Asian Journal of Plant Sciences

ISSN 1682-3974

Asian Journal of Plant Sciences 9 (4): 215-222, 2010
ISSN 1682-3974

Plant Growth Substances in Crop Production: A Review

[1]M. Mohamed Amanullah, [1]S. Sekar and [2]S. Vincent
[1]Department of Agronomy,
[2]Department of Crop Physiology, Tamil Nadu Agricultural University,
Coimbatore-3, India

Abstract: Plant growth regulators are chemical substances and when applied in small amounts, they bring rapid changes in the phenotypes of the plant and also influence the plant growth, right from seed germination to senescence either by enhancing or by stimulating the natural growth regulatory system. Plant growth substances are known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates thereby helping in effective flower formation, fruit and seed development and ultimately enhance the productivity of crops. An attempt is made to review the influence of some of the important growth substances like salicylic acid, boric acid, panchagavya and pink pigmented facultative methilotrophs on growth and productivity of the crops.

Key words: Growth substances, translocation, assimilates, productivity, crops

INTRODUCTION

Nutrients are important and crucial elements, which are required for the plant for its growth and development. The translocation of photosynthates from source to sink is very important for the development of economic part. Plant growth regulators are chemical substances and when applied in small amounts, they bring rapid changes in the phenotypes of the plant and also influence the plant growth, right from seed germination to senescence either by enhancing or by stimulating the natural growth regulatory system. Plant growth regulators are known to enhance the source-sink relationship and stimulate the translocation of photo-assimilates thereby helping in effective flower formation, fruit and seed development and ultimately enhance productivity of the crops.

Growth regulators can improve the physiological efficiency including photosynthetic ability and can enhance effective partitioning of the accumulates from source and sink in the field crops (Solaimalai *et al*., 2001). Foliar application of growth regulators and chemicals at the flowering stage may improve the physiological efficiency and may play a significant role in raising the productivity of the crop (Dashora and Jain, 1994).

Importance of Salicylic Acid (SA): Salicylic acid belongs to an extra-ordinary diverse group of plant phenolics. Salicylic acid is ubiquitously found in all plant species and the highest levels are observed in the inflorescence of thermogenic plants and in plants infected with necrotizing pathogen (Raskin, 1992).

Salicylic acid is ortho-hydroxybenzoic acid and is a secondary metabolite acting as analogues of growth regulating substances. It helps in protection of nucleic acids and prevention of protein degradation. The SA is also known to induce many genes coding for pathogenesis-related proteins in response to biotic and abiotic stresses (Enyedi *et al*., 1992; Yalpani *et al*., 1994).

Foliar application of SA increased the IAA content in broad bean leaves (Xin *et al*., 2000). Foliar application of SA exerted a significant effect on plant growth metabolism when applied at physiological concentration, and thus acted as one of the plant growth regulating substances (Kalarani *et al*., 2002).

Effect of salicylic acid on growth parameters: Jeyakumar *et al.* (2008) reported that application of salicylic acid (125 ppm) increased the dry matter production (21.6 g plant^{-1}) in black gram. Nagasubramaniam *et al.* (2007) reported that foliar application of salicylic acid (100 ppm) on baby corn increased the plant height, leaf area, crop growth rate and total dry matter production.

Khan *et al.* (2003) reported that application of salicylic acid, acetyl salicylic acid and geninic acid enhanced the photosynthetic rate, stomatal conductance and transpiration rate in soybean. Sujatha (2001) reported that foliar application of salicylic acid (100 ppm) on green gram at 75 DAS increased the plant height (50.4 cm), root length (16.9 cm), number of leaves (18.4) and LAI (1.30).

Corresponding Author: S. Sekar, Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore-3, India

Effect of salicylic acid on yield and yield parameters: Jeyakumar *et al.* (2008) reported that application of salicylic acid (125 ppm) in black gram increased the seed yield (855 kg ha^{-1}). Salicylic acid sprayed on mungbean significantly increased the pod number $plant^{-1}$ and yield (Singh and Kaur, 1981). Nagasubramaniam *et al.* (2007) revealed that the cob yield of baby corn was the highest (7703.4 kg ha^{-1}) by the foliar application of salicylic acid (100 ppm).

Sujatha (2001) reported that foliar application of salicylic acid (100 ppm) on green gram at 75 DAS increased number of pods $plant^{-1}$, number of seeds pod^{-1}, seed weight $plant^{-1}$, 100 seed weight and grain yield (840 kg ha^{-1}). In green gram, foliar application of salicylic acid at branching, flower bud initiation stages increased the number of flowers, pods and seeds $plant^{-1}$ and seed yield (Singh *et al.*, 1980).

