

DISCUSSION

1.6. DISCUSSION

Many cucurbitaceous vegetable crop plants growing in India suffer from the drawback of having undesired excessive vegetative growth which often cause serious impairment of crop yield and thus in many occasions vigorous plant growth and higher productivity becomes inversely correlated (Shil, 1990). The present experimental plant chayote was also not found to be an exceptional species showing this generalized behaviour of cucurbits. Keeping in mind this prime negative yield attributing characters of chayote plant an attempt was made to increase crop yield simply by restraining the undue vigour using some growth retarding chemicals which had been established as potent suppressor of vegetative growth of many agricultural and horticultural plants. In fact, growth retardants exert their physiological action by slowing down cell division and cell elongation without altering their gross morphology and causing any drastic adverse effects (Cathey, 1964; Bhattacharjee *et al.* 1986). We are now quite aware of the fact that yield impairment is resulted in many crop plants owing to their unwanted excess vigour which consequently deprive the reproductive sinks of their optimum need of assimilates (Weaver, 1972; Bhattacharjee *et al.*, 1984; Milthrope and Moorby, 1988).

In the present investigation, three growth retarding chemicals namely Na-dikegulac, chlormequat and maleic hydrazide were used as the test chemicals with a view to obtaining the desired modification of growth, metabolism and yield of a less explored promising hilly cucurbit chayote (*Sechium edule*). After initial screening of a suitable varietal type (type C, vide table 1.2), determining the discrete phases in the life cycle of this species and selecting of optimum concentration range of the growth retardants suitable for this plant, applications were timed at three different developmental stages of the plant viz., sprouting stage of fruits, sapling stage and preflowering stage of the plant. The retardant-induced changes of some growth and biochemical parameters were analysed at different developmental stages of the plant and reflection of such changes on yield attributes were recorded. Again, combined treatments with retardants followed by plant hormones like IAA, kinetin and GA₃ were given at the flowering stage of plant growth and changes in modification of growth, metabolism and yield were analysed. The results obtained in this investigation were discussed at length from the available literature in this field and allied fields of research.

The present investigator and his associates after a thorough exploration in the chayote growing regions of Darjeeling hills, reported the existence of ten varietal types which somewhat differ among themselves with respect to their productivity, morphological characters of mature fruits, vine length and branching pattern (Lama *et al.*, 1984). The type C (table 1.2) was found superior in all respects. Important events in the life cycle of this varietal type were analysed and found that vigorous vegetative growth starts around 50 days of plant age and continue up to active fruiting phase and this was determined as the log phase of plant growth (table 1.2 and figure 1).

Results on whole fruit treatment with Na-dikegulac, chlormequat and maleic hydrazide revealed that the chemicals, irrespective of their concentrations, failed to induce any permanent effect on modification of growth, metabolism and yield of chayote plant. Data on biochemical changes in leaves showed that the retardant-induced increase in chlorophyll and protein (table 1.7), soluble and insoluble carbohydrate (table 1.8), RNA and DNA (table 1.9) levels were recorded at the seedling and sapling stages of plant development and subsequent changes were found to be statistically at par with that of control values. Likewise, activities of peroxidase and catalase enzymes (table 1.10) remained subdued in the retardant-treated samples only up to sapling phase and activities of the catabolic enzymes IAA-oxidase and RNase (table 1.11) remained unchanged almost throughout the observation periods after a transient decrease at seedling stage. Growth parameters like vine length was reduced and stem circumference was increased (table 1.12) by the retardant treatments up to sapling stage and thereafter all changes were found insignificant.

Such results are indicative of the fact that the retardants possibly hindered the biosynthetic processes of the macromolecules which actively occur at the early stage of plant development, but with the progress of plant age the inhibitory effects were nullified because of diminished action of the retardants and consequent revival of the biosynthetic machinery of the cellular components. The resultant biochemical changes were correspondingly reflected in the plant growth as evident from the reduced vine length and enhanced stem circumference recorded at seedling and sapling stages only.

