INFLUENCE OF SUPPLEMENTAL AGRONOMIC MANAGEMENT ON GROWTH AND YIELD OF SOYBEAN

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CERTIFICATE

This is to certify that the thesis entitled **'Influence of Supplemental Agronomic Management on Growth and Yield of Soybean'** 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 bonafide research work carried out by **Nidhi Chakma**, Registration number: **09-03377** 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: 31·05·2015
Dhaka, Bangladesh

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DEDICATED

TO

MY BELOVED PARENTS

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The Author

INFLUENCE OF SUPPLEMENTAL AGRONOMIC MANAGEMENT ON GROWTH AND YIELD OF SOYBEAN

ABSTRACT

The experiment was conducted during the period from 14 January, 2014 to 8 May 2014 to study the influence of supplementary agronomic management on growth and yield of soybean. The experiment was carried out by two soybean varieties as V_1: BARI Soybean 5 and V_2: BARI Soybean 6 and six supplementary managements as M_1: Control i.e. Normal cultivation; M_2: Urea spray at flowering; M_3: MoP spray at flowering; M_4: DAP spray at flowering, M_5: Cytokinin spray at flowering and M_6: Water stress at flowering of soybean. The experiment was laid out in split-plot design with three replications. Data on different growth parameters, yield attributes and yield were significantly varied for different parameters. The highest dry weight (17.14g plant^{-1}) and higher pod remaining (36.35 %) was found from the variety BARI Soybean 6 whereas 1000-seed weight (100.41g) and seed yield (1.15 t ha^{-1}) in BARI Soybean 5. The supplemental application of DAP (M_4) at flowering stage resulted higher dry weight plant^{-1} (18.19g) and seeds pod^{-1} (2.42). The highest seed yield was given by supplemental urea spray (1.21 t ha^{-1}) that similar to DAP application (1.18 t ha^{-1}). The highest flower and pod droppings (72.77%) were revealed in V_1M_6 (BARI Soybean 5) with water stress in reproductive phase). Supplemental application of cytokinin and MoP gave the lowest total dropping (59.56% and 60.16% respectively). The BARI Soybean 5 with application of DAP at flowering resulted the highest seed yield (1.48 t ha^{-1}) and stover yield (1.26 t ha^{-1}). The lowest seed yield (0.79 t ha^{-1}) was found in the variety BARI Soybean 6 with water stress during reproductive phase.

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CHAPTER I

INTRODUCTION

Soybean (*Glycine max* L. Merril) is a very important recognized oil seed and protein crop in the world. Soybean plays an important role in supplying oil and protein needed by humans (Agarwal, 2007; Shi and Cai, 2010). Soybean is called "Protein hope of future" for its nutritional value. It contains 40-45 % protein, 18-20 % edible oil, 24-26 % carbohydrate and a good amount of vitamins (Kaul and Das, 1986). The oil produced from soybean grains is highly digestible and contains no cholesterol (Essa and Al-Ani, 2001). Soybean accounts for approximately 50 % of the total production of oilseed crops in the world (FAO, 2007). The multipurpose use of soybean is gradually increasing day by day in our country.

Almost all soybeans used in Bangladesh are imported. In Bangladesh the total demand for edible oil is around 1.3 million ton per year of which less than 0.2 million ton comes from mustard while the rest is met with imported soybean oil and palm oil. In the 2009-10, soybean was grown in around 50,000 ha of land with an average yield of 1.5 t/ha in Bangladesh (Pradhan *et al.*, 2013).

As a grain legume, it is gaining important position in the agriculture of tropical countries including Bangladesh. Now, soybean producing areas in Bangladesh are Barisal, Bhola, Faridpur, Patuakhali, Meherpur, Jessore, Rangpur, Kurigram, Thakurgaon, Tangail, Mymensingh, Jamalpur, Chandpur, Feni, Noakhali and Laxmipur (Chowdhury *et al.*, 2013). Soybean production area is increasing day by day and in the year 2013 it reaches above 61000 ha. The average yield of soybean in the world is about 3.0 t ha-1 while in Bangladesh, it is only 1.2 t ha^{-1} (SAIC, 2007). Farmers of this area generally grow local variety of soybean with no or limited application of fertilizer. For this reason, the yield of soybean in this region is much below than that of potential yield level. Experimental evidences reveal that the crop is highly responsive to different fertilizers and its yield can be increased remarkably through the judicious fertilization (BARI, 1988; Mohamed, 1984; Roy and Singh, 1986; Kazi *et al.*, 2002).

Soybean is known to be highly nitrogen demanding crop, since the end product is very rich in protein. Soybean meets its nitrogen needs by both N_2 fixation and soil nitrate absorption. The amount of atmospheric N_2 fixed by soybean crop varies widely. Typical values are about 100-175 kg N per ha, which represents about 50 % of crop needs (Harper, 1999). On an average, 50-60% of soybean N demand was met by biological nitrogen fixation. In most situations the amount of nitrogen fixed was not sufficient to replace N export from the field in harvested seed. The gap between crop N uptake and N supplied by N_2 fixation (BNF) tended to increase higher seed yields for which associated crop N demand is higher (Salvagiotti *et al.*, 2008).

Diammonium phosphate (DAP) is widely used phosphorus fertilizer, containing 18% N_2 and 46% P_2O_5. Phosphorus deficiency can limit nodulation, growth and yield of soybean and phosphorus fertilizer application can overcome the deficiency (Carsky *et al.*, 2001, Kumaga and Ofori, 2004).

Potassium is one of the three major essential nutrient elements required by plants. Unlike nitrogen and phosphorus, potassium does not form bonds with carbon or oxygen, so it never becomes a part of protein and other organic compounds (Hoeft *et al.*, 2000). Although K is not a constituent of any plant structures or compounds, it is involved in nearly all processes needed to sustain the plant life. It is known to help crop to perform better under water stress. Young seedlings of soybean do not use much potassium, but the rate of uptake climbs to a peak during the period of rapid vegetative growth. The potassium in vegetative parts is transferred to seed during pod fill process. The mature soybean seed contains nearly 60% of the total K in plant (Hoeft *et al.*, 2000). It is to be noted that on weight basis, soybean seed contains more than twice as much potassium as corn grain.

Limitation of source and plant growth regulators (PGR's) or hormone may also responsible for lower yield. Plant growth regulators (PGR's) are organic compounds, which in small amounts, somehow modify a given physiological plant process. It plays an essential role in many aspects of plant growth and development (Patil *et al.*, 1987 and Dharmender *et al.*, 1996). Cytokinin is a growth regulator plays a role in regulating flower and pod development in soybeans (Reese *et al.*, 1995). So it could be assumed that cytokinin increase pod yield by stimulating flower production.

Water deficiency has adverse effects on plant growth, average yield and crude protein in legume crops. Ghassemi-Golezani and Lotfi (2012) reported that soybean is a sensitive crop to water stress at reproductive stages. Water disruption during flowering and grain filling stages can lead to severe loss in yield and yield components of soybean cultivars.

Objectives:

The experiment was conducted with supplementary urea, MoP, DAP, cytokinin spray and water stress at flowering with the following objectives:

- To study the varietal responses of soybean towards different agronomic management practices
- To study the effect of agronomic management on growth, flower and pod droppings and yield of different soybean varieties
- To find out the interaction of variety and management effects on growth and yield of soybean

Chapter II

Review of Literature

CHAPTER II
REVIEW OF LITERATURE

Soybeans (*Glycine max*) serve as one of the most valuable crops in the world, not only as an oil seed crop and feed for livestock and aquaculture, but also as a good source of protein for the human diet and as a biofuel feedstock. Despite suitable climatic and edaphic conditions, the yield of soybean is very low in Bangladesh. The lower yield at farmer's level is attributed to the poor agronomic management practices and also due to use of low quality seed (Rahman and Islam, 2006). Planting of low quality seeds results in poor seedling emergence and non uniform plant establishment. Moreover, unavailability of quality seeds is also a cause of limited adoption of the crop. However, researches are going on in home and abroad to maximize the yield of soybean with different cultivars. Here, some of the important and informative works and research findings related to the variety and supplementary managements (e.g., urea spray, MoP spray, DAP spray, cytokinin spray and water stress at flowering) so far been done at home and abroad have been reviewed in this chapter under the following headings-

2.1 Effect of varietal performance of soybean in relation to growth and yield

An experiment was conducted by Rahman *et al*. (2013) to investigate the effect of row spacing and cultivars on the growth and yield of soybean. Three soybean cultivars: (1) Bangladesh Soybean-4 (G- 2), (2) BARI soybean -5 (BS-5) and (3) Shohag (PB-1) and four row spacing, (1) 20 cm, (2) 30 cm, (3) 40 cm and (4) 50 cm were used in the experiment in a split-plot design with row spacing in the main plot and cultivars in the sub-plot. The highest seed yield was obtained from 20 cm spacing and yield decreased with increased spacing irrespective of cultivars. Among cultivars the highest yield was given by cultivar BS-5 which was followed by PB-1. It was concluded that the soybean cultivars BS-5 and PB-1 could be selected for sowing in *Kharif-II* season and should be planted at 20 cm a part rows for achieving higher yield.

To study effect of nitrogen fertilization and variety on soybean leaf senescence and crop yield an experiment was conducted by Golparvar *et al.* (2012) in Iran. The treatments were two soybean cultivars (L_{17} and Zan), nitrogen fertilizer (urea and ammonium nitrate) and rate of nitrogen (15, 25 and 35 kg ha^{-1}). Seed yield in cv. L_{17} treated with nitrate ammonium and cv. Zan treated with urea could be increased up to 6700 and 5100 kg ha^{-1}, respectively.

To evaluate the effect of cow dung and poultry manure with chemical fertilizer on the yield and quality of soybean cv. BINA soybean-2 Khaim *et al.* (2013) conducted an experiment. The overall finding of this study indicated that organic manure in combination with the recommended dose of chemical fertilizers can be applied to achieve better yield and quality of soybean as well as to improve soil fertility status.

To study the effect of planting dates on agronomical and physiological features of some soybean varieties, Zargar *et al.* (2011) conducted an experiment. Treatments included four planting dates with four soybean varieties. The results indicated that the effect of treatments and interactions significantly affected all traits; the only exception was pod shell weight which showed no response to the interaction of planting date × variety.

Kocjan Ačko and Trdan (2009) observed that the field trials with ten soybean cultivars in the period from 2001 to 2005 show important differences in productivity of the cultivars when sown to 50 cm row spacing (wide rows) compared to the row spacing of 25 cm (narrow rows), in the length of the growing period of individual cultivars and also the differences between individual years were detected.

Biabani *et al.* (2008) was carried out a field study to assess whether intercropping of two commonly used cultivars of soybean with different morphological characteristics may increase seed yield in Iran. The results indicated that the highest seed yield was obtained from 50:50 ratios of the cultivars which had land equivalent ratio (LER) above 1.11.

Mabapa *et al.* (2010) carried out an experiment to assess the effects of phosphorus (P) rates on the growth and yield of three soybean cultivars. The experiments consisted of a factorial combination of P fertilizer rates (0, 30 and 60 kg P ha-1) and soybean cultivars (Pan 520RR, Highveld Top, and LS 555). P did not affect crop biomass at harvest maturity but the effect of cultivar was significant (P = 0.01); LS 555 had lower grain yield (701 kg ha^{-1}) compared with Pan 520RR (1457 kg ha-1) and Highveld Top (1241 kg ha^{-1}).

Ghassemi-Golezani and Lotfi (2013) conducted an experiment to investigate the effects of different irrigation treatments on oil and protein content of three soybean cultivars. The results showed that with increasing water stress at reproductive stages protein percentage was increased, but oil percentage was decreased. Grain yield and protein and oil amounts per grain and yields per unit area were also decreased as a consequence of water limitation.

Kobraee *et al.* (2011) conducted an experiment to investigate the effects of water stress on production of soybean cultivars, Main plot treatments consisted of four different irrigation regime and sub plot treatments were four cultivars. Analysis of variance showed that Grain yield, biological yield, number of pod, seed and 100-seed weight per main stem, sub stem and plant was significantly affected by irrigation regimes

Hintz *et al.* (1992) conducted an experiment to evaluate the effects of cultivars, row spacing, planting density and harvest maturity on the yield and quality of soybean forage.

In a study conducted by Hatami *et al.* (2009), cultivar and N fertilizer significantly effected on seed yield. With increasing of N fertilizer application, seed yield increased significantly.

Arshad *et al.* (2005) conducted a field experiment in New Delhi, India, to assess the growth characteristics, seed and oil yield of two cultivars of soybean i.e. PK-416 (V_1) and PK-1024 (V_2) in relation to sulphur and nitrogen nutrition. Maximum response was observed with treatment having 40 kg S and 44 kg N ha^{-1}.

2.2 Effect of urea on the growth and yield of soybean

The protective application of nitrogen fertilizer can accelerate the development of soybean symbiotic nitrogen fixation system, regulate the soybeans demand for the symbiotic nitrogen and the soil fertilizer and can decrease the application quantity of nitrogen fertilizer, at last can reach the effect of high yield, high nitrogen fixation and high economic effect (Shude *et al.*, 2008).

To study effect of nitrogen fertilization and variety on soybean leaf senescence and crop yield an experiment was conducted by Golparvar *et al.* (2012) in Iran. The treatments were two soybean cultivars (L_{17} and Zan), nitrogen fertilizer (urea and ammonium nitrate) and rate of nitrogen (15, 25 and 35 kg ha^{-1}). With increasing of nitrogen rate, leaf chlorophyle content index increased significantly, compared to the check plots. Seed yield in cv. L_{17} treated with nitrate ammonium and cv. Zan treated with urea could be increase up to 6700 and 5100 kg ha $-^{1}$, respectively.

In a study conducted by Flavio *et al.* (2004), fertilization with 80 kg N ha at the beginning of the seed filling period of soybean lengthened it by 3 days. In this study, N also reduced the total amount of fallen leaves at harvest by 10%.

Bly *et al*. (1998) reported that when soybean fertilized with 20 kg N/ha at early flowering stage, its branches per plant increased 33%.

Ghosh (2004) carried out a net house pot experiment to investigate the role of S (0 or 25 kg ha-1) supplied to typic ustrochrept soil on the performance of potted soybeans under a balanced nutrition program. N was supplied @ 0, 30, and 60 kg ha^{-1}, while P was supplied @ 0, 37.5 and 75 kg ha^{-1}. Seed yield, stover yield and harvest index increased with the application of N, P and S.

In experiments Hatami *et al*. (2009) showed that Nitrogen fertilizer significantly increased grain yield was 150 kg nitrogen per hectare so the application compared to control treatments resulted in increased grain yield was 28%.

Fathi *et al*. (2001) showed that nitrogen application up to 100 kg.N/ha by increasing the number and weight of soybeans from 2430 to 3387 and 4230 kg/ha, respectively, in the application of 50 and 100 kg N/ha increased.

Taylor *et al*. (2005) observed that application of nitrogen fertilizer in late planted soybean yield is improved.

Brevendan *et al*. (1978) reported that increased nitrogen levels during soybean flowering period, number of pods per node and number of pods per plant, respectively, 22 and 40% compared to control (no nitrogen consumption) increased.

Chafi *et al*. (2012) conducted an experiment to assess the effect of management of irrigation and nitrogen fertilizer on yield of soybean cultivars Chernika pilot. The results showed that the management of irrigation, nitrogen fertilizer and its effect on grain yield was significant at the 5% level. Fertilizer value of the zero level to higher levels, grain yield increases. The lowest yield in terms of fertilizer value of 3888.1 kg per hectare was but with increasing amounts of fertilizer significantly increased grain yield, 90 kg of nitrogen fertilizer on the surface so that the maximum yield of 5228.1 kg per hectare was achieved.

Yagoub *et al.* (2012) conducted a field experiment for two consecutive seasons (2009/2010 and 2010/2011) to study the effect of some fertilizers on growth and yield of soybean. The fertilizer treatments consisted of three types fertilizers: urea (180 kg/ha), NPK (361 kg/ha), compost and control. The results showed that fertilizer treatments in first season had significance difference on number of pods/plant, economic yield, harvest index and highly significant difference on green, biological and straw yield. In second season fertilizers treatments had significant difference on plant height at 30 days, leaf area at 45 and 60 days, green yield, biological yield and straw yield.

Hungria *et al.* (2007) carried out several experiments in Brazil and observed that a supply of N fertilizer at sowing (20-40 kg N ha^{-1}), early flowering (R2; 20-100 kg N ha-1), or mid pod-filling stage (R4; 50 kg N ha-^{1}) decreases nodulation with no benefits to the grain yield, in both conventional and notillage systems in cultivars with different maturation cycles.

Shehata and El-Helaly (2010) carried out a field experiment in 2009-2010 reported that the highest mean plant height in the first season was 32.65 cm given by urea treatment, in the second season was 31.38 cm given by control.

