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Review Article

INFLUENCES OF PLANT GROWTH REGULATORS ON YIELD OF SOYBEAN

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ABSTRACT
Plant growth regulators play important roles in plant growth and development, but little is known about the roles of plant growth regulators in manifestation yield components, yield and seed qualities of soybean. An attempt has been made to elaborate the subject with emphasis on important plant growth regulators viz. auxins, cytokinins, Gibberellins and abscisic acid and others. Some environmental stresses which happen to be usually in the way of crop maturity also been discussed. It is revealed the plant growth regulators when applied in proper stage of growth and concentration influenced positively the yield components and yield of soybean.

Keywords: *Soybean, Plant Growth Regulators, Yield, Yield Components*

INTRODUCTION
Soybean is a grain legume crop. As food and feed soybean plays an important role throughout the different countries of the world. It provides oil as well as protein to the living beings. This very useful crop is grown in many countries but land coverage is highest in United States of America.
It is noted that the productivity of soybean is related with the number of seeds per square meter and the weight of the seeds. Hence, high number of seeds and high seed weight are important for higher productivity. Medium duration and medium height plants are most favored. Average production is about 2.5 t/ha.
The minimum age at which plants can be induced to flower varies with species and with environmental conditions. Flowering of soybeans occurs most rapidly under short day conditions. It had also been shown that soybean yields tend to reach a maximum at populations of 50,000 to 1,00,000 per acre. Drought stress is the most important limiting factor at the initial phase of plant growth and establishment. Soybean is particularly sensitive to the lack of moisture during the blooming process (growth stages R_1 and R_2) and during the legume and seed growing processes (growth stages R_3–R_6).
Plant growth regulators play important roles in plant growth and development, but little is known about the roles of plant growth regulators in improving the yield components and seed qualities of soybean. Endogenous plant growth regulators determine many growths and development processes ultimately manifesting yield components and yield.
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 crop. Growth regulators can improve the physiological efficiency including photosynthetic ability and can enhance the effective partitioning of accumulates from source to sink in the field crops (Solamani *et al*., 2001). Soybean plants differentiate abundant floral buds, but most of them fail to grow pods and abort during development. It is noted that cytokinins play a role in regulating flower and pod development in soybean (Reese *et al*., 1995). Carlson *et al.,* (1987) and Nooden *et al*., (1990) have demonstrated a correlation between endogenous levels of cytokinins and the level of flower abortion and set.
Application of exogenous benzyladenine (BA) to individual racemes has been shown to prevent abortion of flowers and/or pods (Dyer *et al*., 1988; Peterson *et al*., 1990; Mosjidis *et al.*, 1993; Reese *et al.*, 1995). Abortion of significant percentage of flowers and pods commonly occurs in soybean (Abernethy *et al*., 1997; Dybing *et al*., 1986). The aborted flowers have generally been pollinated and fertilized, but tend to grow more slowly than the flowers that set (Huff and Dybing, 1980). Most proximal flowers set while

most distal flowers abort, removal of proximal flowers can induce set of distal flowers (Wiebold, 1990). Compared with setting flowers, the sink intensity is lower in aborting flowers as early as 3 day after anthesis (Brun and Betts, 1984).

Conflicting data suggest that nutritional availability (carbohydrates and nitrogen) may play a role(s) in the number of flowers formed and the total number of mature soybean fruits and seeds that develop (Hayati *et al*., 1995).

Research findings indicate that the concentration of endogenous auxin and cytokinin in racemes changes in a different manner, and that cytokinins have a positive, and auxin a negative effect on pod setting when respective hormones are applied to racemes after the anthesis stage. Thus, in soybean, the pod formation, development and filling i.e. both number of pods and the growth of pods is determined by the assimilate supply and the balance of endogenous plant growth regulators. And the exogenous application and time of application of plant growth regulators have no doubt play some influences in manifestation of yield components and yield of soybean. Hence, it is interesting to understand the responses of plant growth regulators applied exogenously.

Auxins

IAA has been found to increase the plant height, number of leaves per plant, fruit size with consequent enhancement of seed yield in groundnut (Lee, 1990), cotton (Kapgate *et al*., 1989), cowpea (Khalil and Mandurah, 1989) and rice (Kaur and Singh, 1991). It also increases the flowering, fruit set, the total dry matter of crops (Gurdev and Saxena, 1991). It is also known that auxin suppresses axillary bud outgrowth (Shimuzu-Sato *et al.*, 2009).