Effect of salicylic acid on quality parameters: Jeyakumar *et al.* (2008) reported that the highest seed protein content in black gram was recorded (24.5%) by foliar application of salicylic acid (125 ppm). Hussein *et al.* (2007) indicated that in maize hybrid, all determinate amino acids concentration such as tyrosine (31.16%), lysine (22.30%), aginine (20.68%), alinine (2.65%), lucine (2.78%) except methionine were increased with the application of salicylic acid (200 ppm). Proline concentration increased when using salicylic acid as foliar application under salt stress condition. Sujatha (2001) revealed that foliar application of Salicylic acid (100 ppm) on green gram at 75 DAS increased seed protein (23.98%) and soluble protein (12.9%). Kalpana (1997) found that foliar spray of salicylic acid increased the soluble protein in rice.

Effect of salicylic acid on nutrient uptake: Gunes *et al.* (2007) at Turkey demonstrated that exogenously applied salicylic acid increased the plant growth in maize significantly both in saline and non-saline conditions. This may be related to its inhibiting effect on Cl^{-1} and Na^{+1} and improving the uptake of N, Mg, Fe, Mn and Cu due to its effect on lipid peroxidation.

Importance of boron: Boron is one of the important micronutrients, which has basic role in stabilizing certain constituents of cell wall and plasma membrane, enhancement of cell division, tissue differentiation and metabolism of nucleic acid, carbohydrate, protein, auxin and phenols (Marschner, 1997). Though the symptoms of boron are very striking, its role in plant metabolism is uncertain. Boron has been found to be involved in the carbohydrate transport system within the plant. Boron deficiency causes delay in tassel formation, decrease in pollen size, pollen germination and pollen production capacity of maize (Agarwala *et al.*, 1981). Among the micro nutrients, boron is stated to influence many growth parameters and filling up of seeds (Blamey, 1976).

Effect of boron on growth parameters: Vishwakarma *et al.* (2008) revealed that in groundnut maximum plant height (60.33 cm) and number of branches (5.83 $plant^{-1}$) were recorded with application of borax as soil application.

Dixit and Elamathi (2007) reported that foliar application of boron (0.2%) in green gram increased the plant height (32.26 cm), number of nodules $plant^{-1}$ (30.8) and dry weight $plant^{-1}$ (12.9 g).

Garg *et al.* (1979) found that germination capability, size and fertility of pollen grains of rice were considerably improved as a result of boron application at 2.5 ppm concentration. They also reported that inclusion of boron in the nutrient solution with optimum level induced some stimulatory effects on the pollen vitality and there by improved the grain yield of rice.

Effect of boron on yield and yield parameters: The highest number of pods $plant^{-1}$ (26.66), pod and kernel yield (25.46 and 16.34 q ha^{-1}, respectively) were recorded with application of borax as soil application in groundnut (Vishwakarma *et al.*, 2008). The maize crop sprayed with boric acid @ 0.3% produced higher grain yield (6444 kg ha^{-1}) than no spray treatment (Sekar *et al.*, 2009).

Dixit and Elamathi (2007) reported that foliar application of boron (0.2%) in green gram increased the number of pods $plant^{-1}$ (18.1), 1000 seed weight (28.7 g), grain yield (7.53 q ha^{-1}) and haulm yield (30.0 q ha^{-1}). Susheela (1996) revealed that foliar spraying of borax at 0.2% increased percentage of filled seeds in sunflower. This might be due to better pollen germination, increased pollen viability and fertilizing capacity.

Khan *et al.* (1990) found that dusting of borax at 2 kg ha^{-1} on sunflower heads during seed filling stage significantly increased the seed yield by 87%, test weight by 60%, seed filling by 25% and head diameter by 21% compared to control. They also found dusting borax on ear heads gave the highest germination per cent of 96 and vigour index of 2162 compared to control (84% germination and 1263 vigour index, respectively).

Fernandez (1990) reported that the requirement of boron was maximum during flowering and the plant was therefore most susceptible to limitations and so the content of the 5th and 6th leaves under the flowering head should be maintained at 20 and 40 ppm, respectively. Sarkar and Sasmal (1989) found that applying 0.5 kg ha^{-1} boron to sunflower grown in *rabi* (winter) season increased the capitulum diameter, number of filled seeds $head^{-1}$, 1000 seed weight and seed yield.

Randhawa and Nayyar (1982) reported that application of boron was found to be beneficial in increasing the yield of wheat and paddy. Satyanaryana *et al.* (1997) reported that application of boron at 2 and 4 kg ha^{-1} increased the yield of sunflower by 38 and 59%, respectively over control. Rao and Vidyasagar (1981a) reported that foliar application of boron increased the plant height, stem girth, dry matter accumulation, total seed number per head, number and weight of filled seed per head, test weight and seed oil content.

