REVIEW OF LITERATURE
A large number of workers have done experiments on the growth response of different plant species after treatment with growth promoting substances. Most of them used the hormones through the culture medium of tissue-culture technique but some of them also followed the foliar spray method. Also, a large number of workers used the soaking of seeds or the propagule in the solution of growth promoter. The time of soaking depended upon the structure of seeds or propagules.

During vegetative propagation also, influence of growth promoters like IAA, NAA, IBA and GA has been studied by a number of workers in the last quarter of the 20th century. Most worked-out plant species are yams (different species of Dioscorea, i.e D. rotundata, D. alata, D. deltoidea, D. bulbifera, D. pentaphylla, D. composita and D. floribunda etc.). In these plants, under-ground or above-ground tuber is the perenating organ and was used as a ‘seed’ material for vegetative propagation. The other most worked-out species is Colocasia, in which vegetative propagation is done by under-ground rhizomes. Allium cepa is also an important species whose growth behaviour has been studied under the influence of growth regulatory substances. The perenating organ in it, is under-ground bulb and usually dipping the bulbs in growth regulator solutions for 6 to 24 hours has been followed. This treatment is generally given only once, i.e. before sowing, however, foliar spray is done many times. The frequency is sometimes once every month or even as early as two times a week. Cultivated varieties of Xanthosoma sagittifolium and Amorphophallus campanulatus have been studied by soaking their corms.
These investigations were aimed to initiate sprouting, flowering, fruiting and seeding in those species which are normally cultivated by vegetative propagation. Several species of *Zingiber* and a few species of *Curcuma* have also been investigated in the past, but not to a large extent. A limited amount of success has also been obtained in these species in enhancing rhizome yield and initiating flowering.

A systematic account of the works done in the last 25 years is given below:

Das and Nair (1976) reported that urea at 2% containing NAA at 200 and 400 ppm was applied to 5 ginger cultivated varieties in June and the crop was harvested in the following February. The production of dry ginger was highest in the cultivar Maran, followed by Sierra Leone, China, Thinladium and Rio-de-Janeiro. The best treatment was urea + NAA (Planofix) at 200 ppm.

Takagi and Auba (1976) observed that Gibberellic Acid (GA) applied during inflorescence formation stimulated bulblet formation and increased the number of cloves/bulb in garlic but delayed storage leaf formation and inhibited their development. NAA at 50-800 ppm also inhibited formation and development of storage leaves. Habibasha and Behairy (1977) noticed that GA, Mn and Mg treatments increased the weight of various plant parts, i.e. bulb weight of Onion. The greatest response occurred with the combined Mn+Mg+GA treatment.

Alam and McDavid (1978) reported that the foliar sprays of 250 and 1000 ppm GA at 4, 6 and 8 weeks after planting promoted flowering within 130 days after the initial application in *Colocasia esculenta var. esculenta*, *C. esculenta var. antiquorum* and
Xanthosoma sagittifolium. Flower-promoting effects of GA varied between different types of Colocasia. It was suggested that the differential response may be related to differences in endogenous gibberellin levels.

Nandi and Chatterjee (1978) reported that the tuber pieces of Dioscorea composita, D. pentaphylla and D. bulbifera var. pulchella were pre-treated with Ethrel (Ethephon), GA or potassium thiocyanate, each at 20 and 200 μg/ml for 24 hours before planting in pots. Sprouting and flower initiation of D. bulbifera var. pulchella and flower initiation in D. pentaphylla were hastened by Etheral at the lower rate, but GA delayed growth and flowering of all three species. Diosgenin synthesis of all species was enhanced by Ethrel at the lower concentration (20 to 100 ppm) and by GA at either concentration. Yield of yams was also increased by Ethrel at the lower rate and by potassium thiocyanate at high concentration.

Asahira and Yazawa (1979) noticed that in the stem segments of Dioscorea opposita, the auxins IAA, NAA and GA₃ induced bulbil formation. Singh and Singh (1980) observed that the application of 100 ppm NAA to Dioscorea floribunda nodes resulted in rooting in 90% of the nodes and shoots were formed from 70% and 40% of the air and ground layers, respectively. The 100 ppm treatment was more effective than other treatments and gave more rapid root initiation.