In soybean it was noted that both tryptophan and IAA induced root nodules formation. Additionally, these extracellular hormones also increased shoot and root dry weight as well as soybean yields. Highest root modules number and soybean yield were observed from the treatment of 1.0 ppm tryptophan applied in early planting. It seemed that higher concentrations of tryptophan or IAA are required when applied at early planting, presumably because of its concentration decreases prior to root hairs formed (Sudadi, 2012).

Sarkar *et al*., (2002), in an experimental with soybean cv. BS-3 when sprayed at three different times with two concentrations (100 and 200 ppm) of indole acetic acid (IAA) noted that 100 ppm IAA produced increase in plant height, number of flowers, number of pods, percent of fruit set, number of seeds per plant, seed yield per plant and seed yield (t/ha), as compared to control (Table 1).

Table 1: Influence of IAA on Development and Seed Yield of Soybean

Treatment	No. of Flowers/ Plant	No. of Pods/ Plant	Percent Fruit Set	No. of Seeds/ Plant	100 Seed Weight (g)	Seed Yield per Plant(g)
IAA						
Control	16.78	12.67	64.06	26.56	6.41	1.69
100 ppm	24.67	19.11	71.97	39.67	8.82	3.56
200 ppm	22.00	16.78	69.50	36.44	8.94	3.30

The growth regulator napthaleneacetic acid (NAA) delayed the flowering of soybean, hence, delayed maturity. Chaudhuri *et al*., (1980) observed that NAA delayed the senescence of rice so that translocation of assimilates from source to sink is more and hence the yield. Fruiting was also delayed in NAA treated plants.

NAA treated plants utilized more material in the vegetative parts of the plant. Fewer early pods were set on these plants. Dhakne *et al.*, (2015) noted that application of 40 ppm of NAA increased the yield of soybean.

In an experiment the effects of the application of 1-napthaleneacetic acid (NAA) solutions of 0, 10, 25, 50 and 100 ppm to soybean SJ2 and SJ4 was studied using three applications of each dose at vegetative stage, flowering stage and pod setting stage. The result indicated that the spraying of 10 ppm NAA resulted in 15 percent increase of number of pods per plant and gave 26 percent increase of seed yield. Application of higher dose of NAA to soybean plant would obtain bigger seed size and higher protein content but lower oil content.

Soybean SJ4 showed higher response to the application of NAA than SJ2 in that the yield, seed size, seed protein and fat content of SJ4 are greater than that of SJ2 (Phanophot *et al*., 1986). Merlo *et al*., (1987) also reported that NAA application on soybean at flowering increased branches per plant and average pod weight. 100 seeds weight were increased with 20 ppm of NAA (Ravikumar and Kulkarni, 1998). Deotale *et al*., (1998) studied the effect of NAA on growth parameter of soybean and obtained highest values for plant height, number of leaves per plant, number of branches per plant, leaf area, dry matter, days to maturity and seed yield with 100 ppm. It is also noted that NAA at 40 ppm foliar spray improves total chlorophyll content, nitrate reductase activity, soluble protein and thereby pod yield in soybean (Senthil, 2003).

In 3 soybean varieties application of NAA at 50 ppm increased the number of pods per plant, number of seeds per pod, 100 seed weight, harvest index, and grain yield significantly than the control (Kalyankar *et al*., 2007). Khaswa *et al*., (2014) observed that application of 100 ppm of NAA at 30 and 65 DAS increased grain yield over control.

Synthetic auxin herbicides have long been utilized for the selective control of broadleaf weeds of crop and non-crop environments. Recently, it has been tried to develop soybean with resistance to 2, 4-D and dicamba which might lead to an increase in the application of these herbicides in soybean production areas in the future.

Again there are newly discovered synthetic auxin herbicides, aminocyclopyrachlor. Two field trails were conducted in 2011 and 2012 to evaluate the effects of sublethal rates of 2, 4-Damine, aminocyclopyrachlor, aminopyralid, dicamba, fluroxypyr, picloram and briclopy on soybean phytotoxicity and seed yield components applied at V_3 and R_2 stages of growth at 0.028, 0.28, 2.8 and 28 g ae ha^{-1}.