Effect of boron on quality parameters: Application of boron either alone or in combination with FYM and sulphur helped in improving the quality of groundnut (Dongale and Zende, 1976; Survase *et al.*, 1986; Patil *et al.*, 1987). Sekar *et al.* (2009) recorded higher starch content in hybrid maize sprayed with boric acid @ 0.3%.

Effect of boron on nutrient uptake: Jain *et al.* (2007) revealed that Rhizobium inoculation along with zinc and boron in green gram gave better response in terms of N uptake as compared to Rhizobium alone. Ateeque and Malewar (1992) reported that uptake of N, P and boron was the highest when fertilized with boronated super phosphate as compared to SSP and DAP.

Rao and Vidyasagar (1981b) reported that boron when applied to soil resulted in increased N content of leaf, K content of stem and P content of petiole during early vegetative stage, N and P contents of leaves during flowering stage and P contents of leaves and stems, and N and K contents of petioles at harvest. Boron when sprayed on foliage helped to increase the mineral composition of leaves, stems and petioles during different growth stages of sunflower. They also noticed that foliar sprayed boron influenced the absorption and preferential translocation of mineral elements into different parts of the plant.

Effect of boron on economics: Dixit and Elamathi (2007) reported that foliar application of boron (0.2%) in green gram increased the B: C ratio (1.54). Susheela (1996) revealed that net return and B: C ratio was higher with 60 kg P_2O_5 ha $^{-1}$ combined with of 2% DAP and 0.2% borax spray in sunflower.

Importance of panchagavya: In 1950, James F. Martin of USA made a liquid catalyst (living water) from milking cow, using dung, sea water and yeast and it was claimed that it was capable of greening degraded land (Vivekanandan *et al.*, 1998). Cows ghee had been used in ancient and medieval times (Kautilya 321-296 BC and Someshwara Deve 1126 AD) for managing seedling health. The ghee contains vitamin A, vitamin B, calcium, fat and also glycosides, which protects cut wounds from infection. Cows curd is rich in microbes (*Lactobacillus*) that are responsible for fermentation (Chandha, 1996).

Panchagavya has got reference in the scripts of Vedas (divine scripts of Indian wisdom) and Vrkshayurveda (Vrskha means plant and ayurveda means health system). The texts on Vrskhayurveda as systematization of the practices that the farmers followed at field level, placed in a theoretical frame work and it defined certain plant growth stimulants; among them Panchagavya was an important one that enhanced the biological efficiency of crop plants and quality of fruits and vegetables (Natarajan, 2002). The positive effect of panchagavya on growth and productivity of crops has been reviewed and documented by Somasundaram and Amanullah (2007).

Effect of panchagavya spray on growth parameters: Mohanalakshmi and Vadivel (2008) revealed that ashwagandha plant sprayed with panchagavya (3%) produced higher number of leaves $plant^{-1}$ (670). Vennila and Jayanthi (2008) revealed that application of 100% recommended dose of fertilizer along with panchagavya spray (2%) significantly increased the okra plant height (131.7 cm) and dry matter production (5.90 g $plant^{-1}$).

Biogas slurry with panchagavya combination is adjudged as the best organic nutrition practice for sustainability of maize-sunflower-green gram system by its overall performance on growth, productivity, quality of crops, soil health and economics (Somasundaram *et al.*, 2007).

Panchagavya was tested for different crops such as turmeric, paddy, onion, gingely, sugarcane, banana, vegetables and curry leaf and it was found that it enhanced the growth, vigour of crops, resistance to pest and diseases and improvement of keeping quality of vegetables and fruits (Natarajan, 2002).

Xu (2001) reported that Effective Micro Organism (EMO) cultures could synthesize phytohormones i.e., auxins and other growth regulators that stimulated maize plant growth and they contained proactive substances that could significantly affect leaf stomatal response in maize. Leaf stomata of the EMO treated maize opened more rapidly than water treated control plants and when leaves were subjected to dehydration, the stomata closed more slowly (i.e., remained open longer) thus showed that, EMO contained bioactive substances that could have significantly affected leaf stomata response and led to increased LAI.

Effect of panchagavya spray on yield and yield attributes: Mohanalakshmi and Vadivel (2008) revealed that application of poultry manure (5 t ha^{-1}) + panchgavya (3%) in aswagandha exhibited significantly superior performance by registering the highest root yield of 1354.50 kg ha^{-1}. Vennila and Jayanthi (2008) revealed that application of 100 per cent recommended dose of fertilizer along with panchagavya spray (2%) significantly increased the number of fruits $plant^{-1}$ (21.8), fruit weight g $fruit^{-1}$ (13.9) and fruit yield q ha^{-1} (12.7) of okra.