Reports exist in the literature that growth retardants temporarily exert inhibitory effects on seedling growth and metabolism (Knypl and Chylinska, 1972; Ben-Gad *et al.*, 1979; Bhattacharjee, 1984; Bhattacharjee *et al.*, 1986). Ben-Gad *et al.* (1979) observed that elongation of *Citrus* seedlings was initially retarded by SADH treatment but vigorous growth was resumed thereafter. Similar retardant-induced transient inhibition followed by rapid growth was also observed by Monselise *et al.* (1966), Sachs and Mock (1975), Bhattacharjee (1984) and many others who reported such effect using conventional retardants like CCC, SADH, 2,4- DNC, AMO 1618, MH morphactin etc. but reports with Na-dikegulac are rather uncommon. Since first reporting and establishment of Na-dikegulac as a potent growth suppressor by Bocion *et al.* (1975), a considerable volume of work has been accumulated.

There are reports in the literature that Na-dikegulac affect seedling growth and metabolism of a good number of plant species (Bocion and De Silva, 1976; Arzee *et al.*, 1977; Purohit, 1979; 1980a,b,c; Bhattacharjee and Gupta 1981a,b; Bhattacharjee *et al.*, 1986). Arzee *et al.* (1977) showed that the overall seedling growth of zinnia, sunflower and chrysanthemum was affected with regard to the shortening of internodes, abnormal growth of leaves and disruption of apical dominance. Several reports revealed that Na-dikegulac reduced the seedling growth of sunflower (Purohit, 1979, 1980 a,b), *Avena sativa* (Purohit and Chandra, 1980), *Brassica campestris* (Purohit, 1980c) or *Glycine max* (Purohit and Chandra, 1981) and the effect was found to be concentration dependent. Purohit (1979, 1980 a,b) also reported that concomitant with the reduction of seedling growth, Na-dikegulac adversely affected chlorophyll biosynthesis and reduced protein as well as sugar contents.

The results of this investigation was thus in conformity with the reported observations with growth retardants on some other plants. Initial retardation of growth and metabolism in chayote plant followed by alleviation of such inhibitory effects might be explained considering the proposition made by Ben-Gad *et al.* (1979). From their experiments on the distribution of ^{14}C labelled assimilates in SADH-treated plants, the authors concluded that assimilates and growth substances accumulated during the period of inhibition. Such accumulated materials and growth hormones were utilized fully during the subsequent periods when normal growth and metabolism and consequent rejuvenation of the plants

resumed. In fact, such accumulation of growth substances during the periods of inhibition by growth retardants was also found in several studies (Frydman and Wareing, 1974; Kuo and Pharis, 1975; Phillipovich and Rowe, 1977). Arzee *et al* (1977) using Nadikegulac showed that overall seedling growth of zinnia, sunflower and chrysanthemum was affected with regard to the shortening of internodes, abnormal growth of leaves, disruption of apical dominance, inhibition of DNA synthesis and chlorosis of leaves. In their investigation, the authors showed by whole plant autoradiography that the chemical moved towards acropetal direction and triggered its physiological action from the shoot-tips. They further reported that the adverse effects were later overcome and in all the three species convoluted and chlorotic leaves were regreened after a transient degreening.

The temporary inhibitory effect, as observed in the present study, as a result of whole fruit treatment at the sprouting stage, might therefore be the effect of the growth retardants in the arrestation of the activities of overall biochemical machinery within the plant tissue and these cumulatively resulted in subdued plant metabolism and consequent shortening of vine length as well as increased radial growth of stem.

Results of the retardant-induced whole fruit treatment at the sprouting stage also revealed that yield components of chayote, recorded in terms of fruit number, fruit weight and tuberous root weight per plant as well as days for inception of plant senescence (table 1.13) remained unchanged at all the concentrations of the chemicals. This result can be substantiated from the normal behaviour of growth and metabolism as well as unchanged potential of the plants during flowering, fruiting and senile stages after a transient initial adverse effect. In fact, as yield components and senescence inception time were recorded at the advanced stage in the life cycle of the plant, the initial adverse effects of the retardants were totally nullified leaving their no residual influence on modulating the yield components and senescence.

The present observation on the futile effect of the growth retardants on modifying yield attributes can be corroborated from the findings of Lovett and Orchard (1976) who reported that CCC could augment yield alongwith inducing morphological and anatomical changes of sunflower when applied at log phase of plant growth only, and its application at lag phase was ineffective. Similar observation was recorded by Dorrel

(1973). In sunflower Bhattacharjee (1984) reported that seed treatment or early seedling treatment with some growth retardants neither impaired or stimulated productivity. In the present study with chayote the results thus accord with reports of previous workers.