The only herbicide applied that resulted in no yield loss at either stage was 2, 4-Damine. Results indicate that there are vast differences in the relative phytotoxicity of these synthetic auxin herbicides to soybean and that the timing of the synthetic auxin herbicide exposure will have a significant impact on the severity of soybean height and/or yield reduction (Solomon and Bradley, 2014). Previous research has demonstrated in general, that the likelihood of soybean yield loss increases, when exposure to the auxin herbicide occurs closer to the time of soybean reproductive development (flowering or later) and as the dose of the herbicide increases (Kelley *et al*., 2005). Tri-iodo benzoic acid (TIBA) hasten flowering and fruiting of plants.

TIBA is known for its antiauxin physiological activities. TIBA appeared to have an effect similar to shortening the photoperiod or removing the auxin producing young leaves. It is hypothesized that TIBA slows auxin production or action in young leaves and meristems of the plants, therefore lowering the competition of the vegetative parts of the plant for growth materials.

An increase in seed yield was shown for TIBA treated plots at stage 2 in the range of 15 to 120 ppm. Higher levels were injurious to the plants.

It facilitates better conditions for pod set and fruit growth. Soybean genotypes grown in sub-tropical climate may exhibit lodging. Treatment with TIBA ($10gha^{-1}$) under field condition reduced lodging to soybean plants.

Grain weight increased linearly when the levels of TIBA increased. There was a negative correlation between lodging and grain yield and a positive correlation between plant height and lodging. There was also a negative correlation between injury caused by the application of plant regulators and lodging (Buzzello *et al.,* 2013). Chung and Kim (1989) investigated the effect of TIBA on soybean cultivar Hwang Keumkong.

TIBA reduced stem length and lodging however increased stem diameter, podding rate, number of pods and seeds per plant and seed yield. TIBA was effective to healthy growth and to increase seed yield. Optimum treatment method for healthy plant growth and higher seed yield was 2-3 times spray with 5 days interval from 6 leaf stage (V_6) of soybean plants. Soybean seed yield in the plot of TIBA treatment with 3 times from 6 leaf stage was 20% higher both in early and ordinary seeding field than those of non-treatment plots. Kumar *et al*., (2002) noted that seed yield was significantly higher with TIBA (50 ppm) application which was associated with higher number of pods and seeds per plant in soybean genotypes (Table 2).

Gibberellins

Gibberellins (GA_3) constitute a group of tetracyclic diterpenoids, involved in plant growth and development. Gibberellic acid (GA_3) a well known phytohormone, has numerous physiological effects on plants including seed germination, growth, stem elongation, leaf expansion, photosynthesis, flowering and cell expansion (Taiz and Zeiger, 2010; Yuan and Xu, 2001). Exogenous application of GA_3 to plants causes the increase in activities of many key enzymes like carbonic anhydrase (CA), nitrate reductase (NR) (Aftab *et al*. 2010) and ribulose – 1, 5 biophosphate carboxylase / oxygenase (RuBPCO) (Yuan and Xu, 2001).

Results indicate that seeds primed with GA_3 @100 ppm for 12 hr had significantly higher germination percentage over untreated control of soybean. The seed priming significantly influenced the seed yield and yield contributing characters of soybean cv. JS-9305 showing to the corresponding favorable improvement in number of pods per plant, number of seeds per pod, test weight, seed yield and biological yield (Agawane and Parhe, 2015) (Table 3).

Upadhyay and Ranjan (2015) observed that application of GA_3 (20 ppm) at bud initiation and 50% flowering of soybean cv. Harit Soya increased the biological yield and seed yield along with test weight and harvest index (Table 4).

Field experiment with different levels (0, 125, 250 and 375 ppm) of GA_3 on soybean genotypes M11 and L17 when applied showed that interactions between different levels of GA_3 and the soybean genotypes had significant effect on pod number per plant, seeds per pod, 1000 seed weight and economic yield of soybean (Azizi *et al*., 2012).

Leite *et al*., (2003) in a pot experiment studied the effects of GA_3 on soybean at the rate of 100 mgl^{-1} as foliar spray on leaves at the physiological stage V_3/V_4 and 15 days after. Foliar application of GA_3 led to an increase in plant height, first node height and stem diameter. Leaf area and dry matter production also increased as a result of GA_3 foliar application.

The effect of gibberellic acid on the growth and yield components of soybean cultivar (Clark 63) was studied for its influence when applied to the different stages of growth. Gibberellin proved to be potential in increasing the yield components like the number of nodes pods and seeds which resulted to the increase in yield per hectare.