Wilson (1981) found out that the gibberellic acid (GA) at 1500 ppm applied as foliar spray or pre-plant soak effectively promoted flowering in Xanthosoma sagittifolium and Colocasia esculenta. A foliar spray of technical grade GA gave better results than foliar spray of commercial GA formulation. A pre-plant soak was least effective.
But, Wilson et al. (1982) studied C. esculenta plants treated with foliar applications of 500, 1000 and 1500 ppm GA applied at the 3-5 leaf stage. They observed that increasing concentration of GA resulted in increased number of inflorescence per plant, with the maximum number of inflorescence per plant obtained with 1500 ppm GA. Loper and Waller (1982) reported that GA$_3$ at 25, 50 and 500 ppm applied to Allium cepa sown in late autumn in Arizona USA, significantly increased bolting and seed yield. Seed weight was significantly increased at the highest level of GA$_3$ tested.

Nambiar et al. (1982) at Central Plantation Crop Research Institute (CPCRI) Kasragod, Kerala, investigated 11 cultivars of Curcuma aromatica and six of Curcuma longa. In Curcuma aromatica, (1) the flowering period was July-September, (2) flowering occurred between 06.00 and 07.00 h and lasted 94 - 104 days, (3) seeds matured in 23-29 days and germinated in 10-16 days, (4) average germination ranged from 35.8 to 62.5% and (5) seedling, like their parents, had 2n=84 chromosomes. Although flowering occurred in the triploid species of Curcuma longa but fruit set was not observed because microsporogrnesis was irregular and pollen fertility ranged from 45.74 to 48.48%. Singh et al. (1983) noticed that treatment of Onion bulbs with GA at 40 ppm gave the best plant growth, highest yield (249.8 q/ha) and good bulb quality of Onion. The control yield was 140 q/ha. Treatment of seed bulbs with NAA at 40 ppm gave the next best results.

Alvarez et al. (1984) observed that in pot experiments with pre-sprouted true seeds of Dioscorea rotundata, a very high yield of marketable seed yams (42 t/ha of tubers weighing from 100 g to 1.2 kg) was obtained. Propagation with the aid of NAA increased the
multiplication ratio from the traditional 1:4 to 1:90. Tubers of both *D. rotundata* and *D. alata*, dipped in 500 and 1000 mg NAA/litre showed increased survival and rooting. Tuber yield ranged from 80 g to 1.25 kg at 7 months after planting. Singh *et al.* (1984) noticed that soaking the seeds of Onion for 8 hours in a solution of NAA of 20 ppm gave the highest yield of Onion (326.5 q/ha) as compared with 206.3 q/ha in the control. The next best treatment was GA at 75 ppm which gave 245.49 q/ha.

Okezie (1985) reported that the small tubers of *Dioscorea rotundata* in storage were pre-sprouted for 4 weeks after treatment with 0-750 mg of IBA per litre of water and then planted in the field. IBA stimulated sprouting by inducing profuse root formation, followed by emergence of sprouts which became longer than those formed on the untreated control tubers by the 4th week of pre-sprouting in the greenhouse. Optimum IBA concentration for sprout formation was 500 mg/litre, giving 100 % sprouting within 3 weeks. During field growth, dry weight determinations showed that IBA treatment brought a rapid reduction of the mother tuber, resulting in earlier establishment of an autotrophic plant with higher leaf, stem and root dry weight, earlier initiation of the new tuber and higher yield at harvest.

Abd *et al.* (1986) reported that only GA$_3$ at 100 ppm applied once or twice to the seed bulbs of Onion (*Allium cepa*) increased the yield slightly in relation to the control whereas all other treatments decreased it slightly especially GA$_3$ at 200 ppm applied once. The treatment did not generally have beneficial effect on quality of Onion but pungency was slightly increased.
Irawati et al. (1986) reported that the lateral buds from the corms of elephant yam (*Amorphophallus campanulatus*) of field-grown plants were cultured on Murashige and Skoog (MS) medium supplemented with NAA and kinetin, and on MS medium lacking hormones. Callus and plantlet development was optimal at 0.5 ppm NAA and 0.05 ppm kinetin. Plantlets transferred to soil after 24-36 weeks of culture grew normally.

