INFLUENCE OF SOWING DATE AND WEED CONTROL METHOD ON THE GROWTH AND YIELD OF SOYBEAN

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INFLUENCE OF SOWING DATE AND WEED CONTROL METHOD ON THE GROWTH AND YIELD OF SOYBEAN

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This is to certify that the thesis entitled “ ***INFLUENCE OF SOWING DATE AND WEED CONTROL METHOD ON THE GROWTH AND YIELD OF SOYBEAN”*** *submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfillment of the requirements for the degree of* ***MASTER OF SCIENCE (M.S.)*** *in* ***AGRONOMY,*** *embodies the results of a piece of bona fide research work carried out by* ***NASRIN AKTER,*** *Registration. No.* **07-02512** *under my supervision and guidance. No part of this thesis has been submitted for any other degree or diploma.*

I further certify that such help or source of information as has been availed of during the course of this investigation has duly been acknowledged.

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INFLUENCE OF SOWING DATE AND WEED CONTROL METHOD ON THE GROWTH AND YIELD OF SOYBEAN

ABSTRACT

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during December, 2012 to June, 2013 with a view to find out the influence of sowing date and weed control method on the growth and yield of soybean cv. BARI Soybean-6. The experiment was consisted of four sowing dates viz. 18 December (S_1), 2 January (S_2), 17 January (S_3), 1 February (S_4); and four weed management treatments i.e. no weeding (control), hand weeding at 20 and 40 DAS (W_1), hand hoe weeding at 20 and 40 DAS (W_2) and chemical control by Whip Super 9 EC (Fenoxaprop-P-ethyl) @ 615 ml ha^{-1} at 20 DAS (W_3) as post-emergence herbicide in the sub plot. The trial was set up in split plot design. The different sowing date and weed control methods showed significant effect on plant height, number of branches $plant^{-1}$, dry weight $plant^{-1}$, number of plants m^{-2}, number of pods $plant^{-1}$, pod length, number of seeds pod^{-1}, 1000-seed weight, seed yield, stover yield, biological yield and harvest index of soybean. Among the infested weed species in the experimental field the dominant weeds were *Lindernia procumbens* (44.78 %), *Echinochloa colonum* (25.44 %) and *Vicia sativa* (20.59 %). Results revealed that early sowing (2 January) gave the highest seed yield (2.17 t ha^{-1}). Two times hand weeding controlled the weeds most effectively which produced the highest seed yield (2.23 t ha^{-1}) which was statistically similar with herbicide application @ 2.19 t ha^{-1}. Interaction effect showed that highest seed yield (2.50 t ha^{-1}) which was obtained from 2 January sowing when the crop was weeded by hand at 20 and 40 DAS.

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LIST OF ACRONYMS AND ABBREVIATIONS

AEZ	Agro-Ecological Zone
Agric.	Agriculture
Agril.	Agricultural
BARC	Bangladesh Agricultural Research Council
BARI	Bangladesh Agricultural Research Institute
BBS	Bangladesh Bureau of Statistics
cm	Centi-meter
CV	Coefficient of Variance
cv.	Cultivar
DAS	Days after sowing
df	Degrees of freedom
DMRT	Duncan's Multiple Range Test
Environ.	Environmental
et al.	And others
etc.	Etcetra
g	Gram (s)
HI	Harvest index
i.e.	*id est* (L), that is
J.	Journal
kg	Kilogram (s)
m^2	Meter squares
M.S	Master of Science
pod^{-1}	Per pod
Res.	Research
SAU	Sher-e-Bangla Agricultural University
Sci.	Science
SRDI	Soil Resource Development Institute
$t\ ha^{-1}$	Ton per hectare
viz	Namely
%	Percentage
^0C	Degree centigrade
@	At the rate

Chapter 1

Introduction

CHAPTER I

INTRODUCTION

Soybean [*Glycine max* (L.) Merrill] is a leguminous crop and belongs to the family Leguminosae and sub-family Papilionaceae. It is the most important grain legume of the world and a new prospective crop for Bangladesh (Rahman *et al.,* 2011). It is classified more as an oil seed crop than as a pulse (Devi *et al.,* 2012). The protein and oil content together account for about 60% of dry soybean by weight: protein at 40% and oil at 20% (Sodangi *et al.,* 2006). The soybean is an excellent source of major nutrients including vitamins A, B and D, rich in unsaturated fatty acids and minerals like Ca and P that can meet up different nutritional deficiencies (Rahman, 1982). Soybean has 3% lesithine which is helpful for brain development. Malik *et al.* (2006) and Dugje *et al.* (2009) depicted that soybean oil is consisted of 85% cholesterol free unsaturated fatty acids. Soybean protein contains essential amino acid in desired quantity. Hence, it is regarded as a well balanced protein food. Due to its high nutritional value there is an increasing demand of soy food e.g. soymilk, soybean sprouts, soy nuts, several types of tofu, cottage cheese and curd (Rao *et al.,* 2002). It is a good source of isoflavones and therefore it helps in preventing heart diseases, cancer and HIVs (Kumar, 2007). Gesimba and Langart (2005) reported that, among seed oils, soybeans has had an extra-ordinary growth due to rising consumption of livestock products and concurrent rapid growth in meal demand; as well as the fact that it is a cheap source of proteins especially in developing nations. Soybean, like other legumes, has the ability to fix atmospheric N though root nodule bacteria (*Bradyrhizobium japonicum*) and thus enrich the soil fertility (*Kureh et al.,* 2005). This can compensate around 80-90% demand for nitrogen by the crops. Because of its high nutritional value and myriad form of uses, it is recognized as ‘Golden Bean’ and has become the miracle crop of the 21st century.

Soybean grows and develops in 30^0C and the proper temperature for emergence of seedling from seedbed is 25-33^0C (FAO, 2007). The climatic and the edaphic conditions of Bangladesh are favorable for soybean production. Soybean can be cultivated throughout the year in Bangladesh. The yield of this crop is very low in this country compared to other soybean growing countries. Among the different reasons for low yield, the improper agronomic management, such as, sowing at wrong time may be a cause for this problem. Planting date is an important factor influencing soybean growth and yield (Calvino *et al.,* 2003 and Bastidas *et al.* 2008). Delayed planting reduces yields when compared with earlier plantings (Beatty *et al.,* 1982 and FAO, 2007) and also reduces the number of days to flowering and also reduce the number of days to maturity and decrease the length of regulative and reproductive periods of development (Board *et al.,* 1992; Kazemi *et al.,* 2005). The growth and yield responses of soybean to planting date depend on the environment, variety and production practice. If planted too early, soybean may have poor emergence or limited growth because of hot temperature when soybeans are exposed to day shorter than critical length, they progress rapidly to maturing. If this occurs before the plant reaches an adequate size, the soybean is stunted and give low yield (Boquet and Clawson, 2007). Appropriate planting date causes optimal utilization of the climate factors such as temperature, humidity, day length and also anthesis time adaptation with proper temperature (Hashemi, 2001).

Weeds compete with crop plants and utilize considerable amount of moisture, nutrients and space in photosphere and atmosphere, thus deprive opportunities for the crop to express its potential yield. Weed infestation removed 21.4 kg N and 3.4 kg P ha^{-1} in soybean (Pandya *et al.,* 2005). Soybean are not strong competitors in the early part of the season, therefore weeds that germinated at the same time as soybeans, grow faster and maintain a canopy above and below the top of the soybean canopy. Therefore, they intercept photosynthetically active radiation (PAR) at the expense of soybeans. This results to elongation of soybean stems with a decrease in diameter, causing lodging (Jannink *et al.,* 2000). The most critical period of weed competition in soybean is the early stage of growth (Sodangi *et al.,* 2007). Soybean usually develops a full canopy cover at 8 weeks after emergence and can then compete with weeds up to maturity. Little or no reduction in yield occurs if soybean are kept weed free for the first 4 weeks this is the critical period for weed competition in soybeans (Jannink *et al.,* 2000). The reduction in soybean yield due to weed infestation varies from 20-77 % depending on the type of soil, season and intensity of weed infestation (Daugovish *et al.,* 2003 and Kuruchania *et al.,* 2001). The higher reduction in seed yield due to weeds is more as compared to other factors limiting the soybean production. It has been estimated that soybean growers lost an average of 1.8 million US$ per year due to yield reductions from weed infestation (Anderson and Bridges, 1992).

In peasant agriculture, weed control is usually achieved by hand-pulling, or hoe-weeding. Manual removal of weeds is the major traditional method of weed control in the tropics (Akobundu, 1987). This is usually done 2 or 3 times for effective weed control (Akobundu and Poku, 1987). It is estimated that about 40-60% of production cost is spent on manual weeding (Remison, 1979). In addition to high cost, labour availability is uncertain, thus making timeliness of weeding difficult to attain, leading to greater yield loss (Adigun and Lagoke, 2003).

Herbicide use is one of the developments which was introduced later to control weeds in crop production. It is more adapted to large scale production and labour saving (Anon, 1994). Other factors that have made chemical weed control more popular than manual weeding include reduction of drudgery in chemical weed control, it protects crops from the adverse effects of early weed competition which can avert economic losses in soybean that needs early weed control in the first four weeks as this is the critical period of weed competition in soybean (Gesimba and Langart, 2005). It is a faster weed control method (Akobundu, 1987). Regarding chemical weed control, selective herbicides may be effective against annual weeds and achieve high soybean and legume yield (Hassanein, 2000; El-Metwally and Saad El-Din, 2003; Sha, 2004; El-Razik, 2006). Under these circumstances effective weed control methods needed to be developed to reduce yield loss due to weed infestation. The research in this line is highly scarce in Bangladesh. Therefore, the present research work was undertaken with a view to investigate the effect of sowing date and weed control methods on growth, yield and yield contributing characters of soybean with the following objectives:

i. To find out the optimum date of sowing to ensure yield maximization as well as soybean growth,
ii. To determine the effective weed control method for soybean cultivation and
iii. To find out combined effect of sowing date and weed control methods on soybean yield.

Chapter 2

Review of literature

CHAPTER II

REVIEW OF LITERATURE

Soybean is an important grain legume crop in the world. It is quite wide spread in different regions of the world and seems to grow well from the tropical and subtropical regions. Researches on the sowing date of soybean with weed control methods have been carried out by a large number of researchers throughout the world. In Bangladesh, researches on sowing date and weed control methods of soybean are very few. However, some important findings have been reviewed in this chapter under the following headings.

2.1 Effect of sowing date on growth and yield of soybean

2.1.1 Plant height

Pedersen and Lauer (2004) concluded that planting date did not have an effect on plant height at harvest. Hamzeh *et al.* (2004) also expressed that with delay in planting, plant height and height of the first node sheathed surface decreases.

Khan *et al.* (2003) stated that the plants planted in early May, had more height than plants planted in August. Ponnuswamy *et al.* (2001) showed that plant height was influenced by sowing date. Plant height, lodging, pod formation height from the surface of soil and ripeness time will be reduced by the delay in planting and also the three-day delay in planting caused a day delay in maturity (Arshi, 2001).

In general, the result of the present research clearly brings out the fact that delayed planting resulted in reduced plant heights, though the degree and trend in plant height varied with varieties. Such results are not unusual and have been reported by several workers (Olufajo and Pal, 1991 and Futuless and Odo, 1999).

Kang *et al.* (1998) conducted a field trial at Cheju, Korea Republic, soybean cv. Baegunkong and Namhaekong were sown on 8 or 23 june or 8 july. They reported that plant height decreased with delay planting. Nijafi *et al.* (1997) observed that soybean cv. Williams and Harcor grown at sowing dates of 15 or 31 May. They found that plant height was reduced with later sowing.

Adjei and Splittstoesser (1994) investigated the effect of environmental variation on growth and development of soybean plated at 10 days interval from 17 June to 17 July. Pfeiffer and Harris (1990) observed that, plant height measurements are used as an indicator of vegetative growth.

2.1.2 Number of branches plant^{-1}

Moosavi *et al.* (2011) study the effects of different planting dates on the grain yield of soybean cultivars. They showed that there was meaningful difference between different sowing dates for all traits being studied except number of seeds per pod. Sowing dates of 27 May and 5 June were placed in one group for number of pod in main bough, height of each plant and a weight of 100 seed. Also the mentioned traits had the highest in the expressed sowing dates. Sowing date of 27 May had the highest amount for pods per sub-bough, number of nodes per sub-bough, number of nodes in the main bough and the final yield.

Number of branches plant^{-1} reflects the overall plant growth. It is the important morphological parameters contributing to yield. Several workers reported that seed yield was significantly and positively correlated with number of branches plant^{-1} (Datta, 2004; Haque, 2005). A positive association of number of branches was observed with pods plant^{-1} (Islam, 2005; Kisic *et al.*, 2006).

Chettri (2003) experimented with some Mexican soybean varieties to evaluate their yield and yield contributing characters and the result revealed that high yielding genotypes had greater branches number plant^{-1} than low yielding ones in soybean.

Bello (2000) stated that experiment in the Southern Guinea earlier sowings increase the number of pods per plant, number of branches and ultimately increase yield. Soybean yield reduction in late-planted has been attributed to a lack of sufficient vegetative growth, low number of pods/plant and reduced seed weight (Ball *et al.,* 2000).

2.1.3 Dry weight plant^{-1}

According to Oh *et al.* (2007) not only TDM production, but also the capacity of efficient partitioning between the vegetative and reproductive parts may produce high economic yield. A better understanding of crop growth and yield parameters and the partitioning of assimilates into seed would help to expedite yield improvement of field crops.

Late planting date decreases life cycle of product between 13-25 days in comparison with early planting date and it causes the collection of dry material and active photosynthesis radiations to be decreased (Purcell *et al.,* 2002). In the end of growth season which unsuitable condition of temperature prevents the production of enough assimilate, dry material plays an important role in increasing weight of grain (Fanaie *et al.,* 2008).

JinWoong *et al.* (2005) was carried out a research during 2003 and 2004 in southwest part of Korea with 22 soybean cultivars. The result total dry matter (TDM) ranged from 27 g to 54 g per plant, and Sorokong was the greatest value by 54 g at R4 stage and Tawonkong was the lowest by 27 g.

According to Board and Moadli (2005) the assimilate partitioning shifted from vegetative plant parts to the seed, where it contributes to yield with no change in total biomass. They also stated that environmental influences on yield act mainly through effects on total dry matter (TDM) accumulation during the emergence to R5 period (seed filling), TDM at R1 (first flowering) and TDM at R5 are promising predictors for optimal yield. The study indicated that 200 g m^{-2} and 600 g m^{-2} at R1 and R5, respectively, were valid predictors for optimal yield.

Purcell *et al.* (2002); Pedersen and Lauer (2004) indicated that soybean plant with early planting produces more DM rate than late planting soybean plant. Delay in planting decreases produced dry material, grain yield and its quality (Jose *et al.*, 2004).

The grain yield was positively and significantly correlated with total dry matter production in soybean. Seed dry weight response to source-sink manipulations in 4 soybean genotypes was determined by Borras *et al.* (2004) in Argentina during the period of 2003 and stated that a maximum dry matter was produced around physiological maturity.

Shiraiwa *et al.* (2004) reported that dry matter production was positively correlated with the amount of foliage developed in the upper 50% of canopy. It seems that the foliage developed in the lower part of the canopy has little or negative contribution to dry matter production in soybean.