Soaking the seed with gibberellic acid with a concentration of 10 ppm before seeding then spraying with the same substance during the vegetative and flowering stages was proven to give the highest yield producing 2.62 tons per hectare which has a significant difference over the control which was 1.72 tons per hectare.

The growth substance, however, did not significantly accelerate and increase germination, plant height, fertility of nodes and weight of 1000 seeds (Domingo, 1981).

When plants of soybean cv. BS-3 were sprayed at three different times with two concentrations (100 and 200 ppm) of gibberellic acid, GA_3 at 100 ppm had regulatory effect to enhance the plant height, number of branches, number of leaves, leaf area per plant, number of flowers, number of pods, percentage of fruit set, number of seeds per plant, seed yield per plant, 1000 seed weight and seed yield (tha^{-1}) (Sarkar *et al.*, 2002) (Table 5).

The study to know the effect of GA_3 applications on physidogocal and productive parameters an experiment performance with soybean cultured in the field for 3 crop seasons and in the greenhouse for 1 crop season sprayed at the R_2 physiological stages and 7 days later at the rate 300 gl^{-1}.

GA_3 treated plants had longer shoots. Although, there were no differences in number of pods, GA_3 treated plants had the number of seeds per pod lower. GA_3 spray increased oil content but reduced seed proteins (Travaglia *et al.*, 2009).

Cytokinins

Studies indicate that soybean seed yield is more decisively determined by the number of pods than by other components of production (Yashima *et al*., 2005). The amount of flowers that give rise to the pods until reaching maturity is a key factor for giving high yields.

Although, soybean flowers are produced abundantly, a large number of flowers and young pods abort naturally (Nonokawa *et al*., 2012).

Some researches show that, in normal conditions, the abscission of the reproductive structures of soybean can vary between 20 and 82% of the total number of the number of flower produced (Crosby *et al.,* 1981; Carlson *et al*., 1987; Yashima *et al*., 2005; Peterson *et al*. 2005).

The mechanisms responsible for flower and pod fixing are completely established. According to Dario *et al*., (2005) the application of growth regulators could raise the productivity above levels established until now.

Researches point out the use of plant growth regulators to reduce the pod abortion (Crosby *et al.,* 1981; Nonokawa *et al*., 2012; Passos *et al*., 2011). Abortion prevention may result in an increased number of pods and seeds, thus leading to gain in seed yield (Nonokawa *et al.*, 2012).

Exogenous application of cytokinin to raceme tissues of soybean has been shown to stimulate flower production and to prevent flower abortion (Nagel *et al.*, 2001). In the greenhouse, application of 3.4 x 10^{-7} moles of 6-benzylaminopurine resulted in a 79% increase in seed yield compared with controls. Results of field trials showed much greater variability within treatments, with consistent, but non-significant increases in seed number and total yields of about 3%.

Data suggest that cytokinin levels play a significant role in determining total yield in soybeans, and that increasing cytokinin concentrations in certain environments may result in increased total seed production (Nagel *et al*., 2001).

Leite *et al*., (2003) in a pot experiment on soybean, cytokinin (30 mgl^{-1}) was sprayed on leaves at the physiological stage V_3/V_4 and 15 days after. Cytokinin applied to leaves during vegetative growth was not effective in modifying any of the plant growth variables. Kumar *et al*., (2002) in a field experiment with soybean genotypes with determinate and semideterminate nature studied the effect of plant growth regulators.

Cytokinin improved all the parameters and the effect was seen more in determinate genotype. The seed yield was 10 to 15% higher with kinetin which was associated with higher number of pods and seeds per plant (Table 6).

Dhakne *et al.,* (2015) also noted that application of Kinetin 40 ppm recorded significantly higher yield and net return in soybean. Cytokinin has long been known to have an important involvement in controlling shoot branching (Leyser, 2003). Cytokinin promotes axillary bud out growth (Shimizu-Sato *et al*., 2009).

In soybean raceme cytokinin concentration was high for a short period with a peak at 9 days after anthesis. Again cytokinin concentration was higher in basal portions of racemes. In contrast, 6-benzylaminopurine (BA) applied to racemes before anthesis tended to reduce the number of flowers and pods, and that applied around 7 days after anthesis significantly increased the pod set percentage (Nonokawa *et al*., 2007). Genetic improvement of synthesis and transport of endogenous cytokinins from the root system, via conventional breeding or molecular approaches may strengthen pod set capacity of agriculturally significant genotypes.