Katsura et al. (1986) noticed that the gibberellic acid at 200 and 1000 ppm, sprayed on *Colocasia esculenta* plantlets stimulated flowering. In all cultivars, flag leaves were induced, indicating the transformation from vegetative to reproductive growth. In cultivars which do not flower readily, only spadixless flowers were induced; in readily flowering cultivars, some abnormal flowers were noted. It was concluded that flower stimulation may be a continuous process rather than a single event.

Manuel (1986) observed that the flowering in *Colocasia esculenta* was induced in pot-grown plants of 3 cultivars treated at 45 days from planting with surfactant-enhanced foliar sprays of the gibberellic acid $\text{GA}_3$ at concentrations from 250 to 1000 mg/litre. Two cultivars, which flower only sporadically under field conditions showed synchronous and profuse flowering at all concentrations (100% flowering at the higher concentrations). Only a few plants flowered in a cultivar not known to flower under natural conditions. No flowering occurred in controls of any of the three cultivars. $\text{GA}_3$ also elicited other physiological and morphogenetic responses, such as enhanced petiole elongation.
Miyazaki et al. (1986) found that the flowering occurred in 4 out of 6 *Colocasia esculenta* cultivars treated with gibberellic acid (GA). Differences were noted in response to GA concentration (200-1000 ppm) and treatment type (soaking apical buds). The percentage of plants showing the flowering was 100% 10 weeks after soaking. Treated plants produced inflorescences 3 weeks before untreated plants; these inflorescences had fewer florets and bract-like deformities were observed on the GA-induced inflorescences of the other cultivars. Pollen production occurred only in one cultivar and was inconsistent. In other cultivars, no pollen from GA-induced inflorescences germinated. Pollen germination of GA treated cultivars was 24.7%. Miyazaki et al. (1987) after a prolonged investigation reported that the flowering in *C. esculenta* plants treated with GA began about 10 weeks after treatment. The impact of GA revealed differences between such characters as duration of different phases of flower development, morphology of the flowers and size distribution of the pollen grains.

Balashanmugam and Vanangamudi (1987) studied the influence of NAA on *Curcuma longa*. They reported that in the trials with turmeric (*Curcuma longa*), Planofix (NAA) at 10 ppm. was applied once, twice and thrice between the 5th and 7th month after sowing. The highest yield of fresh rhizomes (29950 kg/ha) was obtained by spraying the hormone once at 6 months after sowing.

Katsura et al. (1987) reported that in field trials in Japan 50 *Colocasia esculenta* cultivated varieties were treated with 200 and 1000 ppm GA₃ over 3 years to induce flowering for breeding purposes. Treated plants began tillering after approximately 40 days. Spadixless flowers with only a peduncle and spathe appeared in many cultivated varieties. Inflorescences with sexual organs appeared after 60-70 days
in several cultivated varieties. The more readily a cultivar flowered, the more responsive it was to GA treatment. GA treatment produced some abnormal flowers with branched or double spathes in the more responsive cultivars and only spadixless flowers in less responsive cultivars. GA$_3$, GA$_4$ and GA$_7$ were effective in stimulating flowering but GA$_2$, GA$_6$, GA$_{11}$ and GA$_{15}$ were ineffective. GA treatment resulted in loss of apical dominance and the production of corms under every tiller but these were fused to each other. GA$_3$ produced long, slim, cormels.

Mozie (1987) investigated large tubers of *D. rotundata* dipped in 2, 4-D, IAA, NAA and IBA solutions at 1-1000 mg/litre before storage. They observed that all concentrations of IAA, NAA and IBA stimulated sprouting of tubers, the effect being concentration dependent. Sprouting was inhibited at all concentrations of 2, 4-D. Tuber dormancy terminated after 24 weeks of storage at 1-10 mg/litre of NAA but continued for up to 52 weeks at higher concentration.