Swaminathan *et al*. (2007) concluded that application of panchagavya at 3% as foliar spray on 15, 25, and 40 DAS on black gram recorded the highest grain yield of 1195 kg ha^{-1}. Kanimozhi (2003) revealed that application of *panchagavya* at 4 per cent spray was found to be superior in respect of root yield (12.4 kg/plot) compared to control (5.23 kg $plot^{-1}$) in *Coleus forskohili.*

Foliar spray of *Panchagavya* @ 3 per cent on 15, 25, 40 and 50 DAS with no fertilizers was the most effective low cost technology in terms of grain yield of greengram (Somasundaram *et al*., 2003). *Panchagavya* and vermicompost combination has given the highest pod yield of french bean variety Ooty 2, which was 36 per cent higher than the conventional method (Selvaraj, 2003). The treatment combinations of poultry manure + neem cake + panchagavya along with increased dose of fertilizers increased the stick yield of moringa (Beaulah *et al*., 2002). Balasubramanian *et al.* (2001) reported that dipping of rice seedlings in *panchagavya* before transplanting enhanced the growth and yield.

In panchagavya, Effective Micro Organisms (EMO) were the mixed culture of naturally occurring, beneficial microbes (mostly lactic acid bacteria (Lactobacillus), yeast (Saccharomyces), actinomyces (Streptomyces), photosynthetic bacteria (Rhodopsuedomonas) and certain fungi (*Aspergillus*)) and that improved the soil quality and growth and yield of sweet corn, which was equal to or higher than what was obtained from chemical fertilizers (Xu, 2001).

In jasmine, spraying two rounds of panchagavya, one before the flower initiation and another during bud setting phase ensured continuous flowering and in annual moringa sprayings doubled the stick yield besides giving resistance to pests and diseases (Vivekanandan, 1999). Panchagavy*a* sprayed on 25 and 40 DAS advanced the paddy harvest by 10 days (Vivekanandan, 1999).

Effect of panchagavya spray on quality parameters: Vennila and Jayanthi (2008) revealed that application of 100% recommended dose of fertilizer along with panchagavya spray (2%) in okra resulted in higher crude protein, ascorbic acid and Barletts index. The presence of auxin in panchagavya controls the water regulation in developing fruits. Regular and uniform water supply to the developing fruits resulted in increased ascorbic acid content, Barletts index and crude protein content.

Yadav and Lourduraj (2006b) revealed that foliar spray of panchagavya and organic manures recorded better cooking qualities and physical characteristics of rice as well as higher sensory score as compared to recommended N, P and K through fertilizers.

Effect of panchagavya spray on nutrient uptake: Presence of macro (N. P, K and Ca) and micro (Zn, Fe, Cu, Mn) nutrients besides total reducing sugars (glucose) were observed in panchagavya. Chemolithotrops and autotropic nitrifiers (ammonifers and nitrifers) present in panchagavya which colonize in the leaves increase the ammonia uptake and enhance the total N supply (Papen *et al*., 2002).

Beaulah (2001) reported that the secondary and micronutrients (Ca, S and Fe) and macronutrients (NPK) contents of leaves and pods of annual moringa were superior under poultry manure + neem cake + panchagavya treatments. Higher nutrient uptake and nutrient use efficiency in both main and ratoon crops of annual moringa were also observed. Similarly, the quality parameters viz., crude fibers, protein, ascorbic acid, carotene content and shelf life were also higher under organic manure applied with panchagavy*a* spray (Beaulah *et al*., 2002).

Influence of panchagavya spray on soil fertility: Microbial flora of soil play an important role in soil health. The microorganisms present in the rhizospheres environment around the roots influence the plant growth and crop yield. The beneficial microorganisms from panchagavya and their establishment in the soil improved the sustainability of agriculture.

Effect of panchagavya spray on economics: Swaminathan *et al*. (2007) reported that application of panchagavya at 3% as foliar spray on 15, 25, and 40 DAS on black gram under irrigated condition recorded the highest net return (Rs. 28544 ha^{-1}) and B:C ratio (4.91).

Application of 50 per cent N through composted poultry manure + 50 per cent N through green leaf manure along with panchagavya spray recorded higher net returns (Rs. 17822 ha^{-1}), followed by recommended NPK through panchagavya spray (Rs. 15586 ha^{-1}) in rice (Yadav and Lourduraj, 2006a).

Importance of Pink Pigmented Facultative Methylotroophic bacteria (PPFMs): Pink Pigmented Facultative Methylotrophs (PPFMs) belonging to the genus *Methylobacterium* are persistently present in the rhizosphere and phyllosphere regions of plants and even on the surface of the seeds of various plants. They were revealed on leaves of almost all plants (Corpe and Rheem, 1989).

Methylotrophs have received a great deal recently due to their importance in the biosphere and their potential commercial applications. Holland (1997) reported that the invention provided a method for increasing productivity of a plant by spraying PPFM on a plant. The invention also related to increasing productivity of a plant under stress by applying PPFM to a plant and subsequently applying an aqueous solution-containing methanol to the plant.