In the present investigation, results on foliar treatment with Na-dikegulac, chlormequat and maleic hydrazide at the sapling stage (30-day-old plants) revealed that the retardant-induced changes in chlorophyll and protein (table 1.14), soluble and insoluble carbohydrate (table 1.15), RNA and DNA (table 1.16) levels as well as activities of peroxidase and catalase (table 1.17) enzymes in leaves were inhibitory only at the initial observation period of 40-day-old plants. Such inhibitory effects were erased shortly, and the levels of the biochemical variables were higher than control values that persisted till the senile stage of the plant. In case of soluble carbohydrate (table 1.15) and DNA (table 1.16) the retardant-induced changes recorded at preflowering, fruiting and senile stages were insignificant after a transient increase of soluble carbohydrate and a decrease of DNA levels at the initial observation period (sapling stage). Again after a fleeting increase of IAA-oxidase and RNase (table 1.18) activities, a consistent decrease in the activities of the enzymes were recorded till senile stage of the plant. Retardant-induced shortening of vine length and increase of stem circumference (table 1.19) were however recorded throughout the observation periods.

Results of foliar application of the retardants at the sapling stage of 40-day-old plants thus indicate that higher levels of chlorophyll, protein, insoluble carbohydrate and RNA as well as enhanced activities of the anabolic enzymes like catalase and peroxidase in retardant-treated plants maintained vital functional life of the plant for longer duration. Thus, after experiencing a transient set-back with respect to potential performance of the species at sapling stage, all the retardant-treated plants revealed higher metabolic status and showed enhanced plant potential throughout its life span. However, the initial inhibitory effect may be justified by an immediate strong retardation action rendered the chemicals on plant metabolism which started relinquishing with the progress of plant age. The adverse effects thus did not at all persist for a longer duration. A perpetuating retardation action of the chemicals at later stages of plant development was clearly reflected on the overall growth of the chayote plant as evident from the reduction of vine length and enhancement of radial growth of stem which persisted till the senile stage of plant

growth.

Retardant-induced reduction in plant height is amply documented (Cathey, 1964; Lovett and Campbell, 1973; Guardia *et al.*, 1974; Clark and Fedak, 1977; Knypl, 1979; Bhattacharjee, 1984; Bhattacharjee and Gupta, 1984). Cathey (1964) in his excellent review lucidly reported the work of many workers on various physiological roles of growth retardants and the very common and significant visible effect of the chemicals is the shortening of plant height. Whitehead (1965) showed that both shortening and xeromorphism could be induced in sunflower through CCC application. Guardia *et al.* (1974) observed that CCC and SADH efficiently reduced plant height and produced thicker as well as stronger stem in sunflower. Bhattacharjee (1984) reported that in sunflower shortening of plant height and increase of stem circumference were associated with profuse development mechanical tissues and enhanced lignification in stem. Effect of Na-dikegulac on the alteration of plant growth and metabolism was studied by a number of workers (Bocion *et al.* 1975; De Silva *et al.* 1976; Hield *et al.* 1978; Orson and Kofranek, 1978; Bhattacharjee and Gupta, 1984; Bhattacharjee *et al.*, Mattia, 1984). Bocion *et al.* (1975) reported that Na-dikegulac retarded the growth of a wide range of plant species which included cereals, cultivated as well as weed grasses and woody plants. Na-dikegulac-induced inhibition of growth was observed by Shulmann and Lavee (1983) in grapevine and olive shoots. A number of reports exist in the literature that Na-dikegulac like other conventional growth retardants exert influence on plant metabolism (Bocion and De Silva, 1976; Gressel and Cohen, 1977; Zilkah and Gressel, 1978; 1979; 1980; Purohit and Chandra, 1981; Bhattacharjee and Gupta, 1981a,b and 1984). Inhibition of chlorophyll biosynthesis has been studied in *Zinnia*, *Chrysanthemum* and *Helianthus* (Arzee *et al.* 1977), *Azalea* (Bocion and De Silva, 1977a) in *Helianthus annuus* (Purohit, 1979).

The existing literature pertaining to the retardant-induced effects on the changes in growth and metabolism thus; corroborate the overall findings of this investigation done with a different plant species.