Xuewen (1990) carried out a field experiment and observed that nitrogen fertilization can promote vegetative growth of soybean, and plants can be flowered around 33 days after sowing. Generally, high nitrogen levels of 60 and 120 kg ha-^{1} delayed flowing whereas lower nitrogen levels had no influence on flowering.

2.3 Effect of DAP on the growth and yield of soybean

Diammonium phosphate (DAP) is the world's most widely used phosphorus fertilizer, containing 18% N and 46% P_2O_5. Soybean is known to be highly nitrogen demanding crop, since the end product is very rich in protein. Biological N_2 fixation and mineral soil or nitrogen fertilizer are the main source of meeting the nitrogen requirement of high-yielding soybean (Salvagiotti *et al.*, 2008).

Phosphorus like nitrogen is essential for growth of soybeans. Phosphorus plays an important role in cell division (Rooyani and Badamchian, 1986) and this helps in growth of root and consequently the whole structure of the plant including the meristem. Murata (2003) reported that low application rates are limiting factor in soybean growth. Phosphorus deficiency can be linked to the reduction of nitrogen content in the plant and metabolism activity as well as growth and activity of nodules (Sa and Israel, 1995; Tang *et al.*, 2001). Tsvetkova and Georgiew (2003) found a decrease in total nodule respiration rate.

Since P is important in legumes for grain formation and root establishment, it needs to be applied in adequate quantities. Malik *et al.* (2006) argued that soybean requires no N fertilizer (if inoculated) but more P as it plays a vital role in getting higher yield with better grain quality.

Phosphorus deficiency can limit nodulation, growth and yield of soybean and phosphorus fertilizer application can overcome the deficiency (Carsky *et al.* 2001; Kumaga and Ofori 2004).

Mokoena (2013) observed that maximum seed yield and highest harvest index was obtained with the combination of inoculation and phosphorus fertilizer application. Similar result was reported by Farani (1988) and Ali *et al.* (2004) that an increase in seed yield and harvest index due to increased levels of phosphorus.

A field trial was conducted by Salih *et al.* (2015) to study the effect of rhizobium, mycorrhiza inoculation and diammonium phosphate (DAP) on growth, nodulation and yield of soybean. The result showed that the effect and interaction of rhizobium, mycorrhiza and diammonium phosphate rhizobium significantly increased nodulation number/plant, relative growth rate and yield of soybean over control.

Abuli *et al.* (2013) conducted an experiment to find out the effect of phosphorus sources on yield of soybean. The result indicated that the phosphorus sources effect on soybean grain and biomass yield is attributable to their ability to deliver the soil nutrients the critical growth stage of crop. The soybean treated with manure and DAP had higher yields than control yields by 78% and 70% respectively.

Landge *et al.* (2002) carried out a field experiment in Akola, Maharashtra, India, during kharif season of 1994-95 to study the response of soybean to nitrogen and phosphorus with higher and lower doses of N and P than the recommended dose. They observed that yield and yield contributing characters were increased with the application of 15 kg N + 37.5 kg P_2O_5 ha^{-1} + *Bradyrhizobium*.

A field experiment was conducted by Devi *et al.* (2012) during rainy seasons of 2007-2009 in India (Manipur) to study the effect of different sources and levels of phosphorus on productivity of soybean [*Glycine max* (L.) Merrill]. The treatments consisted of four sources of phosphorus [Single super phosphate (SSP), Di-ammonium phosphate (DAP), Single super phosphate (SSP)+Phosphate solubilizing bacteria (PSB), Di-ammonium phosphate (DAP)+Phosphate solubilizing bacteria (PSB)], four levels of phosphorus (20, 40, 60 and 80 kg P2O5 ha-1) and one absolute control(without any fertilizer and PSB). Application of SSP+PSB produced significantly higher number of nodules per plant, dry weight of nodules per plant, number of pods per plant and 100-seed weight than the other treatments. Maximum grain yield and total phosphorus uptake were also recorded when using SSP+PSB. Yield attributing characters, grain and stover yield were increased with increasing levels of phosphorus.

Ahsan *et al.* (2012) conducted a field experiment to study the integrated use of phosphate solubilizing bacteria (PSB), *Bradyrhizobium* and P on nodulation and sustainable soybean production. Significant differences among the different treatment combinations in terms of yield and yield contributing characters were observed. Integrated nutrient management with application of 60% of the recommended dose of phosphorus (RP), phosphate solubilizing bacteria (PSB) and biofertilizer (*Bradyrhizobium*) has significantly increased plant height, number of nodule per plant, nodule dry weight per plant, pods per plant, grains per pod, grain yield, oil and protein contents. Co-inoculation of *Bradyrhizobium* seemed to help reduce the P requirement in soybean cultivation. Overall results indicate that the application of integrated nutrient management of biofertilizer (*Bradyrhizobium*) with recommended dose of P would produce the best quality of soybean with higher nodulation and yield.

2.4 Effect of MoP on the growth and yield of soybean

Potassium is an important macro nutrient for metabolic, growth and stress adaptation (Tiwani *et al.,* 2001). The overall functioning of the plant parts depends on the mobility of potassium as it is responsible for sustaining the movement of other ions like H^+, sugars and nitrate throughout the whole plant (Marschner, 1995c). Most of the potassium deficiencies are seen at late stages of soybean growth (flower to seed filling stages) since its concentration decreases at crop maturity (Aulakh *et al.*, 2002).

Dixit *et al.* (2011) reported that K use efficiency increased with K application, which suggests that higher application of potash should be tested. At 8.25 kg grain for each kg K_2O applied, application of 40 kg K_2O ha^{-1} brings an additional net income of Rs. 5,970 per ha, or an Incremental Cost Benefit Ratio (ICBR) of 15.06, which should be very lucrative for farmers.

Mokoena (2013) conducted an experiment to determine the direct effect of P and K application to a soybean crop in terms of production and quality. The results for the field trial showed that K significantly improved plant height, canopy closure and 100-seed mass as compared to the control. A significant improvement in grain yield was observed through application of K. The highest grain yield (2.60 t ha^{-1}) was observed at the highest K level (100 kg K ha^{-1}).

Kheirelseed (1999) carried out a field experiment and observed that the soybean grain yield increased with the application of 50 kg K_2O ha^{-1}.

Shripukar *et al.* (2006) conducted an experiment and reported that the application of recommended dose of N: P_2O_5: K_2O (30: 60: 0 kg/ha) + 10 kg Zn/ha+ 10 t FYM/ha significantly contributed in the yield and yield contributing characters such as number of pods, number and dry weight of nodules, grain yield and stover yield and hence ultimately the increased productivity of soybean.

Jones *et al.* (1977) conducted an experiment to investigate the effects of P and K fertilization on number and weight of soybean nodules; chemical composition of leaves, nodules and seed; number of pods per plant and seed yield. Annual P rates of 0, 15, 30, and 60 kg/ha were applied with 0 and 112 kg K/ha in one field experiment. In another, annual K rates of 0, 28, 56, and 112 kg/ha were applied with 0 and 60 kg P/ha. Either P or K applied alone increased the number of nodules per plant and per unit volume of soil. Applied K increased the number of nodules, total and individual weight of nodules, and the number of pods per plant more than P, but increases were largest when both P and K were applied. A good yield response was obtained from 28 kg K/ha and to increasing rates of K when 60 kg P/ha was added, thus indicating the higher requirement of soybeans for K than for P.

Farhad *et al.* (2010) conducted a field experiment to study of role of potassium and sulphur on the growth, yield and oil content of soybean (BARI soybean 5). The experiment included four levels of potassium viz. 0, 20, 40 and 70 kg K/ha and four levels of sulphur viz. 0, 10, 20 and 40 kg S/ha. Potassium showed significant effect on yield and yield attributes of soybean. Application of potassium @ 40 kg/ha produced the highest plant height, seed yield, 1000-seed weight and straw yield. Sulphur fertilizer also had significant effect on yield and yield attributes of soybean. Potassium in combination with Sulphur showed significant effect on yield and yield attributes of soybean. Combined application of Potassium @ 40 kg/ha and sulphur @ 20 kg/ha resulted the highest seed yield, plant height, 1000-seed weight, straw yield, protein and oil contents of soybean.

The effect of potassium on the yield and quality was studied by Li *et al.* (2005) in the field. The result showed that potassium had a positive effect on the factors of yield, a good effect on the yield and quality of soybean. With potassium application, the yield of soybean increased. An yield of dongnong343 increased to 2727kg/ hm~2 and that of heinong35 increased to 2651kg/ hm~2 when the amount of the potassium applied in field was 150kg/hm~2.The application of potassium fertilizer had a positive effect on oil content and a negative effect on protein content of soybean.

Pot-experiments were carried out by Yan *et al.* (2008) to study the effect of potassium fertilizer on dry matter accumulation, yield and quality of soybean. Five potassium fertilizer supply levels 0, 0.034, 0.068, 0.102, 0.136 g K_2O kg^{-1} soil denoted as K_1, K_2, K_3, K_4, K_5, were used in this experiment. The results showed that potassium enhanced the dry matter accumulation at flowering (R_1), however, no significant difference was observed for the five K treatments. The dry matter accumulation showed increased and then decreased trend with the increment of potassium amount at podding (R_3) and pod filling (R_5),and significant difference among different treatments were observed at pod filling (R_5) but not at podding(R_3).The optimum application rate of potassium was K_3 (0.068 g K_2O /kg soil) for dry matter accumulation at podding (R_3) and pod filling (R_5).The ratio of root to shoot decreased with the growing of soybean, which was lowest at pod filling (R_5).The root to shoot ratio declined sharply after the peak in K_2 with potassium fertilizer application at flowering (R_1) and podding (R_3). K_3 was the maximum value for the root to shoot ratio at pod filling stage (R_5).The application of potassium fertilizer was beneficial to oil accumulation but not to protein accumulation. The more the application of potassium fertilizer, the more yield soybean would reach. The optimum rate of potassium fertilizer for yield was K_5 (0.136 g K_2O /kg soil), which was significantly superior to no-potassium (K_1) treatment.

2.5 Effect of Cytokinin on the growth and yield of soybean

Soybean seed yield is dependent on fruit and seed numbers (Lehman and Lambert, 1960; Pandy and Torrie, 1973) which are directly related to successful fruit-set. Therefore, the factors controlling fruit-set in soybean and other crops are of great interest. Work with other legumes (Davey and Staden, 1978) suggests that hormones such as cytokinins are important in seed and fruit development and more research efforts need to be directed at soybeans.

Plant growth regulator enhances yield attributes and yield might involve in fruit setting to enhance yield (Nickell, 1982).

An experiment was carried out by Islam *et al.* (2010) in the field laboratory of the Department of Crop Botany, Bangladesh Agricultural University, Mymensingh, to investigate the flowering pattern, floral and pod abscission under untreated and GABA (mixture of GA3 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. GABA treated plants produced more nodes per plant and followed lower trend in flower and pod abscission indicated the efficacy of higher yield. It indicated that external application of plant growth regulators in the form of spray enhanced yield of soybean.

Gupta *et al.* (2014) conducted an experiment to observe the effect of nitrogen and plant growth regulators on soybean. The results showed that the foliar application of plant growth regulators (tricontenol, NAA and cytokinin) and basal application of nitrogen @ 20 kg per ha had positive effects on seeds per pod under late sown conditions.

Nagel *et al.* (2001) reported that exogenous application of cytokinin to raceme tissues of soybean has been shown to stimulate flower production and to prevent flower abortion. Data suggests that cytokinin levels play a significant role in determining total yield in soybeans and that increasing cytokinin concentration in certain environments may result in increased total seed production.

2.6 Effect of Water stress on the growth and yield of soybean

Water stress is considered as a major factor limiting plant performance and yield of soybean (Desclaux *et al.*, 2000; Lobato *et al.*, 2008). The various growth stages of soybean respond differently to water stress (Desclaux *et al.*, 2000; Egli and Bruening, 2004). Water stress during reproductive development often decreases the grain size in soybean (Momen *et al.*, 1979; Kadhem *et al.*, 1985).

Bravedan and Egli (2003) reported that short periods of water stress during grain filling of soybean caused substantial yield reduction (39%) due to fewer and smaller grains.

The need for water in soybean increases with plant development, peaking during the flowering- grain filling stages (7-8 mm day^{-1}) and decreasing thereafter. The total water requirement for maximum productivity varies between 450 and 800 mm, depending on weather conditions, crop management practices and cycle timing (Embrapa, 2011). The loss of productivity under water deficit conditions depends on the soybean phonological stage, duration and intensity of water shortages (Doss & Thurlow, 1974).

A pot experiment was conducted by Hajare *et al.* (2001) to find out the effect of moisture stress on biomass yield of soybean. The experimental data of pot culture during two seasons indicated that a stress for seven days during the period of seedling establishment resulted in yield loss up to 4.6 to 8.0 percent and 5.9 to 18.4 percent at grand growth stage. A maximum of 52.8 to 53.9 per cent loss in biomass was observed due to stress at pod formation and grain filling stages.

Chafi *et al.* (2012) conducted an experiment to find out the management of irrigation and nitrogen fertilizer on yield of soybean cultivars Chernika pilot in crop year 2011. The main factors include the management of no irrigated (dry land) and irrigation with Intervals 0, 6, 12 and 18 days, and nitrogen fertilizer treatments containing 0, 30, 60, 90 and 120 were considered as minor. Management of irrigation and nitrogen fertilizer and its effect on grain yield, pods and biological significant at the 5% level. The highest yield of irrigation management 12 days to the 5125.6 kg ha, respectively. Fertilizer value of the zero level to higher levels, grain yield increases 5228 kg per hectare was achieved.

Raper and Kramer (1987) reported that water stress imposed during flowering and early pod development reduces photosynthesis and the amount of photosynthetic assimilates allocated to floral structures, which was likely to increase the rate of abortion.

In order to investigate the effects of water stress on production of soybean cultivars, an experiment was conducted by Kobraee *et al.* (2011). Main plot treatments consisted of four different irrigation regime: I_1: irrigation during all growth stages as control treatment, I_2: omit irrigation at the onset of flowering stage (R_1), I_3: omit irrigation at the onset of pod set stage (R_3) and I_4: omit irrigation at the onset of seed–filling stage (R_6). Subplot treatments were four cultivars: V_1=M_7, V_2=M_9, V_3=Gorgan$_3$ and V_4=Williams. Analysis of variance showed that grain yield, biological yield, number of pod, seed and 100-seed weight per main stem, sub stem and plant was significantly affected by irrigation regimes (α=0.01). Withholding irrigation at R_1 (omit irrigation at the onset of flowering stage) had the most effect on number of sub branch, number of pod and seed per main stem, sub stem and plant. Water deficit at seed-filling stage (R_6) had the most effects on reducing 100-seed weight. Withholding irrigation at R_3 had more effect on reducing pod and seed dry weight.

An experiment was conducted by Ghassemi-Golezani and Lotfi (2012) to investigate the effects of different irrigation treatments (I_1, I_2, I_3 and I_4: well-watering after 70 mm evaporation from class A pan and irrigation disruptions during flowering, during grain filling and during flowering and grain filling stages, respectively) on ground cover and yield of three soybean cultivars (Clark, Williams and L_{17}). Water stress at reproductive stages reduced percentage and duration of ground cover, plant biomass, pods per plant, grains per plant, mean grain weight, harvest index and grain yield per unit area. However, grains per pod did not differ significantly among irrigation treatments. Reduction in grain yield was increased with increasing duration of water stress at reproductive stages. Williams was a superior cultivar in ground cover, plant biomass, mean 100 grain weight and grain yield per unit area. Interaction of cultivar × irrigation was not significant for yield and yield component. Plant biomass was statistically similar for Clark and L17. Grain yield of L17 was 4.49 % and 17.33 % less than that of Clark and Williams, respectively.

Chapter III

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

The experiment was conducted during the period from 14 January, 2014 to 8 May, 2014 to study the influence of supplemental agronomic managements on flower dropping, growth and yield of Soybean. This chapter includes materials and methods that were used in conducting the experiment are presented below under the following headings:

3.1 Experimental site

The experiment was conducted at the farm of Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka, Bangladesh. The experimental site is situated between $23^0 74'$N latitude and $90^0 35'$E longitude and at an elevation of 8.4 m from sea level (Anon., 1989).

3.2 Soil

The soil of the experimental site belongs to Tejgaon series under the Agro-ecological zone, Madhupur Tract (AEZ-28), which falls into Deep Red Brown Terrace Soils. Soil samples were collected from the experimental plots to a depth of 0-15 cm from the surface before initiation of the experiment and analyzed in the laboratory. The soil was having a texture of sandy loam with pH and CEC were 5.6 and 2.64 meq 100 g $soil^{-1}$, respectively. The morphological characteristics of the experimental field and physical and chemical properties of initial soil of the experimental field is given in Appendix I and II.

3.3 Climate

The climate of experimental site is subtropical, characterized by three distinct seasons, the monsoon from November to February and the pre-monsoon period or hot season from March to April and the monsoon period from May to October. The monthly average temperature, humidity and rainfall during the crop growing period were collected from Weather Yard, Bangladesh Meteorological Department and presented in Appendix III.

