GROWTH, YIELD AND QUALITY OF SOYBEAN AS INFLUENCED BY PLANT GROWTH REGULATORS AND THEIR STAGES OF APPLICATION

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DECEMBER, 2014

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BY

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REG. NO. : 08-02987

A Thesis
Submitted to the Faculty of Agriculture
Sher-e-Bangla Agricultural University, Dhaka
in partial fulfilment of the requirements
for the degree
of

MASTER OF SCIENCE (MS)
IN
AGRONOMY

SEMESTER: JULY-DECEMBER, 2014

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CERTIFICATE

This is to certify that the thesis entitled **'GROWTH, YIELD AND QUALITY OF SOYBEAN AS INFLUENCED BY PLANT GROWTH REGULATORS AND THEIR STAGES OF APPLICATION'** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **Master of Science** in **Agronomy**, embodies the result of a piece of bona fide research work carried out by **Sonia Khatun**, Registration number: **08-02987,** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that any help or source of information, received during the course of this investigation has duly been acknowledged.

Dated:
Dhaka, Bangladesh

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DEDICATED TO

MY

BELOVED PARENTS

ACKNOWLEDGEMENTS

All praises are due to the Almighty Allah, the great, the gracious, merciful and supreme ruler of the universe to complete the research work and thesis successfully for the degree of Master of Science (MS) in Agronomy.

The author expresses the deepest sense of gratitude, sincere appreciation and heartfelt indebtedness to her reverend research supervisor ***DrTuhinSuvra Roy****, Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his scholastic guidance, innovative suggestion, constant supervision and inspiration, valuable advice and helpful criticism in carrying out the research work and preparation of this manuscript.*

The author deems it a proud privilege to acknowledge her gratefulness, boundless gratitude and best regards to her respected co-supervisor **Dr.Md.JafarUllah** *Professor, Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka for his valuable advice, constructive criticism and factual comments in upgrading the research work and this documents.*

The author would like to express her deepest respect and boundless gratitude to all the respected teachers of the Department of Agronomy, Sher-e-Bangla Agricultural University, Dhaka, for their valuable teaching, sympathetic co-operation, and inspirations throughout the course of this study and research work.
The author wishes to extend her special thanks toMahfujakhanam, Rajesh chakraborty and Md. NazmulHaque for their help during experimentation. Special thanks to all of her friends for their support and encouragement to complete this study.

The author is deeply indebted to her father and grateful to her respected mother, brother, sister and other relative's for their moral support, encouragement and love with cordial understanding.

Finally, the author appreciate the assistance rendered by the staff members, of the Department of Agronomy and Agronomy Field Laboratory, Sher-e-Bangla Agricultural University, Dhaka, who have helped her during the period of study.

The Author

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ABSTRACT

A pot experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during November, 2013 to March, 2014 with a view to find out the influence of different plantgrowth regulators and their stages of application on the growth, yield and quality of soybean cv. BARI Soybean-6. The experiment was consisted of four plantgrowth regulators *viz.,* Control (water) (H_0), Salicylic acid 50 ppm (H_1),Gibberellic acid(GA_3) 100 ppm (H_2),Kinetin500 ppm (H_3) and four stages of application *i.e*., Vegetative stage (S_1) at 25 Days after sowing (DAS), flower initiation stage (S_2) at 40 DAS, pod initiation stage (S_3)at 50 DAS and flower + pod initiation stage (S_4) at 40 and 50 DAS.The two factor experiment was set up in a Randomized Complete Block Design (RCBD) with five replications. The different plant growth regulators and / or stages of application showed significant effect on plant height, chlorophyll content (SPAD value), average length of internode,100-seed weight, seed yield,harvest index, protein content and moisture percentage in seed of soybean. Results revealed that salicylic acid gave the highest seed yield (4.12 g plant^{-1}), which was statistically similar to GA_3 (3.52 g plant^{-1}) and kinetin (4.09g plant^{-1}). Application of plant growth regulators atflower + pod initiation stage was found to be the most effective that produced the highest seed yield (4.54 g plant^{-1}), which was statistically similar to vegetative (3.54g plant^{-1}) and flower initiation stage (3.15 g plant^{-1}). Among the treatment combinations the application of salicylic acid at flower and pod initiation stage showed the highest seed yield and maximum proteincontent compared to those of other growth regulators. So salicylic acid acts an important role for increasing soybean yield as well as protein content, when it was applied at flower and pod initiation stage.

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LIST OF ACRONYMS AND ABBREVIATIONS

AEZ	Agro-Ecological Zone
Adv.	Advanced
Agric.	Agriculture
Agril.	Agricultural
Agron.	Agronomy
Anon.	Anonymous
Appl.	Applied
BARI	Bangladesh Agricultural Research Institute
Biom.	Biomedical
Bio.	Biological
Biotec.	Biotecnology
cm	Centi-meter
CV	Coefficient of Variance
cv.	Cultivar
DAS	Days after sowing
df	Degrees of freedom
LSD	Least Significance Difference
Environ.	Environmental
et al.	And others
FAO	Food and Agriculture Organization
G	Gram (s)
Gr.	Growth
HI	Harvest index

i.e.*id* est (L), that is

lISTOF ACRONYMS AND ABBREVIATIONS (cont'd)

J.	Journal
Physiol.	Physiology
t ha^{-1}	Ton per hectare
NaOH	Sodium hydroxide
Ornam.	Ornamental
Physiol.	Physiology
pod^{-1}	Per pod
Res.	Research
Reg.	Regulation
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
SRDI	Soil Resource Development Institute
Intl..	International
Uni.	University
viz	Namely
%	Percentage
^{0}C	Degree centigrade

Chapter 1

Introduction

CHAPTER I

INTRODUCTION

Soybean (*Glycine max* L.)belongs to the family leguminosae, sub-family Faboideae is one of the leading oil and protein containing crops of the world. The crop is about 90.19 million hectare of land and annual production is approximately 220.5 metric ton in the world (FAO, 2009).Nowadays soybean production area is increasing day by day and in the year 2013 it reaches above 61000 ha (Chowdhury*et al.,* 2014).It is the most important grain legume of the world and a new prospective crop for Bangladesh (Rahman*et al.,* 2011).It is classified more as an oil seed crop than as a pulse (Devi *et al.,* 2012). The protein and oil content together account for about 60% of dry soybean by weight: protein at 40% and oil at 20% (Sodangi*et al.,* 2006). Soybean has 3% lesithine which is helpful for brain development. Malik *et al.* (2006) and Dugje*et al.* (2009) depicted that soybean oil is consisted of 85% cholesterol free unsaturated fatty acids. Soybean protein contains essential amino acid in desired quantity. Hence, it is regarded as a well-balanced protein food. Due to its high nutritional value there is an increasing demand of soy food e.g. soymilk, soybean sprouts, soy nuts, several types of tofu, cottage cheese and curd (Rao*et al.,* 2002). It is a good source of isoflavonoids and therefore it helps in preventing heart diseases, cancer and HIVs (Kumar, 2007). Among seed oils, soybeans has had an extra-ordinary growth due to rising consumption of livestock products and concurrent rapid growth in meal demand; as well as the fact that it is a cheap source of proteins especially in developing nations. Soybean, like other legumes, has the ability to fix atmospheric N though root nodule bacteria (*Bradyrhizobiumjaponicum*) and thus enrich the soil fertility (Kureh*et al.,* 2005). This can compensate around 80-90% demand for nitrogen by the crops. Because of its high nutritional value and myriad form of uses, it is recognized as ‘Golden Bean’ and has become the miracle crop of the 21st century.

Soybean grows and develops in 30^0C and the proper temperature for emergence of seedling from seedbed is 25 to 33^0C (FAO, 2007). The climatic and the edaphic conditions of Bangladesh are favorable for soybean production. Soybean can be cultivated throughout the year in Bangladesh. Yield of soybean is very low in Bangladesh and such low yield however is not an indication of low yielding potentiality of this crop, but may be attributed to a number of reasons, *viz.*, unavailability of seeds of high yielding varieties with indicative quality, delayed sowing, fertilizer management especially micronutrients, disease and insect infestation, modern cultivation and improper or limited irrigation facilities, flower and pod dropping at initial stage.

In farmer's field average yield of soybean is much lower due to lack of improved agricultural practices of which different plant growth regulators application and stages of application and plant growth regulators is an important determinant for better performance of soybean. Plant growth regulators (PGR's) are organic compounds, which in small amounts, somehow modify a given physiological plant process. 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 ultimate enhance productivity of the crops. Growth regulators can improve the physiological efficiency including photosynthetic ability and can enhance the effective partitioning of accumulates from source and sink in the field crops (Solamani*et al.*, 2001). Reports so far been made to indicate a promising results on yield of soybean and other oil crops due to the use of bio-chemical substances or hormone such as Salicylic acid, Gibberelic acid (GA_3), Kinetin etc.

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 closure, ion uptake, inhibition of ethylene biosynthesis, transpiration and stress tolerance (Khan *et al*., 2003 and Shakirova*et al*., 2003). Salicylic acid, a naturally occurring plant hormone acting as an important signaling molecule adds to tolerance against abiotic stresses. It plays a vital role in plant growth, ion uptake and transport. 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 substances (Kalarani*et al*., 2002). Salicylic acid is also involved in signaling to trigger plant defense against pathogens (Khan *et al*., 2003). Salicylic acid can also play a significant role in plant water relations (Barkosky and Einhelling, 1993), photosynthesis, growth and stomatal regulation under abiotic stress conditions (Khan *et al*., 2003; Arfan*et al*., 2007).

Gibberelic acid (GA_3)plays an essential role in many aspects of plant growth and development, stem elongation and flower development (Yamaguchi and Kamiya, 2000). The cytokinin and their exogenous analogues play a crucial role in decreasing flower abortion, increasing pod setting and the individual weight of the seeds, resulting in a greater. The highest kinetin concentrations resulted in the highest yields. The growth regulator salicylic acid enhances the plant growth, flower induction, nutrient uptake and photosynthesis (Hayat and Ahmed, 2007). Therefore, flower and pod dropping of soybean can be minimized by using GA_3, kinetin, and salicylic acid.

Kinetin is known to stimulate or inhibit a great number of physiological processes. For soybean, however, great variability can be observed in reported results. Kinetin can be utilized in a variety of applications, from the treatment of seeds (Riedell*et al*., 1985) to applications during flowering (Dyer *et al*., 1986) and the same is true about GA_3 (Khafagi*et al*., 1986; Urwiler*et al*., 1988; Maske*et al*., 1997). The potential yield of the soybean crop is mainly influenced by the production, fixing and transformation of the reproductive structures into pods with the grains, thus the spatial dynamics of these structures need to be studied and correlated with yield (Pires*et al.,* 2000). Application of vegetal bio-regulators is becoming a useful practice that has improved the yield of soybean (Vieira and Castro, 2004). Dissimilar results primarily occur because of differences between concentrations utilized and differences in the physiological stages at which these products are applied. Under the above perspective and above all situation the present experiment was conducted on BARI Soybean-6 with the following objectives:

a. To study the effect of plant growth regulators on growth, yield and quality of soybean
b. To determine optimum concentration and stages of application of plant growth regulators formaximizing yield and quality of soybean.

Chapter 2
Review of literature

CHAPTER II

REVIEW OF LITERATURE

Soybeanis one of the leading oil and protein containing crops of the world and as well as Bangladesh. Plant growth regulators and their stages of application play an important role in improving soybean growth and yield. But research works related to plant growth regulators and their stages of application are limited in Bangladesh context. However, some of the important and informative works and research findings related to the growth regulators and their stages of application so far been done at home and abroad have been reviewed in this chapter under the following headings-

2.1.Plant growth regulators on growth, yield and quality of soybean

2.1.1. Plant height

Li *et al*. (2014)conducted an experiment to explore effects of different concentrations of GA_3, ABA, and 6-BA on soybean root growth, which could provide a theoretical basis for a further control of soybean root architecture through phytohormone. The seedlings of soybean cultivar "HN89" were treated with 0.05, 0.50, 1.00, and 5.00 micro mol. L^{-1} gibberellin (GA_3), abscisic acid (ABA) and cytokinin (6-BA) respectively for 4 days, and then root morphological parameters were quantified and analyzed. The results showed that 0.05 micro mol. L^{-1} GA_3 promoted the total root length of soybeans, but increasing GA_3 concentration would constrain primary root and lateral root growth, which decreased the total root length. GA_3 decreased average root diameters, hence resulting in fine roots. 0.05 micro mol. L^{-1} ABA did not affect the soybean root growth, while increasing ABA concentration higher than 0.5 micro mol. L^{-1} inhibited primary root and lateral root growth, decreasing the total root length, and slightly increasing average root diameters. 6-BA significantly constrained the soybean root growth and development, for instance, it inhibited primary root elongation, lateral rooting, and the total root length, but it promoted average root diameter, resulting in thick roots.

Fiorezee*et al*. (2013) carried out an experiment to evaluate the effects of kinetin and calcium applications on the physiologic and productive traits of soybean plants, subjected to drought and shade conditions, at flowering. Soybean plants cultivated in pots were sprayed with calcium and kinetin, alone or mixed, and subjected to drought and shade during 12 days. After stress period, plants were cultivated under appropriate water and light availability. Calcium and kinetin application resulted in maintenance of the relative water content after four days of drought beginning. Membrane damage, measured at the end of stress period, was lower in plants sprayed with calcium and kinetin. CO_2 assimilation diminished by stress condition, mainly under drought, and grain yield decreased at the same intensity in both environments.

Wan *et al*. (2013) conducted an experiment to understand, the response of soybean to uniconazole at V_4 stages (The third trifoliolate leaf fully developed), morphological characters such as the height, the diameter of stem, the leaf morphological and the content of chlorophyll of soybean [*Glycine max* (L.) Merr.] cv. Gongxuan 1. The results showed that plant height and stem slenderness ratio (H:D) decreased and stem diameter increased after seed treatment with uniconazole powder (0, 3, 6, 9, 12 and 15 $mgkg^{-1}$ seed). Uniconazole also significantly increased the petiole length, leaf length and leaf width. In addition, it enhanced the content of chlorophyll and the ratio of chl-a andchl-b. Thus, results suggested that uniconazole treatment could improve plant growth which would be conducive to greater use of light source areas and favourable to gain light sources efficiently.

A study was conducted by Qi *et al*. (2013)to investigate the effect of exogenous DTA_6 is an artificial tertiary amine with low molecular weight and high bioactive regulators on the plant growth, gas exchange, PSII photochemistry, and phytohormone in soybean seedlings. To achieve this objective, a pot experiment was carried out in growth chamber to determine the response of corn and soybean plants to foliar treated with different concentrations of DTA_6. DTA_6 treatments increased the plant height, root length and leaf areas, promoted dry matter accumulation, and improved root to shoot ratio in corn and soybean seedlings. Also, DTA_6 treatments markedly enhanced IAA, zeatinribosideand GA_3 content, but decreased ABA content. Optimal concentration of DTA_6 sprayed on corn and soybean seedlings at V_3 stage were 20 mg L^{-1} and 10 mg L^{-1}, respectively.

Abbas (2011) conducted an experiment to study the effect of foliar sprays of different concentrations of Gibberellic acid on growth and some physiological characterizes in soybean. The results revealed that the more plant height affected significantly by the 50 ppm concentration of GA_3 which was in comporison to the other concentrations.The increase in plant height may be due to the effect of GA_3 on the cell division and cell enlargement, and also GA_3 stimulated the growth and expansion of cells through increasing the wall plasticity of cells.

Eraslan*et al.* (2007) reported that application of an aqueous solution of SA on shoots of soybean significantly increased growth of the plant. Kinetin and SA may regulate plant growth and development by enhancing GA_3 metabolism of the plants (Mukharjee and Kumar, 2007). The maximum of plant height of treatments 50 ppm $GA_3$was obtained exogenous application of salicylic acid, enhanced growth, physiological process and antioxidant activity of carrot plants grown under salinity stress. They observed a significant increase in growth characteristic, pigment contents and photosynthetic rate and plant height in maize, sprayed with salicylic acid. Several studies have demonstrated that exogenous SA application enhances plant growth and development

Hayat and Ahmed (2007) found that salicylic acid is a plant growth regulator that increases plant bioproductivity. With regard to the stimulatory effect of SA and VE on different estimated characteristics of soybean it could be attributed to the effect of this components upon the endogenous phytoplant growth regulators specially the growth promoters *i.e.*Auxins, gibberellins and cytokinins (Waffaa*et al*., 1996). Also, to remark that most of the applied treatments increased each of branches and leaves number that could be reversed upon the number of formed flowers and settled fruits. In agreement with that results Gharib(2007) on basil and marjoram and Fathy*et al.*(2003) on soybean they mentioned that salicylic acid and vitamin E increased plant height, number of branches and leaves per plant and dry weight as well they found that application of SA increased chlorophyll a and b as well as carotenoids in Syngonium pod phyllum plants. Also, Fathy*et al.*(2000) found that foliar application with VE and other antioxidant increased photosynthetic pigmentation intomato plants.

