CHAPTER TWO

Review of Literature

2.1. Prevalence and Status of Major Insect Pests of Paddy

The countries of South East Asia are famous for paddy production. After the introduction of high yielding varieties of paddy, the problem of insect pest infestation has become a serious concern for their management. Not all the insect pests are equally prevalent in all the countries .The prevalence of several major insect pests of paddy is furnished in the table 2.1.1.

Table 2.1.1:Prevalence of paddy pests in different countries of South East Asia

Scientific name	Common English name	Countries with the pest status							
		Bangladesh[1]	Burma[2]	India[3]	Indonesia[4]	Malayasia[5]	Philippines[6]	Srilanka[7]	Thailand[8]
Tryporyza incertulus (Walker)	Yellow rice borer (YSB)	++	++	++	++	-	++	-	+
Tryporyza innotata (Walker)	White stem borer (WSB)	-	-	+	++	-	++	x	-
Sesamia inferens (Walker)	Pink stem borer (PSB)	+	-	+	-	+	+	-	-
Nilaparvata lugens (Stal)	Brown plant hopper (BPH)	++	-	++	++	+	-	++	+
Orseolia oryzae (Wood-Mason)	Rice gall midge (GM)	+	-	++	++	x	+	++	++
Leptocorysa acuta (Fabricius)	Rice bug (PB/RB)	+	+	++	++	+	++	x	++

(+): Minor pest, variable year to year causing yield losses of 5% in at least one major region in a country, (++): Major pest, perennial losses of 5% in at least one major region within a country, (-): Data not available, (x): Pest not recorded from the country.

Sources: **(1)** Islam *et al.*2004, Nurzaman *et al.* 2000, **(2)** Premchand 1984, Rao *et al.*1966, **(3)** Raman 1983, Krishnaiah *et al.* 2006, Krishnaiah *et al.*1985, Matteson 2000, Chelliah *et al.* 1980, Bhavani 2006, Pillai *et al.* 1983, Heinrichs *et al.* 1985, Kabir *et al.* 1988, Kenmore 1996, Tripathy 1999, Razak 1986, Sankaran 1987 **(4)** Krishnaiah 1993, Shepard *et al.* 2001, Pincus 1994, Kishi *et al.* 1995. Karimuna 2004, Shepard *et al.* 2001, **(5)** Ho 1996, Catling *et al.* 1987, **(6)** Marciano *et al.* 1981. Heong *et al* .1991, Southhood 2003, **(7)** Hidaka *et al.* 2000, **(8)** Marjunath 1968, Landis *et al.* 1992, Miyashita 1963, Islam *et al.*1990.

Again, in all the states of India the major insect pests are not equally frequent. The prevalence of three major pests in different states is shown in the table 2.1.2

Table.2.1.2: Prevalence of three major insect pests of paddy in different states of India

Name of States	Insect pests		
	Yellow stem borer	**Gall midge**	**Brown plant hopper**
Andhra Pradesh	+ + +	+ +	+ + +
Assam	+ +	x	x
Bihar	+	+ +	x
Gujrat	+	x	x
Haryana	x	x	x
Himachal Pradesh	x	x	x
Jammu and Kashmir	x	x	x
Karnataka	+ +	+ +	+
Kerala	+ +	+ +	+ + +
Madhya Pradesh	+ +	+ + +	+
Maharastra	+ + +	+	+
Manipur	x	+ + +	x
Meghalaya	++	x	x
Nagaland	+	x	x
Orissa	+ + +	+ + +	+ + +
Punjab	++	x	x
Rajasthan	x	x	x
Tamilnadu	+ +	+	+ + +
Tripura	x	+	x
Uttar Pradesh	+ +	+	x
West Bengal	+ + +	+ +	+ + +

(+): Low, (+ +): Moderate, (+ + +): Severe, (x): Data not available.

Source: Manual on Integrated Pest Management in rice, Directorate of Plant Protection, Quarantine and Storage, N.H.IV. Faridabad, 2004

One of the urgent requirements of modern IPM is to determine the ETL index of a particular pest in an area based on single or group of criteria. The same criterion or the group may not be fixed for the pest over a wide geographical area. However, in the following table (2.1.3), the ETL indicates major pests in several states of India.

Table.2.1.3: Economic threshold levels (ETLs) of four major insect pests of paddy as determined at different status and places of India

States and places of record	Growth stages of paddy	Recommended threshold level indices of the four pests			
		YSB % of DH/WH or egg mass/ m^2 or adult/m^2	BPH No. of nymphs+ adult/hill	GM No. of galls/ m^2 or % of affected tillers	PB No. of nymphs +adults / m^2
West Bengal (Chinsurah and Kharagpur)	Pre-tillering	5% DH or 1 egg mass or 1 moth	5 - 10	1gall/m^3 (in epidemic areas) 5% affected tillers(in non epidemic areas	x
	Mid – tillering	5% DH	5 - 10	x	x
	Panicle initiation	1 moth	5 - 10	x	x
	Flowering	1 moth or 1 egg mass or 6% WH	10	x	1 – 2
Punjab (Kapurthala)	Pre-tillering	5% DH	x	x	x
	Mid – tillering	5% DH	5 - 10	x	x
	Panicle initiation	x	x	x	x
	Flowering	1 moth	10	x	x
Orrisa (Cuttack)	Pre-tillering	5% DH	x	x	x
	Mid – tillering	5% DH	x	x	x
	Panicle initiation	x	x	x	x
	Flowering	1 moth	x	x	1 – 2
Andhra Pradesh (Hyderabad and Warangal)	Pre-tillering	1 egg mass or 1 moths	10	2 – 3 gall/m^2	x
	Mid – tillering	5% DH	5 - 10	x	x
	Panicle initiation	1 moth	5 - 10 or 25 (in epidemic areas)	x	x
	Flowering	1 moth	10	x	x
Haryana (Hisar)	Pre-tillering		10	x	x
	Mid – tillering	5% DH	x	x	x
	Panicle initiation	1 moth	5 - 10	x	x
	Flowering	1 moth	x	x	1 – 2

(x): Data not available

Sources: Modified after Perkins (1980), Sing and Dhaliwal (1994), Simwat (1994).

A single pest may not equally prevalent in the same area over a large period of time. This is obvious for differences in the paddy varieties, cultivation practices, rainfall, fertilizer inputs and pests management practices (Table 2.1.4).

Table.2.1.4: Dynamics of major paddy pests in West Bengal since 1965

Common English name	Scientific name	Dynamics through times			
		1965-1974	1975-1984	1985-1994	1995-2004
Yellow stem borer	*Tryporyza incertulus* (Walker)	+	++	++	+++
White stem borer	*Tryporyza innotata* (Walker)	+	+	++	+++
Pink stem borer	*Sesamia inferens* (Walker)	+	+	++	+++
Brown plant hopper	*Nilaparvata lugens* (Stal.)	x	x	+	+++
Rice gall midge	*Orseolia oryzae* (Wood-Mason)	x	+	+	++
Paddy(Rice) bug	*Leptocorysa acuta* (Thung.)	+	+	+	++

(+ + +): Severe, (+ +): Moderate, (+): Low

Sources: Major paddy pests of West Bengal and their relative occurrence through the course of times (in Bengali), RRS, Chichura, West Bengal (Unpublished.)

The cultivation of paddy during *kharif* and *boro* seasons should not follow rigidly a simple schedule. Depending on multiple factors the schedule is ought to vary at differ locations and area. Before the present investigation was contemplated it was found that most of the farmers in the three blocks observe almost a common practice / schedule in relation to the cultivation time (Table.2.1.5). Such a single schedule appeared to be inadequate in all the three blocks and in all lands of a single block. This warrants for micro-level studies for evolving suitable cultivation practices for individual localities.

Table. 2.1.5: Existing cultivation practices and the time schedules in all the three blocks of the District Uttar Dinajpur

Category	Fertilizer application							Pesticide application at (DAT)	Hand weeding at (DAT)
	During main land preparation			During top dressing (DAT)					
				First		Second			
	N	**P**	**K**	**N**	**Days**	**N**	**Days**		
Time of cultivation									
High yielding variety, Swarna Mashuri									
Pre-kharif (autumn rice)	x	8	8	8	15-20	8	30-35	-	-
kharif (Winter rice)	5	10	10	10	15	5	35-40	35	25
boro (summer rice)	7	12	10	12	15-20	8	30-35	35	40
Low yielding local variety, Tulaipanji									
Short duration	5	10	10	10	15	5	30-35	35	40
Pattern of crop establishment									
Direct seeded	8	8	4	8	15-20	8	30-35	44	25, 50
Transplanted (autumn)	8	6	4	8	15-20	6	30-35	-	30, 60
Transplanted (winter)	8	8	8	8	40	8	75	-	30, 65

(-): Not specified

Sources: Agricultural Manual for Proper Cultivation (in Bengali),2006, Lok Kalyan Parisad, Kolkata,2006.

District Annual Plan on Agriculture, Uttar Dinajpur, Office of the Agricultural Officer, Uttar Dinajpur, West Bengal. 2002- 2003.

Nayban and Choudhury 2000

One of the natural suppressions of the incidence of insect pests is done by their natural enemies. The incidence of these enemies in the paddy field depends on several factors. As the factors are not always uniform in all the places and at all the times in the places, the occurrence, and hence suppression efficiencies should necessarily vary at different places (Table 2.1.6).