Clarification of the physical and chemical properties of the rhizosphere optimizing synthesis of endogenous cytokinins in roots should improve pod set. In soybean cultivation there seems to be a link between exogenous benzyadenine and reduction of flower and pod abortion (Nagel *et al.*, 2001). It is observed that benzyladenine application reduced pod abortion in the lower, middle and upper third of the canopy of soybean. Soybean plants treated with benzyladenine showed higher yields than control plants. The highest productivity was obtained in soybean plants treated with a concentration of 300 mgl^{-1}. Benzyladenine application at the end of flowering is a promising management practice for soybean cultivation (Borges *et al.,* 2014).

Table 2: Influence of TIBA on Seed Yield and Yield Attributes

Treatment	Plant Height (cm)		Biomass (g plant^{-1})		No. of Pods (plant^{-1})		No. of Seeds (plant^{-1})		Seed Yield (g plant^{-1})	
	MACS124	**JS335**	**MACS124**	**JS335**	**MACS124**	**JS335**	**MACS125**	**JS335**	**MACS124**	**JS335**
Control	30.86	64.44	16.67	17.20	33.80	49.00	68.03	61.64	10.21	9.12
TIBA (50 ppm)	25.16	58.89	20.08	19.22	43.69	64.56	93.49	83.93	13.37	12.27
TIBA (100 ppm)	23.78	56.72	19.16	18.95	38.80	58.00	86.92	79.00	12.25	11.31

Table 3: Effects of Seed Priming on Germination, Yield Attributes and Seed Yield of Soybean

Treatment	Germination (%)	Pods per Plant	Test Weight (g)	Seed Yield (t/ha)
Control	83.00	94	12.95	2.29
Hydration with 100 ppm GA_3 (12 hr)	87.33	160	14.18	2.89

Table 4: Effects of GA_3 on Seed Yield of Soybean

Treatment	Test Weight (g)	Seed Yield (g/plant)	Biological Yield (g/plant)	Harvest Index (%)
Control	128	12.0	35.6	33.73
GA_3 (20 ppm) spray	161	21.1	45.1	46.66

Table 5: Effects of GA_3 on Yield Components and Seed Yield in Soybean

Treatment	No. of Flowers Per Plant	No. of Pods Per Plant	Percentage of Fruit Set	No. of Seeds Per Plant	Seed Yield Per Plant (g)	1000 Seed Weight (g)
Control	16.78	12.67	64.00	26.56	1.69	64.10
GA_3 (100ppm)	35.44	26.00	77.64	54.22	5.87	107.60
GA_3 (200ppm)	29.78	22.00	71.33	46.78	4.52	96.30

Table 6: Effects of Kinetin on Yield Attributes and Yield of Soybean

Treatment	Plant Height (cm)		Biomass (g plant^{-1})		No. of Pods Per plant		No. of Seeds Per plant		Seed Yield (g plant^{-1})	
	MACS124	**JS335**	**MACS124**	**JS335**	**MACS124**	**JS335**	**MACS125**	**JS335**	**MACS124**	**JS335**
Control	30.86	64.44	16.67	17.20	33.80	49.00	68.03	61.46	10.21	9.12
Kinetin (25 ppm)	29.66	64.46	17.83	18.37	34.10	52.40	73.96	68.32	11.43	10.44
Kinetin (50 ppm)	30.27	64.89	18.48	19.30	34.53	54.60	74.21	68.47	11.57	10.60

Abscisic Acid

The roles of abscisic acid (ABA) in basic physiology have been extensively studied, but information regarding participation of this hormone in field crops eco-physiology is rather limited. The evaluation of stress effects under artificially controlled conditions is very useful to recognize the physiological plant response and allows determining the presence of resistance. However, the plant responses under these conditions may not be representative of what happens in field conditions. Soybean monoculture generates a selective decreasing of the soil nutrients and can generate their exhaustion and the necessity of adding more fertilizers. Again, to achieve high yield the unfavorable environmental conditions during the critical period of crop must be minimized, especially the most frequent factor that is water deficit.