Leite*et al.* (2003)carried out a pot experiment to study effects of GA_3 and cytokinin on the vegetative growth of the soybean. GA_3 (50 mg L^{-1}) was applied as seed treatment, leaving plants with water application as control. GA_3 (100 mg L^{-1}) and cytokinin (30 mg L^{-1}) were sprayed on leaves at the physiological stage V_3/V_4, and 15 days after, cytokinin (30 mg L^{-1}), also as foliar spray. Seed treatment decreased plant emergence and initial soybean root growth, but as the season progressed, differences in root growth disappeared; plants were shorter, and presented a decrease in the number of nodes, in stem diameter, in leaf area and in dry matter yield. Conversely, 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. There was no effect of exogenous gibberellin and cytokinin on the number of soybean leaves, number of stem branches and root dry matter. Joint application of gibberellin and cytokinin tended to inhibit gibberellin effects. Cytokinin applied to leaves during soybean vegetative growth was not effective in modifying any of the evaluated plant growth variables.

Khalil *et al.* (1989) found that kinetin treatments decreased plant height. These results are in agreement with those obtained by on cowpea. Menawhile, the present study showed significant increase in the number of branches and leaves due to the different treatments.

2.1.2.Chlorophyll content

Rahbarian*et al*.(2014) found that the highest value of chlorophyll of a, b was total and sum of pigments in level of 400 mg L^{-1} BA+100 mg L^{-1} GA_3 with average of 18/48, 10/74, 28/73 and 33/87 g L^{-1}. By increasing concentration of GA_3, value of chlorophyll a is increased]. Application of 100 mg L^{-1} GA_3 +200 mg L^{-1} BA, 200mg L^{-1} GA_3 and 100 mg L^{-1} GA_3 +100 mg L^{-1} BA with averages of 19.59, 18.8 and 18.66 g L^{-1} followed highest value of sum of pigments and its minimum was obtained in100 mg $L^{-1}$$GA_3$ and control application with average of 11.1 and 11.82 g L^{-1} (Salehi*et al.,* 2014a). Effect of different concentrations of GA_3 on chlorophyll a was significant ($p<0.01$). Chlorophyll a content was enhanced by increase in GA_3 concentration up to 250 mg L^{-1} (Salehi*et al.*, 2014b; Rahbarian*et al.,* 2014).Use of plant growth regulators, the growth rate of indoors plants can be stimulated through increasing synthesis of photosynthetic pigments by applications of GA_3 and BA.

Yaghoubi*et al*. (2013) observed that by increasing concentration of GA_3 and BA, value of chlorophyll a is increased. Results related to attribution, showed chlorophyll of leaf that application of GA_3 has a meaningful difference with control application that these results adapted with results of Mynett*et al.* (2001) in Freesia and in Bellisperennis about effect of GA_3 on increase of greenness index. GA_3 has structural role in membrane of chloroplast and causes to stimulate photosynthesis (Janowsk and Jerzy, 2003).

Abdel-Wahid (2008) found that application of SA increased chlorophyll a and b as well as carotenoids in Syngoniumpodphyllum plants. Moreover, salicylic acid significantly increased chlorophyll a and b and carotenoids (Shakirova*et al.,* 2003; El-Mergawi*et al*, 2007; Zaki and Radwan, 2011).

Arteca(1996) observed that chlorophyll has primary basic role from view of absorption and use of light energy in photosynthesis. So, effects of regulators of plant growth are effective on biosynthesis and decomposition of chlorophyll on photosynthesis, directly.

2.1.3. Number of branches plant^{-1}

Zhang (2011) conducted an experiment in a greenhouse.The leaf's hormone concentrations, main-stem and branch yield response to the combination of shade and drought. Pot experiments were conducted under shade of soybean and normal irradiance (HI). Shade stress was removed once soybean was harvested. Manipulative progressive soil drying period at branching stages under good soil conditions (HW) and water stress treatment (LW) were applied in 2010, while well-watered (WW) and moderate drought (MD) were applied in 2009. Under shade stress, seedling height and first interned 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. 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 the yield reduction of the main-stem.

Naeem*et al.* (2004) concluded that in control plants the number of branches recorded were 2 after 30 days. However, GA_3 revealed no branching after 30 days i.e., a single main branch was only present. In 500 mg L^{-1} IAA the number of branches increased up to 4 after 30 days. Kinetin showed no increase or decrease in the number of branches as compared to control. In mixed dose of GA_3 + IAA GA_3 + kinetin branching was delayed and only one branch was observed. On the other hand IAA + kinetin had more number of branches *i.e.*, 4 after 30 days as compared to control. The combined effect of GA_3 + IAA + kinetin showed insignificant increase as compared to control.

Malik *et al*. (1992) observed multiple shoot formation by applying cytokinin in *Pisumsativum*. Application of GA_3 showed a single main branch after 30 days.

More number of branches were observed in IAA treatment as compared to control. Applied kinetin induced more branching in lentil .The mixed dose of GA_3 + IAA and GA_3 + kinetin showed decrease in the number of branches. However, IAA + kinetin exhibited more number of branches. When all the three plant growth regulators were applied, a significant decrease was observed in the number of branches as compared to control.

2.1.4. Average length of internode

Naeem*et al.* (2004) concluded that the numbers of internodes observed in control plants were 13.6 after 30 days and 17.4 after 60 days. The GA_3 treated plants showed an increase in the number of internodes *i.e.* 21.6 after 30 days and 25.4 after 60 days. This may have been due to the increase in length. The extraneous IAA as well as kinetin showed no significant increase or decrease in the number of internodes thus showing no effect of the above mentioned plant growth regulators. In the mixed doses of GA_3 + IAA, an increase in the number of internodes was observed *i.e.,* 18.2 and 22.0 after 30 and 60 days respectively. Similarly GA_3 + kinetin also showed increase in the number of internodes which being 16.4 and 18.8 after 30 and 60 days, respectively as compared to control. The IAA + kinetin showed an inhibition in the number of internodes i.e., 11.0 and 15.2 after 30 and 60 days, respectively when GA_3 + IAA + kinetin were applied. There was an increase in the number of internodes which being 17.4 after 30 days and 20.4 after 60 days as compared to control.

2.1.5. Number of pods plant^{-}

An experiment was carried out in the field laboratory of the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, by Islam*et al*. (2010)to investigate the flowering pattern, floral and pod abscission under untreated and GABA (mixture of GA_3 and Abscissic acid) treated soybean and their trends concern to yield. The variety of soybean PB-1 (Shohag) was used in the investigation. GABA at 0.5, 1.0 and 2.0 mg L^{-1} of water with a control (only water) were used for foliar spray. Flower and pod initiation started from 54 and 60 DAS in all plants irrespective to GABA treatment. Flower production trend showed a deltoid pattern where pod production was gradually increased and slowed down at 74 DAS but not in GABA treated plant. The 4th node produced the highest number of flowers, then decreased and got zigzag pattern in upper nodes. GABA treated plants produced more nodes plant^{-1} and followed lower trend in flower and pod abscission indicated the efficacy of higher yield.

Martin-Max *et al*. (2005) observed that flowering is another important parameter that is directly related to yield and productivity of plants. Salicylic acid has been reported to induce flowering in a number of plants. Different plant species including ornamental plant Sinningiaspeciosa flowered much earlier as compared to the untreated control, when they received an exogenous foliar spray of salicylic acid on cucumber and tomato, the fruit yield enhanced significantly when the plants were sprayed with lower concentrations of salicylic acid.It was reported that the foliar application of salicylic acid to soybean also enhanced the flowering and pod formation. In recent years, some studies have indicated that salicylic acid can enhance the plant growth, yield and quality (Khodary, 2004).

Awan*et al*. (1999) observed that applied exogenous GA_3 showed early flowering. Early flowering was accompanied by more number of flower buds. GA_3 had stimulatory effect on floral stem length and number of flowers in rice Application of IAA showed no delay in flowering. In applied kinetin, there was no delay in flowering time as well as no significant increase in flower buds was observed. In the mixed dose of GA_3 + IAA and GA_3 + kinetin early flowering was initiated, however, decrease in the number of flower buds was observed. IAA + kinetin showed insignificant delay in flowering. Early flowering with decrease in number of flower buds was observed in the combined dose of GA_3 + IAA + kinetin.

Zhlobak (1986) reported that Kinetin treatment increased the number and weight of pod and seeds 40 mg L^{-1} kinetin showed the highest significant response. Such findings may be attributed to the increase of the number of flowers accompanied with decrease of the percentage of flower abscission. Increase of yield of some legumes by cytokinins (Kinetin or BA) on soybean,. The significant increase of seed weight may be attributed to the influence of kinetin on source sink relation in reproductive development by manipulating photoassimilates production and partitationing. Kinetin treatments showed increase in flower potential. Increase of the number of flowers by cytokinins was recorded in other plants such as beans and soybean.

2.1.6. Yield

The experiment was undertaken by Azizi*et al.* (2012) to study the effect of different levels of gibberellic acid (GA_3) as a hormone on the yield components of soybean genotypes at the experimental farm of Lorestan Meteorological Office in Khorramabad. 4 levels of GA_3 concentration (0, 125, 250, and 375 ppm) were sprayed over the plants and 2 levels of soybean genotypes (M11 and L17) were used for the experiment. The results showed that interactions between different levels of GA_3 and the soybean genotypes had significant effect on pod number plant^{-1}, seed number pod^{-1}, 1000-seed weight, and economic and biological yield. The results showed that the highest seed yield (4240 kg ha^{-1}) was achieved with 125 PPM of GA_3 and the M11 genotype while the lowest seed yield (1620 kg ha^{-1}) was produced from 375 PPM of GA_3 and the L17 genotype. The main impact of different levels of GA_3 was a decreasing effect on the parameters of pod number plant^{-1}, 1000-seed weight, biological yield, and seed yield. There was a significant positive correlation (0.903) between biological yield and seed yield that indicated the highest correlation among all the measured parameters.

Martins *et al.* (2011) conducted an experiment to evaluate the effect of kinetin and potassium nitrate applied to leaves, at the R_3phenological phase, on some agronomic characteristics of soybean plants and their yield plant^{-1} in the field. The experiment was carried out in Itutinga, MG, using five kinetin concentrations (0, 250, 500, 750 and 1.000 mg kinetin ha^{-1}) combined with four potassium nitrate concentrations (0, 5, 10 and 15 kg ha^{-1}) in a factorial scheme using a randomized block experimental design, with three replications. The positioning of numbers of pods $plant^{-1}$ was evaluated in three positions in the canopy: lower, middle and upper. The application of potassium nitrate did not influence the studied characteristics. Kinetin increased the total set pod number by 27.4% in contrast to the control, mainly in the lower and middle thirds of the canopy. The kinetin increased the pod set number up to 20.7%, in the middle third. The yield $plant^{-1}$ was increased up to 27.1% using the highest kinetin concentration. The increases were attributed to an increase in the endogenous cytokinin levels that contribute to the higher production and better redistribution of assimilates to the pods and seeds.

Copur*et al.* (2010) assessed significantly maximum number of pods $plant^{-1}$ and test weight,biological yield and harvest index were recorded in all the concentrations of NAA followed by GA_3 and Kinetin.

Khalil*etal.*(2006) explained that all used concentrations of kinetin led to significant increase in all tested parameters of lentil yield (number and dry weight of pods, number Protein and dry weight of seeds $plant^{-1}$ and seed index). Maximum increase was recorded by the highest concentration of kinetin (40 mg L^{-1}) which amounted to 138.70% of control with respect

A two-year study was conducted by Leyla*et al*. (2006) to determine the effects of some Plant Growth Regulators (PGRs) and nutrient complexes on biomass weight, seed yield and yield components of both main and double cropped soybean grown under hot and dry conditions. Atonik, Biomaster, GA_3, Kinetic, Maxicrop, Cytozyme and Megahix were used as plant growth regulators. The soybean cultivar was A3935 (MG III). Application of PGRs had different effects on biomass weight, seed yield and yield components of both main and double cropped soybean. The highest biomass weight was obtained from Maxicrop and the lowest was obtained from Megahix applied plots in main cropped soybean. Under double crop conditions, however, the highest biomass weight was obtained from Cytozyme and the lowest was obtained from control. Application of PGRs increased the seed yield and yield components of soybean under both main and double cropped conditions. The highest seed yield was obtained from Atonik with 3876 kg ha^{-1} for main crop soybean and 47 kg ha^{-1} for double cropped soybean. The lowest seed yields were obtained from no chemical applied control plots of both main and double cropped soybean with 3386 and 838 kg ha^{-1}, respectively. Application of Atonik, Cytozyme and Maxicrop could be suggested to alleviate heat stress and increase seed yield of both main and double cropped soybean grown under hot and dry conditions..

Hayat *et al*. (2005) who found that foliar application of salicylic acid to soybean enhanced the flowering, pod formation and consequently yield of soybean .Tomato seedlings treated with salicylic acid 10-6 M had significantly higher yield compared to untreated control. However, there was no significant difference among salicylic acid 10-2 M, 10-8 M and control. This increasing of yield closely linked to increase the number of bunch per bush. It was reported that salicylic acid application promotes cell division and cell enlargement.

2.1.7. Protein content

Khodary (2004) indicated that salicylic acid can enhance the protein percentage of soybean. Tagade*et al.* (1998) concluded an experiment with soybean.They observed that the significantly highest protein content was recorded in all the treatment of NAA followed by GA_3 and Kinetin.

2.2. Stages of application on yield attributing characters and yield of soybean

The study was undertaken by Sapkal*et al.* (2011) at experimental field of Seed Technology Research Unit, during kharif season. The experiment was laid out in a randomized block design with three replications of seven different treatments of plant growth regulators (PGRs) *viz.,* T_1 (TIBA 100 ppm), T_2 (NAA 50 ppm), T_3 (GA_3 50 ppm), T_4 (CCC 500 ppm), T_5 (CCC 1000 ppm), T_6 (water spray) and T_7 (Control). The three foliar applications were given at on interval of 15 days starting from 21 days after sowing. The result exhibited that, foliar application of GA_3 (50 ppm) recorded significantly more plant height (41.66 cm) at 50% flowering stage which was at par with T_2 NAA 50 ppm (40.83 cm).

A three-year study was conducted by Devi *et al*. (2011) in India (Manipur) to study the response of soybean variety JS 335 to salicylic acid @ 50 ppm, Ethrel @ 200 ppm, Cycocel @ 500 ppm and control (water spray) applied as foliar spray at different stages *viz*. flower-initiation (40 DAS), pod-initiation (60 DAS) and flower-initiation + pod-initiation. The study revealed that application of Ethrel @ 200 ppm at both flower-initiation (40 DAS) + pod-initiation (60 DAS) gave higher vegetative growth, yield, net returns and B:C ratio as compare to salicylic acid @ 50 ppm, Cycocel @ 500 ppm and control. However, maximum chlorophyll content and carotenoids were obtained from cycocel @ 500 ppm treated plants.

Kalyankar*et al*. (2008) carried out an experiment on the fields of department of agricultural university, Parbhanikharif. The certified seeds of three soybean verities viz., MAUS 61, MAUS 61-2 and MAUS 71 were obtained from soybean Research Station, Parbhani. The plants were treated with foliar application of various concentrations of GA_3, NAA at 30 days after sowing and CC after 40 days after sowing. Untreated plants were used as control. All the application time of GA_3, NAA and CCC increased the number of pods $plant^{-1}$, number of grains pod^{-1}, 100 seed weight, harvest index, grain yield and biological yield significantly than the control.

Paul and Mark (1987) conducted an experiment with field-grown soybean plants (*Glycine max* (L.) Merr. cv. Evans) were treated with gibberellic acid (GA_3; 10 g L^{-1}) and/or (2-chloroethyl)-trimethylammonium chloride (CCC; 0.8 g L^{-1}) and subsequent anthesis, pod set, seed size, seed number, and seed yield were determined at one node by The treatments were applied to five leaves in the center of each plant and reproductive development at the node in the center of those leaves was monitored. Gibberellin A_3 applied "Early" (about 3d before anthesis of the first flower at the monitored node) had no effect on the number of flowers produced, but decreased the fraction of flowers that set pods in both experimental years (by 32% in 1983 and 76% in 1984). Seed size was slightly decreased by the GA_3 treatment in 1983 but not in 1984. The "Middle" GA_3 treatment (applied about 3 days after the "Early" treatment) slightly decreased the number of pods set; and "Late" treatments (9 days after) had no effect. None of the monitored parameters were affected by CCC. The "Early" experiments were repeated with two additional genotypes, Lincoln and T210. Genotype T210 is a single-gene, dwarf mutant of Lincoln whose stem elongation and leaf expansion are insensitive to GA_3. Gibberellin A_3 affected the reproductive parameters in Lincoln very similarly to Evans but those in T210 were unaffected. This indicates that GA_3 exerts its effect by increasing the mass of vegetative tissue and thus diverting assimilates away from the pods. However, since the mutation in T210 might affect a receptor that is in flowers as well as shoots, it is possible that GA_3 exerted its effect on the normal genotypes directly on the developing pods, rather than indirectly by diverting photoassimilates.

From the above reviews it is clear that plant growth regulator is an important factor for the production of any crop. On the other hand, stages of application of plant growth regulators play an important role in growth and development of soybean.

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

This chapter presents a brief description about experimental period, site description, climatic condition, crop or planting materials, treatments, experimental design and layout, crop growing procedure, plant growth regulators application, intercultural operations, data collection and statistical analyses.

3.1. Experimental period

The experiment was conducted during the period from November 7, 2013 to March 23, 2014 in Rabi season.

3.2. Site description

3.2.1. Geographical location

Theexperimental area was situated at 23°77' N latitude and 90° 33' E longitude at an altitude of 8.6 meter above the sea level (Anon., 2004).