Table.2.1.6: Major natural enemies of insect pests of paddy and their relative occurrence in three districts of West Bengal

Group of the enemy	Scientific name	Common English name	Status of predation / parasitism In three districts		
			Burdwan	Midnapore	Bankura
Predators					
Spider	*Argiope pulchella* (Thorell)	Orb spider	+ + + +	+ + +	+ + +
	Lycosa sp. (Boesenberg and Strand)	Wolf spider	+ + + +	+ + +	+ +
	Phidippus sp.	Jumping spider	+ + +	+ + +	+ + +
	Oxyopes javanus (Thoroll)	Lynx spider	+ + + +	+ +	+ + + +
	Tetragnatha maxillosa (Thorell)	Long jawed spider	+ +	+ + +	+ + + +
Beetle	*Micraspis crocea* (Mulsant)	Lady bird beetle	+ + +	+ + + +	+ + +
	Menochilus sexmaculata (Fab).	Lady bird beetle	+ + +	+ +	+ + + +
	Ophionea nigrofasciata (Schmidt-Goebel)	Ground beetle	+ + +	+ +	+ + +
Bug	*Cyrtorhinus lividipennis* (Reuter)	Plant bug	+ + + +	+ + +	+ +
	Mesovelia spp.	Water bug	+ + + +	+ + +	+ +
Fly	*Agriocnemis pygmaea*	Damsel fly	+ + + +	+ + +	+ + + +
Parasites					
Stem borer eggs	*Telenomus rowani* (Gahan)	Egg parasite	+ + + +	+ + + +	+ + +
	Tetrastichus schoenobii (Ferriere)	Egg parasite	+ + + +	+ + +	+ + + +
	Trichogramma sp.	Egg parasite	+ + +	+ + + +	+ +
	Cotesia (= Apanteles) angustibasis (Gahan)	Egg parasite	+ + + +	+ +	+ +

(++++): Highly effective, (+++): effective, (++): Sporadic, (+): Negligible

Source: Interim survey on the potential paddy field natural enemies in the southern parts of Bengal, RRI, Chinchura, 2004 (unpublished)

2.2. Abundance, Bioecology and Nature and Extent of Damage Caused by Major Insect Pests of Paddy

2.2.1 Stem borers

2.2.1.1 Distribution and importance: Stem borers (SBs) are key group of insect pests of rice. Among the borers, yellow stem borer (YSB), *Scirpophaga incertulas* Walker is distributed through out India and is regarded as the most dominating and destructive species (Banerjee 1967, Walker 1975, Panda *et al.*1976, Prakash *et al.* 2005). The other two borers recorded during the present investigation were *Tryporyza innontata* Walker, the white stem borer (WSB) and *Sesamia inferens* Walker, the pink stem borer (PSB).

2.2.1.2 Bioecology of YSB: The adult YSB moths are strongly phototactic and can readily be collected in light traps and by sex pheromones (Krishnaiah *et al.* 2004). The adult moths mate after sunset, lay eggs mainly on the older and broad leaves of soft plants (Koyama 1955). The eggs are laid in clusters on the sheaths and blades of leaves and are covered with felt like hairs and scales (Shiraki 1917).The frequency of YSB females has an association with the rice varieties having longer, wider and softer leaves, internodal length and higher responsiveness to nitrogen fertilizers (Raj *et al.* 1973). Islam *et al.* (1996) have reported that plants at the active tillering and before flowering stages are preferred by the moths for egg laying. The optimum temperature for egg laying is 28-29^{0}C and the relative humidity is 60%. The egg stage lasts for 5-9 days (Kulshrestha 1971). The larvae show congregation and nibble at leaf sheaths before they bore into the tissues of the tillers. 75% larvae gain entry into the plant tissue (Aikins 1957). Depending on temperature the larval period varies from 27 to 30 days. At low temperature regimes, the larvae undergo diapause by remaining in the basal nodes of the stems or in soil. Solid stem of seedlings and the epidermal silica in high yielding varieties cause obstacle to the immediate entry of larvae (Bowden 1976). When full grown, the larvae pupate inside the stem, straw or stubble. Low starch content in rice stem has been reported to enhance larval dispersion from infested stem to new plants (Pathak 1967). The pupal period ranges from 2 to 6 days. The number of generations depends on biotic and abiotic factors of the environment (Malhi *et al.*1998). Sing *et al.* (1977) reported that the borer completes more than one generation in a year.

2.2.1.3 Nature of damage: The larvae bore into the tillers by feeding internodal soft tissue, grow and cause the characteristic symptoms of 'dead hearts' (DH) or 'white ears' (WH) depending on the stages of the standing crop. At tillering stage, the feeding frequently results in severing the apical parts of the plant from the base, central leaf whorl does not unfold, turns brownish and dries out although the lower leaves remain green and healthy, a condition known as 'dead heart'(DH) (Panda *et al.*1976). Affected tillers dry without bearing panicles. During panicle exertion, severing of the growing parts from the base results in the drying out of panicles. The empty panicles are very conspicuous in field as they remain stiff, straight, whitish and are called 'white ears' or white head (WH). Infestation results in partial / total chaff-ness of the glumes and ill-filled grains (Tripathy *et al.* 1995)

2.2.1.4 Extent of damage: The level of SB's induced yield losses have been estimated to range from 30 to 70% in outbreak years and from 2 to 20% in non outbreak years in Bangladesh. In India the value ranged from 3 to 95% while it varied up to a scale of 33% in Malaysia and 95% in Indonesia (Tripathy *et al.*1995, Prakash *et al.* 2005). Catling *et al.* (1987) have reported that each 2% stem damage at harvesting results in yield loss up to 1%. Tripathy *et al.* (1995) have estimated a loss of 29-49 kg / ha depending on the rice varieties. Evaluation conducted by CRRI, Cuttak showed that every 1% increase of damage by SBs registered a loss of 0.28% at vegetative stage and 0.62% at heading stage. Ishikura (1967) estimated the pre harvest losses due to SBs damage in diversified agro ecological situation ranging from 10 to 65%. A considerable yield loss has also been reported by Ragini *et al.* (2000) from Tamil Nadu. Catling *et al.* (1987) assessed a variable yield losses in deep water rice due to YSB in Bangladesh and Thailand. Israel *et al.* (1967) attempted to assess the crop losses due to SBs attack in tropical area and found variable results.

2.2.1.5 Seasonality of occurrence of YSB: The seasonal abundance of *S. incertulas* , monitored at Titabar (Assam) during 1975-1979, revealed that adult activity occurred throughout the year, with one moderate peak in April and the next smaller one in August. A high positive correlation of the moth abundance with the temperature, rainfall, and relative humidity and sunshine hours was observed by Ishaque and Rahman (1983). The appearance of the pest at field level depends upon the availability of food plant and the prevailing climatic factors (Rai *et al.* 2002). Experiment conducted over a period of 26 years in Bihar revealed that YSB appeared as early as in first fortnight of February and formed the peak either during September or first fortnight of October. Prakash *et al.* (2005) showed that in wet season SB incidence was intensified during October-November. Tripathy *et al.* (1999) observed in Orissa the appearance of successive two peaks of YSB in the last week of September and another in the second week of November.

2.2.1.6 Differential abundance in relation to crop phenology: Ragini *et al.* (2000) reported that YSB infestation was predominant from early to maximum tillering stage and decreased gradually with the increase of pink stem borer (PSB) number from flowering stage. Among the three stages of crop growth, at maximum tillering stage highest infestation was recorded, followed by at flowering and early tillering stages (Padhi *et al.* 2004). Wagan *et al.* (1999)
und that the activity of YSB was guided by the growth stage related
logical changes of paddy plants. Sastrodihardjo *et al.* (1972) from West
donesia) reported that the adult catches were low in the first month after
g but increased rapidly at the later growth stages. Observation also
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ansplanting. Alam (1988) recorded similar observations while
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AT) followed by the peak at 60 DAT. Alam *et al.*(1992)
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2.2.2 Plant hoppers

Among the hoppers, brown plant hopper (BPH), *Nilaparvata lugens* Stal., green leaf hopper *Nephotettix virescens* Distant and white backed plant hopper (WBPH), *Sogatella furcifera* Horvath have gained major pest status on rice crop in recent years.

2.2.2.1 Distribution and importance: BPH is common in rain fed and irrigated wetland environments, distributed through out South East Asia and part of the Pacific and Australia. It dominates especially during the reproductive stage of rice plant (Stapley 1975). Mixed population of BPH and WBPH occurs towards crop maturity causing heavy yield losses in several rice growing areas (Basavanna *et al.* 1976, Velusamy *et al.*1978, Natarajan *et al.* 1988).

2.2.2.2 Bioecology: Adult BPH are dimorphic, with fully winged macropterous and truncate winged brachypterous forms. The macropterous are potential migrants and after settling down on the rice plants produce the next generation of which most of the females are wingless and males are winged (Zhu *et al.* 2000). Adults usually mate on the day of emergence and the females start laying eggs from the day following mating. Brachypterous females lay 300-350 eggs and macropterous females lay fewer eggs depending on the cultivation practices (Nailnakumari *et al.*1975). The eggs are pushed in a straight line generally along the mid-region of the leaf sheath, though sometime eggs are laid on the leaf mid-ribs. The ovipositing sites appear as brownish streaks. Eggs hatch in about 6-9 days. Newly hatched nymph is cottony white and turns purple brown in an hour. It feeds on the plant sap and undergoes five moults to become an adult in 10-18 days depending on the availability of the food and other environmental factors (Hao *et al.* 2000).

2.2.2.3 Nature of damage: BPH prefers irrigated and rain fed and wet land to upland rice and directly sown to transplanted rice fields (Chelliah *et al.* 1973). Both adults and nymphs suck the sap from the base of the tillers, resulting in yellowing and drying of plant. Initially round patches appear in the fields which soon turn brownish due to drying up of the plant. The symptom spreads as patches of concentric circles, a condition known as 'hopper burn'. Apart from direct damage, the BPH is also a vector of grassy stunt virus (Natarajan *et al.* 1988).

2.2.2.4 Extent of damage: Chelliah *et al.* (1973) reported the frequent occurrence of hopper burn in Tamilnadu. Intensive BPH damage was observed in Andhra Pradesh in the year 1959 causing 20-25% losses covering an area of 9000 ha (FAO 1959). Srivastava (1976) and Verma *et al.* (1979) reported the outbreak of BPH from Uttar Pradesh. Hopper burn was also reported by Upadhyay *et al.* (1992) from Bihar. Koya (1974) viewed that BPH could be regarded as one of the major destructive pests in South East Asia. Rizvi *et al.* (1983) also reported from Uttar Pradesh the perilous activity of BPH leading to crop failure.

2.2.2.5 Seasonality of occurrence: Alam (1971) obtained 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 than in the second. From the available data from India, Bangladesh, and the Philippines, it is difficult to standardize the relationship between the number of insects caught in a light trap during the immigration period and the occurrence of hopper burn in subsequent generations, because the environments in which the generations develop such as a fall in temperatures and farming practices differ from place to place and year to year (Natarajan *et al.* 1988).

