Review of Literature
PLANT GROWTH REGULATORS

A growth regulator is an organic compound that promotes, inhibits or qualitatively modifies growth and development of plants. Plant growth regulators (PGRs) may be considered as chemical compounds produced either naturally by the plant or synthetically by a chemist. PGRs are biologically active at very low concentrations and elicit responses similar to those observed from plant hormones. Since most plant growth and development processes are regulated by natural plant hormones, these processes may be manipulated either by altering the plant hormone level or changing the capacity of the plant to respond to its natural hormones. In recent years synthetic PGRs have been investigated for their ability to alter plant growth and development in an attempt to control growth and to improve the productivity (Oosterheus and Robertson, 2000).

The application of PGRs as a foliar spray increases the plant growth and yield. Significant increase in bacterial numbers was recorded in the rhizosphere of 2, 4-D-treated plants and this effect was independent of the concentration employed and the age levels (Singh, 1956). Different concentrations of plant growth regulators (IBA) increase the rooting success and survival of air layered Psidium guajava L. twigs and Anacardium occidentale L. (Sen and Chakraborty, 1972; Tabres et al., 1987; Singh, 2001).

The effects of foliar application have increased the yield, pumping of sugars and other exudates from roots into the rhizosphere for maintaining beneficial microbial population, resistance to diseases and insect pests, improved drought tolerance and enhanced crop quality that depend on the concentration, frequency of application and plant species. This enhanced biological activity increases the availability of nutrients, disease suppressive biochemicals, vitamins and other factors beneficial to the plant with its economic value generally deemed greater for horticultural than for agronomic crops (Moore, 1989).
Foliar application is often timed to coincide with specific vegetative or fruiting stages of growth and the fertilizer formula is adjusted accordingly. Application may also be used to aid plants in recovery from transplant shock, hail damage or the results of the weather extremes. Foliar application can be 8 to 20 times as efficient as ground application (Kuepper, 2003).

SYNTHETIC PLANT GROWTH REGULATORS

AUXINS

The natural auxin, indole acetic acid (IAA) exists in a variety of chemical status in plant tissues. Free auxins are readily extractable, while bound auxins are liberated from tissues when subjected to enzymolysis, hydrolysis or autolysis. Free auxin apparently is the form immediately utilizable for plant growth. Bound auxins generally are considered storage forms from which IAA can be released (Moore, 1989). Fullick et al., (2006) reported that IAA initiates cell growth, cell division and cell elongation. It also stimulates root growth at low concentration and shoot growth at high concentration.

Indole acetic acid (IAA) is synthesized in many species of seed plants, bacteria, fungi and algae and may be ubiquitous in the plant kingdom for many years. IAA was the one critically identified auxin and thought of as the only natural auxin (Gloaguen et al., 1996; Cooke et al., 2002; Thimann, 1977). The effect of plant growth regulator showed significant increase in the number of female flowers in bottle gourd (Lagenaria siceraria L.) crop. Maleic hydrazide spray of 200 ppm proved to be superior amongst other growth regulators in enhancing the female to male ratio 1:2 and yield (263.50 q ha\(^{-1}\)) (Choudhary and Patil, 1962; Costacurta and Vanderleyden, 1995).

An auxin transport inhibitor, methyl-2-chloro-9-hydroxyfluorene-9-carboxylate (CFM) shows inhibition of geotropism in pea roots i.e. disruption of auxin transport by interfering with auxin. The morphactin inhibits negative geotropism, causing cellular swelling and induction of root hair formation in
roots of intact *Pisum sativum* L. seedlings. Indole acetic acid (IAA) prevented the expression of CFM because IAA inhibited the accumulation of CFM into the tissue sections. CFM inhibits the accumulation of IAA and 2, 4-dichlorophenoxyacetic acid into excised root tips (*Douglas and Gaither, 1975*). Chemical regulation (GA and IAA) of sex expression on relation of growth and yield in cucumber (*Cucumis sativus* L.) was reported by *Misheea et al.*, (1976). *Sarn and Mehta, (1985)* reported the effect of growth regulators GA, IAA and KN on the growth and yield (10% over control) of mustard plants (*Brassica rapa* L.).