3.2.2. Agro-Ecological Zone

The experimental site belongs to the agro-ecological zone of "ModhupurTract", AEZ-28 (Anon., 1988a). This was a region of complex relief and soils developed over the Modhupur clay, where floodplain sediments buried the dissected edges of the Modhupur Tract leaving small hillocks of red soils as 'islands' surrounded by floodplain (Anon., 1988b). The experimental site was shown in the map of AEZ of Bangladesh in Appendix I.

3.2.3. Climate of the experimental site

Experimental site was located in the sub-tropical monsoon climatic zone, set aparted by winter during the months from November, 7 to March, 23 (Rabi season). Plenty of sunshine and moderately low temperature prevails during experimental period, which is suitable for soybean growing in Bangladesh. The weather data during the study period at the experimental site are shown in Appendix II.

3.3. Details of the Experiment

3.3.1. Experimental treatments

The experiment consisted of two factors such as different plant growth regulators and stages of application. The treatments were as follows:

Factor A: Different plant growth regulators (4 types)

i H_0: Control condition (application of water only)

ii. H_1: Salicylic acid @ 50 ppm

ii. H_2: GA_3 @ 100 ppm

iii. H_3: Kinetin @ 500 ppm

Factor B: Different stages of application (4 stages)

i. S_1: Vegetative stage [1 time at 25 Days after sowing(DAS)]

ii. S_2: Flower initiation stage (1 time at 40 DAS)

iii. S_3: Pod initiation stage (1 time at 50 DAS)

iv. S_4: Flower + pod initiation stage (2 times at 40 DAS and 50 DAS)

There were 16 (4 × 4) treatment combinations such as H_0S_1, H_0S_2, H_0S_3, H_0S_4, H_1S_1, H_1S_2, H_1S_3, H_1S_4, H_2S_1, H_2S_2, H_2S_3, H_2S_4, H_3S_1, H_3S_2, H_3S_3 and H_3S_4.

3.3.2. Design and layout of the experiment

The two factors experiment was laid out in Randomized Complete Block Design (RCBD) with five replications. Each replication contain by 16 pots where 16 treatment combinations were allotted at random. There were 80 unit pots altogether in the experiment.

3.4. Planting material

The variety BARI Soybean-6 was used as the test crops. The seeds were collected from the Agronomy Division of Bangladesh Agricultural Research Institute (BARI),Joydebpur, Gazipur. BARI collected different germplasms from different country and through selection process in 2009 released the variety BARI Soybean-6, which was recommended by the national seed board of Bangladesh. This variety is suitable both for Rabi and Kharif-2 cultivation and the life cycle of this variety ranges from 100-110 days. Maximum seed yield is 1.8-2.1 t ha^{-1}.

3.5. Crop management

3.5.1. Preparation of the pot

The experimental pots (L10.5and D 9.5 inch) were first filled at 01 November, 2013 with 10 kg soil. Potted soil was brought into desirable fine tilth by hand mixing. The stubble and weeds were removed from the soiland then cowdung was mixed. The final pot preparation was done on 07 November, 2013.The soil was treated with insecticides (cinocarb 3G @ 4 kg ha^{-1}) at the time of final pot preparation to protect young plants from the attack of soil inhibiting insects such as cutworm and mole cricket.

3.5.2. Fertilizer application

Urea, Triple super phosphate (TSP), Muriate of potash (MoP), gypsum, boric acid and molybdenum were used as a source of nitrogen, phosphorous, potassium, sulphur, boron and molybdenum, respectively. The fertilizers urea, TSP, MoP, gypsum, boric acid and molybdenum were applied at the rate of 42, 105, 72, 57.5, 0.025 and 0.013 g pot^{-1}, respectively following the Bangladesh Agricultural Research Institute (BARI) recommendation (BARI, 2011). All of the fertilizers were applied during the final pot preparation.

3.5.3. Sowing of seeds in the pot

The seeds of BARI Soybean-6 were sown in the pot on November 7, 2013 having a depth of 2-3 cm. During seed sowing 0.5 g Bavistin were mixed with seeds.

3.5.4. Preparation and application of plant growth regulators

Gibberellins and Kinetin solution made by dissolved in NaOH in 20 mg and then mixed with 500 ml water. Salicylic acid was dissolved in ethanol for preparation of solution. Plant growth regulators were foliar sprayed as per treatment. Salicylic acid @ 50 ppm, Gibberellic Acid (GA_3) @ 100 ppm, Kinetin (kinetin puriss CHR: 6-Furfurylaminopurine, $C_{10}H_5OH$) @ 500 ppm and water were applied as per treatments of the different stages of application by a mini hand sprayer.

3.5.5. Intercultural operations

After raising seedlings, various intercultural operations such as weeding, watering, pest and disease control etc. were accomplished for better growth and development of the soybean seedlings.

3.5.5.1. Weeding

The hand weeding was done as when necessary to keep the pots free from weeds.

3.5.5.2. Watering

Light watering was given by a watering cane in each pot with equal amount as necessary at afternoon.

3.5.5.3. Pest and disease control

The soybean plants were infested by hairy caterpillars (*Dlaerisia oblique*) and cutworm at early growth stage which was controlled by applying Sumithion 50 EC @1.01 ha^{-1}. On the other hand picking of infested leaves with caterpillar larvae was also done as a control measure. Diseased or off type plants were uprooted as and when required.

3.5.6. General observations of the experimental site

Regular observations were made to see the growth stages of the crop. In general, the pot looked nice with normal green plants which were vigorous and luxuriant.

3.5.7. Crop sampling and data collection

One plant from each treatment were randomly selected and marked with sample card. Plant height and number of branches plant^{-1} were recorded from selected plants at an interval of 15days started from 30 DAS to 90 DAS and at harvest.

3.5.8. Harvest and post-harvest operations

Maturity of crop was determined when 95 (%)of the pods become brown in color. Harvesting was done at 23 March, 2014. The matured pods were collected by hand picking from each pot.

3.5.9. Data collection

The following data were recorded -

A. Crop growth characters

i. Plant height at 30, 45, 60, 75, 90 DAS and at harvest
ii. Number of branches plant^{-1}45 DAS to harvest
iii. Chlorophyll content(SPAD value) 30 DAS to 75 DAS
iv. Average length of internode 30 DAS to 75 DAS

B .Yield contributing characters

v. Number of pods plant^{-1}
vi. Pod length (cm)
vii. Number of seeds pod^{-1}
viii. Weight of 100-seed (g)
ix. Seed yield (g plant^{-1})
x. Stover yield (g plant^{-1})
xi. Biological yield (g plant^{-1})
xii. Harvest index (%)

C. Quality contributing characters

xiii. Seed grading (% by weight)
xiv. Moisture percentage
xv. Protein percentage

3.5.10. Procedure of data collection

A brief outline of the data recording procedure followed during the study is given below:

A. Crop growth characters

i. Plant height

The height of the soybean plants was recorded at 30, 45, 60, 75, 90 DAS and at harvest. The heights of sample plants were measured from the ground level to the tip of the shoot.

ii. Number of branches plant^{-1}

The total number of branches plant^{-1} was counted from each selected plant.

iii. Chlorophyll content

Chlorophyll content of leaves was measured at an interval of 15 days starting from 30 DAS till harvest. Mature leaves were measured all time. Three mature plant of each pot were measured by using portable chlorophyll Meter (SPAD - 502, Minolta,japan) and calculated an average SPAD value for each pot each sampling time. The chlorophyll meter Soil plant Analysis Development (SPAD-502) is a simple and portable diagnostic tool that measures the greenness or the relative chlorophyll concentration of leaves (Kariya*et al.,* 1982; Torres-netto*et al.*, 2005). It provides instantaneous and non-destructive readings on plants based on the quantification of the intensity of absorbed light by the tissue sample using a red LED (wavelength peak is ~650nm) as a source.An infrared LED, with a central wavelength emission of approximately 940 nm, acts simultaneously with the red LED to compensate for the leaf thickness (Minolta camera Co. Ltd., 1989).

iv. Average length of internode

Average length of internode was calculated by using the following formula:

$$\text{Average length of internode} = \frac{\text{Plant height}}{\text{Number of nodes}}$$

B .Yield contributing characters

v. Number of pods plant^{-1}

Numbers of total pods of selected plants from each pot were counted and the mean numbers were expressed as plant^{-1} basis.

vi. Pod length

Pod length was taken of randomly selected ten pods and the mean length was expressed on pod^{-1} basis.

vii. Number of seeds pod^{-1}

The number of seeds pods^{-1} was recorded from randomly selected 10 pods at the time of harvest. Data were recorded as the average of 10 pods from each pot.

viii. Weight of 100- seeds

One hundred cleaned, dried seeds were counted from each harvest sample and weighed by using a digital electric balance and weight was expressed in gram (g).

ix. Seed yield (g plant^{-1})

The seeds collected from each plant were cleaned. The weight of seeds was taken and recorded in g plant^{-1}.

x. Stover yield (g plant^{-1})

The stover collected from each plant was sun dried properly. The weight of stover was taken and recorded in g plant^{-1}.

xi. Biological yield

Biological yield was calculated by using the following formula:

Biological yield= Grain yield + straw yield

xii. Harvest index (%)

Harvest index is the relationship between grain yield and biological yield (Gardner *et al.,* 1985). It was calculated by using the following formula:

$$\text{HI (\%)} = \frac{\text{Grain yield}}{\text{Biological yield}} \times 100\,.$$

C. Quality contributing characters

xiii.Seed grading (% by weight)

Seeds harvested from each pot were graded by weight into the large, medium, small and converted to percentage. Greater than 135g, 100-135g and less than 100 g per 1000-seed weight regarded as large, medium and small size seed respectively.

xiv. Procedure of data collection for Moisture and protein percentage

For assessing quality character parameters data were collected from selected plants from each of the pots. After collecting the seed, the seed sample were sun dried and then pack in polythene bag by proper labeling. These labeled packed sample were immediately sent to Bangladesh Council of Scientific and Industrial Research (BCSIR), Dhaka for determination of moisture percentage and crude protein percentage .The analysis has been presented in Appendix III.

3.5.11. Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of plant growth regulators and stages of application. The mean values of all the characters were calculated and analysis of variance was performed by the ‘F’ (variance ratio) test. The significance of the difference among the treatment means was estimated by the Least Significant Difference (LSD) at 5% level of probability (Gomez and Gomez, 1984).

Chapter 4

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

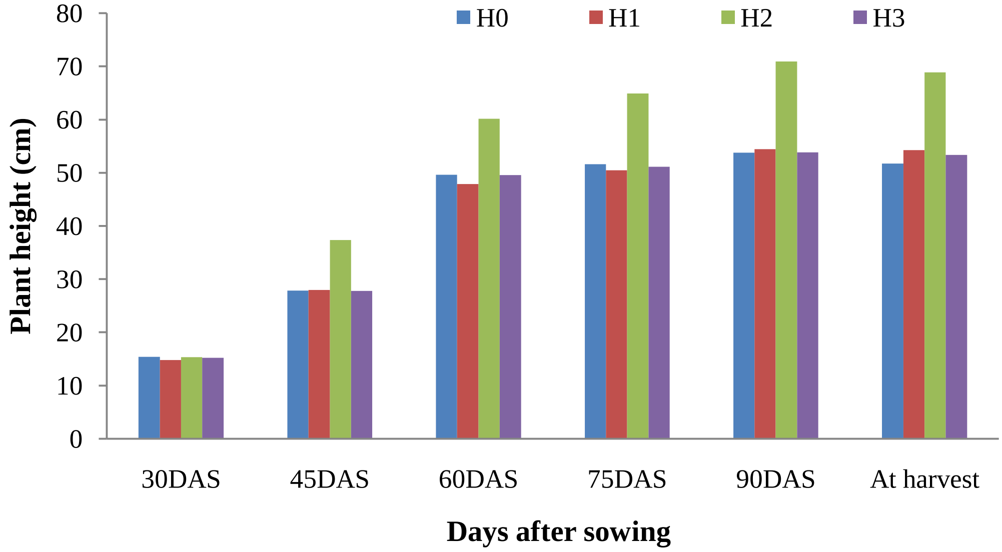
The research work was accomplished to investigate the plantgrowth regulators effect on growth, yield and quality of soybean. Some of the data have been presented and expressed in table and other in figures for easy discussion, comparison and understanding. The results of each parameter have been discussed and possible interpretations where ever necessary have been given under the following headings:

4.1. Crop growth characters

4.1. 1. Plant height

4.1.1.1. Effect of differentplant growth regulators application

Plant height of soybean varied significantly due to differentplant growth regulators at different days after sowing (DAS) but non-significant at only 30 DAS (Figure 1 and Appendix IV). Plant height gradually increased up to 90 DAS and thereafter slightly decreased at harvest irrespective of different plant growth regulators due to senescence of plant. At 30 DAS, numerically control (water) showed the tallest plant (15.38 cm) whereas, the shortest (14.77 cm) was found from the salicylic acid (H_1). At 45, 60, 75, 90 DAS and at harvest, GA_3 gave the tallest plant height (37.3, 60.15, 64.93, 70.94 and 68.87 cm, respectively).Control (water) produced the shortest(53.78 and 51.71cm) at 90 DAS and at harvest. Figure 1 showed that at 90 DAS, GA_3 increased plant height 31.90% over control. Mislevy*et al*. (1989) observed that applying 100 ppm GA_3 increased plant height 34.85% over control. These findings also correlate the above mentioned finding. The increase in plant height may be due to the effect of GA_3 on the cell division and cell enlargement, and also GA_3 stimulated the growth and expansion of cells through increasing the wall plasticity of cells.Khalil *et al.* (1989) found that plant height generally decreased with kinetin treatment. In our experiment, plant height also decreased by the foliar application of kinetin compared to that of GA_3. But little bit increased compared to control.



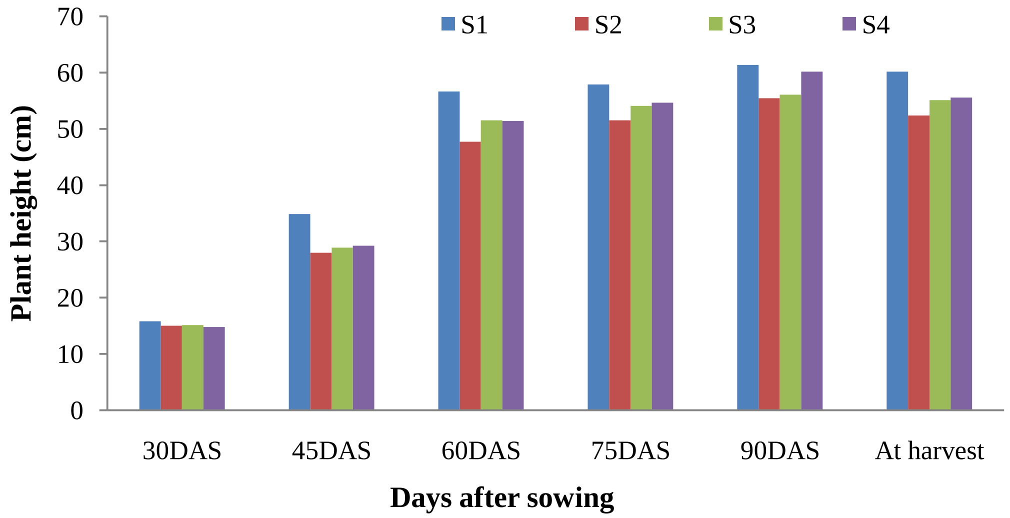
H_0= Control (water), H_1= Salicylic acid 50 ppm, H_2= GA_3 100 ppm,H_3 = Kinetin 500 ppm

Figure 1.Effect of plant growth regulatorsapplication on the plant height of soybean at different days after sowing

$LSD_{(0.05)}$=3.25, 4.93, 5.08, 5.15 and 5.88 for 45, 60, 75, 90 DAS and at harvest, respectively

4.1.1.2. Effect of stages of application

Plant height of soybean varied significantly due to stages of application at different days after sowing (Figure 2 and Appendix IV). The figure 2 demonstrated that plant height showed an increasing trend with increasing the age of plant up to 90 DAS but at harvest it was slightly decreased. At 30, 45, 60, 75, 90 DAS and at harvest, the longest plant height (15.78, 34.85, 56.61, 57.86, 61.33 and 60.17 cm, respectively) was obtained from vegetative stage (S_1),which was statistically similar (54.06, 54.67, 60.17, 55.11 and 55.54 cm, respectively) to pod initiation (S_3) and flower + pod initiation stage (S_4) whereas, the shortest(28.00, 47.72, 51.51, 55.47 and 52.38 cm, respectively) was recorded from flower initiation stage (S_2).



S_1= Vegetative stage at 25 DAS, S_2 = Flower initiation at 40 DAS, S_3 = Pod initiation at 50DAS and S_4= Flower +Pod initiation at 40 and 50 DAS

Figure 2. Effect of stages of application on the plant height of soybean at different days after sowing

$LSD_{(0.05)}$ = 3.25, 4.93, 5.08, 5.15 and 5.88 at 45, 60, 75 and 90 and at harvest, respectively.