The results obtained in the experiments with soybean grown in field conditions support the idea that ABA enhances yield by a combination of factors. Therefore, foliar application (300 mgl^{-1}) of ABA may be an alternative tool for enhancing yield of short-cycle soybean, since it gives relief to temporary situations of water stress, such as the stress that happens in the hours of maximum irradiance, where an imbalance between water transpiration and absorption it is frequently produced. ABA seems to improve a combination of factors that contribute to increase the number of lateral roots and the density of radial system, to protect the photosynthetic apparatus, to keep the stomata conductance more stable over the time, and to enhance carbon allocation and partitioning to the seeds (Reinoso *et al*., 2011). Chung and Kim (1989) reported that when ABA was sprayed on soybean plants reduced stem length and lodging, however, increased stem diameter, podding rate, number of pods per plant and seed yield with 2-3 times spray at 6 days interval at 6 leaf stage (V_6). The study to investigate the effect of ABA application on physiological and productive parameters with soybean cultured in field for 3 crop seasons and in the greenhouse for 1 season at the rate of 300 mgl^{-1} sprayed at V_7 and R_2 physiological stages revealed that ABA treated plants had greater dry weight of aerial parts and root density and also leaf area and chlorophyll content. ABA application increased soybean yield by enhancing carbon allocation and partitioning to the seeds (Travaglia *et al*., 2009).

When the effect of S-abscisic acid application on soybean seed yield in response to water stress was evaluated, the results indicated that the application of 2-ppm S-ABA by foliar spray at reproductive stages increased soybean seed yield, seed number and pod number under optimum and mild water stress conditions, while under severe water stress conditions, the application of S-ABA was not effective to increase soybean seed yield. The application of S-ABA also increased the water use efficiency of soybean plants (Kamal *et al*., 1998).

A study on the effect of ABA application on pod formation and seed yield of soybean plants was carried out. The results indicated that the application of 1 and 10 ppm ABA foliar spray before the flowering (V_7) and flowering stages promoted pod set, filled pod number, pod respiration, glucose and fructose contents in leaf, petiole and pod shell and yield of soybean plants. However, the application of 100 ppm ABA tended to inhibit pod respiration, glucose and fructose contents and grain yield of soybean plants (Takahashi *et al*., 1996). The effect of exogenous ABA on rate of sucrose uptake by soybean embryos was evaluated in an in vitro system. In addition, the concentrations of endogenous ABA in seeds of three soybean Plant Introduction (PI) lines, differing in seed size, were compared to their seed growth rates. ABA (10^{-7} molar) stimulated in vitro sucrose uptake in soybean cv. Clay embryos removed from the plants grown in a controlled environment chamber, but not in embryos removed from field grown plants of the three PI lines. However, the concentration of ABA in seeds of three field grown PI lines correlated well with their in situ seed growth rates and in vitro (14C) sucrose uptake rates.

Across genotypes, the concentration of ABA in seeds peaked at 8.5 micrograms per gram fresh weight, corresponding to the time of most rapid seed growth rate and declined to 1.2 micrograms per gram at physiological maturity. Seeds of the large-seeded genotype maintained an ABA concentration at least 50% greater than that of the small seeded genotype throughout the latter half of the seed filling. A higher concentration of ABA was found in seed-coats and cotyledons than in embryonic axes. Seed coats of the large seeded genotype always had a higher concentration of ABA than seed coats of small seeded line. It is suggested that this higher, concentration of ABA in seed coats of the large seeded genotypes stimulate sucrose unloading into the seed-coat apoplast and that ABA in cotyledons may enhance sucrose uptake by the cotyledons (Schussler *et al*., 1984).

Variation in light intercepted during and after seed initiation has been found a major environmental determinant of soybean seed size. Investigation on the influence of light enrichment and shading on seed growth rate, effective filling, cotyledon cell number, cell volume and endogenous ABA concentrations of cotyledons/testas during seed filling of soybean had been undertaken.

Even, an indeterminate Group O soybean, was subjected to light reduction and enrichment treatments from the beginning of pod formation until final harvest for two years in Massachusetts. Higher rates of seed growth, greater seed dry weight, and higher cotyledon cell number, along with a significant lowering of endogenous ABA levels in testa and cotyledon with shade. The level of ABA in cotyledon during seed development was significantly correlated with seed growth rates only under shade treatments (Liu *et al*., 2006).