*Alam and Islam, (1989)* reported the effects of IBA, NAA, Cycocel and 2, 4-D on the growth, yield and chemical composition of potato (*Solanum tuberosum* L.). It was observed that IBA (50ppm) increased shoot extension, weight of haulm, total sugar, starch content and yield. NAA at 100ppm gave the best results in relation to yield 83.06/g/plant. *Taylor and El-kheir, (1993)* reported 10 fold increase in the number of lateral root initials over 72 hrs incubation of detached tomato roots in 5μg of NAA. *Rao (1995)* observed that seed treatment with phytohormones (IAA and GA) showed increase in seed number (5.6%), yield (10.5%) and quality of *Pisum sativum* L. and *Arachis hypogea* L. than when compared to control.

The effect of fertilizers and alpha naphthalene acetic acid on growth and yield of *Lycopersicon esculentum* cv. was studied. The results of this investigation indicated that the application of 0.1ppm of NAA significantly increased the growth (76.08/Av.cm) and yield (24.23/Av.no/plant) of treated plants than the control (67.78/Av.cm and 20.05/Av.no/plant) *Chhonkar and Ghufran, (1996)*. Application of plant growth regulators (50,100,150 and 200ppm of IAA) in cotton (*Gossypium arboretum* L.) plants was carried out and it was observed that 100ppm of IAA showed good physiological response and yield (15%) than compared with control (*Zhao and Oosterhuis, 1997*).
The effect of growth regulators on seed production of radish (*Raphanus sativus* L.), barley (*Hordeum vulgare* L.) and grapes (*Vitis vinifera* L) was observed. Eleven treatment consisted of three concentrations of GA$_3$ (50, 75 and 100ppm), four concentrations of triacontal (2.0, 5.0, 7.5 and 10.0ppm), three concentrations of NAA (50, 75 and 100ppm) and one control were tested in Randomized Block Design with three applications. Among three growth regulators, the germination percentage, highest seed weight and yield were obtained with 100ppm of NAA in radish (Yadav *et al.*, 1977; Verma and Singh, 1978; Sharma, 1995; Bhople *et al.*, 1998).

Seeds soaked in IAA and kinetin showed increased chlorophyll, nitrogen in leaves and protein in *Lycopersicon esculentum* L. Better result was noted in all these traits at 100ppm of IAA and 25ppm of kinetin. Comparing these two regulators, IAA proved to be the best and it increased the yield by 38.81% when compared to control (Singh, 1956; Tagade *et al.*, 1998).

The effect of foliar spray of indole acetic acid and gibberellic acid on the growth of *Trigonella foenumgraceum* and *T.corinuculata* was observed. Application of IAA at 100ppm increases dry weight of the roots, shoot length, leaf area and number of pods. But 50ppm of IAA treated plants showed maximum number of leaves and shoot biomass. *T. corniculata* exhibited highest shoot length and number of leaves at 10ppm of GA$_3$ whereas 50ppm of IAA treated plants showed maximum number of pods, leaf area, dry weight of the shoot and root. In *Trigonella spp.* 100ppm of GA$_3$, increased the leaf area, number of pods and dry weight of shoot with maximum root. 50ppm of GA$_3$ increased the biomass. GA$_3$ increased the shoot length and reduced the number of branches in both the species of *Trigonella* (Anand and Sharma, 1998).

Field experiment conducted during Kharif season at Udaipur to study the effect of four levels of phosphorous (0, 20, 40, and 60 kg P$_2$O$_5$/ha) and four treatments of plant growth regulators (control, mixtatol (2ppm), naphthalene acetic acid (20ppm) and mixtatol + NAA 20ppm) on growth and yield of black
gram var T9 (*Vigna mungo* L.). Growth characteristics like plant height, number of branches per plant, dry matter production per plant and chlorophyll content significantly increased with the application of phosphorous up to 60 kg/ha. Mahla *et al.*, (1999). Sachan and Sarayya, (1999) studied the effect of plant growth regulators and urea on growth and sex expression in bitter gourd (*Momordica charantia* L.) The results revealed that 50ppm of naphthalene acetic acid was found to be useful in respect of sex modification and better fruit yield (93.3 yield/plant) when compared with control (39.93 yield/plant).