4.1. 1.3. Interaction effect of different plant growth regulators and stages of application

Interaction effect of different plant growth regulators and stages of application in terms of plant height also exposed significant variation at different days after sowing except 75 DAS (Table 1 and Appendix IV). Plant height increased with increasing its growing period up to 90 DAS but at harvest it slightly decreased. At 30 DAS, the tallest plant (17.44 cm) was obtained from the combination of control (water) and vegetative stage which was statistically similar to H_1S_1 (15.86 cm), H_2S_3 (16.48 cm), H_2S_4 (15.26 cm), H_3S_2 (16.12 cm) and the shortest (14.00 cm) was obtained from H_1S_3. At 45, 60, 90 DAS and at harvest, the tallest plant (38.00, 55.64, 61.16 and 59.84 cm, respectively) was recorded from H_2S_1 treatment combination which was statistically similar to H_2S_4(81.46 cm) treatment combination whereas, the shortest(24.40 and 45.38 cm) was recorded from H_2S_2 treatment combination at 45 and 60DAS. The combination of H_3S_4 (48.50cm) produced the shortestat 90DAS.The minimum plant height was observed from H_1S_2 (57.34cm) at harvest. At 75 DAS, numerically tallest plant height (59.24 cm) was produced from H_2S_2 treatment combination whereas, the shortest (49.42 cm) was recorded from H_0S_4.

Table 1. Interaction effect of plant growth regulators and stages of application on plant height (cm) of soybean (cv. BARI Soybean-6)

Treatment combination	Plant height(cm)					
	30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At harvest
H_0S_1	17.44 a	28.40 cd	48.44c	51.32	52.38bc	48.20 bc
H_0S_2	14.74bc	27.40 cd	49.04c	50.02	51.62 bc	50.64 bc
H_0S_3	14.72 bc	28.00cd	53.30 c	55.74	59.42 b	55.70 bc
H_0S_4	14.62 bc	27.60 cd	47.82 c	49.42	51.96 bc	51.30 bc
H_1S_1	15.86 a-c	27.80 cd	47.76 c	49.66	52.14 bc	53.78 bc
H_1S_2	14.60bc	30.00cd	50.40 c	52.40	55.62 bc	54.34 bc
H_1S_3	14.00 c	24.60cd	47.46 c	50.86	53.78 bc	53.54 bc
H_1S_4	14.64 bc	29.60 cd	45.82c	48.86	56.28 bc	52.30 bc
H_2S_1	14.90 bc	38.00a	55.64a	59.24	61.16 a	59.84 a
H_2S_2	14.70bc	24.40 d	45.38 c	53.44	60.00 b	54.86 bc
H_2S_3	16.48ab	37.00b	54.28 c	58.00	58.34 bc	52.94 bc
H_2S_4	15.26 a-c	31.00 bc	54.90b	50.02	59.46 b	53.84 bc
H_3S_1	14.92 bc	26.20 cd	53.60c	52.24	59.36 b	58.84b
H_3S_2	16.12 a-c	30.20 cd	46.04 c	50.18	54.64bc	51.66 bc
H_3S_3	15.22 bc	26.00 cd	50.96c	51.66	52.62bc	58.28 b
H_3S_4	14.50 bc	28.80cd	47.60 c	50.38	48.50 c	44.74 c
$LSD_{(0.05)}$	2.18	6.50	9.86	ns	10.30	11.76
CV (%)	11.39	17.03	15.03	14.58	13.98	16.66

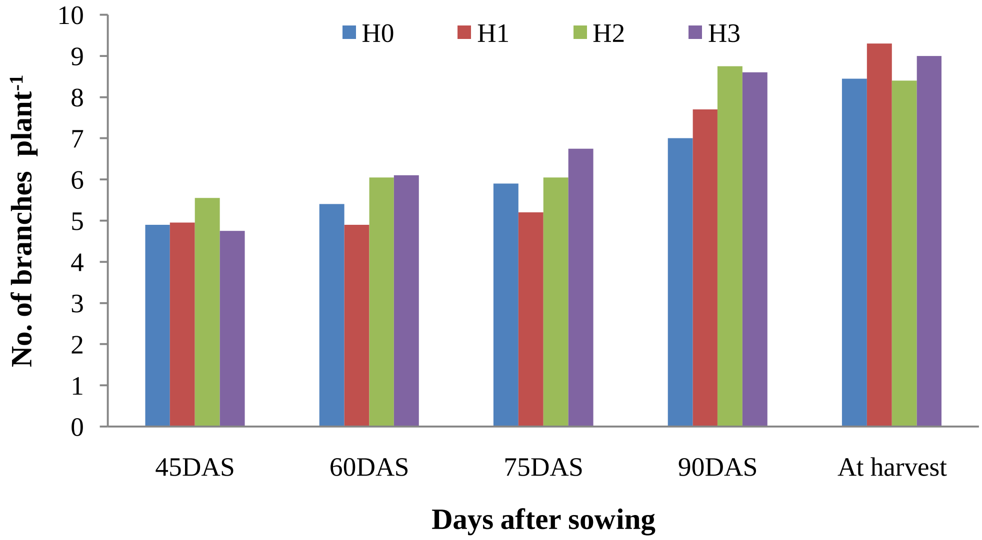
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

H_0= Control (water), H_1=Salicylic acid 50 ppm,H_2=GA_3 100ppm,H_3= Kinetin 500ppm S_1=Vegetative stage at 25 DAS, S_2=Flower initiation at 40 DAS,S_3=Pod initiation at 50 DAS and S_4=Flower +Pod initiation at 40 and 50 DAS,ns = non-significant.

4.1.2. Number of branches plant^{-1}

4.1.2.1. Effect of plant growth regulators application

Number of branches plant^{-1} of soybean varied significantly with different plant growth regulators application at different days after sowing but non - significant effect at 45 DAS, 60 DAS and at harvest (Figure 3 and Appendix V). The figure 3 indicated that number of branches plant $^{-1}$ increased with advancement of growth stage irrespective of plant growth regulatorsapplication. At 45 DAS, numerically the maximum number of branches plant $^{-1}$ (5.55) was recorded from GA_3 (H_2) whereas, the minimum (4.75) was recorded from kinetin (H_3). At 60 and 75 DAS, the highest number of branches plant $^{-1}$ (6.10 and 6.75) was recorded from kinetin (H_3) whereas; the lowest (4.90) was recorded from salicylic acid (H_1) and GA_3 (H_2). At 90 DAS, the maximum number of branches plant $^{-1}$ (8.75) was recorded from GA_3 (H_2) which was statistically similar (7.70 and 8.60) to H_1 and H_3 whereas, the minimum (7.00) was recorded from control (water) (H_0). At harvest, the maximum number of branches plant $^{-1}$ (9.30) was recorded from salicylic acid (H_1) whereas, the minimum (8.42) was obtained from control ($H_{2.}$).Fathy*et al*. (2003) on soybean they mentioned that foliar application of salicylic acid and vitamin E increased number of branches plant^{-1}.



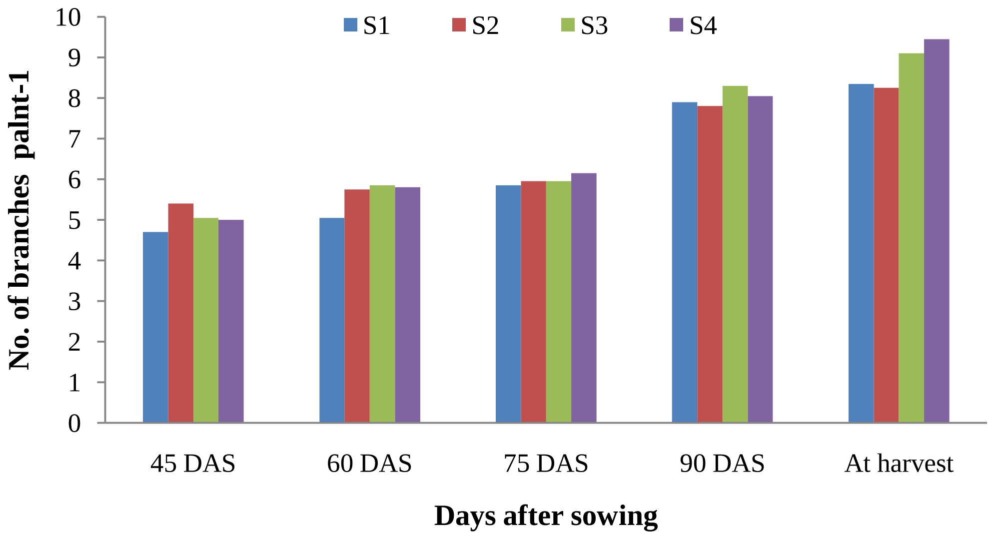
H_0 = Control (water), H_1 = Salicylic acid 50 ppm, H_2 = GA_3 100 ppm,H_3 = Kinetin 500 ppm

Figure 3. Effect of plant growth regulators application on the number of branches plant^{-1} of soybean at different days after sowing

$LSD_{(0.05)}$= 0.99, 1.20 at 75 and 90 DAS, respectively

.4.1.2.2. Effect of stages of application

Number of branches plant^{-1} of soybean had no significant effect with different stages of application at different days after sowing and had significant effect at harvest (Figure 4 and Appendix V). Number of branches plant^{-1} increased with increasing its growing period up to at harvest. It can be inferred from the figure 4 that at 45 DAS, numerically the maximum number of branches plant^{-1} (5.40) was recorded from flower initiation stage (S_2) whereas, the lowest (4.70) was recorded from vegetative stage (S_1). At 60 and 90 DAS, numerically the maximum number of branches plant^{-1} (5.85 and 8.30) was recorded from pod initiation stage (S_3) whereas, the minimum (5.05) was recorded from vegetative stage (S_1) and flower initiation stage (S_2).



S_1= Vegetative stage at 25 DAS, S_2 = Flower initiation at 40 DAS, S_3 = Podinitiation at 50 DAS and S_4 = Flower +Pod initiation at 40 and 50 DAS

Figure 4. Effect of stages of application on the number of branches of soybean at different days after sowing

$LSD_{(0.05)}$ = 1.15 at harvest

4. 1.2.3. Interaction effect of different plant growth regulators and stages of application

Interaction effect of different plant growth regulators and stages of application on number of branches plant^{-1} was also significant at different days after sowing (Table 2 and Appendix V). At 45 DAS, the H_1S_2 and H_3S_2treatment combination produced maximum number of branches (6.00) which was statistically similar to H_0S_1, H_0S_2, H_0S_3, H_0S_4, H_1S_3, H_1S_4, H_2S_1, H_2S_2, H_2S_3, H_2S_4, H_3S_3 and H_3S_4 whereas, the minimum (3.80) was recorded from H_1S_1treatment combination. At 60 DAS, the highest number of branches plant^{-1} was produced from H_3S_2 (6.80) which was statistically similar to H_0S_1, H_0S_2, H_0S_3, H_0S_4, H_1S_2, H_1S_3, H_1S_4, H_2S_1, H_2S_2, H_2S_3, H_2S_4, H_3S_1, H_3S_3 and H_3S_4whereas, the lowest was observed from H_1S_1 (3.84). At 75 DAS, the maximum number of branches plant^{-1} (7.60) was recorded from H_3S_2 treatment combination which was statistically similar to H_0S_1, H_1S_4, H_2S_1, H_3S_3 and H_3S_4 whereas, the minimum (4.20) was observed from H_1S_1 treatment combination. At 90 DAS, the maximum number of branches (9.80) was recorded from H_3S_3 treatment combination which was statistically similar toH_0S_1, H_0S_4, H_1S_3, H_1S_4, H_2S_1, H_2S_2, H_2S_3, H_2S_4, H_3S_1, H_3S_2 and H_3S_4 whereas, the minimum (6.20) was recorded from H_0S_3 treatment combination. At harvest, the maximum number of branches (11.00) was recorded from H_1S_4 treatment combination which was statistically similar to H_3S_4, H_0S_1 , H_0S_3 , H_0S_4 , H_1S_2., H_1S_3, H_3S_2, H_3S_3 and H_3S_4 whereas, the minimum (7.00) was recorded from H_0S_2 treatment combination.

Table 2.Interaction effect of plant growth regulators and stages of application on the number of branches plant^{-1} of soybean (cv. BARI Soybean-6)

Treatment combination	Number of branches plant^{-1}				
	45DAS	60DAS	75DAS	90DAS	At harvest
H_0S_1	5.40ab	5.60 ab	6.80 a-c	7.40a-d	9.00a-c
H_0S_2	4.40ab	5.00 ab	5.60 b-e	7.00b-d	7.00 c
H_0S_3	5.00 ab	5.60 ab	6.00a-e	6.20d	9.00 a-c
H_0S_4	4.80 ab	5.40 ab	5.20 c-e	7.40a-d	8.80a-c
H_1S_1	3.80 b	3.84 b	4.20e	7.20b-d	7.60 bc
H_1S_2	6.00 a	5.20ab	5.60b-e	6.80 cd	8.80a-c
H_1S_3	4.80 ab	5.00 ab	4.80de	9.00 a-c	9.80ab
H_1S_4	5.20ab	5.60 ab	6.20 a-d	7.80a-d	11.00 a
H_2S_1	5.80 ab	6.00ab	6.60a-d	9.00 a-c	8.20 bc
H_2S_2	5.20 ab	6.00ab	5.00c-e	8.40a-d	8.60 bc
H_2S_3	5.80ab	6.40a	6.80a-c	8.20a-d	8.20 bc
H_2S_4	5.40ab	5.80ab	5.80a-e	9.40 ab	8.60 bc
H_3S_1	3.80b	4.80ab	5.80a-e	8.00a-d	8.60 bc
H_3S_2	6.00a	6.80a	7.60 a	9.00a-c	8.60ab
H_3S_3	4.60ab	6.40a	6.20a-d	9.80a	9.40 ab
H_3S_4	4.60ab	6.40a	7.40 ab	7.60 a-d	9.40ab
$LSD_{(0.05)}$	2.05	2.45	1.99	2.41	2.30
CV (%)	10.22	26.43	32.25	34.64	20.73

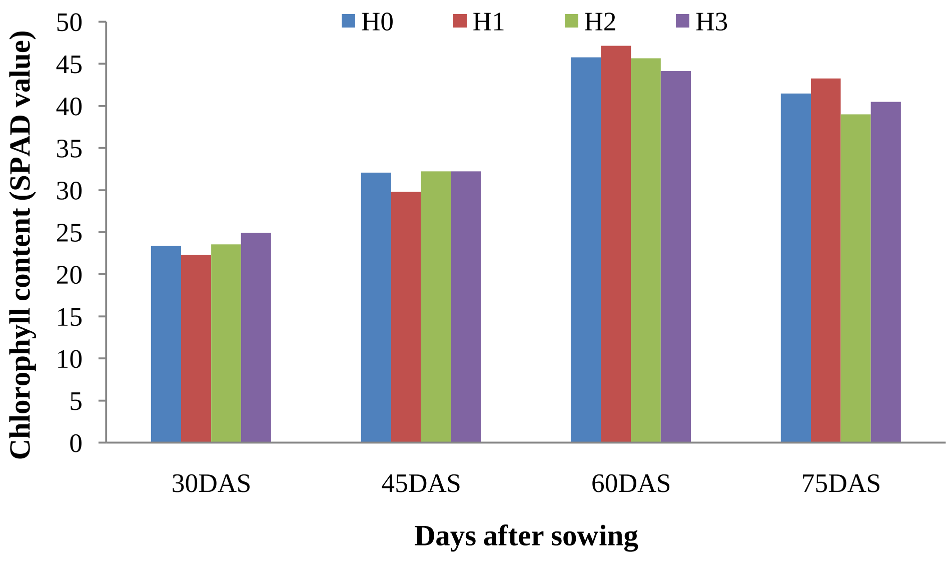
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

H_0 = Control (water), H_1=Salicylic acid 50 ppm, H_2= GA_3 100 ppm, H_3= Kinetin 500 ppm. S_1=Vegetative stage at 25 DAS, S_2=Flower initiation at 40 DAS, S_3= Pod initiation at 50 DAS and S_4= Flower +Pod initiation at 40 and 50 DAS

4.1.3. Chlorophyll content (SPAD value)

4.1.3.1. Effect of different plant growth regulators application

Chlorophyll content of soybean had significant effect with different plant growth regulators application at different days after sowing but no significant effect was observed at 45 and 60 DAS (Figure 5 and Appendix VI). The figure 5 indicated that chlorophyll content increased 30 to 45 DAS and at 60 DAS slightly decreased and 75 DAS again increased. At 30 DAS, the maximum chlorophyll content (24.93) was recorded from kinetin (H_3), which was statistically similar with control (H_0) and GA_3 (H_2) whereas, the minimum (22.28) was recorded from salicylic acid (H_1). At 75 DAS, the maximumchlorophyll content (43.26) was recorded from salicylic acid (H_1) which was statistically similar to control (H_0) and kinetin (H_3) whereas, the minimum (39.00) was obtained from GA_3 (H_2). Abdel-Wahid (2008) found that application of SA increased chlorophyll a and b as well as carotenoids in Syngonium pod phyllum plants. The effect of salicylic acid in increasing chlorophyll contents may be due to the reduction in cell size resulting in dense cytoplasm. The chlorophyll content was enhanced as the chlorophyllase enzyme, which is responsible for chlorophyll growth retardant. Salicylic acid application protected the chlorophyll molecule from photo-oxidation and thereby increased chlorophyll content.