Under shade stress, seedling height and first internode length increased, stem diameter decreased, abscisic acid (ABA) and zeatin (ZT) concentration decreased, while indole acetic acid (IAA) and gibberellins 3 (GA_3) concentration increased (Table 7). More also, branch numbers, pod number of branches and seed number of branches increased.

Branch yield did not reduce significantly under shade stress, which was related to the decrease of ABA and IAA. Based on the results soybean yield decreased under shade and drought stresses was mainly due to yield reduction of the main stem (Zhang *et al.,* 2011).

Table 7: Effects of Drought and Shade on Plant Hormone of Soybean

Treatment	ABA (ngg^{-1}FW)	GA^3 (ngg^{-1}FW)	ZT (ngg^{-1}FW)	IAA (ngg^{-1}FW)
2009				
HI WW	26.62	227.29	52.66	47.36
MD	358.55	205.64	38.08	22.15
LI WW	14.55	411.81	49.01	117.07
MD	285.79	278.74	33.46	78.08
2010				
HI HW	24.50	128.29	37.45	79.60
LW	207.41	104.01	30.86	61.86
LI HW	15.57	300.26	32.87	136.06
LW	125.12	274.58	24.61	76.55

HI – Normal irradiance ; LI – Low irradiance ; WW – Well water ; MD – Moderate drought ; LW – Low water, HW – high water.

Drought and shade stress have effects on auxin, cytokinins and abscisic acid concentrations (Davies, 2010). Water stress at the seeding and at the flowering stage decreases soybean yield by 20 and 46% respectively (Shou *et al.,* 1991) due to decreased photosynthetic rate, stomatal conductance and transpiration rate of soybean (Ohashi *et al*., 2006; Vu *et al*., 2001). Moreover, shade treatments have been shown to reduce yield and seeds per plant.

The effects of PGRs including benzyladenine (BA), uniconazole (S_{180}), brassinolide (Br) and abscisicacid (ABA) on leaf water potential (Ψ), Chlorophyll (Chl), photosynthetic rate (Pn), PSII photochemical efficiency (Fv/FM) and seed yield of soybean cv. Keng 5 were studied under water deficit. PGRs were applied at R_1 of 50, 100, 0.1 and 50 mgl^{-1} for BA, S_{180}, Br and ABA respectively. Two levels of soil moisture stress were applied at R_1. The result indicated that water deficit decreased biomass of stems and leaves, and induced yield loss significantly.

PGRs treatments increased soybean yields both under well watered and water deficit conditions except BA under water deficit. It was noted that PGRs treatments minimized the yield loss caused by water deficit (Zhang *et al.,* 2004) (Table 8).

Cycocel

Cycocel (2-Chloroethyl, trimethyl ammonium chloride) a plant growth retardant has been used to check the abscission of flower and modify the crop canopy for improving the yield in gram (Bangal *et al.*, 1982), pigeopea (Vikhi *et al.*, 1983) and soybean (Singh *et al.*, 1987). Grewal *et al.*, (1993) reported that cycocel improves the translocation of photosynthates. More protein content stored in the seeds might be due to improvement of translocation of photosynthates to the seeds.

In a three-year study conducted during 2006-2008, when cycocel at the rate of 500ppm applied as foliar spray at flower initiation, pod initiation and flower initiation + pod initiation of growth, there was an increase in chlorophyll content and carotenoids in leaves as well as increase in seed yield (Devi *et al.*, 2011) (Table 9).

Kumar *et al*., (2002) also noted a higher seed yield of soybean with the application of 250 ppm of CCC which was associated with higher number of pods and seeds per plant (Table 10).

Ethrel

Ethylene released from ethrel (2-chloroethyl phosphonic acid) could possibly be utilized for promoting growth as Abbas (1991) has shown that early pod development is related to higher ethylene levels, thus, decreasing flower and pod shedding and thereby reducing abscission and improving better pod set. Ethrel induced increase in cell division resulting in increase fruit and yield have been reported in tomato fruits (Atta-Aly *et al.,* 1999). Study revealed that application of Ethrel 200 ppm at flower initiation + pod initiation gave higher, vegetative growth and yield in soybean (Devi *et al.*, 2011) (Table11).