The role played by indole acetic acid was one of the major defense factors of the host plant in vascular wilt diseases. *Fusarium* wilts of banana (Panama disease) caused by *Fusarium oxysporum*, which occludes host vascular system. Two experiments on resistance induction with banana plants (cv. Dwarf Cavendish) were carried out in glass greenhouse with different indole acetic acid treatments. The result showed that the exogenous application of indole acetic acid to banana plants induced resistance to panama disease and was more effective when performed using low doses and frequent applications (Fernandez *et al.*, 2003). Woodward and Bartel, (2005) reported regulation, action and interaction of auxins in various plants.

To study the efficiency of plant growth regulators, their concentrations and wrappers on rooting success and survival of the air layered guava twigs an experiment was carried out by Singh (2005). The results revealed that use of indole butyric acid was beneficial in enhancing the callus formation, number, length and diameter of both primary and secondary roots and survival of air layered twigs. 20,000 ppm of plant growth regulators was shown to be optimum for better rooting success and survival. This result was significantly superior to 5,000, 10,000 and 15,000 ppm of plant growth regulator.
GIBBERELLIC ACIDS

Sex expression and sex ratio in cucumber (*Cucumis sativus* L.) and sponge gourd (*Roem cymbindrica* L.) was affected by application of 200ppm of gibberellic acid (Choudhary and Pathak, 1960; Pandey et al., 1976).

Gibberellic acid at various concentrations (30, 50, 70, 90 and 110ppm) was sprayed on sahibi table grapes (*Vitis vinifera* L.) 10 days before initial bloom. Concentrations of 30, 90 and 110ppm produced complete seedless berries while 50 and 70ppm produced less seeded (1 to 2) berries (Walli et al., 1987). Banerji and Chatterjee, (1988) studied the effect of growth regulators on the *in vitro* growth and cytology of *Vicia faba*. They observed that 2,4-D and kinetin were most effective for callusing. Gaskin et al., (1995) worked on 3-epigibberellin A that occur naturally in plants and involved in art factual formation from gibberellin A₁. The inhibitory effect of several modified gibberellins in plants was studied by King et al., (1997).

ABSCISIC ACID

Abscisic acid and ethylene induced deforestation of *Radermacchera sinica* L. and *Ricia fluitans* L. (Heliwege and Hartung, 1997; Dunlap et al., 1994). Mitra and Rugini (1988) investigated the interaction of auxin and abscisic acid in rooting of plant cuttings. Abscisic acid at 10mg/l significantly promoted rooting while at 20, 50, 100 mg/l ABA was found to inhibit rooting. The promoting effect of ABA was noted, in the presence of IAA and IBA also. The effect of IAA was more pronounced in production of roots, when ABA was used at 20mg/l (22.7 roots/cutting), while for IBA it was more (36.6 roots/cutting).

CYTOKININ

Bairu et al., (2006) reported the effect of growth regulators and subculturing on somaclonal variation in Cavendish banana. Auxins (IAA, IBA and
NAA and cytokinins were used to multiply shoots for ten generations. Bands generated through RAPD-PCR were scored based on their presence or absence of somaclonal variation. The relationship between multiplication rate and somaclonal variation was assessed using correlation analysis. Results indicated that treatments showed higher multiplication rate and produced more variants. A dwarf-specific band, about 1500 kb in size, was amplified by the primer OPC-15. The band appeared consistently in normal plants but was absent in all dwarf plants.