Maurya and Lal (1987) analysed the effect of IAA, NAA and GA on growth and yield of onion (*Allium cepa*) and vegetable chilli (*Capsicum annum*) at Horticultural Research sub-station, Dunda, Uttarkashi. They observed that the growth and yield was influenced by GA. The highest Onion yield was 256.82 q/ha. with GA at 60 ppm as compared to 183 q/ha. in the control. Singh et al. (1987) also reported that the growth regulators have a significant influence on the Onion yield. They observed highest yield of 216 q/ha after application of NAA. This was 59% more than that in the control. Similarly, Saxena et al. (1988) found that in Onion GA$_3$ increased percentage germination of bulbs, root length and root and shoot dry weight after 120 hours. Tomar et al. (1988) reported that GA at 200 ppm gave the best results
in terms of bulb yield in Onion. On the other hand, Vanangamudi et al. (1988) noticed that in Onion, soaking the seeds in GA$_3$ at 100 ppm for 3 hours broke dormancy which improved the germinability, vigour index and emergence of seedlings in the nursery. It did not influence the bulb and seed yield, but significantly increased flowering percentage.

Viana and Filippe (1988 a) studied the rooting behaviour of stem cuttings in Dioscorea composita from 1- and 2-year-old plants having stem diameters of 2 and 5 mm, and treated with IBA. The number of cuttings which produced roots was 5 times higher in cuttings with 2 mm stems than that in cuttings with 5 mm stems. It is suggested that this effect is due to differences in the rate of translocation of IBA in the stems of the cuttings. Viana and Filippe (1988 b) in another investigation, reported that the tubers of D.composita contain a high level of diosgenin, which is used in steroid synthesis. Levels of diosgenin vary greatly in different clones, therefore vegetative propagation was studied with a view to obtaining plants with high diosgenin levels. Cuttings from 1-year-old plants were treated with a single application of IBA and several applications of BA (as a foliar spray). No rooting was observed in untreated cuttings, but cuttings treated with IBA produced callus and roots. Early application of BA after IBA treatment delayed senescence but inhibited callus and root formation. One application of IBA followed by applications of BA at 48hr intervals starting two weeks after IBA application gave the best results. In the second phase of study, rooted cuttings were transferred to pots containing soil and treated with various growth regulators starting one week later. The growth regulators were applied as foliar sprays, twice a week, for 60 days. Sixty percent of cuttings treated with BA produced tubers and aerial buds as compared with only 10% of
untreated cuttings. No tubers or aerial buds were produced with GA$_3$ or IAA and the cuttings became dormant.

Rao et al. (1989) studied in a field trial carried out in 1988 - 89 that turmeric cultivar plants were sprayed with NAA and 2, 4-D of 5, 10, 15 and 20 ppm at 30 and 60 days after planting. Distilled water spray was used as a control. All treatments resulted in increased growth in pseudostem, leaf number per plant and rhizome tuberization rate and rhizome yield as compared with the control. Highest pseudostem height (42.8 cm), leaf number/plant (7.60) and leaf area/plant (1444 cm$^2$) were obtained with 20 ppm 2, 4-D treatment and rhizome yield (20.11 t/ha) was obtained with 20 ppm NAA treatment.

Salah and Abd (1989) reported that application of GA$_3$ and NAA increased vegetative growth in Allium cepa as measured by plant height, leaf length, number of leaf per plant, fresh weight of plants and percentage dry matter as compared with the control plants. Total yield and average bulb weight of Onion also increased due to the impact of these growth regulators. The use of either NAA or GA$_3$ at 150 ppm was recommended. But, Deore and Bharud (1991) reported that GA at 60 ppm applied either as root dip or foliar spray resulted in great plant growth and yield in Allium cepa as compared with the other treatments (GA 30, NAA 10 or 20 ppm respectively). Highest yield of Onion (294.98 q/ha,) was obtained with 60 ppm treatment of GA as a root dip.

Singh et al. (1991) reported that the single-node stem cuttings of medicinal yam (Dioscorea floribunba) about 4 cm long, were taken from the middle portion of vines of mother plants and dipped in various
growth regulators for 15 minutes before planting in nursery beds. The highest proportion of rooted plantlets (98.6%) was obtained with cuttings treated with Seradix-B2 which contains IBA. Treatment with 2000 ppm IBA achieved 86.0% rooting, while only 40% of untreated cuttings were rooted.