3.4 Planting material

Two Soybean varieties were used in the experiment. The seeds were collected from the Oil Crops Division of Bangladesh Agricultural Research Institute (BARI), Joydebpur, Gazipur. BARI Soybean 5 and BARI Soybean 6 were the released varieties of Soybean, which was recommended by the national seed board. Both varieties are grown in Rabi season. The features of two varieties presented below.

BARI Soybean 5: This variety released by BARI in 2002. Pod color of this variety is brown and seed color is cream. This variety takes 95-115 days to mature. Seed yield of this variety is 1.6-2.0 ton/ha

BARI Soybean 6: This variety released by BARI in 2002. Seed color of this variety is cream. This variety takes 100-110 days to mature. Seed yield of this variety is 1.8-2.10 ton/ha.

3.5 Land preparation

The land was irrigated before ploughing. After having 'zoe' condition the land was first opened with the tractor drawn disc plough. Ploughed soil was brought into desirable fine tilth by 4 ploughing and cross-ploughing, harrowing and laddering. The stubble and weeds were removed. The first ploughing and the final land preparation were done on 12 and 13 January, 2014, respectively. Experimental land was divided into unit plots following the design of experiment.

3.6 Treatments of the experiment

The experiment consists of two factors:

Factor A: Soybean variety (2)

i) V_1: BARI Soybean 5

ii) V_2: BARI Soybean 6

Factor B: Supplementary managements (6)

i) M_1: Control i.e., Normal cultivation

ii) M_2: Urea spray at flowering

iii) M_3: MoP spray at flowering

iv) M_4: DAP spray at flowering

v) M_5: Cytokinin spray at flowering

vi) M_6: Water stress at flowering

There were 12 (2×6) treatment combinations such as V_1M_1, V_1M_2, V_1M_3, V_1M_4, V_1M_5, V_1M_6, V_2M_1, V_2M_2, V_2M_3, V_2M_4, V_2M_5 and V_2M_6.

3.7 Fertilizer application

Urea, Triple super phosphate (TSP), Muriate of potash (MoP), gypsum and boric acid were used as a source of nitrogen, phosphorous, potassium, gypsum, sulphur and boron, respectively. Urea, Triple super phosphate (TSP), Muriate of potash (MoP), gypsum, and boric acid were applied at the rate of 60, 175, 120, 115 and 10 kg hectare^{-1}, respectively following the Bangladesh Agricultural Research Institute (BARI) recommendation. All of the fertilizers were applied during final land preparation as basal dose for all the treatments. Additional management was imposed at flowering as per respective treatment.

3.8 Experimental design and layout

The two factors experiment was laid out in split-plot design with three replications. An area of 21.5 m × 20.5 m was divided into blocks. The two varieties were assigned in the main plot and six supplementary treatments in sub-plot. The size of the each unit plot was 3m × 3m. The space between two blocks and two plots were 1.0 m and 0.5 m, respectively. The layout of the experiment is shown in Figure 1.

Replication-1		Replication-2		Replication-3	
V_1M_5	V_2M_3	V_2M_6	V_1M_4	V_1M_2	V_2M_5
V_1M_2	V_2M_4	V_2M_1	V_1M_6	V_1M_5	V_2M_1
V_1M_6	V_2M_5	V_2M_2	V_1M_1	V_1M_4	V_2M_3
V_1M_4	V_2M_6	V_2M_5	V_1M_3	V_1M_1	V_2M_2
V_1M_3	V_2M_1	V_2M_3	V_1M_2	V_1M_6	V_2M_4
V_1M_1	V_2M_2	V_2M_4	V_1M_5	V_1M_3	V_2M_6

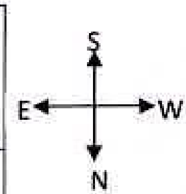

Figure 1. Field layout of the experiment in the split-plot design

Factors A: Soybean variety

V_1: BARI Soybean 5
V_2: BARI Soybean 6

Factors B: Supplementary managements

M_1: Control i.e. normal cultivation
M_2: Urea spray at flowering
M_3: MoP spray at flowering
M_4: DAP spray at flowering
M_5: Cytokinin spray at flowering
M_6: Water stress at flowering

3.9 Sowing of seeds in the field

The soybean seeds were sown on January 14, 2014 in furrows having a depth of 2-3 cm and row to row distance was 30 cm.

3.10 Application of supplementary management

As a supplementary management, Urea, MoP, DAP and Cytokinin was sprayed at starting of flowering and water stress introduced during flowering.

3.10.1 Urea spray at flowering

Urea was applied when flowering started and it was done on 15 March at 60 days after sowing (DAS). Selected 6 plots were sprayed with urea @ 20% of recommended urea e.g., 65 g urea in 10 liter water was mixed and sprayed in selected six plots when flowering starts.

3.10.2 MoP spray at flowering

MoP solution was made by mixing 130 g MoP fertilizer with 10 liter water to spray on 54m^2 or selected 6 plots. Spraying was done at 15 March or 60 DAS.

3.10.3 DAP spray at flowering

DAP was sprayed when flowering started and the mixture was made by mixing 45 g DAP fertilizer with 10 liter water to spray on 54 m^2 or selected 6 plots. Spraying was done on 60 DAS.

3.10.4 Cytokinin spray at flowering

Cytokinin was sprayed by mixing 2 mg Cytokinin powder with 10 liter water to spray on 54 m^2 or selected 6 plots. Spraying was done at 60 DAS.

3.10.5 Water stress at flowering

Water stress was introduced by withdrawing irrigation at selected 6 plots during flowering stage to observe the effect on pod development.

3.11 Intercultural operations

3.11.1 Thinning

Thinning was done two times; first thinning at 15 DAS and second at 25 DAS to maintain optimum plant population of 30 cm × 5 cm.

3.11.2 Irrigation and weeding

Irrigation was provided as and when needed throughout the whole growing period in all experimental plots equally except treatments having water stress during reproductive period. The crop field was weeded as per requirement.

3.11.3 Protection against pest

At early stage of growth worms (*Agrotis ipsilon*) infested the young plants. At later stage of growth, pod borer (*Maruca testulalis*) attacked the plant. Ripcord 10 EC was sprayed at the rate of 1 mm with 1 liter water for two times after seedlings germination to control the insects.

3.12 Crop sampling and data collection

Five plants from each plot were randomly selected and marked with sample card. Plant height, leaflet number, branches plant^{-1} and dry matter plant^{-1} were recorded from selected plants at an interval of 25 days started from 25 DAS to 100 DAS.

3.13 Harvest and post harvest operations

Harvesting was done when 90% of the pods became brown in color. The matured pods were collected by hand picking from a pre demarcated area of 5.4 m^2 at the center of each plot.

3.14 Data collection

The following data were recorded

i. Plant height (cm) at 25, 50, 75 and 100 DAS
ii. Number of leaflet at 25, 50, 75 and 100 DAS
iii. Number of branches plant^{-1} at 50, 75 and 100 DAS
iv. Dry weight (g) plant^{-1} at 25, 50, 75 and 100 DAS
v. Flower dropping (%)
vi. Pod dropping (%)
vii. Total (flower and pod) dropping (%)
viii. Pod remaining (%)
ix. Number of pods plant^{-1}
x. Pod length (cm)
xi. Number of seeds pod^{-1}
xii. 1000-seed weight (g)
xiii. Shelling percentage
xiv. Grain yield (t ha^{-1})
xv. Stover yield (t ha^{-1})
xvi. Biological yield (t ha^{-1})
xvii. Harvest index (%)

3.15 Procedure of data collection

3.15.1 Plant height

The heights (cm) of randomly selected five plants from each plot were recorded from the base of the plant to the tip of the tallest leaf and expressed as mean values. The plant heights were measured at an interval of 25 days after sowing (DAS), e.g., 25 DAS, 50 DAS, 75 DAS and 100 DAS.

3.15.2 Leaflet number

The number of leaflets per plant was counted at 25, 50, 75 and 100 DAS from selected 5 plants. The average number of leaflets per plant was determined.

3.15.2 Number of branches plant^{-1}

The number of branches plant^{-1} was counted at 50, 75 and 100 DAS from selected plants. The average number of branches plant^{-1} was determined.

3.15.3 Dry weight plant^{-1}

Leaving the harvest area and sample plants destructive harvest of five plants plot^{-1} was done at 25, 50, 75 and 100 DAS. The sample was chopped into very thin pieces and put into envelope then placed in an oven maintained at 70^0C temperature for 72 hours. It was then transferred into desiccators and allowed to cool down at room temperature. Then dried plant weighed by using a digital electric balance and weight was expressed in gram (g).

3.15.4 Flower dropping

Flower dropping was counted for 5 selected plants and recorded in each plot. Dropping of flower was counted in every morning by placing clean paper at the ground of the sample plants as per plate during flowering time and finally averaged.

3.15.5 Pod dropping

Pod dropping was counted for 5 selected plants and recorded in each plot. Dropping of pod was counted in every morning as per the way of counting flower dropping during pod development stage and recorded.

3.15.6 Total dropping (flowers and pods dropping)

Total dropping was calculated by adding flower dropping and pod dropping from 5 selected plants and recorded in each plot.

3.15.7 Number of pods plant^{-1}

Numbers of total pods of selected plants from each plot were counted and the mean numbers were expressed as plant^{-1} basis. Data were recorded as the average of 5 plants selected at random from the inner rows of each plot.

3.15.8 Pod length (cm)

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

3.15.9 Number of seeds pod^{-1}

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

3.15.10 1000-seed weight (g)

One thousand cleaned, dried seeds were counted from each harvest sample and weighed by using a digital electric balance.

3.15.11 Shelling percentage

The mass of seeds obtained from the pods that were randomly drawn from a bulk sample and calculated the shelling percentage by using the following formula:

$$\text{Shelling percentage} = \frac{\text{Seed mass}}{\text{Pod mass}} \times 100$$

3.15.12 Grain yield ($t\ ha^{-1}$)

The grains collected from 5.4 (1.8 m ×3 m) square meter of each plot were sun dried properly. The weight of seeds was taken and converted the yield in $t\ ha^{-1}$.

3.15.13 Stover yield ($t\ ha^{-1}$)

The stover collected from 5.4 (1.8 m ×3 m) square meter of each plot was sun dried properly. The weight of stover was taken and converted the yield in $t\ ha^{-1}$.

3.15.14 Biological yield $hectare^{-1}$ ($t\ ha^{-1}$)

Seed yield and stover yield together were regarded as biological yield. The biological yield was calculated with the following formula:

$$\text{Biological yield} = \text{Grain yield} + \text{Stover yield}$$

3.15.16 Harvest index (%)

Harvest index was calculated from the grain yield and stover yield of soybean for each plot and expressed in percentage.

$$\text{HI (\%)} = \frac{\text{Economic yield (grain weight)}}{\text{Biological yield (Total dry weight)}} \times 100$$

3.16 Statistical analysis

The data obtained for different parameters were statistically analyzed to find out the significant difference of different soybean varieties and supplementary managements on growth and yield contributing characters. 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) test at 5% level of probability (Gomez and Gomez, 1984).

Chapter IV

Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

The experiment was conducted to study the influence of supplementary agronomic management e.g., Urea, TSP, MoP, DAP and water stress on growth, flower droppings and yield of soybean. The analyses of variance (ANOVA) of the data on different parameters are presented in Appendix IV-X. The results have been presented with the help of table and graphs and possible interpretations given under the following headings:

4.1 Plant height (cm)

4.1.1 Effect of variety

Statistically significant variation was recorded on plant height of BARI Soybean 5 and BARI Soybean 6 at 25, 50 and 100 DAS and at 75 DAS variation was not significant (Appendix IV and Figure 2). At 25, 50 and 100 DAS the taller plants (10.83, 33.56 and 57.39 cm, respectively) were recorded from V_1 (BARI Soybean 5), whereas the shorter plants (9.3, 29.21, 51.96 cm,

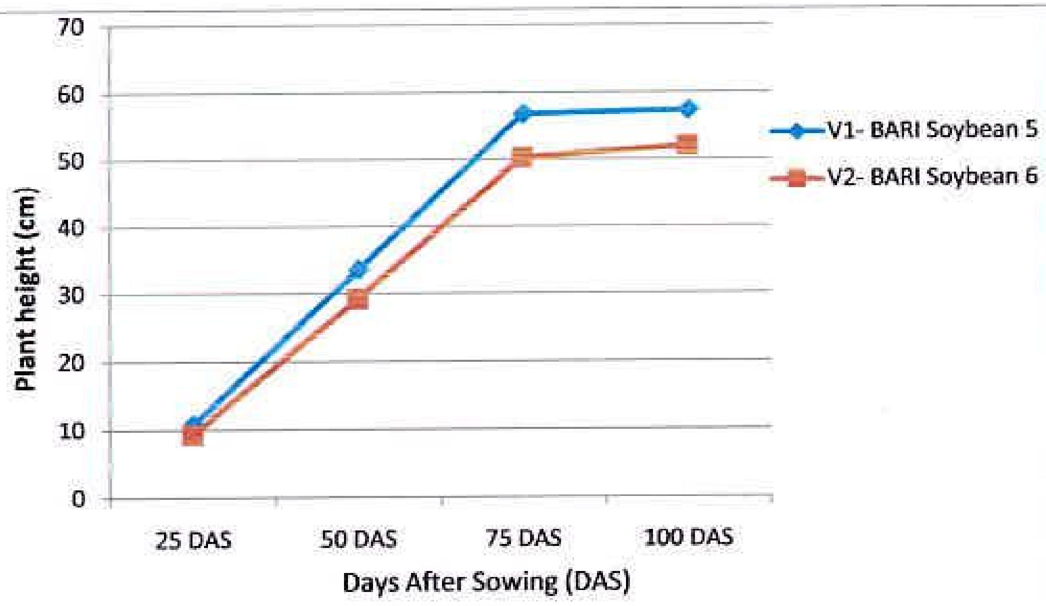

Figure 2. Effect of variety on plant height of Soybean at different days after sowing (LSD at 5% were 0.95, 4.01, NS and 4.54 at 25, 50, 75 and 100 DAS respectively)

respectively) were found from V_2 (BARI Soybean 6). At 75 DAS numerically maximum plant height (56.82 cm) was found in V_1 and minimum height (50.21 cm) was found in V_2. Different varieties produced different plant height on the basis of their varietal characters and improved varieties is the first and foremost requirement for initiation and accelerated production program. Rahman *et al.* (2013) reported various plant heights for different soybean varieties.

4.1.2 Effect of supplementary managements

Plant height at 25 DAS showed significant variation for different supplementary managements that applied as urea, TSP, MoP, DAP, Cytokinin (Appendix IV and Figure 3). But plant height at 50, 75 and 100 DAS did not show any significant variation. At 25 DAS, the tallest plant (10.95 cm) was found from M_1 (Control), which was statistically similar (10.09) to M_3 (supplemental MoP application) and followed (10.03) by M_5 (Cytokinin spray at beginning of flowering), while, the shortest plant (9.68 cm) was observed from M_6 (Water stress at flowering). At 50 DAS numerically maximum plant height (32.15 cm) was found in M_1 and minimum plant height (30.80 cm) was found in M_5. At 75 and 100 DAS numerically maximum plant height (55.69 and 58.42 cm respectively) was found in M_4 and minimum plant height (50.74 and 51.68 cm respectively) was found in M_5. Similar result was found by Yagoub *et al.* (2012), Win (1996) and Shehata and El-Helaly (2010). Meanwhile, Hantolo (1995) indicated that plant height decreased with increased urea. On the other hand, Farhad *et al.* (2010) reported that different doses of potassium fertilizer had significant effect on the plant height of soybean. Nitrogen fertilization increased the mean plant height, reported by Starling *et al.* (1998), Chuansong (1990), Xuewen (1990) and Akbari *et al.* (2001). Falodun and Osaigbovo (2010) conducted an experiment and reported that the plant height was enhanced by organic and inorganic fertilizers.