In this study, growth retardants like Na-dikegulac and chlormequat resulted in a significant increase of yield components like fruit number, fruit weight as well as tuberous root weight per plant. The retardants also showed a tendency towards deferring plant

senescence (table 1.20). Increased crop yield by the two retardants as well as significant senescence delaying effect of Na-dikegulac (2000 µg/ml) and above all a general tendency for delaying of senescence and enhancement of yield can be substantiated from the enhanced plant potential as evident from the biochemical analyses of this investigation. Unlike sprouting whole fruit treatment, foliar treatment with the growth retardants at the sapling stage enhanced the levels of vital cellular components like chlorophyll, protein, insoluble carbohydrate, RNA as well as the activities of the scavenger enzyme catalase and peroxidase particularly at the fruiting and senile stages of the plant. During active fruiting phase or grain-filling phase of plants developing fruits or grains function as reproductive sinks which show a strong sink demand and thus accumulate assimilates from the source leaves or contributory leaves (Bhattacharjee *et al.*, 1984; Milthroe and Moorby, 1988). Prolonged assimilate transport due to strong sink demand enhance plants capital, and delaying of the senescence of plants cause augmentation of yield in many plants (Bhattacharjee 1984; Bhattacharjee *et al.* 1986; Kumar and Purohit, 1997; Biswas and Ghosh 1999). In the present investigation, it seems apparent that increased crop yield in chayote is possible due to maintenance of vital functional life of the source leaves by delaying of senescence which in turn efficiently transported assimilates for a longer duration.

Whatever might be the mechanism of senescence in this monocarpic vegetable crop, it seems quite likely that enhanced plant potential, deferred plant senescence, desired plant type modification and possibly prolonged assimilate transportation during fruit development cumulatively resulted in a substantial enhancement of yield at least in two retardant treated plants. Some authors critically analysed scientific crop production as well as source-sink relationship in various crop plants including a few vegetable crops and came to the conclusion that a balanced source-sink relationship is an important determinant for crop yield (Thakur, 1975; Milthroe and Moorby, 1988; Biswas and Ghosh, 1999). Retardants, in general, delay the onset of senescence in plants (Orchard and Lovett, 1976; Weaver, 1972; Bhattacharjee, 1984; Bhattacharjee *et al.*; 1986). Retardant-induced delaying of seed senescence and consequent enhancement of seed potential in some species have been established (Bhattacharjee and Gupta, 1985; Bhattacharjee and Choudhuri, 1986; Chhetri *et al.*, 1993; Basu, 1994; Rai *et al.* 1995; Bhattacharjee *et al.*, 1999; Maity *et al.* 1999). Deferral of senescence in vegetables, cut flowers and even in mushroom and the resultant longevity have also been documented

(Halevy, and Wittwer, 1966). While studying the processes of monocarpic senescence Nooden *et al* (1979) concluded that the prevention of the internally programmed degeneration might open a way to yield improvement. In the present study thus the augmented yield in the treated plants can be justified from the reported observations with respect to manipulation of source-sink, senescence as well as plant type.

Experiment on foliar treatment with growth retardants at preflowering stage and retardant followed by hormone treatment at the flowering stage seemed to be more interesting. In this experiment, all the three growth retardants, regardless of their concentrations, caused to increase the levels of chlorophyll and protein (table 1.21) soluble and insoluble carbohydrates (table 1.22), RNA and DNA (table 1.23) as well as the activities of peroxidase and catalase (table 1.24) enzymes. Such increases were further enhanced as a result of IAA and kinetin application at flowering stage. Again, retardant-induced decrease in IAA-oxidase and RNase activities (table 1.25) decreased to a further extent in the IAA-and kinetin-treated samples. Biochemical changes in leaves were associated with the changes in vine length and stem circumference (table 1.26). While the retardant-induced reduction of vine length was substantially overcome in combined treatments with IAA and kinetin, stem circumference in the chemical treated plants was found to increase steadily throughout the observation periods in IAA and kinetin-treated plants and thus combined treatments were found more effective.

