments were carried out at late vegetative stage of *kharif* crop in five replications and the average value of 4 years (2003-2006) was considered.

Distribution of both LBB and BPH was further noted against two conditions, constant temperature but variable illumination and variable temperature but constant illumination in laboratory situation.

Impact of planting directions on the distribution of both LBB and BPH was recorded only in field with 20 x 20 cm hill spacing. All other management conditions remained constant during such observation.

4.9.4.1 Distribution of LBB and BPH in relation to hill distances

4.9.4.1.1 In field condition: Distribution of LBB and BPH was noted at three specific hypothetical equidistant successive zones constructed from the top to the bottom of the plant (Z1, Z2 and Z3) under 3 hill spacing conditions (10 x 10, 20 x 20 and 25 x 20 cm) in *Swarna Mashuri* fields planted at north-south direction and fertilized with 120 kg N/ha. Observation was made at three specific time schedule (6:00 am, 12:00 noon and 4:00 pm) throughout the day.

Assessment on the microclimatic environment: Evaluation of the different microclimatic components was done in the three time schedules at the three zones, above canopy (Z1), within canopy (Z2) and base of the canopy (Z3) along the vertical length of the plant. A distinct pattern of microclimatic gradients was noted along the length. The lowest temperature (18.1°C) and illumination (40%) was recorded at Z3 at 10 x 10 spacing at 6:00 am. The temperature (26.2°C) and illumination (84.2%) at Z1 in 25 x 20 cm spacing was the highest limit at 12:00 noon and at par with the ambient conditions. Microclimatic components at Z2 were intermediate between Z1 and Z3. Higher the hill distances, accordingly higher would be illumination and higher would be the temperature at all the zones. Hill distances exhibited positive relation with the temperature (0.786) and illumination (0.624) and negative with the humidity gradient (0.721) at all the distances (Fig 4.9.5).

Assessment on the field population: The distribution (%) of the LBB and BPH population was assessed in three zones at late vegetative stage at the three specific times (Fig.4.9.6c).

Distribution of LBB:10 x 10 cm spacing restricted the entry of LBB to the lower part of the canopy. Most of the LBB congregate in Z1 at 6:00 am and 4:00 pm. However, at 12:00 noon nearly 60% of LBB occupied the Z2 but very little moved to Z3.

During 6:00 am at 20 x 20 cm spacing, 70%, 20% and 10% were distributed at Z1, Z2 and Z3 respectively. Nearly 40% and 30% LBB occupied Z1 and Z2 respectively at 12:00 noon. Most of the LBB concentrated to Z1 at 4:00 pm (Fig 4.9.6b).

At 20 x 25 cm hill spacing, majority of the beetle congregated at Z1 while a considerable portion occupied at Z2.Very few beetles were observed at Z3. At 12:00 noon the change in the percentage of congregation was, recorded at Z1 and Z2. But no major change of distribution was observed at Z3. At 4:00 P.M assemblage of the beetle population was in the descending proportion Z1=Z2>Z3. So hill spacing influenced LLB distribution.

Distribution of BPH: Distribution of the BPH in relation to the hill distances differed considerably. Of all the spacings, Z3 shared the highest number of BPH and the distribution was in descending order of Z3>Z2>Z1. At 6:00 am Z3 harboured about 57, 65 and 73% of BPH population at 10 x 10, 20 x 20 and 20 x 25cm spacings respectively. At 12:00 noon, Z3 accommodated 75-90%. At 4:00 pm. Z1 and Z2 shared 15-35 and 30-40% population respectively (Fig 4.9.6a).

Closer spacing of 10 x 10 cm restricted the rate of predation due to the poor effective contact due to limited access of the beetle within the plant canopy. Spacing at 20 x 20 and 20 x 25 cm allowed considerable entry of LBB. Z2 appeared superior to others for effective contact and are thus suitable for predation. Due to the maximum niche overlapping predation was maximum at 6:00 am followed by at 4:00 pm (Figs.4.9.7a, b and c).

Table.4.9.5: Correlation study of different hill distances with the microclimatic components

Hill distances (cmxcm)	**Temperature (°C)**		**Humidity (RH%)**		**Light intensity (Lux)**
	Tmax	Tmin	RHmax	RHmin	
15 x 10	0.489	0.812*	-0.788*	0.342	0.144
15 x 20	0.543*	0.611*	-0.564*	- 0.534*	0.656*
25 x 25	0.643*	0.521*	-0.498	- 0.621*	0.654*

Significant at 5% level

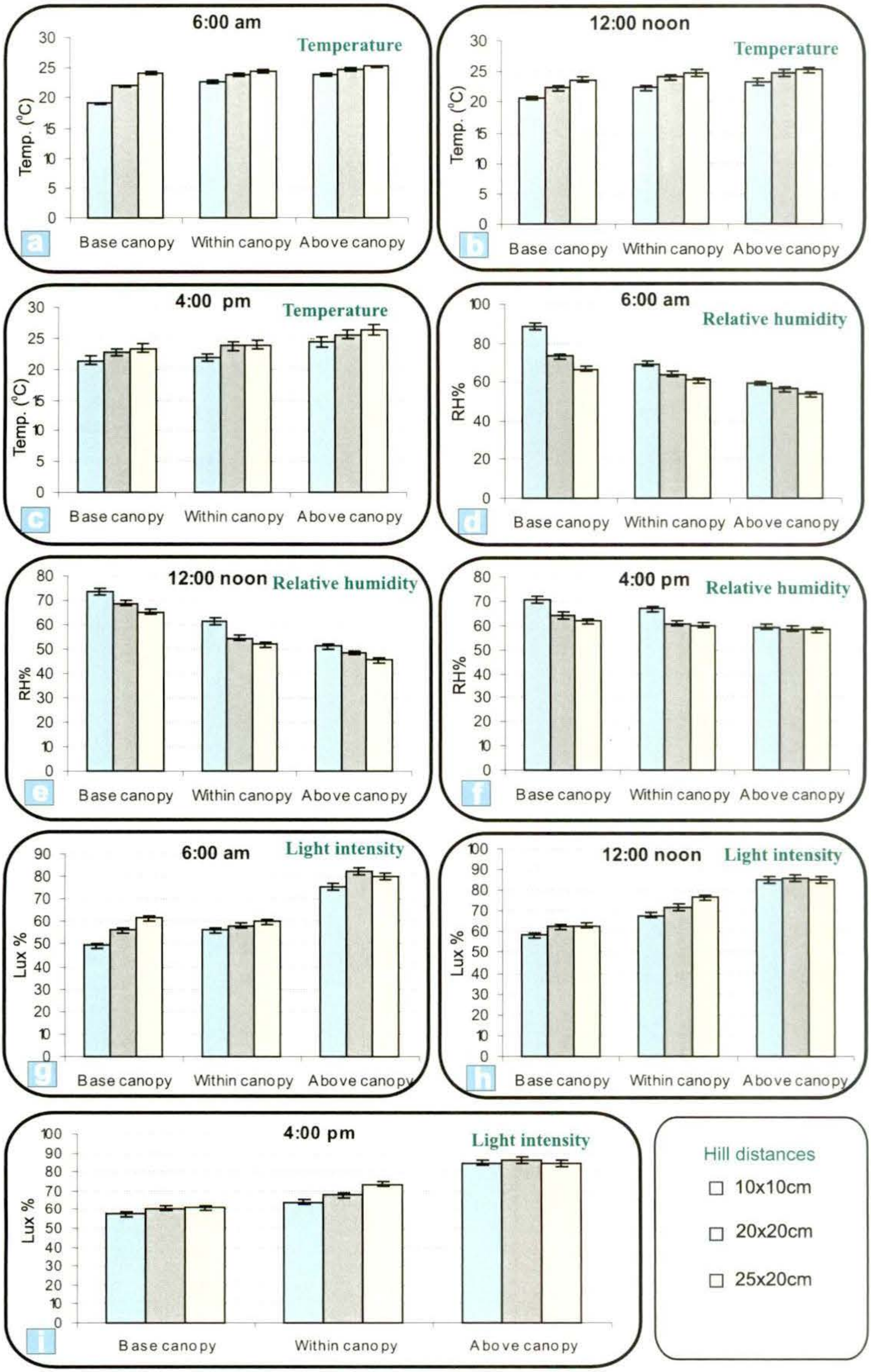


Fig. 4.9.5: Vertical differences in physical condition within paddy bushes at different spacing at 120kg inorganic N fertilizer inputs in different times. a,b &c: Temperature, d,e & f: Relative humidity, g,h & i: Light intensity.

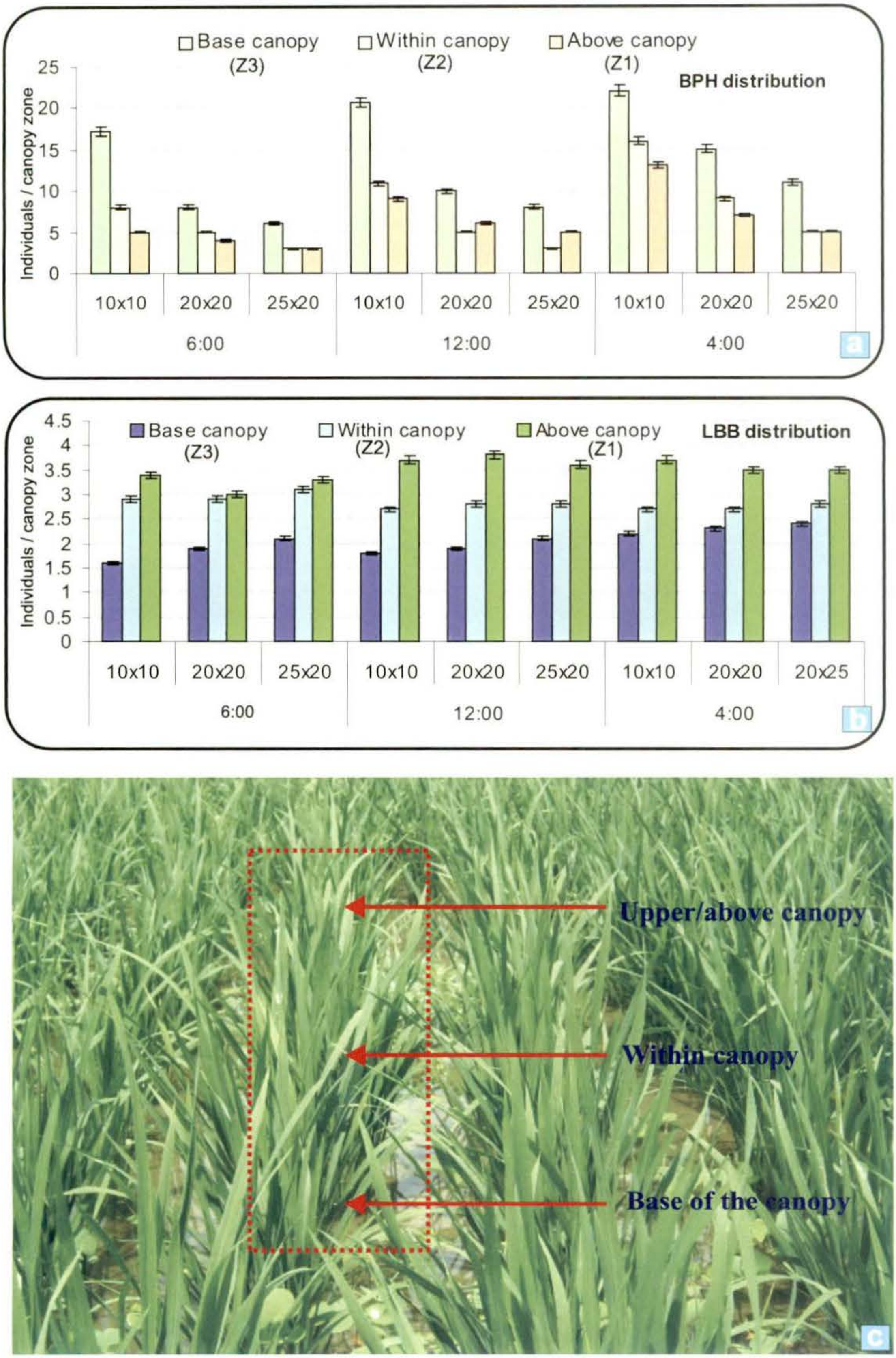


Fig. 4.9.6: Distribution of Lady bird beetle (LBB) and brown plant hopper (BPH) in relation to hill distances. a: BPH and b: LBB. C: Vertical micro climatic zones of paddy plant.

Hill distances positively influenced the microclimatic components such as Tmax and Tmin and negatively RHmax and RHmin. But the effect was significantly positive on light intensity (Table.4.9.5).

4.9.4.1.2 In laboratory condition

In constant light: Fifty LBB and BPH were separately released inside an elongated (65 x 6 x 6 cm) vial with the extremities having 0°c ice cube and100°c hot water combination (3.8.5.2 in materials and methods). A gradient of 'temperature zone' was thus established within the tube .The number of the beetles and BPH were counted in relation to the six equidistant zones (Figs 4.9.8c and 4.9.8d).

LBB: An aggregation of higher number of LBB was observed in the Z1 while the least in Z6.

BPH: Higher number of aggregation occurred at low illuminated zone. Lower the range of light intensity higher the number of individuals assembles. Maximum level of BPH occurrence was noted under Z6.

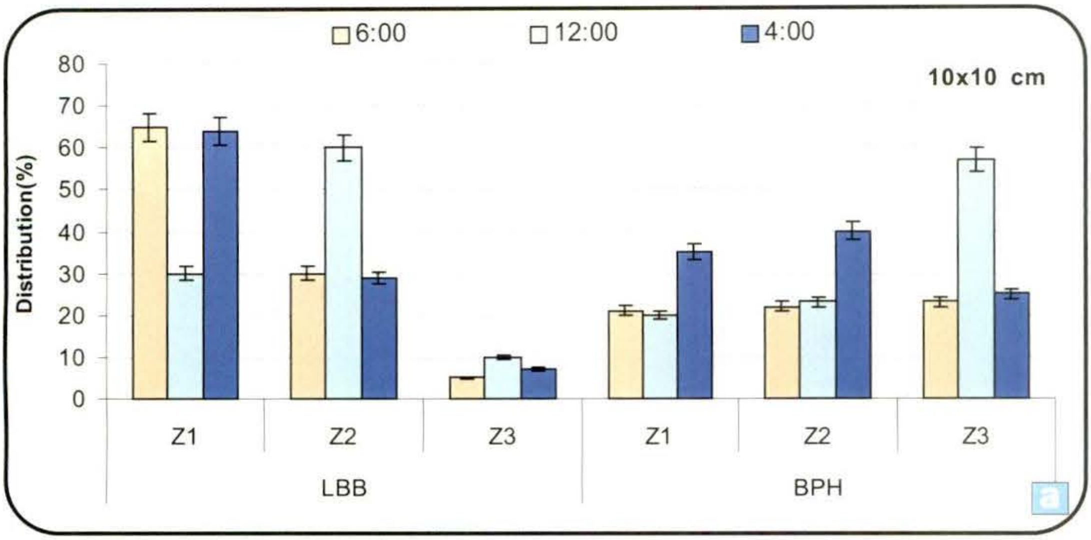
In constant temperature: The elongated vial was wrapped by the cellophane paper of variable thickness along the length of the tube so that 'illumination gradient' is created from thinner to thicker wrapping. Maximum lux was recorded at Z6 while the minimum at Z1. A constant range of temperature (22-24°C) and humidity (80-90%) was maintained. LBB and BPH were released separately into the vial and were counted after their complete settlement (4.9.8a and 4.9.8b).

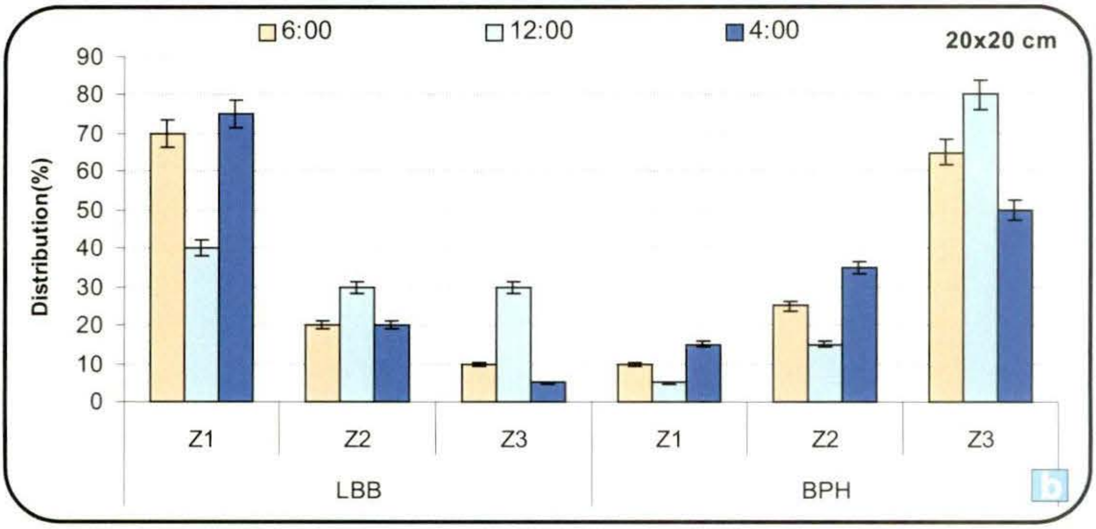
LBB: Higher aggregation of beetle occurred at Z6 while the least in zone 1.

BPH: Lower the illumination, higher was be the number of the BPH aggregation. Highest number colonized at the Z1 while the lowest at the Z6.

4.9.4.2 Distribution of LBB and BPH in relation to planting direction

The light intensity at all the zones along the perpendicular transect of the plant was found to be influenced both by the spacing and the direction of plantation.