Dutta (2001) stated that total dry matter production was largely dependent on the solar radiation interception over the growing season and also indicated that total grain yield was influenced by photosynthesis and the distribution of photosynthates within the plant.

2.1.4 Number of Plant m^{-2}

Moosavi *et al.* (2011) conducted an experiment in research farm of Ardabil Islamic Azad University in 2009. There was meaningful difference between different planting dates in all studied features, except dry weight of leaves. The obtained results show that delay in planting soybean in Ardabil region the plant does not reach to potential capacity because of unsuitable conditions and the performance decreases. So 27th of May and 5th of June planting dates are recommended for planting soybean in cold climate of Ardabil.

With delay in planting due to high sensitivity of soybean to light period duration and temperature affects yield negatively by reducing the duration of vegetative and reproductive growth and yield components drop (Kazemi *et al.,* 2005). Egli and Bruening (2000) observed low initial stands of plants in early sowing.

2.1.5 Number of pods plant^{-1}

Jamshidi *et al.* (2014) investigate the effect of planting date and seed mixing ratio on the yield and yield components of soybean. They reported that, the effect of planting date on the yield and yield components of soybean was significant except on 1000-seed weight. The results showed that the highest and the lowest seed yield respectively belonged to the first planting date by 1619.51 g m^{-2} and the third planting date by 888.43 g m^{-2}. Moreover, the results showed that the highest number of pods per plant belonged to the first panting date by 47.533 pods per square meter.

Number of pods per plant on different planting dates could be explained in terms of fewer flowering nodes, rainfall pattern and suppression of both primary and secondary branches (Board and Tan, 1995). Gungula *et al.* (1998) and Futuless (2010) attributed an increase in number of pods per plant to higher number of flowers.

Mokhtarpoor *et al.* (2008) stated that the delay in planting date led to the decrease of number of pods per plant, final yield of seed, and plant height which was consistent with the results of the research.

Early planting date of traits like pods in the main stem, number of pods per sub bough, number of pods per plant, number of two seed pod, number of three seed pod and seed yield had the highest amount (Salahi *et al.,* 2006).

Number of pod depends on number of nodes per plant and on the other hand, delay in planting during the growing plant and pod formation will be less, followed by a reduced number of pods on the plant production (Azizi *et al.,* 2005).

Early planting date creates higher number of seed, pod and harvest index, but less number of seeds per pod than the late planting date is produced (Pedersen and Lauer, 2004). Pods per plant and 100-grain weight in soybean have also been reported to differ in different sowing dates (Wafaa *et al.*, 2002).

2.1.6 Pod length

Rahman (2004) reported after performed a laboratory experiment with 162 soybean genotypes that the pod length of PB-1 (Shohag) was 3.51 cm, CM3 was 3.64 cm, F85-11347 was 3.52 cm, GC-840079-5-1 was 3.57 cm and AGS-276 was 3.49 cm.

The number of days to pod formation, pod filling and maturity was less for plants sown on 15 May compared with those sown on 8 April (Zahir and Mir, 1989, Turman *et al.,* 1995). Kim *et al.* (1995) reported that two vegetable soybean varieties were sown at Suwan in 1992 under 3 sowing dates (April 15, May 15 and June 15). Earlier sowing (April 15) of the vegetable soybean varieties increased the yield of green pods as well as quality.

2.1.7 Number of seeds pod^{-1}

Zeinali and Soltani (2013) concluded that planting date had significant influence on the number of pods per plant, seed weight, plant height and seed yield per unit area, but the number of seeds per pod and the number of main stem nodes were not affected by planting date. Highest number of pods per plant on 5 May that was planted on 20 May was not significantly different between planting date, 22 June and 6 July planting date showed no significant difference.

Yagoub and Hamed (2013) conducted an experiment in semi-desert region in Sudan. In season 2009/10 the result showed that (23 -June) and (30-June) obtained the lowest values of yield components. The results of season 2010/11 showed significant differences for number of pods/plant, number of seeds/pods and highly significant difference was obtained in weight of pods/plant, weight of seeds/plant, 100 seed weight, yield and harvest index. The (16-June) mid June, obtained the highest values and (30- June) gave the lowest values of the above parameters. The sowing date in mid June is the best sowing date, and sowing date in late June must be avoided due to reduction in yield and yield components.

Early planting has been observed to have more nodes (Wilcox and Frankenberger, 1987; Beaver and Johnson, 1981) as well as more pods and seeds for a given area (Pedersen and Lauer, 2004) which can in result in high yield (Robinson *et al.*, 2009).

Perez-Bidegain *et al.* (2007) reported that higher growth and performance to date has related to early planting and late planting reduced the yield and yield components in soybean. The maximum the number of secondary branches, plant height, the number of pods per plant, the number of seed per pod, 100 grain weight was obtained in first planting date (5 May).

Woong and Yamakawa (2006) reported that the number of pods and seed per plant decreased as planting date delayed. Based on the experimental results Pedersen and Lauer (2004) early date of sowing of increase the number of seed pods and harvest index, but compared with late sowing reduced number of seeds per pod.

Datta (2004) studied 21 soybean genotypes for yield contributing characters and found that there was a significant variation in seeds pod^{-1} ranging from 1.93 to 2.26. Uddin (2004) reported the number of seeds pod^{-1} was increased in December planting compared to November one in all genotypes.

Zynali *et al.* (2003) expressed that planting date affects significantly number of pods per plant, plant height and 100 seed weight affected but the number of seeds per pod were not affected by planting date.

2.1.8 1000-seed weight

Heydari zadeh and Khajepour (2007) reported that weight of grain in bush decreased with delay in planting form the first planting to the fourth planning date. Jian *et al.* (2007) showed that seed yield was positively correlated with 100-seed weight in soybean. Shafig *et al.* (2006) indicated that the weight of one thousand grains of soybean with delay in planting shows decrease.

Temperature decrease in flowering step cause difference in filling of grain and decrease in grain weight. Shortness of growth season was affected by delay in planting which results in decrease in received radiation in growing duration and results in decrease in produced dry material and decrease in grain yield (Rondanini *et al.,* 2006).

Khadem *et al.* (2004) also reported that the weight of one hundred grains affected by planting date meaning fully which a falling trend was observed with delay in planting. Hamzeh *et al.* (2004) also reported that 100 seed weight was significantly affected by planting date, so that with delay in sowing, the weight rate of 100 seed decreases.

Pedersen and Lauer (2004) stated that average seed weight from early sowing was higher than that from late sowing. Early planted varieties got more time and growth period to accumulate more photo-assimilates. Furthermore, high temperature caused shrinking of seeds during late planting.

Late planting dates decrease grain filling period and increase the rate of grain filling compared with earlier planting dates (Atri *et al.,* 1999). Boquet (1990) stated that the results of the effect of planting date on 1000-grain weight were highly variable, so that some researchers reported that delay planting caused the increase of grain weight, and some reported the decrease of grain weight and some reported no changes on the grain weight.

2.1.9 Seed yield

Rehman *et al.* (2014) revealed that higher numbers of pods per plant and number of seeds per plant were produced by 28th January. Similarly maximum seed yield (1647.10 kg ha^{-1} and 1440.23 kg ha^{-1}) were also produced by 28th January and 21st January, respectively. Thus 28th January planting was the best for high yield of spring soybean.

Barati *et al.* (2013) conducted an experiment in 2010-2011 in research farm, Shahrekord research station, Shahrekord city, Shahrekord province, Iran. Planting date was significant on plant height, the number of pods per plant, 100 grain weight, seed yield, biological yield and harvest index. First planting date (5 May) had obtained the maximum seed yield and oil yield in comparison other planting dates.

Ibrahim (2012) conducted a field trial for two consecutive seasons (2009/10 and 2010/11), at the Gezira Research Station, central Sudan, to study the effect of sowing date on grain yield and yield components of irrigated soybeans. Sowing date had a significant effect on grain yield. The highest grain yield was obtained at mid June sowing date, in both seasons. In the first season, TGx 1905-2E variety achieved a maximum grain yield at mid June sowing date (2322 kg ha^{-1}) but declined 12.4 % when sowing date was delayed to late June (2035 kg ha^{-1}). In the second season, TGx 1905-2E variety achieved a maximum grain yield at mid June sowing date (2209 kg ha^{-1}) but declined 19.9 % when sowing date was delayed to late June (1812 kg ha^{-1}). The result of this study illustrates the importance of early sowing for maximizing the yield potential of irrigated soybean. The optimum sowing date for irrigated soybean in central Sudan is mid June.

Bastidas *et al.* (2008) expressed that delaying planting after 1 May led to significant linear declines of 17kg/ha in 2003 and 43kg/ha in 2004, denoting the importance of early planting for capturing the yield potential available in soybean plant production when moisture supply is not limiting. Late sowing dates (30-June) may lead to a lack of sufficient vegetative growth, low number of pods/plant and reduced seed weight and ultimately lower grain yields.

Ram *et al.* (2010) reported that the highest grain yield (2537 kg ha^{-1}) was recorded in June 5 sown crop which was significantly higher than June 25 sowing (2169 kg ha^{-1}) but statistically at par with June 15 sowing (2386 kg ha^{-1}) in 2008. In 2009 June 15 sowing (1811 kg ha^{-1}) recorded highest grain yield which was statistically on par with June 5 (1704 kg ha^{-1}) but significantly higher than June 25 sowing (1350 kg ha^{-1}). As the sowing date delayed, the thermal heat units were found to be reduced for 50% flowering and maturity.

Looking at yield trends of soybean across planting dates show progressively greater yield decline will occur in soybean production with a delay in planting (De Bruin and Pedersen, 2008; Egli and Cornelius, 2009).

According to Elgi and Cornelius (2009) the point of rapid decline in soybean yield begins May 30th in the Midwest. Billore *et al.* (2009) reported that timely planting of soybean (second fortnight of June) showed superiority over the late planting with respect to all the parameters along with grain yield.

Bastidas *et al.* (2008) investigated the response characteristics of vegetative and reproductive 14 genotypes of soybean maturity group three in the Northern United States reported that delayed planting from early May to July line reduction yield of 17 kg ha^{-1} per day in 2003 and 43 kg ha^{-1} per day in 2004.

Across years, soybean yields have shown to improve with early May planting. The yield gain from planting date is dependent upon the cultivar chosen as well as the environmental effects of location and weather (De Bruin and Pedersen, 2008). Lopez-Billido *et al.* (2008) reported a decrease in yield due to delayed planting.

The delaying of planting time than 28th January caused decrease in seed weight. Seed yield is affected by the seed weight (Adeniyan and Ayoola, 2007). Azizi *et al.* (2005) reported that planting date was effective on seed yield and delayed planting caused the weakness of performance so that the highest on the first planting and the third seeding date had lowest performance.

Kumar *et al.* (2005) reported that early sowing (end May to early June) provides long vegetative and reproductive growth periods thereby, facilitating the crop to produce more biomass, which enhanced the number of pods per plant, grains per pod and 100-grain weight.

Egly and Bruening (2000) indicates that planting date effects on yield of soybean cultivars and with respect to time delay, reduces the desired yield; considering that soybean is a short day plant, so if exposed to short day length it flowers. Longer day increases the flowering delay with the delay in planting, because, plants exposed to earlier days get a short height, shorter, fewer branches and weak growth period before flowering and get a shorter flowering period that all these factors cause the formation of fewer pods and fewer transfer material to the sheath and the photosynthetic performance is reduced (Azizi *et al.*, 2005).

Khan *et al.* (2004) observed steady decrease in yield when sowing was delayed from May to August. Decrease in yield of grain is related to decrease in biomass in time of ripe and variations in oil percentage are related to harvest index and temperature during flowering (Robertson *et al.*, 2004). Rezai-Zadeh (2004) stated that planting date effects on seed yield is significant that is correspondent to the results of this test.

General delay in planting resulted in, reduction of potential crop yield, since part of solar radiation is not received by the shadow picture (Jose *et al.*, 2004). Ozer

(2003) reported that eduction in yield of canola seed in late planting history, state as reason for reduced number of pods per plant and decrease of harvest index.

Veni *et al.* (2003) studied the performance of soybean cultivars under different dates of sowing and reported 22.85 per cent loss in yield by sowing the crop on August 27 over the optimal time of sowing on June 28. Buehring *et al.* (2003) in a study conducted in Verona Mississippi reported that all soybean cultivars were obtained more yield from first planting date than two subsequent planting dates.

Wrather *et al.* (2003) observed that the plant averaged over years was significantly greater for mid-April and mid-June plantings and yields of cultivars of soybean were similar within plating date. Mackinnon and Fettel (2003) with effect of sowing rate showed a significant effect of planting date and cultivar on yield and yield reduction was caused delays in planting.

Reduce the size of the canopy than desirable size, and shorten the growth period of vegetative stated as one of the main reasons for reduced seed yield history of late sowing (Hocking and Stapper, 2001). Calvin and Brent (2001) expressed that highest soybean yield was 2594 kg/ha in the early planting date, late May.

Late planting due to the loss of suitable time for the growth, the plant was not achieved its potential ability because light interception and crop simulates partitioning were severely affected and consequently lead to yield decline. In case of early planting there was more time for plant growth in optimum temperature and moisture, so seed yield increasing is rational. With late planting the growth period becomes short. High temperature during flowering decreases the seed yield and yield components of soybeans. In another studies, the delayed planting decrease the yield (Egli and Bruening, 2000; Kantolic and Slafer, 2001).

Late sowings may produce lower grain yields due to a variety of reasons including shortening of growth period, less accumulation of photosynthetically active radiation (Purcell *et al.,* 2002) and less number of heat units and helio-thermal units (Dhingra *et al.*, 1995).

Atri *et al.* (1999) stated that earlier planting date of soybean increased the yield of soybean. Mohammadi (1999) stated that the decrease of soybean grain yield in delayed planting was due to the shortening of reproductive period and also the decrease of assimilates and dry matter.

2.1.10 Stover yield

Futuless *et al.* (2011) found significant differences on most of growth and yield parameters, flowering was delayed due to delay in planting dates. They demonstrated maximum productivity of 2042.1 kg ha^{-1} and 1950.2 kg ha^{-1} in 2009 and 2010 when planted on 21 June in both years. These results therefore indicate that soybean planting dates had impact on soybean growth, development, and yield and as well as agricultural development.

Soybean plants sometimes partially compensate for delayed planting with increases in seed mass (Robinson *et al.,* 2009), but this doesn't always occur (Pedersen and Lauer, 2004; De Bruin and Pedersen, 2008). Mackinnon and Fettel (2003) showed that the effect of planting date on yield and yield losses were significant.

2.1.11 Biological yield

Yari *et al.* (2013) investigate the effect of planting date on yield and yield components of soybean. Result of this experiment showed that the effect of planting data on yield and component was significantly effect. Planting date on plant height, seed weight, seed yield, and biological yield had a significant effect, so that the maximum plant height, seed weight, seed yield, biological yield was on 10 May.

It was shown that the late planting date, biological yield decreased because the flowers appear in late summer and produced terminal buds, leaves, new growth and the plant stops. Lopez-Billido *et al.* (2008) reported a reduction in yield due to delayed planting.