2.2.2.6 Differential abundance in relation to crop phenology: The hoppers prefer lowland to upland paddy. Growth stage dependent phenological changes of the paddy plant positively influence the pest structure (Chelliah *et al.* 1973). Higher number of seedlings / hill and the input of high doses of inorganic N fertilizer bringing the canopy compactness are the prime factors responsible for pest development (Stapley 1975).Thick bushy canopy with high moisture regimes and low temperature accommodate greater number of hoppers. Direct sown fields harbour comparatively higher number of hoppers than the transplanted one due to the relative variation of the crop structure (Srivastava 1976).

2.2.3 Gall midge

2.2.3.1 Distribution and Importance: Gall midge (*Orseolia oryzae* Wood-Mason), primarily a pest of low land rice field, is found in irrigated or rain fed shallow lowlands through out the tropics during the tillering stage of rice plant (Budharja *et al.* 1979). It has also been reported in upland and deepwater rice (Rao 1981).

2.2.3.2 Bioecology: The adult gall midge (GM) is mosquito like and essentially a pest of irrigated and wet season crop (Rao *et al.* 1970). Adults are highly phototropic and nocturnal in habit. Adult female lays eggs either singly or in groups on the under surface of the rice leaves or sometime on the leaf sheaths. A single female lays 100-200 eggs. Eggs are long, tubular, and shiny white, sometimes pink, red or yellow. Eggs require high humidity for hatching and the incubation period is around 3-4 days. The newly hatched maggots are grey-white, fairly with a pointed anterior end (Rao 1981). The neonate larva or maggot eventually locates on the growing point of the apical or side buds at a node for feeding (Budharja *et al.* 1979). Its feeding causes tubular gall formation at the base of the tiller (Dale, 1994, Popov *et al* .1998). The gall (modified leaf sheath) enlarges with continuous feeding of the maggot. Development of both larvae and pupae is completed inside the gall. Four larval stages of variable duration are observed in 15-20 days. Pupal period lasts for 2-8 days. The entire life cycle is completed within 25-38 days (Rao 1981).

2.2.3.3 Nature of damage: The feeding by maggot on the growing tip suppresses the leaf primordial differentiation and eventually causes necrosis (Pieris 1977). This is followed by an elongation of the leaf sheath leading to the formation of a hollow tubular structure around the larva. With the progress of feeding the gall enlarges at the base of the plant and elongates resembling an onion leaf (Rao 1981, Katarki and Bhagwat 1960). Galls appear within a week after the larvae reach the growing point. In some cases there may be no gall development but necrosis of the growing tip is noticed (Reddy 1967). Panda and Mohanty (1970) observed gall-induced profuse tillering and stunting of plants. Prakasa Rao (1975) noted that bushy appearance of the crop, prolonged vegetative phase; delayed flowering and uneven ripening are symptoms of the midge attack. Israel *et al.* (1968) noted that infestation at early stages of crop growth resulted in the death of primary tillers, thereby inducing subsidiary tillering. Similarly, Prakasa Rao (1972) documented that at early growth stages each infested tiller induced the production of new tiller from its node below.

2.2.3.4 Extent of damage: Chatterjee *et al.* (1976) reported the yield loss ranged from 3-70% depending on the severity of attack and the variety under cultivation. Hill (1983) showed that in occasional cases the damage may reach up to 100% resulting in total crop failure. Herd (1991) claims that Asian GMs are one of the major pests enhancing considerable yield loss. Nayak *et al.* (2000) found that the incidence was less in resistant varieties. The magnitude of damage could be reduced after the adoption of resistant varieties with hygienic cultivation as suggested by Sing *et al.* (2001). Rao (1981) detailed that *O. oryzae* was major pest of late planted rice in the wet season (May-November) in Krishna and Godavari deltas of Andhra Pradesh resulting in considerable loss. Gubbaiah and Revanna (1996) spotted severe infestation of GM in southern Karnataka for the first time in *kharif* season. Devi and Devi (1997) accounted that the infestation of gall midge (Biotype 5) may extend to the level of 60-90% covering an area of 30 % of Kuttanad, Kerala. Wickremasinghe (1969) reported up to 80 % crop loss due to severe attack. Deshmukh *et al.* (1990) and Khandalkar *et al.* (1996) noted that the yield was distinctly affected under high GM infestation.

2.2.3.5 Seasonality of occurrence: Reddy (1967) reported that the GM became active at the onset of monsoon and completed one or two generations on grasses before moving to rice. Hidaka *et al.* (1980) opined that though the heavy infestation of GM is season specific, but it is available throughout the year. Dale (1994) noted that the pest population was rapidly declined in December because of the limited availability of suitable hosts. Through GM is primarily a pest of irrigated and wet season rice but it is found to occur during winter season too (Kalode and Viswanathan 1976) in both low and upland fields (Rajamani *et al.* 1987). It attained the epidemic form in Madhya Pradesh during wet seasons of 1971, 1975, 1976, and 1978 (Srivastva *et al.* 1984). In general, the species is found to be an important paddy pest in Indian subcontinent covering most of the rice growing areas except in Western Ghats and Himalayan region. It gains the potentiality of damage in Andhra Pradesh, Kerala, Chattrisgarah, Maharastra, Manipur and Orissa under favourable agro-ecological conditions (Prakash *et al.* 2005). Favourable weather conditions, cultivation of high tillering varieties, intensive management practices and low rate of parasitization are conducive to the rapid multiplication of this pest. A study on the population dynamics of *O. oryzae* at Rajendranagar, Andhra Pradesh (India), in four consecutive years has revealed that the pest appears in late August, reaches a peak in October and declines by December (Sain and Kalode 1992).

2.2.3.6 Differential abundance in relation to crop phenology: The GM was found to occur on the rice plant from nursery to the end of the tillering stage (Dale 1994). Israel *et al.* (1959) observed that the incidence of the pest was higher at 90-day old rice plant than at 60 days old, justifying that the incidence of the GM is growth stage dependent. The pest starts infestation during tillering stage of crop as reported by Rajamani *et al.* (1979). However, Prakasha *et al.* (2005) reported that, galls (silver shoot) are formed generally during the tillering stage and after panicle primordia initiation. Instead of a normal panicle, a distorted panicle or miniature imprecised leaves emerge. GM appears in the years of late planting when the rain prolongs beyond October as it happened in 2001, in some places of West Bengal (Interim Survey Report, Shuttle Breeding Programme, 2001, Dept. of Agriculture, Govt. of West Bengal, unpublished). Rajamani *et al.* (1979) reported that the pest incidence was high during July and August if rainfall prevailed during daytime. This period normally coincides with the maximum tillering phase of paddy. Though infestation to plant is confined mainly to the vegetative phase, occasionally damage during reproductive phase leading to development of panicle galls or spikelet galls is also reported. (Kittur and Agrawal 1983, Joshi and Venugopala 1984). Falerio and Patil (1991) reported that during *kharif* season of 1989 and 1990 the damage by GM reached a peak at maximum tillering (49 DAT) and early heading (56 DAT) stages of crop growth respectively in the southern states of India. However, Bhardwaj *et al.* (1988) observed a peak infestation during late tillering to boot leaf stage of the crop. The crop is most susceptible to the attack on 30-45 days after transplanting as reported by Wongsiri *et al.* (1971). Infested shoots estimation showed a rate of about 170 pupae per 5000 tillers after the first week of transplantation is very crucial for pest out break. A decline in the population was followed by a rise at the end of the first month after transplantation with the variable range from 114 to 560 pupae per 5000 tillers. The damage was most apparent from 60 to 75-day after transplanting (Sastrodihardjo *et al.* 1972). Huang *et al.*(1996) reported that the late cultivated varieties were more severely damaged than that of the early cultivated one. In Assam, the GM infestation was increased by 2.85% for each week delay in planting beyond July 15^{th} to second week of September. Oudhia *et al.*(1999) extrapolated that maximum infestation of GM occurred with continuous submergence of rice with mid season drainage for two days during the maximum tillering stage. It is also known that gall morphology is determined by the host genotype since purple varieties produce purple gall, while tall cultivars have very long galls (Joshi and Venugopala 1985).

2.2.4 Gundhi bug / paddy bug

2.2.4.1 Distribution and importance: Gundhi bugs are also known as paddy bugs (PB).Three species of PB are responsible for damage of paddy crop in India, *Leptocorisa acuta* Thunberg (=*L. oratorius*), *L. varicornis* Fabricius and *L. chinensis* Dallas each having distinct areas of occurrence as major pests (Banerjee *et al.* 1965). In the eastern rain fed region of India, *L. acuta* is the major species in states of Assam, Bihar, Orissa and West Bengal.

2.2.4.2 Bioecology: Eggs are laid mostly in single rows, preferably towards the mid rib portion of the leaf. They are reddish brown to black and the nymphs hatch in 5 to 6 days. The nymphal period varies from 13-17 days. Nymphs pass through 5 moults before attaining the adult stage. The adult females are more active fliers. All the stages of the insect prefer lower shady portions of the plants during the day. Of the different grasses *Echinochloa colonum* has been found to be a potential host for successful survival and multiplication (Banerjee *et al.*1965). The bugs have also been found to successfully multiply and migrate from early to the late flowering varieties of paddy when there is unequal ripening in the fields.

2.2.4.3 Nature of damage: The adults and nymphs suck the milk from the developing grains in the early stage of grain formation. Young succulent leaves and shoots are also attacked before the grain formation. Infestation is characterized by the discoloration of the panicles as well as the presence of some empty or ill-formed grains in the panicles. (Israel and Rao 1961, Rao and Kulshreshtha 1985).

2.2.4.4 Extent of damage: Rao and Kulshrestha (1985) reported that PB infestation was responsible for grain discoloration and chaffy grain formation. Banerjee and Chatterjee (1982) found 25-35% yield losses due to severe PB attack. The extent of damage may extend up to 40% in some agro ecological situations as reported by Rao and Kulshreshta (1985). Dresher (1955) reported that PB was most destructive in non flooded fields and the damage could be 100 % loss to the rice crop in some occasions. Srivastava and Saxena (1964) reported that in case of severe infestation, the entire crop might be destroyed but in general 10-40 % field losses were common. The pest caused damage up to 90% of rice grains by rendering them unfilled.