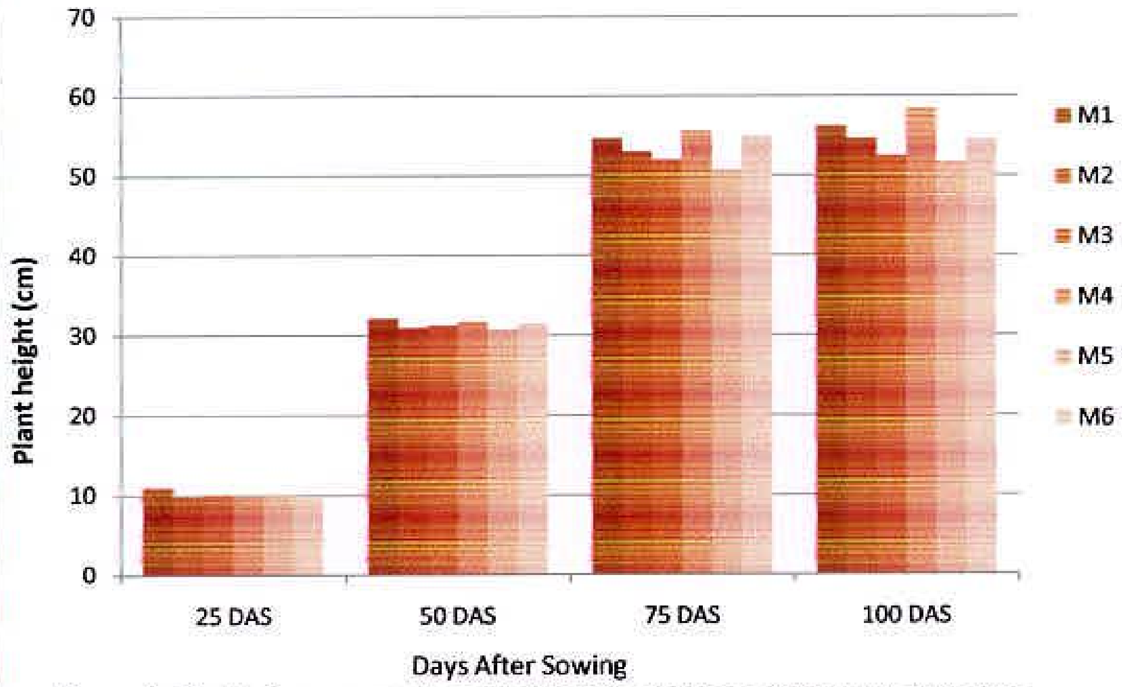

Figure 3. Effect of management on plant height ofsoybean at different days after sowing (LSD at 5% were 0.95, NS, NS and NS at 25, 50, 75 and 100 DAS respectively)

M_1: Control; Normal cultivation
M_2: Urea spray at flowering
M_3: MoP spray at flowering
M_4: DAP spray at flowering
M_5: Cytokinin spray at flowering
M_6: Water stress at flowering

4.1.3 Interaction effect

Interaction effect of soybean varieties and different supplementary managements showed significant differences on plant height at 25 and 50 DAS (Appendix IV and Table 1). At 75 and 100 DAS there was no significant difference in plant height. At 25 and 50 DAS, the tallest plant (12.37 and 35.03 cm, respectively) was recorded from V_1M_1 (BARI Soybean 5 and control), while the shortest plant (8.93 and 27.39 cm, respectively) was found from V_2M_6 (BARI Soybean 6 and water stress at flowering) and V_2M_5 (BARI Soybean 6 and cytokinin spray at flowering). At 75 and 100 DAS numerically maximum plant height (60.14 and 61.0 cm) was found in V_1M_4 (BARI Soybean 5 and DAP spray at flowering) and minimum plant height (49.17 and 49.7 cm) was found in V_2M_5. Rahman *et al.* (2013) found that the interaction effect of varieties and row spacing had no effect on plant height.

Table 1. Interaction effect of variety and supplementary managements (e.g., urea, MoP, DAP, cytokinin and water stress at flowering) on plant height of soybean

Variety × Managements	Plant height (cm)			
	25 DAS	50 DAS	75 DAS	100DAS
V_1M_1	12.37 a	35.03 a	59.09	60.80
V_1M_2	10.00 b-d	31.71 a-f	56.47	58.47
V_1M_3	11.09 a-c	33.73 a-d	54.58	54.40
V_1M_4	10.00 b-d	32.93 a-e	60.14	61.00
V_1M_5	11.10 ab	34.21 ab	52.30	53.67
V_1M_6	10.42 b-d	33.75 a-c	58.37	56.00
V_2M_1	9.53 b-d	29.26 ef	50.28	51.67
V_2M_2	9.60 b-d	30.16 b-f	49.54	50.90
V_2M_3	9.10 d	28.74 ef	49.37	50.53
V_2M_4	9.70 b-d	30.59 a-f	51.25	55.83
V_2M_5	8.97 d	27.39 g	49.17	49.70
V_2M_6	8.93 d	29.13 ef	51.67	53.13
$LSD_{(0.05)}$	1.62	4.39	NS	NS
Level of significance	0.05	0.05	0.05	0.05
CV (%)	9.47	8.20	13.99	12.48

V_1: BARI Soybean 5; V_2: BARI Soybean 6
M_1: Control; Normal cultivation M_2: Urea spray at flowering
M_3: MoP spray at flowering M_4: DAP spray at flowering
M_5: Cytokinin spray at flowering M_6: Water stress at flowering

4.2 Number of leaflets plant^{-1}

4.2.1 Effect of variety

Leaflet number plant^{-1} of BARI Soybean 5 and BARI Soybean 6 didn't show any significant variation at 25, 50, 75 and 100 DAS (Appendix V and Figure 4). At 25, 50, 75 and 100 DAS the numerically maximum number of leaflets (5.42, 28.1, 68.88, 25 respectively) was observed from V_1 (BARI Soybean 5) and the minimum number of leaflets plant^{-1} (4.99, 25.89, 66.63, 24.71 respectively) from V_2 (BARI Soybean 6). Management practices may influence the number of leaflets plant^{-1} but variety itself also manipulated it. Amin *et al.* (2009), reported different number of leaflets produced from different varieties

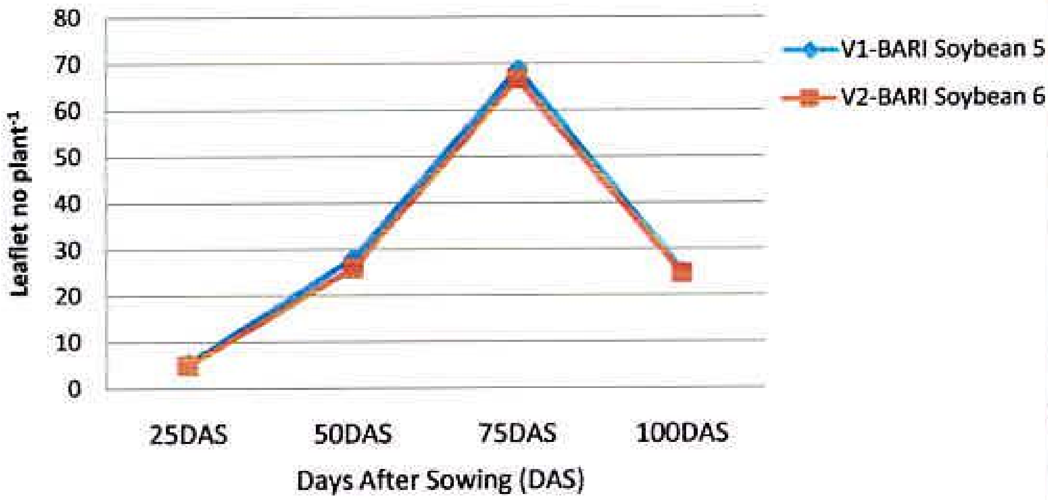

Figure 4. Effect of varieties on leaflet no of soybean at different days after sowing (LSD at 5% were NS at 25, 50, 75 and 100 DAS)

4.2.2 Effect of supplementary managements

Different supplementary managements that applied as urea, MoP, DAP, cytokinin and water stress showed significant variation for number of leaflets plant^{-1} at 25 DAS but there was no significant variation at 50, 75 and 100 DAS (Appendix V and figure 5). At 25 DAS, the highest number of leaflets plant^{-1} (5.77) was found from M_1 (Control), which was statistically similar (5.37) to M_3 (supplemental MoP application) and followed (5.3) by M_5 (Cytokinin spray at beginning of flowering), while, the minimum number of leaflets plant^{-1} (4.87) was observed from M_4, which was statistically similar (4.97 and 4.97) to M_6 (Water stress at flowering) and M_2 (urea spray at flowering). At 50 and 100 DAS, numerically maximum number of leaflets (28.23 and 27.6) was found in M_1 and minimum number of leaflets (25.47 and 23.13) was found in M_2 and M_3 respectively. At 75 DAS, numerically maximum number of leaflets (72) was found in M_6 and minimum number of leaflets (62.5) was found in M_3.

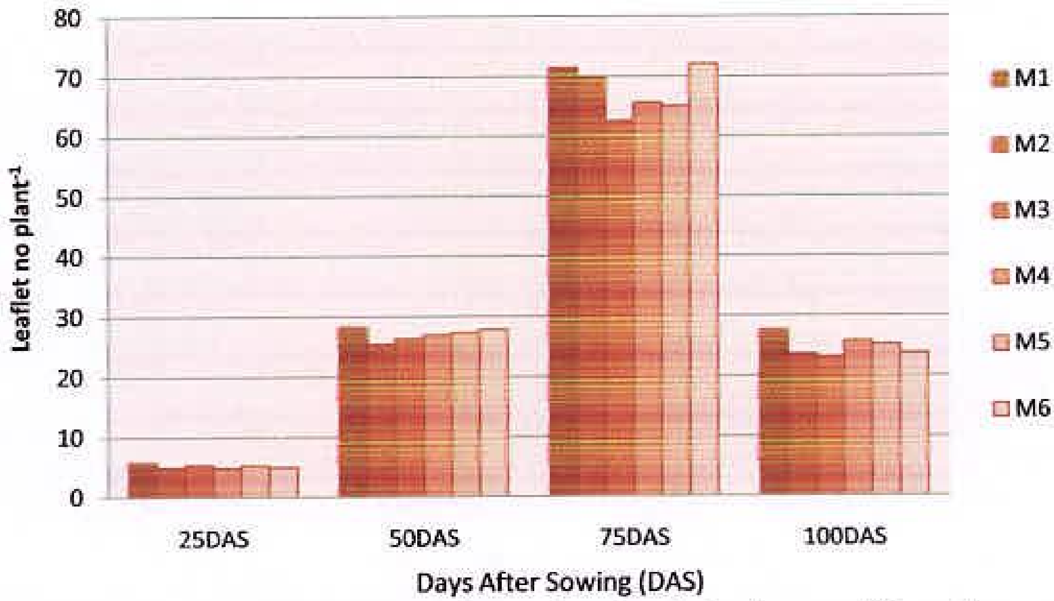

Figure 5. Effect of managements on leaflet number plant^{-1} of soybean at different days after sowing (LSD at 5% were 0.72, NS, NS and NS at 25, 50, 75 and 100 DAS respectively)

M_1: Control; Normal cultivation
M_2: Urea spray at flowering
M_3: MoP spray at flowering
M_4: DAP spray at flowering
M_5: Cytokinin spray at flowering
M_6: Water stress at flowering

Similar result was found by Yagoub *et al.* (2012), Akbari *et al.* (2001) and Singh *et al.* (2001). Xuewen (1990) showed the difference in nitrogen levels had slight influence on the mean number of leaves per plant.

4.2.3 Interaction effect

Soybean varieties and different supplementary management interaction effect showed significant differences on number of leaflets plant^{-1} at 25 DAS (Appendix V and table 2) but at 50, 75 and 100 DAS there was no significant variation was observed. At 25 DAS the highest number of leaflets plant^{-1} (6.27) was attained from V_1M_1 (BARI Soybean 5 and normal cultivation), whereas the lowest number of leaflets plant^{-1} (4.73) from V_1M_2 (BARI Soybean 5 and urea spray at flowering). At 50 and 100 DAS numerically maximum number of leaflet (29.73 and 29.8) found from V_1M_1 and the minimum number of leaflets (23.73 and 19.93) was found from V_2M_3 and V_1M_3. At 75 DAS, numerically the highest number of leaflets (74.8) was found from V_2M_6 (BARI Soybean 6 and water stress at flowering) and the lowest number of leaflets (61.2) was found from V_2M_3 (BARI Soybean 6 and MoP spray at flowering. Amin *et al.* (2009) reported the lowest number of leaflets from treatment where irrigation applied at flowering in Bangladesh Soybean-4 variety.

Table 2. Interaction effect of variety and supplementary managements (e.g., urea, MoP, DAP, cytokinin and water stress at flowering) on number of leaflets $plant^{-1}$ of soybean

Variety × Managements	**Number of leaflets at**			
	25 DAS	50 DAS	75 DAS	100 DAS
V_1M_1	6.27 a	29.73	74.4	29.80
V_1M_2	4.73 c	26.07	73.33	22.27
V_1M_3	6.00 ab	28.87	63.80	19.93
V_1M_4	4.87 c	28.33	69.89	26.27
V_1M_5	5.67 a-c	28.07	62.67	27.07
V_1M_6	5.00 a-c	27.53	69.20	24.67
V_2M_1	5.27 a-c	26.73	68.60	25.40
V_2M_2	5.20 a-c	24.87	66.40	24.93
V_2M_3	4.73 c	23.73	61.20	26.33
V_2M_4	4.87 c	25.43	61.40	25.33
V_2M_5	4.93 c	26.53	67.40	23.40
V_2M_6	4.93 c	28.07	74.80	22.87
$LSD_{(0.05)}$	1.02	NS	NS	NS
Level of significance	0.05	0.05	0.05	0.05
CV (%)	11.53	19.41	27.70	25.69

V_1: BARI Soybean 5; V_2: BARI Soybean 6

M_1: Control; Normal cultivation M_2: Urea spray at flowering

M_3: MoP spray at fkowering flowering; M_4: DAP spray at flowering

M_5: Cytokinin spray at flowering M_6: Water stress at flowering

4.3 Number of branches plant^{-1}

4.3.1 Effect of variety

Number of branches plant^{-1} of BARI Soybean 5 and BARI Soybean 6 didn't show any significant variation at 50, 75 and 100 DAS (Appendix VI and figure 6). At 50, 75 and 100 DAS, maximum number of branches plant^{-1} (2.81, 3.93 and 3.58, respectively) was observed from V_1 (BARI Soybean 5) and the minimum number (2.26, 3.79 and 3.46, respectively) from V_2 (BARI Soybean 6). Management practices may influence the number of branches plant^{-1} but varieties itself also manipulated it.

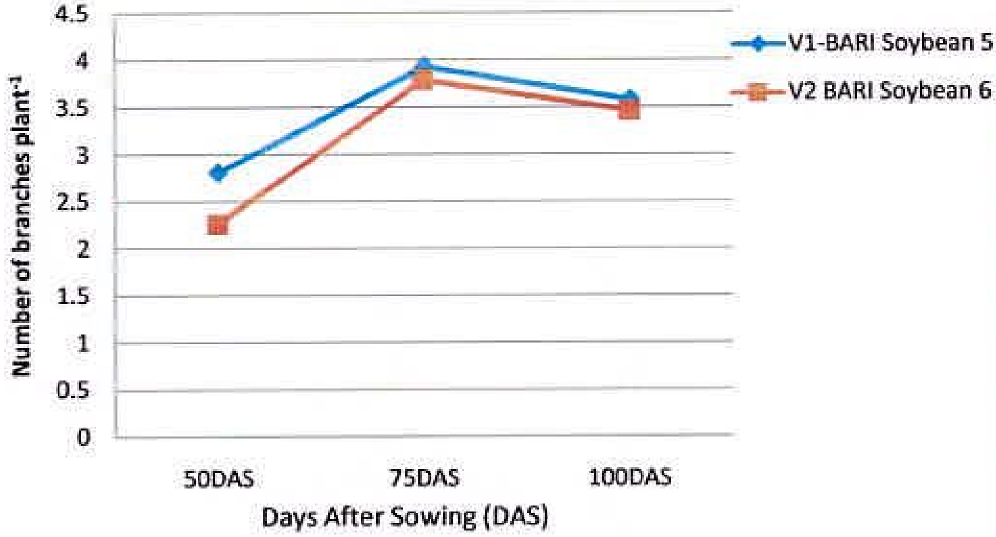

Figure 6. Effect of variety on branch no plant^{-1} of Soybean at different days after sowing (LSD at 5% were NS at 50, 75 and 100 DAS)

4.3.2 Effect of supplementary managements

Different supplementary managements that applied as urea, MoP, DAP, cytokinin and water stress didn't show any significant variation for number of branches plant^{-1} at 50, 75 and 100 DAS (Appendix VI and figure 7). At 50, 75 and 100 DAS, numerically maximum number of branches plant^{-1} (2.83, 4.23 and 4.23, respectively) was recorded from M_6 (water stress at flowering), while the minimum number (2.33 and 3.53) was found from M_3 and (3.33) was found from M_1. Chowdhury *et al.* (2014), reported that soil test based fertilizer application gave the highest number of branch plant^{-1} of soybean. Falodun and Osaigbovo (2010) stated that total number of branches plant^{-1} was enhanced by organic and inorganic fertilizers. Patwary (2003) observed that application of P and S increased the branches plant^{-1}. Bly *et al.* (1998) reported that when soybean fertilized with 20 kg N ha^{-1} at early flowering stage, its branches per plant increased 33%.