EFFECT OF COMBINED ACTION OF AUXIN AND GIBBERELLIC ACID IN PLANTS

The physiological studies on seed set in sunflower (*Helianthus annus* L.) and significance of the dwarfening of the plant size using growth regulators was reported by Pando and Srivastava, (1985). Sarkar and Choudhari, (1985) reported that the effect of IAA, GA and BA which influences the glycolate metabolism in sunflower (*Helianthus annus* L.) during plant growth. Glycolate metabolism was enhanced by IAA and GA at vegetative stage and flowering stage. Epicotyls of GA₃ and IAA treated seeds of *Phaseolus aconitifolius* L. showed greater dry matter accumulation than the control. Seedling growth studies of *Phaseolus aconitifolius* after treatment of seeds with morphocatin GA₃ and IAA were investigated by Gupta and Mukerjee (1986). They reported hypocotyl, seed lengthening, fresh weight per seedling and dry weight changes in *Phaseolus aconitifolius* L. All concentration of morphocatin and higher concentration of IAA had inhibitory effect on hypocotyl and primary root length.

Seed treatment with plant growth regulators was carried out by Sharma and Govil, (1988). The growth substances IAA, MH, GA₃, COU, CCC (100, 200 and 500ppm) and KN (10, 25 and 50ppm) caused significant changes in hypocotyl length of *Citrullus lanatus* var *fistulosus*. High concentration of IAA and GA₃ (500ppm) adversely affected the growth of hypocotyl, whereas other
plant growth regulators MH, COU and CCC (100,200 and 500ppm) gradually increased the hypocotyls growth in *Citrullus lanatus var fistulosus*.

The effect of IAA, GA, MH, CCC, COU (100,200 and 500ppm) and KN (10, 25 and 50ppm) was analysed on fresh and dry weight of the roots, shoots and leaves of *Physalis peruviana* and *P. angulata*. Total fresh weight and dry weight of the plants increased at all concentration (100-300ppm) of GA, KN and MH. Besides, this low concentration (10ppm) of IAA, CCC and COU showed increase in total fresh weight of the plant *P. angulata* (Raghava and Murty, 1988). Goyal and Murty (1988) studied the enhancement of ecological energetic in *Arachis hypogea* L. by plant growth regulators. The ecological energetic including caloric value, standing crop energy of the different plant parts and energy conserving efficiency of ground nut with the application of 10, 50mg/lit each of IAA, GA3, 2, 4-D and MH were studied. IAA (50mg/lit) increased root (3.65Kcal/g) and fruit (5.98Kcal/g) and energy over control (3.48Kcal/g of root and fruit 5.43Kcal/g).

Singh (1990) investigated the effect of auxin treatment in *Bougainvillea cv thimma*. The study reports that IBA and NAA at 3000ppm had higher percentage (32.83 and 36.01cm) of survival of both the types of root cuttings (soft wood and semi hard wood) in all the three plantings (July, September and February). Plant growth regulators (IAA, 2, 4-D, NAA, GA, and KN at 0.1 and 1.0ppm) influence the growth even under salt stress in *Azolla pinnata* than the control plants (Malliga and Subramanian, 1990). Srivastava and Choudhri, (1990) investigated the effect of gibberellic acid in stimulating plant growth under salt stress. The maximum germination was recorded with 15ppm of GA in all varieties of wheat and germination range between 24.66% and 100% over control. The effect of dipping flower clusters in gibberellic acid showed increase in fruit set, bunch, berry size, yield and fruit quality of grapes (*Vitis vinifera* L.). Also the length of the berry increased from an average of 1.45 to 1.94cm. (Varma, 1991).
Twelve high yielding varieties of hulled (husked) barley (*Hordeum vulgare* L.) grown under agro climatic conditions were evaluated for malting quality in terms of total crude protein, carbohydrates, total soluble sugars (reducing and non reducing sugars), starch and total polyphenols. The analytical data revealed that 10ppm of GA$_3$ may be used for producing good quality malt from *Hordeum vulgare* L. (Verma *et al.*, 1996; Kara *et al.*, 1996).

The field experiment conducted during Kharif, showed the highest increase in seed yield of soybean (*Glycine max* L.) with seed soaking treatment in GA$_3$ and NAA upto 50 and 150ppm respectively. NAR (non assimilation rate) was recorded with 50ppm NAA (0.025/g/dm$^2$/day) followed by 125ppm of GA$_3$ (0.022/g/dm$^2$/day) than the other concentration of during 45-60 DAS (Maske *et al.*, 1998).