2.2.4.5 Seasonality of occurrence: Srivastava and Saxena (1964) reported that the insect over-wintered from December to March, passed the summer *i.e*, April-June as adults on the grasses and other plants. However, Banerjee and Chatterjee (1965) found low population of *L. acuta* hibernated on trees during the relative colder and drier months of December to March. Pathak (1968) has noted that the population becomes maximum during September-October in the Philippines and after that the adult bugs undergo diapause on grasses.

2.2.4.6 Differential abundance in relation to crop phenology: The intensity and type of damage caused by the PB depends on the population density, stages of the crop and prevailing ecological conditions. Smith (1981) has noted that PB migrates from the grasses when rice plant started flowering with the advent of rainy season. Before flowering the bugs feed on seedlings by sucking the sap from leaves and tender shoots accounting a low level of damage. After flowering stage and onwards, severe damage and almost complete crop destruction may happen in some cases (Banerjee *et al.* 1982).

2.2.5 Assessment of economic threshold level (ETL): The present practice as suggested by district agricultural office to determine ETL is to count the number or egg masses or the adult of a particular pests or the pest induced symptoms in relation to the growth stages of paddy which is tabulated in the table.2.2.1.

Table.2.2.1: Construction of the economic threshold level (ETL) for four major pests in relation to the growth stage of paddy

Name of the pests		BPH	YSB	GM	PB
Threshold levels in relation to growth stages		Individuals/ hill	Individuals/ hill, Egg mass /mt ^{2}or DH (%)	gall/mt ^{2} SS (%)	Individuals/ hill (adult + nymph)
Growth stages of paddy	Seed bed	5	1 egg mass, 5 DH	x	>0.5
	Vegetative	>15	1.4 moths, 5 DH	1 gall, 5 SS	>1.00
	Reproductive	>8	2.0 egg masses, 10 DH	>5 SS	>1.5
	Ripening	>5	>2 moths, 12 DH	>5% SS	>1.00

(x): No symptoms appeared

2.3. Prevalence of Natural Enemies of Insect Pest of Paddy and their Efficacy for Pest Suppression

Cultivation of paddy in temporal and spatial continuity has evolved a stable relationship between rice insect pests and their natural enemies (Ooi and Shepard 1994). In most instances, the predators are higher in number than those of the pest populations, when little or no insecticides are used (Way and Heong 1994). Understanding the biology of the natural enemies is a prerequisite for successful utilization and further manipulation of the natural enemy for judicious pest management with least toxic input.

2.3.1 Predator: Predators have distinct environmental preferences (Clement *et al.* 2004). Whitecomb and Bell (1964) identified 600 predator species representing 45, 19, and 4 families of insects, spiders and mites respectively from the paddy fields. Resurgence of pests are often attributed to the disruption of the natural control agents by broad spectrum pesticides (Kidd and Jervis 1996).

2.3.1.1 Spider

2.3.1.1.1 Distribution and importance: Spiders are the most abundant predators in terrestrial ecosystem (Heidger *et al.*1989, Heong *et al.*1991) showing distinct environmental preference (Bora *et al.* 2004). A total of 432 spider species belonging to 131 genera under 27 families are documented from the rice fields of South and South-East Asia. The five most dominant families, Araeneidae (16 species), Clubionidae (42 species) Theridiidae (40 species), Thomoisidae (39 species) and Salticidae (36 species) account 63.5 % of the total paddy field bio-control agents. Lycosidae (27 species), Eusparassidae (16 species), Melidae (14 species), Tetragnathidae (13 species) and Gnaphosidae (10 species) are moderately abundant families. Categorically, three prominent spider guilds, orb-webers, space-webers and hunting spiders are noted. Of the orb-weavers, *Tetragnatha mandibulata* followed by *T. japonica* are particularly abundant in the rice fields. The upland spider community is more diversified and represents an admixture of both rain-fed and irrigated low land communities (Bommarco *et al.* 2002). Among the ten mostly prevalent rice spiders, nine are abundant in upland fields showing wider adaptability. *Leucauge delorata* is almost absent in upland rice while *Oxyopes javanus* and *Lycosa pseudoannuata* are less abundant in uplands compared with in low lands. Irrespective of the environments, space-web spider, *Atypena formosana* dominates in all the fields. But Satpathi (2004) has found that the spider diversity and guild composition increase with the crop age and the rank in decreasing order has been irrigated wet land > rain-fed wet land > upland. Bambaradeniya and Edirisinghe (2001) have documented 60 spider species from the irrigated Sri Lankan paddy fields as the prominent predatory group. In Philippines upland environment accommodates nearly half of the total reported 176 spider species of the country (Chandra 1978, Chatterjee *et al.*1976). In north Bihar, *L.pseudoannulata* is most prevalent (21.78%) in the paddy fields followed by *A. formosana* (16.33%), *A.catenulata* (14.56%) and *C. japonicola* (8.59%).

2.3.1.1.2 Efficacy of control: Relative predatory potential of the spiders depends on the niche characters within the crop canopy and the web generating capacity. *T. maxillosa* decorates 96% web on the top and middle portion of the crop canopy and the trapping consists of 55.9% dipterans and 14% moths (Reddy and Heong 1991). *Paradosa* sp. inhabits in the lower part of the canopy while *Agriope* sp. and *Tetragnatha* sp. occupy the upper part. Sing *et al.* (2001) have noted that predation is increased in undisturbed ecosystem. Symondson *et al.* (2002) also comment that pesticide unsprayed paddy fields increase predation rate. Tiwari *et al.* (2001) have observed in Jabalpur, India that only predation by spider can effectively control the paddy pest population. Murugesan *et al.*(1982) observed that *L. pseudoannulata* consumed an average of 6 fifth instar BPH nymphs/day. When brachypterous and macropterous forms of BPH adults were provided as food at 1:1, each spider consumed 7 adults / day. Satpathi (2004) observed the feeding potentiality of different types of spiders (Table.2.3.1).

Table.2.3.1: Feeding potentiality of different species of spiders (Satpathi 2004)

Spider species (adult)	No.of fourth instar nymphs of *Aphis gossypii* consumed / day	Duration of maximum population size
Lycosa pseudoannulata	3-5	Sept-Oct
Pardosa sp.	3-5	Sept-Oct
Oxyopes lineatipes	5-8	Sept-Oct
Tetragnatha maxillosa	3-5	Sept -Oct

2.3.1.2 Bug

2.3.1.2.1 Distribution and importance: Heong *et al.* (1991) recorded 46 species of predators (heteropteran bugs and spiders) and 14 species of hymenopteran parasitoids of auchenorrynnchous homopteran pests in Philippine rice fields.

2.3.1.2.2 Efficacy of control: In natural condition the actual predatory potential can hardly be realized, so the observation is restricted mainly to the green house or laboratory situations. From second to fifth instars of the bug, *Amyotea malbarica* (Fabricius) can kill 73 fifth instar larvae of *Pelopidas mathias* and *Panrava naso* in 18 days. Geetha and Gopalan (2001) have shown that *C. lividipennis* can effectively control the BPH population up to 50%.The average predation rate respectively ranges from 14.4-20.6 eggs and 1.6-3.6 nymphs/day. Manjunath (1978) observed that rampant application of pesticide reduces the predation rate. *Rhynocoris fuscipes* consumed 3.2 adults of rice hispa / day in laboratory observation.

2.3.1.3 Beetle

2.3.1.3.1 Distribution and importance: Beetles are distributed world wide and occupy all the habitats and niches of prey. As a predatory order, Coleoptera ranks first and the family Coccinellidae is nearly predacious (Laster 1974, Mareno *et al.*1992). 368 coleopteran species are associated with rice fields. Upland environment are habitats to arboreal carabid beetles. Indian coccinellid comprises of 57 genera having approximately 300 species of which 261 have known prey records. They have a seasonal occurrence in synchrony with their prey population, environmental conditions (Sakurai *et al.*1993, Bora *et al.*2004) as well as the taxa (Ives 1981), which cause them to occur at the same places and substrata of the prey. Table.2.3.2 gives brief record in India.

Table.2.3.2: Important coccinellid species, their status-wise distribution and prey species in India

Coccinellid species	Distribution	Prey species
Brumoides suturalis	Delhi, A.P, Assam	White backed plant hopper (WBPH), *Sesamia* sp, Green leaf hopper(GLH),WBPH, Leafhoppers
Coccinella repanda	Assam, Tamil Nadu, Orrisa	WBRH
C. septempuncata	M.P	Some rice pests
C. octomaculata	-	*Empoascanara* sp.
C. repanda	Karnataka	Some pests
Menochilus sexmaculata	Tamil Nadu and some other states of India	BPH,WBPH
Micrapsis inops	Tamil Nadu	GLH, WBPH
M. discolour	Assam	BPH, WBPH
Rodolia concolor	Tamil Nadu	BPH, WBPH
Sticholotis victoris	M.P	Aphids

(-): data not available

Sources: Bhardwaj *et al.* (1987), Sahayaraj (2004)

2.3.1.3.2 Efficacy of control: According to laboratory observation a single hungry fourth instar larva of *C. sexmaculata* and *C. septempunctata* can easily devour more than three hundred aphids in a day (Bind *et al.* 2000). The feeding voracity of the fourth instar larvae of *C. transversalis* increases proportionately with prey density showing a functional response. The regression values of functional response when plotted show a linear relationship between log numbers of prey density with the log number of prey consumption. An adult carabid ground beetle *Casnoidea indica* could consume BPH at a rate of 6 nymphs / day. In a single day, adult staphilinid beetle, *Paederus fuscipes* in the rice field of Tamil Nadu predates 8.3, 8.7 and 8.4 adult BPH, WBPH and GLH respectively during January-February (Rajendran and Gopalan 1988). The predation efficacy of *Paederus* sp. on GM pupae may extend up to 11%.