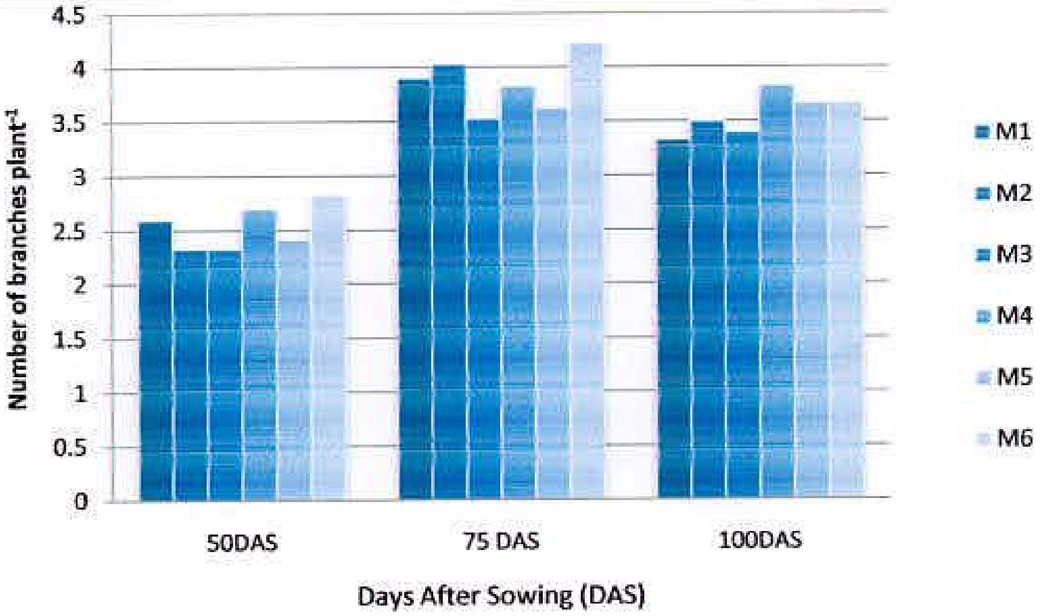

Figure 7. Effect of managements on branch number plant^{-1} of soybean at different days after sowing (LSD at 5% were NS at 25, 50, 75 and 100 DAS respectively)

M_1: Control; Normal cultivation
M_2: Urea spray at flowering
M_3: MoP spray at flowering
M_4: DAP spray at flowering
M_5: Cytokinin spray at flowering
M_6: Water stress at flowering

4.3.3 Interaction effect

Soybean varieties and different supplementary management's interaction didn't show any significant differences on number of branches plant^{-1} at 50, 75 and 100 DAS (Appendix VI and table 3). At 50 DAS, numerically maximum number of branches plant^{-1} (3.07) was found in V_1M_6 (BARI Soybean 5 and cytokinin spray at flowering) and minimum number of branches (1.73) found in V_2M_3 (BARI Soybean 6 and MoP spray at flowering). At 75 and 100 DAS the maximum number of branches plant^{-1} (4.33 and 4.2) was attained from V_1M_4 (BARI Soybean 5 and DAP spray at flowering), whereas the minimum number of branches plant^{-1} (3.2 and 3.0) from V_1T_5 (BARI Soybean 5 and cytokinin spray at flowering).

Table 3. Interaction effect of variety and supplementary managements (e.g., urea, MoP, DAP, cytokinin and water stress at flowering) on number of branches plant^{-1} of soybean

Variety × Managements	Number of branches at		
	50 DAS	75 DAS	100DAS
V_1M_1	2.87	3.93	3.20
V_1M_2	2.2	4.27	3.80
V_1M_3	2.93	3.60	3.27
V_1M_4	3.00	4.33	4.20
V_1M_5	2.80	3.20	3.00
V_1M_6	3.07	4.27	4.00
V_2M_1	2.33	3.87	3.47
V_2M_2	2.47	3.80	3.20
V_2M_3	1.73	3.47	3.53
V_2M_4	2.4	3.33	3.47
V_2M_5	2.03	4.07	3.73
V_2M_6	2.60	4.20	3.33
$LSD_{(0.05)}$	NS	NS	NS
Level of significance	0.05	0.05	0.05
CV (%)	31.52	26.92	26.49

V_1: BARI Soybean 5; V_2: BARI Soybean 6
M_1: Control; Normal cultivation M_2: Urea spray at flowering
M_3: MoP spray at flowering; M_4: DAP spray at flowering
M_5: Cytokinin spray at flowering M_6: Water stress at flowering

4.4 Dry weight (g) plant^{-1}

4.4.1 Effect of variety

At 25, 50, 75 and 100 DAS dry weight plant^{-1} of BARI Soybean 5 and BARI Soybean 6 didn't show any significant variation (Appendix VII and figure 8). Data revealed that at 25 and 50 DAS, numerically maximum weight plant^{-1} (0.21 g and 2.5 g, respectively) was found from V_1 (BARI Soybean 5), while

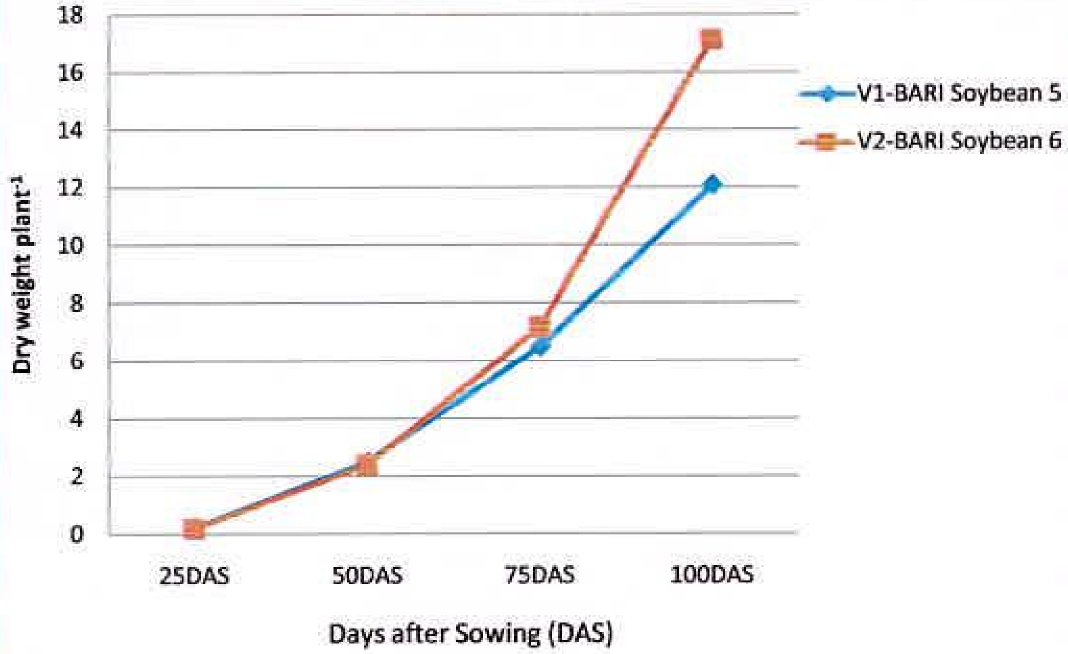

Figure 8. Effect of variety on dry weight plant^{-1} of soybean at different days after sowing (LSD at 5% were 0.05, 0.88, 1.70, 23.66 at 25, 50, 75 and 100DAS

the minimum dry weight plant^{-1} (0.19 g and 2.39 g, respectively) was recorded from V_2 (BARI Soybean 6). At 75 and 100 DAS numerically maximum weight plant^{-1} (7.15 g and 17.14 g, respectively) was observed from V_2 and minimum weight plant^{-1} was recorded from V_1.

4.4.2 Effect of supplementary managements

Statistically no significant variation was recorded for dry weight plant^{-1} at 25, 50, 75 and 100 DAS from different supplementary managements that applied as supplementary urea, MoP, DAP, cytokinin and water stress at flowering (Appendix VII and figure 9). At 25 DAS, the maximum dry weight plant^{-1} (0.22 g) was observed from M_3 and minimum dry weight plant^{-1} (0.18 g) was observed from M_5 (Cytokinin spray at flowering). At 50 and 75 DAS maximum dry weight plant^{-1} (2.72 and 5.82, respectively) was observed from M_4 (DAP spray at flowering). At 100 DAS the maximum dry weight plant^{-1} (18.19 g) was observed from M_4, whereas the minimum dry weight plant^{-1} (11.08 g) was recorded from M_6 (Water stress at flowering).

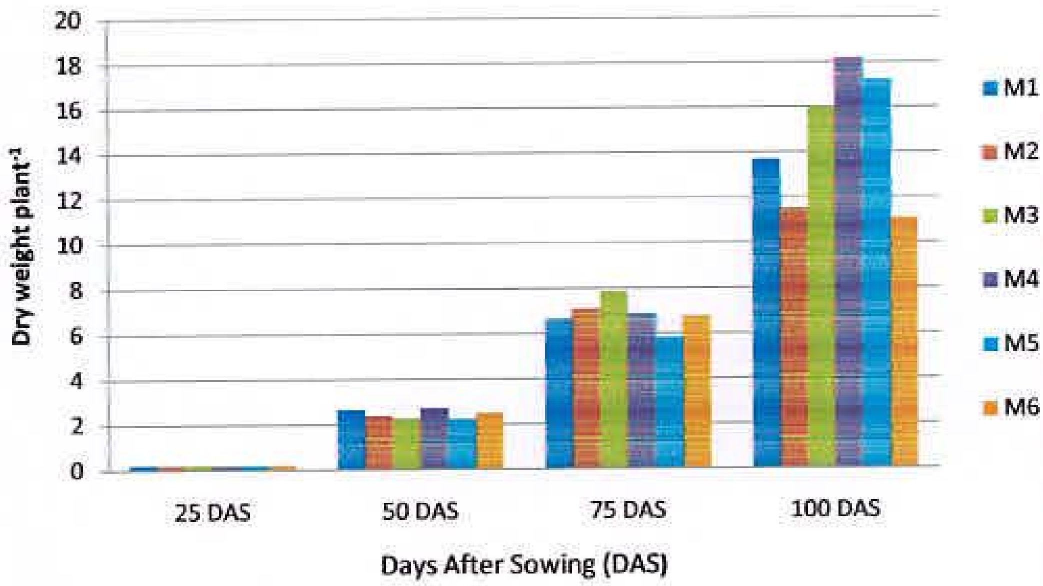

Figure 9. Effect of managements on dry weight plant^{-1} of soybean at different days after sowing (LSD at 5% were NS at 25, 50, 75 and 100 DAS).

M_1: Control; Normal cultivation
M_2: Urea spray at flowering
M_3: MoP spray at flowering
M_4: DAP spray at flowering
M_5: Cytokinin spray at flowering
M_6: Water stress at flowering

4.4.3 Interaction effect

Dry weight plant^{-1} at 25, 50, 75 and 100 DAS didn't show significant variations in the result of the interaction effect of soybean varieties and different supplementary managements (Appendix VII and table 4). At 25, 50, 75 and 100 DAS the maximum dry weight plant^{-1} (0.24 g, 2.82 g, 8.1 g and 23.04 g, respectively) was attained from V_2M_6 (BARI Soybean 6 and water stress at flowering), V_1M_6 (BARI Soybean 5 and water stress at flowering), V_2M_2 (BARI Soybean 6 and urea spray at flowering) and V_2M_2 (BARI Soybean 6 and urea spray at flowering) respectively. At 25 DAS, minimum dry weight plant^{-1} (0.17 g) was observed in V_1M_4 (BARI Soybean 5 and DAP spray at flowering), V_2M_2 (BARI Soybean 6 and urea spray at flowering) and V_2M_5. At 50 and 100 DAS the minimum dry weight plant^{-1} (1.94 g and 8.94 g, respectively) was recorded from V_1M_3 (BARI Soybean 5 and MoP spray at flowering. Amin *et al.* (2009) reported that, the effect of interaction between irrigation and variety on number of leaflets plant^{-1} was significant at different growth stages of soybean.

Table 4. Interaction effect of variety and supplementary managements (e.g., urea, MoP, DAP, cytokinin and water stress at flowering) on dry weight plant^{-1} of soybean

Variety × Managements	Dry Weight (g) at			
	25 DAS	50 DAS	75 DAS	100DAS
V_1M_1	0.22	2.71	6.09	11.46
V_1M_2	0.23	2.43	5.68	9.64
V_1M_3	0.23	1.94	8.51	8.94
V_1M_4	0.17	2.90	6.16	18.38
V_1M_5	0.20	2.22	5.21	13.70
V_1M_6	0.20	2.82	7.33	10.42
V_2M_1	0.20	2.58	7.15	15.94
V_2M_2	0.17	2.29	8.51	13.38
V_2M_3	0.20	2.59	7.12	23.04
V_2M_4	0.22	2.54	7.58	17.99
V_2M_5	0.17	2.23	6.43	20.73
V_2M_6	0.24	2.13	6.13	11.74
$LSD_{(0.05)}$	NS	NS	NS	NS
Level of significance	0.05	0.05	0.05	0.05
CV (%)	26.85	38.07	40.65	59.47

V_1: BARI Soybean 5; V_2: BARI Soybean 6
M_1: Control; No additional management; M_2: Urea spray at flowering
M_3: MoP spray at fkowering flowering; M_4: DAP spray at flowering
M_5: Cytokinin spray at flowering M_6: Water stress at flowering

4.5 Flower dropping (%)

4.5.1 Effect of variety

No significant variation was observed in terms of flower dropping of BARI Soybean 5 and BARI Soybean 6 (Appendix VIII and figure 10). The numerically lower flower dropping (50.53%) was recorded from V_2 (BARI

Soybean 6), whereas the higher flower dropping (53.80%) was recorded from V_1 (BARI Soybean 5).

4.5.2 Effect of supplementary managements

Flower dropping of soybean didn't show statistically significant differences for different supplementary managements that applied as supplementary urea, MoP, DAP, cytokinin and water stress at flowering (Appendix VIII and figure 11). The numerically lowest flower dropping (49.12%) was found from M_5 (cytokinin spray at flowering. Nagel *et al.* (2001) reported that exogenous application of cytokinin to raceme tissues of soybean has been shown to stimulate flower production and to prevent flower abortion. The highest flower dropping (55.30%) was observed from M_2 (urea spray at flowering).

4.5.3 Interaction effect

Interaction effect of soybean varieties and different supplementary managements didn't show significant variation in terms of flower dropping (Appendix VIII and table 5). The lowest flower dropping (48.24%) was recorded from V_2M_6 (BARI soybean 6 + Water stress at flowering). This may be due to water stress at reproductive phase so there was lower amount of flower in plants. The highest flower dropping (56.87%) was found from V_1M_6 (BARI Soybean 5 and Water stress at flowering).

4.6 Pod dropping (%)

4.6.1 Effect of variety

Pod dropping of BARI Soybean 5 and BARI Soybean 6 didn't show statistically significant variation under the present trial (Appendix VIII and figure 10). The lower pod dropping (13.62%) was observed from V_2 (BARI Soybean 6), while the higher pod dropping (15.89%) was found from V_1 (BARI Soybean 5).