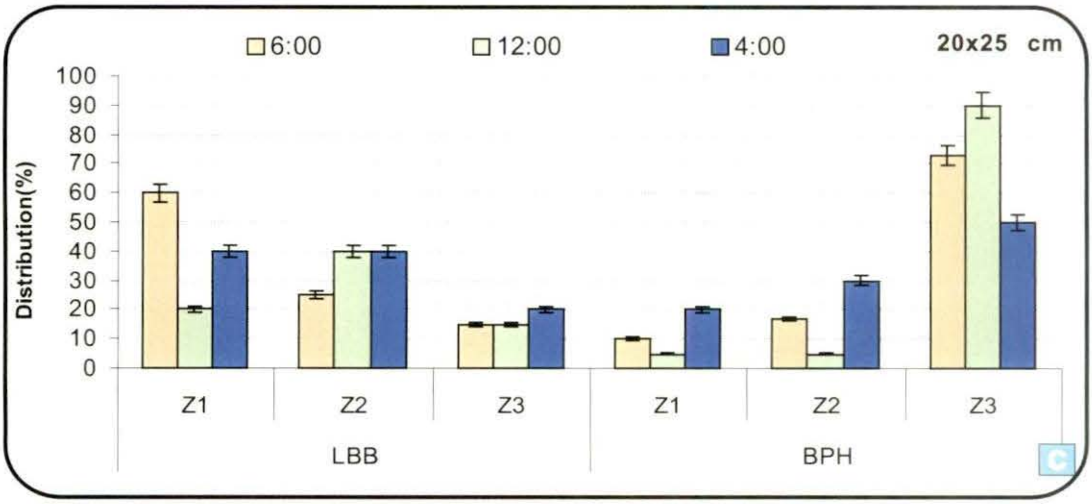


Fig. 4.9.7: Niche overlapping of LBB and BPH in respect of different temperature and light intensity along the vertical transect of paddy bush at tillering stage.

Plantation in east-west direction caused comparatively high intensity of light in the canopy than in the plants of north-south direction (Fig 4.9.9). Observation at three specific times of a day showed that greater the hill distances, greater was light intensity. Due to directional changes of solar radiation with the progress of the day, at 6.00 a.m. plants which were planted at east-west direction all the three zones got higher light intensity than the plants at north-south directions .At 12.00 noon, illumination was nearly the same in case of both the directions. At 4.00 noon, again the east-west direction received higher light intensity than in the north-south direction (Fig. 4.9.10).

In general, the pattern light transmission ratio (LTR) was higher in east-west direction at 6.00 a.m. At 12.00 noon the LTR in both the directions was same. High LTR was observed at 4:00 pm at east-west direction (fig.4.9.7c).

Distribution of LBB: Z1 accommodated 65%(6:00), 55%(12:00) and 68% (4:00) beetles at 20x20 spacing. In case of north-south plantation Z1 supported 70 %(6:00), 40%(12:00) and 75%(4:00) during east-west plantation. Direction of plantation did not influence the LBB distribution at 12:00 noon. LLB distribution follow in the descending frequency 30-45% (Z2) and 5-20 % (Z3) in east-west direction and the value varies from 7-10%(Z2) and 6-10%(Z3) (Fig.4.9.11a).

Distribution of BPH: At 6:00 am, maximum number of BPH concentrated at Z3 in east-west plantation in comparison to that of north-south plantation. Direction of plantation did not affect the BPH distribution at 12:00 noon. However at 4:00 noon Z3 shared 82 and 71% population at east-west and north-south directions respectively (fig.4.9.11b).

Discussion: As the growth stage of paddy advances microclimatic conditions vary along the vertical regime of bushes. At early growth stages no specific microclimatic zones are established, thus the entire plant length acts as a complete territory for both the LBB and BPH and enhances the rate of predation. Due to gradual formation of microclimatic zones from the late vegetative stage along the height of the tiller, the BPH moves downwards while the LBB to the contrary, moves upwards.

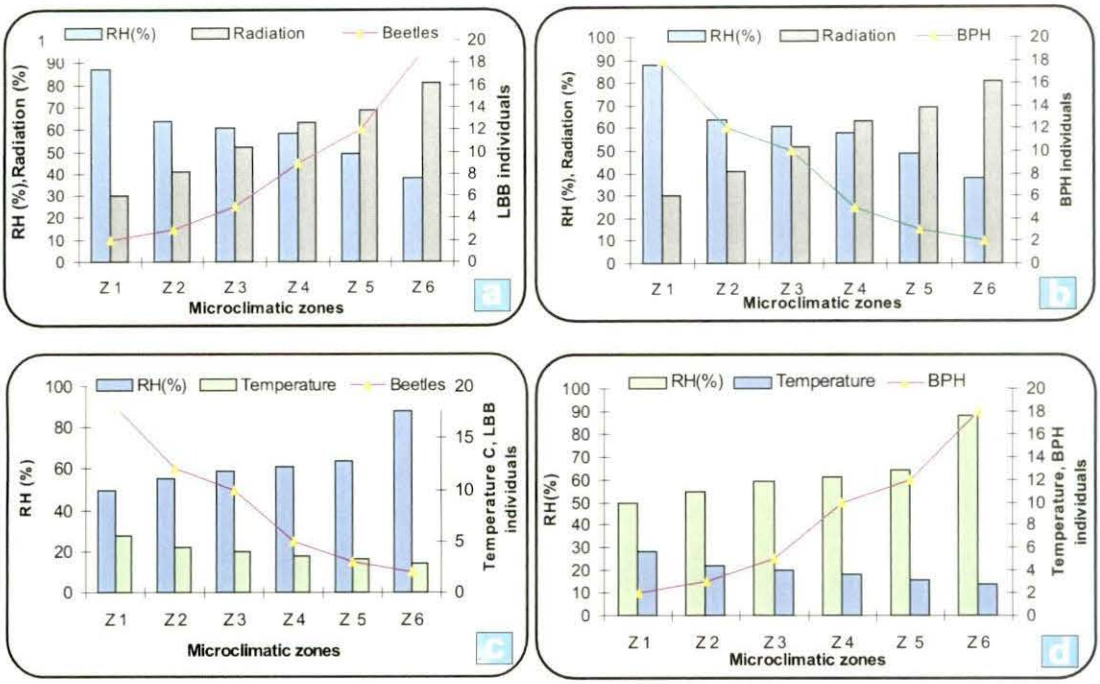


Fig. 4.9.8: Niche overlapping of LBB and BPH in respect of different temperature and light intensity. a: LBB at constant temperature with variable light intensity, b: BPH at constant temperature and variable light intensity, c: LBB at constant light with variable temperature, d: BPH at constant light intensity with variable temperature.

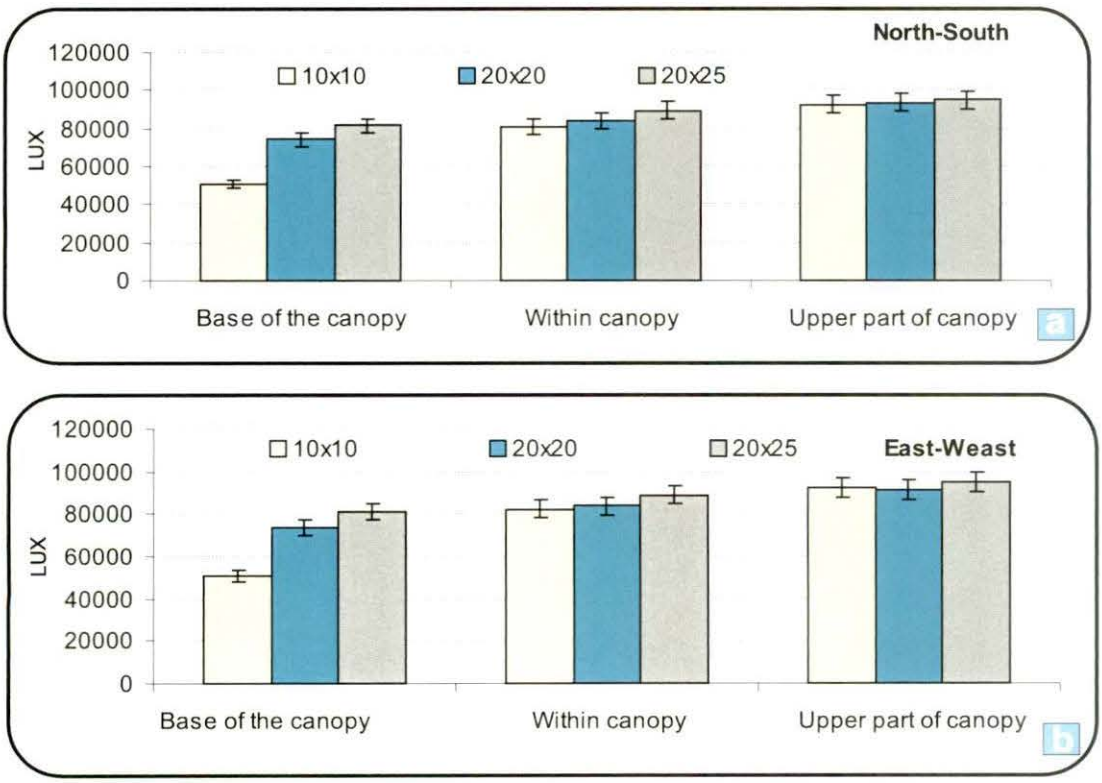


Fig. 4.9.9: Light intensity(LUX) as affected by planting directions and spacing at maximum tillering stage at 6:00 am. a: North-south, b: East-weast.

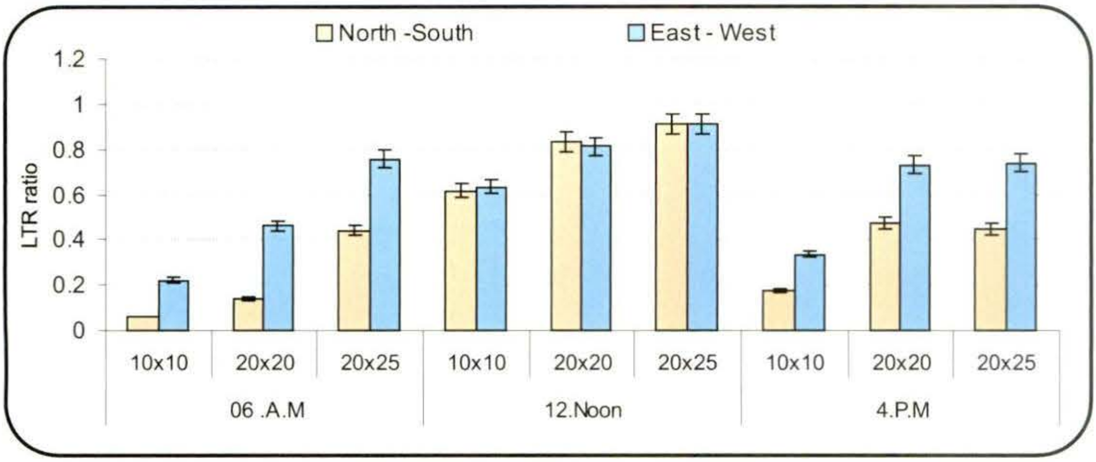


Fig. 4.9.10: Light intensity (LUX) ratio as affected by planting directions and spacing at maximum tillering stage.

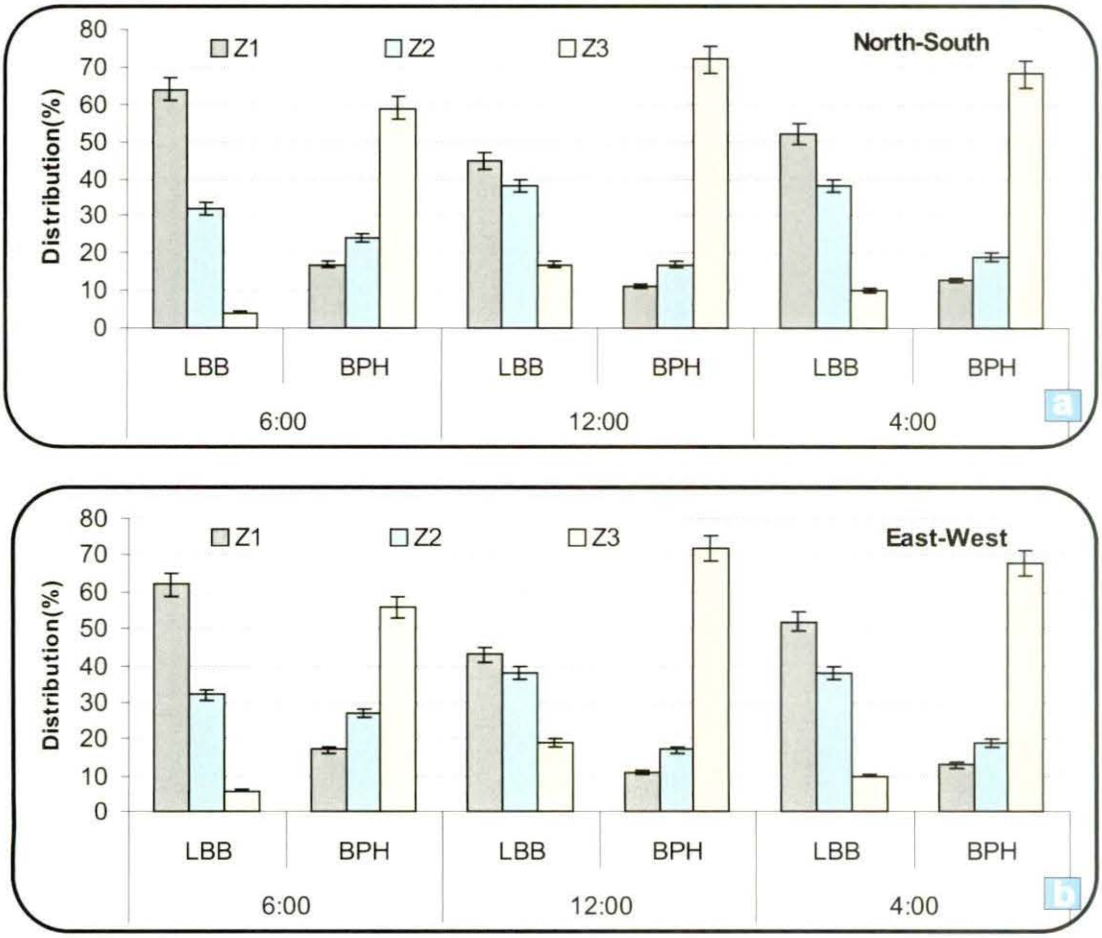


Fig. 4.9.11: Distribution of LBB and BPH along the perpendicular transect of the paddy plant at tillering stage as affected by the direction of plantation.

Microclimatic variations change the territorial regimes of both the pest and enemy. BPH prefers moist humid environment while the LBB favours relatively illuminated zones. Behavioral distinction results in the formation of two distinct niche .The niche of BPH gradually narrows from the early morning to the mid day and restricts the individuals to the base of the plant .After mid noon, the niche of the BPH population is extended, when it overlaps with the niche of LBB and the probability of rate of predation is increased.

Habitat structure influences the distribution of natural enemies on spatial scale (Bugg 1993, Landis 1994, Landis *et al.* 1998). But information on such 'niche-assembly' and 'dispersal-assembly' models of species coexistence in paddy field ecosystem is almost nil. Microclimatic alteration due to alternative hill spacing dictates territorial change resulting in niche displacement. Conditions near the base of the paddy hill are humid and shaded (Varca and Feuer 1976) which favour BPH and disfavours its natural enemies (Nishida 1975). Plant placing plays an important role on the distribution of BPH and LBB. LTR was season independent. Interception by crop canopy varied insignificantly by planting dates (Bardi 1985) but significantly by growth stages (Ghosh 2000). In contradiction to the present findings Sain *et al.* (2001) noted that the population builds up of hopper, and its mirid bug predators were higher in close spacing than wider spacing. Though the two preferred opposite microclimatic zones.

Predatory efficacy of LBB is thus more prominent at vegetative stage in comparison to the rest of the stages. Such finding is contrary to the common belief that BPH and LBB ratio of 1:2 are uniformly efficacious throughout the growth stages of paddy.

4.10 Assessment of Pest Induced Yield Loss

The differences between actual and attainable yield due to successive pests attack under different management practices and changeable climatic conditions are considered during yield loss assessment. Such consideration ultimately helps to adopt the proper pest management decisions (Walker 1975). The present crop loss survey was undertaken simply to justify the prevailing paddy pest controlling measures and accordingly to suggest the future cultivation strategy.

4.10.1 Yield loss due to YSB

In relation to the paddy growth stages: Completely chaffy grain was formed due to the simultaneous loss to both plant parts and grains while partial chaffy was due to the restricted attack to late reproductive stage (Fig 4.10.3). Pooled average data showed that the completely chaffy grain may be up to 41 % in *kharif* and 23 % in *boro* seasons. However the formation of partially chaffy grain ranged up to 11% in *kharif* and 5% in *boro* seasons (Fig.4.10.1a).

A significant negative relation was noted between the field YSB population and both the yield (Y) and yield attributing characters. The maximum level of damage occurred at tillering and panicle initiation stages at significant level (Table.4.10.1).

Table.4.10.1: Correlation values between YSB number in the field and yield attributing characters of paddy

Yield and yield attributing model	R value of functional components
Y = 4.95 -0.29 YSB (maximum tillering stage)	-0.511*
Y = 3.35 -0.12 YSB (panicle initiation stage)	-0.692*

Significant at 5% level

In relation to the climatic conditions: Damage to the paddy plant by YSB is season specific. WH formation and grain chaffy-ness were comparatively higher in *kharif* season than in *boro* due to climatic conditions conducive for pest multiplication. The value of DH was 20% and 12% in *kharif* and *boro* seasons respectively. The extent of WH was on an average 32 % and 16% in *kharif* and *boro* seasons respectively in pesticide unprotected fields.