2.3.1.4 Dragon and damsel fly

2.3.1.4.1 Distribution and importance: Dragonflies and damselflies are amongst the most conspicuous insects associated with the integrated rice fields. Dragon flies are generally larger than damselflies and are usually hold their wings apart when they rest. There are many species of dragon flies as predator of paddy pests globally. During the present study only one species of dragon fly was recorded and identified and was found to predate on eggs of YSB and BPH. Also three species of damselflies were obtained during field study of which two species could be identified. The major Indian species and their reported distribution are given in the table.2.3.3.

Table.2.3.3: Dragon and damsel fly species, their state wise distribution and prey species in India

Taxonomic status	Distribution	Prey
Ceriagrion coromandelianum	Orrisa, Assam	Adults of YSB and LF nymphs and of adult GLH
Ischnura delicate	Assam	Nymphs and adults of GLH,WBPH
Orthetrum Sabina	Orissa, Assam	Adults of YSB and LF
Potamarcha obscura	Orissa	Adults of YSB and LF
Brachythemis contaminate	Orissa	Adults of YSB
Trithemis pallidinervis	Orissa	Adults of YSB and case worm.
Rhyothemis variegate	Orissa	Adults of YSB and LF
Pantala flavescens	Assam	Adults of YSB and LF
Agriocnemis pygmaea	Assam, Orissa, M.P	WBPH,GLH and *Cofana sprectra*

Sources: Rajendran and Gopalan (1988), Sahayaraj (2004)

2.3.1.4.2 Efficacy of control: Very little information is available regarding the predatory potential of the flies. The adult dragonflies and damselflies are generalized predators and have been observed to predate on adult of YSB borer and leaf folder. Their activity is mostly restricted to the upper part of the plant canopy. The aquatic damsel flies are most prevalent in the lowlands (Israel and Padmanabhan 1976, Krishnasamy *et al.*1984). Nymphs of dragonflies and damselflies are voracious predators feeding on variety of small invertebrates. These also predate on the eggs of YSB and BPH (Bora *et al.* 2004).

2.3.1.5 Guild composition of predatory complex in the agro ecological condition of North East India

Species guilds, rather than single species, often act as the determining factor for pest regulation (Table.2.3.4).

Table.2.3.4: Important predators of insect pests of paddy recorded from pesticide free fields

Scientific name of the enemies	**Common name**	**Relative abundance**	**Insect pests of paddy and their stages predated**
**Menochilus sexmaculatus*	Lady bird beetles	Medium	**Plant hoppers** : eggs, nymphs, adults
**Ophionea nigrofasciata*	Ground beetle (Carabid)	High	**Plant hoppers and leaf folders:** larvae
Anaxipha longipennis	Crickets	High	**Stem borers, plant hoppers and leaf hoppers: eggs**
**Mesovelia spp.*	Water bugs	Low	**Stem borer larvae and hopper nymphs** : larvae that fall on the water surface
**Cyrtorhinus lividipennis*	Plant bugs	High	**Plant hoppers:** eggs, nymphs and adults
**Agriocnemis pygmaea*	Damselfly	High	**Leaf folder:** moths, **Plant hopper:** nymphs and adults
**Agriocnemis femina*	Damselfly	High	**Leaf folder:** moths, **Plant hopper:** nymphs and adults
**Crocothemis* sp.	Dragonfly	High	**Leaf folder:** moths, **Plant hopper:** nymphs and adults
Euborellia stali	Earwigs	Low	**Stem borer and occasionally on leaf folder:** larvae
**Lycosa pseudoannulata*	Wolf spider	High	**Stem borer:** moths, **Plant hopper and leaf hopper:** nymphs
**Oxypes javanus*	Lynx spiders	Low	**Stem borer and leaf folder:** moths
Atypena (= *Cailitrichia*) *formosana*	Dwarf spiders	Low	**Plant hopper and leaf hopper:** nymphs
* *Argiope patenulata*	Orb spiders	Low	**Grasshopper:** nymphs and crickets
**Tetragnatha maxillosa*	Long jawed spiders	Medium	**Leaf hopper, gall midge and stem borer:** adults

Sources: Rajendran and Gopalan (1988), Geetha *et al.* (2001) and Sahayaraj (2004).

* Recorded in the present investigation

2.3.1.6 Factors affecting predation levels: Susceptible varieties support comparatively high range of beetle population. Bottrell *et al.* (1998) reviewed plant resistance that influences the predatory interaction of natural enemies. In Sri Lankan paddy fields the predator *Ophiona* sp. (Thumb.) was ten times more abundant on susceptible cultivar *indica* (H-9) than on *japonica* (Koshihikari) variety although pest population was equally frequent in both the cases. But variety independent predatory activity was noted by Pasalu *et al.* (1999). The varietal resistance and rate of predation was found to be synergistic as suggested by Panda (2002). Patnaik (1983) noted that phosphamidon was most toxic to *Micrapsis discolor* and *M. vincta.* Predation by *L. pseudoannulata* to induce BPH mortality was respectively 77.1 and 77.5% in resistant and susceptible varieties (Kumar and Velusamy 1996). Successful integration of plant-pest-natural enemy interactions is essential for effective biological control. *L.pseudoannulata* responses to the sex pheromone of YSB (Singha and Kumar 1998). Kairomonal activity of honey-dew of rice hoppers attracts all the life stages of *C.lividipennis* (Jhansilakshmi *et al.* 2000). But an inadequate prey number indulges the cannibalistic behaviour of predators which hinders predatory efficiency.

2.3.1.7 Paddy growth stage specific interaction of predators: Tiwari *et al.* (2001) have conducted field experiment during 1999-2000 to determine the paddy growth stage dependent variation of natural enemies in Jabalpur, Madhya Pradesh, India. As the growth stage advances the relative composition of the species structure considerably varies. During *kharif* crop of 1999, collectively nine major predators have been recorded at the early crop growth stages namely spider, dragonfly (*Crocothemis* sp.), damselfly (*Agriocnemus* sp.), predatory cricket, rover beetle (*Paederus fuscipes*), ground beetle (*Ophionea indica* [*Casnoidea indica*]) predatory grasshopper (*Conocephalus* sp.) and brown bug (*Andrallus spinidens*). Only the first four predators have been recorded at maturity stage of paddy. The population of all predators, except for damselfly, has been higher at early growth stages than at the maturity stage.

2.3.1.8 Effect of cultural practices on predatory guild: Cultural practices may enhance or inhibit colonization of natural enemies in the crop fields and their efficiency. Cultural practices alter the paddy field environment directly which in turn influences the pest distribution (Herzog and Funderburk 1985, Andow1997). Planting and harvesting dates, seedling density, row width, water management and tillage practices significantly affect both the host and natural enemy populations (Herzog and Funderburk1986). Disapproval of natural enemy colonization by herbicide application is doubtful. But clean cultivation proves detrimental as it deliberately removes alternative weed hosts for natural enemies (Herzog and Funderbuck 1986 and Duffey 1981).

2.3.2 Parasite of SBs and GM

2.3.2.1 Distribution and importance

The SBs are attacked by at least 27 species of egg, 91 species of larval and 17 species of pupal parasites. Eulophid egg parasite, *Tetrastichus schoerobii*, has been found to destroy as much as 75% of eggs of *Tryporyza incertulus* in India and up to 90% in Bangladesh. *Tetrastichus* and *Trichogramma are* respectively identified as the major paddy pest limiting factors in Wargal (Andhra Pradesh) and Kapurthala (Punjab). *T.dignoides* is widely distributed in Orissa. Hikim (1988) found that irrespective of season, *Telenomus* sp. was the most dominant parasite in the southern parts of West Bengal.

2.3.2.2 Efficacy of control: Parasitoids lay eggs in or on host insects and the larvae feed parasitically on the living host and eventually kill it. Larval parasitism of *T. incertulus* by *Tropobracon schoenobii* may be as high as 90 per cent in some parts of India (Rao 1972). In Sarawak, Malayasia, natural mortality of SBs usually exceeds 98% of which parasites and predators may account for 90%. *T. dignoides* parasitizes YSB eggs in Orissa with an efficacy of 7.1-35.2% (Senapati and Panda 1999). In some exceptional cases the rate may extend up to 100% (Gubbaiah *et al.* 1987). Gupta *et al.* (1985) noted that the activity of *T. schoenobii* was 30.6% in *kharif* and 23.7% in *rabi* season.

In Haryana, collective activity of *T. dignus* and *T japonicum* ranges up to 88%. A study at CRRI, Cuttack in 2000 indicates that the rate of parasitization is YSB egg mass dependent. Relative rate of parasitization varies widely, 3-20% at Chinsurah (West Bengal), 73.6-96.9% in Eastern-Ghat zone (Orrisa), 87.6% at Navsari (Gujrat) and 86.7% at Karnataka. Gupta *et al.* (1985) noticed that in laboratory condition the rate of parasitization may extend up to 48% in comparison to 23.7-30.6% in field condition.

2.3.2.3 Seasonality of occurrence: Ridgway *et al.* (1974) found that the activity of the parasite was season specific and species dependent. In India, the outbreak of *Nephotettix* sp. after extreme weather could hardly be managed by the activity of the parasites. Nagarkatti *et al.* (1973) found that the extremely cold or hot weather was unfavourable for some natural enemies and prevent them from building up their population. *Tetrastichus schoenobii* was most dominant except during May to August when *Telenomus rowani* was dominant. They collectively parasitized about 80 and 100% egg masses in March and September respectively. The population of *Trichogramma japorium* was always moderately prevalent through out the year. Arida *et al.* (1987) showed that YSB egg parasitization was season specific and comparatively higher in transplanted fields than in directly seeded ones. Patnaik (1983) observed that the rate of parasitization by GM parasites was moderate in January, decreased at early February followed by the gradual increase at middle of May which was maintained up to first week of June.

2.3.2.4 Guild composition of parasitic complex in the agro ecological condition of North East India: Species guilds, rather than single species, often act as the determining factor for pest regulation which is given in the table 2.3.5.