Biological yield is used to show the collection of dry material in plant system. Plant yield can be increased by increasing all produced dry material in farm or yield coefficient and /or both of them. Biological yield is affected by weather condition factors of soil and plant (Pedersen and Lauer, 2004).

2.1.12 Harvest index

Barati *et al.* (2013) conducted an experiment in 2010-2011 in research farm, Shahrekord research station, Shahrekord city, Shahrekord province, Iran. Planting date was significant on plant height, the number of pods per plant, 100 grain weight, seed yield, biological yield and harvest index. First planting date (5 May) had obtained the maximum seed yield and oil yield in comparison other planting dates.

Bastidas *et al.* (2008) found that yield was significantly affected by planting date. Heydari zadeh & Khajepour (2007) indicated that harvest index is affected by planting date effect and late spring planting dates.

Khan *et al.* (2004) who reported that delaying sowing date gave smaller seed compared with all traits. Early planting date results in higher of grains, number of sheath and harvest index (Pedersen and Lauer, 2004).

In (Mirza khani *et al.*, 2002) study, harvest index decreased with late planning. Increase in harvest index can result from relative decrease in biomass rate or increase in grain yield Biological yield is dependent on bush height.

Seong and Seong (2002) observed that sowing date of soybeans is one of the production components in cultural systems. Early sowing resulted in higher branches, pods and seeds than late sowing. Late sowing appeared to have higher harvest index and total dry weight increased to a maximum at the physiological maturity stage and then declined slightly at full maturity. The highest seed yield was obtained with mid sowing and no differences were found among sowing dates on growth characteristics.

2.2 Effect of weed control methods on growth and yield of soybean

2.2.1 Relative weed density

Imoloame (2014) showed that herbicide treatments significantly reduced weed infestation compared to the weedy check. This weed control method also resulted in significantly better growth and higher yield.

Chattha *et al.* (2007) reported that use of herbicide tribunal 70 WP (methabenzthiazuron) @ 2 kg ha^{-1} at 2 - 3 leaf stage of weeds + hand-weeding at 50 DAS gave promising results in terms of weed reduction. Maximum reduction in density and biomass of the weeds was observed by chemical-weeding at 2-3 leaf stage of weeds + hand-weeding at 50 DAS.

Application of the previous treatments was effective in controlling weed and consequently competition was limited and lighter, and water and nutrients were available to promote soybean growth compared to other treatments. These results are in agreement with those recorded by Galal (2003) and Mohamed (2004).

Chauhan *et al.* (2002) revealed that the application of alachlor at 1.5 kg and, pendimethalin 1.5 kg/ha as pre-emergence and two hand weeding at 20 and 35 DAS in soybean crop drastically reduced weed density, weed biomass and increased the yield of crop.

2.2.2 Weed dry matter

Hassan (2013) showed that the favorite weed control treatments were hoeing (twice) followed by trifurlin and diphenamid in 1st and 2nd season, hoeing (twice) treatment gave the highest decrease in total fresh weight of weeds, followed by pndimethalin, dinitramine and linuron.

Abdelhamid and El-Metwally (2008) reported that two hand hoeing treatments resulted in the highest weed depression expressed as the lowest fresh and dry weights of broadleaved, grassy and total weeds. The reduction percentage in weed dry matter compared to the nonweeded treatment was 98.3, 92.64 and 96.9% in broadleaved, grassy and total weeds, respectively. Application of the three herbicides at higher or recommended doses significantly reduced fresh and dry weight of the weeds compared to the nonweeded treatment.

Hoeing twice is the most effective weed control practice for reducing weed dry matter accumulation in soybean fields (Mandloi *et al.,* 2000, Singh and Jolly, 2004; Kushwah and Vyas, 2005). The reduction of weed dry weight may be due to the inhibition effect of herbicide treatments on growth and development of weeds (Sha, 2004; Behera *et al.,* 2005).

Heavy rainfall with prevailing high temperatures during growing period favoured weed germination from soil and vigorus growth that resulted higher dry matter of weeds in 2006. Similar statement was mentioned by Bogdan (2002). Crop-weed competition is minimized by pre-emergence herbicide spray, resulting in decreasing weed dry matter and increasing crop yield (Jeyabal *et al.,* 2001; Mohamed, 2004; Sha, 2004).

2.2.3 Weed control efficiency

Marangoni *et al.* (2013) verified that the optimal time for sowing soybeans was the month of November, and that under these conditions, the cultivars had higher competitive ability against weeds. Late sowing affected the cycle, development, and yield of the soybean cultivars; this effect was greater under the influence of the weed community.

Rajput and Kushwah (2004) observed that two hand weeding alone 20 and 30 DAS after sowing gave highest weed control efficiency 85.6% with seed yield 1860 kg/ha. Ahmed *et al.* (2001) reported that application of two hand hoeing is more effective in suppressing weeds and increasing soybean seed yield.

2.2.4 Plant height

Pholan (1986), Pandey *et al.* (1996) and Kuruchania *et al.* (1996) observed continuous decrease in plant height with the increasing of weeds competition which was attributed to growth habit of a variety.

2.2.5 Dry weight plant^{-1}

Abdelhamid and El-Metwally (2008) indicated that the herbicides at rates higher than the recommended markedly decreased the root, shoot and total dry weight plant^{-1}, while application of two hand hoeing treatments significantly increased these traits.

2.2.6 Number of pods plant^{-1}

Several studies indicate a reduction in the number of pods of soybean plants under weed competition (Martins, 1994; Pittelkow *et al.* (2009). Reductions in seed yield per pod during competition between weeds and soybeans (Silva *et al.,* 2008).

Abdelhamid and El-Metwally (2008) revealed that two hand hoeing treatments gave the highest values of number of pods per plant^{-1}, weight of pods per plant^{-1}

and number of seeds per plant^{-1} by 140.7, 150.0 and 59.8%, respectively, compared to the nonweeded treatment.

In addition, there is an important role of hoeing in improving soil properties, i.e. soil structure, aeration, water penetration and the availability of some nutrients. In this respect, the increments due to application of hand weeding twice than weedy check were reported in branches and pods number plant^{-1} (Kushwah and Vyas, 2005). Veeramani *et al.* (2001) reported more pods with integrated use of herbicides with hand weeding.

2.2.7 1000-seed weight

Significant reductions in the 1000-seed weight of soybeans when the crop suffers the competition from weeds (Silva *et al.*, 2008; Pittelkow *et al.*, 2009), especially at higher densities of infestation.

2.2.8 Seed yield

Peer *et al.* (2013) that hand weeding twice and both fluchoralin and pendimethalin integrated with hand weeding recorded far superior yields of soybean seed. Sodangi *et al.* (2013) revealed that hoe weeding three times at 3, 5 and 7WAS produced the highest grain yields.

Abdelhamid and El-Metwally (2008) found that, oxadiargyl at the recommended rate (480 g ha^{-1}) was the best treatment for promoting seed yield (g plant^{-1}) and seed yield (kg ha^{-1}) compared to the nonweeded treatment by 87.3 and 85.0, respectively.

Nepomuceno *et al.* (2007) evaluated weed interference in soybean in conventional sowing system and reported a 32% drop in the yield of the crop when it coexisted with weeds throughout their cycle. Sodangi *et al.* (2006) also reported a soybean yield loss of 90% due to weed infestation in the Sudan Savanna zone of Nigeria.

The increments due to application of hand weeding twice than weedy check were reported in seed yield (Pandya *et al.,* 2005).

Pires *et al.* (2005), assessing the competitive potential of soybean cultivars against weeds, observed reductions of approximately 480 kg ha^{-1}, regardless of the variety used in average levels of productivity of 2.570 kg ha^{-1}. Pandya *et al.* (2004) found that two hand weedings and clomazone with hand weeding produced higher grain yield. Crop geometrics failed to record significant influence on grain yield.

Rohitshav *et al.* (2003) reported that pre-emergence application of pendimethalin 1.5 kg /ha produced soybean grain yields similar to weed free treatment. Jannink *et al.* (2000) reported that root and shoot interference is the main factors that cause soybean yield reduction.

2.2.9 Stover yield

Abdelhamid and El-Metwally (2008) reported that two hand hoeing treatments and pre-emergence herbicides at the recommended rates markedly increased soybean yield and its attributes.

2.2.10 Biological yield

Abdelhamid and El-Metwally (2008) found that, oxadiargyl at the recommended rate (480 g ha^{-1}) was the best treatment for promoting biological yield (g $plant^{-1}$) compared to the nonweeded treatment by 88.2%.

Chapter 3

Materials and Methods

CHAPTER III

MATERIALS AND METHODS

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

3.1 Location

The field experiment was conducted at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka during the period from December 2012 to June 2013. Geographically the experimental field is located at 23°46' N latitude and 90° 22' E longitude (Google maps, 2014) at an elevation of 8.2 m above the sea level belonging to the Agro-ecological Zone “AEZ-28” of Madhupur Tract (BBS, 2011). The location of the experimental site has been shown in Appendix I.

3.2 Soil

The soil of the research field is slightly acidic in reaction with low organic matter content. The selected plot was above flood level and sufficient sunshine was available having available irrigation and drainage system during the experimental period. Soil samples from 0-15 cm depths were collected from experimental field. The analyses were done from Soil Resources Development Institute (SRDI), Dhaka. The experimental plot was also high land, having p^H 5.8. The physiochemical property and nutrient status of soil of the experimental plots are given in Appendix IIA, IIB and IIC.

3.3 Climate

The experimental area is situated in the sub-tropical climatic zone and characterized by heavy rainfall during the months of April to September (Kharif Season) and scanty rainfall during the rest period of the year (Biswas, 1987). The Rabi season (October to March) is characterized by comparatively low temperature and plenty of sunshine from November to February (SRDI, 1991). The weather data during the study period at the experimental site are shown in Appendix III.

3.4 Plant materials and features

The variety of soybean used in this experiment was BARI Soybean-6. The seed of this variety was collected from Bangladesh Agricultural Research Institute, Joydbpur, Gazipur. This released variety has excellent seed quality and superior to others. This variety was released by selection procedure from different collected foreign germplasm during 2009. Its field duration was about 100-110 days. Its height is about 50-55 cm. BARI Soybean-6 contains 20-21% oil and 42-44% protein. Seed yield is about 1.80-2.10 t ha^{-1} (BARI, 2011).

3.5 Experimental treatments

The experiment consisted of two treatment factors as mentioned below:

a) Factor A: Sowing date

i) S_1 = 18 December
ii) S_2 = 2 January
iii) S_3 = 17 January
iv) S_4 = 1 February

b) Factor B: Weed control methods

i) W_0 = No weeding (control)
ii) W_1 = Hand weeding at 20 and 40 days after sowing (DAS)
iii) W_2 = Hand hoe weeding at 20 and 40 DAS
iv) W_3 = Whip Super 9 EC (Fenoxaprop-P-ethyl)

The description of the weeding treatments is given below.

i) No weeding: Weeds were allowed to grow in the plots from sowing to harvesting of the crop. No weeding was done.

ii) Hand weeding: Two hand weedings were done at 20 and 40 DAS, respectively.

iii) Hand hoe weeding: Two hand hoe weedings were done at 20 and 40 DAS, respectively.

iv) Whip Super 9 EC (Fenoxaprop-P-ethyl: $C_{18}H_{16}C_{l}NO_5$): Whip Super 9 EC was foliar sprayed @ 615 ml ha^{-1} at 20 DAS as post-emergence herbicide.

3.6 Description of herbicide

A short description of the herbicide used in the experiment is given below.

Trade name: Whip Super 9 EC

Common name: Fenoxaprop-P-ethyl

Mode of action: Systemic

Selectivity: Rice, Tomato

Time of application: Post-emergence

3.7 Design and layout

The experiment was laid out in a split plot design with three replications. The size of the individual plot was 4 m x 2.5 m and total numbers of plots were 48. There were 16 treatment combinations. Each block was divided into 16 unit plots. Sowing date was placed along the main plot and weeding treatments were placed in the sub plot. Layout of the experiment was done on December 17, 2012 with interplot spacing of 0.50 m and inter block spacing of 1 m. A layout of the experimental plot is given on Appendix X.

3.8 Land preparation

The land of the experimental field was first opened on December 10, 2012 with a power tiller. Then it was exposed to the sunshine for 7 days prior to the next ploughing. Thereafter, the land was ploughed and cross-ploughed to obtain good tilth. Deep ploughing was done to produce a good tilth, which was necessary to get better yield of the crop. Laddering was done in order to break the soil clods into small pieces followed by each ploughing. All the weeds and stubbles were removed from the experimental field.

3.9 Fertilizer application

All the fertilizers were applied at BARI recommended dose as 55 kg ha^{-1} N, 165 kg ha^{-1} P, 110 kg ha^{-1} K, 100 kg ha^{-1} S (BARI, 2011). All the fertilizers were applied at the time of final land preparation.

3.10 Seed treatment

Seeds were treated with Vitavex-200 @ 0.25% before sowing to prevent seeds from the attack of soil borne disease.

3.11 Seed sowing

Seeds were sown as per treatments of the experiment in 30 cm apart rows and seeds were sown continuously in rows. Furrows were made by hand rake and seeds were placed in the furrows by hand and then covered properly with soil.

3.12 Intercultural operations

The following intercultural operations were done for ensuring the normal growth of the crop.

3.12.1 Thinning

At 15 DAS, excess plants were thinned out and maintained plant to plant distance 5cm.

3.12.2 Weeding

Weed control methods were followed as per treatments as mentioned in section 3.5.

3.12.3 Irrigation

Irrigation was done at 30 DAS after sowing (pre-flowering) stage and then at 60 DAS (pod formation stages) as per recommendation (BARI, 2011). Proper drainage system was also made for draining out excess water.

3.12.4 Plant protections

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

3.13 General observations of the experimental field

Regular observations were made to see the growth stages of the crop. In general, the field looked nice with normal green plants which were vigorous and luxuriant in the treatment plots than that of control plots.

3.14. Sampling

Ten sample plants were collected randomly from each plot. These 10 plants were used for taking yield attributes data.

3.15 Harvest and post-harvest operation

Maturity of crop was determined when 95 % of the pods become brown in color. The plants of central 1 m^2 area were harvested by placing quadrate for recording yield data. Harvesting was done at 18 April, 2 May, 17 May, 1 June, 2013. The harvested crops from each plot were tied up into bundles separately, tagged and brought to the clean threshing floor. The same procedure was followed for sample plants.

3.15.1 Threshing

The crop bundles were sun dried for four days by spreading them on the threshing floor. Seeds were separated from the stover by hand machine and rubbing.

3.15.2 Drying

Seeds and stover were cleaned and dried in the sun for four consecutive days. After proper drying of seeds to a moisture content of 12 % were kept in polythene bags.

3.15.3 Cleaning and weighing

Dried seeds and stover was weighed plot wise. After that the weights were converted into t ha^{-1}.

3.16 Collection of weed and crop characters data

Ten plants in each plot were selected and tagged. All the growth data (except dry weight) were recorded from those 10 selected plants. The following data were recorded during the experimentation.