Methylobacterium have some sort of beneficial interaction with plants (Holland and Polacco, 1992, 1994). Pink pigmented facultative methylotrophs (PPFMs) isolated from the liverwort stimulated growth of the liverwort (*Scapania nemorosa)* and *Streptocarpus prolixus* (flowering plant) in tissue cultures and a positive commensal interaction was proposed (Corpe and Basile, 1982). Effect of PPFMs on germinating seeds has been suggested to be mediated by cytokinin or other plant growth promoting substances (Holland and Polacco, 1994) and a possible connection between bacterial and plant metabolism has also been suggested (Holland and Polacco, 1992).

Effect of PPFM spray on growth attributes: Under the pot culture condition in blackgram variety CO_2, the plant height was significantly increased (37.28 cm) by foliar application of urea and phyllosphere spraying of *Methylotrophs extorquees* PPFMs-Vm-11, which was superior to uninoculated control (30.28 cm plant^{-1}) (Madhaiyan, 2003).

Madhaiyan (2003) reported that inoculation of *Methylobacterium* and methanol spray significantly increased the plant height and dry matter production of cotton than uninoculated control. The inoculation of *M. extorquens* PPFM-GO-71 by phyllosphere spray with methonal had significantly increased the plant height (84.3 cm plant^{-1}) and dry matter production (15.12 g hill^{-1}) than all the other treatments.

Sundaram *et al.* (2002) stated that PPFMs influenced seed germination and seedling growth by producing plant growth regulators zeatin and related cytokinin. Due to the production of plant hormone and vitamins by pink pigmented facultative methylotrophic bacteria colonizing on the phyllosphere regions of maize, PPFM enhanced the seedling vigour in maize. Inoculation of *Methylobacterium* sp. PPFMs-Ah recorded maximum plant growth of groundnut at harvest (57.0 cm) which was followed by *Methylobacterium* sp. PPFMs-Os (52.7 cm) and *M. extorquens* AMI (51.1 cm) (Reddy, 2002).

Effect of ppfm spray on yield and yield attributes: Radhika *et al.* (2008a) revealed that the highest maize cob yield (7785 kg ha^{-1}) was obtained from foliar application of PPFMs at 5 L ha^{-1}. The highest cob yield was due to significant increase in length, diameter and weight of cob and corn. Exogenous methanol of plant stimulated the growth of *methylobacterium* sp, which provided plants with cytokinins and auxin which in turn enhanced plant development and ultimately increased the yield (Lidstrom and Chistoserdova, 2002). This might be due to supply of cytokinin by PPFMs. Cytokinin helps in promotion of cell division, delaying of senescence, counteracting apical bud dominance, translocation of assimilates and thereby improve the yield potential of plants (Madhaiyan *et al.*, 2005).

Madhaiyan (2003) observed that application of PPFMs as foliar spray significantly increased the boll numbers, boll weight and kapas yield of cotton. Foliar application of urea and phyllosphere spraying of *M. extorquens* PPFMs-Vm-11 significantly increased the seed weight of black gram (7.52 g plant^{-1}) over uninoculated control (5.12 g plant^{-1}) (Madhaiyan, 2003).

The highest boll and seed weight of cotton was obtained with phyllosphere spraying *M. extorquens* AMI with methanol spray followed by seed imbibitions of *M. extorquens*, PPFMS-GO-71 reported by (Madhaiyan, 2003). Reddy (2002) revealed that the inoculation of PPFMs isolate *Methylobacterium* sp. PPFMs-Ah recorded higher number of nodules at 60 (30.33), 90 (52.32) and 120 DAS (61.22) than other treatments in groundnut. Reddy (2002) revealed that *Methylobacterium* sp. PPFMs-Ah recorded maximum pod weight of groundnut (10.60 g) by seed imbibition method, where as *Methylobacterium* sp. PPFMs-Os recorded 8.98 g and M. extorquenes AMI 8.86 g.

Effect of PPFM spray on quality of crops: Radhika *et al.* (2008b) concluded that application of pink pigmented facultative methylotrophs at 5 L ha^{-1} increased the productivity as well as quality parameters of baby corn. Madhaiyan *et al.* (2005) revealed that inoculation of PPFM resulted in significant increase in sugar cane plant growth, cane yield and sugar quality.

CONCLUSION

From the foregoing review it can be concluded that plant growth substances help to bring rapid changes in the phenotypes of the plants and also improves the growth, translocation of nutrients to economic parts and ultimately improve the productivity of the crops.

REFERENCES

Agarwala, S.C., P.M. Sharma, C. Chatterjee and C.P. Sharma, 1981. Development and enzymatic changes during pollen development in boron deficient maize plant. J. Plant Nutr., 3: 329-336.