Babu et al. (1992 a) investigated the inflorescence (1 to 10 day old flower buds) of Zingiber officinale cultivars when cultured on modified MS medium supplemented with 1 mg NAA/litre. The plantlets from the individual flowers and immature flower buds produced profuse roots. Over 80% of these plantlets established easily in soil. It is concluded that ginger can be propagated in vitro from immature inflorescences and that this method could be useful in limiting the spread of rhizome rot (Pythium spp.) and bacterial wilt (Pseudomonas solanacearum) through vegetative propagation. In another study, Babu et al. (1992 b) reported that the excised tissues from young leaves of ginger cultivar Maran were cultured on MS liquid medium with 5.4 ppm of NAA. They found that plantlets developed extensive root systems. The establishment of these plantlets in soil was about 80%.

Barthakur and Bordoloi (1992) pointed out that C. amada (mango ginger) is used as a spice, but it also has carminative and stomachic properties, and is used for contusions and sprains. Its essential oil has antifungal properties. They observed that rhizome explants of this species produced shoots and roots simultaneously when cultured on B5 medium containing NAA (0.5mg/litre) and BA (4 mg/litre). In vitro-produced plants, on transfer to the field, had a survival percentage of 60-70%, therefore, they recommended that this technique could be utilized for cultivation and conservation.
Chatterjee et al. (1992) analysed Zingiber officinale plants sprayed with urea (1, 2 or 4%) and NAA (20 mg/litre), alone or in combination at 90 days after planting on a sandy loam soil. They recorded greatest plant height (84.66 cm), highest number of tillers/plant (7.00), maximum number of leaves/plant (66.70) and maximum rhizome yield (268 g/plant and 428.8 q/ha) with 2% urea + 20 mg NAA/litre treatment combination. They also investigated the effect of this combination of the chemical fertilizer urea and the growth regulator NAA on N, P and K contents of leaves and observed a remarkable increase in them after 160 days of planting.

Nandekar et al. (1992) carried out an extensive study on the effect of growth regulators on growth, yield and quality of kharif Onion. They tested the effect of dipping 6 week old Onion bulbs in NAA and GA of 0, 20, 30 and 40 ppm for 24 hours before planting. They observed that treatment of GA at 40 ppm was most effective, giving significant increase in the number, length and width of leaves, number of roots, the size and weight of bulbs, number of scales present and the percentage of grade A bulb.

Nirmal et al. (1994) carried out an experiment on the effects of growth substances on yield and yield contributing traits in Onion. They studied the seedlings of Onion dipped in GA and NAA solutions before transplanting and found that bulb yield was highest (274.98 q/h) after a root dip in 60 ppm GA. Yield was 250 q/ha in the control. The increased yield was attributed to the increased bulb diameter due to the impact of growth regulator.

Das et al. (1995) reported the results of field trials carried out in 1990-91 at Mondouri Horticultural Research Station, West Bengal, for soaking the corms of elephant foot yam (Amorphophallus
campanulatus) for 6 hours in water, thiourea, KNO₃ and gibberellic acid etc. Increased sprouting percentage and growth was recorded in the hormone treated corms as compared with those in the control. The highest corm yield was obtained by soaking them in 200 ppm gibberellic acid.

Recently, Singh et al. (1995) reported that GA₃ and NAA treatment increased plant height, number and size of leaves and number of umbels per plant in Onion at concentration upto 300 ppm. Surprisingly, they noticed that 450 ppm concentration of these growth regulators was less effective. The highest 1000-seed weight (2.904-3.096 g) and seed yield (5.131-5.417 g) were obtained with 300 ppm NAA.

Indira et al. (1996) investigated the flowering induction and associated physiological changes under field conditions in several normally non-flowering varieties of Colocasia and Xanthosoma. Flowering with seed setting could be achieved in Colocasia by fortnightly applications of 500 ppm ascorbic acid or 1000 ppm GA₃ from 2.5 months until 6 months after planting. Ascorbic acid also hastened flower initiation. In Xanthosoma, only GA₃ could induce flowering.

In the present programme also, preliminary experiments relating to the influence of GA₃, NAA and IBA on the sprouting behaviour of rhizomes as well as on the further growth of plants of four Curcuma species are planned.

************