The plant growth regulators 10 and 20ppm of GA$_3$ and NAA were sprayed on eight ber (*Ziziphus mauritiana* L.) cultivars. Two percent of fruit weight and seed size were increased appreciably with 20ppm of GA$_3$. The maximum decrease (1.0%) in fruit weight was recorded with 10ppm of NAA and the fruit quality was improved with 20ppm GA$_3$ (Kale *et al.*, 2000).

The effect of plant growth regulators (GA) on sex ratio and yield (25.6%) of bottle gourd (*Lagenaria siceraria* L.) was higher when compared with control (Ingle *et al.*, 2000). Rajula and Padmadevi (2000) performed the HPLC analysis of the extracts of leaf explants and nodal segments of naturally growing *Gymnema sylvestre* plant on MS medium treated with IAA, NAA, KN, IBA and BA (0.10, 0.25, 0.50, 1.0, 2.0 and 5.0 mg/l) to show that the main components of the active principles namely gymnemic acids and gymnemagenin were present in sufficiently large amounts in the cultured undifferentiated cells. Callus induction was observed in 0.5 mg/l of 2, 4-D supplemented medium for both explants.

The effect of plant growth regulators on the quality of bast fibers in *Abelmoschus esculentus* L. Moench was studied by Fathima and Balasubramanian, (2006). This investigation highlighted the effect of plant
growth regulators like gibberellic acid and naphthalene acetic acid on the quality of bast fibers in *A. esculentus*.

**PLANT GROWTH REGULATORS FROM NATURAL SOURCE**

**PLANT GROWTH REGULATORS FROM BACTERIA**

Auxin formation by rhizosphere bacteria as a factor for root growth of plants was reported (Brown 1972; Prikrval et al., 1985; Tilak et al., 2005). Auxin production from *Pseudomonas syringae* was reported by Glickman et al., (1998). Ivanova et al., (2001) observed the synthesizing ability of auxins by aerobic methyllobacteria. Tokala et al., (2002) hypothesized that root and nodule colonization of *Streptomyces* acts as a naturally occurring plant growth-promoting bacterium in pea and possibly other leguminous plants.

Egamberdiyeva and Hoflich (2003) reported that the root and shoot growth of cotton (*Gossypium arboretum* L.) and pea (*Pisum* sp.) significantly increased with the inoculation of effective bacterial strains *Pseudomonas* alcaligenes PsA15, *P. denitrificans* PsD6, *Bacillus polymyxa* BcP26 and *Mycobacterium phlei* MbP18. Georgieva, (2003); Senthilkumar et al., (2006) observed the effect of *Enterobacter cloacae* and *Methyllobacterium* sp. as a growth regulator in greenhouse cucumbers (*Cucumis sativus* L.).

**PLANT GROWTH REGULATORS FROM FUNGI**

Chakraborti et al., (1993) stated that endogenous level of auxin appeared to play a major role in pathogenesis of bottle gourd (*Lagenaria siceraria* L.) wilt caused by *Fusarium solani*. Young leaves and stems of infected bottle gourd plants showed 75% and 154% endogenous auxin respectively when compared to healthy plants. Pathogenic activity in infected plants resulted from lower activity of IAA oxidase. In resistant plants auxin activity came down after an initial increase at 20 and 40 days after sowing. Almost all combinations except those with 2, 4-D cause shoot up tip from explants.
Deoxycyclopaldic acid and cyclopaldic acid were isolated from cultures of the fungus *Penicillium* sp. which were identified as plant growth regulators and their structures was established by spectroscopic evidence. The biological activity of these two compounds has been examined using bioassay methods with lettuce and rice seedlings (Shimada *et al*., 2002).