Unlike the results of foliar treatment of the retardants at sapling stage, the consistent increase of chlorophyll, protein, soluble and insoluble carbohydrate, RNA and DNA levels as well as the activities of catalase and peroxidase enzymes indicate that their application at the preflowering stage of active log phase of growth resulted in a steady and unflinching enhancement of plant potential which persisted till senile stage. Further potentiation of the retardant-treated plants by IAA and kinetin as evident from the biochemical changes and rejuvenated plant growth is indicative of the fact the plants under combined treatment could successfully defer the inevitable internally programmed degeneration occurring during senescence. The data of this investigation thus prove the senescence deferral property of the chemicals.

In the physiology of plant senescence, it is now well established that senescence is accompanied by the decrease of chlorophyll and protein levels and/or increase of their degradation (Osborne, 1967; Leopold and Kriedemann, 1975; Beevers, 1976; Van Staden *et al.* 1988; Biswas and Ghosh, 1999). There are reports that the activities of enzymes like protease and IAA-oxidase increase and catalase activity decrease during senescence (Biswas, 1978; Bhattacharjee, 1984) and alteration of such senescence indices by growth retardants indicate their senescence deferral action. While studying the processes of monocarpic senescence in soybean Nooden *et al.* (1979) concluded that prevention of the internally programmed degeneration might open a way for strengthening plant potential and consequent enhancement of yield. Whatever might be the mechanisms of senescence (Thomas and Stoddart, 1980; Thimann, 1980; Biswas and Choudhuri, 1981; Roy and Choudhuri, 1981; Choudhuri and Mondal 1988; Choudhuri, 1988; Nooden and Leopold, 1988; Engvild, 1989; Nooden *et al.*, 1997) it is now well documented that deferral of plant senescence results in an enhanced plant vigour and such invigouration in many occasions is associated with enhanced productivity (Biswas and Choudhuri 1978; Nooden *et al.* 1979; Bhattacharjee *et al.* 1984; Biswas and Ghosh 1999).

Results of yield analysis alongwith senescence of plants (table 1.27) and flower productivity (table 1.28) using growth retardants and growth promoters respectively at preflowering and flowering stages, as observed in the present investigation, seemed to be more encouraging. Strong senescence deferral action in conjunction with higher productivity particularly in combined treatments can be explained by the enhanced potential of the plants by growth retardants and effective utilization of the potentiated vigour by stimulating the sink demand using IAA and kinetin at the appropriate stage i.e. flowering stage of plant development. Again, a significant increase of flower numbers (table 1.28), particularly female flowers, in combined treatments, showed an additive effect to the enhanced productivity. In fact, higher number of female flowers resulted in corresponding increase of fruit numbers and consequent increase of total yield of fruits per plant. Now the question arises why tuberous root weight and also weight of fruits per plant increased both in single (with retardants only) and in combined treatments although the increase was distinctly differential in single and combined treatments. This observation can be well explained from the available literature on source-sink and translocation system relationship of plants and particularly that of monocarpic plants where a balancee

relationship of source, sink and translocation system plays a crucial role for optimum productivity.

In crop plants physiological basis of yield was demonstrated and it was shown that enhanced plant potential becomes futile if plants fail to exploit vigour by efficiently drawing assimilates to the reproductive sinks during fruiting (Evans, 1975; Bhattacharjee, 1984; Bhattacharjee *et al.* 1984; Milthrope and Moorhy, 1988). In the present investigation at least two systems were vitalized i.e. source and sink, while translocation system remained unexplored. Potentiation of source system was well documented in this work where the treated plants got rejuvenated as evident even by visual appearance and this was biochemically substantiated by analysing some senescence variables like enhancement of chlorophyll, protein, carbohydrate, nucleic acids as well as activities of catalase and peroxidase enzymes and suppression of deleterious enzymes like IAA-oxidase and RNase during active fruit development and senile stages. Efficiency of the reproductive sinks was supposed to be enhanced by the hormonal (IAA and kinetin) treatments during flowering stage where endogenous hormone-induced sink stimulation was further augmented by exogenous application of the hormones at the appropriate assimilate filling stage.