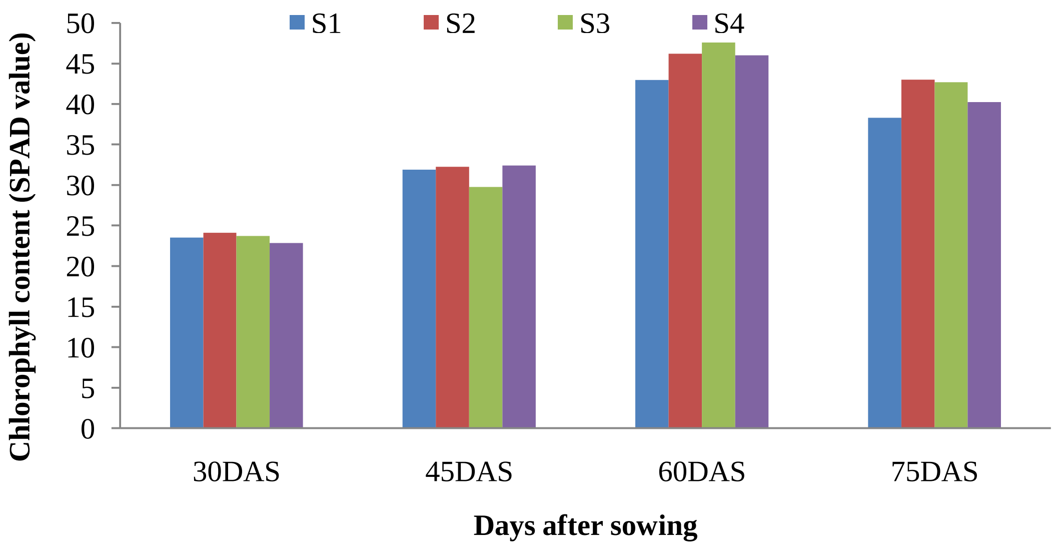
H_0 = Control (water), H_1 = Salicylic acid 50 ppm, H_2 = GA_3 100 ppm, H_3 = Kinetin 500 ppm

Figure 5. Effect of plant growth regulators application on chlorophyll content of soybean at different days after sowing

$LSD_{(0.05)}$ = 2.54 and 3.13 at 30 and 90 DAS

4. 1.3.2. Effect of stages of application

Chlorophyll content of soybean had significant effect with different stages of application at different days after sowing but non-significant effect at 30 DAS and 45 DAS (Figure 6 and Appendix VI). The figure 6 indicated that at 30 DAS, numerically the maximum chlorophyll content (24.10) was recorded from flower initiation stage (S_2) whereas, the minimum (22.84) was recorded from flower + pod initiation stage (S_4). At 45 DAS, numericallythe maximum chlorophyll content (32.42) was recorded from flower + pod initiation stage (S_4) whereas, the minimum (29.75) was recorded from pod initiation stage (S_3). At 60 DAS, pod initiation stage (S_3) produced the maximum (47.57) which was statistically similar (46.22) and (45.99) to S_2 and S_4 whereas the minimum (42.98) was recorded from vegetative stage (S_1). At 75 DAS, highest chlorophyll content (42.99) was recorded from flower initiation stage (S_2) which was statistically similar (42.69) and (40.25) to S_3 and S_4 whereas, the smaller (38.29) was observed from vegetative stage (S_1).



S_1 = Vegetative stage at 25 DAS,S_2 = Flower initiation at 40 DAS, S_3 = Pod initiation at 50DAS and S_4 = Flower +Pod initiation at 40 and 50 DAS

Figure 6. Effect of stages of application on chlorophyll content of soybean at different days after sowing

$LSD_{(0.05)}$= 3.54 and 3.13 at 60 and 75DAS

4. 1.3.3. Interaction effect of different plant growth regulators and stages of application

Interaction effect of different plant growth regulators and stages of application on chlorophyll content was also significant at different days after sowing (Table 3 and Appendix VI). At 30 DAS, the maximum chlorophyll (27.26) was recorded from H_3S_2 treatment combination which was statistically similar to H_0S_1, H_0S_2, H_1S_1, H_1S_2, H_1S_3, H_2S_1, H_2S_3, H_2S_4, H_3S_1, H_3S_3 and H_3S_4 whereas, the minimum (20.96) was found from H_1S_4 treatment combination. At 45 DAS, the maximum chlorophyll (34.08) was recorded from H_2S_2 treatment combination which was statistically similar to H_0S_1, H_0S_2, H_0S_3, H_0S_4, H_1S_1, H_1S_4, H_2S_1, H_2S_2, H_2S_3, H_2S_4, H_3S_1, H_3S_2, H_3S_3 and H_3S_4 whereas, the minimum (25.60) was recorded from H_1S_3 treatment combination. At 60 DAS, the maximum chlorophyll (50.36) was obtained from H_2S_2 treatment combination which was statistically similar to H_1S_4, H_0S_1, H_0S_2, H_0S_3, H_0S_4, H_1S_2, H_1S_3, H_2S_2, H_2S_3, H_2S_4, H_3S_2, H_3S_3 and H_3S_4 whereas, the smaller (40.56) was recorded from H_3S_1 treatment combination. At 75 DAS, the highest chlorophyll (46.64) was recorded from H_1S_3 treatment combination which was statistically similar to H_0S_1, H_0S_2, H_0S_3, H_1S_2, H_1S_3, H_1S_4, H_0S_4, H_1S_4, H_0S_1, H_3S_2 and H_3S_3 whereas, the lowest (33.78) was observed from H_2S_4 treatment combination.

Table 3. Combined effect of different plant growth regulators and stages of application on the chlorophyll content (SPAD value)of soybean (cv. BARI Soybean- 6)

Treatment combination	Chlorophyll content (SPAD value)			
	30 DAS	**45 DAS**	**60 DAS**	**75 DAS**
H_0S_1	25.48 a-c	32.50 a	47.58 a-d	41.22 a-c
H_0S_2	24.62 a-c	32.20 a	44.12 a-d	40.70 a-c
H_0S_3	21.42 bc	31.54 a	44.66 a-d	40.60 a-c
H_0S_4	21.90 bc	32.06 a	46.78 a-d	43.34 ab
H_1S_1	22.62 a-c	32.78 a	43.08 b-d	39.30 b-d
H_1S_2	22.60 a-c	29.52 ab	45.68 a-d	42.50 a-c
H_1S_3	22.96 a-c	25.60 b	50.36 a	46.64 a
H_1S_4	20.96 c	31.32 ab	49.44 ab	44.58 ab
H_2S_1	23.58 a-c	30.32 ab	40.70 cd	36.38 cd
H_2S_2	21.92 bc	34.08 a	50.38 a	46.54 a
H_2S_3	24.32 a-c	30.86ab	47.60 a-d	39.30 b-d
H_2S_4	24.46 a-c	33.64 a	44.04 a-d	33.78 d
H_3S_1	22.36 a-c	32.04 a	40.56 d	36.26 cd
H_3S_2	27.26 a	33.22 a	44.68a-d	42.20 a-c
H_3S_3	26.10 ab	31.00 ab	47.66 a-c	44.22 ab
H_3S_4	24.02 a-c	32.64 a	43.70 a-d	39.30b-d
$LSD_{(0.05)}$	5.08	5.93	7.08	6.27
CV (%)	17.07	14.86	12.26	12.08

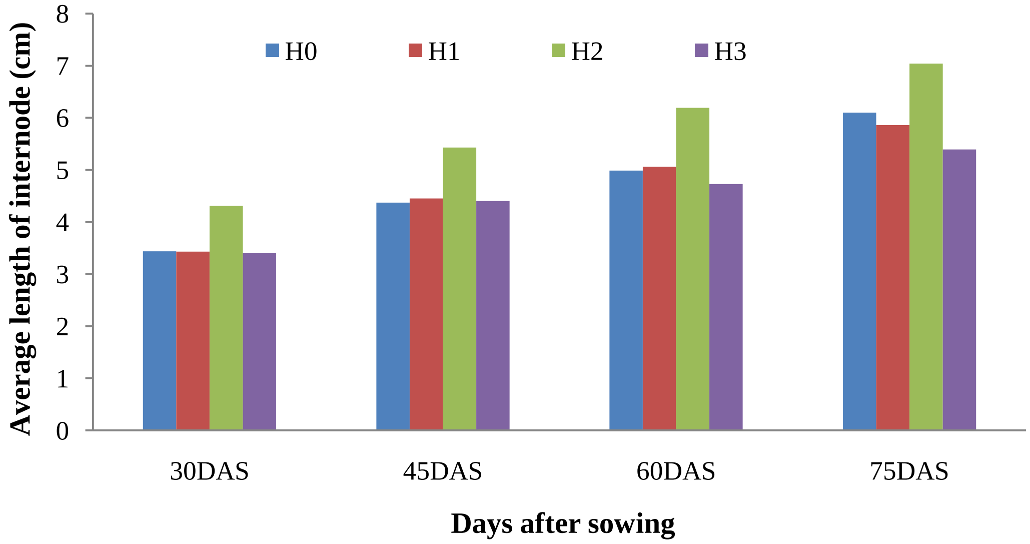
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

H_0 = Control (water), H_1=Salicylic acid 50 ppm, H_2= GA_3 100 ppm, H_3= Kinetin 500 ppm. S_1=Vegetative stage at 25 DAS, S_2=Flower initiation at 40 DAS, S_3= Pod initiation at 50 DAS and S_4= Flower +Pod initiation at 40 and 50 DAS

4.1.4.Average length of internode

4. 1.4.1. Effect of different plant growth regulators application

Average length of internode of soybean had significant effect with different plant growth regulators application at different days after sowing (Figure 7 and AppendixVII). The figure 7 showed that average length of internode exhibited an increasing trend with advancement of growth stages of plant irrespectiveall growth regulators application. The rate of increase was found slower up to 45 DAS, after that average length of internode increased steadily up to 75 DAS irrespective of all plant growth regulators application. The figure 7 indicated that at 30, 45, 60 and 75 DAS, the maximum average length of internode (4.31, 5.43, 6.19 and 7.04 cm) was recorded from GA_3 (H_2). The minimum average length of internodes (3.40, 4.73 and 5.39 cm) was observed from kinetin (H_3)at 30, 60 and 75 DAS. At 45 DAS control (water) produced lowest (4.37 cm) average length of internode. Rai*et al*. (2006) concluded that the treatment GA_3 (100 ppm) maintained significantly higher length of internode (5.54 cm) and it was statistically at par with the treatments GA_3 (50 ppm, 5.51 cm) and ASA (200 ppm, 5.24 cm) while minimum length was recorded in treatment control (4.57 cm) at last picking. Similar results were found by Naeem*et al.* (2004). These results are supported by the findings of Kof*et al.* (1998) and Rai*et al*.(2006). These results are in agreement with the findings of our research. Due to cell elongation and cell division the length of internode increased hence here GA_3 played an important role.



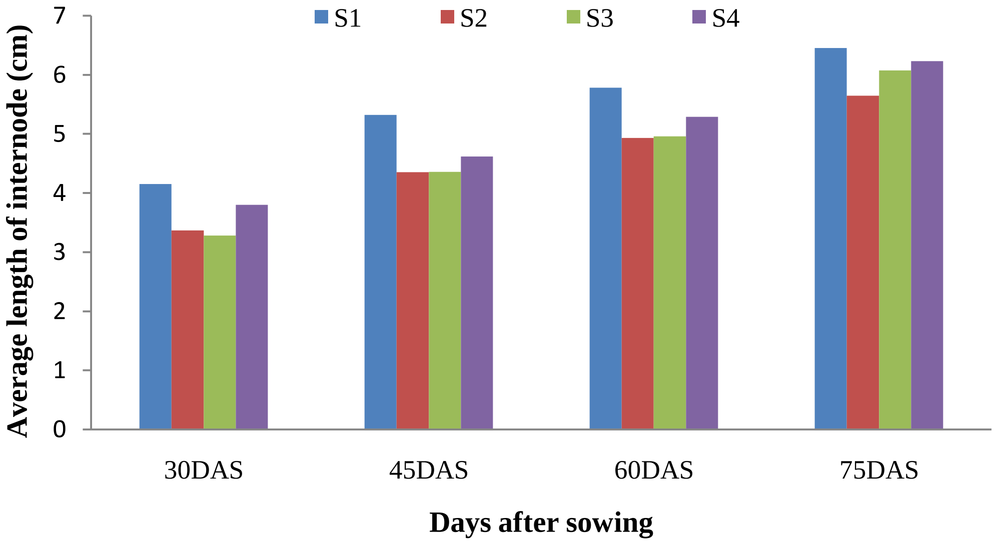
H_0 = Control (water), H_1 = Salicylic acid 50 ppm, H_2 = GA_3 100 ppm, H_3 = Kinetin 500 ppm

Figure 7. Effect of plant growth regulators application on average length of internode of soybean at different days after sowing

LSD $_{(0.05)}$= 0.36, 0.49, and 0.67 and 0.87at 30, 45, 60 and 75 DAS, respectively

4.1.4.2. Effect of stages of application

Average length of internode of soybean had significant effect with different stages of application at different days after sowing except 75 DAS (Figure 8 and Appendix VII). The figure 8 showed that average length of internode exhibited an increasing trend with advancement of growth stages of plant irrespective all stages of application. Similar trends of internode length were observed in all growing stages.At 75 DAS, numerically the highest average length of internode (6.45 cm) was recorded from vegetative stage (S_1) whereas, the minimum(5.64cm) was recorded from flower initiation stage ((S_2).



S_1 = Vegetative stage at 25 DAS, S_2 = Flower initiation at 40 DAS, S_3 = Pod initiation at 50 DAS and S_4 = Flower +Pod initiation at 40 and 50 DAS

Figure 8. Effect of stages of application on average length of internode of soybean at different days after sowing

LSD$_{(0.05)}$ = 0.36, 0.49 and 0.67 at 30, 45 and 60 DAS, respectively.

4.1.4.3. Interaction effect of different plant growth regulators and stages of application

Average length of internode of soybean had significant effect with plant growth regulators application and different stages of application at different days after sowing (Table 4 and Appendix VII). At 30 DAS, the maximum average length of internode (6.07cm) was recorded from H_2S_1 treatment combination whereas, the minimum (2.95cm) was obtained from H_1S_3 treatment combination. At 45 DAS, the highest average length of internode (7.08cm) was recorded from H_2 S_1 treatment combination whereas, the lowest (3.87cm) was obtained from H_3S_2 treatment combination. At 60 DAS, the maximum average length of internode (7.74cm) was recorded from H_2S_1 treatment combination which was identical (6.97 cm) to H_2S_4whereas, the minimum (4.30cm) was recorded from H_3S_3 treatment combination. At 75 DAS, the maximum average length of internode (8.79 cm) was recorded from H_2S_1 treatment combination which was statistically similar to H_2S_4 whereas, the minimum (5.17cm) was recorded from H_3S_3 treatment combination.

Table 4.Combined effect of different plant growth regulators and stages of application on the average length of internode (cm) of soybean (cv. BARI Soybean -6)

Treatment combination	Average length of internode (cm)			
	30DAS	**45DAS**	**60DAS**	**75DAS**
H_0S_1	3.67 b-d	4.61cd	5.12 b	6.05 c
H_0S_2	3.22 cd	4.24 cd	4.70 b	5.63 c
H_0S_3	3.31cd	4.46cd	5.08 b	6.65bc
H_0S_4	3.57 b-d	4.15 cd	5.05 b	6.09c
H_1S_1	3.58 b-d	4.56cd	5.03 b	5.59 c
H_1S_2	3.52 b-d	4.73cd	5.47 b	6.15 c
H_1S_3	2.95 d	4.27 cd	5.28 b	6.67 bc
H_1S_4	3.69 bc	4.25 cd	4.48 b	5.03 c
H_2S_1	6.07 a	7.08 a	7.74 a	8.79 a
H_2S_2	3.19 cd	4.54cd	4.85 b	5.41c
H_2S_3	3.78 bc	4.30cd	5.19 b	5.81c
H_2S_4	4.21 b	5.81b	6.97 a	8.17ab
H_3S_1	3.27 cd	5.03bc	5.22 b	5.37 c
H_3S_2	3.54 bd	3.87 d	4.72 b	5.39 c
H_3S_3	3.06 cd	4.41cd	4.30 b	5.17 c
H_3S_4	3.73 bc	4.27 cd	4.67 b	5.63 c
$LSD_{(0.05)}$	0.72	0.99	1.35	1.74
CV (%)	15.63	16.80	20.46	22.59

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

H_0 = Control water, H_1=Salicylic acid 50 ppm, H_2= GA_3 100 ppm, H_3= Kinetin 500 ppm
S_1=Vegetative stage at 25 DAS, S_2=Flower initiation at 40 DAS, S_3= Pod initiation at 50 DAS and S_4= Flower +Pod initiation at 40 and 50 DAS

4.2.Yield contributing characters

4.2.1. Number of pods plant^{-1}

4.2.1.1. Effect of different Plant growth regulators application

Number of pods per plant had no significant effect on different plant growth regulators application (Table 5 and Appendix VIII). Numerically the highest number of pods plant^{-1} (30.40) was obtained from GA_3 (H_2) and the lowest (23.55) was recorded from control water(H_0).Table 5 showed that GA_3increased number of pods plant^{-1} 29% over control. Copur*et al.* (2010) assessed significantly maximum number of pods per plant was recorded in all the concentrations of NAA followed by GA_3 and Kinetin. Such findings may be attributed to the increase of the number of flowers accompanied with decrease of the percentage of flower abscission. Similar results were observed by Khalil and Mandurahm (1989).