A. Weed parameters

i. Weed density
ii. Relative weed density (%)
iii. Weed dry matter (g m^{-2})
iv. Weed control efficiency (%)

B. Crop growth parameters

i. Plant height (cm) at 20, 40, 60, 80 DAS and at harvest
ii. Number of branches $plant^{-1}$ at 60, 80 DAS and at harvest

iii. Dry weight of plant^{-1} at 20, 40, 60, 80 DAS and at harvest

C. Yield and other crop characters

i. Number of plants m^{-2}
ii. Number of pods plants^{-1}
iii. Pod length (cm)
iv. Number of seeds pod^{-1}
v. Weight of 1000 seeds (g)

D. Yield and harvest index

i. Seed yield (t ha^{-1})
ii. Stover yield (t ha^{-1})
iii. Biological yield (t ha^{-1})
iv. Harvest index (%)

3.17 Methods of recording data

A. Weed parameters

i. Weed density

The data on weed infestation were collected from each unit plot at 20 DAS and up to 60 DAS at 20 days interval. A plant quadrate of 1.0 m^2 was placed at three different spots of 10 m^2 of the plot. The middle quadrate was remained undisturbed for yield data. The infesting species of weeds within the first and third quadrate were identified and their number was counted species wise alternately at 20, 40 and 60 DAS.

ii. Relative weed density (%)

Relative weed density was calculated by using the following formula:

$$\text{RWD} = \frac{\text{Density of individual weed species in the community}}{\text{Total density of all weed species in the community}} \times 100$$

iii. Weed dry matter

The weeds inside each quadrate for density count were uprooted, cleaned and separated species wise. The collected weeds were first dried in the sun and then kept in an electrical oven for 72 hours maintaining a constant temperature of 60^0C. After drying, weight of each species was taken and expressed to g m^{-2}.

iv. Weed control efficiency (%)

Weed control efficiency was calculated with the following formula developed by Sawant and Jadav (1985):

$$\text{Weed control efficiency (WCE)} = \frac{DWC - DWT}{DWC} \times 100$$

Where,

DWC = Dry weight of weeds in unweeded treatment

DWT = Dry weight of weeds in weed control treatment

B. Crop growth parameters

i. Plant height (cm)

The height of the soybean plants was recorded at 20, 40, 60, 80 DAS and at harvest. The heights of 10 preselected sample plants were measured from the ground level to the tip of the shoot. Then the data was averaged and expressed in cm.

ii. Number of branches plant^{-1}

Total branch number was taken at 60, 80 DAS and at harvest. All the branches present on 10 preselected sample plants were counted and averaged them to have number of branches plant^{-1}.

iii. Dry weight of plant^{-1}

The dry weight of soybean plants was recorded at 20, 40, 60, 80 DAS and at harvest. Five plants were collected randomly from the inner rows of each plot and dried separately for 72 hours in an electric oven set at 60^0C. The dry weight of the samples was taken using a sensitive digital electric balance. The mean weight was calculated and the weight was expressed in g plant^{-1}.

C. Yield and other crop characters

i. Number of plants m^{-2}

A quadrate of 1.0 m^2 was placed in each plot and the total number of plants was counted within the quadrate.

ii. Number of pods plants^{-1}

All the pods of the preselected 10 sample plants in each plot were counted and averaged them to have pods plant^{-1}.

iii. Pod length

The length of 10 randomly selected pods taken from sample plants were measured. Mean data was expressed in centimeter (cm).

iv. Number of seeds pod^{-1}

Number of total seeds of ten sample plants from each plot was noted and the mean number was expressed per pod basis.

v. Weight of 1000 grains (g)

One thousand sun dried cleaned seeds were counted randomly from the seed stock of sample plants. Weight of 1000 seeds were then recorded by means of a digital electrical balance and expressed in g.

D. Yield and harvest index

i. Seed yield

Seeds obtained from harvested 1.0 m^2 area of each unit plot were dried in the sun and weighed. The seed weight was expressed as t ha^{-1} on 12% moisture basis. Grain moisture content was measured by using digital moisture meter.

ii. Stover yield

The stovers obtained from the harvested 1.0 m^2 area of each unit plot were dried separately and weights were recorded. These weights were converted to t ha^{-1}.

iii. Biological yield

Biological yield was calculated by using the following formula:

Biological yield= Grain yield + straw yield

iv. Harvest index (%)

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

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

3.18 Statistical analysis

The data obtained for different characters were statistically analyzed following the analysis of variance techniques by using MSTAT-C computer package programme. The significant differences among the treatment means were compared by Duncan's Multiple Range Test (DMRT) at 5% level of probability (Gomez and Gomez, 1984).

Chapter 4
Results and Discussion

CHAPTER IV

RESULTS AND DISCUSSION

This chapter comprises presentation and discussion of the results obtained from a study to investigate the influence of sowing date and different weed control method on the growth, development and yield of soybean. The results of the weed parameters and crop characters as influenced by different sowing date and weed control treatments have been presented and discussed in this chapter.

4.1 Weed parameters

4.1.1 Infested weed species in the experimental field

Twenty weed species belonging to eleven families were found to infest the experimental crop. Local name, English name, botanical name, family and morphological type of the weed species have been presented in Table 1. The density and dry weight of weeds varied considerably in different weed control treatments.

The most important weeds of the experimental plots were *Lindernia procumbens, Echinochloa colonum, Vicia sativa, Cynodon dactylon, Digitaria sanguinalis, Chenopodium album, Cyperus rotundus, Eleusine indica*. Among the twenty species fifteen were broad leaved, four were grasses and one was sedge (Table 1). Kushwah and Vyas (2006) found *Caesulia axillaris*, *Echinochloa colona*, *Cyperus iria*, *Cyperus rotandus*, *Commelina benghalensis*, *Digitaria sanguinalis* and *Acalypha indica* in soybean crop. Malik *et al.* (2006) identified *Celosia argentea*, *Digera arvensis*, *Echinochloa colona*, *Dactyloctenium aegyptium*, *Cyperus rotandus* and *Trianthema portulacastrum* in soybean field. Idapuganti *et al.* (2005) observed *Echinochloa colona*, *Cyperus rotandus*, *Trianthema portulacastrum*, *Digera arvensis*, *Commelina benghalensis*, *Digitaria sanguinalis*, *Phyllanthus niruri* and *Dactyloctenium aegyptium* in soybean crop. Guliqbal (2005) reported *Cyperus* rotandus, *Dactyloctenium aegyptium*, *Eragrostis piolsa* and *Commelina benghalensis* in soybean field. Balyan and Malik (2003) noticed *Trianthema monogyna*, *Echinochloa colona*, *Celosia argentea*, *Digera arvensis*, *Cyperus* *rotandus*, *Physalis minima* and *Dactyloctenium aegyptiumin* soybean crop. Rohitashav *et al.* (2003) observed *Trianthema monogyna*, *Echinochloa colona*, *Celosia argentea*, *Dactyloctenium aegyptium*, *Eleusine indica*, *Cleome viscosa*, *Cucumis trigonus* and *Commelina benghalensis* in soybean field. Gaikwad and Pawar (2003) found, *Brachiaria ramosa*, *Cyanodon dactylon*, *Echinochlo acrus galli*, *Convolvulus arvensis* and *Acalyphain dica* in soybean crop. The present result varied a little bit and this might be due to seasonal variation and location.

Table 1. Weed species found in the experimental plots of Soybean (BARI Soybean-6) at different date of sowing

SL. No.	Local name	English Name	Botanical Name	Family	Types
1	Durba	Bermuda grass	*Cynodon dactylon*	Poaceae	Grass
2	Bathua	Lambs quarter	*Chenopodium album*	Chenopodiaceae	Broad Leaf
3	Mutha	Nutgrass	*Cyperus rotundus*	Cyperaceae	Sedge
4	Khetpapri	Prostate false pimpernel	*Lindernia procumbens*	Scrophulariaceae	Broad Leaf
5	Malncha	Alligator weed	*Alternanthera philoxeroides*	Amaranthaceae	Broad Leaf
6	Bon Masur	Wild lentil	*Vicia sativa*	Fabaceae	Broad Leaf
7	Boro Anguli	Scrab grass	*Digitaria sanguinalis*	Poaceae	Grass
8	Khude Shama	Jungle rice	*Echinochloa colonum*	Poaceae	Grass
9	Chapra	Indian goosegrass	*Eleusine indica*	Poacease	Grass
10	Hatishur	Wild clary	*Heliotropium indicum*	Boraginaceae	Broad Leaf
11	Bon Mula	Wild raddish	*Raphanus raphanistrum*	Brassicaceae	Broad Leaf
12	Shetlomi	Common cudweed	*Gnaphalium luteoalbum*	Asteraceae	Broad Leaf
13	Bon sarisha	Wild mustard	*Brassica kaber*	Brassicaceae	Broad Leaf
14	Chanchi	Sessile joyweed	*Alternanthera sessilis*	Amaranthaceae	Broad Leaf
15	Chochalo Begun	Spiny night shade	*Solanum rostratum*	Solanaceae	Broad Leaf
16	Foska begun	Clammy ground chery	*Physalis heterophylla*	Solanaceae	Broad Leaf
17	Kheshuti	White eclipta	*Eclipta prostrata*	Asteraceae	Broad Leaf
18	Arich	Tora weed	*Cassia tora*	Fabaceae	Broad Leaf
19	Shushni Shak	4-leaved water clover	*Marsilia quadrifolia*	Marsileaceae	Broad Leaf
20	Helencha	Harkuch	*Enhydra fluctuans*	Asteraceae	Broad Leaf

4.1.2 Relative weed density (%)

Weed competes with another weed plants for their existence. In this experiment, several weed species were found to dominate the field at different dates (Table 2). This might be due to crop-weed competition, weed-weed competition or allelopathic effect (chemical secretion of one plant that inhibit the growth of others) of one plant to others. Although, occurrence of weed in the crop field mainly depends on various environmental factors (climate, rainfall etc.) and abiotic factors (soil types, topography of land etc.). Broad leaf and grass weeds dominated the field during the experimental period. In case of first sowing, at 20 DAS *Vicia sativa* (20.59 %), 40 DAS *Lindernia procumbens* (27.32 %) and at 60 DAS *Echinochloa colonum* (25.44 %) dominated the experimental field. In case of second sowing, *Lindernia procumbens* (18.50, 17.88 and 14.93 %, respectively) dominated the experimental field at 20, 40 and 60 DAS. In case of third sowing, *Cynodon dactylon* (16.30 %) and *Lindernia procumbens* (28.78, 38.78 %), respectively were the dominant weed species at 20, 40 and 60 DAS. In case of fourth sowing, *Lindernia procumbens* (32.81, 41.03 and 44.78 %, respectively) was the dominated weed species at 20, 40 and 60 DAS. Relative density of several weed species decreased at later stages due to their completion of life cycle.

Table 2. Relative density (%) of different weed species at different date after sowing in the experimental area

Common name	Relative weed density (%) at											
	18 December, 2012			2 January, 2013			17 January, 2013			1 February, 2013		
	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS	20 DAS	40 DAS	60 DAS
Durba	13.52	12.00	6.16	15.73	12.89	12.56	16.30	9.32	9.49	6.99	5.91	7.49
Bathua	12.96	2.01	1.43	7.54	4.15	5.07	4.05	0.80	0.20	0.20	0.00	0.00
Mutha	13.11	0.00	5.23	9.73	10.39	9.04	13.32	13.20	9.20	14.20	11.34	3.60
Khetpapri	10.46	27.32	23.54	18.50	17.88	14.93	16.16	28.78	38.78	32.81	41.03	44.78
Malncha	8.14	0.10	0.00	4.60	3.33	7.07	6.05	5.60	2.60	4.30	1.04	0.00
Bon Masur	20.59	0.30	7.88	11.25	8.73	3.15	9.05	4.34	1.43	3.41	0.00	0.00
Boro Anguli	6.22	16.46	8.11	9.36	6.86	11.79	5.05	6.92	8.92	7.18	9.92	10.63
Khude Shama	0.00	26.39	25.44	10.00	9.14	9.63	8.01	11.14	10.82	9.23	12.44	12.12
Chapra	0.00	0.00	0.00	6.20	4.15	7.86	5.00	6.34	3.64	8.34	4.64	11.46
Bon Masur	9.00	6.45	3.17	0.00	5.82	6.68	7.00	1.20	0.12	1.20	0.00	0.00
Hatishur	0.00	0.40	1.06	0.00	3.12	3.79	3.40	3.70	4.70	3.70	6.33	2.54
Bon Mula	0.00	0.00	1.34	0.00	3.72	0.00	1.30	0.00	0.00	0.00	0.00	0.00
Shetlomi	0.00	0.08	12.00	2.20	0.00	0.00	0.40	0.00	0.00	0.00	0.00	0.00
Bon Sharisha	6.00	7.85	4.00	4.86	3.14	2.16	2.00	1.09	0.50	0.30	0.00	0.00
Chanchi	0.00	0.00	0.00	0.00	0.00	0.00	0.60	1.30	1.30	3.10	2.13	3.33
Chochalo Begun	0.00	0.16	0.50	0.00	3.33	3.15	1.41	4.30	4.30	3.40	2.30	1.92
Foska begun	0.00	0.16	0.00	0.00	3.33	3.15	0.90	1.20	2.10	1.20	1.20	0.08
Kheshuti	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.04	0.54	0.08	0.64	0.76
Arich	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.33	0.06	0.63	0.86
Shushni Shak	0.00	0.24	0.14	0.00	0.12	0.00	0.00	0.30	0.33	0.10	0.43	0.43
Helencha	0.00	0.08	0.00	0.03	0.02	0.03	0.00	0.40	0.70	0.20	0.02	0.00

4.1.3 Weed dry matter

4.1.3.1 Effect of sowing date

The significant effect on weed dry weight was found due to different sowing date at 40 and 60 DAS and showed non-significant effect at 20 DAS (Appendix IV and Table 3). Table 3 illustrated that at 20 DAS, numerically the maximum weed dry matter was produced by S_4 (1.96 g m^{-2}) and minimum was found from S_1 (1.90 g m^{-2}). At 40 DAS, S_4 produced the highest amount of weed dry weight (11.86 g m^{-2}) and the lowest was produced by S_2 (7.52 g m^{-2}). At 60 DAS, the highest amount of dry matter was obtained from S_4 (15.62 g m^{-2}) which was statistically similar with S_3 and the lowest was from S_2 (10.58 g m^{-2}). Suitable vegetative growth period provided a good chance for the soybean to produce the highest dry weight and to increase its produced biomass as much as possible. Due to lack of time for dry matter accumulation in plant, late planting dates do not provide the plant with the necessary time for its increase, so the total dry weight in soybean is less than that of earlier planting dates. The results were consistent with the findings of Kouchaki (1994).