Ateeque, M. and G.U. Malewar, 1992. Uptake of N, P and boron by sunflower as influenced by sources and levels of phosphorus with and without boron. J. Soils Crops, 2: 12-14.

Balasubramanian, A.V., K. Vijayalakshmi, S. Sridhar and S. Arumugasamy, 2001. Vrkshayurveda experiments linking ancient texts and farmers practices. COMPAS Magazine March, pp: 36–39. http://www.compasnet.org/afbeeldingen/Magazines/CM4/cm4_12.PDF.

Beaulah, A., 2001. Growth and development of moringa (*Moringa oleifera* Lam.) under organic and inorganic systems of culture. Ph.D. Thesis, Tamil Nadu Agric. Univ., Coimbatore.

Beaulah, A., E. Vadivel and K.R. Rajadurai, 2002. Studies on the effect of organic manures and inorganic fertilizer on the quality parameters of moringa (*Moringa oleifera* Lam.) cv. PKM 1. Proceedings of the UGC Sponsored National Seminar on Emerging Trends in Horticulture, (ETH02), Annamalai University, Annamalai Nagar, Tamil Nadu, pp: 127-128.

Blamey, F.P.C., 1976. Boron nutrition of sunflowers (*Helianthus annuus* L.) on an avalon medium sandy loam. Agrochemophysica, 8: 5-10.

Chandha, M., 1996. Butter milk as plant growth promoter. Honey Bee, Jan-Mar Issues.

Corpe, W.A. and D.V. Basile, 1982. Methanol-utilizing bacteria associated with green plants. Dev. Indus. Microbiol., 23: 483-493.

Corpe, W.A. and S. Rheem, 1989. Ecology of the methylotrophic bacteria on living leaf surfaces. Microb. Ecol., 62: 243-249.

Dashora, L.D. and P.M. Jain, 1994. Effect of growth regulators and phosphorus levels on growth and yield of soybean. Madras Agric. J., 81: 235-237.

Dixit, P.M. and S. Elamathi, 2007. Effect of foliar application of DAP, micronutrients and NAA on growth and yield of green gram (*Vigna radiata* L.). Legume Res. Int. J., 30: 305-307.

Dongale, J.H. and G.K. Zende, 1976. Response of groundnut to the application of manganese, boron and sulphur both in the presence of absence of FYM through soil and foliar spray. Ind. J. Agron., 21: 321-326.

Enyedi, A.J., N. Yalpani, P. Silverman and I. Raskin, 1992. Localization, conjugation and function of salicylic acid in tobacco during the hypersensitive reaction to tobacco mosaic virus. Proc. Natl. Acad. Sci. USA., 89: 2480-2484.

Fernandez, G.P., 1990. Recent developments in use of boron and diagnosis of requirements in the field. Report on an International Workshop Johns College, Oxford, England, pp: 23-25.

Garg, O.K., A.N. Sharma and G.R.S.S. Kona, 1979. Effect of boron on the pollen vitality and yield of rice plants (*Oryza sativa* L. Var. Jaya). Plant Soil, 52: 591-594.

Gunes, A., A. Inal, M. Alpaslam, F. Erslan, E.G. Bagsi and N. Cicek, 2007. Salicylic acid induced changes on some physiological parameters symptomatic for oxidative stress and mineral nutrition in maize (*Zea mays* L.) grown under salinity. J. Plant Phsiol., 164: 728-736.

Holland, M.A. and J.C. Polacco, 1992. Urease-null and hydrogenase-null phenotypes of a phylloplane bacterium reveal altered nickel metabolism in two soybean mutants. Plant Physiol., 98: 942-948.

Holland, M.A. and J.C. Polacco, 1994. PPFMs and other covert contaminants. Is there more to plant physiology than just plant?. Annu. Rev. Plant Physiol. Plant Mol. Biol., 45: 197-209.

Holland, M.A., 1997. Occams razor applied to hormonology (Are cytokinins produced by plants?). J. Plant Physiol., 115: 865-868.

Hussein, M.M., L.K. Balbaa and M.S. Gaballah, 2007. Salicylic acid and salinity effect on growth of maize plants. J. Agric. Biol. Sci., 3: 321-328.

Jain, A.K., S. Kumar and J.D.S. Panwar, 2007. Response of mungbean (*Vigna radiata*) to phosphorus and micronutrients on N and P uptake and seed quality. Legume Res., 30: 201-204.

Jeyakumar, P., G. Velu, C. Rajendran, R. Amutha, M.A.J.R. Savery and S. Chidambaram, 2008. Varied responses of blackgram (*Vigna munga*) to certain foliar applied chemicals and plant growth regulators. Legume Res. Int. J., 31: 110-113.

Kalarani, M.K., M. Thangaraj, R. Sivakumar and V. Mallika, 2002. Effect of salicylic acid on tomato (*Lycopersion esculentum*) productivity. Crop Res., 23: 486-492.