Table.2.3.5: Important parasites of insect pests of paddy recorded from pesticide free field

Scientific name	Relative abundance	Stage parasitized	Common name of insect pest parasitized
**Tetrastichus schonobii*	High	Egg	Stem borer
**Telenomus rowani*	Low	Egg	Stem borer
Copidosomopsis nacoleiae	Low	Egg	Leaf folder
Xanthopimpla flavolineata	Medium	Larvae	Stem borer
**Stenobracon* sp.	Medium	Larvae	Stem borer
**Cotesia (= Apenteles) angustabasis*	Medium	Larvae	Leaf folder
**Cotesia (= Apenteles) flavipes*	Medium	Larvae	Stem borer
**Trichogramma* spp.	Low	Egg	Stem borer and leaf folder
**Apanteles* sp.	Low	Egg	Stem borer and leaf folder
Isotima sp.	Medium	Larvae	Leaf folder

Sources: Patnaik and Satpathy (1984), Hikim (1988) and Manju *et al.*(2002)
* Recorded in the present investigation.

2.3.2.5 Factors affecting the rate of parasitism: The rate of YSB egg mass parasitization ranges from 84.6 to 100% in wet season and 28.0 to 74.7% in dry season. Patnaik and Satpathy (1984) commented that hairy covering of the SB egg masses circumvent the parasitic activity. Hikim (1979) concluded that the rate of parasitism was positively correlated with the available adult YSB population. Manju *et al.* (2002) found insignificant positive relation between the egg mass and the rate of parasitization. Sukhija *et al.* (1991) noted higher rate of parasitism in pesticide untreated plots (32.8-81.6%) in comparison to the pesticide treated conditions (56.21%). Application of quinalphos effectively restricts the rate of parasitization up to 40.06%. In laboratory condition, Eco-neme and Neem-Azal are comparatively safer to parasites. Mephosfolan (1.5 kg a.i./ha) was highly toxic to the parasites while isophenphos was least toxic.

2.3.2.6 Paddy growth stage specific interaction and parasite: At early growth stages of paddy the parasitized eggs is less abundant. But as the growth stage advances the rate of parasitization is accordingly enhanced. Though YSB female deposits the eggs at the same plant height but *Trichogramma* sp. is comparatively less active in maturing plants than the newly transplanted ones. Inappropriate microclimatic conditions due to profuse tillering from early reproductive stage adversely restrict the egg searching ability of the parasites at the lower part of the canopy. Usha Rani (2003) has reported the presence of kairomonal compounds from the YSB infested stems which induce parasitic attraction.

2.3.2.7 Effect of cultural practices on parasites: Parasitization by *Trichogramma* sp. was higher when the soybean fields are in contiguity with *Desmodium* or cotton than the fields associated with grasses or in monocultures. Sprenkel *et al.* (1979) found that predation on soybean caterpillar was high on early planted than on late planted soybeans. Tillage after harvest detrimentally affects parasite population disallowing their over wintering sites especially the stubbles and the ratoon crops (Carl 1979, Holmes 1982). But Andow (1992) commented that conservative tillage systems positively alter natural parasitism. He noted that parasitization of *Ostrinia nubinalis* by *Trichogramma* sp. was higher in chisel-plowed condition and lowest in no-tillage system.

2.4 Management of Paddy Insect Pests by Cultural Methods

Agronomic practices modify microclimatic regimes of paddy fields. Proper regulation of microclimatic regimes by way of adopting suitable cultural practices is expected to have a negative impact on pest population and / or an encouraging effect on predators and parasites of the pests. Cultural practices have been the most important method for managing pests and preventing crop losses in the developing countries (Brader 1979).

2.4.1 Necessity of cultural control: Inevitability of the cultural control arises due to the troubles and hazards related to the pesticide application and the consequences of variability and changes of paddy pest biology following the rampant field application.

2.4.1.1 Problems relating to pesticide application

Specificity: Selective spray formulation is effective against particular pests among the heterocomplexes in a particular field. Several insecticides have been tested against rice GM and SBs. As for example, Monocrotophos has been found effective against SBs but not against GM (Korat *et al.* 1999, Zhuang *et al.* 2000, Dash *et al.* 2001).

Knowledge of farmers: A Field application of pesticide are expensive and requires knowledge on both the chemicals, existing pest pattern and the growth stages of paddy plant (Sehgal *et al.* 2001, Jana 2002, Sing *et al.* 2004). Seed treatment is normally inexpensive and can be economically justified in many cases (Dash *et al.* 2001). Foliar sprays have to be repeated to obtain desired results as the insecticides are washed off by frequent rains. Granular insecticides are effective, but required dosages are too much expensive (Tripathy *et al.* 1999, Dash *et al.* 2001). Seed treatments are inconsistently effective against SBs and BPH populations (Liu *et al.* 2001, Tomar *et al.* 2003).

Phytotoxicity: Singaram and Manickam (1978) reported that the N uptake by the plants was enhanced due to the broadcasting of granular carbofuran @ 1.0 k.g a.i / ha. Chelliah (1979) has also noted an increase in micronutrients in plants following carbofuran application which brings about changes in bush pattern that favours pest build up. Sontakke *et al.* (1998) gave confirmation to the phytotonic effect of carbofuran. Sen *et al.* (1984) observed that application of carbofuran had a positive influence on WH formation.

Pest resurgence: Insecticide applications bring about changes in insect biology (Raman1981, Kenmore *et al.* 1984), feeding and ovipositional behavior resulting in a steady population build up leading to resurgence (Kobayashi 1961, Chandy1979, Abraham *et al.* 1975, Seetharaman *et al.* 1984, Krisnaiah 1995, Badji *et al.* 2004). Altered sex ratio (Raman 1981) increased fecundity (Chandy 1979) shortened nymphal period (Heinrichs *et al.* 1984) and increased adult longevity (Chelliah *et al.* 1980) are common in BPH feeding on some insecticide applied rice plants.

Wood (1973) has reviewed the history of several pest outbreaks in developing countries where broad spectrum contact insecticides have been in use. In Java, *Pachydiplosis oryzae* (Wood-Mason) was relatively unimportant before aerial application of phosphamidon against SBs but subsequently promoted to the heavy infestation by GM (Smith 1972). Ripper (1956) listed some 50 instances of pesticide induced pest outbreak. BPH resurgence has been reported from Bangladesh (Alam and Karim 1977), India (Chandy 1979). Indonesia (Oka 1978), Philippines (Annual report, IRRI 1979) and Solomon Islands (Stapley *et al.* 1975). Lim (1970) found evidence that chemical control tended to aggravate damage by SBs. Chian and Hudson (1972) reported that the rampant use of soil insecticides multiplied SB populations. Rothschild (1970) pointed out that SB infestation peaked with the higher doses of pesticide application. Following the application of organo-phosphorus insecticides, particularly parathion, EPN and diazinon *T. incertulas*, which was the most destructive pest of rice in Taiwan, was reduced to minor pest status. However, *C.suppressalis* which was previously a minor pest became a major destructive pest (Chu 1971). Smith (1972) reported secondary outbreak in rice fields in Java resulted from attempts to control rice stem borers chemically.

2.4.1.2 Variability of pest biology

Polyphagy

Stem borer: Most of the SBs have alternative host plants particularly the weeds, on which the pests survive / subsist in the absence of paddy. This population act as the reservour for the subsequent crop deterioration (Rezwany and Schahosseini 1977). Aikins (1957) reported that *Sesamia* sp., *Eldana* sp, and *Busseoia* sp. which are economically important SBs in Ghana, survive the dry spell by finding fresh cereals or grassy fields suitable for oviposition and subsequent development. Kalshoven (1981) reported that *S. innotata* larvae undergo aestivation in absence of food crop. *S. incertulus*, also aestivates in adverse conditions (Perrau *et al.* 1965).

Brown plant hopper: Many species of weeds act as alternative hosts of BPH in tropical Asia (Heinrichs and Medrano 1984) and in Bangladesh (Zaherudden *et al.*1985). In the absence of rice, wheat, maize, barely, oats, millet, peanut, black gram and jute can act as alternative host for BPH. Further, *Eleusine coracana, Leersia hexandra, L. japonica, Saccharum officinarum, Zea mays, Zizania latifolia* and *Zizania longifolia* may serve the purpose (Grist and Lever 1999).

Gall midge: Rao (1983) reported 28 grasses on which GMs survive during paddy off season. Midge can complete its life cycle on several species of weeds such as *Echinochloa crus-galli*, as evident from severe shoot generation (Natarajan *et al.*1988, Kalode and Bentur 1989).

Paddy bug: *Leptocorisa oratorius* and *L. acuta* adults aggregate on trees, or other shady moist site of plant canopy. Bermuda grass, wild rice, water hyacinth, torpedo grass, kodo, sugarcane and tomato are also found as alternative hosts of PB (Sands 1977).

Migration

SBs are active fliers and can travel up to a distance of 10 kilometer. BPH can passively migrate long distance by wind (Zhu *et al.*2000). Though GM and PB are less dispersive species, small size of the cultivation fields allow them to migrate to the field border vegetations. Cooter (1979) reported that BPH could migrate a long range depending on the generation in China, Korea and Japan. In China most migrant BPH took off between late afternoon and Dusk, climbed to between 300-1000m, and continued flight for several hours, dispersing down wind, mainly to the south west (Ohkubo 1973).

2.4.2 Process of cultural control: In consideration of the limitations of pesticide applications and variability of pest biology delineated above pest control by cultural practices can be manifested by following ways:

2.4.2.1 Age and number of seedling and landscape conditions: Crop of adjacent fields should be so selected that the pest of one crop may not be affected by the other crop (Doyle *et al.* 2001, Karimuna 2004). Planting of rice at different densities influences variable concentration of nitrogen in plants (Mc Garry *et al.* 2001). Plant density has effects on growth, yield and pest performance (Sewaram *et al.* 1973, Shukla *et al.* 1994, Prasad *et al.* 2007). Higher seeding rates will lead to higher plant population, more competition for limited resources, and possibly more lodging and smaller grain size. Lower seeding rates will result in increased tillering with more variation in maturing within the panicle, and higher weed populations and grain moisture content at harvest (Machado *et al.* 2005). Delayed nutrition may lead to delayed growth and crop maturing which increases the probability that the crop is affected by adverse weather coupled with the high pest population before harvesting season (Kadirgamathaiyah *et al.* 1970, Surugesan *et al.* 1987, Kabir *et al.* 2004). Injudicious shifting of planting dates imparted a negative effect on the final yield (Chakraborty1975, Saroja *et al.* 1985, Mukhopadhyay *et al.* 1987, Ganguli *et al.* 2001, Prasad *et al.* 2007).