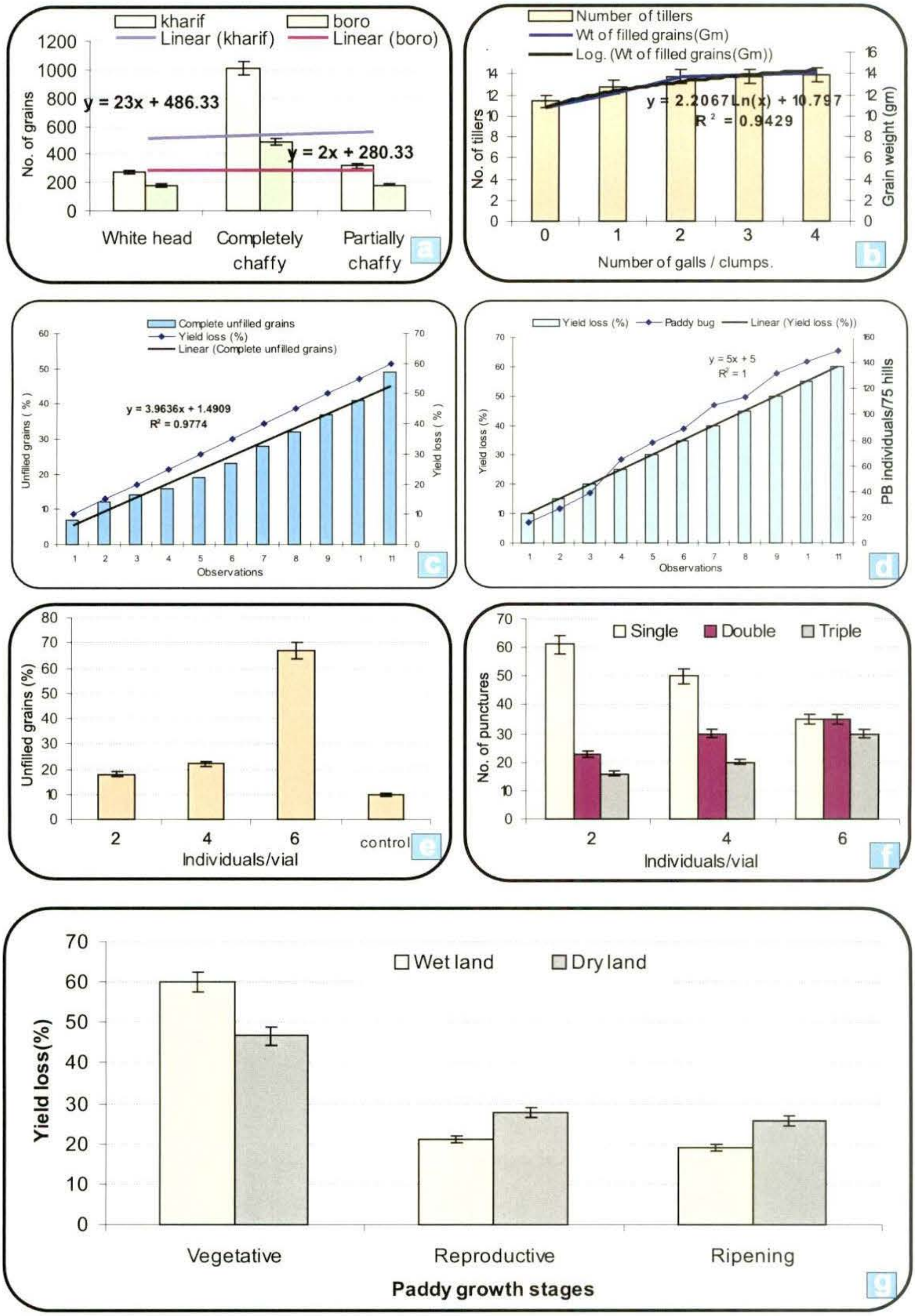


Fig. 4.10.1: Relative loss caused by the pests in the prevailing cultural practices. a: By YSB in both *kharif* and *boro* crops, with 120 kg. Inorganic N input/ha, b: By GM induced gall on tillers generation and paddy yield, c: Unfilled grains and yield loss due to PB, d: Number of unfilled grains in relation to the number of PB, e and f: Number of punctures caused by PB and unfilled grains. g: Yield loss due to agro-ecological conditions.

4.10.2 Yield loss due to BPH

In relation to the paddy growth stages: The highest yield loss at each growth stage infestation was estimated in 20 fields each having variable ranges of BPH individuals/hill. During such observation alternately one growth stage was free from pesticide among the four growth stages, which may be designated as substractive method (Table.4.10.2).

Table.4.10.2: Paddy growth stage specific extent of BPH attack and consequent final paddy yield loss

Growth stages of paddy	BPH individuals / hill	Extent of reduction of final yield (%)
Seed bed	6-10	18-29
Vegetative	9- 18	13-37
Reproductive (early)	13-22	17-37
Reproductive (late)	23-32	38- 69

The quantum of loss was determined on the basis of status of BPH incidence at maximum tillering stage and the final yield obtained. The farmers are allowed to follow their prevailing cultural practices (Table.4.10.3).

Table:4.10.3: Degree of damage of paddy and corresponding yield loss

Extent of damage	Progressive damage symptoms	*Panicle damaged (%)	Yield loss (%)
Mild	No withering but with very low degree of sooty mould	28	13
Low	Low level of scornful leaves with high degree of sooty mould	40	35
Medium	Yellowish brown leaves parts with higher degree of sooty mould	50	45
High	75% damaged panicle due to hopper burn	70	67
Severe	Complete crop failure with a few panicles	90	85

* About 75% tillers at panicle initiation stage

In relation to damage to the crop parts: The flag leaf influences the grain filling. Loss in areas of different leaves of a tiller due to mechanical removal either by plucking or damage by BPH infestation and consequent impact on the grain formation was studied assessing a relation among pest threshold level, leaf area loss and the yield loss.

Mechanical removal and yield reduction: Mechanical removal of single or different combinations of leaves steadily reduces the leaf area and hence the rate of photosynthesis. Available leaf area in an undisturbed tiller was about 190 cm^2. The leaf area was reduced up to 58 % when all but the flag leaf were detached. Due to the removal of 4th leaf the area was reduced by nearly 170 cm^2. The other combinations of mechanical plucking resulted in different degrees of available leaf area (Fig.4.10.2a).

Thus the quantum of leaf area damage may be used as an index for estimating the field BPH level without arduous task of counting BPH individuals round the day. For this purpose 8 Fields of variable threshold levels of BPH were assessed. In all the cases, higher the pest level lesser was the available leaf area (Fig.4.10.2b).

Removal of flag leaf badly influenced the number and distributions of heavy grains on the panicle. Both photosynthesis and assimilation were restricted due to the reduction in leaf area, accordingly the relative grain distribution on the spikelets differed. Poorly filled grains on secondary branches and on the lower parts of the panicle were noted when the leaf area reduction was greater. Removal of the flag leaf alone affected the grain development considerably. Elimination of the flag leaf or the 4^{th} leaf had the same functional leaf area. However, removal of the 4th leaf increased the number of heavy grains on primary branches and terminal spikelets of secondary branches. When two leaves from the bottom or the top of a tiller were removed, the proportional decrease of the leaf area was similar in both the cases. But the removal of the top leaves had more adverse effects on the number of heavy grains (Fig.4.10.2c).

Therefore, irrespective of the position of a leaf the overall leaf area was not critical factor for grain generation, but the locations of the leaves on a tiller is important. Grain filling was not related to the distance of a particular leaf from the panicle. The impact of mechanical damage of the leaf areas on grain yield can be treated as equivalent to the damage imparted by BPH infestation. So, damage to 4^{th} leaf had an positive effect on grain weight.

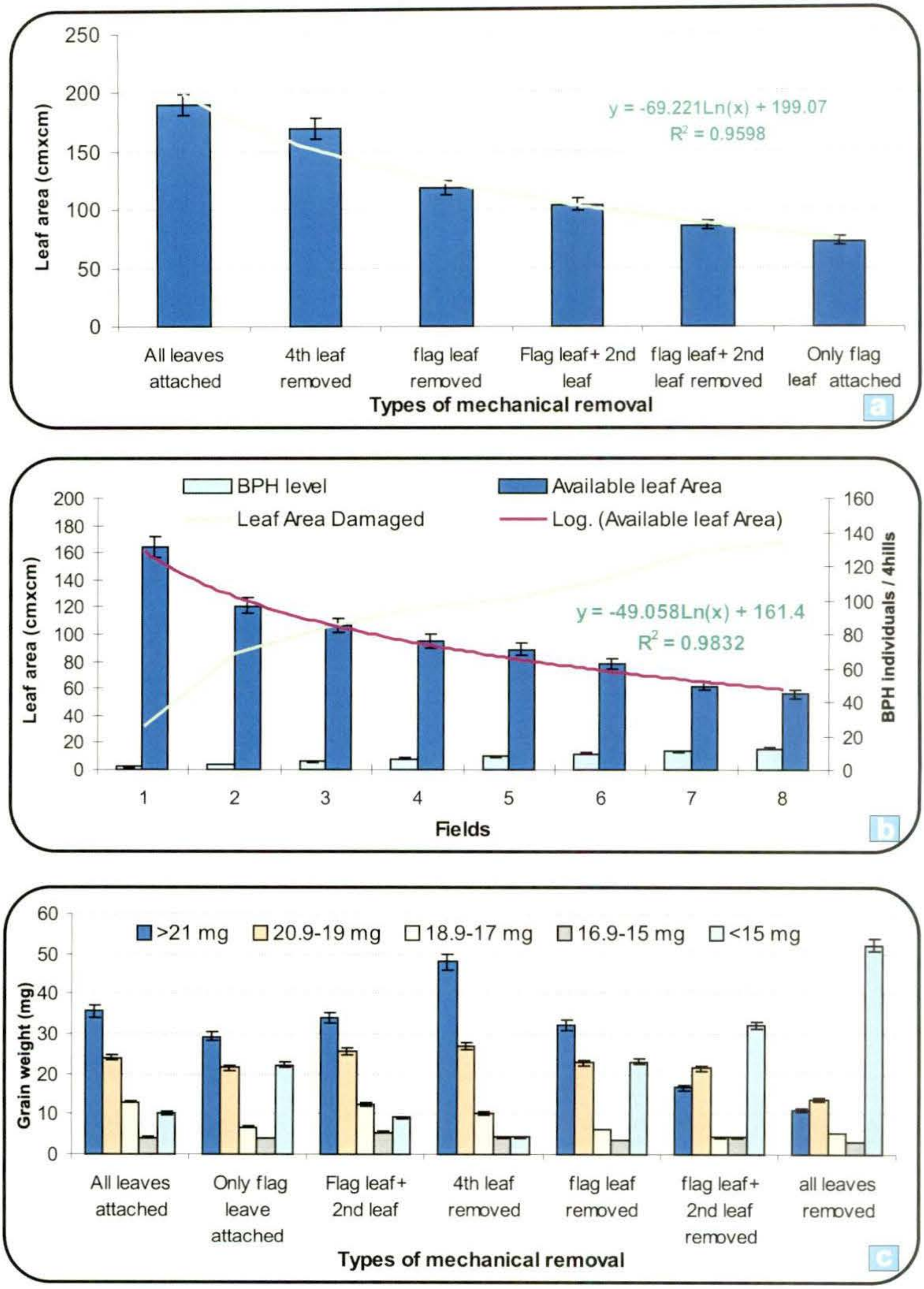


Fig. 4.10.2: Damage of leaf area by BPH and grain yield per hill. a: Mechanical removal of different leaves of a hill and available leaf area, b: BPH incidence in relation to leaf area damage, c: Effect of mechanical leaf area damage on the grain weight.

As the activity of the BPH was primarily related to the deterioration of the leaf parts, the magnitude of grain production was thus found to be influenced by the field BPH level.

BPH levels and yield reduction: Field population with 20 BPH / hill resulted in nearly the same available leaf area when flag leaf and 2nd leaf were mechanically removed, indicating that such level of pest was equally potent to bring equivalent amount of damage. Similarly, 32 BPH / hill had an identical damage with that of the mechanical removal of flag leaf and second leaf jointly. A significant negative relation (r=-0.876) was found between the number of BPH / hill with the extent of leaf area damaged. With the increase of BPH number a steady decrease of damaged leaf area was noted. Reduction of area due to BPH damage was high at the early vegetative stage; it gradually decreased as the crop grew older in spite of as increased number of BPH attack (Fig.4.10.2c).

In relation to the climatic conditions: Appearance of two major peaks per year strongly suggested that BPH induced damage was governed more prominently by the surrounding rice-cropping pattern than by the climate as there were two / three crop cycles per year but only one climatic cycle (Fig.4.1.4a). Further, the seasonality of BPH density was inconsistent indicating that the annual climate was less important. Contiguous crop fields facilities the dispersion of adult individuals. Correlation study between the yield attributing characters and BPH number reflected significant positive relations (Table.4.9.4). However the average range of damage was more intensified in *kharif* season (45-67%) than *boro* (23-49%).

Primary infestation of BPH reduced water contents of rice plants from about 72% to 84% (Santa 1959).The BPH severely damages rice growing plants in the post flowering stage in most rice growing areas (Chandy 1979). In Japan plants at the tillering stage are attacked by about 10 plant hoppers / hill for a week resulting in rapid yellowing of leaves, yield loss is about 10 to 40%. Infestation by 10 to 50 BPH / hill for 10 to 14 days eventually showed hopper burn and reduced the yield by 20-50%. Bae and Pathak (1970) noted that in field yield reduction ranged from 17-65%, with an average of 44%.

4.10.3 Yield loss due to GM

In relation to the paddy growth stages: Farmers paddy fields under need based protections were periodically surveyed especially during *kharif* season for the gall formation and consequent final yield were noted. A maximum limit of 4 galls / clumps(hill) was observed during both early and late infestations. Both the tiller number / hill and number of filled grains / hills were influenced by the midge infestation. Infestation by GM at vegetative stage compensates by new vigorous tiller generation. Higher the galls / clumps, greater would be the frequency of the tiller numbers and additional number of filled grains / tiller. Significant positive linear relation exists between the number of gall and the extent of yield generation. Highest grain weight was observed under 4 galls / clump against the no gall condition (Fig.4.10.1b).

Table:4.10.4 Yield loss in relation to number of gall produced / clump at late growth stages

Gall number/ clump	Yield q / ha	Yield reduction (%)
0.0(complete protection)	34.65	0.00
1.0	34.48	0.42
2.0	34.34	0.65
4.0	34.27	0.88

But late infestation at early reproductive stage caused the stunting of the plant and the formation of the 'onion shoot' resulting in considerable loss. Early infestation registered a yield increase up to 0.34 % when there were 4 galls / clump. Increase by single gall at late growth stage amplified the yield loss to the extent 0.88% (Table.10.4.4).

In the fields where farmers follow minimum management programme, the extent of loss can be evaluated by the following equation:

Regression equation (q/ha)	Regression value (r value)	% incidence
Y=26.76-0.230x	0.591*	0.681*

*Significant at 5% level

In relation to the climatic conditions: The activity of GM was primarily restricted to the *kharif* season. Meteorological parameters during the tillering stage of paddy at the period, 37- 44 SMW was conducive for the pest. The yield loss ranged between 4 and 56% with complete crop failure at some occasions in unprotected fields. The average yield losses were ranged 39%, 28% and 13% in Raiganj, Hemtabad and Itahar Blocks respectively.

4.10.4 Yield loss due to PB

In relation to the paddy growth stages: Farmer' fields were inspected periodically during *kharif* season. Twenty hills were diagonally selected and the percentage of unfilled grains was correlated with the number of the nymph and adult PB number / mt ^{2}. From 25 - 50 DAT nymphs constituted the greater part of PB population. At about 60 DAT both nymph and adult forms were equally frequent, after which adult PB dominated. Maximum damage to the plant was conferred at late stage of panicle formation. Significant positive relation ($r = 0.782$) between the number of unfilled grains and the extent of yield losses was noted (Fig.4.10.1c). Both the adult and nymphal forms of PB showed significant linear positive R value in relation to growth stages of paddy. The highest extent of 60% yield loss with nearly 48% unfilled grains was noted. As the number of PB was increased the extent of loss was linearly increased. Highest level of 60% loss was attributed to 2.16 bug / hill in fields without pesticide protection (Fig.4.10.1d).

Repeated sucking to the developing grain resulted in empty grains.Extent of grain sucking by *Leptocorysa* sp was evaluated (3.6.2.4 in materials and methods). The early maturing panicles with different number of PBs were encaged in the fields and the damage profile in relation to the particular growth stage was evaluated. The study was replicated thrice and the average value was taken (Fig.4.10.1e and f).

Unfilled grains and grain weight: Percentage of grain damage in different vials was computed against the vial without nymphs, considered as control. Unfilled grains increase steadily as the nymph number / vial is increased. the highest was scored with 6 bugs / vial.

Fig. 4.10.3: Successive stages of plant part deterioration due to YSB attack.