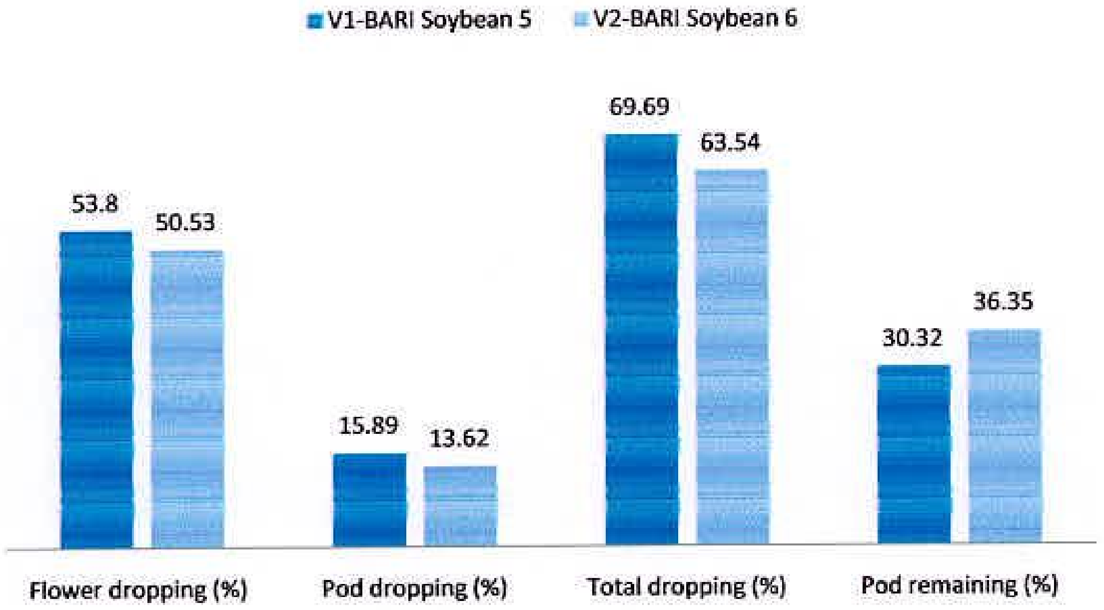

Figure 10 . Effect of variety on flower dropping, pod dropping, Total dropping and pod remaining percentage of soybean (LSD at 5% were NS)

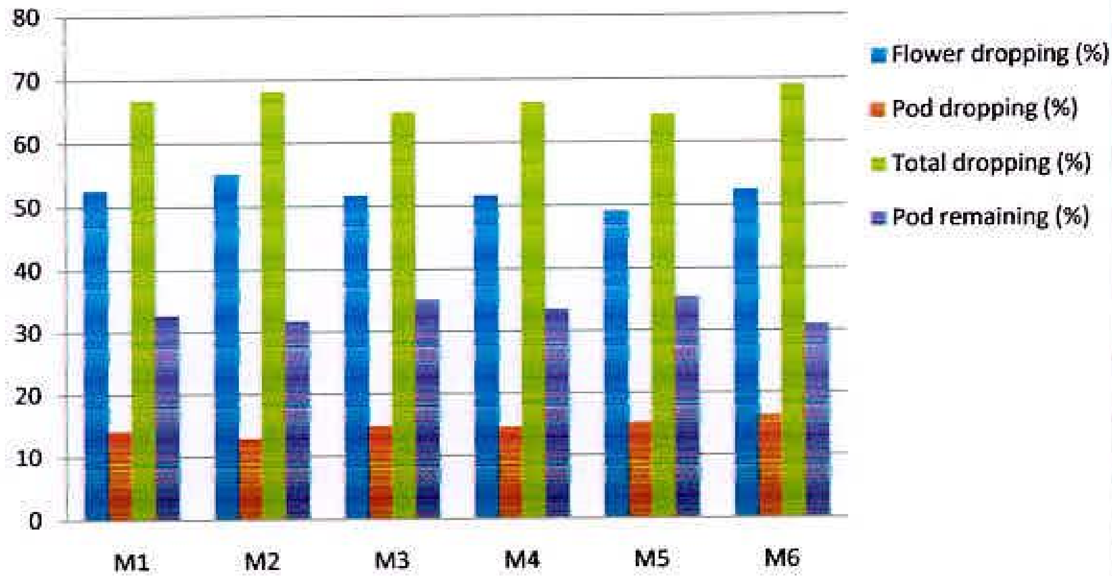

Figure 11. Effect of managements on flower dropping, pod dropping, total dropping and pod remaining percentage of soybean (LSD at 5% level were NS)

M_1: Control; Normal cultivation
M_2: Urea spray at flowering
M_3 : MoP spray at flowering
M_4: DAP spray at flowering
M_5: Cytokinin spray at flowering
M_6: Water stress at flowering

4.6.2 Effect of supplementary managements

Statistically no significant variation was recorded for pod dropping of soybean due to the application of different supplementary managements that applied as supplementary urea, MoP, DAP, cytokinin and water stress at flowering (Appendix VIII and figure 11). The lowest pod dropping (12.93%) was recorded from M_2 (urea spray at flowering)), while the highest pod dropping (16.44%) was found from M_6 (Water stress at flowering). Nayyar *et al.* (2006) reported that the pod setting stages appear to be the most sensitive stages to water stress.

4.6.3 Interaction effect

Interaction effect of soybean varieties and different supplementary managements showed significant differences on pod dropping (Appendix VIII and table 5). The minimum pod dropping (11.11%) was recorded from V_2M_5 (BARI soybean 6 and cytokinin spray at flowering), whereas the maximum pod dropping (19.55%) from V_1M_5 (BARI soybean 5 and cytokinin spray at flowering) which was statistically closely similar (16.98%) to V_2M_4 (BARI soybean 6 and DAP spray at flowering) and (12.57%) to V_1M_2 (BARI soybean 5 and urea spray at flowering)

4.7 Total (flower and pod) dropping (%)

4.7.1 Effect of variety

Statistically no significant variation was recorded in terms of total (flower and pod) dropping of BARI Soybean 5 and BARI Soybean 6 (appendix VIII and figure 10). The numerically higher total dropping (69.69%) was observed from V_1 (BARI Soybean 5) and the lower (63.54%) was found from V_2 (BARI Soybean 6). Aziz *et al.* (1960) reported 20-50% flower and pod dropping in chickpea.

4.7.2 Effect of supplementary managements

Total dropping of soybean showed no significant variation for different managements (Appendix VIII and figure 11). The lowest total dropping (64.45%) was found from M_3 (MoP spray at flowering), whereas the highest total dropping (68.99%) was observed from M_6 (Water stress at flowering).

4.7.3 Interaction effect

Interaction effect of soybean varieties and different supplementary managements showed significant differences on total dropping (Table 6). The lowest total dropping (59.59%) was observed from V_2M_5 (BARI Soybean 6 and cytokinin spray at flowering), while the highest total dropping (72.77%) was found from V_1M_6 (BARI Soybean 5 and Water stress at flowering).

4.8 Pod remaining (%)

4.8.1 Effect of variety

There was no significant variation was recorded for pod remaining of BARI Soybean 5 and BARI Soybean 6 (Appendix VIII and figure 10). The higher pod remaining (36.35%) was found from V_2 (BARI Soybean 6), while the lower pod remaining (30.32%) from V_1 (BARI Soybean 5).

4.8.2 Effect of supplementary managements

Different supplementary managements that applied as urea, MoP, DAP, cytokinin and water stress at flowering showed no significant variation in terms of pod remaining of soybean (Figure 11). The highest pod remaining (35.55%) was found from M_5 (cytokinin spray at flowering), while the lowest pod remaining (31.01%) was observed from M_6 (Water stress at flowering).

4.8.3 Interaction effect

Soybean varieties and different supplementary managements varied significantly for pod remaining due to interaction effect (Table 5). The highest pod remaining (40.41%) was found from V_2M_5 (BARI Soybean 6 and cytokinin spray at flowering) and the lowest (27.23%) from V_1M_6 (BARI Soybean 5 and Water stress at flowering).

Table 5. Interaction effect of variety and supplementary managements (e.g., urea, MoP, DAP, cytokinin and water stress at flowering) on flower dropping (%), pod dropping (%), total dropping (%) and pod remaining of soybean

Variety × Managements	**Flower dropping (%)**	**Pod dropping (%)**	**Total dropping (%)**	**Pod remaining (%)**
V_1M_1	55.36	16.31 a-d	71.67 ab	28.33 a
V_1M_2	55.77	12.57 ab	68.35 ab	31.65 ab
V_1M_3	52.81	16.66 a-c	69.47 ab	30.59 ab
V_1M_4	52.25	14.32 a-e	66.58 ab	33.42 ab
V_1M_5	49.76	19.55 a	69.31 ab	30.69 ab
V_1M_6	56.87	15.89 b-e	72.77 a	27.23 b
V_2M_1	49.86	12.13 de	61.98 ab	37.35 ab
V_2M_2	53.83	13.29 b-e	68.13 ab	31.87 ab
V_2M_3	50.64	13.19 b-e	60.16 b	39.84 ab
V_2M_4	51.13	15.04 ab	66.16 ab	33.84 ab
V_2M_5	48.48	11.11 f	59.59 b	40.41 a
V_2M_6	48.24	16.98 b-e	65.22 ab	34.78 ab
$LSD_{(0.05)}$	NS	4.24	12.58	12.68
Level of significance	0.05	0.05	0.05	0.05
CV (%)	13.21	16.85	11.09	22.33

V_1: BARI Soybean 5; V_2: BARI Soybean 6
M_1: Control; Normal cultivation; M_2: Urea spray at flowering
M_3: MoP spray at fkowering flowering; M_4: DAP spray at flowering
M_5: Cytokinin spray at flowering M_6: Water stress at flowering

4.9 Pods plant^{-1}

4.9.1 Effect of variety

Statistically no significant variation was recorded in terms of pods plant^{-1} of BARI Soybean 5 and BARI Soybean 6 (Appendix IX and figure 12). Numerically maximum pods plant^{-1} (68.62) was found from V_2 (BARI Soybean 6), while the minimum (63.34) was observed from V_1 (BARI Soybean 5). Number of pods plant^{-1} for different varieties might depend on genetical and environmental influences as well as management practices. Mirzakhani *et al.* (2013) reported that the number of pods in the plant had no significant differences between the different cultivars.

4.9.2 Effect of supplementary managements

Pods plant^{-1} of soybean showed no significant variation for different supplementary managements that applied as supplementary urea, MoP, DAP, cytokinin and water stress at flowering (Appendix IX and Table 6). The maximum pods plant^{-1} (69.47) was observed from M_2 (Urea spray at flowering), whereas the minimum (62.70) was recorded from M_6 (Water stress at flowering). Hafiz (2000) reported that late supplementary foliar spraying with aqueous solution of 1% urea significantly increased yield components. Bicer *et al.* (2004) reported that number of pods plant^{-1} was higher under irrigated than rainfed conditions. Mokoena (2013) reported that pod number per plant was reduced by applying P.

4.9.3 Interaction effect

No significant variation was observed due to the interaction effect of soybean varieties and different supplementary managements on pods plant^{-1} (Appendix IX and table 7). The numerically maximum pods plant^{-1} (74.87) was found from V_2M_1 (BARI Soybean 6 and normal cultivation) and the minimum pods plant^{-1} (57.91) from V_1M_5 (BARI Soybean 5 and cytokinin spray at flowering). Similar results were reported by Yagoub *et al.* (2012). Hantolo (1995) and Chuansong (1990) observed that increasing the levels of nitrogen fertilization had no effect on the mean number of pods per plant. The number of seeds per pod was slightly affected by nitrogen fertilization as noticed by Xuewen (1990), Akbari *et al.* (2001), Agha *et al.* (2004). Brevendan *et al.* (1978) reported that increased nitrogen levels during soybean flowering period, number of pods per node and number of pods per plant, respectively, 22 and 40% increased compared to control (no nitrogen consumption).

4.10 Pod length (cm)

4.10.1 Effect of variety

Pod length of BARI Soybean 5 and BARI Soybean 6 varied significantly under the present trial (Appendix IX and figure 12). The longer pod (3.53 cm) was recorded from V_1 (BARI Soybean 5), whereas the shorter pod (3.38 cm) was found from V_2 (BARI Soybean 6). Different varieties responded differently for pod length to input supply, method of cultivation and the prevailing environment during the growing season.

4.10.2 Effect of supplementary managements

No significant variation was recorded in terms of pod length of soybean for different supplementary managements (Appendix IX and table 6). The numerically longest pod (3.51 cm) was found from M_2 (Urea spray at flowering). On the other hand, the shortest pod (3.41 cm) was recorded from M_4 (DAP spray at flowering). Bicer *et al.* (2004) reported that pod length were higher under irrigated than rainfed conditions.

4.10.3 Interaction effect

Interaction effect of soybean varieties and different supplementary managements showed significant differences on pod length (Appendix IX and table 7). The longest pod (3.86 cm) was found from V_1M_3 (BARI Soybean 5 and MoP spray at flowering), while the shortest pod (3.25 cm) was observed from V_2M_3 (BARI Soybean 6 and MoP spray at flowering).

4.11 Seeds pod^{-1}

4.11.1 Effect of variety

Statistically no significant difference was observed in terms of seeds pod^{-1} of BARI Soybean 5 and BARI Soybean 6 (Appendix IX and figure 12). The maximum seeds pod^{-1} (2.39) was recorded from V_1 (BARI Soybean 5) and the minimum seeds pod^{-1} (2.36) was recorded from V_2 (BARI Soybean 6). The variation for number of seeds pods^{-1} might be due to input supply, method of cultivation and the prevailing environment during the growing season.

4.11.2 Effect of supplementary managements

Different supplementary managements that applied as supplementary urea, MoP, DAP, cytokinin and water stress at flowering showed statistically significant variation in terms of seeds pod^{-1} of soybean (Appendix IX and table 6). The maximum seeds pod^{-1} (2.42) was found from M_4 (DAP spray at flowering), which was statistically similar (2.43) with M_3 (MoP spray at flowering) and closely followed (2.37) by M_2 (urea spray at flowering) and M_5 (cytokinin spray at flowering), again the minimum seeds pod^{-1} (2.33) was observed from M_1 (control i.e., normal cultivation) and closely followed by M_6 (Water stress at flowering). Bicer *et al.* (2004) reported that number of seeds pods^{-1} was higher under irrigated than rainfed conditions.

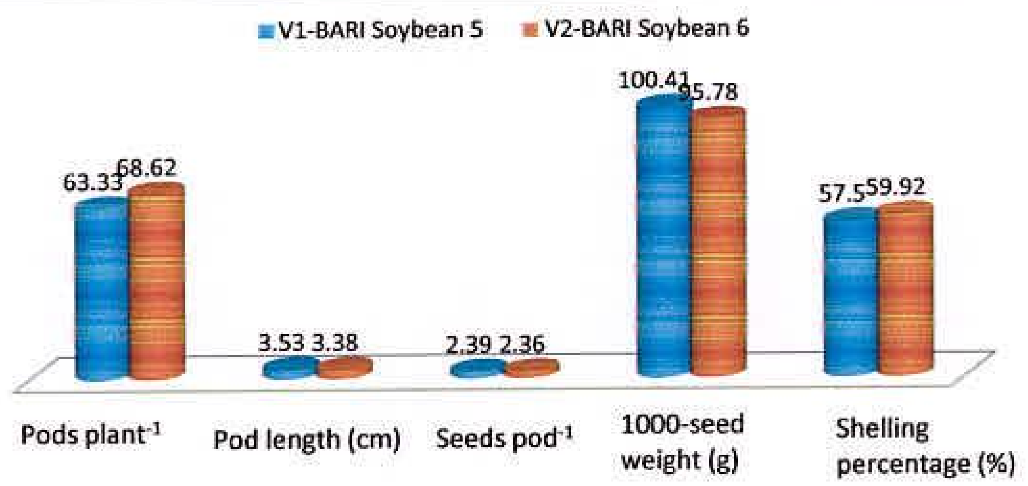

Figure 12 . Effect of variety on pods plant^{-1}, pod length (cm), seeds pod^{-1}, 1000 seed weight (g), shelling percentage (%) of soybean (LSD at 5 % were NS, 0.064, NS, NS and NS respectively)

4.11.3 Interaction effect

Seeds pod^{-1} of soybean showed significant differences due to the interaction effect of soybean varieties and different supplementary managements (Appendix IX and table 7). The maximum seeds pod^{-1} (2.48) was recorded from V_1M_3 (BARI Soybean 5 and MoP spray at flowering) which was statistically similar (2.43) to V_1M_4 (BARI Soybean 5 and DAP spray at flowering), whereas the minimum seeds pod^{-1} (2.29) from V_1M_1 (BARI Soybean 5 and normal cultivation).

4.12 1000-seed weight

4.12.1 Effect of variety

Statistically no significant variation was recorded in terms of 1000-seed weight of BARI Soybean 5 and BARI Soybean 6 (Appendix IX and figure 12). The maximum 1000-seed weight (100.41 g) was found from V_1 (BARI Soybean 5), while the minimum 1000-seed weight (95.78 g) was attained from V_2 (BARI Soybean 6). Mirzakhani *et al.* (2013) reported that 100 seed weight in the plant were not significantly varied for the different cultivars.

4.12.2 Effect of supplementary managements

1000-seed weight of soybean showed significant variation for different supplementary managements (Appendix IX and table 6). The maximum weight of 1000-seed (104.04 g) was recorded from M_1 (normal cultivation), which was statistically similar (102.39 g and 97.55 g, respectively) to M_2 (urea spray at flowering) and M_5 (cytokinin spray at flowering) and closely followed (96.59 g and 95.74 g) by M_3 (MoP spray at flowering) and M_4 (DAP spray at flowering), whereas the minimum weight of 1000-seed (92.25 g) from M_6 (water stress at flowering). In soybean, seed weight increased under nitrogen fertilization as indicated by Xuewen (1990), Akbari *et al.* (2001).

Table 6. Effect of managements (e.g., urea, MoP, DAP, cytokinin and water stress at flowering) on pods plant^{-1}, pod length, seeds pod^{-1}, 1000-seed weight and shelling percentage of soybean

Managements	Pods plant^{-1} (No.)	Pod length (cm)	Seeds pod^{-1} (No.)	1000-seed weight (g)	Shelling percentage (%)
M_1	67.43	3.44	2.33 c	104.04 a	57.38
M_2	69.47	3.51	2.37 bc	102.39 ab	57.94
M_3	62.9	3.47	2.41 ab	96.59 a-c	62.22
M_4	67	3.41	2.42 a	95.74 a-c	57.93
M_5	66.36	3.50	2.37 bc	97.55 a-c	59.58
M_6	62.7	3.43	2.34 c	92.25 c	57.23
$LSD_{(0.05)}$	NS	NS	0.04	8.63	NS
Level of significance	0.05	0.05	0.05	0.05	0.05
CV (%)	26.59	2.42	1.33	7.30	8.31

M_1: Control; Normal cultivation; M_2: Urea spray at flowering
M_3: MoP spray at fkowering flowering; M_4: DAP spray at flowering
M_5: Cytokinin spray at flowering M_6: Water stress at flowering

4.12.3 Interaction effect

Soybean varieties and different supplementary managements showed significant differences on weight of 1000-seed due to interaction effect (Appendix IX and table 7). The maximum weight of 1000-seed (111.33 g) was observed from V_1M_1 (BARI Soybean 5 and normal cultivation) and the minimum 1000-seed weight (88.83 g) from V_2M_6 (BARI Soybean 6 and water stress at flowering).