Table 3. Effect of sowing date and weed control method on weed dry weight and weed control efficiency at different days after sowing of soybean

Sowing date	Weed dry matter (g m^{-2}) at			Weed control efficiency (%) at	
	20 DAS	40 DAS	60 DAS	40 DAS	60 DAS
S_1	1.90	9.07 c	13.88 b	59.42 b	63.23
S_2	1.91	7.52 d	10.58 c	61.65 ab	63.30
S_3	1.94	10.39 b	14.48 ab	62.04 a	61.70
S_4	1.96	11.86 a	15.62 a	60.02 ab	62.18
SE	0.082	0.308	0.433	0.703	0.636
CV (%)	14.69	10.97	11.00	4.01	3.52
Weed control methods					
W_0	1.97	24.76 a	36.42 a	0	0
W_1	1.87	3.42 d	4.12 d	86.25 a	88.97 a
W_2	1.96	6.32 b	7.99 b	74.62 c	77.67 c
W_3	1.91	4.35 c	6.03 c	82.26 b	83.77 b
SE	0.072	0.242	0.276	0.795	0.671
CV (%)	13.05	8.63	7.01	4.53	3.71

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

S_1=18th December, S_2=2nd January, S_3=17th January, S_4=1st February. W_0=No weeding, W_1= Hand weeding at 20 and 40 DAS, W_2= Hand hoe weeding at 20 and 40 DAS, W_3= Whip Super 9 EC (Fenoxaprop-P-ethyl)

4.1.3.2 Effect of weed control method

Significant differences in weed dry weight were observed due to different weeding treatments at 40, 60 DAS and non-significant effect at 20 DAS (Appendix IV and Table 3). At 20 DAS, numerically the maximum weed dry matter was produced by W_0 (1.97 g m^{-2}) and minimum was found from W_1 (1.87 g m^{-2}). At 40 DAS, the highest amount of dry matter was obtained from W_0 (24.76 g m^{-2}) and the lowest was from W_1 (3.42 g m^{-2}). At 60 DAS, W_0 produced the highest amount of weed dry weight (36.42 g m^{-2}) and the lowest was produced by W_1 (4.12 g m^{-2}).

4.1.3.3 Interaction effect of sowing date and weed control method

Weed dry weight significantly influenced by the combination of different sowing date and weed control method at 40, 60 DAS and exerted non-significant effect at

20 DAS (Appendix IV and Table 4). At 20 DAS, numerically the maximum amount of dry matter (2.02 g m^{-2}) was found from S_3W_0, S_4W_0, S_4W_2 treatment combinations and the minimum was obtained from S_4W_1 (1.82 g m^{-2}). At 40 and 60 DAS, S_4W_0 produced the highest amount of weed dry matter (29.70 and 41.30 g m^{-2}, respectively) and the lowest was found from S_2W_1 (2.47 and 2.23 g m^{-2}, respectively) which was statistically similar with S_2W_3 and S_1W_1.

Table 4. Interaction effect of sowing date and weed control method on weed dry weight and weed control efficiency at different days after sowing of soybean

Treatment combination	Weed dry matter (g m^{-2}) at			Weed control efficiency (%) at	
	20 DAS	40 DAS	60 DAS	40 DAS	60 DAS
S_1W_0	1.93	22.32 c	37.70 b	0	0
S_1W_1	1.88	3.47 hi	3.47 hi	84.66 ab	90.88 a
S_1W_2	1.90	6.07 f	7.40 def	72.95 ef	80.39 cd
S_1W_3	1.87	4.43 gh	6.93 def	80.07 b-d	81.64 cd
S_2W_0	1.90	19.63 d	28.87 c	0	0
S_2W_1	1.87	2.47 i	2.23 i	87.46 a	92.39 a
S_2W_2	1.97	4.57 f-h	7.90 de	76.60 de	72.54 e
S_2W_3	1.90	3.40 hi	3.33 hi	82.55 a-c	88.25 ab
S_3W_0	2.02	27.37 b	37.80 b	0	0
S_3W_1	1.90	3.53 hi	6.33 ef	87.11 a	83.34 c
S_3W_2	1.93	5.93 fg	7.67 de	78.32 cd	78.90 d
S_3W_3	1.89	4.73 f-h	5.83 fg	82.73 a-c	84.56 bc
S_4W_0	2.02	29.70 a	41.30 a	0	0
S_4W_1	1.82	4.22 h	4.43 gh	85.76 a	89.25 a
S_4W_2	2.02	8.70 e	8.73 d	70.63 f	78.83 d
S_4W_3	1.98	4.83 f-h	8.00 de	83.69 ab	80.62 cd
SE	0.145	0.484	0.552	1.590	1.341
CV (%)	13.05	8.63	7.01	4.53	3.71

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

S_1=18th December, S_2=2nd January, S_3=17th January, S_4=1st February. W_0=No weeding, W_1= Hand weeding at 20 and 40 DAS, W_2= Hand hoe weeding at 20 and 40 DAS, W_3= Whip Super 9 EC (Fenoxaprop-P-ethyl)

4.1.4 Weed control efficiency

4.1.4.1 Effect of sowing date

Weed control efficiency was significantly affected by different sowing date at 40 DAS and showed non-significant effect at 60 DAS (Appendix IV and Table 3). At 40 DAS, the highest weed control efficiency was achieved from S_3 (62.04 %) which was statistically similar with S_2 and S_4 whereas, the lowest was observed from S_1 which was statistically similar with S_4 and S_2. At 60 DAS, numerically the maximum result was obtained from S_2 (63.30 %) and the minimum was from S_3 (61.70 %).

4.1.4.2 Effect of weed control method

Weed control method had significant effect on weed control efficiency of soybean at 40 and 60 DAS (Appendix IV and Table 3). Treatment W_1 showed the best result at 40 and 60 DAS. At 40 DAS weed control efficiency of W_1 was 86.25 % where it increased to 88.97 % at 60 DAS. The lowest weed control efficiency (74.62 and 77.67 %, respectively) was shown by W_2 at 40 and 60 DAS.

4.1.4.3 Interaction effect of sowing date and weed control method

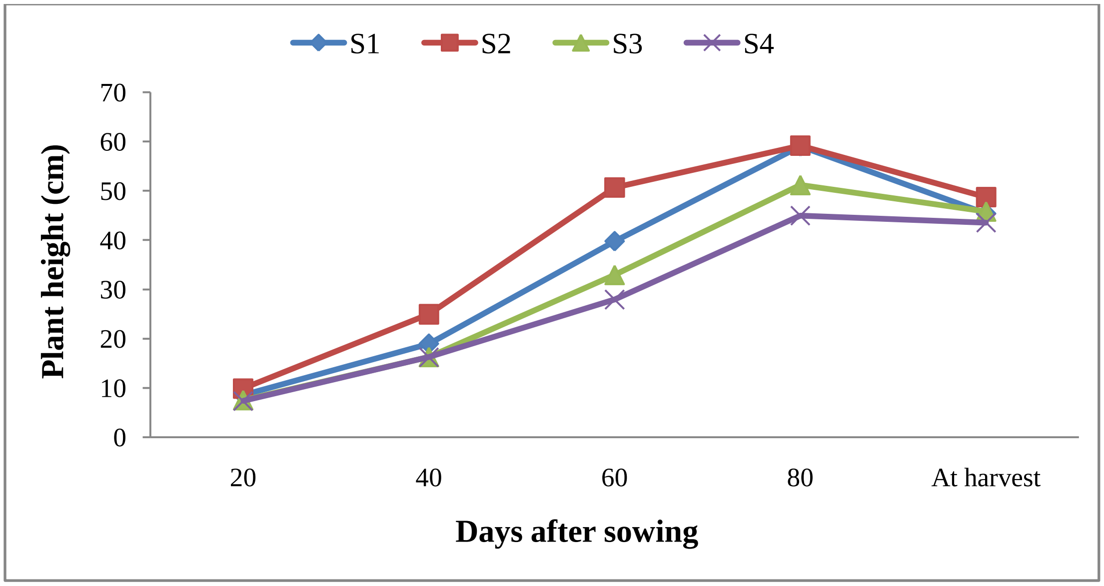
Due to interaction effect of sowing date and weed control method weed control efficiency of soybean was significantly affected at different date after sowing (Appendix IV and Table 4). At 40 DAS, the best weed control efficiency was achieved from S_2W_1 (87.46 %) which was statistically similar with S_3W_1, S_4W_1, S_1W_1, S_4W_3, S_2W_3 and S_3W_3 whereas, the lowest was from S_4W_2 (70.63 %) which was statistically similar with S_1W_2. At 60 DAS, the highest weed control efficiency was obtained from S_2W_1 (92.39 %) which was statistically similar with S_1W_1, S_4W_1 and S_2W_3 whereas, the lowest was found from S_2W_2 (72.54 %).

4.2 Crop growth parameters

4.2.1 Plant height

4.2.1.1 Effect of sowing date

The significant result was found in plant height of soybean by the sowing date at different growth stages (Appendix V and Fig. 1). The figure indicated that plant height showed an increasing trend with advancement of time upto 80 DAS for all sowing dates. The rate of increase was found slower upto 40 DAS after that plant height increased sharply upto 80 DAS. From 80 DAS, the height reduced slightly and it continued upto at harvest irrespective of sowing dates. It could be inferred from the figure that sowing date S_2 showed the tallest plant (9.91, 24.99, 50.69, 59.18 and 48.74 cm) and S_4 showed the shortest plant (7.36, 16.26, 27.94, 44.95 and 43.53 cm) for sampling dates of 20, 40, 60, 80 DAS and at harvest, respectively. Plant height decreased significantly with delay in planting. Reduced plant height with delay in planting might be due to quick changes in photoperiod, which accelerated development towards reproductive stages and hence less time was available for vegetative growth. The greater plant height recorded in 30th December was probably due to comparatively longer growing period along with the optimum environmental conditions. These results were in line with those of reported by Wade and Johnston (1975) who stated that photoperiod sensitivity had marked reduction in growth period due to delayed seeding might account for decrease in plant height. Other researchers have also found that plant height generally decreased with delayed planting by Hamzeh *et al.* (2004); Zynali *et al.* (2003) and Arshi (2001).

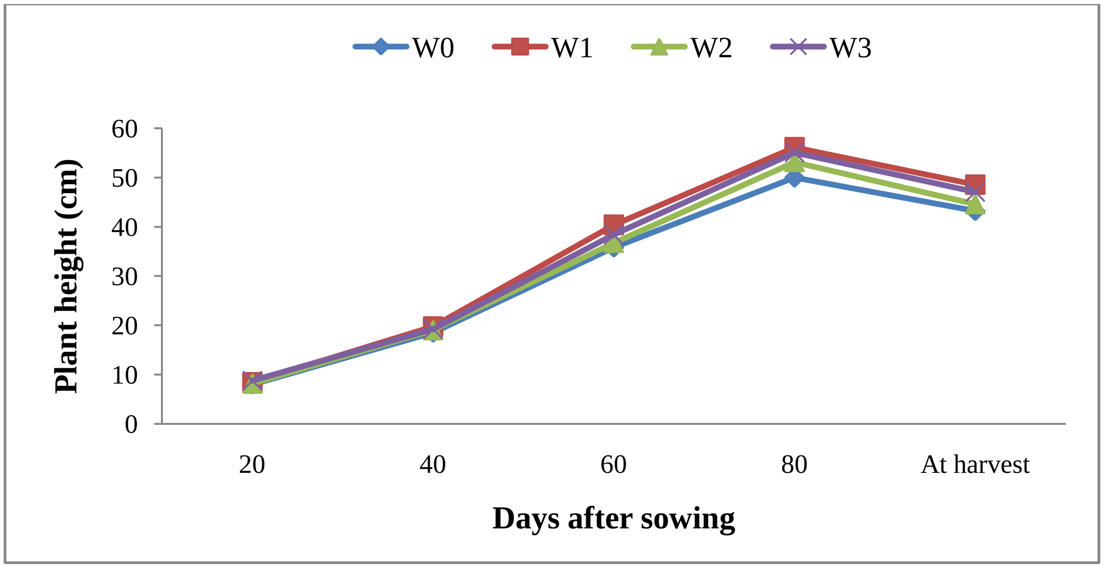


S_1=18th December, S_2=2nd January, S_3=17th January, S_4=1st February

Fig. 1. Effect of sowing date on plant height at different days after sowing of soybean (SE value= 0.249, 0.625, 1.410, 2.189 and 0.959 at 20, 40, 60, 80 DAS and at harvest, respectively)

4.2.1.2 Effect of weed control method

Weed control method had significant effect on plant height of soybean at 20, 60, 80 DAS and at harvest stage and non-significant effect at 40 DAS (Appendix V and Fig. 2). The figure demonstrated that plant height showed an increasing trend with increasing the age of plant upto 80 DAS for all weed control method. The rate of increase was found slow upto 40 DAS after that plant height increased sharply upto 80 DAS. From 80 DAS, the height reduced slightly and it continued upto at harvest irrespective of all weed control method. It can be deduced from the figure that weed control method W_1 showed the tallest plant (8.45, 19.77, 40.39, 56.15 and 48.57 cm) and W_0 produced the shortest plant (7.98, 18.51, 35.81, 50.01 and 43.23 cm) for sampling dates of 20, 40, 60, 80 DAS and at harvest, respectively.



W_0=No weeding, W_1= Hand weeding at 20 and 40 DAS, W_2= Hand hoe weeding at 20 and 40 DAS, W_3= Whip Super 9 EC (Fenoxaprop-P-ethyl)

Fig. 2. Effect of weed control method on plant height at different days after sowing of soybean (SE value= 0.202, 0.503, 1.180, 1.576 and 1.460 at 20, 40, 60, 80 DAS and at harvest, respectively)

4.2.1.3 Interaction effect of sowing date and weed control method

Due to interaction effect of sowing date and weed control method plant height of soybean was significantly affected at different growth stages (Appendix V and Table 5). At 20 DAS, the tallest plant was observed from S_2W_3 (10.13 cm) which was statistically similar with S_2W_1, S_2W_2 and S_2W_0 and the shortest was obtained from S_3W_0 (6.83 cm) which was statistically similar with S_4W_0, S_4W_2, S_3W_2, S_4W_1, S_3W_1 and S_4W_3. At 40 DAS, the tallest plant was observed from S_2W_1 (26.15 cm) which was statistically similar with S_2W_3, S_2W_2 and S_2W_0 whereas, the smallest was obtained from S_4W_0 (15.57 cm) which was statistically similar with S_3W_0, S_4W_2, S_3W_2, S_4W_3, S_3W_1, S_3W_3, S_4W_1 and S_1W_0. At 60 DAS, the longest plant was observed from S_2W_1 (53.50 cm) which was statistically similar with S_2W_3, S_2W_2 and S_2W_0 whereas, the smallest was obtained from S_4W_0 (25.78 cm) which was statistically similar with S_4W_2, S_4W_3, S_4W_1, S_3W_2 and S_3W_0. At 80 DAS, the tallest plant was observed from S_1W_1 (61.98 cm) which was statistically similar with S_1W_3, S_2W_1, S_2W_3, S_2W_2, S_2W_0, S_1W_2, S_1W_0, S_3W_1, S_3W_3 and S_3W_2 whereas, the smallest was obtained from S_4W_0 (41.02 cm) which was statistically similar with S_4W_2, S_4W_3, S_3W_0 and S_4W_1. At harvest, the longest plant was observed from S_2W_1 (50.58 cm) which was statistically similar with S_1W_0, S_1W_1, S_1W_2, S_1W_3, S_2W_0, S_2W_2, S_2W_3, S_3W_1, S_3W_2, S_3W_3, S_4W_1, S_4W_2 and S_4W_3 whereas, the smallest was obtained from S_4W_0 (39.93 cm) which was statistically similar with S_1W_0, S_1W_1, S_1W_2, S_1W_3, S_2W_0, S_2W_2, S_2W_3, S_3W_0, S_3W_1, S_3W_2, S_3W_3, S_4W_1, S_4W_2, and S_4W_3.