4. 2.1.2. Effect of stages of application

Number of pods per plant had no significant effect on different stages of application (Table 6).Numerically the highest number of pods plant^{-1} (29.45) was obtained from vegetative stage (S_1) while the lowest (25.00) was recorded from pod initiation stage (S_3). The foliar application of plant growth regulators at flower initiation and pod formation stage might have reduced flower drop. This might have significantly increased the number pods plant^{-1} as reported by Ganapathy*et al.* (2008). Optimum supply of all plant growth regulators at flower initiation and pod formation stages of crop growth might have caused efficient translocation of photosynthates from source to sink. Decreased flower drop due to prolonged assimilatory activity of leaves might be another possible reason for higher number of pods plant^{-1}. Further, the foliage applied plant growth regulators at the initial stages might have been effectively absorbed and translocated to the pods resulting in more number of pods plant^{-1}.

4.2.1.3. Interaction effect of different plant growth regulators and stages of application

Interaction effect of different plant growth regulators and stages of application on the number of Pods plant^{-1} of soybean showed significant variation (Table 7and Appendix VIII).The maximum number of pods plant^{-1} of soybean (41.00) was recorded from H_2S_4 treatment combination which was statistically similar to H_3S_2, H_3S_1,H_2S_2,H_2S_1, H_1S_4, H_1S_3, H_1S_2, H_1S_1, H_0S_4 and H_0S_3 whereas, the minimum (19.60) was recorded from H_0S_1 treatment combination.

4.2.2. Length of pod

4.2.2.1. Effect of different plant growth regulators application

Different plant growth regulators application showed non-significant effect on pod length of soybean (Table 5 and Appendix VIII). Numerically the largest pod length (2.39cm) was found from kinetin (H_3) and the shortest (2.24 cm) was obtained from control water (H_0).

4.2.2.2. Effect of stages of application

Different stages of application had significant effect of the length of pod (Table 6 and Appendix VIII). The highest length of pod (2.42cm) was obtained from pod initiation stage (S_3) which was statistically similar to S_2 and S_4 whereas, lowest (2.18cm) was obtained from vegetative stage (S_1).

4.2.2.3. Interaction effect of different plant growth regulators and stages of application

Interaction effect of plant growth regulators and stages of application had significant effect on length of pod (Table 7 and Appendix VIII). The maximum length of pod of soybean (2.60 cm) was recorded from H_1S_2 treatment combination which was statistically similar to H_0S_3, H_0S_4, H_1S_3, H_1S_4, H_2S_1, H_2S_3, H_2S_4, H_3S_1, H_3S_2, H_3S_3 and H_3S_4 whereas, the minimum (2.00cm) was recorded from H_0S_1 treatment combination.

4.2.3. Number of seeds pod^{-1}

4.2. 3.1. Effect of different plant growth regulators application

Number of seeds pod^{-1} was exposed significantly with plant growth regulators application (Table 5 and Appendix VIII).The highest number of seeds pod^{-1} (1.60) was recorded from salicylic acid (H_1) which was statistically similar (1.43) to GA_3 100 ppm (H_2) whereas, the minimum (1.30) was recorded from control (water) (H_0) treatment. Table 5 showed that salicylic acid increased number of seeds pod^{-1} 23% over control.

4.2.3.2. Effect of stages of application

Number of seeds pod^{-1} had no significant effect on different stages of application (Table 6 and Appendix VIII). Numerically the highest number of seeds pod^{-1} (1.54) was obtained from flower + pod initiation stage (S_4) and the lowest (1.42) was obtained from vegetative stage (S_1). Devi *et al.* (2011) observed that number of seeds of soybean increased by the application of 50 ppm salicylic acid at flower + pod initiation stage. These findings also correlate the above mentioned findings.

4.2.3.3.Interaction effect of different plant growth regulators and stages of application

Interaction effect of plant growth regulators and stages of application had significant effect on number of seeds pod^{-1} (Table 7 and Appendix VIII). The maximum number of seeds pod^{-1} of soybean (1.76 cm) was recorded from H_1S_3,H_1S_4 and H_3S_1 treatment combination which is statistically similar to H_0S_3, H_1S_2, H_2S_1, H_2S_4,H_3S_2 and H_3S_3 whereas, the minimum (1.12 cm) was recorded from H_0S_1 treatment combination.

4.2.4. 100-seed weight

4.2.4.1. Effect of different plant growth regulators application

100-seed weight was exposed significantly with plant growth regulators application (Table 5 and Appendix VIII).The maximum 100-seed weight of soybean (11.58g) was recorded from kinetin (H_3) which was statistically similar to salicylic acid (H_1) and GA_3 (H_2) whereas, the minimum (9.65 g) was recorded from control (H_0) treatment. Table 5 showed that kinetin(H_3) increased 20% 100-seed weight over control. Zhlobak (1986) reported that Kinetin treatment increased the number and weight of pod and seeds 40 mg L^{-1}kinetin showed the highest significant response.

Table 5. Effect of different plant growth regulators on yield contributing characters of soybean (cv. BARI Soybean -6)

Treatment	Number of pods plant^{-1}	Pod length (cm)	Number of seeds pod^{-1}	Weight of 100-seed (g)
H_0	23.55	2.24	1.30 b	9.65 b
H_1	27.60	2.38	1.60 a	10.87 ab
H_2	30.40	2.37	1.43 ab	10.05 ab
H_3	27.65	2.39	1.54 a	11.58 a
LSD $_{(0.05)}$	ns	ns	0.19	1.84
CV (%)	50.49	14.76	21.16	27.61

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

H_0= Control (water),H_1=Salicylic acid 50 ppm,H_2=$GA_3$100ppm,H_3=kinetin 500ppm.,ns = non- significant

4.2.4.2. Effect of stages of application

100-seed weight had significant effect on different stages of application (Table 6 and Appendix VIII). The maximum100-seed weight (12.00 g) was obtained from flower + pod initiation stage (S_4) whereas, the minimum (9.65g) was recorded from vegetative stage (S_1). Devi *et al.* (2011) observed that 100-seed weight of soybean increased by the application of 500 ppm kinetin at flower+ pod initiation stage. The present results also correlate above mentioned findings. These results might be due to the increased 100-seed weight attributed to increased mobilization of metabolites to the reproductive sinks.

Table 6. Effect of stages of application on yield contributing characters of soybean (cv. BARI Soybean -6)

Treatment	Number of pods plant^{-1}	Pod length (cm)	Number of seeds pod^{-1}	Weight of 100-seed (g)
S_1	29.45	2.18 b	1.42	9.65b
S_2	27.10	2.40 ab	1.42	9.58b
S_3	25.00	2.42a	1.49	10.93 ab
S_4	27.65	2.38ab	1.54	12.00 a
LSD $_{(0.05)}$	ns	0.21	ns	1.84
CV (%)	50.49	14.76	21.16	27.61

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

S_1 = Vegetative stage at 25 DAS, S_2 = Flower initiation at 40 DAS, S_3 = Pod initiation at 50 DAS and S_4 = Flower +Pod initiation at 40 and 50 DAS), ns = non- significant

4.2.4.3. Interaction effect of different plant growth regulators and stages of application

Interaction effect of plant growth regulators and stages of application had significant effect on 100-seed weight (Table 7 and Appendix VIII). The maximum 100-seed weight of soybean (16.79g) was recorded from H_1S_4 treatment combination which was statistically similar to H_3S_3 whereas, the minimum (7.99g) was recorded from H_1S_2 treatment combination.

Table 7. Interaction effect of different plant growth regulators and stages of application on yield contributing characters of soybean (cv. BARI Soybean-6)

Treatment combination	Number of pods $plant^{-1}$	Pod length (cm)	Number of seeds pod^{-1}	Weight of 100-seed (g)
H_0S_1	19.60 c	2.00d	1.12 e	8.33cd
H_0S_2	20.40 bc	2.16 b-d	1.24c-e	9.73 cd
H_0S_3	28.60 a-c	2.50 a-c	1.48 a-e	9.26 cd
H_0S_4	25.60 a-c	2.32 a-d	1.36 b-e	11.29 b-d
H_1S_1	32.80 a-c	2.10cd	1.28 c-e	9.27 cd
H_1S_2	25.60a-c	2.60 a	1.60 a-c	7.99d
H_1S_3	28.00 a-c	2.52a-c	1.76 a	9.43cd
H_1S_4	24.00 a-c	2.32 a-d	1.76 a	16.79a
H_2S_1	27.80 a-c	2.22 a-d	1.54 a-d	11.02 b-d
H_2S_2	29.80a-c	2.36 b-d	1.32b-e	8.81cd
H_2S_3	23.00 bc	2.36 a-d	1.20 de	11.31 b-d
H_2S_4	41.00 a	2.56ab	1.68 ab	9.05cd
H_3S_1	37.60ab	2.42 a-d	1.76 a	9.98cd
H_3S_2	32.60 a-c	2.48 a-c	1.52 a-d	11.77 bc
H_3S_3	20.40 bc	2.32 a-d	1.52a-d	13.73 ab
H_3S_4	20.00 c	2.340a-d	1.36b-e	10.85 b-d
$LSD_{(0.05)}$	17.44	0.43	0.39	3.68
CV (%)	50.49	14.76	21.16	27.61

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

H_0 = Control (water), H_1=Salicylic acid 50 ppm, H_2= GA_3 100 ppm, H_3= Kinetin 500 ppm.S_1=Vegetative stage at 25 DAS, S_2=Flower initiation at 40 DAS, S_3= Pod initiation at 50 DAS and S_4= Flower +Pod initiation at 40 and 50 DAS

4.2. 5.Seed yield (g $plant^{-1}$)

4.2.5.1.Effect of different plant growth regulators application

Yield of soybean varied significantly with plant growth regulators application (Table 8 and Appendix IX).The maximum yield of soybean (4.12 g $plant^{-1}$) was recorded from salicylic acid (H_1)which was statistically similar (4.09 g $plant^{-1}$ andGA_3 100 ppm (3.52 g $plant^{-1}$) with kinetin 500 ppmwhereas, the minimum (2.38 g $plant^{-1}$) was recorded from control (H_0). Salicylic acid increased seed yield 73% over control. Yield obviously is the ultimate goal in growing any crop. Thus, the economic importance of plant growth regulators is their ability to increase crop yields. Kumar *et al*. (1999) reported that the foliar application of salicylic acid to soybean enhanced yield. Similar results were recorded with Salicylic acid by Hayat *et al.* (2005).It was reported that salicylic acid application promotes cell division and cell enlargement.

4.2.5.2. Effect of stages of application

Different stages of application also influenced significantly the yield of soybean (Table 9 and Appendix IX).The maximum yield of soybean (4.54g plant^{-1}) was obtained from flower + pod initiation stage (S_4) which was statistically similar to S_1 and S_2 while the minimum (2.87g plant^{-1}) was obtained from pod initiation stage (S_3). Devi *et al.* (2011) observed that yield of soybean increased by the application of 50 ppm salicylic acid at flower+ pod initiation stage. These findings also correlate the above mentioned findings. The increased yield might be due to enhanced yield attributes like number of pods plant^{-1}, number of seeds pod^{-1} due to increased uptake of plant growth regulators by soybean by effective translocation of plant growth regulators from sink to reproductive area of crop.

4.2.5.3. Interaction effect of different plant growth regulators and stages of application

Interaction effect of plant growth regulators and stages of application had significant effect on yield of soybean (Table 10 and Appendix IX). Numerically the maximum yield of soybean (6.38g plant^{-1}) was recorded from H_1S_4 treatment combination which was statistically similar toH_2S_1, H_2S_4, H_3S_1, H_3S_2, and H_3S_4 whereas, the minimum (1.87 g plant^{-1}) was recorded from H_0S_1 treatment combination.

4.2.6. Stover yield (g plant^{-1})

4.2.6.1. Effect of different plant growth regulators application

Stover yield of soybean had no significant effect on plant growth regulators application (Table 8 and Appendix IX). Numerically the maximum Stover yield of soybean (6.39 g plant^{-1}) was recorded from kinetin (H_3) whereas, the minimum(5.32 g plant^{-1}) was recorded from GA_3 (H_2).

4.2.6.2.Effect of stages of application

Different stages of application also influenced significantly the Stover yield of soybean (Table 9 and Appendix IX).The maximum stover yield of soybean (6.46g plant^{-1}) was obtained from vegetative stage (S_1) which was statistically similar to S_2 and S_3 while the minimum (5.15g plant^{-1}) was obtained from flower + pod initiation stage (S_4).

4.2.6.3. Interaction effect of different plant growth regulators and stages of application

Interaction effect of plant growth regulators and stages of application had significant effect on yield of soybean (Table 10 and Appendix IX). The maximum Stover yield of soybean (6.92g plant^{-1}) was recorded from H_0S_1 treatment combination which was statistically similar with all treatment combination except one, which was the lowest stover yield produce(4.48 g piant^{-1})H_2S_4.

4.2.7.Biological yield (g plant^{-1})

4.2.7.1. Effect of different plant growth regulators application

Biological yield of soybean had non-significant effect on plant growth regulators application (Table 8 and Appendix IX). Numerically the maximum biological yield of soybean (10.48 g plant^{-1}) was recorded from kinetin (H_3) whereas, the minimum (8.85g plant^{-1}) was recorded from GA_3 (H_2). Copur*et al.* (2010) assessed significantly biological yield was recorded in all the concentrations of NAA followed by GA_3 and Kinetin.

4.2.7.2. Effect of stages of application

Different stages of application had non- significant effect on the biological yield of soybean (Table 9 and Appendix IX). Numerically the maximum biological yield of soybean (10.02 g plant^{-1}) was obtained from vegetative stage

(S_1) whereas, the minimum (8.96g plant^{-1}) was recorded from flower initiation stage (S_2).

4.2.7.3. Interaction effect of different plant growth regulators and stages of application

Interaction effect of plant growth regulators and stages of application had significant effect on biological yield of soybean (Table 10 and Appendix IX).The maximum biological yield of soybean(11.10g plant^{-1}) was recorded from H_1S_4 treatment combination which was statistically similar with all treatment combination except H_2S_2 (7.05g plant^{-1}) .

4.2.8. Harvest index(%)

4.2.8.1. Effect of different plant growth regulators application

Harvest index of soybean had significant effect on plant growth regulators application (Table 8 and Appendix IX).The maximum harvest index of soybean (39.06 %) was recorded from salicylic acid (H_1) whereas, the minimum (26.51%) was recorded from control water (H_0). Salicylic acid increased harvest index 40% over control. Harvest index was increased due to spraying the plants with plant growth regulators as compared to control.

Table 8. Effect of different plant growth regulators on yield contributing characters of soybean (cv. BARI Soybean-6)

Treatment	Seed yield (g plant^{-1})	Stover yield (g plant^{-1})	Biological yield(g plant^{-1})	Harvest index (%)
H_0	2.38 b	6.34	8.95	26.51 b
H_1	4.12 a	5.63	9.73	39.06 a
H_2	3.52 ab	5.32	8.85	37.19 a
H_3	4.09 a	6.39	10.48	37.27 a
LSD $_{(0.05)}$	1.40	ns	ns	8.35
CV (%)	62.68	32.18	33.38	37.72

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability.

H_0 = Control (water), H_1 = Salicylic acid 50 ppm, H_2 = GA_3 100 ppm, H_3 = Kinetin 500 ppm
ns = non-significant.

4.2.8.2. Effect of stages application

Different stages of application also influenced significantly the harvest index of soybean (Table 9 and Appendix IX).The maximum harvest index of soybean (43.42 %) was obtained from S_4 which was significantly varied with other treatment *i. e*different stages of application. The minimum harvest index was recorded in S_3 stage application. On the otherhand S_1 and S_2 were statistically similar.

Table 9. Effect of stages of application on yield contributing characters of soybean (cv. BARI Soybean-6)

Treatment	Seed yield (g plant^{-1})	Stover yield (g plant^{-1})	Biological yield (g plant^{-1})	Harvest index (%)
S_1	3.54 ab	6.46 a	10.02	33.81 b
S_2	3.15 ab	5.82 ab	8.96	33.18 b
S_3	2.87 b	6.24 ab	9.34	29.61 c
S_4	4.54 a	5.15 b	9.69	43.42 a
LSD $_{(0.05)}$	1.40	1.20	ns	8.35
CV (%)	62.68	32.18	33.38	37.72

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

S_1= Vegetative stage at 25 DAS, S_2 = Flower initiation at 40 DAS, S_3 = Pod initiation at 50 DAS and S_4 = Flower +Pod initiation stage at 40 and 50 DAS, ns = non-significant.

4.2.8.3. Interaction effect of different plant growth regulators and stages of application

Interaction effect of plant growth regulators and stages of application had significant effect on harvest index of soybean (Table 10 and Appendix IX).The maximum harvest index of soybean(52.76 %) was recorded from H_1S_4 treatment combination which was statistically similar to H_0S_3, H_0S_4, H_1S_1,

H_1S_2, H_2S_1, H_2S_4, H_3S_1 and H_3S_2 whereas, the minimum (21.85%) was recorded from H_0S_1 treatment combination.