Table 7. Interaction effect of variety and supplementary managements (e.g., urea, MoP, DAP, cytokinin and water stress at flowering) on pods plant^{-1}, pod length, seeds pod^{-1}, weight of 1000-seed and shelling percentage of soybean

Variety × Managements	Pods plant^{-1} (No.)	Pod length (cm)	Seeds pod^{-1} (No.)	1000-seed weight (g)	Shelling percentage (%)
V_1M_1	60.00	3.44 c-e	2.29 g	111.33	55.44 b-d
V_1M_2	58.47	3.49 b-d	2.42 bc	104.33	53.35 d
V_1M_3	63.20	3.68 a	2.48 a	98.66	63.77 a
V_1M_4	66.93	3.41 de	2.43 ab	99.57	59.66 a-d
V_1M_5	57.91	3.58 bc	2.37 c-e	92.87	56.25 a-d
V_1M_6	73.47	3.59 b	2.35 de	95.67	56.55 a-d
V_2M_1	74.87	3.44 de	2.37 c-e	96.74	59.32 a-d
V_2M_2	66.93	3.36 de	2.33 ef	100.44	62.53 a-c
V_2M_3	62.60	3.25 e	2.34 ef	94.52	60.67 a-d
V_2M_4	67.07	3.41 de	2.4 b-d	91.91	56.19 a-d
V_2M_5	74.80	3.43 de	2.37 c-e	102.23	62.90 ab
V_2M_6	65.47	3.42 de	2.33 ef	88.83	57.90 a-d
$LSD_{(0.05)}$	NS	0.14	12.58	NS	8.31
Level of significance	0.05	0.05	0.05	0.05	0.05
CV (%)	26.59	2.42	11.09	7.30	8.31

V_1: BARI Soybean 5; V_2: BARI Soybean 6

M_1: Control; Normal cultivation; M_2: Urea spray at flowering

M_3: MoP spray at fkowering flowering; M_4: DAP spray at flowering

M_5: Cytokinin spray at flowering M_6: Water stress at flowering

4.13 Shelling percentage

4.13.1 Effect of variety

Shelling percentage of BARI Soybean 5 and BARI Soybean 6 didn't varied significantly under the present trial (Appendix IX and figure 12). The numerically higher shelling percentage (59.92) was recorded from V_2 (BARI Soybean 6) and the lower shelling percentage (57.50) was recorded from V_1 (BARI Soybean 5).

4.13.2 Effect of supplementary managements

Statistically no significant variation was recorded in terms of shelling percentage of soybean for different supplementary managements that applied as urea, MoP, DAP, cytokinin and water stress at flowering (Appendix IX and table 6). The highest shelling percentage (62.22) was found from M_3 (MoP spray at flowering), while the lowest shelling percentage (57.23) was observed from M_6 (water stress at flowering). Hafiz (2000) reported that chickpea cultivars Giza 1, Giza 88 and Giza 195 and early soil application of nitrogen fertilizer up to 40 kg N ha^{-1} significantly increased shelling percentage.

4.13.3 Interaction effect

Interaction effect of soybean varieties and different supplementary managements showed significant differences on shelling percentage (Appendix IX and table 7). The highest shelling percentage (63.77) was recorded from V_1M_3 (BARI Soybean 5 and MoP spray at flowering) and closely (62.90) followed by V_2M_5 (BARI Soybean 6 and cytokinin spray at flowering) which are both statistically similar. Again, the lowest shelling percentage (53.35) from V_1M_2 (BARI Soybean 5 and urea spray at flowering).

4.14 Seed yield (t ha^{-1})

4.14.1 Effect of variety

Statistically no significant variation was recorded in terms of seed yield of BARI Soybean 5 and BARI Soybean 6 (Appendix X and figure 13). The higher seed yield (1.15 t ha^{-1}) was observed from V_1 (BARI Soybean 5), whereas the lower seed yield (0.95 t ha^{-1}) was found from V_2 (BARI Soybean 6). Varieties plays an important role in producing high yield of soybean and yield also varied for different varieties might be due to genetical and environmental influences as well as management practices as reported by Mabapa *et al.* (2010) reported that soybean cultivars affect the seed yield.

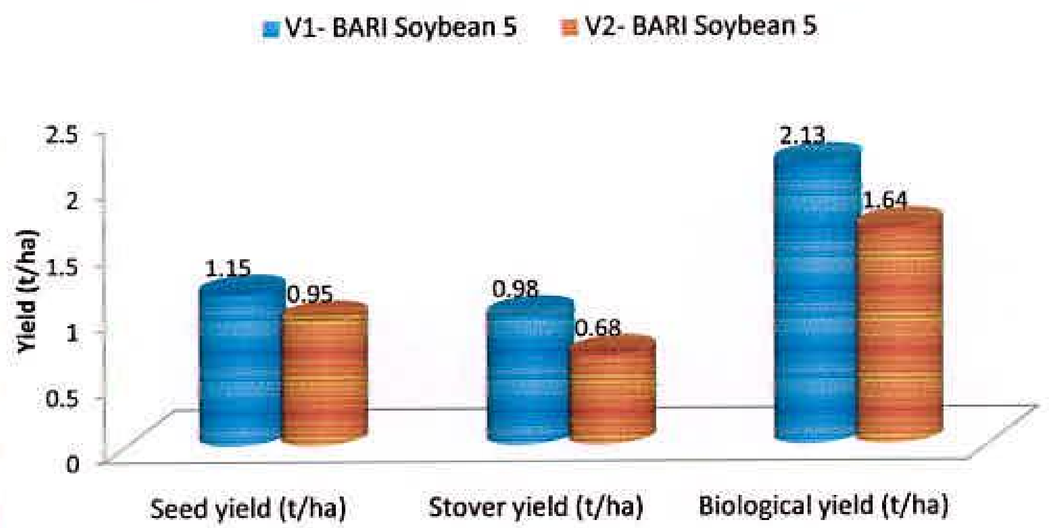

Figure 13. . Effect of varieties on seed yield ha^{-1}, stover yield ha^{-1} and biological yield ha^{-1} of soybean (LSD at 5% were NS, NS and 0.33 respectively).

4.14.2 Effect of supplementary managements

Different supplementary managements that applied as supplementary urea, MoP, DAP, cytokinin and water stress at flowering showed significant variation for seed yield of soybean (Appendix X and table 8). The highest seed yield (1.21 t ha^{-1}) was recorded from M_2 (urea spray at flowering), which was statistically similar (1.18 t ha^{-1}) to M_4 (DAP spray at flowering) and closely followed (1.07 t ha^{-1} and 1.03 t ha^{-1}) by M_3 (MoP spray at flowering) and M_1 (normal cultivation), while the lowest seed yield (0.83 t ha^{-1}) was attained from M_6 (water stress at flowering). Yamika and Ikawati (2012) found that the combination of inorganic with organic fertilizers (0, 0.5 and 1 t ha^{-1}) increased the seed yield up to 3.5 t ha^{-1}. Golparvar *et al.* (2012) reported that the interaction of soybean cultivar × fertilizer on seed yield was significant at 1%, regardless on the fertilizer rate.

4.14.3 Interaction effect

Seed yield of soybean varied significantly due to the interaction effect varieties and different supplementary managements (Appendix X and table 9). The highest seed yield (1.48 t ha^{-1}) was found from V_1M_4 (BARI Soybean 5 and DAP spray at flowering) and the lowest seed yield (0.79 t ha^{-1}) from V_2M_6 (BARI Soybean 6 and water stress at flowering). Mabapa *et al.* (2010) observed that the interaction effect of cultivar and phosphorus didn't show any significant variation.

4.15 Stover yield (t ha^{-1})

4.15.1 Effect of variety

Stover yield of BARI Soybean 5 and BARI Soybean 6 didn't show statistically any significant variation under the present trial (Appendix x and figure 13). The higher stover yield (0.98 t ha^{-1}) was observed from V_1 (BARI Soybean 5), while the lower stover yield (0.69 t ha^{-1}) was recorded from V_2 (BARI Soybean 6).

4.15.2 Effect of supplementary managements

Statistically no significant variation was recorded for stover yield of soybean due to different supplementary managements that applied as urea, MoP, DAP, cytokinin and water stress at flowering (Appendix X and table 8). The numerically highest stover yield (1.02 t ha^{-1}) was found from M_4 (DAP spray at flowering). On the other hand, the lowest stover yield (0.732 t ha^{-1}) was found from M_6 (water stress at flowering). Dikshit and Khatik (2008) observed that application of organic and inorganic fertilizers increased the stover yield of soybean. Forhad and Malik (2010) also reported that application of P and K increased the stover yield. Khaim *et al.* (2013) reported that the stover yield of soybean was maximum when poultry manure with chemical fertilizers added.

Table 8. Effect of managements (e.g., urea, MoP, DAP, cytokinin and water stress at flowering) on grain yield, stover yield, biological yield and harvest index of soybean

Managements	Seed yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
M_1	1.03	0.81	1.84	55.37 ab
M_2	1.21	0.91	2.11	57.94 ab
M_3	1.07	0.73	1.79	59.01 a
M_4	1.18	1.02	2.21	53.54 ab
M_5	0.99	0.81	1.79	55.52 ab
M_6	0.83	0.73	1.57	52.56 b
$LSD_{(0.05)}$	NS	NS	NS	6.40
Level of significance	0.05	0.05	0.05	0.05
CV (%)	33.94	32.17	31.44	9.55

M_1: Control; Normal cultivation; M_2: Urea spray at flowering
M_3: MoP spray at fkowering flowering; M_4: DAP spray at flowering
M_5: Cytokinin spray at flowering M_6: Water stress at flowering

4.15.3 Interaction effect

Interaction effect of soybean varieties and different supplementary managements showed statistically significant variation in terms of stover yield (Appendix X and table 9). The highest stover yield (1.26 t ha^{-1}) was recorded from V_1M_4 (BARI Soybean 5 and DAP spray at flowering), whereas the lowest stover yield (0.6 t ha^{-1}) was observed from V_2M_6 (BARI Soybean 6 and water stress at flowering).

Table 9. Interaction effect of variety and supplementary managements (e.g., urea, MoP, DAP, cytokinin and water stress at flowering) on grain yield, stover yield, biological yield and harvest index of soybean

Variety × Managements	Seed yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
V_1M_1	1.17 ab	0.91 a-c	2.08 ab	55.01 a-c
V_1M_2	1.28 ab	1.13 ab	2.40 ab	53.47 a-c
V_1M_3	1.21 ab	0.82 a-c	2.03 ab	59.35 a-c
V_1M_4	1.48 a	1.26 a	2.75 a	54.41 a-c
V_1M_5	0.88 ab	0.89 a-c	1.77 ab	49.84 c
V_1M_6	0.88 ab	0.86 a-c	1.74 ab	51.17 c
V_2M_1	0.88 ab	0.71 bc	1.59 b	55.14 a-c
V_2M_2	1.13 ab	0.69 bc	1.81 ab	62.42 a
V_2M_3	0.92 ab	0.64 c	1.56 b	58.67 a-c
V_2M_4	0.87 ab	0.78 bc	1.66 b	52.68 bc
V_2M_5	1.11 ab	0.71 bc	1.82 ab	61.20 ab
V_2M_6	0.79 b	0.60 c	1.39 b	53.94 a-c
$LSD_{(0.05)}$	0.61	0.46	1.01	9.05
Level of significance	0.05	0.05	0.05	0.05
CV (%)	33.94	32.17	31.44	9.55

V_1: BARI Soybean 5; V_2: BARI Soybean 6

M_1: Control; Normal cultivation; M_2: Urea spray at flowering

M_3: MoP spray at fkowering flowering; M_4: DAP spray at flowering

M_5: Cytokinin spray at flowering M_6: Water stress at flowering

4.16 Biological yield (t ha^{-1})

4.16.1 Effect of variety

Biological yield of BARI Soybean 5 and BARI Soybean 6 showed statistically significant variation under the present trial (Appendix X and figure 13). The higher biological yield (2.13 t ha^{-1}) was recorded from V_1 (BARI Soybean 5), while the lower (1.64 t ha^{-1}) was found from V_2 (BARI Soybean 6).

4.16.2 Effect of supplementary managements

Statistically no significant variation was recorded for biological yield of soybean due to different supplementary managements that applied as urea, MoP, DAP, cytokinin and water stress at flowering (Appendix X and table 8). The numerically maximum biological yield (2.21 t ha^{-1}) was observed from M_4 (DAP spray at flowering) and the minimum biological yield (1.57 t ha^{-1}) was recorded from M_6 (water stress at flowering).

4.16.3 Interaction effect

Interaction effect of soybean varieties and different supplementary managements showed statistically significant variation in terms of biological yield (Appendix X and table 7). The highest biological yield (2.75 t ha^{-1}) was found from V_1M_4 (BARI Soybean 5 and DAP spray at flowering), whereas the lowest (1.39 t ha^{-1}) was obtained from V_2M_6 (BARI Soybean 6 and water stress at flowering).

4.17 Harvest index (%)

4.17.1 Effect of variety

Harvest index of BARI Soybean 5 and BARI Soybean 6 showed statistically no significant variation under the present trial (Figure 14 and Appendix X). The maximum harvest index (57.44%) was found from V_2 (BARI Soybean 6), while the minimum (53.87%) was recorded from V_1 (BARI Soybean 5).

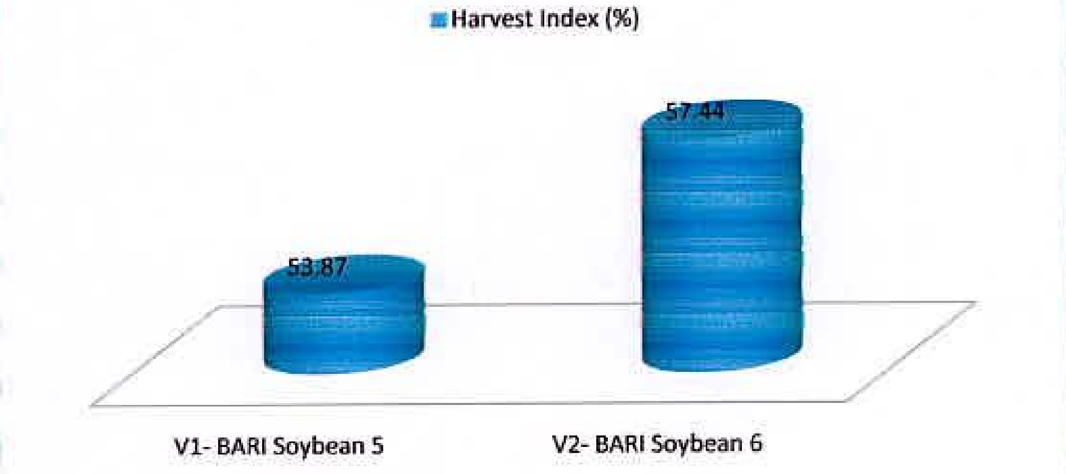

Figure 14. Effet of variety on harvest index (%) of soybean (LSD at 5% was NS)

4.17.2 Effect of supplementary managements

Statistically significant variation was recorded for harvest index of soybean due to different supplementary managements that applied as urea, MoP, DAP, cytokinin and water stress at flowering (Appendix X and table 8). The maximum harvest index (59.01%) was found from M_3 (MoP spray at flowering), which was statistically similar (57.94%, 55.52%, 55.37% and 53.54%) repeatedly to M_2 (urea spray at flowering), M_5 (cytokinin spray at flowering), M_1 (no additional management) and M_4 (DAP spray at flowering), whereas the minimum (52.56%) was found from M_6 (water stress at flowering).

4.17.3 Interaction effect

Interaction effect of soybean varieties and different supplementary managements showed statistically significant variation in terms of harvest index (Appendix X and table 9). The maximum harvest index (62.42%) was recorded from V_2M_2 (BARI Soybean 6 and urea spray at flowering), whereas the minimum (49.84%) was observed from V_1M_5 (BARI Soybean 5 and cytokinin spray at flowering). Mabapa (2010) reported no variation of harvest index in soybean due to phosphorus application. However, other studies (Malik *et al.*, 2006) have reported significant effect of phosphorus rates on harvest index of soybeans.