**PLANT GROWTH REGULATORS FROM PLANTS**

*Owolade *et al*., (2000) evaluated the growth regulating (inhibitory) effect of some leaf extracts of *Ocimum gratissimum*, *Acalypha ciliata*, *Vernonia amygdalina*, *Mangifera indica* and *Azadirachta indica* over *Fusarium moniiforme* on seeds of maize (*Zea mays*). The seeds were soaked with distilled water in 10, 20 and 30 (w/v) for 12, 24 and 48 hrs. All the plant extract had significant inhibitory effect against *Fusarium moniiforme*. *Acalypha ciliata* extract showed more effect than the other plant extracts and compared favorably with benomyl in the control of the pathogen.

**PLANT GROWTH REGULATORS IN ANIMALS**

An experiment was carried out to investigate whether plant growth regulators (auxins and gibberellins) could affect lipid peroxidation (Malondialdehyde level) in erythrocyte, muscle, liver, heart and kidney tissue. 75ppm of indole acetic acid (IAA) and kinetin were administered orally to 6 rats for 25 days. Liver and kidney MDA levels were increased significantly by IAA administration in rats, kinetin did not affect the MDA levels in erythrocyte and other tissues. Hence IAA might affect lipid peroxidation in animals at sub acute treatment (Taylor and El Kheir, 1993; Tanimoto and Eiichi, 2005).
PLANT GROWTH REGULATORS FROM CYANOBACTERIA

Some cyanobacteria are able to reduce atmospheric dinitrogen to ammonia, a process where oxygen evolved by photosynthetic activity in the same cell is detrimental to nitrogen fixation. In some filamentous cyanobacteria, nitrogen fixing heterocyst are formed. Heterocyst are differentiated cells whose interior becomes anaerobic mainly as a consequence of respiration allowing the oxygen gaining process of nitrogen fixation to continue (Joshi and Shukla, 1973).

The effect of BGA biofertilizer on nitrogen fixation extends upto 20 to 30 kg N/kg. Besides nitrogen, the algae excrete vitamin B₁₂, auxins and ascorbic acid which may contribute to the rice plants (Singh et al., 1978). Pedurand and Reynaud, (1987) screened 133 cyanobacterial strains in logarithmic growth phase to study their effects on rice germination and growth. In unialgal, non axenic culture 30% of the strains had no effect, while 70% of the strains had a negative effect on germination. In contrast, growth of rice was stimulated by 21% of the isolates and inhibited by 12% although 57% of the unicellular strains had a positive effect and many Nostoc strains had a negative effect.

The effect of IAA on growth, dinitrogen fixation and heterocyst frequency of Anabaena PCC 7119 and Nodularia sp. were studied. Concentrations of IAA ranging from $10^{-10}$ to $10^{-4}$ did not change the growth of Anabaena PCC 7119, whereas concentrations higher than $10^{-4}$M were inhibitory. Similar results were found in Nodularia sp. with the inhibitory effect appeared at $10^{-5}$M of IAA. Neither the nitrogenase activity nor the heterocysts frequency was enhanced by IAA treatment. The eight strains of Anabaena sp. showed a stimulatory effect on growth. Only Anabaena 77S19 remained effective in axenic culture (Leganes et al., 1987). Cyanobacteria also have some soil phosphate solubilizing species. Phosphorous is the second important nutrient element after nitrogen for plants and microorganisms (Mishra and Pabbi, 2004).
Growth promoting substances from cyanobacteria influences the amino acids and sugars in paddy field was reported by Misra and Kausik, (1989). *Nostoc muscorum* were isolated from argentine *Oryza sativa* L. fields with auxin activity and characters similar to indole acetic acid (Caire *et al*., 1991).

Many biologically active compounds produced by microalgae were reported by Metting and Pyne, (1996). Nishida and Murata, (1996); Stirk *et al.* (1999) reported the positive effect of nutrient content and soil structure on the addition of cyanobacteria. Satapathy (1999) conducted a field experiment to study the performance of blue green algae and azollae as biofertilizer for rice in comparison to various organic manures and urea. These microorganisms are distributed worldwide and improve the growth and development of the plants with which they share the habitat, because they; 1. Contribute to soil fertility in many ecosystems 2. Produce various biologically active substances and 3. Have higher efficiency in absorption of heavy metals (Bioremediation).