Salicylic Acid

Salicylic acid ($C_7H_6O_3$) is an endogenous growth regulator of phenolic nature, which participates in the regulation of physiological processes in plant, such as stomatal closures, ion uptake, inhibition of ethylene biosynthesis, transpiration and stress tolerance (Khan *et al.,* 2003; Shakirova *et al.,* 2003). Foliar application of salicylic acid exerted a significant effect on plant growth metabolism when applied at physiological concentration and thus, acted as one of the plant growth regulating substance (Kalarani *et al.,* 2002). Salicylic acid increased the number of flowers, pods per plant and seed yield of soybean (Gutierrez-Coronado *et al.,* 1998). In a soybean cv. JS 335 when salicylic acid was applied at 50 ppm as foliar spray at flower initiation, pod initiation and flower initiation + pod initiation increased seed yield (Devi *et al.,* 2011) (Table 12).

Khatun *et al.,* (2016) in an experiment with BARI soybean, when salicylic acid was sprayed on leaves and plants at the vegetative stage, flower initiation stage, pod initiation stage, flower + pod initiation stages in pot experiment under field condition gave the highest number of seeds pod^{-1}, harvest index, small size seed, protein and moisture content in seed (1.60, 39.06%, 19.47%, 44.45% and 12.91% respectively). Salicylic acid application at flower and pod initiation stages showed the highest yield attributes and maximum protein content.

Conclusion

Plant growth regulators when applied exogenously no doubt modify the growth and yield of soybean plant. But the concentration and the time of application should be taken care of to utilize properly the promoters. In soybean flower abscission and pod set is a major problem and attempts have mostly been taken to achieve maximum manipulation in the account. The important facet is seed growth. Improvement of source-sink balance by the application of plant growth regulators is thus one important aspect of consideration. Genetic improvement of synthesis and transport of endogenous plant growth regulators in the plant system via. conventional breeding and molecular approaches may strengthen pod-set capacity, source – sink balance of agriculturally significant genotypes. Clarification of the physical and chemical properties of the rhizosphere optimizing synthesis of endogenous cytokinins in roots should improve pod set. Recent molecular and genomic analyses have facilitated the discovery of genes involved in regulating abiotic stresses, enabling genetic engineering using functional or regulatory genes to activate pathways involved in stress tolerance. Similar attempts to incorporate these genes into soybean are being undertaken. Such recent advances have been magnificent, and we must put efforts to be able to design ideal crop soon.

Table 8: Effects of Water Deficit and Plant Growth Regulators on Biomass and Seed Yield of Soybean

Treatment	Stems + Leaves Biomass (g plant^{-1})		Seed Yield (g plant^{-1})	
	Well Watered (–0.02 MPa)	Water Deficit (–0.06 MPa)	Well Watered (–0.02 MPa)	Water Deficit (–0.06 MPa)
CK	8.94	6.17	3.14	2.27
BA	9.34	6.54	3.35	2.48
S_{180}	9.32	7.01	3.71	2.79
Br	10.20	7.18	3.51	2.83
ABA	11.80	6.61	3.96	2.78
Mean	9.91	6.70	3.53	2.63

CK = Check

Table 9: Effect of Cycocel on Yield of Soybean (Average of Three Years)

Treatment	Seed Yield (tha^{-1})		
	Flower Initiation	Pod Initiation	Flower Initiation + Pod Initiation
Control	1.08	1.05	1.09
Cycocel 500 ppm	1.22	1.19	1.27

Table 10: Effect of Cycocel on Yield of Soybean

Treatment	Plant Height (cm)		Biomass (g plant^{-1})		No. of Pods (plant^{-1})		No. of Seeds (plant^{-1})		Seed Yield (g plant^{-1})	
	MACS124	JS335	MACS124	JS335	MACS124	JS335	MACS125	JS335	MACS124	JS335
Control	30.86	64.44	16.67	17.20	33.80	49.00	68.03	61.46	10.21	9.12
CCC 250 ppm	26.25	61.17	19.99	20.93	37.13	55.60	76.43	72.45	12.06	11.22

Table 11: Effect of Ethrel on Yield of Soybean

Treatment	Seed Yield (tha^{-1})		
	Flower Initiation	Pod Initiation	Flower Initiation + Pod Initiation
Control	1.08	1.05	1.09
Ethrel 200 ppm	1.69	1.68	1.88

Table 12: Effect of Salicylic Acid on Yield of Soybean

Treatment	Seed Yield (tha^{-1})		
	Flower Initiation	Pod Initiation	Flower Initiation + Pod Initiation
Control	1.08	1.05	1.09
Salicylicacid50 ppm	1.45	1.41	1.68

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