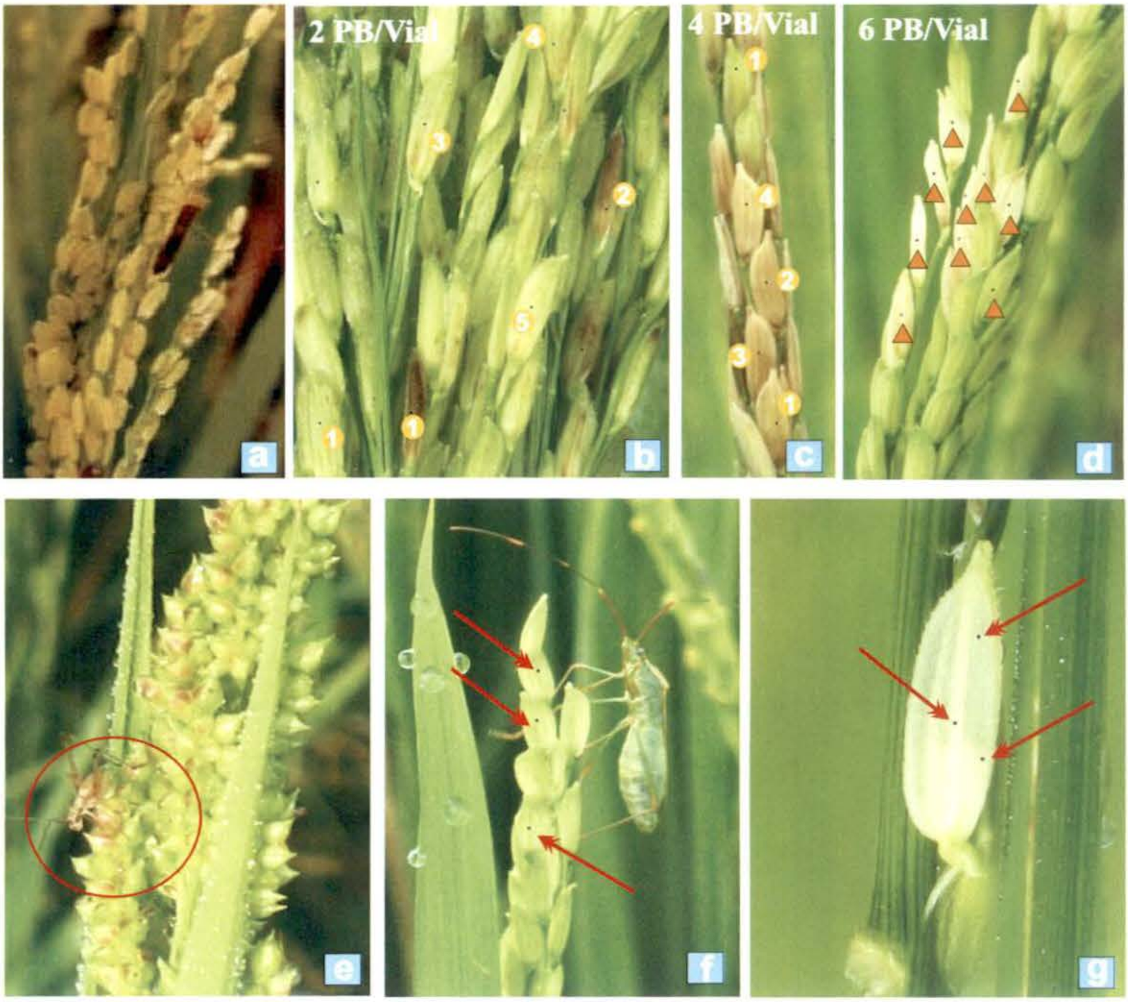


Fig. 4.10.4: Consequences of different number of PB/vial a: PB was sucking grains b: Two individuals c: Four individuals d: Six individuals. e: PB on alternative hosts f: Multiple punctures due to nymphs sucking g: Emty grain formation due to simultaneous PB attack.

Number of visible punctures: The number of punctures on a grain differed in relation to the abundance of the nymphs. About 60% grains with single puncture, was found when the panicles were reared with 2 nymph but the number gradually decreased from 50-36% with the corresponding increase in the number of nymph from 4 to 6. Side by side, the double and triple punctures were also increased, 4 punctures /grain was very rare (Fig.4.10.4).

Nymphs feed at flowering and the adults up to hard dough stage. External appearances of puncture marks were not visible instantly but only after milks exuded from the grain following the sucking. About 19 and 63 % loss of in grain weight was observed when damage was caused by 2 and 6 nymphs respectively. However 4 nymphs registered 29 % weight loss. Increase in the nymph's number caused multiple attacks to the same grain for food. However, first puncture was more crucial for grain weight reduction.

Number of punctures is not influenced by the plantation dates. Effective puncture is related to the time of carbohydrate translocation through the plant. Virmani (1999) reported that 30-40% and 60-70 % of the rice grain carbohydrates are assimilated before and after heading. Puncture before heading stage provides partial diet. Fields with comparatively high level of PB population at the early stage of heading results in more punctures. While infestation after heading stage results in less punctures.

In relation to damage to the climatic conditions: Activity of PB was recorded in both *kharif* and *boro* crops. Multiple overlapping generations with comparatively high magnitude of damage (65%) was observed in *kharif* cropthan the *boro* crop (18%).

4.10.5 Yield loss due to agro-ecological conditions: Yield loss assessment was carried out by subtractive method for two types of land, dry and wet (3.8 in materials and methods). During such process chemical protection was offered to two growth stages while the remaining stage got no protection. In dry land condition, damage to vegetative stage resulted maximum yield loss (up to 65%). In wet land condition, protection free reproductive and ripening stages contributed nearly the same range of loss (Fig.4.10.1g).

Damage to vegetative, reproductive and ripening stages in unprotected condition shared about 45%, 35% and 25% loss respectively. Growth stage related experiment showed that damage to vegetative stage in dry land condition resulted in maximum loss while the damage to reproductive and ripening stages recorded the highest loss in a wet land paddy. Heterogeneity of landscape influenced the distribution of the pests and accordingly the extent of damage differed. Dry land allowed early colonization followed by rapid multiplication of BPH. Stagnant water in wet land disapproved BPH accumulation. Furthermore, high doses of inorganic fertilizer normally applied to the dry lands intensified YSB and GM activity.

Significant positive relation was noted between the yield (Y) and the yield attributing characters (Table 4.10.5). Villages with sandy loam soil with high organic contents as in the Block of Raiganj comparatively yielded higher (35.4q/ha) than low organic content in muddy soil of Itahar Block (29.2q / ha)

Table.4.10.5: Relation between yield and yield attributing characters

Yield and yield attributing model	R value
Y = 1.131 + 0.006 panicle +0.012 grain weight (gm.)	0.611*
Y = 1.436 + 0.006 panicle +0.033 plant height + 0.038 leaf area	0.773*

Significant at 5% level

Panicle length and the grain weight significantly influenced the final yield generation at positive level. Significant positive effects of plant height ($r = 0.675$), panicle length ($r = 0.711$) and available leaf area ($r = 0.603$) on yield generation were also noted. Greater the plant height, higher would be the panicle length together with the higher range of leafy canopy which positively influenced the grain filling, accordingly the yield increased.

Discussion: Average yield loss in the three blocks ranged between 37.6 and 57.8% in pesticide untreated fields. At IRRI farms, Philippines, the average yield loss has been about 40 % under insecticide free condition (Heinrichs 1994). The extent of loss under traditional agricultural situation in India is 10 % (Pradhan 1964). In consideration of the maximum realizable yield Siddiq (2000) has estimated that yield gap is 37.1, 34.4 and 15.6 in West Bengal, Karnataka and Tamil Nadu respectively. Moderate range of yield gap has been observed in Orrisa (64.5%), Manipur (57.3%), Uttar Pradesh (56.5 %) and Tripura (53.7%). High yield gap has been reported from the Eastern parts of Uttar Pradesh (71.5%), Bihar (70.2%) and Assam (69.6%).

Yield loss is climate dependent and highly variable. Damage to vegetative, reproductive and ripening stages in unprotected condition shared about 45%, 35% and 25% loss respectively. Growth stage related experiment showed that damage to vegetative stage in dry land condition resulted in maximum loss while the damage to reproductive and ripening stages recorded the highest loss in a wet land paddy. YSB, BPH, GM and PB registered an average yearly loss ranged 26-32%, 40-45%, 28-24% and 17-29% respectively.

4.11 Proposal of New Pest Management Protocol

Based on the comprehensive assessment of dynamics of the four major pests in the 20 villages, suitable cultivation module (CM) is suggested for the area.

4.11.1 Outline of survey operation: In each block fields were extensively surveyed from the time of panicle initiation stage of *kharif* crop. Six plots (50 x 50 mt.) were selected from each of the 20 villages, so a total of 120 crop plots were examined. One hundred hills in each plot were diagonally examined for the damage symptoms, and the plots were categorized depending on the damage frequency.

4.11.1.1 Ranking of the blocks in relation to the damage symptoms: Not all the pests were equally abundant in the selected plots of 20 villages. For ranking the collective pest frequency of all the plots in a block were considered (Table 3.5, 3.6, 3.7 and 3.8 in materials and methods).

In consideration of YSB: YSB caused maximum damage in Raiganj. Only 22 fields did not show any damage symptoms in Raiganj. Except in one plot with 80% DH and WH, in most of the plots the symptoms remained below 70%. The lowest frequency of DH was noted in Itahar (Table.4.11.1).

In consideration of BPH: Maximum BPH induced damage was noticed in Raiganj and the minimum in Hemtabad. Plots in Itahar had moderate range of damage. Complete crop failure was rare (Table.4.11.2).

In consideration of GM: Damage caused by GM was maximum in Itahar while it was minimum in Hemtabad. GM was moderate in all the villages of Raiganj (Table.4.11.3).

In consideration of PB: The frequency of damage by PB was nearly the same in the entire block. Fields with about 80 % damage symptoms constituted only 4%, 4% and 3% in Raiganj, Hemtabad and Itahar respectively (Table.4.11.4).

Table.4.11.1: Frequency of DH and WH in different plots of the three blocks

Blocks	Number of plots and damage per cent in them															
	00	05	10	20	25	30	35	40	45	50	55	60	65	70	75	80
Raiganj	22	19	11	12	10	9	8	5	7	5	4	2	2	1	1	1
Hemtabad	28	17	11	10	9	8	6	6	6	5	5	2	2	2	2	1
Itahar	30	12	9	8	12	12	8	6	5	5	4	3	2	2	1	1

Table.4.11.2: Percentage of damage symptoms due to BPH in the three blocks

Blocks	Number of plots and the damage per cent in them											
	00	05	10	15	20	30	40	50	60	70	80	90	100
Raiganj	12	12	9	9	9	9	13	11	8	7	7	7	3
Hemtabad	20	18	16	13	11	8	9	7	6	4	3	3	2
Itahar	25	16	12	11	11	11	8	9	7	4	4	1	1

Table.4.11.3: Percentage of damage symptoms caused by GM in the three blocks

Blocks	Number of plots and damage per cent in them										
	00	05	10	15	20	30	40	50	60	70	80
Raiganj	34	22	15	11	10	6	7	7	3	2	3
Hemtabad	44	12	11	9	10	8	6	6	6	6	2
Itahar	16	10	14	16	12	12	11	9	9	6	5

Table.4.11.4: Percentage of damage symptoms induced by PB in the three blocks

Blocks	Number of plots with damage per cent in them										
	00	04	10	15	20	30	40	50	60	70	80
Raiganj	21	15	15	15	10	9	9	9	7	6	4
Hemtabad	22	14	14	13	13	10	8	8	8	6	4
Itahar	22	15	14	13	12	12	9	8	6	6	3

4.11.1.2 Gradation of the villages depending of pest intensity: Depending on the pest intensity, the villages are categorized following the Standard Evaluation System (SES) which is a ten point scale in descending order (Table.4.11.5). Lower the grade, minimum was the occurrence of the particular pest infestation.

Table 4.11.5: Gradation of villages depending on extent of damage determined by Standard Evaluation System (IRRI)

Villages	Pests and damage symptoms (%)			
	YSB	BPH	GM	PB
	Dead heart+ White head	Hopper burn	Silver shoot	Unfilled grains
Bhatole	1	9	0	1
Bindole	3	5	5	5
Bhagilata	5	7	5	1
Khoksa	1	5	7	0
Maharajahat	7	5	1	1
Sitgram	5	9	5	7
Lohanda	7	5	5	5
Bahin	5	1	1	5
Subhasganj	7	5	0	0
Rupahar	5	7	5	7
Bharatpur	5	0	1	1
Malone	5	1	0	5
Bishnupur	3	1	1	0
Madhabpur	3	5	1	1
Bangalbari	5	5	5	1
Balitpur	0	5	9	5
Bhagnail	1	5	7	1
Chandigram	5	7	7	5
Durlavpur	0	5	5	1
Marnai	3	5	7	1

4.11.1.3 Categorization of the villages depending on pest incidence: An Indian level common ETL determinant appears to be inadequate for formulating measures at local levels. In spite of almost similar climatic conditions in all the blocks, the pest abundance and extent of damage differed considerably depending on the agro-ecological situation, pedological differences and the cultural practices. Pest intensity of two distantly located villages may be the same. Furthermore, the dynamics of two adjoining villages may differ and regarding a single pest species two villages may be alike, while others may differ considerably. Higher the similarities between the domains lesser would be the differences in management practices.

4.11.1.4 Categorization of the prime factors for a particular major pest: Importance of the importance cultural practices on the bionomics of the pests was assessed. Most of the cultural practices significantly influence the occurrence of YSB and BPH and required thus an immediate judicious attention. GM was influence moderately while PB at marginal level (Table.4.11.6).

Table.4.11.6: Gravity of the different cultural practices on pest bionomics

Cultural practices		**Pests**			
Description and variables	**Unit**	**YSB**	**BPH**	**GM**	**PB**
Plantation time (X1)	22 SMW(*kharif*) 48 SMW (*boro*)	-0.678*	-0.787*	-0.591*	-0.511*
Fertilizer input (X2)	120 kg / ha	-0.897*	-0.776*	-0.566*	0.501*
Light trapping (X3)	200 watt	-0.897*	-0.945*	-0.432	-0.454
Hill spacing (X4)	At 20x 20cm	-0.517*	-0.885*	-0.553*	0.441
Water stress management (X5)	Alternative stagnation and draining	-0.564*	-0.675*	-0.231	-0.334
Crop rotation (X6)	Green manure-paddy	-0.786*	-0.445*	-0.411	0.154
Field scouting for YSB eggs (X7)	At 75-80 DAT	-0.786*	-0.122	0.432	0.123
Tillage time (X8)	Double plowing + double harrowing	-0.711*	-0.423	-0.242	0.114
Hand weeding (X9)	At 25 and 75 DAT	-0.511*	-0.653*	-0.564*	-0.503*

*Significant at 5% level

The important cultural practices are graded depending on their negative effect on the pest induced yield loss. Each of the all cultural practices was assessed separately and the yield protection incurred was noted.

The principal component analysis is taken as the basis of investigation. Variables, whose *eigen* values were nearly similar were taken in one group. Depending on the likeliness, three groups were constructed.

Table.4.11.7: Gradation of the important cultural practices depending on their negative effect on the pest induced yield loss

Grade (G)	Important cultural practices	Total variance	% of variance	Cumulative (%)
1	Plantation time(X1), fertilizer management (X2), light trapping (X3) and hill spacing(X4)	13.37	58.13	58.13
2	Water stress management (X5), crop rotation (X6) and field scouting (X7)	6.02	26.09	84.23
3	Tillage operation (X8) and hand weeding(X9)	2.76	12.02	96.26

The prime cultural practices are termed as G-1. Practices which required least attention are placed in G-3.G-2 enlisted the practices which required intermediate attention in consideration of the other two groups (Table.4.11.7).

Four practices in G-1(X1, X2, X3 and X4) were relatively more crucial than the rests. Interrelationship among the variables belonging to G-1 was also done.

Table.4.11.8: Relationship among the major cultural practices

Variables	Equation of relation	r value
X1	-140.21+ 163.23 X2 + 1.861 X3 + 2.962 X4	0.91*
X2	-231.56 + 143.45 X1 + 1.792 X3 + 2.612 X4	0.87*
X3	-561.67 + 156.21 X4 + 1.781 X1 + 2.562 X2	0.82*
X4	-163.24 + 261.21 X3 + 1.521 X2 + 2.111 X1	0.93*

* Significant at 5% level

Relative importance of the variables of G-1 was worked out by component analysis. The numerical values, given by the equation $\xi = Lx$ as a critation for comparing the degree of resemblances of the hierarchical pattern was followed. The principal component analysis with varimax orthogonal rotation was employed to find out the lodging of the variables of G-1. Result indicated that the time of plantation followed by fertilizer management was the foremost important cultural practices to check the pest incidence. Grossly, no major variation of the four major variables belonging to G-1 was noted in the selected nine villages, three from each of the blocks which indicated that these cultural practices were equally important at all the places (Table 4.11.8 and 4.11.9)

Table.4.11.9: Lodging of the first eigen vectors of the four variables of the villages

Blocks	Villages	Value of the variables			
		X1	X2	X3	X4
Raiganj	Bhatole	0.987	0.768	0.678	0.564
	Bindole	0.879	0.678	0.712	0.534
	Maharajahat	0.876	0.645	0.655	0.567
Hemtabad	Sitgram	0.786	0.634	0.634	0.589
	Lohanda	0.789	0.711	0.609	0.599
	Bahin	0.856	0.723	0.688	0.634
Itahar	Balitpur	0.866	0.745	0.611	0.611
	Bhagnail	0.876	0.786	0.563	0.645
	Marnai	0.897	0.772	0.677	0.634

4.11.1.5 Generation of a new ETL in relation to the pest threshold level

Depending on the relative threshold values, the pests or their pest symptoms are divided into three (for YSB,GM and PB) or four (for BPH) tolerant grades, accordingly the relative importance of management practices differ (Table.4.11.10). No special attention to the field is required in case of '*permissible threshold*' as the pest status is below ETL. At '*functional threshold*' the pest status approached to the limit of ETL and the situation could be managed only after taking special attention to some cultural practices. '*action threshold*' required the steady prophylactic alteration of the cropping practices while in '*battle threshold*' (only in case of BPH) immediate pesticidal input together with the adoption of the corrective measures for future crop cultivation was given priority. Collective contemplation of the four grades for BPH and three grades for each of YSB, GM and PB reflected that in relation to the four growth stages of paddy the pests could occur in a total of 164 matrix combination matrices (Table4.11.11). Each combination indicated its relative occurrence and the potential of damage. Combinations which were supposed to require the same pattern of prophylactic or corrective measures were taken in one group, regarded as Cultivation Module (CM). A total of 12 CMs were formed of which 6 were found to be economically and ecologically more important (indicated by * in the table 4.11.11). After assessing the pest status in the field, farmers would be able to follow the appropriate group combination and adopt suitable prophylactic or corrective measures (Table.4.11.12).

Domain dominance: Each of the 12 domains has its individuality and is characterized by the presence or absence of the activity of pest(s) (indicated in the table 4.11.11). Threshold combinations under the same domain have nearly same pest intensity and accordingly require more or less same cultural practices.

Table.4.11.10: Categorization of the major pests into different grades depending on the observable field threshold

Pests with unit of observations	Grade(s)	Threshold level(s)
Brown plant hopper Individual(s)/hill	A1	0.0-5.0
	A2	5.1-10
	A3	10.1-20
	A4	20.1<
Yellow stem borer Egg mass(s)/mt.^{2}	B1	0.0-0.9
	B2	1.0-1.9
	B3	2.0<
Gall midge Individual(s)/mt.^{2}	C1	0.0-0.5
	C2	0.6-1.2
	C3	>1.3
Paddy bug Individual(s)/hill	D1	0.0-0.4
	D2	0.5- 1.5
	D3	1.6<

1: Permissible threshold, 2: Functional threshold, 3: Action threshold, 4: battle threshold

Table.4.11.11: Multiple threshold combinations of the four major pests from the paddy fields and their categorization into cultivation modules (CMs).