Chapter V

Summary and Conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The experiment was conducted during the period from 14 January, 2014 to 8 May, 2014 to study the influence of supplementary management e.g., urea spray, MoP spray, DAP spray, cytokinin spray and water stress at flowering. BARI Soybean 5 and BARI Soybean 6 were used as the test crops. There are two factors in this experiment: Factor A: Soybean variety (2) as V_1: BARI Soybean 5 and V_2: BARI Soybean 6, Factor B: Supplementary managements (6 levels) as M_1: Control i.e., normal cultivation; M_2: Urea spray at flowering; M_3: MoP spray at flowering; M_4: DAP spray at flowering; M_5: Cytokinin spray at flowering and M_6: Water stress at flowering stage of soybean. The two factors experiment was laid out in split-plot design with three replications. Data on different growth parameters, yield attributes and yield were recorded and statistically significant variation was recorded for different parameters.

At 25, 50, 75 and 100 DAS the taller plant (10.83 cm, 33.56 cm, 56.82 cm and 57.39 cm, respectively), maximum number of leaflets plant^{-1} (5.42, 28.1, 68.88 and 25.0 respectively) was recorded from V_1 (BARI Soybean 5), whereas the shorter plant (9.3 cm, 29.21cm, 50.21cm and 51.96cm, respectively) and minimum number of leaflets plant^{-1} (4.99, 25.89, 66.63 and 24.71 respectively) was recorded from BARI Soybean 6 at same DAS. At 50, 75 and 100 DAS the maximum number of branches plant^{-1} (2.81, 3.93 and 3.58 respectively) was found from V_1 (BARI Soybean 5) and the minimum number of branches plant^{-1} (2.26, 3.79and 3.46 respectively) was found from V_2 (BARI Soybean 6). At 25 and 50 DAS the highest dry weight plant^{-1} (0.21g and 2.50g, respectively) was found from V_1 and at 75 & 100 DAS the lowest dry weight plant^{-1}(0.19 g and 2.39 g, respectively) was found from V_2 (BARI Soybean 6) whereas at 25 and 50 DAS the highest dry weight plant^{-1} (7.15 g and 17.14 g, respectively) was found from V_2 (BARI Soybean 6) and lowest dry weight plant^{-1} (6.49 g and 12.09 g, respectively) was found from V_1 (BARI Soybean 5). The lower flower dropping (50.53%), lower pod dropping (13.62%), lower total dropping (63.54%), higher pod remaining (36.35%), maximum pods plant^{-1} (68.62), higher shelling percentage (59.92), and maximum harvest index (57.44%) was recorded from V_2, whereas the higher flower dropping (53.80%), higher pod dropping (15.89%), higher total dropping (69.69%), lower pod remaining (30.32%), minimum pods plant^{-1} (26.03), lower shelling percentage (57.50), and minimum harvest index (53.87%) was recorded from V_1. Longer pod (3.53 cm), maximum seeds pod^{-1} (2.39), maximum weight of 1000-seeds (100.41 g), higher seed yield (1.15 t ha^{-1}), higher stover yield (0.98 t ha^{-1}), higher biological yield (2.13 t ha^{-1}) was recorded from V_1 and shorter pod (3.38 cm), minimum seeds pod^{-1} (2.36), minimum weight of 1000-seeds (95.78 g), lower seed yield (0.95 t ha^{-1}), lower stover yield (0.69 t ha^{-1}), lower biological yield (1.64 t ha^{-1}) was recorded from V_2.

At 25 and 50 DAS, the tallest plant (10.95 cm and 32.15cm, respectively) was found from M_1 and the shortest plant (9.68 cm and 30.8 cm, respectively) was found from M_6 and M_5 respectively. At 75 and 100 DAS, the tallest plant (55.69 cm and 58.42 cm, respectively) was found from M_4 and shortest plant (50.74 cm and 51.68 cm, respectively) was found from M_5. At 25 and 50 DAS, the maximum number of leaflets plant^{-1} (5.77 and 28.23, respectively) was found from M_1 and minimum number of leaflets plant^{-1} (4.87 and 25.47, respectively) was found from M_4 and M_2 respectively. At 50 and 75 DAS, maximum number of branches plant^{-1} (2.83 and 4.23, respectively) was found from M_6 and minimum number of branches plant $^{-1}$ (2.33, 3.53, respectively) was found from M_2 and M_3 respectively. At 100 DAS, maximum number of branches plant^{-1} (3.83) was found from M_4 and minimum number of branches plant^{-1} (3.33) was found from M_1. At 25, 50, 75 and 100 DAS maximum dry weight plant^{-1} (0.22 g, 2.72, 6.87 and 18.19 g, respectively) was found from M_6, M_4, M_4 and M_4, respectively, while the minimum dry weight plant^{-1} (0.18 g, 2.23 g, 5.82 g and 4.65 g, respectively) was observed from M_5, M_5, M_5 and M_6, respectively. The lowest flower dropping (49.12%), the lowest pod dropping (12.92%), the lowest total dropping (64.45%), the highest pod remaining (35.55%), the maximum pods plant^{-1} (69.47), the longest pods (3.51 cm), the maximum seeds pod^{-1} (2.42), the maximum weight of 1000-seeds (104.04 g), the highest shelling percentage (62.22), the highest seed yield (1.21 t ha^{-1}), the highest stover yield (1.02 t ha^{-1}), higher biological yield (2.21 t ha^{-1}) and maximum harvest index (59.01%) was found from M_5, M_2, M_3, M_5, M_2, M_2, M_4, M_1, M_3, M_2, M_4, M_4 and M_3 respectively. Again, the highest flower dropping (55.30%), highest pod dropping (16.44%), the highest total dropping (68.99%), the lowest pod remaining (31.01%), the minimum pods plant^{-1} (62.7), the shortest pod (3.41 cm), the minimum seeds pod^{-1} (2.33), the minimum weight of 1000-seeds (92.25 g), the lowest shelling percentage (57.23), the lowest seed yield (0.83 t ha^{-1}), the lowest stover yield (0.73 t ha^{-1}), lower biological yield (1.57 t ha^{-1}) and minimum harvest index (52.56%) was observed from different managements.

At 25, 50 and 75 DAS the tallest plant (12.37 cm, 35.03 cm and 60.14 cm, respectively) was found from V_1M_1 and the shortest plant (8.93 cm, 27.39 cm, 49.17 cm, respectively) was found from V_2M_6 and V_2M_5. The maximum number of leaflets plant^{-1} (6.27, 29.73, 74.8 and 29.8, respectively) was found from V_1M_1 and V_2M_6 at 25, 50, 75 and 100 DAS, respectively. Various number of branches plant^{-1} and different dry weight plant^{-1} was found from different interactions at different growth stage of soybean. The maximum flower dropping (56.87%) and highest total dropping (72.77%) in V_1M_6 and the highest stover yield (1.26 t ha^{-1}), highest seed yield (1.48 t ha^{-1}), highest biological yield (2.75 t ha^{-1}) was found from V_1M_4 (BARI Soybean 5 and DAP spray at flowering). The lowest flower dropping (48.24%) was found from V_2M_6 (BARI Soybean 6 and Water stress at flowering) and lowest total dropping (59.59%) was found from V_2M_5 (BARI Soybean 6 and cytokinin spray at flowering). Again, lowest stover yield (0.6 t ha^{-1}), lowest seed yield (0.79 t ha^{-1}), lowest biological yield (1.39 t ha^{-1}) was found from V_2M_6 (BARI Soybean 6 and water stress at flowering). The highest number of seeds pod^{-1}

(2.48), longest pod (3.68 cm) and highest shelling percentage (63.77) was found from V_1M_3 (BARI Soybean 5 and MoP spray at flowering), whereas lowest number of seeds pod^{-1} (2.29), shortest pod (3.25 cm) and lowest shelling percentage (53.35) was found from V_1M_1, V_2M_3 and V_1M_2, respectively. The highest 1000 seed weight (111.33 g) and the highest harvest index (62.42%) was found from V_1M_1 and V_2M_2 respectively. Again, the lowest 1000 seed weight (88.83 g) and lowest harvest index (49.84%) was found from V_2M_6 and V_1M_5, respectively.

Considering the findings of the present experiment, following conclusions may be drawn:

- BARI Soybean 5 cultivation with DAP application at flowering revealed maximum yield and yield contributing characters compared to the others.
- Before recommendation of variety and supplementary management (DAP spray at flowering), further study is needed in different agro-ecological zones for optimizing soybean production in Bangladesh.

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Appendices

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Appendix I. Physical properties of the soils of the experimental field

Soil properties	Analytical data
Sand (%)	29.04
Silt (%)	41.80
Clay (%)	29.16

Appendix II. Chemical properties of the soils of the experimental field

Soil properties	Analytical value
pH	5.8
Organic matter (%)	1.34
Total N (%)	0.08
Available P (ppm)	31.15
Exchangeable K (meq/100 g)	0.18
Exchangeable Ca (meq/100 g)	0.12
Exchangeable Mg (meq/100 g)	--
Available S (ppm)	0.02
Zinc (ppm)	--
Boron (ppm)	--

Appendix III. Monthly record of air temperature, relative humidity, rainfall, and sunshine of the experimental site during the period from January 2014 to May 2014

Month	*Air temperature (°c)		*Relative humidity (%)	Total Rainfall (mm)	*Sunshine (hr)
	Maximum	Minimum			
January, 2014	25.2	12.8	69	00	5.8
February, 2014	27.3	16.9	66	39	6.8
March, 2014	31.7	19.2	57	23	8.1
April, 2014	33	23	56	14	10.8
May, 2014	32	25	70	134	11.2

* Monthly average,

Source: Bangladesh Meteorological Department (Climate & weather division) Agargoan, Dhaka – 1212

Appendix IV. Means square values for plant height of soybean at different growth duration

Sources of variation	df	Mean square			
		Plant height (cm) at			
		25 DAS	50 DAS	75 DAS	100 DAS
Replication	2	1.04	7.41	10.51	9.34
Variety (V)	1	20.92	170.48	393.23	265.15
Error (a)	2	0.44	7.79	24.27	10.03
Supplementary managements (M)	5	1.256	1.54	22.49	36.32
Interaction (V×M)	5	1.524	6.14	7.26	8.85
Error (b)	20	0.91	6.63	56.07	46.54

Appendix V. Means square values for leaflets number plant^{-1} at of soybean at different growth duration

Sources of variation	df	Mean square			
		Leaflets no. at			
		25 DAS	50 DAS	75 DAS	100 DAS
Replication	2	0.32	6.18	198.158	518.97
Variety (V)	1	1.69	43.78	45.47	0.75
Error (a)	2	1.61	61.65	1721.89	2.51
Supplementary managements (M)	5	0.69	6.13	91.18	17.15
Interaction (V×M)	5	0.67	5.59	55.18	25.35
Error (b)	20	0.36	27.44	352.34	40.78

Appendix VI. Means square values for number of branches plant^{-1} of soybean at different growth duration

Sources of variation	df	Mean square		
		Number of branches plant^{-1} at		
		50 DAS	75 DAS	100 DAS
Replication	2	0.89	69.49	0.01
Variety (V)	1	2.72	100.0	0.13
Error (a)	2	3.58	54.97	3.59
Supplementary managements (M)	5	0.26	84.39	0.23
Interaction (V×M)	5	0.34	91.96	0.58
Error (b)	20	0.64	100.26	0.87

Appendix VII. Means square values for dry weight plant^{-1} of soybean at different growth duration

Sources of variation	df	Mean square			
		Dry weight plant^{-1} (g) at			
		25 DAS	50 DAS	75 DAS	100 DAS
Replication	2	0.001	12.25	27.58	62.79
Variety (V)	1	0.001	0.11	3.86	229.17
Error (a)	2	0.001	0.38	1.41	272.03
Supplementary managements (M)	5	0.001	0.24	2.55	53.26
Interaction (V×M)	5	0.003	0.29	4.02	39.34
Error (b)	20	0.003	0.87	7.71	75.48

Appendix VIII. Means square values for flower, pod & total dropping and pod remaining of soybean

Sources of variation	df	Mean square			
		Flower dropping (%)	Pod dropping (%)	Total dropping (%)	Pod remaining (%)
Replication	2	103.29	7.16	150.66	159.32
Variety (V)	1	96.30	46.15	340.40	327.01
Error (a)	2	2.43	80.59	88.83	92.89
Supplementary managements (M)	5	23.88	8.16	19.57	20.00
Interaction (V×M)	5	14.69	21.69	31.58	30.13
Error (b)	20	47.47	6.18	54.54	55.39

Appendix IX. Means square values for pods plant^{-1}, pod length, seeds pod^{-1}, weight of 1000-seed and shelling percentage of soybean

Sources of variation	df	Mean square				
		Pods plant^{-1} (No.)	Pod length (cm)	Seeds pod^{-1} (No.)	Weight of 1000-seed (g)	Shelling percentage (%)
Replication	2	423.30	0.02	0.001	19.25	104.94
Variety (V)	1	252.12	0.19	0.011	192.89	52.42
Error (a)	2	72.61	0.002	0.000	44.38	30.02
Supplementary managements (M)	5	42.83	0.01	0.008	115.25	21.93
Interaction (V×M)	5	142.28	0.037	0.009	92.91	39.65
Error (b)	20	307.94	0.007	0.001	51.31	23.82

Appendix X. Means square values for grain yield, stover yield, biological yield and harvest index of soybean

Sources of variation	df	Mean square			
		Seed yield ($t\ ha^{-1}$)	Stover yield ($t\ ha^{-1}$)	Biological yield ($t\ ha^{-1}$)	Harvest index (%)
Replication	2	0.029	0.077	0.056	74.52
Variety (V)	1	0.35	0.76	2.17	114.42
Error (a)	2	0.037	0.12	0.052	152.87
Supplementary managements (M)	5	0.55	0.076	0.33	36.81
Interaction (V×M)	5	0.58	0.027	0.202	43.36
Error (b)	20	2.54	0.072	0.35	28.26

Appendix XI. Photograph showing the location of the experimental site

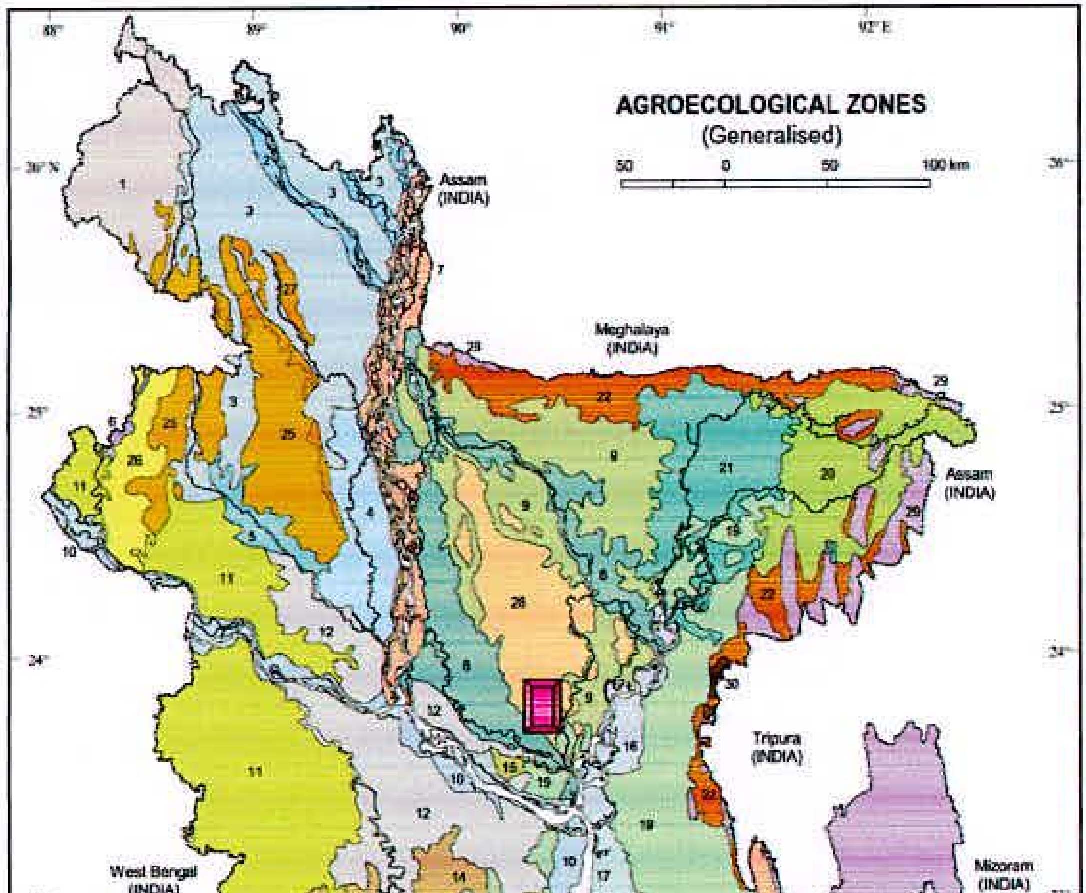

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Plate 1. Field view of the experiment

Plate 2. Soybean flower with pod

Plate 3. Dropped flower

Plate 4. Matured pod