Kalpana, S., 1997. Studies on the effect of botanicals, chemicals and plant growth regulators on growth and productivity in rice (*Oryza sativa* L.) var. ADT 36. M.Sc. Thesis, Tamil Nadu Agric. Univ., Coimbatore.

Kanimozhi, S., 2003. Organic production package of coleus forskohlii. M.Sc. Thesis, Horticultural College and Research Institute, Tamil Nadu Agric. Univ., Coimbatore.

Khan, T.A., K. Venugopal, S.C. Devaiah and K. Seenappa, 1990. Effect of secondary nutrients and boron on some growth characters and yield in sunflower. J. Oilseeds Res., 7: 136-139.

Khan., W., P. Balakrishnan and L.S. Donald, 2003. Photosynthetic responses of corn and soybean to foliar application of salicylates. J. Plant Physiol., 160: 485-492.

Lidstrom, M.E. and L. Chistoserdova, 2002. Plants in the pink: Cytokinin production by *Methylobacterium*. J. Bacteriol., 184: 1818-1818.

Madhaiyan, M., 2003. Molecular aspects, diversity and plant interaction of facultative methylotrophs occurring in tropical plants. Ph.D. Thesis, Tamil Nadu Agric. Univ., Coimbatore.

Madhaiyan, M., S. Poonguzhali, H.S. Lee, K. Hari, S.P. Sundaram and T.M. Sa, 2005. Pink pigmented facultative methylotrophic bacteria accelerate germination, growth and yield of sugarcane clone CO86032 (*Saccharam officinarum* L.). Biol. Fertl. Soils, 41: 350-358.

Marschner, H., 1997. Mineral Nutrition of Higher Plants. 2nd Edn., Academic Press, The Netherlands, ISBN: 0-12-473543-6.

Mohanalakshmi, M and E. Vadivel, 2008. Influence of organic manure and bioregulators on growth and yield of aswagandha. Int. J. Agric. Sci., 2: 429-432.

Nagasubramaniam, A., G. Pathmanabhan and V. Mallika, 2007. Studies on improving production potential of baby corn with foliar spray of plant growth regulators. Ann. Plant Phsiol., 21: 154-157.

Natarajan, K., 2002. Panchagavya–A Manual. Other Indian Press, Mapusa, Goa, India, pp: 333.

Papen, H., A. Gabler, E. Zumbusch and H. Rennenberg, 2002. Chemolitho autotrophic nitrifiers in the phyllosphere of a spruce ecosystem receiving high nitrogen input. Curr. Microbiol., 44: 56-60.

Patil, C.D., M.D. Patil, N.D. Patil and R.N. Adsule, 1987. Effect of boronated superphosphate, single superphosphate and borax on the yield and quality of groundnut. J. Maharastra Agric. Univ., 128: 168-170.

Radhika, S., K. Velayutham and N. Thavaprakaash, 2008a. Yield parameters and yield of baby corn (*Zea mays* L.) as influenced by nutrients and plant growth regulators. Int. J. Trop. Agric., 26: 259-262.

Radhika, S., K. Velayutham and N. Thavaprakaash, 2008b. Effect of nutrients and plant growth regulators on the quality parameters and yield of baby corn (*Zea mays* L.). Int. J. Trop. Agric., 26: 255-258.

Randhawa, N.S. and V.K. Nayyar, 1982. Crop response to applied micronutrients: Review of soil research in India. Proceedings of the 12th international Congress on Soil and Science, (SS82), New Delhi, India, pp: 392-411.

Rao, H.G. and C. Vidyasagar, 1981a. Effect of nitrogen, phosphorus and potassium along with foliar and soil applied boron on sunflower (*Helianthus annus* L.) I. Growth, yield, seed oil content and varietal performance. Andhra Agric. J., 28: 150-155.

Rao, H.G. and C. Vidyasagar, 1981b. Effect of nitrogen, phosphorus and potassium along with foliar and soil applied boron on sunflower (*Helianthus annus* L.) II. Content of N, P and K in plant at various stages of growth. Andhra Agric. J., 28: 210-214.

Raskin, I., 1992. Role of salicylic acid in plants. Ann. Rev. Plant Physiol. Plant Mol. Biol., 43: 439-463.

Reddy, S., 2002. Studies on pink pigmented facultative methylotrophs as a new bioinoculant for groundnut (*Arachis hypogaea* L.). M.Sc. Thesis, Tamil Nadu Agric. Univ., Coimbatore.

Sarkar, R.K. and T.K. Sasmal, 1989. Response of sunflower to application of micronutrients on rice follow Gangetic alluvial soil. Ind. Agric., 33: 39-44.

Satyanaryana, T., K.M. Varadan, V.P. Badanur and G.V. Haranagi, 1997. Note on the effects of secondary and trace elements on sunflower yield. Ind. J. Agric. Res., 11: 122-124.