CMs	Threshold Combinations (TC)
CM1 **(Nil)**	A1B1C1D1, A1B2C1D2, A1B1C2D1
*CM2 **(BPH+YSB)**	A2B2C1D1, A2B2C1D2, A2B2C1D3, A2B2C2D1, A2B2C2D2, A2B2C2D3, A2B2C3D1, A2B2C3D2, A2B2C3D3, A2B3C1D1, A2B3C1D2, A2B3C1D3, A2B2C2D1, A2B3C2D1, A2B3C2D2, A2B3C2D3, A2B3C3D1, A2B3C3D2, A2B3C3D3, A3B2C1D1, A3B2C1D2, A3B2C1D3, A3B2C2D1, A3B2C2D2, A3B2C2D3, A3B2C3D1, A3B2C3D2, A3B2C3D3, A3B3C1D1, A3B3C1D2, A3B3C1D3, A3B3C2D1, A3B3C2D2, A3B3C2D3, A3B3C3D1, A3B3C3D2, A3B3C3D3, A4B1C2D2, A4B2C1D1, A4B2C1D2, A4B2C1D3, A4B2C2D1, A4B2C2D2, A4B2C2D3, A4B2C3D1, A4B2C3D2, A4B2C3D3, A4B3C1D1, A4B3C1D2, A4B3C1D3, A4B3C2D1, A4B3C2D2, A4B3C2D3, A4B3C3D1, A4B3C3D2, A4B3C3D3
CM3 **(BPH+GM)**	A3B1C2D1, A3B1C2D2, A3B1C2D3, A3B1C3D1, A3B1C3D2, A3B1C3D3, A3B2C2D1, A3B2C2D2, A3B2C2D3, A3B2C3D1, A3B2C3D2, A3B2C3D3, A3B3C3D1, A3B3C3D2, A4B1C2D3, A4B1C3D2, A4B1C3D3,
*CM4 **(GM+PB)**	A1B1C2D2, A1B1C2D3, A1B1C3D2, A1B1C3D3, A1B2C2D2, A1B2C2D3, A1B2C3D2, A1B2C3D3, A1B3C2D2, A1B3C2D3, A1B3C3D2, A1B3C3D3, A2B1C2D3, A2B1C3D2, A2B1C3D3, A2B2C2D3, A2B3C2D2, A2B3C2D3, A3B3C3D3, A4B1C2D3, A4B1C3D1, A4B1C3D2, A4B1C3D3, A4B3C3D3
*CM5 **(YSB+PB)**	A1B2C1D2, A1B2C1D3, A1B3C1D2, A1B3C1D3, A2B2C1D2, A2B2C1D3, A3B3C1D2, A3B3C1D3, A3B3C2D2, A3B3C2D3, A4B2C1D2, A4B3C1D2, A4B3C1D3
*CM6 **(BPH+PB)**	A2B1C1D2, A2B1C1D3, A2B1C2D2, A2B3C1D2, A2B3C1D3, A3B1C1D3, A3B1C2D2, A3B1C2D3, A3B1C3D2, A3B1C3D3, A3B2C1D2, A3B2C1D3, A3B2C2D2, A3B2C2D3, A3B2C3D2, A3B2C3D3, A4B1C1D2, A4B1C1D3, A4B1C2D3, A4B2C1D3, A4B2C3D3, A4B3C2D2, A4B3C2D3
*CM7 **(BPH+GM+PB)**	A2B1C2D1, A2B1C2D2, A2B1C2D3, A2B1C3D1, A2B1C3D2, A2B1C3D3, A2B3C3D1, A2B3C3D2, A2B3C3D3, A3B3C3D3, A4B1C1D1, A4B1C2D2, A4B3C3D2, A4B3C3D3
*CM8 **(YSB+GM+PB)**	A1B2C2D1, A1B2C2D2, A1D2C2D3, A1B2C3D1, A1B2C3D2, A1B2C3D3, A1B3C2D1, A1B3C2D2, A1B3C2D3, A1B3C3D1, A1B3C3D2, A1B3C3D3, A2B2C2D1, A2B2C2D2, A2B2C3D2, A2B2C3D3, A2B3C2D1, A2B3C2D2, A2B3C2D3, A3B3C2D1, A3B3C2D2, A3B3C2D3, A4B1C2D2, A4B2C2D1, A4B2C2D2, A4B2C2D3, A4B2C3D1, A4B2C3D2, A4B2C3D3, A4B3C2D1, A4B3C2D2, A4B3C2D3, A4B3C3D1
CM9 **(YSB)**	A1B2C1D1, A1B3C1D1, A2B3C1D2
CM10 **(BPH)**	A2B1C1D1, A3B1C1D1, A3B1C1D2, A4B1C1D1
CM11 **(GM+PB)**	A1B1C2D1, A1B1C3D1, A1B2C3D1
CM12 **(PB)**	A1B1C1D2, A1B1C1D3, A1B2C2D3

* Major domains

Table.4.11.12 Categorization of the 12 CMs on the basis of four grades for adopting suitable pest management measures. Grades are indicated by number of + sign.

Practices	CM1	CM2	CM3	CM4	CM5	CM6	CM7	CM8	CM9	CM10	CM11	CM12
Prophylactic												
Organic fertilizer	++	++++	++++	++	+++	+++	++++	+++	++++	++++	++	++
Inorganic fertilizer	+	++	+	++	++	++	++	+++	++	++	+	++
Weeding	++	++++	+++	++	++++	+++	+++	+++	+++	++++	++++	++
Water stress management	++	++++	+++	++	+++	+++	++++	+++	+	++++	+++	+
Light trap	+	++++	+++	+	++++	+++	++++	+++	+++	++++	+	+
Field scouting	+++	+++	++++	++	+++	+++	++	++++	+++	++++	++	++++
Corrective												
Variety	++	+++	+++	++	+++	+++	++++	++++	++++	++++	+++ +	++
Tillage and stubble management	+	++++	+	+	+++	+	+	++++	++++	+	+	+
Crop rotation	++	+++	++	+	+++	++	++	++++	++++	++	+	+
Spacing	+	+++	++++	++++	+	++++	++++	++	+++	++++	++++	+
Plantation time	++	+++	+++	+++	+++	++++	++++	++++	+++	++++	+++ +	++
*Pesticide application	+	++	+++	+	+++	++++	++++	++++	++++	++++	+++	++

+:Least attention +++:Steady attention:; ++: Normal attention, ++++: Special attention .

* if necessary

4.11.2 Schematic corridor diagram representing the flow of information system in a socio-cognitive frame work for the effective implementation of the proposed pest control module

Continuous monitoring and fine tuning of the system are essential to maximize the benefit from the recommended cultivation modules (CMs). Success of the recommended CMs further depends on the perception of the farmers, interloping of the working machinery and time bound adoption of the components as presented in the following corridor diagram:

Primary components	Action pathway	Schematic relation between the paths	Socio-cognitive frame works
Basic survey phase	Identification and subsequent specification of the key pest(s) prevailing in the area		Structural components for knowledge generation.
	Estimation of pest level in relation to the meteorological conditions by conducting basic survey work at the locality		
	Identification of the nature and extent of infestation of different pests in relation to the growth stages of paddy		
Definition phase	Determination of the pest levels by adopting standard insect sampling techniques and accordingly switching to the appropriate pest threshold level as below		Measurement of the generated knowledge, attitude and perception (KAP) regarding cultivation process.
	Permissible threshold: No special control measures except daily supervision is required as the pest is below the threshold level		
	Functional threshold: The species is going to attain the pest status hence an immediate adoption of the functional system of the insect protection protocol is required		
	Action threshold: The pest is at the economic injury level and required immediate action to check the pest		
	Battle threshold: The pest is above the ETL hence requires steady pest monitoring with effective pesticidal input.		

Contd...

	Action pathway	Schematic relation between the paths	Socio-cognitive frame works
	Switching on to controlling measures		Purposeful application of knowledge with positive attitude for future perception.
	Gearing up of the decision making system to select pest control protocol		
	Choosing of appropriate protocol ***Prophylactic***: Crop rotation, weeding, light trapping. fertilizer and water stress management ***Corrective***: Pesticide application, spacing, adjustment of the time of plantation, stubble management		Negotiation, group formation and leader selection.
	Selection of control option(s) from a particular category of CMs		
	Evaluation of result of each of the control protocols consisting of batches of application options in relation to yield attributes	+/-	
Schedule fixation stage	Fixing up of a particular protection system in consideration of pest(s), agro-ecological conditions and the cost effectivity		Application of the protocol at community level by the establishment of farmers field school and through the *Krishi Projukti Sahayak*(KPS)
	Percolation of the best protectional system to the farmers through a technology transfer model and to expedite the highest benefit with proper application of KAP system	+/-	
	Continuous feed back with a diagnostic attitude to quantify the major pests, key pest status, specific pest : defender ratio, changeable value of ETL, multiple crop loss assessment, damage rating and determination of multiple pest damage thresholds to run the system at a steady state		

Contd...

Key to the symbols

Symbol	Meaning
■	Integration of variables
⟶	Direction of flow of variables
▲	Valves in a flow, indicating decision making system.
-●-	Constant parameters
●	Intermediate variables
+/-	Positive or negative feed back

4.11.3 Advantages of the proposed CMs: Farmers are the instruments in the conventional 'top-down' agricultural system. The suggested CM includes both simple prophylactic and corrective measures. Within a CM, farmers, extension agents and field workers can work together as equal partners, each having definite contributory role. The superiority of CM is its regional specificity in respect of the following:

Specificity in respect of cultivating crops: CMs inexpensively elaborate the 'level of control' which is set only for the abundant pests at area. Recommendation is made in due consideration of the growth stages of the cultivar Swarna *Mashuri* and the prevailing crop rotation practices. Paddy intercropping with maize renders high incidence of BPH and GM in the block Raiganj in every year. So CM8 can aptly be followed for this region.

Specificity in respect of agro-ecological conditions of an area: Heterogeneity and the spatial distribution of a pest suggest the necessity of more region specific suitable pest control strategy. The recommended protocol is agro-ecologically compatible for the area of study. However, the model can be adopted for other zones having similar environment or with suitable modifications for other situations.

Study conducted by RRI, Chinsurah (West Bengal) has shown that the mealy bug (*Brevenia rehi*) is a minor pest in Bankura district but assumed a major pest status in district Purulia. The leaf folder

(*Cnapholocrosis medinalis*) a minor pest in paddy fields of Purulia, attained a major status in Bankura. However BPH is the major pest in both the districts. Similarly, through BPH is an epidemic pest in the Disticts of Uttat Dinajpur and Dakshin Dinajpur, the rice mealy bug is negligible in these two districts.

Specificity of technology compatible to the environmental factors: During the formulation of a CM attention has been given for the judicious application of pesticides and fertilizers. Side by side regional climatic parameters and pedological heterogeneity have been duly considered. The pest profiles of the three blocks differed, though the climatic parameters were nearly the same. The extended flood prone zone with heavy clay soils having higher water holding capacity resulted in water stagnation which impeded BPH out break in Itahar.

Intermittent rainfall, fluctuating average daily temperature, high humidity and nearly the same topographic location cause GM outbreak in the districts of Uttar and Dakshin Dinajpur.

4.11.4 Assessment of efficacy of the new CMs: The relative superiority of the recommended CMs has been evaluated with the prevailing alternative pest management protocols such as natural biocontrol (NBC), need based protection (NBP) and schedule based protection (SBP). Each CM has specific entity and accordingly requires specific management strategy. Among the CMs, six have appeared the importance. Average number of pests in these under these six CMs has been considered as recommended practice (RP). Farmers who did not follow the RP have termed as non adopted farmers (NAF). NAF either followed the schedule based protection (SBP) or need based protection (NBP). The pest number from NAF plots were graphically plotted against the values of six CMs. Inter-module comparisons was further made to assess their relative superiority of the six CMs.

4.11.4.1 Impact on pest bionomics: In all the CMs the pest status was below the ETL.

Incidence of YSB

In relation to existing modules: Highest number of YSB was counted under NBC (10.6 individuals / 5 hill) at 60 DAT followed by NBP. RP scored lowest in number of YSB (Fig.4.11.1a).

Within the recommended CMs: CMs considerably checked the DH(%) at the vegetative stage (4.11 to 5.22%) as compared to NAF (12.28%). Best control was obtained in CM6 (3.92%) followed by CM2 (4.09% DH) and CM7 (4.14%). Least number of WH (%) was found under CM6 (1.98%) followed by higher order in CM2 (2.09%) and CM4 (2.17%). Thus the best control was achieved in CM6 due to the judicious application of the fertilizer at early tillering stage (Fig.4.11.1b).

Incidence of BPH

In relation to existing modules: The NBC plots showed highest number of BPH population (32.9 individuals / hill) followed by NBP (16.64 individuals / hills) and SBP (9.87 individuals / hills). While the least number was observed in case of RP (6.49 hopper / hills) (Fig.4.11.1c).

Within the recommended CMs: Mixed population of BPH and WBPH was noticed at panicle initiation stage of the crop in the proportion of 1:3. CMs reduced the hopper population effectively (12.15 to 4.04 / hill) .The CM8 appeared most effective (3.15 / hill). CM4 was evicted as the second best treatment (4.53 hoppers / hill). However NAF scored 19.25 / hill (Fig.4.11.1d).

Incidence of GM

In relation to existing modules: GM population was 3.8 and 14.1 individuals / 10 hills in case of RP and NBC at tillering stage respectively. Infestation was highest in NBC (40% SS) which was followed by NBP (32% SS). However, the highest incidence of parasitized gall (PG%) was observed in case of NBC (25%) and the least in case of SBP (4%). PG% was nearly the same in SBP and RP (Fig.4.11.1e).

With in the recommended CMs: Lowest SS% was observed under CM5 (7.21%) followed by CM2 (8.47%), the highest was scored under CM6 (11.41%). All the CMs significantly reduced the GM infestation than the NAF (42.58% SS). The CM8 was found most effective. Phorate granule at 20 DAT when applied in case of NAFs, only could control the pest satisfactorily (12.78% SS) (Fig.4.11.1f).

Incidence of PB

In relation to existing modules: Except in case of RP, no major difference in PB number was observed at late tillering stage. However at panicle initiation stage, the highest number was recorded under NBC followed by NBP. SBP and RP did not differ numerically (Fig.4.11.1g).

Within the recommended CMs:: CMs appreciably lowered the PB incidence at ripening stage (5.1to 8.4 individuals / 50 hill) when compared to the incidence in NAF (32.2 individuals / 50hill). Best control was manifested in CM5 followed in ascending order by CM4 and CM2. Accordingly least level of unfilled grains was found under CM5 followed by CM4 (Fig.4.11.1h).

4.11.4.2 Impact on natural enemies

Grossly, in all the new CMs the dynamics and number of the natural enemy population was relatively higher than the other cultivation practices (Figs.4.11.4).

Incidence of spiders

In relation to existing modules: No major differences in the dynamics were recorded in the treatments NBC and NBP. RP supported comparably low level of spiders. The population gradually increased from 10 DAT and maximized at 50 DAT after which it gradually subsumed. From 60 DAT onwards the population showed a nearly stable state in all the treatments (Fig.4.11.3a).

Within the recommended CMs: In case of CM2 the highest number of spiders (2.81 individuals/hill) was noted and the lowest was noted in case of CM7. When in CM4 and CM5 the number was in between the two but higher than in case of NAF (1.15 individuals / hill) (Fig.4.11.3b).

Incidence of bug

In relation to existing modules: A very low number of bugs was observed in SBP, RP and NBP. The bug started to appear from the very early vegetative stage, maximized at 50 DAT and then steadily declined in all the management procedures (Fig.4.11.3c).

Within the recommended CMs: The highest number of the bug was noted in CM6 and the lowest was in CM5 with 1.41 individuals / hill (Fig.4.11.3d).

Incidence of beetle

In relation to existing modules: The coccinellid predator predominated in case of RP and NBC. The lowest number was recorded for under SBC and for NBP the number was in between. With the progress of growth stage, the beetle number gradually increased, maximized at 60 DAT and then gradually declined (Fig.4.11.3e).

Inconsideration of CMs: No major differences were observed among all the CMs. CM2 supported relatively higher number of beetle from the early vegetative stage (2.8 individuals / hill) (Fig.4.11.3f).

Incidence of fly

In relation to existing modules: Relatively low number of fly was noted under SBP. However, the number differed insignificantly in other protection modules (Fig.4.11.3g).

Within the recommended CMs: In all the CMs there was no gross difference in the fly numbers (Fig.4.11.3h).