Table 10.Interaction effect of different hormone and stages of application on yield contributing characters of soybean

Treatment combination	Seed yield (g plant^{-1})	Stover yield (g plant^{-1})	Biological yield (g plant^{-1})	Harvest index (%)
H_0S_1	1.87c	6.92a	8.79 ab	21.85 c
H_0S_2	1.83c	6.30ab	8.16 ab	22.11 c
H_0S_3	2.90bc	6.64ab	10.44 ab	28.41 bc
H_0S_4	2.92bc	5.50ab	8.43 ab	33.67 bc
H_1S_1	3.30bc	6.83ab	10.14 ab	30.77 bc
H_1S_2	3.58bc	5.96 ab	9.48 ab	37.07 a-c
H_1S_3	3.21bc	5.00ab	8.22 ab	35.78 bc
H_1S_4	6.38a	4.71ab	11.10 a	52.76 a
H_2S_1	4.52a-c	5.42ab	9.94 ab	42.62 ab
H_2S_2	2.48bc	4.57ab	7.05 b	31.46 bc
H_2S_3	2.16bc	6.80 ab	8.97 ab	21.91 c
H_2S_4	4.92ab	4.48b	9.43 ab	52.51 a
H_3S_1	4.50a-c	6.69 ab	11.20 a	39.99 ab
H_3S_2	4.70ab	6.45ab	11.16 a	42.10 ab
H_3S_3	3.21bc	6.53ab	9.74 ab	32.34 bc
H_3S_4	3.93 a-c	5.89 ab	9.82 ab	34.66 bc
LSD $_{(0.05)}$	2.80	2.41	4.01	16.71
CV (%)	62.68	32.18	33.38	37.72

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probabilityH_0 = Control (water),

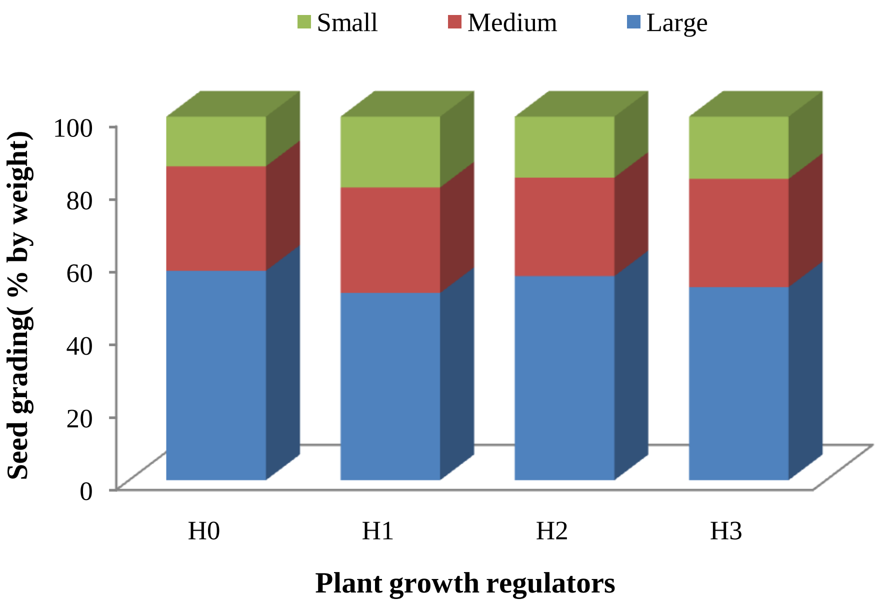
H_1=Salicylic acid 50 ppm, H_2= GA_3 100 ppm, H_3= Kinetin 500 ppm S_1=Vegetative stage at 25 DAS, S_2=Flower initiation at 40 DAS, S_3= Pod initiation at 50 DAS and S_4= Flower +Pod initiation at 40 and 50 DAS

4.3. Quality contributing characters

4.3.1.Seed grading (% by weight)

4.3.1.1. Effect of different plant growth regulators application

Plant growth regulators application had no significant effect on percent of large and medium size seed but had significant effect on percent of small size seed (Figure 9 and Appendix X). Figure 9 showed that 51-57% seeds were regarded as large size and 27-29%, 13-19% were medium and small size seed, respectively.



H_0 = Control (water), H_1= Salicylic acid 50 ppm, H_2= GA_3 100 ppm,H_3= Kinetin 500 ppm

Figure 9.Effect of plant growth regulators application on grading of seed (% by weight)

$LSD_{(0.05)}$ = 5.32 at small size seed

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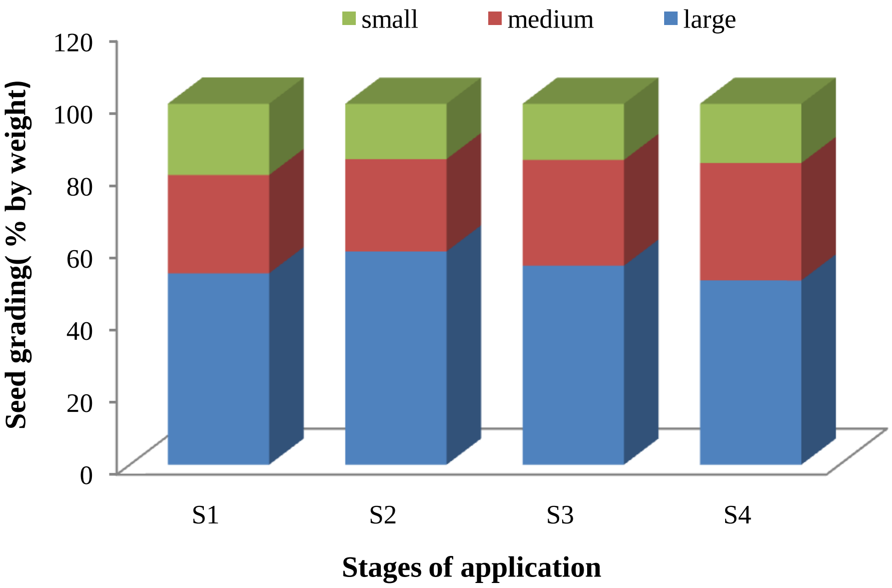
4.3.1.2. Effect of stages of application

Significant amount of large and medium size seed were produced by stages of application but in case of small size seed there was no significant effect (Figure 10 and Appendix X). Among the stages of application 59.09% larger seed produced by flower initiation stage (S_2). Vegetative (S_1) and pod initiation (S_3) also showed the statistically similar result. Among the plant growth regulators application 32.53% medium seed produced by flower + pod initiation stage (S_4). Vegetative (S_1) and pod initiation (S_3) also showed the statistically similar result in case of small size seed (19.15%).



S_1=Vegetative stage at 25 DAS, S_2=Flower initiation at 40 DAS, S_3= Pod initiation at 50 DAS and S_4= Flower +Pod initiation at 40 and 50 DAS

Figure 10. Effect of stages of application on grading of seed (% by weight)

$LSD_{(0.05)}$= 7.78 and 5.76 at large and medium size seed

4.3.1.3. Interaction effect of different plant growth regulators and stages of application

Plant growth regulators application had significant effect on different seeds size (large, medium and small size) (Table. 11 and Appendix X).In case of large size seed, the highest grade of seed (65.43%) was produced by the combination of GA_3 and flower initiation stage which was statistically similar to H_0S_1, H_0S_2, H_0S_3, H_0S_4, H_1S_1, H_1S_3, H_1S_4, H_2S_1, H_2S_3, H_3S_2 and H_3S_3 and the lowest (43.46%) from the combination of H_2S_4.In case of medium, the highest grade of seed (34.42%) was produced by the combination of control and flower + pod initiation stage, which was statistically similar to H_0S_1, H_0S_2, H_0S_3, H_1S_1, H_1S_2, H_1S_3, H_1S_4, H_2S_1, H_2S_3, H_2S_4, H_3S_1, H_3S_2, H_3S_3 and H_3S_4 and lowest (21.84%) was produced by GA_3 treatment, which was followed by flower initiation stage. In case of small size seed, highest grade of seed (24.26%) was produced by the combination of GA_3 and flower + pod initiation stage, which was statistically similar to H_0S_1, H_0S_2, H_0S_3, H_1S_1, H_1S_2, H_1S_3, H_1S_4, H_2S_1, H_3S_1, H_3S_2, H_3S_3 and

H_3S_4 whereas, lowest (7.76%) was produced from combination of control and flower + pod initiation stage.

Table 11. Interaction effect of different plant growth regulators and stages of application on seed grading (% by weight) of soybean (cv. BARI Soybean-6)

Treatment combination	Seed grading (% by weight)		
	Large	**Medium**	**Small**
H_0S_1	54.41 a-d	27.99ab	17.60 a-c
H_0S_2	62.35 ab	24.13 ab	13.52 bc
H_0S_3	55.81 a-d	28.46 ab	15.73 a-c
H_0S_4	57.82 a-d	34.42 a	7.766 c
H_1S_1	52.80 a-d	25.40 ab	21.80 ab
H_1S_2	49.01 b-d	29.71 ab	21.28 ab
H_1S_3	50.12 a-d	29.40 ab	20.49 ab
H_1S_4	54.08 a-d	31.62 ab	14.30 a-c
H_2S_1	58.90 a-d	23.11 ab	17.99 a-c
H_2S_2	65.43 a	21.84 b	12.73 bc
H_2S_3	56.72 a-d	31.16ab	12.11 bc
H_2S_4	43.46 d	32.28 ab	24.26 a
H_3S_1	46.03 cd	32.45 ab	21.52 ab
H_3S_2	59.56 a-c	26.70ab	13.74 a-c
H_3S_3	57.94a-d	28.13 ab	13.92 a-c
H_3S_4	48.89 b-d	31.81 ab	19.30 ab
$LSD_{(0.05)}$	15.57	11.53	10.65
CV (%)	22.54	31.80	50.25

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

H_0 = Control (water), H_1 = Salicylic acid 50 ppm, H_2 = GA_3 100ppm, H_3 = Kinetin 500ppm
S_1 = Vegetative stage at 25 DAS, S_2 = Flower initiation at 40 DAS, S_3 = Pod initiation at 50 DAS and S_4 = Flower +Pod initiation at 40 and 50 DAS

4.3.2. Protein percentage

4.3.2.1. Effect of different plant growth regulators application

Plant growth regulators application had significant effect on protein percentage of soybean (Table 12 and Appendix XI).The maximum protein percentage of soybean seed (44.56%) was recorded from salicylic acid (H_1)whereas, the minimum (42.29%) was obtained from control (H_0). Khodary (2004) indicated that salicylic acid can enhance the protein percentage of soybean.

Table 12.Effect of different plant growth regulators on protein and moisture percentage of soybean (cv. BARI Soybean -6)

Treatment	Protein (%)	Moisture (%)
H_0	42.29 c	13.73 a
H_1	44.56 a	12.91 b
H_2	43.88 b	11.70 c
H_3	43.89 b	12.88 b
LSD $_{(0.05)}$	0.63	0.30
CV (%)	2.30	3.75

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

H_0 = Control (water), H_1 = Salicylic acid 50 ppm, H_2 = GA_3 100ppm, H_3 = Kinetin 500ppm

4.3.2.2. Effect of stages of application

Different stages of application also influenced significantly the protein percentage of soybean (Table 13 and Appendix XI).The maximum protein percentage of soybean (44.31%) was obtained from flower + pod initiation stage (S_4) while the minimum (43.35%) was obtained from vegetative stage (S_1).

4.3.2.3. Interaction effect of different plant growth regulators and stages of application

Interaction effect of plant growth regulators and stages of application had significant effect on protein percentage of soybean (Table14 and Appendix XI). The maximum protein percentage of soybean (45.02%) was recorded from H_1S_2 treatment which was statistically similar toH_1S_1, H_1S_2, H_1S_3, H_1S_4, H_2S_2, H_3S_1, H_3S_3 and H_3S_4 whereas, the minimum (41.53%) was obtained from H_0S_1 treatment combination.

4. 3.3. Moisture percentage

4.3.3.1. Effect of different plant growth regulators application

Moisture percentage of soybean varied significantly due to various treatment of plant growth regulators application (Table 12 and Appendix XI).The maximum moisture percentage of soybean (13.73%) was recorded from control (H_0)whereas, the minimum (11.70 %) was recorded from GA_3 (H_2).

4.3.3.2. Effect of stages of application

Stages of application had significant effect on moisture percentage of soybean. (Table 13 and Appendix XI).The maximum moisture percentage of soybean (13.50%) was recorded from pod initiation stage (S_3)whereas, the minimum (12.38%) was obtained from vegetative stage (S_1).

Table 13. Effect of stages of application on protein and moisture of soybean (cv. BARI Soybean-6)

Treatment	Protein (%)	Moisture (%)
S_1	43.35 b	12.38 c
S_2	43.54 b	12.71 b
S_3	43.42 b	13.50 a
S_4	44.31 a	12.63 bc
$LSD_{(0.05)}$	0.63	0.30
CV (%)	2.30	3.75

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

S_1= Vegetative stage at 25 DAS, S_2 = Flower initiation at 40 DAS, S_3 = Pod initiation at 50 DAS and S_4 = Flower +Pod initiation stage at 40 and 50 DAS

4.3.3.3. Interaction effect of different plant growth regulators and stages of application

Interaction effect of plant growth regulators and stages of application had significant effect on moisture percentage of soybean (Table 14 and Appendix XI). The maximum moisture content of soybean seed (14.68%) was recorded from H_1S_3 treatment combination whereas, the minimum (10.61 %) was observed from H_2S_1 treatment combination.

Table 14. Interaction effect of different hormone and stages of application on protein and moisture of soybean (cv. BARI Soybean-6)

Treatment Combination	Protein (%)	Moisture (%)
H_0S_1	41.53 f	13.33 b-d
H_0S_2	42.20 ef	13.54bc
H_0S_3	41.87 ef	13.55 b
H_0S_4	43.58 b-d	13.35 b-d
H_1S_1	44.41 ab	12.65 ef
H_1S_2	45.02 a	12.50 e-g
H_1S_3	44.44 ab	14.68 a
H_1S_4	44.35 a-c	12.94 c-e
H_2S_1	43.52 b-d	10.61 h
H_2S_2	43.93 a-d	10.90 h
H_2S_3	43.11 c-e	13.34 b-d
H_2S_4	44.95a	11.95 g
H_3S_1	43.94 a-d	12.93 c-e
H_3S_2	43.00 de	12.78 d-f
H_3S_3	44.25a-d	13.55 b
H_3S_4	44.35 a-c	12.27 fg
$LSD_{(0.05)}$	1.27	0.60
CV (%)	2.30	3.75

In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly as per 0.05 level of probability

H_0 = Control (water), H_1 = Salicylic acid 50 ppm, H_2 = GA_3 100ppm, H_3 = Kinetin 500ppm) S_1 = Vegetative stage at 25 DAS, S_2 = Flower initiation at 40 DAS, S_3 = Pod initiation at 50 DAS and S_4 = Flower +Pod initiation at 40 and 50 DAS

Chapter 5

Summary and conclusion

CHAPTER V

SUMMARY AND CONCLUSION

A pot experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during November, 2013 to March, 2014 with a view to find out the influence of different plant growth regulators and stages of application on the growth, yield and quality of soybean cv., BARI Soybean-6 under the Modhupur Tract (AEZ-28). Two factor experiment included 4 *viz.,* control (H_0), Salicylic acid 50 ppm (H_1), GA_3 100 ppm (H_2), Kinetin 500 ppm (H_3) and four stages of application treatments *i.e.*, vegetative stage (S_1) at 25 DAS, flower initiation stage (S_2) at 40 DAS, Pod initiation stage (S_3) at 50 DAS and flower + pod initiation stage (S_4) at 40 and 50 DAS was outlined in a Randomized Complete Block Design (RCBD) with five replications. Total numbers of pots were 80. There were 16treatment combinations. The data on crop growth characters like plant height, number of branches plant^{-1}, chlorophyll content (SPAD value), average length of internode were recorded at different growth stages. Yield and quality contributing parameters like, number of pods plant^{-1}, pod length, number of seeds pod^{-1}, 100-seed weight, seed yield, stover yield, biological yield, harvest index, seed grading (% by weight), protein and moisture percentage were recorded after harvest. Data were analyzed using MSTAT-C computerized package program. The mean differences among the treatments were compared by Least Significance Difference (LSD) at 5% level of significance.

Results showed that plant growth regulators of soybean had significant effect on most of the growth, yield and quality parameters except pod length, no of pods plant^{-1}, stover yield and biological yield. Salicylic acid performed best result in case of number of branches plant^{-1} at harvest, chlorophyll content (SPAD value) at 60 and 75 DAS, number of seeds plant^{-1}, small seed grading (% by weight), seed yield (g plant^{-1}), harvest index, protein of BARI soybean-6) and lowest plant height from 30 DAS, minimum number of branches plant^{-1} from 60DAS, chlorophyll content (SPAD value) at 30 and 45 DAS.

GA_3performed best result in case of plant height 45 DAS to at harvest, number of branches plant^{-1} at 45 and 75 DAS, chlorophyll content (SPAD value) at 45 DAS, average length of internode from 30 DAS to 75 DAS and minimum number of branches at harvest, lowest stover and lowest biological, seed yield. Kinetin produced the smallest plant height from 45 DAS to 60 DAS, medium seed grading (% by weight), number of branches plant^{-1} at 45 DAS, Chlorophyll content (SPAD value) at 60 DAS, average length of internode at 30, 60 and 75 DAS and highest 100- seeds weight, stover yield and biological yield. Control(water)of BARI Soybean-6 adversely affect the growth, yield and yield contributing characters which showed the lowest plant height at 45, 60, 90 DAS and at harvest, number of branches plant^{-1} at 90 DAS, number of pods plant^{-1}, pod length, number of seeds pod^{-1}, 100-seed weight, seed yield and harvest index.