2.4.2.2 Tillage and mulching: Soil tillage reduces insect populations through mechanical damage, by burying them so deeply that they cannot emerge or by bringing them to the surface where they may be killed by weather factors, birds or other natural enemies (Abdullah *et al.* 1998). But some SBs are vulnerable to the changes in soil texture that may be brought about by cultivation, whereas such changes may favour other species (Ekman 2000, Sharma *et al.* 2004).

Tillage before the crop is sown will destroy volunteer plants, stubble and weeds that may provide food and breeding sites for insect pests, such as SBs as well as natural enemies (Cividanes 2002, Legere *et al.* 2004). The effects of tillage on insect population depend on the method and frequency of tillage, and prevailing insect species (Kudo 2003). Plowing when the soil is wet from the first monsoon rains will expose soil insects for birds' predation (Zhou *et al* 2001, Gunnarsson 2007). Zero tillage, however, conserves predators of YSB (Mahli *et al.* 1998, Albert *et al.* 2001, Singh *et al.* 2004). Damage to seedlings was less in an untreated no-tillage system than in insecticide treated conventional tillage systems (Ekman 2000). For this reason the practice of reduced tillage has gained acceptance, resulting in the conservation of the natural enemies in the rice field ecosystem (Epperlein *et al.* 2001). But the problems relating to pre-plant vegetation management, difficulties in establishing stand, limited opportunity to apply nutrients properly and varieties that have performed poorly in no-tillage system are factors that have limited the commercial use of no tillage or other conservation tillage techniques for rice (Phillips *et al.* 1980, Skrebelis 2001, Ekboir *et al.* 2001, Tomar *et al.* 2003).

2.4.2.3 Summer plowing and stubble management: Summer and pre-monsoon plowing will expose soil insects, pupae, white grubs, cutworms etc. to heavy sun and adverse seasonal conditions in which they cannot survive (Razzaq 1997, Sharma *et al.* 2004). Similarly, tillage of soils in and around crop plants tends to reduce soil insect (Shave *et al.* 2004). The high level of mortality of *C. Partellus, C. orichalcociliellus* and *S. calamistis* in horizontally placed stalks was ascribed to the effect of sun and heat, reaching the thermal threshold for poor survival (Pats *et al.* 1997). The crop residues and stubbles carrying the hibernating larvae and infected plant parts can be destroyed by spreading straw over these material and burning (Saha *et al.* 1975).

2.4.2.4 Date and time of plantation and harvesting: Time of transplantation affects the grain conditions and pest infestation during maturation (Dent 2000). Cultural control with the selection of planting time is based on the principle of growing the crop when the pest is not present, or of planting at such a time that the most susceptible stage of crop growth coincides with the time of least pest abundance (Dent 2000, Prasad *et al.* 2004). Chinese farmers maintain proper planting dates to prevent damage by the rice borer, *Schoenobious incertellus*, the wheat stem maggot, *Meromyza americana* and *Chilo infuscatellus.* Rapid crop establishment of an early maturing variety reduces SBs damage (Sharma *et al.* 2004). By planting rice within January, the peak period of SBs and BPH infestation in April, can considerably be avoided on *boro* crop in northern parts of Indian (Saha 1986, Ganguli *et al.* 2001). Abnormally wet weather and late planting are conducive for heavy GM infestation (Dash *et al.* 2003). Planting as soon as the rainy season begins will lower most insect pest populations (Gupta *et al.* 1985). Saha and Saharia (1970, 1975) reported that in Assam, India the delayed transplanting of rice decreased infestation by the YSB. During harvesting the paddy plant should be cut at a time of 20-25% moisture content or when 80-85% of the grains are straw colored and the grains in the lower part of the panicle are in the hard stage. Harvesting rice crops close to ground level will considerably reduce infestation in the neighboring crop fields by SBs (Doyle *et al.* 2001).

2.4.2.5 Spacing and plant density: Spacing affects the relative rate of growth of a plant and pest population, as well as the behavior of the pest in search for food or an oviposition site (Ostman *et al.* 2001). Close spacing may increase the effectiveness of natural enemies and result in greater control of pest populations. On the other hand the micro-environment created by close spacing may favour some pest species (Whitney 1972). Ahmed and Rao (1965) found that increased seeding density and closer spacing led to a reduction in the proportions of WH caused by *Schoenobius incertellus.* They suggested that the risk of SB attack can be avoided by closer spacing, the suggestion is compatible with recommendation for high yielding varieties. Hopper burn symptoms ranged from 100% in closer spacing (10 x 10 cm) to 7-67% in wider spacing (23 x 10 cm). Detailed multi location trials under All India Coordinate Rice Improvement Programme (AICRIP) showed that the population of SBs and GM were more in case of closer spacing (10 x 10cm and 10 x 15cm) than in wider spacing (20 x 15 cm., 20 x 20 cm. and 30 x 30 cm.). On the other hand, closer spacing resulted in lower incidents of green leaf hopper, rice *hispa* and whorl maggot (Sing and Dhaliwal 1994).

2.4.2.6 Crop rotation and intercropping: Deterrence of colonization is probably one of the most promising means of controlling paddy insect pests through intra-field diversity (Pats *et al.* 1996). Growing non-preferred but suitable crops as alternative in each agro-ecosystem, will not only break the chain of host pest relationship, but also reduce pest pressure on both the crops (Sastrawinata 1976). Inter cropping of rice with cotton or pigeon pea, in India, has minimized green leaf hopper and white backed plant hopper populations than the rice alone. But the change in pest status from intercropping is highly location-specific (Garg *et al.*1982) and the net effect can either be beneficial or neutral (Florez *et al.* 2000, Faragalla *et al.* 2001). Aerial-feeding pests would be most affected by intercropping practices (Pats *et al.* 1997, Izumi *et al.* 2004). Intercropping or mixed cropping has been widely practiced from centuries by small scale farmers. Smith (1972) and Kung (1971) observed that following the construction of the Wu-Shan-Tau reservoir in Taiwan, agricultural practices were changed. As a result, the most damaging *T. incertulas*, decreased whereas *C. suppressalis* increased and by 1971 had become the major rice borer pest. The introduction of new varieties of paddy crops discouraging crop rotation over large areas, coupled with the use of intensive cropping systems, provide excellent possibilities for massive pest development (Ganguli *et al.* 2001). Extension of the growing season in irrigated cultures by staggered sowing or planting increased the number of generations of *Tryporyza* sp. Cleare (1927) found that the sugarcane borer, *Diatraea saccharalis* causes serious injury to rice plants and recommended the planting of a pulse crop such as cowpeas or mung beans in rotation between rice crops. But crop rotation has little to no influence on the densities of the many important insect pests, especially migratory insects such as armyworms, corn worms, potato leaf hopper, green clover worms, and corn leaf aphids (Henn 1991).

2.4.2.7 Irrigation and water stress management: Moisture regimes due to irrigation affect insect pest populations by increasing soil moisture (Das *et al.*

1977). Sing *et al.* (1974) found that some insect pests become severe in irrigated condition. Irrigation also indirectly influences pest situations by promoting luxurious plant growth. Intensive and multiple cropping are favourable for some pest generations (Choudhary *et al.* 1960). Choudhury and Sharma (1960) found that methods of irrigation insignificantly affected the pest level. But frequent irrigation increased infestation. Das *et al.* (1985) noted that submergence for variable time influences the nutrient status of dwarf *indica* varieties which in turn influence pest complexity. Das *et al.* (1977) reported from Kerala that the incidences of hopper burn were largely influenced by the field standing water. Flooding immediately after harvest increases the mortality of SB larvae in the stubbles. But the retention of standing water for longer period increases susceptibility to GM.

2.4.2.8 Nutrition and fertilizer management: N enhances the susceptibility of the plant to various diseases and insect pests. Integrated use of organic and inorganic fertilizer with the slow releasing N protectors is the alternative choices to control pest performance (Rinaldi *et al.* 2004). Increased N fertilizer on lowland rice has favoured higher population of plant hopper, leafhopper and leaf folders (Sing and Sing 1977, Mohapatra *et al.*1982, Jiang *et al.* 2003). Greater insect survival is enhanced due to the availability of better nutrition. Larger insects in the presence of more foliage show greater fecundity (Starks *et al.*1971). A lowering of the total level of minerals by erosion, over-cropping and faulty crop rotation may be conducive to some insect species (Dalal 2004, Dimitrov (2003). Ghosh (1962), Raj and Morachan (1973), Saha and Saharia (1970,1975) and Singh and Singh (1977) have noted an increased *T. incertulas* activity with the corresponding addition of field inorganic N. Singh and Singh (1977) elaborated the dose dependent positive effect of inorganic N fertilizer upon the infestation of *T. incertulas.* But the field application of silica increases the resistance of rice plants to *C. suppressalis* (Nakano *et al.* 1961). In the fields of Tamil Nadu populations of *T. incertulas* and *Nephotettix* sp. significantly intensified with higher input of nitrogen and phosphorus. Higher doses of inorganic fertilizer increases the N content in plants which imparts positive effect on the survival of the SBs in fields (Van den Berg *et al.* 1991).

Setamou *et al.* (1993, 1995) noted an accelerated larval development resulting in multiple generations of SBs following high doses of inorganic N input. A linear decrease of yield from 20% with no fertilizer to 11% with 100 kg of nitrogen/ ha was noticed.

2.4.2.9 Weeding and habitat management: Habitat management through weeding may influence arthropod natural enemies over a variety of spatial scale (Bugg *et al.* 1987, Landis 1992) and have an impact on the structure of natural enemy communities (Landis *et al.* 1998, Mareno *et al.* 1999). Increasing habitat fragmentation at a local scale can result in the loss of parasitoid species (Kruess *et al.* 1994). Weeding during the first month after crop establishment will force pests such as BPH which prefers grassy weeds to attack paddy (Yamada *et al.*2007). Hence such early weeding is not prudent. Further, clean cultural practice in the bund or in the fallow land may force BPH to attack rice plant at early growth stages (Rapparini 2001).Yield losses in India are estimated to be 10% and in Philippines 11 % during dry season and 13 % and 16% during the wet season (Shave 2004, Shibayama 2001). AICRIP- weed control estimated that yield losses were maximum in totally unwedded paddy planted plots. The loss may amount to 16.9 % in transplanted rice fields.