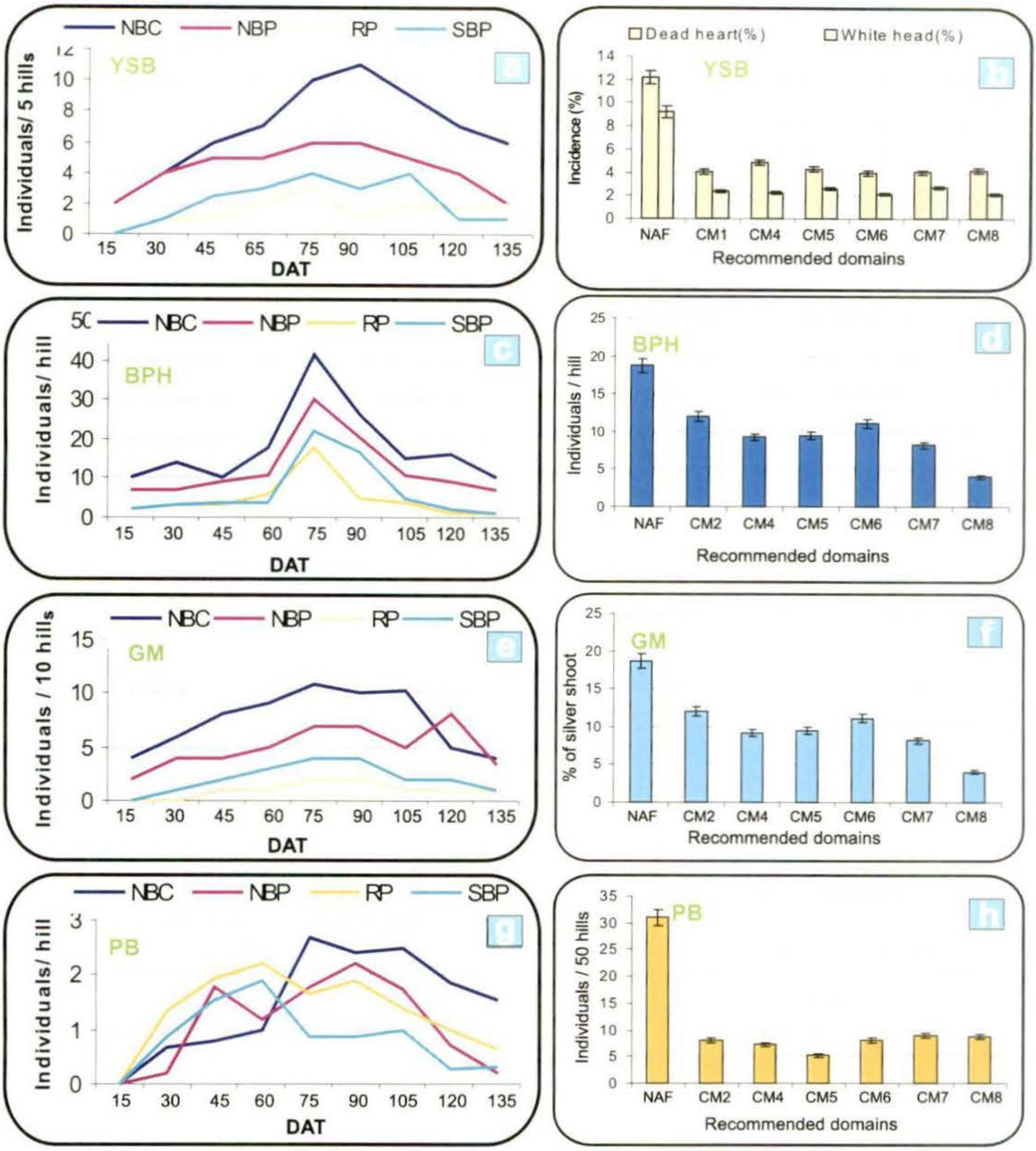


Fig. 4.11.1: Dynamics of the major pests and their consequent extent of damage under different protection schedules. a and b: and b: YSB moths and DH and WH, c and d: BPH and flag leaf area damage, e and f: GM and silver short, g and h: PB and unfilled grains.

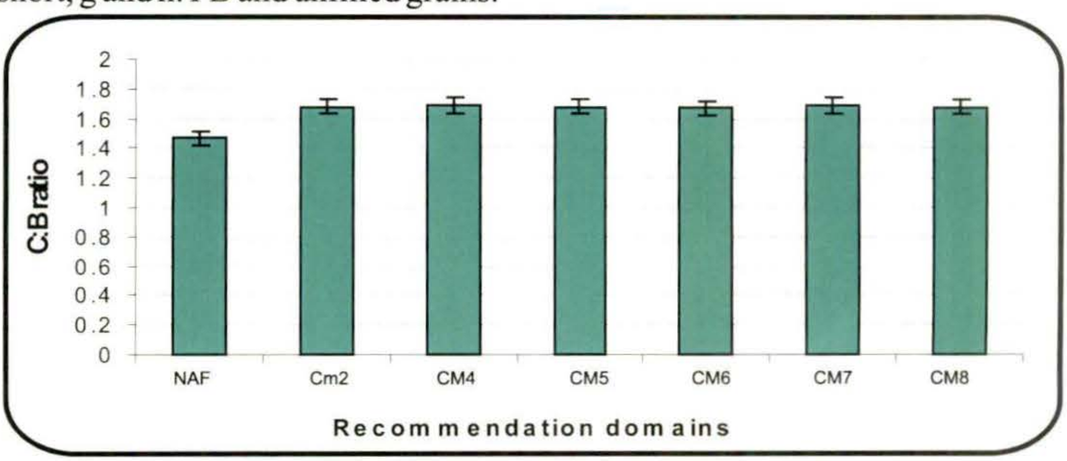


Fig. 4.11.2: Relative C:B ratios between the CMs and without adoption of any of the CMs (NAF *i.e.* Control).

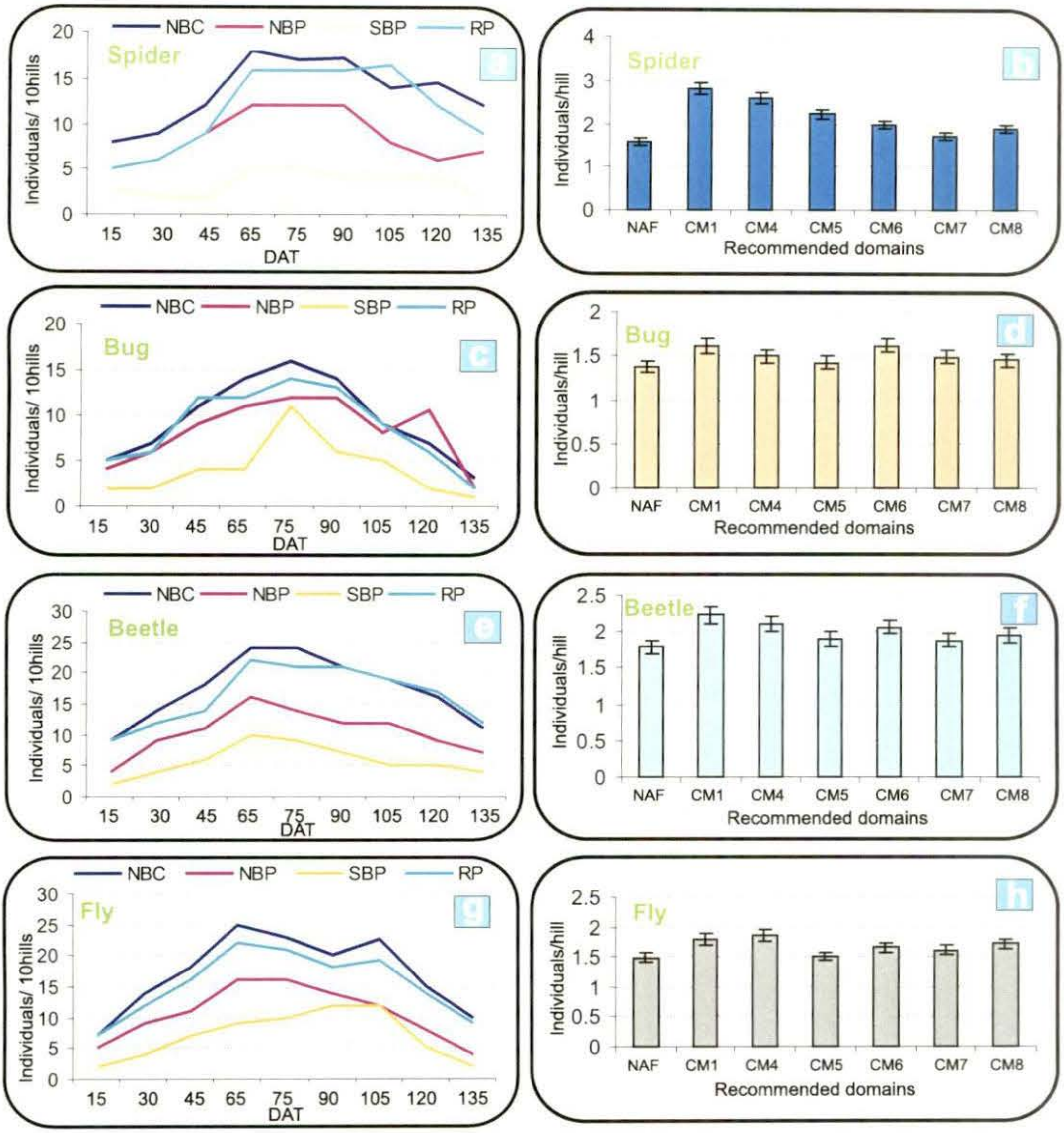


Fig. 4.11.3: Dynamic of four natural enemies under different protection schedules: a and b: Spider, c and d: Bug, e and f: Beetle, g and h: Fly.

Fig. 4.11.4: Natural enemies in the paddy fields following recommended CMs.

4.11.4.3 Impact of CMs on weed incidence

There were wide differences in weed density and biomass in the three blocks due to pedological differences.

Weed pressure

Weed density and canopy: Simply by visual measures the weed density were graded into high (H), moderate (M) and low (L) (3.8.6 in materials and methods). The densities were H, M and L in case of NBC, NBP and SBP respectively. All RP (average of all CMs) exhibited L. CM4 exhibited 'excellent' (very poor density) while the other CMs showed 'good' (low density) canopy pattern.

Table.4.11.13: Impact of weed incidence species composition and weed pressure.

Activity of weed	Protection types								
	NBC	NBP	SBP	CM					
				CM2	CM4	CM5	CM6	CM7	CM8
Density	H	M	L	L	L	L	L	L	L
Canopy	H	S	L (F)	L (G)	L (G)	L (E)	L (E)	L (E)	L (E)
Biomass	44.78 ± 6.98	16.61 ±3.85	12.28 ±2.73	10.41 ±2.33	9.98 ±1.78	10.61 ±2.11	11.21 ±3.13	11.21 ±2.68	9.37 ±2.43

H: high, M: moderate, L: low, G: good, E: excellent, P: poor

Weed biomass: Weed biomass was relatively low under all the CMs. But, weed dry matter / unit area was generally high at reproductive stage of paddy as compared to that at vegetative stages. At all the CMs average biomass was about 21.11, but in case of NBC, it was 70.42 gm / mt^2 biomass (Tables.4.12.13 and 4.12.14).

Weed control efficiency: The efficiency was best in case of the CMs, lowest under NBP and of intermediate nature in case of SBP.

Fig.4.11.5: Grain characteristics under different recommended CMs and existing other alternative pest control practices.

Table.4.11.14: Weed density biomass recorded for different treatments

Blocks	Types of control	Growth stages of paddy.				Weeding status (No weed denotes 100 percent weeding)	
		At tillering		At reproductive		Tillering	Reproductive
		No / mt^2	Mass gm / mt^2	No / mt^2	Mass gm / mt^2		
Raiganj.	NBC	32.41 (5.73)	44.78 (6.72)	23.32 (4.88)	41.61 (6.48)	NA	NA
	NBP	15.92 (4.05)	25.37 (5.08)	13.21 (3.70)	23.41 (4.88)	33.74	42.71
	SBP	11.21 (3.42)	19.98 (4.52)	09.78 (3.20)	16.31 (4.10)	69.71	54.72
	RP	09.53 (3.16)	11.91 (3.52)	12.80 (3.64)	15.11 (3.95)	73.14	81.11
Hemtabad.	NBC	33.72 (5.84)	86.21 (9.31)	72.37 (8.53)	100.32 (10.04)	NA	NA
	NBP	16.61 (4.13)	52.32 (7.26)	50.21 (7.12)	69.32 (8.35)	34.81	49.11
	SBP	12.27 (3.57)	41.21 (6.45)	32.11 5.71	49.79 (7.09)	71.23	56.11
	RP	10.41 (3.30)	36.72 (6.10)	14.20 (3.83)	39.31 (6.30)	75.24	84.52
Itahar.	NBC	28.61 (5.39)	80.27 (8.980	47.11 (6.91)	93.20 (9.67)	NA	NA
	NBP	23.80 (4.92)	24.31 (4.98)	42.31 (6.54)	41.61 (6.48)	31.11	44.31
	SBP	12.21 (3.560	14.71 (3.90)	26.37 (5.18)	30.21 (5.54)	65.71	58.24
	RP	10.21 (3.27)	12.41 (3.59)	18.31 (4.33)	16.72 (4.14)	72.21	75.62
LSD at 5 %		3.48	04.71	04.71	04.36	31.90	NA
		22.31	14.36	14.36	12.92	06.74	NA

Figure in parentheses are square root transformed value

NA: not applicable

4.11.4.4 Yield and cost effectivity: SBP and NBP yielded 32.7 and 29.5 q / ha respectively. The lowest yield was obtained under NBC. Compared with that of SBP the yield was higher in RP. Furthermore, RP resulted in better cost: benefit value among all the treatments. Mean yield in all the CMs was 33.9 q / ha. C:B value was 1:1.66 in RP and 1:1.54 in SBP. CMs resulted in seasonal 12% profit increase due to 5-9 % yield increased. The costs of labour and pesticides decreased due to CMs by about 6 % and 75 % respectively (Fig.4.11.2 and Table 4.11.15).Grain quality also differed considerably (Fig. 4.11.5).

Table.4.11.15 Comparative study on the cost effectivity/bigha of the present recommended practice with other available practices

Block	Type of control	Total input in terms of cost / bigha							Seed+ Labour+ Transport +Irrigation (c)	Total Expenditure C= a+b+c	Yield/benefit/bigha (B)			Benefit Ratio C:B
		Fertilizer			Chemicals									
		Organic	In organic	Cost (a)	Insecticide	Herbicide	Fungicide	Cost (b)			Paddy	Straw	Total	
Raiganj	NBC	300	180	480	x	x	x	x	1200	1680	1868	300	2168	1:1.29
	NBP	300	180	480	80	40	25	145	1200	1825	2324	400	2774	1:1.52
	SBP	300	180	480	80	35	25	140	1280	1900	2633	350	2983	1:1.57
	RP	325	170	495	20	10	09	39	1180	1714	2428	300	2778	1: 1.62
Hemtabad	NBC	200	220	420	x	x	x	x	1200	1620	1839	300	2139	1:1.32
	NBP	200	240	440	85	40	25	145	1200	1785	2116	400	2516	1:1.41
	SBP	200	180	380	85	35	30	150	1200	1730	2314	350	2664	1:1.54
	RPM	200	180	380	25	30	12	67	1180	1627	2433	300	2733	1:1.68
Itahar	NBC	400	180	580	x	x	x	x	1200	1780	2174	300	2474	1:1.39
	NBP	400	200	600	80	40	25	145	1200	1945	2381	400	2781	1:1.43
	SBP	400	190	590	75	35	25	135	1280	2005	2818	350	3168	1:158
	RP	400	165	565	20	10	09	39	1180	1784	2643	300	2943	1:1.65

(X): Not applicable. 1 hectare = 7.5 bigha

4.11.5 Acceptability of the recommended cultivation module (CMs)

Farmers responded variably to the recommended CMs. In order to assess the superiority and acceptability of the recommended modules, farmers were divided in two batches, trial (positive) and non-trial (negative) groups, 25 farmers in each group. Only 20% farmers of the trial group could successfully perform the weeding. The recommended hill spacing and fertilizer use was followed by only 37% and 6% farmers respectively. However 94% adopted the suggested land preparation techniques. The trained farmers (positive group) preferred to follow the CMs meticulously.

At the initial stage, both trial and non trial groups obtained nearly the same quantity of paddy. During demonstration in 2007 for the first *kharif* crop, the yield was low among the trial group. During the first *boro* crop in 2007, however, the yield of the trial group increased marginally. The highest production was obtained only after the second trial. However, in all the cases production of non-trial (negative) group the production increased noticeably after minimizing the quantity of pesticide due to diffusion of knowledge in them from the success of trial groups. Thus, the negative group gradually adopted the SBP protocol. So the effect of the newly recommended CM caused the gradual shift of the anti-IPM practices to the pro-IPM practices.

In some Asian countries, the yield / unit land was increased by 2.46 - 25 % after observing IPM, pesticide cost was reduced by 27 - 86%, and C:B from 1:2.2 to1:2.7 (FAO 1996). Yerriswamy (2001) studied the paddy production under both highly-intensive agricultural system (HIAS) and semi-intensive agricultural system (SIAS) in Tungabhadra Project area (1997-98), Karnataka, and found that the expenditure on fertilizers and plant protection chemicals was lowered under ancient irrigated agricultural system (AIAS).

4.11.6 Short comings of the local model and future directions: The present recommended '*area-specific*' cultivation management or '*precision farming*' compensates the shortcomings of the 'National protocols' and protect environment by rationalizing of the chemical inputs. Such programme, at its initial step, may become more cost efficient for recruitment of the trained persons, field trials and for the improved understanding of target pest and enemy dynamics and continuous fruitful monitoring over a wide area. Present *site-specific* village level farming involves the measurement and analysis of *within-field* yield variability only to the variety Swarna *Mashuri* (MTU 7029) and targetting the four major insect pests. But the future trials may focus on multiple pest constraints on all the cultivars by '*computer based monitoring system*' that will help the decision makers of the district to evolve the appropriate cultivation strategy, based on the following objectives and hypothesis:

Objectives	Hypothesis
1. To test other promising paddy varieties in due consideration of the pest attack in the remaining 6 blocks of the district Uttar Dinajpur having different agro-ecological conditions	**a.** Often the results obtained in on station evaluation of paddy varieties are not reproducible in the farmers' field conditions since the actual constraints relating to the pest deterioration may not be reflected. Hence in each occasion the causes of yield gap should be analyzed
2.To analyze farmers' perception on the acceptability of the local and high yielding varieties	**b.** Farmers perception needs to be assessed for the introduction of new varieties suited to the area, so that the yield of paddy be substantially increase and their living condition be uplifted
3. To expedite regional inter state flow of promising local paddy varieties having higher adaptability for the proliferation of genetic resources.	**c.** The extension of promising varieties across the regions and the states is essential to realize there adaptability and acceptability with a conscious mind to minimize the migratory pest attack.

Contd....

Objectives	**Hypothesis**
4. To verify and refine the *area-specific* technology packages in other districts of West Bengal for the gradual improvement of eco-friendly production of paddy with minimum input of pesticides and application of inorganic N fertilizers.	**d.** Unless research is carried out on area basis for deciphering the problems after using farmers participatory methods, optimum management packages reflecting the ETL of different pests having regional importance cannot be worked out .
5. To exploit the production potential of the varieties after applying ecologically improved upgraded agro technology along with local cultivation protocols for realizing the maximum yield with low pest infestation.	**e.** Farmers may not be aware of the improve agro technology, scientific cultivation protocols specific to the promising varieties and the minimum but timely pesticide input to maximize the yield. Hence evaluation of KAP of farmers and requisite trainings will have to be adopted.