Stages of application also significantly influenced the growth, yield and Quality contributing attributes except plant height at 30 DAS. Vegetative stage produced tallest plant height from 45 DAS to at harvest, minimum number of branches plant^{-1} from 45 to 75 DAS, lowest chlorophyll content from 60 to 75 DAS, highest average length of internode from 30 DAS to 75 DAS, minimum pod length, minimum number of seeds pod^{-1}, highest stover and biological yield. Flower initiation stage produced smallest plant height from 30 DAS to at harvest, maximum number of branches plant^{-1} at 45 DAS, minimum number of branches plant^{-1} at 90 DAS and at harvest, maximum chlorophyll content from 30 and 75 DAS, lowest average length of internode from 45 DAS to 75 DAS and lowest 100 seed weight. Pod initiation stage produced maximum number of branches plant^{-1} at 60 DAS and 90 DAS, maximum chlorophyll content from 30 and 60 DAS, large seed grading (% by weight), minimum chlorophyll content from 45 DAS, lowest average length of internode from 30 DAS, minimum number of pod plant^{-1}, highest pod length, minimum seed yield and lowest harvest index. Flower + Pod initiation stage produced smallest plant height, maximum number of branches plant^{-1} at 75 DAS and at harvest, maximum chlorophyll content from 45DAS, minimum chlorophyll content from 30 DAS, maximum number of seed pod^{-1}, maximum 100-seed weight, maximum seed yield, highest protein percentage and highest harvest index. Interaction effect of plant growth regulators and stages of application also significantly affected growth, yield and quality of soybean. The tallest plant at 30 DAS, biological yield, lowest seed yield was found from control (water) with vegetative stage. The tallest plant at 45 DAS to at harvest, maximum number of average length of internode, lowest moisture content in seed and lowest protein content in seed was found from GA_3 with vegetative stage. Maximum number of pods plant^{-1}obtained from GA_3 with flower + pod initiation stage. Salicylic acid with flower initiation stage produced maximum number of pod length and maximum protein percentage. Salicylic acid with flower + pod initiation stage produced maximum number of branches plant^{-1} at harvest, lowest average length of internode at 75 DAS, maximum number of pod plant^{-1}, 100-seed weight, seed yield and harvest index. Control with flower initiation stage produced minimum seed yield, number of branches plant^{-1} at harvest, minimum chlorophyll content from 30 DAS. Salicylic acid with vegetative stage produced minimum number of branches plant^{-1} from 45 DAS to 60 DAS. Maximum number of branches plant^{-1}60 DAS to 75 DAS, maximum chlorophyll content from 30 DAS, lowest average length of internode at 45 DAS was obtained from Kinetin with flower initiation stage.

Based on the result of present experiment, the following conclusion can be drawn:

1. Among the different plant growth regulators salicylic acid 50 ppm increased seed yield 73%, GA_3 100 ppm 47% and kinetin 500 ppm 71% over control. But in case of 100-seed weight kinetin performed the best.

2. Among the stages of application flower + pod initiation stage at 40 DAS and 50DAS produced highest seed yield, irrespective of plant growth regulators.

3. Among the treatment combinations, application of salicylic acid (50 ppm) at flower + pod initiation stage would be promising practice for soybean yield and quality.

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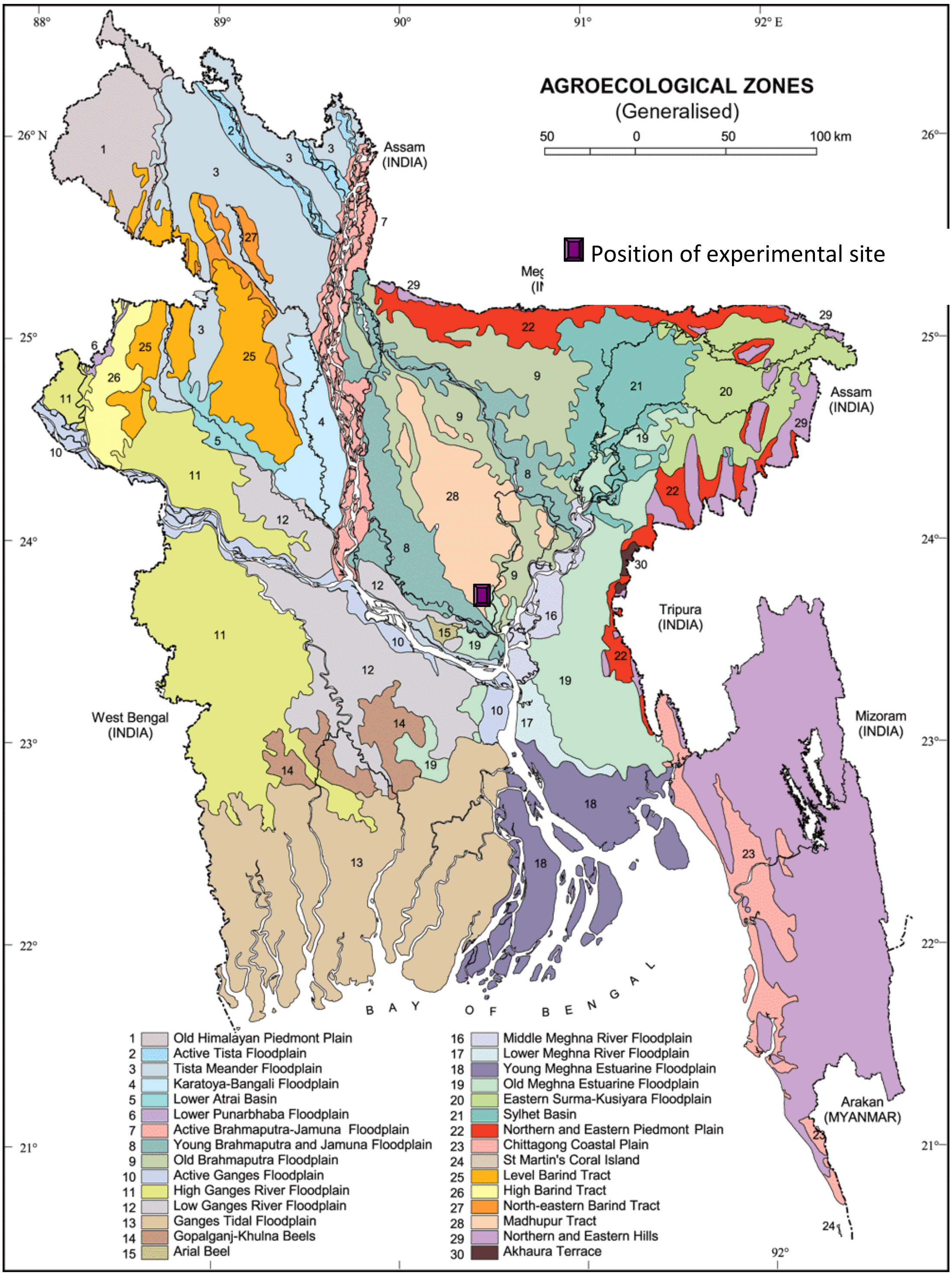
Appendices

APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. Weather data, 2013-2014, Dhaka

Month	Average Relative Humidity (%)	Average Temperature (°C)		Total Rainfall (mm)
		Minimum	Maximum	
November	58.18	6.88	28.10	1.56
December	54.30	5.21	25.36	0.63
January	64.02	15.46	21.17	0.00
February	53.07	19.12	24.30	2.34
March	48.66	22.37	29.78	0.12

Source: Bangladesh Meteorological Department (Climate division), Agargaon, Dhaka-1207.

Appendix III: Methods of analysis

Texture	**Hydrometer methods**
pH	Ptentiometric method
Organic carbon	Walkely-Black method
Total N	Modified kjeldhal method
Soluble P	Olson method(NAHCO^{3}
Exchangeable K	Flame photometer method (Ammonium)

Result obtained from the mechanical analysis of the initial soil sample done in the Soil Resources Development Institute (SRDI), Dhaka.

Appendix IV. Mean square values forplant height at different days after sowing

Sources of variation	DF	Mean square values					
		30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	At harvest
Replication	**4**	10.108	38.063	65.873	63.972	198.458	127.539
Plant growth regulators Application(H)	**3**	1.518^{ns}	448.233*	632.317*	965.630*	1432.153*	600.953*
Stages of application(S)	**3**	3.770^{ns}	193.633*	267.265*	136.523*	172.235*	208.787*
H ×S	**9**	4.753*	283.000*	247.240*	186.533*	315.904*	389.562*
Error	**60**	179.075	26.536	60.774	63.190	66.311	86.470

*Significant at 5 % level

ns- non significant

Appendix V. Mean square values fornumber of branches plant^{-1}at different days after sowing

Sources of variation	DF	Mean square values				
		45 DAS	**60 DAS**	**75DAS**	**90 DAS**	**At harvest**
Replication	**4**	10.019	4.419	9.394	4.419	8.300
Plant growth regulators Application(H)	**3**	2.479^{ns}	6.546^{ns}	8.083*	6.546*	3.813ns
Stages of application(S)	**3**	1.646^{ns}	2.846^{ns}	0.317^{ns}	2.846^{ns}	6.779*
H ×S	**9**	2.679*	1.601*	4.394*	1.601*	3.246*
Error	**60**	2.639	3.779	2.494	3.779	3.320

*Significant at 5 % level

ns- non significant

Appendix VI. Mean square values forChlorophyll content at different days after sowing

Sources of variation	DF	Mean square values			
		30 DAS	45DAS	60 DAS	75 DAS
Replication	4	29.659	101.315	127.153	75.125
Plant growth regulators Application(H)	3	23.707*	28.188	63.631^{ns}	29.888*
Stages of application(S)	3	5.580^{ns}	30.743^{ns}	97.942*	74.961*
H ×S	9	16.311*	13.655*	57.094*	42.502*
Error	60	16.132	22.035	24.592	31.371

*Significant at 5 % level

ns- non significant

Appendix VII. Mean square values for Average length of internode at different days after sowing.

Sources of variation	DF	Mean square values			
		30 DAS	45DAS	60 DAS	75 DAS
Replication	4	0.481	1.125	0.817	4.195
Plant growth regulators Application(H)	3	3.942*	5.295*	8.372*	9.709*
Stages of application(S)	3	3.257*	4.188*	3.080*	2.321*
H ×S	9	1.899*	1.902*	2.820*	5.135*
Error	60	0.326	0.615	1.152	1.900

*Significant at 5 % level

Appendix VIII. Mean square values for number of pods plant^{-1}, pod length, number of seeds pod^{-1},weight of 100- seed of soybean

Sources of variation	DF	Mean square values			
		Number of pods plant^{-1}	Pod length	Number of seeds pod^{-1}	Weight of 100-seed
Replication	4	289.644	0.136	0.031	18.432
Plant growth regulatorsapplication(H)	3	174.683^{ns}	0.096^{ns}	0.346*	14.750*
Stages of application(S)	3	59.017^{ns}	0.244*	0.065^{ns}	26.631*
H ×S	9	268.539*	0.120*	0.226*	27.437*
Error	60	189.790	0.120	0.097	8.468

*Significant at 5 % level

ns - non significant

Appendix IX. Mean square values for Seed yield, stover yield, biological yield ,harvest index of soybean

Sources of variation	DF	Mean square values			
		Seed yield	Stover yield	Biological yield	Harvest index
Replication	4	11.242	4.762	10.071	596.653
Plant growth regulators Application(H)	3	13.192 *	5.638^{ns}	11.565^{ns}	656.548*
Stages of application(S)	3	10.609 *	6.735 ^{ns}	4.095^{ns}	698.241*
H ×S	9	4.934 *	2.069 *	6.536*	302.324*
Error	60	4.912	3.632	10.073	174.379

*Significant at 5 % level

ns- non significant

Appendix X. Mean square values for seed grading (% by weight)of soybean

Sources of variation	DF	Mean square values for seed grading (% by weight)		
		Large	Medium	Small
Replication	4	797.181	259.333	168.420
Plant growth regulators(H)	3	154.444^{ns}	25.552^{ns}	114.115*
Stages of application(S)	3	235.970*	178.639*	83.001 ns
H ×S	9	165.941*	43.197*	101.440*
Error	60	151.423	83.064	70.887

ns- non significant

*Significant at 5 % level

Appendix XI. Mean square values for Protein and Moisture percentage of soybean

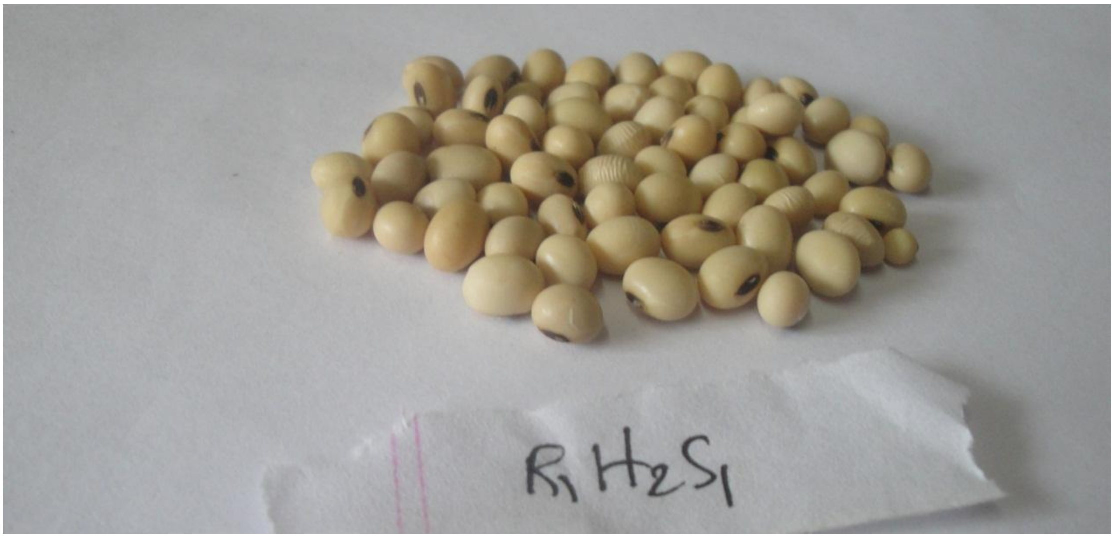
Sources of variation	DF	Mean square values	
		Protein percentage	Moisture percentage
Replication	4	5.614	34.617
Plant growth regulators Application(H)	3	18.428*	13.899*
Stages of application(S)	3	3.936*	4.631*
H ×S	9	1.867*	2.496*
Error	60	1.008	0.231

*Significant at 5 % level

Plate 1: Experimental view

Plate 2 :Germination and Seedling stage of soybean

Plate 3: Plant height at 45 DAS



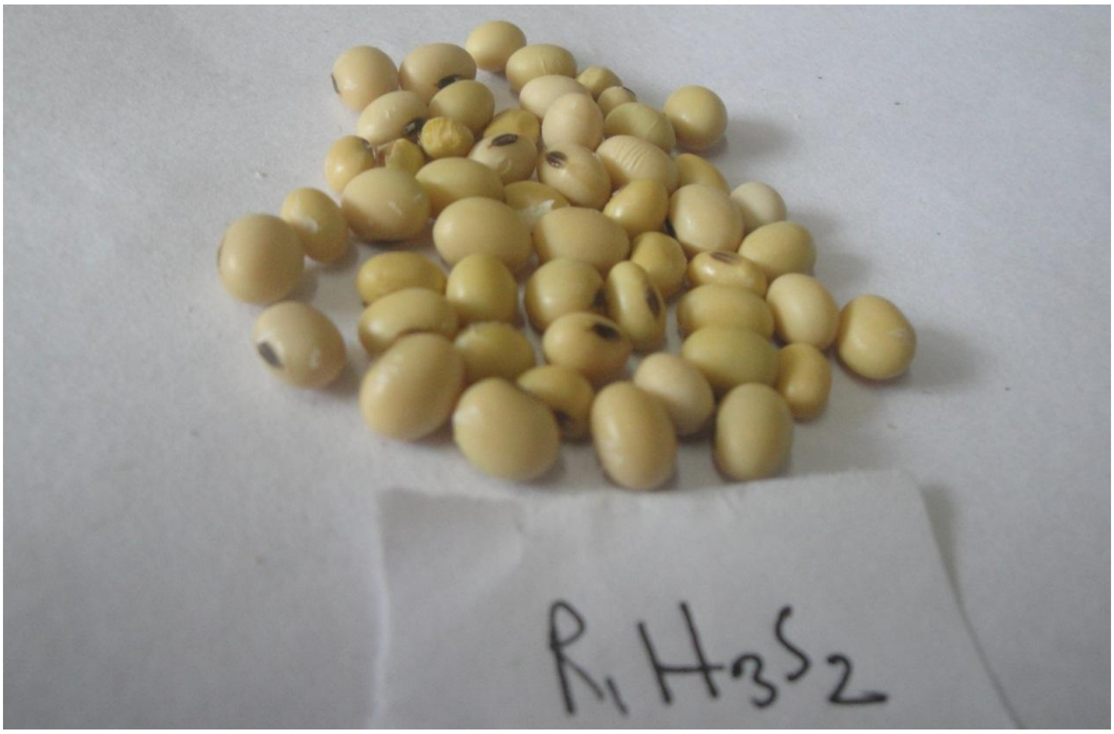


Plate 4: Seeds of soybean