Cyanobacteria are able to concentrate metal iron present in their environment, in addition to intracellular protective mechanism in which the main mechanism of absorption of heavy metals is iron exchange in the cyanobacterial outer cell wall. There are mucilaginous sheath that behave as on "external vacuole". The metal biochemical properties are probably due to high density of anionic charges, especially carboxyl's identified in the capsular polymer (Zaccaro, 2000).

The survival strategies of cyanobacteria occurring as crust in the rice fields under drought conditions were investigated by Adhikary (2000); Deepak *et al.*, (2000). Seven strains of axenic unicellular chlorophyta and three strains of axenic cyanophyta were selected for their high growth rate and positive cytokinin-like activity in the cucumber cotyledon expansion bioassay (Jackson *et al*., 2001).

Cyanobacteria are prokaryotic photosynthetic microorganism that produces a wide array of substances, including plant growth regulators. In the
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case of growth regulators, gibberellins, auxin, cytokinin, ethylene, abscisic acid and jasmonic acid have been detected in cyanobacteria (Sergeeva et al., 2002). Cyanobacteria produces extracellular polymers of diverse chemical composition especially exopolysaccharides that enhance microbial groups, improve soil structure and exoenzyme activity (Stirk et al., 2002). Extract from cyanobacteria influence the growth and yield of Vigna mungo (Ravishankar and Malliga, 2003) and also induce the somatic embryogenesis in sandalwood (Sandalum album L.) (Bapat et al., 1996).

Bioactive compounds are produced by cyanobacteria including plant growth regulators like naphthalene acetic acid (NAA), a toxic substance used in micro propagation. Natural PGR could replace NAA, dangerous for the operator, not only during the regeneration phase but also during the storage of the viable bulblets cultivated in vitro. The evaluation of morphogenetic and antioxidant effects produced by intra and extra cellular substances from Scytonema hofmani during the multiplication in vitro of Lilium alexandrae. NAA reveals the result of increased bulblets production reaching 78% and 83% (Celik et al., 2002). Effect of blue green algal growth hormones on the germination of paddy seed was reported by Gupta and Lata, (1964); Amasino (2005).

The beneficial effects of some extra cellular compounds derived from axenic cultures of cyanobacteria were evaluated. Various compounds of cyanobacteria could be useful sources to enhance or substitute the influence of synthetic PGRs on tissue cultures of recalcitrant plants in vitro. The cyanobacterial compounds in biomass alone have produced lower rates of shoot regeneration and gained smaller fresh weights compared to the PGRs control. They are not like real substitutes of synthetic PGRs but as a supplement in culture media resulting more vigorous cultures and regenerated shoots Molnar and Ordog, (2005).

Manickavelu et al., (2006) indicated that MS with cyanobacterial extracellular product may also be used for screening of rice genotypes like IR 50,
ASD 16 and ADT 36 for water stress condition in which IR 50 showed earlier and good callus induction. The effect of extracellular products of *Plectonema* sp. isolated from *Oryza sativa* L. fields on regeneration of rice reveals that the product added instead of 2, 4-D showed earlier root initiation, more proliferation and tremendous growth of root length in short period.

**TRYPTOPHAN AS A PRECURSOR FOR IAA**

Tryptophan acts as a precursor for biosynthesis of auxin. Tryptophan is converted to indole pyruvic acid via a transaminase reaction, which requires a keto acid and pyridoxal phosphate in addition to the enzyme. Indole pyruvic acid is next decarboxylated to indole acetaldehyde in a reaction requiring a decarboxylase thiamine pyrophosphate, either an oxidase or a dehydrogenase, then oxidizes indole acetaldehyde to IAA. Nicotinamide adenine dinucleotide reportedly is the most effective enzyme (Pattern and Glick, 1996).

IAA biosynthetic pathway from tryptophan via indole-3-pyruvic acid in *Enterobacter* sp. and other species was reported by Adachi and Hidaka, 1991; Koshiba and Matsuyama, 1993; Tabres et al., 1987 and Ostin et al., 1999. Ostin et al., (1998) worked on metabolism of indole-3-acetic acid in *Arabidopsis* and an invitro system from maize seedling for tryptophan independent indole-3-acetic acid biosynthesis.