4.12 Knowledge, Attitude and Perception (KAP) of Farmers and Success of IPM

Limited success of the District level IPM programme is due to the poor response among the farmers which requires an evaluation of their knowledge, attitude and perception to cope up with suitable cultivation strategies. Adoption of prescribed schedule includes time-bound, integrated and adequate cultivation and pest control practices. A coordinated and well articulated adoption of IPM programme is the prime requisite to manage paddy pests in the District Uttar Dinajpur.

4.12.1 Existing cultural control methods: Different cultural procedures either singly or in combinations are in practice by the farmers in the three blocks (Fig.4.12.1).

In Raiganj: 67% farmers rely upon handpicking or sweep net catching of pests. Trimming the tips of seedlings before transplantation is practiced by only about 15%.Use of light traps is very infrequent; season dependent and only about 6% farmers have adopted it. Placing alternative food resources in the fields for pests is almost nil. More than 75% farmers rely on the lucky planting dates while about 34% farmers trust on spiritual praying. Transplantation of young seedlings is done by only about 15% and about 10% relied on suggested planting dates. Water stress management is followed by about 13% farmers. About 52% farmers remove weeds from field periodically. Uses of trap crops are rare phenomenon.

In Hemtabad: About 72% rely on handpicking or sweep netting. Cutting of seedling tips is followed by only about 9% farmers. Use of light traps is very occasional and installed by about 9% farmers. Use of alternative food resource of insects is uncommon. More than 68% farmers rely on the lucky planting dates while 28% prayed to God for good yield. Transplantation with young seedlings is followed by only about 18% and 16% trust on proper planting dates. Alternative flooding and draining of the field is followed by only 17% farmers. Periodic weeding is done by about 42%.Use of trap crops is monitored by about 3% farmers.

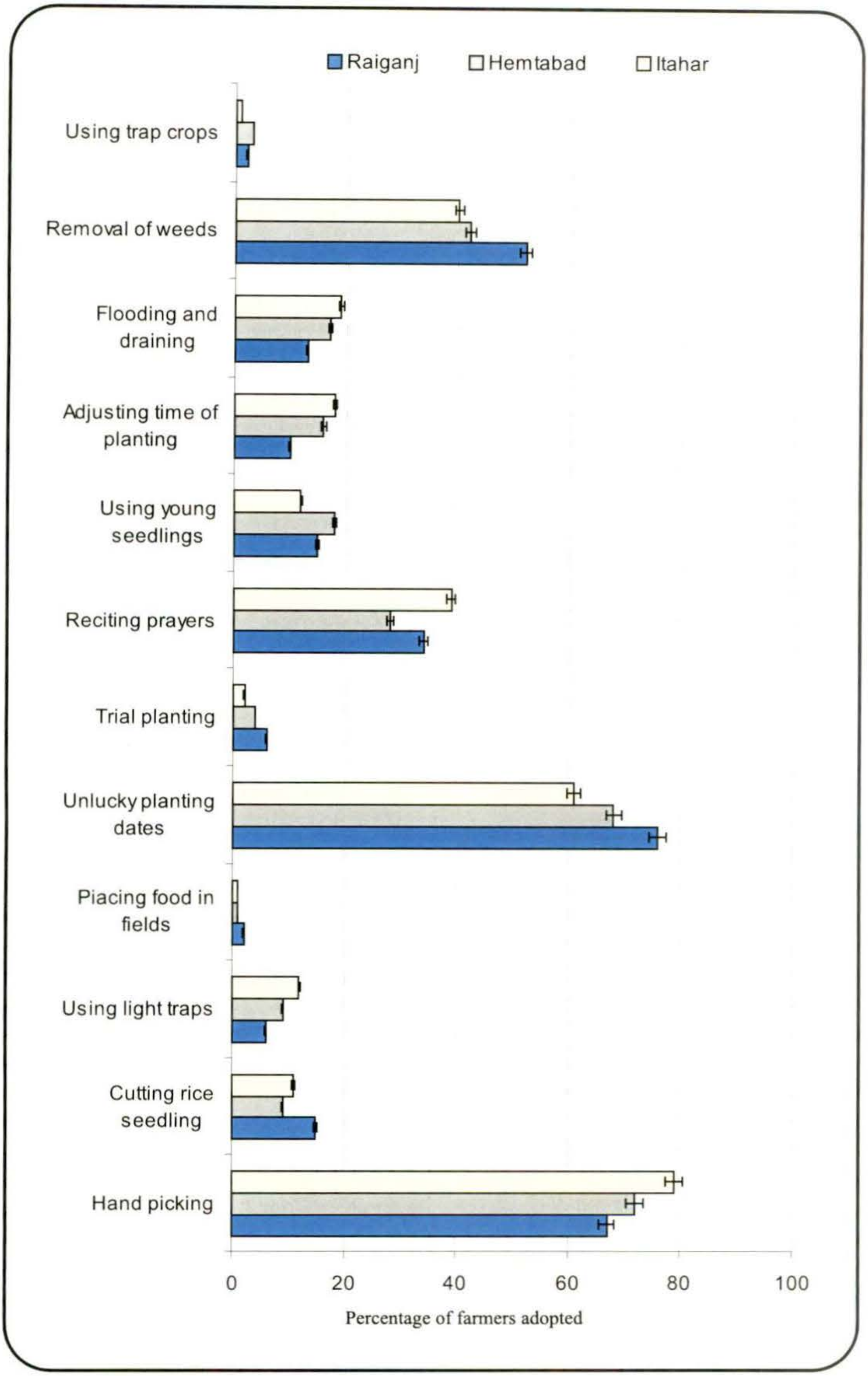


Fig. 4.12.1: Pattern of exiting cultural control methods in the three blocks.

In Itahar: Approximately 79% rely on handpicking or sweep netting. Trimming of seedling tips during transplantation is followed by only 11% farmers. Use of light traps is very occasional and season specific and practised by 12% farmers. Use of alternative food sources is almost none. More than 61% farmers avoid the unlucky planting dates while about 39% farmers resided players. Young seedlings are transplanted by only 12% farmers while 18% observe proper planting dates. Alternate stagnation and draining in the fields are followed by 19% farmers. Weeds are periodically removed by about 50%. A use of insect trap crops is meager, only about 1% farmers have been found to do so.

4.12.2 Evaluation of farmers' knowledge

Farmers having different educational background was interviewed against the prepared questionnaire relating to different cultivation tools and the responses are graphically plotted (Fig.4.12.2f).

Knowledge on pesticides (Fig 4.12.2a)

In Raiganj: 25% farmers select pesticide on the basis of its physical characters such as dust, granules, and liquids, but chemical composition is considered only by 4% farmers. Only 4% are able to account for the mode of action of pesticides. Less than 3% farmers know the proper precautions to be adopted during application of pesticides. 5% of the farmers have the idea of hazardous effect of the pesticides.

In Hemtabad: 29% farmers select pesticide based on its physical characters. Chemical ingredient is considered only by 2% farmers. Mode of pesticide action is known by only 3%. Less than 5% farmers know the proper safety measures to be adopted during application.7% of the farmers are aware of harmful effect of the pesticides.

In Itahar: 21% farmers select pesticide based on its physical character while 3% farmers rely on its chemical component. Only 5% can state the mode of pesticide action. Less than 4% farmers are acquainted with the pesticidal precautions while 7% know the hazardous effect of the pesticides.

Knowledge on the field pests (Fig.4.12.2b)

In Raiganj: About 53% of the farmers know the common or local names of the pests while only 20% could identify them. Only about 9% are able to cite the name. 16% farmers are able to enumerate the name of the paddy varieties, and only about 2% are aware of their resistance against the pest attack.

In Hemtabad: About 40% of the farmers know the names of the pests commonly occurring in the field. But only 14% are able to recognize them while 7% farmers were able to identify by name. Only 22% farmers are aware of the high yielding varieties of paddy but the actual scientific cause of their resistance is known to 3% farmers only.

In Itahar: About 32% are able to name the pests commonly occurring in the field but only 9% can recognize the pests. 5% farmers can identify the pests with their names. About 14% farmers can enlist the paddy varieties but only 4% know the actual causes of resistance of a variety.

Assessment of actual level of DH and WH in the fields (Fig.4.12.2c)

Pre school (no schooling): Only 7% farmers can asses the actual quantum of the DH(%) and WH(%) in the field. But their estimation differs, over estimate by 8 % and low estimate by 5% farmers. Both over and lower estimate differ by 10-15% farmers.

School: Only 13% could account for the actual field level of DH and WH. Results differ by over estimate of 10-15% lower estimate by 10-15%.

Post school: Only 22% farmers are able to estimate the quantum of DH and WH rightly. Most of the farmers either over estimate or under estimate. The range of both over estimation and underestimation differ by 10-15%. The remaining farmers are non-respondent.

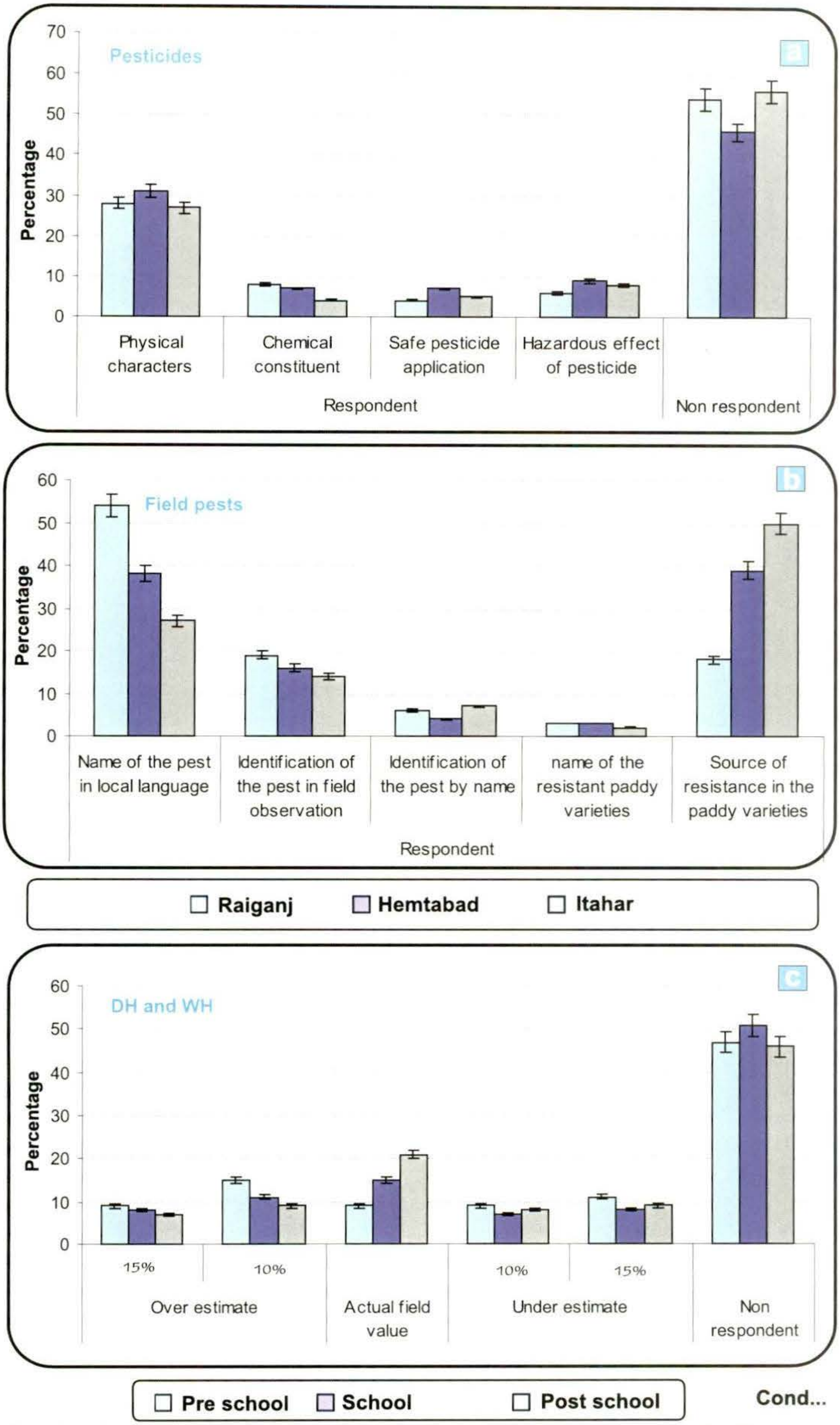


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Fig. 4.12.2: Evaluation of farmer's knowledge. a: Knowledge on fertilizers and pesticides, b: Knowledge on field pests, c: Assessment of actual level of DH and WH.

Assessments of actual level (%) of silver shoot in the fields (Fig.4.12.2d)

Pre school (no schooling): Not more than 5 % of the farmer can estimate the real value of SS (%) at the field level. Most of the farmers either over score or under score the actual count. Such wrong counts differ between 10 and 15%.

School: Nearly 12 % farmers can count the actual field level of SS(%). The count is either overestimated or underestimated by 10-15% than the actual value.

Post school: Only 22% farmers have the ability to count the SS(%) perfectly. They either over count or undercount from the actual. Such differences range between 10 and 15%.

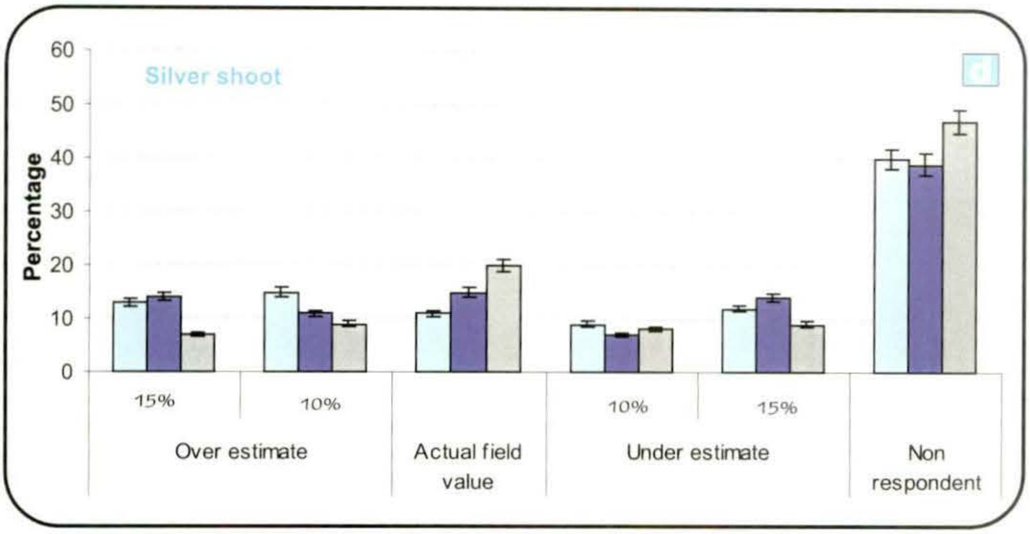
Field knowledge regarding the natural enemy (Fig.4.12.2e)

Pre school (no schooling): Only 9% farmers can recognize the natural enemies but only 4% know their beneficial role and only 1 % is able to identify the enemies with their name.

School: About 11 % are able to identify the natural enemies but only 4% are aware of their beneficial role while 2% can identify them by name.

Post school: Only 12 % farmers can recognize the natural enemies, not more than 4% have the idea of their beneficial role and only 2 % can identify them with name.

Discussion: Based on the data collected from 58 small, 33 medium and 9 big farms in the District of Midnapur,West Bengal Jana *et al.* (2000) classified the farmers into three categories: Pre-school (no schooling),school and post school. The knowledge of the farmers on the management of insect pests of crops was assessed. The authors observed that the said knowledge of all the three categories was of medium level irrespective of their socioeconomic status, extension contact, mass media exposure, level of education and social participation of the families.



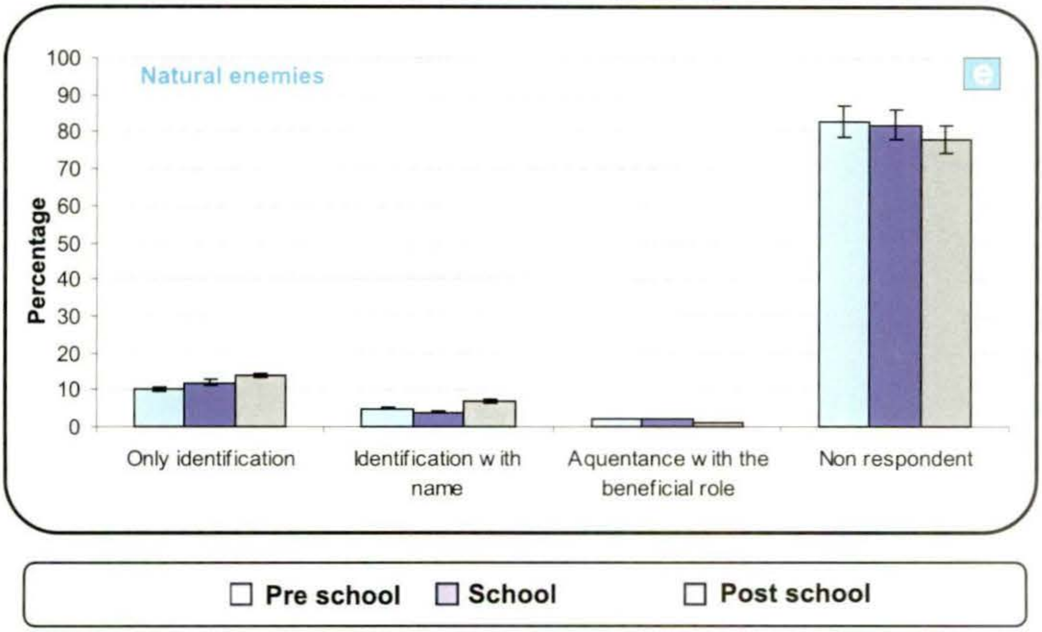


Fig. 4.12.2: d: Assessment of actual level of silver shoot, e: Field knowledge regarding natural enemies, f: Farmers are engaging to evaluated the actual field level of silver shoot.