Sekar, S., M.M. Amanullah, S. Manoharan and K.S. Subramanian, 2009. Influence of fertilizer levels and growth substances on yield and quality of hybrid maize. Green Farming, 2: 889-892.

Selvaraj, N., 2003. Report on the Work Done on Organic Farming at Horticultural Research Station. Tamil Nadu Agricultural University, Ooty, Indian, pp: 2-5.

Singh, G., N. Sekhon and K. Manjit, 1980. Effect of phenolic compounds on the yield potential of gram (*Cicer arietinum* L.). Ind. J. Plant Physiol., 23: 21-25.

Singh, G. and M. Kaur, 1981. Effect of growth regulators on podding and yield of mungbean (*Vigna radiate* L. Wilczek). Ind. J. Plant Physiol., 24: 366-370.

Solaimalai, A., C. Sivakumar, S. Anbumani, T. Suresh and K. Arumugam, 2001. Role of plant growth regulators in rice production: A review. Agric. Rev., 22: 33-40.

Somasundaram, E., N. Sankaran., S. Meena, T.M. Thiyagarajan, K. Chandaragiri and S. Panneerselvam, 2003. Response of greengram to varied levels of *Panchagavya* (organic nutrition) foliar spray. Madras Agric. J., 90: 169-172.

Somasundaram, E. and M.M. Amanullah, 2007. Panchagavya on growth and productivity of crops: A review. Green Farming, 1: 22-26.

Somasundaram, E., M.M. Amanullah, K. Thirukkumaran R. Chandrasekaran, K. Vaiyapuri and K. Sathyamoorthi, 2007. Biochemical changes, nitrogen flux and yield of crops due to organic sources of nutrients under maize based cropping system. J. Applied Sci. Res., 3: 1724-1729.

Sujatha, K.B., 2001. Effect of foliar spray of chemicals and bioregulators on growth and yield of greengram (*Vigna radiata* L.). M.Sc. Thesis, Tamil Nadu Agric. Univ., Coimbatore.

Sundaram. S.P., M. Madhaiyan, M. Senthilkumar and B.V.S. Reddy, 2002. A Novel Microbial Symbiont for Using as a Bioinoculant. In: Microbial Transformations in Soil, Chendrayan, K., Z. Ilamurugu, J. Kennedy and K. Govindarajan, (Eds.). Tamil Nadu Agricultural University, Coimbatore, India, pp: 123-131.

Survase, D.N., J.H. Dongale and S.B. Kandrekar, 1986. Growth, yield, quality and composition of groundnut as influenced by FYM, calcium, sulphur and boron in lateritic soil. J. Maharastra Agric. Univ., 11: 49-51.

Susheela, C., 1996. Studies on the effect of phosphorus and boron on the yield and seed setting of sunflower (*Helianthus annus* L.). M.Sc. Thesis, Tamil Nadu Agric. Univ., Coimbatore.

Swaminathan, C., V. Swaminathan and K. Vijayalakshmi, 2007. Panchagavya Boon to Organic Farming. International Book Distributing Co., India.

Vennila, C. and C. Jayanthi, 2008. Response of okra to integrated nutrient management. J. Soils Crops, 18: 36-40.

Vishwakarma, A.K., K.A. Brajendra, R.S. Pathak and A.L. Singh, 2008. Effect of different sources of boron application on productivity of groundnut in Mizoram. Int. J. Trop. Agric., 26: 157-159.

Vivekanandan, P., R. Chatturagiri, R.S. Narayanan and T. Ranganathan, 1998. Natural Farming Techniques and Animal Husbandry. Gandhigram Rural University, New Delhi.

Vivekanandan, P., 1999. Panchagavya advances paddy harvest by 10 days. Agri News, 2: 11-11.

Xin, L., L. Yan and Z.S. Qiu, 2000. Effect of salicyclic acid on growth and content of IAA and IBA of broadbean seedlings. Plant Physiol., 2: 50-52.

Xu, H.L., 2001. Effects of a microbial inoculant and organic fertilizers on the growth, photosynthesis and yield of sweet corn. J. Crop Prod., 3: 183-214.

Yadav, B.K. and C.A. Lourduraj, 2006a. Effect of organic manures and panchagavya spray on yield attributes and economics of rice (*Oryza sativa*). Crop Res., 31: 1-5.

Yadav, B.K. and C.A. Lourduraj, 2006b. Effect of organic manures and panchagavya spray on rice (*Oryza sativa*) quality. Crop Res., 31: 6-10.

Yalpani, N., A.J. Enyedi, J. Leon and I. Raskin, 1994. Ultra violet light and ozone stimulate accumulation of salicylic acid, pathogenesis-related proteins and virus resistance in tobacco. Planta, 193: 372-376.