2.5 Paddy Plant Protection Scenario in India: A Trustful Reliance on Pesticide

Introduction of high yielding paddy varieties and the accomplishment of the intensive cropping ask fastidious nutritional requirement. Srivastava (1993) discussed a number of situations in India where poor or negative results were obtained after pesticide application. Side by side application of different types of pesticides encouraged various ranges of toxicity with perennial incorporation in the of biotic agents.

2.5.1 Consequences of toxicity in ecosystem

2.5.1.1 Percolation in the paddy field ecosystem: Compounds such as organo-chlorines, arsenicals and parquets are strongly absorbed by clay particles, but others are rarely dissolved in water when applied to the paddy field. Pesticides are taken up by paddy crops from soil and they may also contaminate the ground water. Residues of DDT have been detected in Yamuna river in New Delhi (Pillai and Agarwal 1979) and Ganga river around Farrukhabad region of Uttar Pradesh (Agnihotri *et al.*1995). Kulshrestha (1989) reported the presence of DDT, aldrin and HCH residues in water samples collected from selected crop locations of Madhya Pradesh and Rajasthan. The proportion of pesticide lost to run-off is normally very low, rarely exceeding 0.5% of the total amount applied.

2.5.1.2 Residual pesticide in food stuff and consequent health issues: Carbofuran granules were applied to the rice field at 2000 g.a.i./ha. left post-harvest residues of 0.35-0.79 ppm, 0.43-0.55 ppm in grains, husk and soil respectively. Presence of DDT and HCH residues at a maximum level of 0.1 ppm in market samples of rice and maize flour at Ludhiana, Punjab was documented (Dushoff *et al.*1994, IPMWG 1994). Senapati *et al.* (1988) noted that mean initial residue of 10 ppm (0.05%) and 19.91 ppm (0.01%) were reduced to 3.26 and 5.19 ppm, 10 days after pesticide application, to 1.14 and 2.11 ppm, 20 days after application and to non detectable level 30 days after application. Soil samples from paddy fields in Punjab (Ludhina district) have both DDT and HCH residues. In northern parts of West Bengal market samples of rice were found to contain 0.028-0.972 ppm HCH residues (BCKV 2000).

2.5.1.3 Toxicity to the farmers: Persistent long time accumulation of pesticides in the human body causes metabolic disorders, cytogenetic damage, neurological maladies and impaired aplastic anemia. About 2.9 million cases of acute exposure to pesticides are reported annually from the tropic, out of which 220,000 deaths occurs (Heinrichs *et al.* 1984, Dushoff *et al.* 1994, Kenmore 1996).

2.5.1.4 Consequences of toxicity on the biotic agents: Pesticides harm the populations of natural enemies by direct toxicity or indirectly through the host/prey or through alternative food source (Cohen *et al.* 1999, Schoenly *et al.* 1996). Synthetic insecticides are capable of reducing the effectiveness of the parasite-predator complex by destroying host/prey population on which they depend (Newsom 1967).

2.5.1.4.1 Predatory interaction: Croft and Brown (1975) have reviewed the response of arthropod natural enemies to insecticide and also tabulated the data on toxicity of more common insecticides, 10 species of coccinellid predators, 13 species of other arthropod predators, 17 species of hymenopteran parasites and 1 species of tachinid parasite. Resistant field populations have been reported in more than 500 species including mites, spiders and 14 orders of insects (Georghiou and Lagunes 1991). The distribution in the key orders with the species number was Diptera 177, Lepidoptera 74, Coleoptera 72, and Homoptera 51 and mites 71. Insecticide applications at an early age of paddy plantation destroy the ecological balance, wipes out the predators particularly spiders, predacious water striders of the genera *Microvelia* and *Mesovelia* and the mirid bug *C. lividipennis*. Destruction of such natural enemies had been confirmed as key factor for the emergence of the BPH as secondary pest (Heinrichs *et al* .1984, Kenmore 1996, Orr *et al.* 2001). Shu *et al.* (2000) suggested that by judicious application of Regent (fipronil) spider population can be maintained. Sain *et al.* (2001) suggested that repeated spraying of foliar insecticide quinalphos significantly reduced both mirid and spider populations. Patnaik (1983) found that in laboratory condition phosphamidon was most toxic to *Coccinella repanda*, *Micrapsis discolor* and *M. vincta*. Insecticide-induced resurgence of green leaf hopper, *N. Cincticeps* has been attributed to the destruction of natural enemies especially spiders (Kiritini1971, Heong *et al.* 1998). Kiritani *et al.* (1973) found that BHC applied to irrigated rice field was only imbibed by the green rice leafhopper *N. cincticaps* (Uhler) and passed on to the spider *L. Pseudoannulata*.

2.5.1.4.2 Parasitic interaction: Ishihara (1973) had referred to the elimination of parasites such as *Temelucha* (=*Cremastus*) *biguttula* in many parts of Japan after the second world war due to the consequence of innundative application of DDT. The borer, *Chilo suppressalis* increased in many areas of Japan followed by destruction of the egg parasite viz, *T. japonicum* due to the excessive use of pesticide (Doutt 1961, Chu1971, Wood 1973).

2.5.2 List of some common insecticides applied in the paddy fields throughout the world: Some common insecticides which are applied in the paddy fields are furnished in the table 2.5.1

Table.2.5.1: Some common insecticides used in the paddy fields globally

Active chemicals	Type	Recommended application Rate kg (a.i/ha)	LD50 mg/kg	Toxicity class	Target organism
BPMC of fenobucarb	Carbamate	0.40	623	WHO (II)	GLH,BPH, TH
BPMC+ alphacypermethrin	Synthetic pyrethroid	0.81	79	WHO (II)	PB, DF, SM,GLH, TH
Chlorpyriphus + BPMC	Organic phosphate	0.40	96	WHO (II)	PB,DF, SM,GLH, TH
Buprofezin	Thiadiazine compound	0.05	2194	WHO (III)	BPH, GLH (Nymphs), PB
Carbaryl	Synthetic compound	0.75	246	WHO (II)	GLH, PB (nymphs)
Carbofuran	Carbamate	33.3	8	EPA(II) (Furadan - G)	SM, WM, SB

Active chemicals	Type	Recommended application rate kg (a.i/ha)	LD50 mg/kg	Toxicity class	Target organisms
Cartap-Hcl	Neurotoxin	0.25	325	WHO (II)	SM, WM, SB, NM
Chlorpyriphos	Organic phosphate	0.4	96	WHO (II)	SB ,PB, GLH,TH
Cypermethrin	Synthetic pyrethroid	11	247	WHO (II)	SB,PB, GLH,TH
Deltamethrin	Synthetic pyrethroid	0.015	128	WHO (II)	BPH,GLH
Diazinon	Organic phosphate	1.00	300	WHO (II)	GLH,SB
Dimethoate	Organic phosphate	0.4	225	WHO (II)	GLH,SB,TH
Fipronil	Phenyl pyrazole	0.015-0.050	95	WHO (II)	SB,BPH, GLH
Malathion	Organic phosphate	1.00	1375	WHO (III)	GLH,BPH, TH, PB
Isoprocarb	Carbamate	0.50-0.75	178	WHO (II)	BPH,GLH
Metolcarb+pharate	Carbamate + phenthoate	0.9-1.2	268+ 300	WHO (II)	GLH,BPH
Triazophos	Triazole	1.4	57	WHO (Ib)	SB,GM,PB, TH,WM

SM: seedling magogt, SB: stem borer, GM: gall midge, BPH: brown plant hopper, TH: thrips, WM: worl maggot, GLH: green leaf hopper, NM: nematode

Sources: Cremlyn 1980, Heinrichs *et al.* 1984, Chelliah *et al.* 1990, Dushoff *et al.* 1994, Kenmore 1996

2.5.3 Recommended insecticides for different rice insect pests

The recommended insecticides for controlling the paddy pests in India are furnished in table.2.5.2

Table.2.5.2: Pesticides recommended in India for management of insect pests of Paddy

Pests	Pesticides
Scirpophaga incertulus (Yellow stem borer)	Acephate, Bromophos, Carbaryl, Carbofuran, Cartap, Chlorpyriphos, Endosulfan, Ethion, fenitrothion, Lindane, Monocrotophos, Phosalone, Phorate, Quinalphos
Nilaparvata lugens (brown plant hopper)	Carbaryl, Carbofuran, Diazinon, Endosulfan, Ethion, Fenthion, Lindane, Methamidophos, Monocrotophos, Phorate, Phosphalone, Phosphamidon
Nephotettix sp (Green leaf hopper)	Carbaryl, Carbofuran, Chlopyriphos, Cypermethrin, Decamethrin, Diazinon, Fenitrothion, Monocrotophos, Phosphamidon, Fenthion, Phorate
Orseolia oryzae (Gall midge)	Carbofuran, Chlopyriphos, Diazinon, Fenthion, Mephosfolan, Phorate Phosphamidon ,Quinalphos
Leptocorysa sp (Gundhi bug)	Fenthion, Malathion
Dicladispa armigera (Rice hispa)	Carbaryl, Carbofuran, Chloropyriphos, Fenitrothion, Methylparathion, Monocrotophos, Permethrin, Phorate, Phosphamidon, Phosvel, Quinalphos, Thiodemeton
Cnaphalocrosis medinalis (Leaf folder)	Acephate, Carbaryl, Carbofuran, Cartap, Chlopyriphos, Fenthion, Fenvalerate, Monocrotophos, Permethrin, Phosphamidon, Quinalphos, Triazophos
Mytimna separate (Climbing cut worm)	Aldrin, Carbaryl, Chlopyriphos, Dichlorvos, Endosulfan, fenthion, Malathion, Methyl Parathion, Phosphamidon, Quinalphos,Trichlorphon
Breveninia rehi (Mealy bug)	Carbofuran, Chlordane, Chlorpyriphos, Dimethoate, Dieldrin, Endosulfun, Phorate, Phosphamidon

Sources: Heinrichs *et al* .1984, Chelliah,S *et al.*1990, Srivastava 1993, Kenmore 1996