Differences in the status of knowledge relating to the management of insect pests among the farmers are obstacles to the adoption of proper plant protection measures.

It is thus suggested that the government officials, NGOs and the extension agencies need to follow a systematic, well-planned and coordinated approach for improving the knowledge status of farmers, especially those are in the pre school category.

4.12.3 Evaluation of farmers' attitude

Fifty farmers of each of the categories of educational background were interviewed with a questionnaire relating to the required dose of pesticides depending on the status of pest infestation. The data obtained were graphically plotted (4.12.3c).

Regarding application of pesticides (Fig.4.12.3a)

Pre school (no schooling): Only 9% have the idea of actual requirement. Most of the farmers either over estimate or under estimate the requirement. The range of both the faulty estimates stands between 10 and 15 % of the actual requirement. Both are harmful. Overestimate cause environmental toxicity. Under estimate induces the development of resistance by the pests.

School: Only 12% could state the required dose. Most of the farmers either overestimate or underestimate the requirement. The over estimate and under estimate differ between 10 and 15%.

Post school: Only 16% of the farmers have the knowledge of actual requirements. They either over estimate or underestimate. The range of such wrong estimation differs between 10 and 15%.

Growth stage dependant appropriate selection and application of pesticide are crucial to check the pest outbreak under KAP improvement programme. Application of sub-lethal dose of pesticides accelerates resurgence of BPH, necessitating higher input of pesticides for crop protection. Higher doses exert detrimental effect to the natural enemy and accumulate in the yield and environment.

Regarding the appropriate doses of fertilizer (Fig.4.12.3b)

Pre school (no schooling): 13% could account the actual required dose of fertilizer. The farmers either overestimate or under estimate the actual requirements. The range of wrong estimation differs between 10 and 15%.

School: Only 12% of the farmers have the idea of fertilizer. Mostly either overestimate or under estimate the actual requirements. The range of wrong estimations differs between 10 and 15%.

Post School: Among the farmers only 9% can measure the required dose of fertilizer. Most of them either overestimate or under estimate the requirement. The range of wrong estimations differs from 10-15%.

Discussion: The prime component of modern IPM is to assess before hand the pattern of prevailing cultural protocols commonly practised by the farmers and their consequent impact. Accordingly modification, alteration or addition to the prevailing system are to be evolved by a systematic study (Jana *et al.* 2002). Hand picking is time consuming and may be prove best in all times (Silva *et al.* 2005), light trapping to assess the pest occurrence draw very little attention (Degallier *et al.* 2004, Chen *et al.* 2005). A befitting alternative set of practices for a locality causes an abrupt change to the microclimatic environment that may restrict the pest activity such as observed in case of YSB and BPH incidence (Feng *et al.* 2001).

Improved educational programmes focused on pest controls are being observed in developing countries (Mengech *et al.* 1995, Koul *et al.* 2004). Plant clinics designed to educate farmers about pest biology, identification and appropriate controls have gained momentum. Accurate pest identification, reasonable estimates of potential damage and determination of appropriate control have given in the 'tool box' of alternatives (CAST 2004). Many pest problems such as of BPH require historical data rather than real-time samples. Information about the pest, variety of the paddy, and short/long term consequences of different pest control options is given priority under KAP value programme (Horn 1988). Maredia (2003) has explained that such fundamental knowledge base is closely aligned with progress towards more ecologically based crop management. The Farmer field school (FFS) approach was introduced in Indonesia in 1989 for disseminating IPM technology among the rice growers (Van de Fliert 1993). Studies conducted in South East Asia claims that pesticide application has decreased with more IPM knowledge and FFS training with the production increase up to 25%. Generated idea of FFS can be transmitted to the farmers by Local Agricultural Research Committee (CIAL) (Roger 2003).

The prime constituent of current IPM is to review the existing cultural protocols commonly practised by the farmers and their resultant impact. Accordingly alteration, adjustment or addition of newly suggested methodology was done.

4.12.4 Evaluation of perception

The success of an IPM programme depends upon adoptability of the evolved cultivation protocol by the farmers. Farmers who do not follow the protocol are called 'spoiler holdouts' which may weaken the success of a programme. Besides, some farmers may 'free-ride' and thus hampering the allotted programme to a group of farmers. To overcome 'spoiler holdouts' and 'free riders', it may be essential to enforce a schedule upon an unwilling minority.

Comparative analysis of the perception of the farmers to the recommended protocol

Regarding the rate of the application of the pesticide: The adopted farmers or the positive group (who participated in the training)of farmers before the training applied 70% pesticide, it was reduced up to 30%, two seasons after the training. The negative groups (who did not participate in training) applied nearly 90% pesticide, after the training restricted the application to 50%. The expenditure for pest control was accordingly reduced. During the training period both the groups of farmer showed a positive attitude for reduction of the pesticide use as nearly 60% of the positive and 78% of the negative group relied on the pesticide application. One season after the completion of training in both the groups of farmers a steady decrease of pesticide use was noted (Fig.4.12.4a and b).

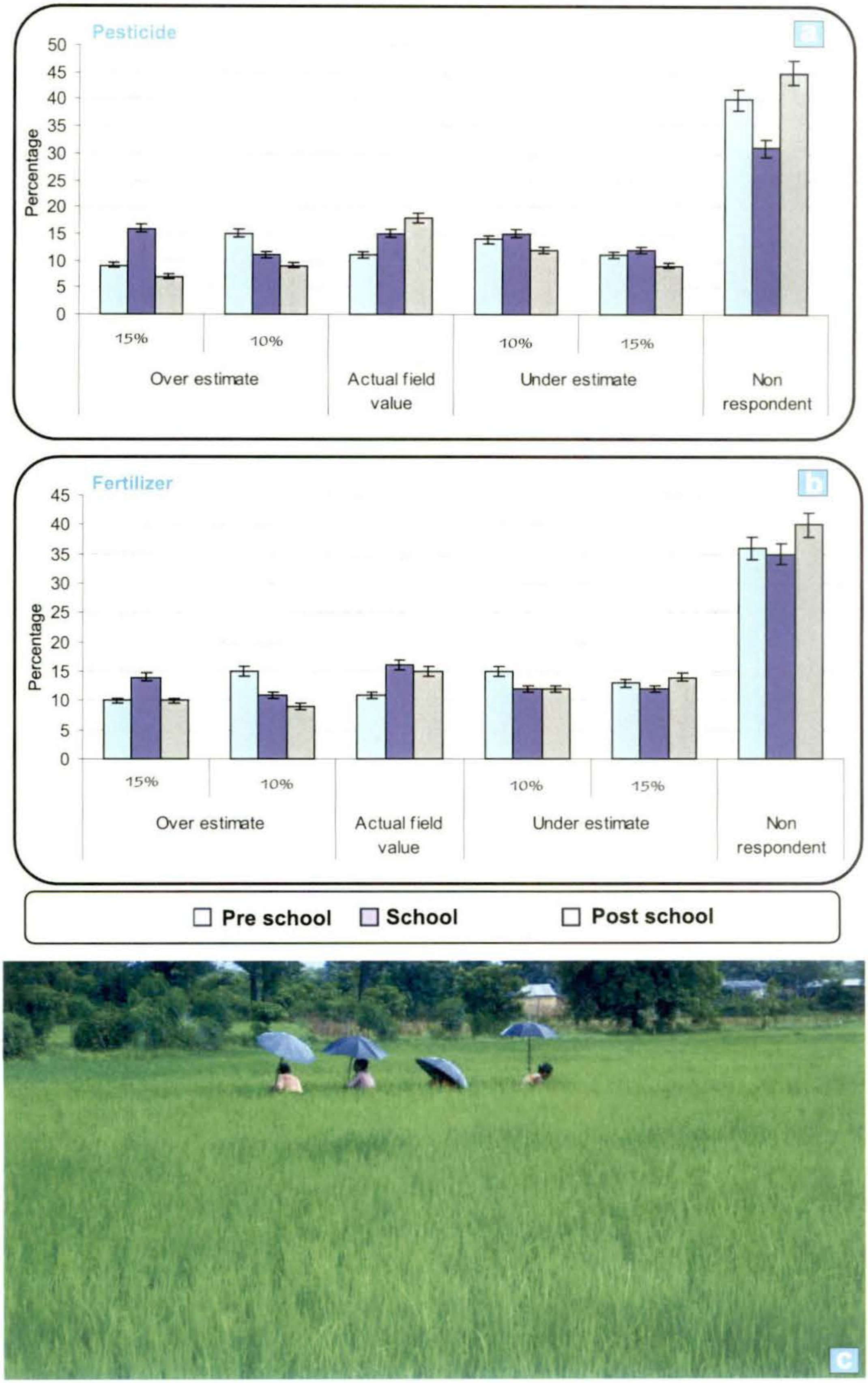


Fig. 4.12.3: Evaluation of farmers attitudes a: Regarding application of pesticides, b: Regarding appropriate dose of fertilizer, c: Farmers are engaging to determine the required dose of fertilizer.

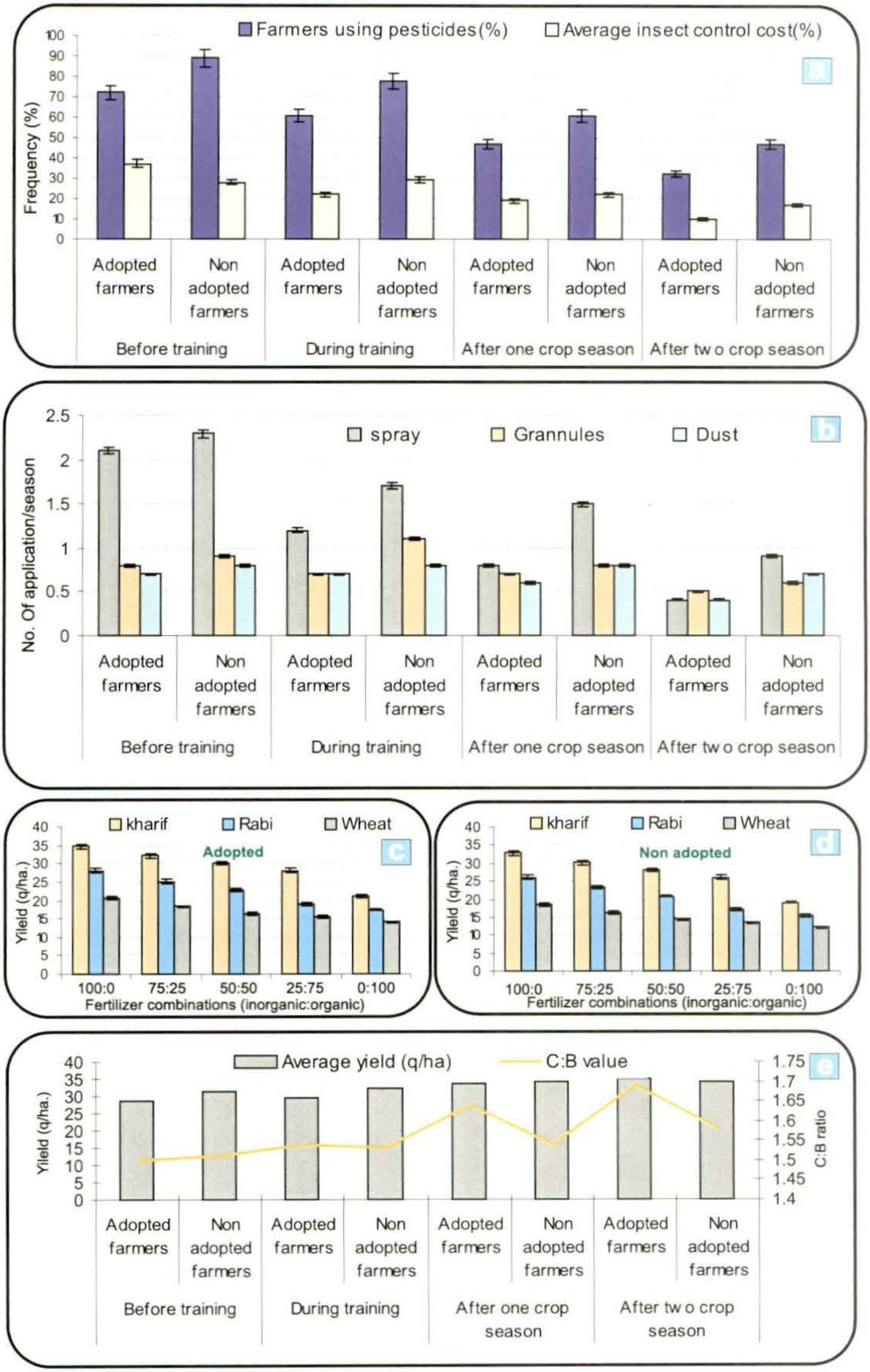


Fig. 4.12.4: Comparative analysis of the perception of the farmers to the recommended protocol a: Regarding the rate of application of the pesticides, b & c: Regarding the yield attributes under proportional application of fertilizer, d: Regarding the quantfication of the yield.

Regarding the yield attributes under proportional application of fertilizer: Perceptual knowledge of farmers to the CM was tested in a paddy-wheat crop rotation system with 5 different proportions of organic and inorganic fertilizers. Highest yield was obtained with completely inorganic input and the least with completely organic input. Non-trained farmers with the exclusive use of inorganics obtained the yield nearly the same like that in case of trained farmers who applied inorganic: organic =75:25, the yield was better. But the non-trained farmers could produce the yield lower than that of trained farmers even after using the same proportion of fertilizers This happened because of lack of knowledge among the non-trained farmers due to lack of exposure for fertilizer application in proper time of a particular growth stage of paddy (Fig.4.12.4b.c and d).

The farmers, who adopted the IPM schedule, reduced pesticide application and relied more on the organics after the training than non-IPM groups. Results thus indicate that educational approaches are preferred for dealing with effectiveness of pesticide management regulations.

Regarding the quantification of the yield: The suggested CMs were tested on a batch of 50 farmers. The relative ability of the farmers to execute the module before, during and after training was assessed in relation to average final yield and cost effectivity (Fig.4.12.4e).

No basic differences were found before their training. The trained farmers (adopted group) obtained slightly higher quantity of yield probably due to the higher perception of the cultivation techniques. During the training programme a steady fall in the yield in case of adopted farmer was observed. Although non-adopted farmers maintained comparatively higher production rate. But for both the groups of farmers an increase of C: B value was observed. After successful completion of training although the yield of adopted farmers remained unaltered like the training period but their C:B value increased. In case of non adopted farmers the yield was slightly lower than the training period but C:B value had improved .

Farmers require time to fully acquaint with and accustomed to the newly recommended technique for at least two seasons. So a boost in the production and cost effectivity were observed after two seasons. Increase in the production and cost effectivity for non trained group of farmers was due to the percolation and transmission of knowledge from trained to non trained groups. Such training programme could be administered through the farmer field school (FFS) and by the field demonstration.

Nurzaman *et al.* (2000) randomly collected data from 120 farmers, 60 out of them were trained in Farmers' Field Schools (FFS) while the remaining 60 were non-FFS. Practice of IPM by the farmers was considered as the dependent variable. 60% of FFS farmers had medium practice, 28% had high practice, and 12% had low practice of IPM, while 57% of the non-FFS farmers had low practice and 43% had medium practice of IPM. Education, family size, organizational participation, cosmopoliteness, extension contact and agricultural knowledge had significant relationship with proper practice of IPM in the case of FFS farmers. Only extension contact and innovativeness correlated with the practice of IPM among non-FFS farmers.

Steady increase in both production and C:B value was only observed for both trained and non trained farmers only after two crop seasons. Steady reduction of the productivity during the training and subsequent first crop season was due to the reliance on the organics and side by side reduced application of pesticide and inorganic fertilizers.

4.12.5 Shifting paradigm

The Changes in the view of the farmers after the adoption of CMs was evaluated with a questionnaire for determining the KAP value (%) which shows the departure from the previous myth (Table.4.12.1).50 farmers were questioned and the persons who responded positively were taken as KAP value.

Table.4.12.1: Assessed KAP value of the farmers after training and adoption of CMs

Previous myths	Present realities	KAP value (%)
Pests can be controlled only by mass killing after using pesticides of different brands	Application of pesticide is only a curative attempt rather than a preventive success.	57
All insects in the field are pests so the applications of the pesticides are beneficially detrimental to all of the pests	Rampant application destroys the natural enemies of the pests also, imbalances the eco system and thus the pesticide-resistant pests take over	62
No relationship exist between the practice of mono-culture and pest incidence	Mono-cropping over large contiguous areas reduce genetic base of paddy which results in an unobstructed proliferation of the pests	51
Rampant application of nitrogenous chemical fertilizers and pest incidence are not related	Dynamics and the intensity of the pests are intermingled with land fertility and applied doses of nitrogen.	63
Prevention of pest incidence is to spray pesticides even when the pest is not present	Pesticide protection as a preventive measure can be adopted only when the pest threshold level crosses the economic status	46
Adoption of newer brands of pesticides, fertilizer and HYV's are the major objective to control pest population.	Manipulation and integration of the appropriate cultural practices can effectively control the field pest population	39
The benefits obtained due to the application of the different brands of newer pesticides outweigh the risks	Detrimental effect of pesticide is extended even after the crop harvesting, basically depending on the spectrum of toxicity.	51
The cultivation practices like water stress management, tillage, sowing dates, weeding, are in no way related to the subsequent unmanageable pest insurgence/resurgence	All the processes individually or collectively influence the field pest level, hence each factor should be duly considered.	69
Higher the input of inorganic fertilizer, greater would be the yield generation; hence it is essentially inevitable to use high quantity of inorganic fertilizer to maximize the yield.	Same amount of yield can be generated by the combinational application of organic and inorganic fertilizer. Furthermore, higher the application of inorganic fertilizer greater would be the pest intensity inducing comparatively higher range of damage.	52

Success of the recommended IPM programme depends on the KAP performance as farmers having different educational background response variably to the CMs. Continuous monitoring and fine tuning of the programme is only possible through the execution of the establishment of IPM schools and the periodic effective field demonstration by the trained agricultural officials to the farmers.