Table 5. Interaction effect of sowing date and weed control method on plant height at different days after sowing of soybean

Treatment combination	Plant height at				
	20 DAS	**40 DAS**	**60 DAS**	**80 DAS**	**At harvest**
S_1W_0	8.37 c-f	18.27 b-d	37.54 c-e	55.47 a-c	41.27 ab
S_1W_1	8.67 b-d	19.32 b	43.66 bc	61.98 a	48.29 ab
S_1W_2	8.60 b-d	19.15 bc	38.91 cd	57.17 ab	44.29 ab
S_1W_3	8.67 b-d	19.22 bc	39.10 cd	61.67 a	47.78 ab
S_2W_0	9.63 a-c	24.37 a	47.00 ab	57.77 ab	47.00 ab
S_2W_1	10.05 a	26.15 a	53.50 a	60.35 a	50.58 a
S_2W_2	9.83 ab	24.65 a	50.11 ab	58.92 a	47.39 ab
S_2W_3	10.13 a	24.78 a	52.16 a	59.67 a	50.00 ab
S_3W_0	6.83 g	15.83 cd	32.92 d-g	45.78 c-e	44.73 ab
S_3W_1	7.60 d-g	16.53 b-d	34.14 d-f	54.14 a-d	48.34 ab
S_3W_2	7.20 e-g	16.25 b-d	31.06 e-g	52.36 a-d	44.82 ab
S_3W_3	8.50 c-e	16.53 b-d	33.69 d-f	52.55 a-d	45.43 ab
S_4W_0	7.10 fg	15.57 d	25.78 g	41.02 e	39.93 b
S_4W_1	7.50 d-g	17.07 b-d	30.26 e-g	48.14 b-e	47.08 ab
S_4W_2	7.17 e-g	16.11 b-d	27.02 fg	44.17 de	41.94 ab
S_4W_3	7.73 d-g	16.29 b-d	28.69 fg	46.48 c-e	45.15 ab
SE	0.405	1.007	2.360	3.152	2.920
CV (%)	8.39	9.11	10.80	10.19	11.02

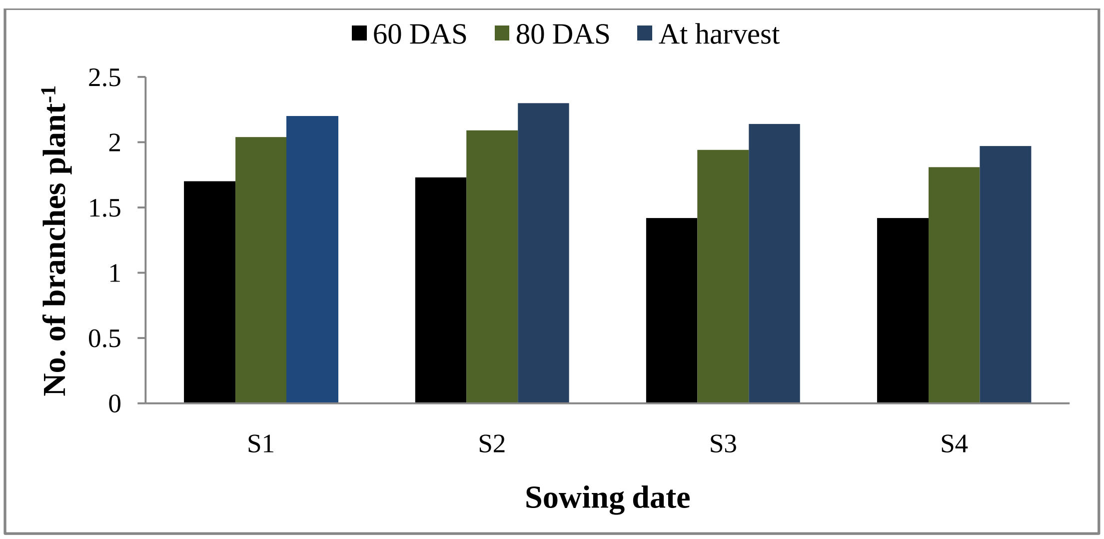
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by DMRT at 0.05 level of probability

S_1=18th December, S_2=2nd January, S_3=17th January, S_4=1st February. W_0=No weeding, W_1= Hand weeding at 20 and 40 DAS, W_2= Hand hoe weeding at 20 and 40 DAS, W_3= Whip Super 9 EC (Fenoxaprop-P-ethyl)

4.2.2 Number of branches plant^{-1}

4.2.2.1 Effect of sowing date

Sowing date had significant effect on number of branches plant^{-1} at different growth stages of soybean (Appendix VI and Fig. 3). The figure indicated that number of branches plant^{-1} increased with advancement of growth stage irrespective of sowing dates. It can be concluded from the figure that sowing date S_2 produced the maximum branch number plant^{-1} (1.73, 2.09 and 2.30) and S_4 showed the lowest (1.42, 1.81and 1.97) for sampling dates of 60, 80 DAS and at harvest. The present result corroborates with the findings of Settimi and Board (1988) and Kang *et al.* (1998) who reported that branch production, and diameter and node number of main stem decreased with delayed planting. Such reduction of the canopy components is responsible for smaller biomass production by reducing the length of vegetative period (Settimi and Board, 1986).

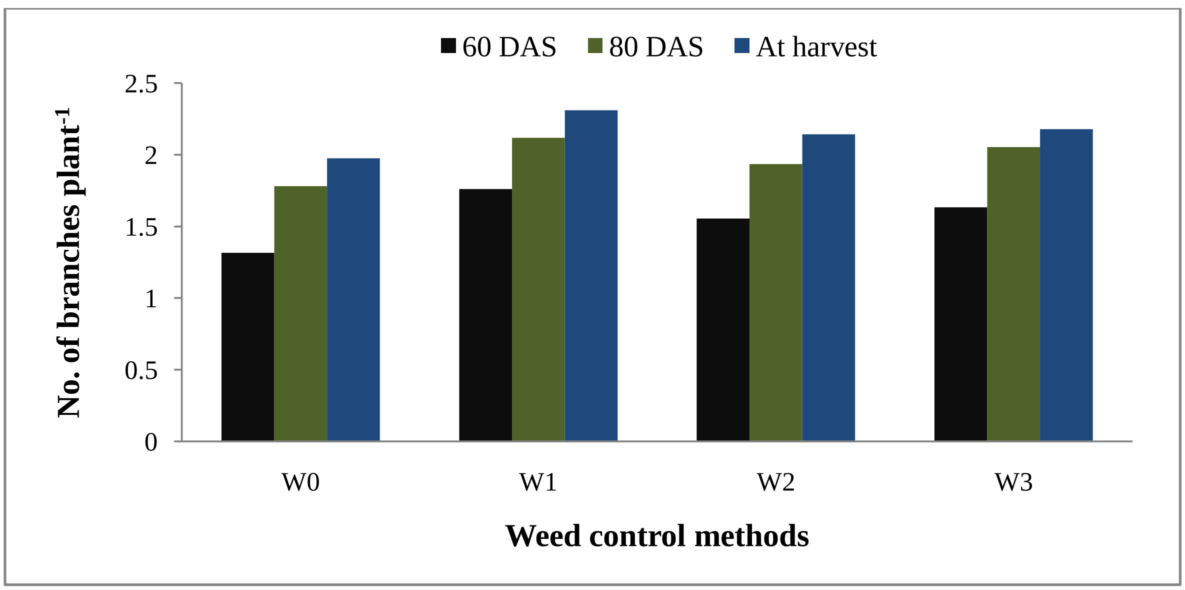


S_1=18th December, S_2=2nd January, S_3=17th January, S_4=1st February

Fig. 3. Effect of sowing date on number of branches plant^{-1} at different days after sowing of soybean (SE value= 0.0695, 0.128 and 0.159 at 60, 80 DAS and at harvest, respectively)

4.2.2.2 Effect of weed control method

Weed control method exerted significant effect on number of branches plant^{-1} of soybean at different days after sowing (Appendix VI and Fig. 4). The figure demonstrated that number of branches plant^{-1} increased with increasing the age of plant irrespective of weed control method. It can be inferred from the figure that weed control method W_1 showed the maximum branch number plant^{-1} (1.76, 2.12 and 2.31) and W_0 produced the lowest (1.63, 2.05 and 2.18) for sampling dates of 60, 80 DAS and at harvest. Increased number of branches as a result of chemical and hand weeding methods has also been reported by Kushwah and Vyas (2005).



W_0=No weeding, W_1= Hand weeding at 20 and 40 DAS, W_2= Hand hoe weeding at 20 and 40 DAS, W_3= Whip Super 9 EC (Fenoxaprop-P-ethyl)

Fig. 4. Effect of weed control method on number of branches plant^{-1} at different days after sowing of soybean (SE value= 0.063, 0.086 and 0.068 at 60, 80 DAS and at harvest, respectively)

4.2.2.3 Interaction effect of sowing date and weed control method

Due to the interaction effect of sowing date and weed control method the number of branches plant^{-1} of soybean was significantly affected at different growth stages (Appendix VI and Table 6). At 60 DAS, the highest number of branches plant^{-1} was produced from S_1W_1 (2.02) which was statistically similar with S_1W_2, S_1W_3, S_2W_1, S_2W_2, S_2W_3 and S_3W_1 whereas, the lowest was found from S_3W_0 (1.17) which was statistically similar with S_1W_0, S_2W_0, S_3W_2, S_3W_3, S_4W_0, S_4W_1, S_4W_2, and S_4W_3. At 80 DAS, the highest number of branches plant^{-1} was observed from S_1W_1 (2.31) which was statistically similar with S_1W_0, S_1W_2, S_1W_3, S_2W_0, S_2W_1, S_2W_2, S_2W_3, S_3W_1, S_3W_2, S_3W_3, S_4W_1, S_4W_2, and S_4W_3 whereas, the smallest was obtained from S_4W_0 (1.61) which was statistically similar with S_1W_0, S_1W_2, S_1W_3, S_2W_0, S_2W_1, S_2W_2, S_2W_3, S_3W_0, S_3W_1, S_3W_2, S_3W_3, S_4W_0, S_4W_1, S_4W_2 and S_4W_3. At harvest, the highest number of branches plant^{-1} was observed from S_1W_1 (2.53) which was statistically similar with S_1W_0, S_1W_2, S_1W_3, S_2W_0, S_2W_1, S_2W_2, S_2W_3, S_3W_1, S_3W_2, S_3W_3 and S_4W_1 whereas, the smallest was obtained from S_4W_0 (1.79) which was statistically similar with S_1W_0, S_1W_2, S_1W_3, S_2W_0, S_3W_0, S_3W_2, S_3W_3, S_4W_1, S_4W_2 and S_4W_3.

Table 6. Interaction effect of sowing date and weed control method on number of branches plant^{-1} at different days after sowing of soybean

Treatment combination	Number of branches plant^{-1} at		
	60 DAS	80 DAS	At harvest
S_1W_0	1.25 e	1.87 ab	2.07 a-c
S_1W_1	2.02 a	2.31 a	2.53 a
S_1W_2	1.68 a-d	1.94 ab	2.10 a-c
S_1W_3	1.86 ab	2.05 ab	2.10 a-c
S_2W_0	1.55 b-e	1.98 ab	2.24 a-c
S_2W_1	1.82 a-c	2.17 ab	2.34 ab
S_2W_2	1.73 a-c	2.03 ab	2.28 ab
S_2W_3	1.80 a-c	2.17 ab	2.32 ab
S_3W_0	1.17 e	1.65 b	1.80 c
S_3W_1	1.67 a-d	2.04 ab	2.28 ab
S_3W_2	1.40 c-e	2.03 ab	2.23 a-c
S_3W_3	1.45 b-e	2.04 ab	2.24 a-c
S_4W_0	1.30 de	1.61 b	1.79 c
S_4W_1	1.53 b-e	1.95 ab	2.08 a-c
S_4W_2	1.41 c-e	1.73 ab	1.96 bc
S_4W_3	1.42 c-e	1.95 ab	2.05 bc
SE	0.124	0.171	0.137
CV (%)	13.71	15.07	11.03

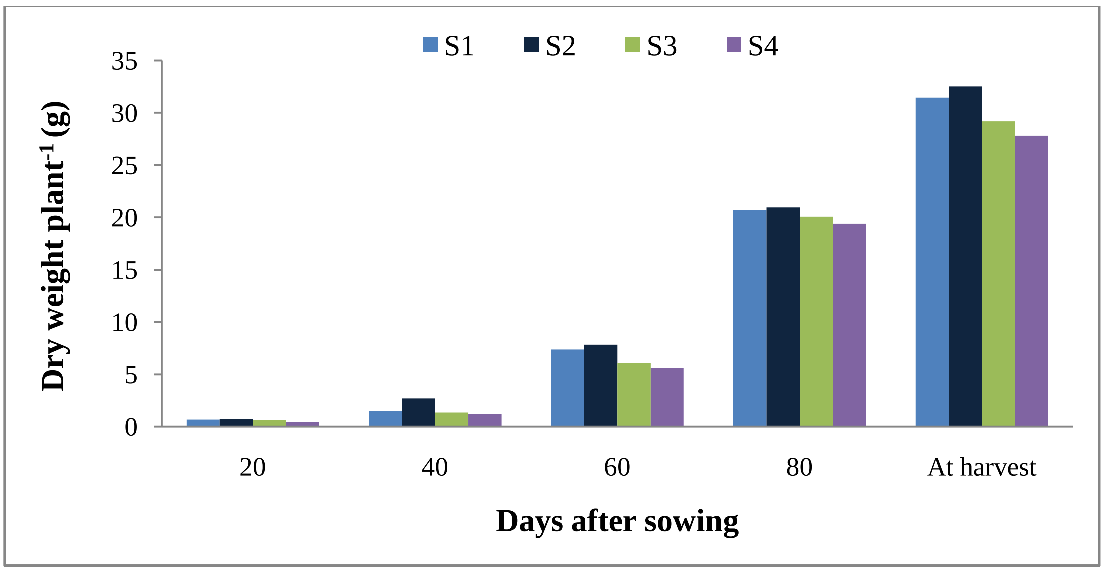
In a column means having similar letter (s) are statistically similar and those having dissimilar letter (s) differ significantly by DMRT at 0.05 level of probability

S_1=18th December, S_2=2nd January, S_3=17th January, S_4=1st February. W_0=No weeding, W_1= Hand weeding at 20 and 40 DAS, W_2= Hand hoe weeding at 20 and 40 DAS, W_3= Whip Super 9 EC (Fenoxaprop-P-ethyl)

4.2.3 Dry weight plant^{-1}

4.2.3.1 Effect of sowing date

Sowing date had significant effect on dry weight plant^{-1} of soybean at 20, 40 and 60 DAS and non-significant effect at 80 DAS and at harvest (Appendix VII and Fig. 5). The figure indicated that dry weight plant^{-1} showed an increasing trend with advances of time for all sowing dates. The rate of increase was found slow upto 40 DAS after that dry weight increased sharply upto harvest irrespective of sowing dates. The figure that sowing date S_2 produced the highest dry weight plant^{-1} (0.69, 2.70, 7.82, 20.95 and 32.37 g) and S_4 showed the lowest weight (0.47, 1.19, 5.59, 19.40 and 27.81 g) for sampling dates of 20, 40, 60, 80 DAS and at harvest, respectively. Late plant takes 13-25 day short time for their completion of life period in comparison with early planting date and it causes the collection of dry material and active photosynthesis radiations to be decreased (Purcell *et al.*, 2002). In the end of growth season which unsuitable condition of temperature prevents the production of enough assimilate; dry material plays an important role in increasing weight of grain (Fanaie *et al.*, 2008). Similar results were found by Rondanini *et al.* (2005).