Hormone-directed translocation of assimilates is an well established phenomenon (Audus, 1959; Davies and Wareing, 1965; Patrick, 1979; Mulligan and Patrick, 1979; Thomas, 1985; Taiz and Zeiger, 1998). It is generally accepted that actively growing meristems and reproductive organs are the potential sinks for photosynthetically produced assimilates, and that activation or repression of apical sink and/or reproductive sinks may result in corresponding changes in growth and yield of plants (Moorby, 1977; Wareing and Patrick, 1975). Growth retardants generally act through suppressing the apical sinks by reducing the hormonal levels therein and consequently by hindering the acropetal mobilization of assimilates (Cathey, 1964; Monselise and Luckwill, 1974; Hoad and Monselise, 1976; Ben-Gad *et al.*, 1979). Bhattacharjee (1984) using ^{32}P showed that feeding of ^{32}P through contributory leaves of sunflower of some retardant treated plants resulted in a strong hindrance of ^{32}P mobilization to the upper leaves and reproductive sinks of the capitulum. He further observed that concomitant with such hindered mobilization of ^{32}P at the apical region basipetal mobilization was stimulated in the

retardant treated plants. Lovett and Orchard (1976) from their experiment with radioactive carbon reported that in sunflower photosynthetic rate as well as assimilate translocation were reduced by CCC treatment in the upper leaves and greater accumulation in CCC-treated plants was noted in roots. Monselise and Luckwill (1974) demonstrated that acropetal translocation of assimilates was hindered by SADH beginning almost immediately after treatment.

Thus, from all the reported observations, it seems likely that in this investigation the retardants induced positive factors of productivity like suppression of excess vigour and invigouration of plants but induced a negative factor for fruit production in chayote i.e. lowering of acropetal mobilization. And the negative factor i.e. reduced acropetal mobilization of assimilates was overcome by exogenous application of IAA and kinetin which possibly compensated or even enhanced sink demand. So, enhanced plant vigour in conjunction with activated reproductive sink resulted in a substantial increase of fruit yield. Again, enhanced yield of tuberous roots can be explained by the reported observation that during retardant-induced basipetal mobilization the tuberous roots acted as the alternate potential sinks at least till the growth promoters are applied at the flowering stage of the plant causing diversion of assimilates to the reproductive sinks. In the present investigation, thus, the retardants alone caused to enhance root yield, and combined treatments with growth retardants followed by growth promoters caused to improve fruit yield. It has been demonstrated by many workers (Lorenzi *et al.* 1988, Ceccarelli and Lorenzi, 1990; DiGregorio *et al.*, 1995; Piaggese *et al.*, 1997; DiGregorio *et al.*, 1997) that in chayote plant hormones like IAA, cytokinin and GA₃ appear during fruiting, and developing fruits yield a considerable amount of the hormones. Thus, enhancement of the levels of these hormones by their exogenous application, as done in the present experiment, resulted in a remarkable enhancement of fruit yield.

Hormonal regulation of sex expression as well as flowering and fruit development in many plants including some cucurbits are well documented (Bose and Nitsch, 1970; Ghosh and Basu, 1982; 1983; 1984; Banerjee and Basu, 1991; 1992). Banerjee and Basu (1992) reported that GA₃ and ethrel enhance female flower production, stimulate fruit setting and fruit development in a monoecious cucurbit, *Momordica charantia*. Enhancement of both male and female flowers per plant by GA₃ application was

demonstrated by Prakash (1977) in the same cucurbit. GA_3 , IAA and HMO-an oxidation product of IAA promoted female flowers in *Momordica* which resulted in yield improvement (Ghosh and Basu, 1983). Influence of Na-dikegulac and IAA in increasing female flower production, decreasing the percentage of abortive female flowers and consequent augmentation of fruit yield was reported by Banerjee and Basu (1991).

In our observation with a different cucurbit (*Sechium edule*) masculinizing and feminizing effect of GA_3 , IAA and kinetin and corresponding enhancement of fruit yield is thus in agreement with reported results. In this investigation this floral stimulation property of the growth promoters was efficiently utilized after modifying plant growth and potentiating the chayote plants by prior application of growth retardants like Na-dikegulac, CCC and MH. Thus retardant- and promoter-induced selective dual action on the plants caused significant augmentation of crop yield in this study.

Thus, it is concluded that selective concentrations of some growth retardants might be used with a view to increasing crop yield of chayote plant. but selection of the optimum stage of the chemical application and exploitation of the imposed higher vigour through hormonal manipulation at a critical stage of plant growth are the important determinants for obtaining the most covetable result.