The plant growth of both shoots and roots content of IAA, free polyamines, micronutrients and macronutrients content in leaves and roots have been evaluated. Trp and Ind showed a similar pattern of action to that of IAA in plant development and mineral uptake (Normandy, 1997; Normanly et al., 1995). Glickman et al., (1998) reported that the auxin production as a common feature in the presence of tryptophan in *Pseudomonas syringae*. A constitutive and possibly tryptophan-dependent production of IAA via the indole-3-pyruvic acid pathway in cyanobacteria was suggested by Sergeeva et al., 2002; Jackson et al., 2001.
Tsavkelova et al., (2005) studied the major pathway in IAA synthesis which involves an initial decarboxylation of tryptophan to form tryptamine. Catalysis by amineoxidase next converts tryptamine to indole acetaldehyde which is in turn oxidized to IAA. In some plant system any one of these pathways apparently occurs to the excision of the other. In other systems both pathways are operative. Francisco et al., (2005) reported the effect of IAA and two IAA precursors l-tryptophan (Trp) and indole (Ind) on the growth, mineral nutrition and potential development under stress conditions of intact pepper (Piper nigrum L.) plants cultivated in hypertonic conditions.

TECHNIQUES FOR IDENTIFICATION OF IAA

The glutamine synthetase from the Synechococcus RF1 was purified to homogeneity by ion exchange, molecular sieving and hydroxyapatite chromatography (Venkatram and Neelakantan, 1967). Quantitative determination of indole-3 acetic acid and gibberellic acid were done by a simplified method of high performance liquid chromatography with a fluorometric detector (Gupta and Agarwal, 1973; Crozier et al., 1988; Horgan, 1988; Akiyama et al., 1983; Edlund et al., 1995; Fernandez 1995).

Accumulation of endogenous indole-3-acetic acid (IAA) in soybean hypocotyl explants was found during adventitious root formation in naphthalene acetic acid (NAA) and indole-3-butyric acid (IBA) treatments. The auxin induced root formation was accompanied by increasing levels of putrescine (Liu et al., 1998). Knoche et al., (1999) reported the significant positive linear relationships between plant response and the logarithm of the droplet/leaf interface area for all growth regulators performing bioassays. Bioassays were adapted to investigate effects of droplet size and carrier volume on performance of diaminozide, gibberellic acid (GA₃) and 2, 4-D using Phaseolus vulgaris L. as a model system. The non-carboxylated active auxin like molecule from plant source (2, 6-dibromo-phenol) was identified by
bioassay (Chhun et al., 2005; Gopi and Vatsala, 2006; Ferro et al., 2006). Quantitative analysis of indole-3-acetic acid metabolites in *Arabidopsis* by HPLC was reported (Kowalczyk and Sandberg, 2001; Qaddoury and Amssa, 2004). Separation of IAA by RPLC from plant extract was done by Klen et al., (2001).

Jung et al., (2001); Jackson et al., (2001); Genkov et al., (1996) reported that auxin could be identified by HPLC and IR (spectrum) and their activity can be analyzed by bioassay methods. They stated the purification and characterization methods of glutamine synthetase from the unicellular cyanobacterium. Auxin like activity detected using bioassay was extracted in methanol and purified by phase partitioning with phosphate buffer and ethyl acetate from cyanobacterial strains. But no auxin like activity was detected in strains of chlorophyta (Stirk et al., 2002).

Sergeeva et al., (2002) reported the possible role of IAA in cyanobacteria in general and their interactions with plants. Auxin like compounds were released by about 38% of the free-living cyanobacteria as compared to 83% of the symbiotic cyanobacterial isolates. Endogenous accumulation and release of IAA was confirmed immunologically (ELISA) using an anti-IAA antibody on 10 of the Salkowski-positive strain and the chemical authenticity of IAA was further verified by chemical characterization using gas chromatography-mass spectrometry. Dobrev et al., (2005) reported that quantification of auxin and abscisic acid could be done even with non-selective detectors in two-dimensional HPLC.