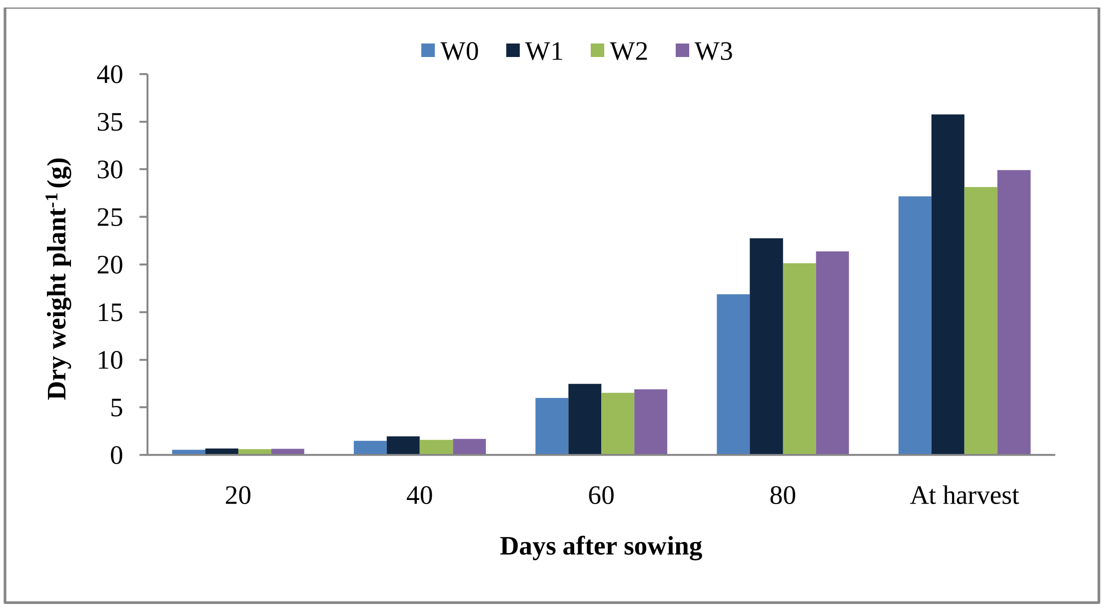


S_1=18th December, S_2=2nd January, S_3=17th January, S_4=1st February

Fig. 5. Effect of sowing date on dry weight plant^{-1} at different days after sowing of soybean (SE value= 0.037, 0.188, 0.414, 0.987 and 2.310 at 20, 40, 60, 80 DAS and at harvest, respectively)

4.2.3.2 Effect of weed control method

Weed control method showed significant effect on dry weight $plant^{-1}$ of soybean at different date after sowing (Appendix VII and Fig. 6). The figure shows that dry weight $plant^{-1}$ showed an increasing trend with advancement of growth stages of plant for all weed control method. The rate of increase was found slower upto 40 DAS, after that dry weight increased steadily upto harvest irrespective of all weed control methods. The figure indicated that weed control method W_1 showed the highest dry weight $plant^{-1}$ (0.67, 1.97, 7.46, 22.76 and 35.75 g $plant^{-1}$) and W_0 showed the lowest weight (0.54, 1.47, 5.99, 16.87 and 27.16 g) for sampling dates of 20, 40, 60, 80 DAS and at harvest, respectively. Van Acker *et al.* (1993) stated that weed interference caused a significant decrease in soybean total aboveground dry weight.



W_0=No weeding, W_1= Hand weeding at 20 and 40 DAS, W_2= Hand hoe weeding at 20 and 40 DAS, W_3= Whip Super 9 EC (Fenoxaprop-P-ethyl)

Fig. 6. Effect of weed control method on dry weight $plant^{-1}$ at different days after sowing of soybean (SE value= 0.024, 0.099, 0.374, 0.770 and 1.588 at 20, 40, 60, 80 DAS and at harvest, respectively)

4.2.3.3 Interaction effect of sowing date and weed control method

Interaction of sowing date and weed control method had significant effect on dry weight plant^{-1} of soybean at 20, 40, 60 DAS, 80 DAS and at harvest (Appendix VII and Table 7). At 20 DAS, the highest dry weight plant^{-1} was observed from S_1W_1 (0.79 g) which was statistically similar with S_1W_2, S_1W_3, S_2W_1, S_2W_2, S_2W_3, S_3W_1 and S_3W_3 whereas, the lowest was obtained from S_4W_0 (0.45 g) which was statistically similar with S_4W_3, S_4W_2, S_4W_1, S_3W_0, S_3W_2 and S_1W_0. At 40 DAS, the highest dry weight plant^{-1} was observed from S_2W_1 (2.87 g) which was statistically similar with S_2W_3 and S_2W_2 whereas, the lowest was obtained from S_4W_0 (1.03 g) which was statistically similar with S_1W_0, S_1W_2, S_3W_0, S_3W_2, S_3W_3, S_4W_1, S_4W_2 and S_4W_3. At 60 DAS, the maximum dry weight plant^{-1} was observed from S_1W_1 (9.01 g) which was statistically similar with S_1W_2, S_1W_3, S_2W_0, S_2W_1, S_2W_2 and S_2W_3 whereas, the lowest was obtained from S_4W_0 (5.06 g) which was statistically similar with S_4W_2, S_1W_0, S_3W_0, S_3W_1, S_3W_2, S_3W_3, S_4W_1 and S_4W_3. At 80 DAS, the highest dry weight plant^{-1} was observed from S_2W_1 (24.25 g) which was statistically similar with S_1W_1, S_1W_2, S_1W_3, S_2W_2, S_2W_3, S_3W_1, S_3W_2, S_3W_3, S_4W_1 and S_4W_3 whereas, the lowest was obtained from S_3W_0 (15.90 g) which was statistically similar with S_1W_0, S_2W_0, S_2W_2, S_3W_2, S_3W_3, S_4W_0, S_4W_2 and S_4W_3.At harvest, the highest dry weight plant^{-1} was observed from S_2W_1 (41.80 g) which was statistically similar with S_1W_1, S_1W_3, S_3W_1 and S_4W_1 whereas, the lowest (23.87 g) was obtained from S_4W_0, S_4W_2 which was statistically similar with S_1W_0, S_1W_1, S_1W_2, S_1W_3, S_2W_0, S_2W_2, S_2W_3, S_3W_0, S_3W_1, S_3W_2, S_3W_3, S_4W_1, S_4W_2, and S_4W_3.

Table 7. Interaction effect of sowing date and weed control method on dry weight plant^{-1} at different days after sowing of soybean

Treatment combination	Dry weight plant^{-1} (g) at				
	20 DAS	40 DAS	60 DAS	80 DAS	At harvest
S_1W_0	0.57 b-f	1.293 de	5.50 bc	17.30 cd	28.73 b-d
S_1W_1	0.79 a	1.800 c	9.01 a	22.04 a-c	34.06 b
S_1W_2	0.65 a-d	1.347 de	7.21 a-c	21.50 a-c	30.99 bc
S_1W_3	0.72 ab	1.41 d	7.82 ab	22.00 a-c	31.98 bc
S_2W_0	0.62 b-e	2.48 b	7.74 ab	17.53 cd	28.42 b-d
S_2W_1	0.72 ab	2.87 a	7.89ab	24.25 a	41.80 a
S_2W_2	0.71 ab	2.66 ab	7.76 ab	20.37 a-d	29.49 b-d
S_2W_3	0.71 ab	2.80 a	7.88 ab	21.66 a-c	29.76 b-d
S_3W_0	0.53 c-f	1.11 de	5.66 bc	15.90 d	26.94 cd
S_3W_1	0.68 a-c	1.86 c	6.50 bc	23.00 ab	33.28 bc
S_3W_2	0.56 b-f	1.19 de	6.04 bc	20.57 a-d	28.22 b-d
S_3W_3	0.65 a-d	1.26 de	6.05 bc	20.83 a-d	28.28 b-d
S_4W_0	0.45 f	1.03 e	5.06 c	16.76 cd	23.87 d
S_4W_1	0.51 d-f	1.34 de	6.42 bc	21.74 a-c	33.86 b
S_4W_2	0.47 ef	1.11 de	5.08 c	18.12 b-d	23.87 d
S_4W_3	0.47 ef	1.277 de	5.78 bc	20.99 a-d	29.63 b-d
SE	0.048	0.097	0.747	1.539	1.983
CV (%)	13.38	10.01	19.27	13.14	11.38

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

S_1=18th December, S_2=2nd January, S_3=17th January, S_4=1st February. W_0=No weeding, W_1= Hand weeding at 20 and 40 DAS, W_2= Hand hoe weeding at 20 and 40 DAS, W_3= Whip Super 9 EC (Fenoxaprop-P-ethyl)

4.3 Yield and other crop characters

4.3.1 Number of plants m^{-2}

4.3.1.1 Effect of sowing date

Sowing date had significant effect on number of plants m^{-2} of soybean (Appendix VIII and Table 8). The highest number of plants m^{-2} (61.33) was observed from S_2 and S_3 whereas, the lowest was found from S_4 (42.00). These results confirm the findings of Egli and Bruening (2000), who observed low initial stands of plants in early sowing.

4.3.1.2 Effect of weed control method

The number of plants m^{-2} of soybean affected significantly by weed control method (Appendix VIII and Table 8). The highest number of plants m^{-2} was observed from W_1 (61.33) and the lowest was found from W_0 (47.83) which was statistically similar with W_2 (51.50).

Table 8. Effect of sowing date and weed control method on yield attributes of Soybean

Treatments	Plants m^{-2} (No.)	Pods $plant^{-1}$ (No.)	Pod length (cm)	Seeds pod^{-1} (No.)	1000-seed weight (g)
Sowing date					
S_1	50.58 b	29.75 a	2.993	1.921 a	111.9 ab
S_2	61.33 a	31.50 a	3.096	1.929 a	117.7 a
S_3	61.33 a	29.33 a	2.969	1.773 b	108.7 b
S_4	42.00 c	24.42 b	2.831	1.610 c	105.6 b
SE	2.401	0.784	0.088	0.033	3.942
CV (%)	15.46	9.44	10.21	6.31	12.31
Weed control method					
W_0	47.83 c	24.50 c	2.795 b	1.695 b	104.2 b
W_1	61.33 a	32.75 a	3.168 a	1.905 a	119.0 a
W_2	51.50 bc	26.83 b	2.949 ab	1.779 ab	109.2 b
W_3	54.58 b	30.92 a	2.977 ab	1.854 a	111.5 b
SE	1.805	0.727	0.099	0.045	2.544
CV (%)	11.62	8.76	11.51	8.49	7.94

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

S_1=18th December, S_2=2nd January, S_3=17th January, S_4=1st February. W_0=No weeding, W_1= Hand weeding at 20 and 40 DAS, W_2= Hand hoe weeding at 20 and 40 DAS, W_3= Whip Super 9 EC (Fenoxaprop-P-ethyl)

4.3.1.3 Interaction effect of sowing date and weed control method

Interaction of sowing date and weed control method had significant effect on number of plants m^{-2} of soybean (Appendix VIII and Table 9). The highest number of plants m^{-2} (73.00) was observed from S_2W_1 and S_3W_1 whereas, the lowest was obtained from S_4W_0 (37.67) which was statistically similar with S_4W_2, S_4W_3, S_1W_0 and S_4W_1.

4.3.2 Number of pods plant^{-1}

4.3.2.1 Effect of sowing date

Sowing date had significant effect on number of pods plant^{-1} of soybean (Appendix VIII and Table 8). The highest number of pods plant^{-1} was obtained from S_2 (31.50) which was statistically similar with S_1 (29.75) and S_3 (29.33) whereas, the lowest was observed from S_4 (24.42). Wafaa *et al.* (2002) observed that number of pods plant^{-1} was significantly affected by sowing date. Early planting date of traits like pods in the main stem, number of pods per sub bough and number of pods per plant had the highest amount than the late planting date (Mokhtarpoor *et al.,* 2008; Salahi *et al.,* 2006; Pedersen and Lauer, 2004).

4.3.2.2 Effect of weed control method

The number of pods plant^{-1} of soybean affected significantly by weed control method (Appendix VIII and Table 8). The highest number of pods plant^{-1} was obtained from W_1 (32.75) which was statistically similar with W_3 (30.92) whereas, the lowest was observed from W_0 treatment (24.50). Severe weed competition in the weedy check might have reduced the number of pods per plant. Weed free treatment produced extra pods than control. Jain (2000) also got highest pods in weed free treatment. This might be due to adequate weed control during the cropping period, which provided maximum moisture and nutrients for healthy plant growth and hence pod formation. Similar results have also been discussed by Pittelkow *et al.* (2009).

4.3.2.3 Interaction effect of sowing date and weed control method

Interaction of sowing date and weed control method exerted significant effect on number of pods plant^{-1} of soybean (Appendix VIII and Table 9). The highest number of pods plant^{-1} was obtained from S_2W_1 (37.67) which was statistically similar with S_3W_1 (35.33) whereas, the lowest was obtained from S_4W_0 (21.33) which was statistically similar with S_3W_0, S_4W_2, S_4W_3 and S_3W_2.

4.3.3 Pod length (cm)

4.3.3.1 Effect of sowing date

Sowing date showed non-significant effect on pod length of soybean (Appendix VIII and Table 8). Numerically the largest pod length was found from S_2 (3.096 cm) and the shortest was obtained from S_4 (2.831 cm). This might be due to decrease vegetative growth and increased reproductive growth, which favored the pod length. These results are in support of Weaver *et al.* (1991).

4.3.3.2 Effect of weed control method

The pod length of soybean affected significantly by weed control method (Appendix VIII and Table 8). The largest pod length was found from W_1 (31.68 cm) which was statistically similar with W_3 (2.977 cm) and W_2 (2.949 cm) whereas, the lowest was observed from W_0 (2.795 cm) which was statistically similar with W_2 (2.949 cm) and W_3 (2.977 cm).

4.3.3.3 Interaction effect of sowing date and weed control method

Interaction of sowing date and weed control method showed non-significant effect on pod length of soybean (Appendix VIII and Table 9). Numerically the largest pod length was found from S_1W_1 (3.237 cm) and the smallest was obtained from S_4W_3 (2.557 cm).

4.3.4 Number of seeds pod^{-1}

4.3.4.1 Effect of sowing date

Sowing date had significant effect on number of seeds pod^{-1} of soybean (Appendix VIII and Table 8). The maximum seeds pod^{-1} was observed from S_2 (1.929) which was statistically similar with S_1 (1.921) and the minimum was found from S_4 (1.610). Fig. 13 clearly indicates that delay in sowing caused considerable decrease in the number of seed pod^{-1}. Number of seeds pod^{-1} depends to genotype and it is independence of environmental factors and just special environmental stress in period of establishment of seed effect on it. Salahi *et al.* 2006; Woong and Yamakawa (2006) reported that the similar results.

4.3.4.2 Effect of weed control method

The number of seeds pod^{-1} of soybean affected significantly by weed control method (Appendix VIII and Table 8). The maximum seeds pod^{-1} was observed from W_1 (1.905) which was statistically similar with W_3 (1.854) and W_2 (1.779) whereas, the lowest was observed from W_0 (1.695) which was statistically similar with W_2 (1.779). Weed competition caused shading and also decreasing resource availability and photosynthesis which resulted compensate relationship between yield components (Carson *et al.*, 1982), with decreasing seeds per pod. Similar results were observed by Rathman and Miller (1981).

4.3.4.3 Interaction effect of sowing date and weed control method

Interaction of sowing date and weed control method had significant effect on number of seeds pod^{-1} of soybean (Appendix VIII and Table 9). The maximum number of seeds pod^{-1} was observed from S_2W_1 (2.00) which was statistically similar with S_1W_1, S_1W_3, S_1W_2, S_3W_1, S_2W_0, S_3W_3, S_2W_2, S_1W_0, S_4W_1 and S_3W_2 whereas, the lowest was obtained from S_4W_0 (1.46) which was statistically similar with S_4W_2, S_4W_3, S_3W_0, S_3W_2 and S_4W_1.

4.3.5 1000-seed weight (g)

4.3.5.1 Effect of sowing date

Sowing date had significant effect on 1000-seed weight of soybean (Appendix VIII and Table 8). The highest 1000-seed weight was observed from S_2 (117.7 g) which was statistically similar with S_1 (111.9 g) and the lowest was found from S_4 (105.6) which was statistically similar with S_3 (108.7 g) and S_1 (111.9 g). This might be due to the short vegetative growth period and long reproductive and grain filling period that significantly raised the 1000-seed weight. These results are similar with Pedersen and Lauer (2004), in case of soybean, who stated that average seed weight from early sowing was higher than that from late sowing. Early planted varieties got more time and growth period to accumulate more photo-assimilates. Similar results also found by Hamzeh *et al.* (2004) and Shafigh *et al.* (2006).

4.3.5.2 Effect of weed control method

The 1000-seed weight of soybean affected significantly by weed control method (Appendix VIII and Table 8). The highest 1000-seed weight was observed from W_1 (119.0 g) and the lowest was found from W_0 (104.2 g) which was statistically similar with W_2 (109.2 g) and W_3 (111.5 g). Several studies show significant reductions in the 1000-seed weight of soybeans when the crop suffers the competition from weeds (Silva *et al.*, 2008; Pittelkow *et al.*, 2009), especially at higher densities of infestation. On the other hand, reduced weed competition as a consequence of weed control measures enabled to affect improved 100-seed weight in soybean possibly due to enhanced availability of nutrients etc. The results are akin to those reported by Vyas and Jain (2003).

4.3.5.3 Interaction effect of sowing date and weed control method

Interaction of sowing date and weed control method showed significant effect on 1000-seed weight of soybean (Appendix VIII and Table 9). The highest 1000-seed weight was observed from S_2W_1 (125.8 g) which was statistically similar with S_1W_1, S_2W_3, S_2W_2, S_3W_1, S_4W_1, S_2W_0, S_1W_3, S_3W_3 and S_3W_2 whereas, the lowest was obtained from S_4W_0 (97.87 g) which was statistically similar with S_3W_0, S_4W_2, S_4W_3, S_1W_2, S_3W_2, S_3W_3, S_1W_3, S_2W_0, and S_4W_1.

Table 9. Interaction effect of sowing date and weed control method on yield attributes of soybean

Treatment combination	Plants m^{-2} (No.)	Pods $plant^{1}$ (No.)	Pod length (cm)	Seeds pod^{-1} (No.)	1000-seed weight (g)
S_1W_0	46.33 d-f	26.67 d-f	2.65	1.80 a-c	106.2 b-d
S_1W_1	52.33 b-d	31.00 b-d	3.24	1.99 a	121.6 ab
S_1W_2	49.67 b-e	28.33 c-f	2.97	1.92 ab	107.5 b-d
S_1W_3	54.00 b-d	33.00 bc	3.12	1.97 a	112.2 a-d
S_2W_0	53.67 b-d	26.33 d-f	3.03	1.86 a-c	112.5 a-d
S_2W_1	73.00 a	37.67 a	3.13	2.00 a	125.8 a
S_2W_2	58.67 bc	29.00 c-e	3.11	1.88 a-c	116.0 a-c
S_2W_3	60.00 b	33.00 bc	3.12	1.97 a	116.3 a-c
S_3W_0	53.67 b-d	23.67 fg	2.78	1.66 b-d	100.1 cd
S_3W_1	73.00 a	35.33 ab	3.13	1.9 a-c	115.3 a-c
S_3W_2	58.67 bc	26.00 e-g	2.85	1.72 a-d	109.4 a-d
S_3W_3	60.00 b	32.33 bc	3.11	1.81 a-c	110.1 a-d
S_4W_0	37.67 f	21.33 g	2.72	1.46 d	97.87 d
S_4W_1	47.00 c-f	27.00 d-f	3.18	1.73 a-d	113.2 a-d
S_4W_2	39.00 ef	24.00 fg	2.87	1.59 cd	103.9 cd
S_4W_3	44.33 d-f	25.33 e-g	2.56	1.66 b-d	107.3 b-d
SE	3.610	1.454	0.198	0.089	5.089
CV (%)	11.62	8.76	11.51	8.49	7.94

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

S_1=18th December, S_2=2nd January, S_3=17th January, S_4=1st February. W_0=No weeding, W_1= Hand weeding at 20 and 40 DAS, W_2= Hand hoe weeding at 20 and 40 DAS, W_3= Whip Super 9 EC (Fenoxaprop-P-ethyl)

4.4 Yield and harvest index

4.4.1 Seed yield

4.4.1.1 Effect of sowing date

Sowing date had significant effect on seed yield of soybean (Appendix IX and Table 10). The maximum seed yield was observed from S_2 (2.17 t ha^{-1}) which was statistically similar with S_1 (1.99) and the lowest was found from S_4 (1.64 t ha^{-1}). Late planting due to the loss of suitable time for the growth, the plant was not achieved its potential ability because light interception and crop simulates partitioning were severely affected and consequently lead to yield decline. In case of early planting there was more time for plant growth and development, so seed yield increased was rational. Similar results were recorded with late planting by Ahmed *et al.* (2010), Calvino *et al.* (2003) and Ngalamu *et al.* (2012).

4.4.1.2 Effect of weed control method

Weed control method exerted significant effect on seed yield of soybean (Appendix IX and Table 10). The highest seed yield was observed from W_1 (2.23 t ha^{-1}) which was statistically similar with W_3 (2.19 t ha^{-1}) and the lowest was found from W_0 (1.39 t ha^{-1}). The enhancement in the seed yield due to various weed control measures was because of the fact that they helped to keep the field comparatively free from weeds, thus resulting in better utilization of resources namely, nutrients, moisture, solar light etc. These consequently led to the production of more vigorous and healthy plants having more pod bearing capacity, more seed per pod and 100-seed weight. The cumulative effect of all these resulted in higher seed yields. The results corroborate the findings of Vyas *et al.* (2000) and Pandya *et al.* (2005) and many others who reported enhanced soybean yield due to various weed control treatments. Weedy check produced lowest yield of soybean which was significantly inferior to different weed control treatments. Drastic yield reduction in weedy check was due to heavy infestation of weeds, especially broad leaved weeds which grow faster and suppressed the crop growth, thus causing reduced yields. The broad leaved weeds on an average contributed 62.65% of total weed population. Howe and Oliver (1987) also reported reduced yield in weedy check due to higher density of weeds especially broad leaved weeds.

Table 10. Effect of sowing date and weed control method on yield and harvest index of soybean

Treatments	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
Sowing date				
S_1	1.99 ab	2.55 ab	4.53 ab	43.93
S_2	2.17 a	2.74 a	4.91 a	44.20
S_3	1.91 b	2.39 ab	4.30 b	44.42
S_4	1.64 c	2.04 b	3.67 c	44.69
SE	0.067	0.151	0.154	1.910
CV (%)	12.07	21.56	12.24	14.95
Weed control method				
W_0	1.39 c	2.02 c	3.41 c	40.76 b
W_1	2.23 a	2.74 a	4.97 a	44.87 a
W_2	1.89 b	2.32 b	4.21 b	44.89 a
W_3	2.19 a	2.63 a	4.82 a	45.44 a
SE	0.045	0.068	0.073	1.068
CV (%)	8.05	9.70	5.83	8.36

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

S_1=18th December, S_2=2nd January, S_3=17th January, S_4=1st February. W_0=No weeding, W_1= Hand weeding at 20 and 40 DAS, W_2= Hand hoe weeding at 20 and 40 DAS, W_3= Whip Super 9 EC (Fenoxaprop-P-ethyl)

4.4.1.3 Interaction effect of sowing date and weed control method

Interaction of sowing date and weed control method had significant effect on seed yield of soybean (Appendix IX and Table 11). The highest seed yield was observed from S_2W_1 (2.50 t ha^{-1}) which was statistically similar with S_2W_3, S_1W_1 and S_1W_3 whereas, the lowest was obtained from S_4W_0 (1.20 t ha^{-1}) which was statistically similar with S_1W_0 and S_3W_0. Nepomuceno *et al.* (2007) evaluated weed interference in soybean in conventional sowing system and reported a 32% drop in the yield of the crop when it coexisted with weeds throughout their cycle, which agrees with this experiment.

4.4.2 Stover yield

4.4.2.1 Effect of sowing date

Sowing date had significant effect on stover yield of soybean (Appendix IX and Table 10). The highest stover yield was obtained from S_2 (2.74 t ha^{-1}) which was statistically similar with S_1 (2.55 t ha^{-1}) and S_3 (2.39 t ha^{-1}) whereas, the lowest was observed from S_4 (2.04 t ha^{-1}) which was statistically similar with S_3 (2.39 t ha^{-1}) and S_1 (2.55 t ha^{-1}). It might be the results of higher plant height, number of plants m^{-2}, pods $plant^{-1}$and higher dry matter accumulation $plant^{-1}$ which resulted evidently due to the profuse branching. Norwal and Malik (1986) revealed the same results.

4.4.2.2 Effect of weed control method

Weed control method had significant effect on stover yield of soybean (Appendix IX and Table 10). The maximum stover yield was obtained from W_1 (2.74 t ha^{-1}) which was statistically similar with W_3 (2.63 t ha^{-1}) and the lowest was observed from W_0 (2.02 t ha^{-1}). Peer *et al.* (2013) seen superior stover yield in different weed control treatment especially weed free treatment.

4.4.2.3 Interaction effect of sowing date and weed control method

Interaction of sowing date and weed control method showed significant effect on stover yield of soybean (Appendix IX and Table 11). The highest stover yield was obtained from S_2W_1 (3.10 t ha^{-1}) which was statistically similar with S_2W_3, S_1W_1 and S_1W_3 whereas, the lowest was obtained from S_4W_0 (1.70 t ha^{-1}) which was statistically similar with S_4W_2, S_1W_0 and S_4W_3.

4.4.3 Biological yield

4.4.3.1 Effect of sowing date

Sowing date had significant effect on biological yield of soybean (Appendix IX and Table 10). The highest biological yield was found from S_2 (4.91 t ha^{-1}) which was statistically similar with S_1 (4.53 t ha^{-1}) and the lowest was obtained from S_4 (3.67). It was shown that the late planting date, biological yield decreased because the flowers appear in late and produced terminal buds, leaves, new growth and the plant stops the reproductive growth. Lopez-Billido *et al.* (2008) reported a reduction in biological yield due to delayed planting. Similar results were recorded with the late planting by Ngalamu *et al.* (2012); Ahmed *et al.* (2010) and Calvino *et al.* (2003) in their experiments.

4.4.3.2 Effect of weed control method

Weed control method had significant effect on biological yield of soybean (Appendix IX and Table 10). The highest biological yield was found from W_1 (4.97 t ha^{-1}) which was statistically similar with W_3 (4.82 t ha^{-1}) and the lowest was observed from W_0 (3.41 t ha^{-1}). Peer *et al.* (2013) reported that biological yield was favorably influenced by various weed control treatments. They recorded higher biological yield over weedy check and produced 51.76, 46.20, 35.12 and 43.06 % more biological yield than un-weed control.

4.4.3.3 Interaction effect of sowing date and weed control method

Interaction of sowing date and weed control method showed significant effect on biological yield of soybean (Appendix IX and Table 11). The highest biological yield was found from S_2W_1 (5.60 t ha^{-1}) which was statistically similar with S_2W_3 and S_1W_1 whereas, the lowest was obtained from S_4W_0 (2.90 t ha^{-1}) which was statistically similar with S_1W_0.

4.4.4 Harvest index

4.4.4.1 Effect of sowing date

Sowing date showed non-significant effect on harvest index of soybean (Appendix IX and Table 10). Numerically the highest harvest index was observed from S_4 (44.61 %) and the lowest was found from S_1 (43.86 %). Heydari zadeh and Khajepour (2007) revealed that harvest index is affected by planting date. Early planting date results in higher harvest index (Pedersen and Lauer, 2004; Mirza khani *et al.* 2002) which was contradictory with the present findings; but Talavaky (1996) reported that harvest index was not affected by planting date which agrees with this experiment.

4.4.4.2 Effect of weed control method

Weed control method showed significant effect on harvest index of soybean (Appendix IX and Table 10). The highest harvest index was observed from W_3 (45.44 %) which was statistically similar with W_2 and W_1 whereas, the lowest was observed from W_0 (40.76 %). Bhandiwaddar and Itnal (1998) reported superiority of various weed control method with respect to harvest index of soybean over unweeded control.

4.4.4.3 Interaction effect of sowing date and weed control method

Interaction of sowing date and weed control method showed significant effect on harvest index of soybean (Appendix IX and Table 11). The maximum harvest index was found from S_4W_3 (46.72 %) which was statistically similar with S_1W_3, S_3W_1, S_4W_2, S_1W_1, S_2W_2, S_3W_2, S_4W_0, S_4W_1, S_2W_0, S_2W_1, S_3W_3, S_1W_2 and S_2W_3 whereas, the minimum was obtained from S_3W_0 (38.84 %) which was statistically similar with S_1W_0, S_1W_1, S_1W_2, S_1W_3, S_2W_1, S_2W_2, S_2W_3, S_3W_1, S_3W_2, S_3W_3, S_4W_0, S_4W_1 and S_4W_2.

Table 11. Interaction effect of sowing date and weed control method on yield and harvest index of soybean

Treatment combination	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
S_1W_0	1.29 h	2.00 f-h	3.29 hi	39.21 b
S_1W_1	2.37 ab	2.89 ab	5.26 ab	45.06 ab
S_1W_2	1.97 d-f	2.48 b-e	4.45 de	44.27 ab
S_1W_3	2.32 a-c	2.81 a-c	5.13 bc	45.22 ab
S_2W_0	1.73 fg	2.25 d-g	3.99 fg	43.36 ab
S_2W_1	2.50 a	3.10 a	5.60 a	44.64 ab
S_2W_2	2.05 c-e	2.55 b-e	4.60 de	44.57 ab
S_2W_3	2.39 ab	3.06 a	5.44 ab	43.93 ab
S_3W_0	1.34 h	2.11 e-g	3.45 h	38.84 b
S_3W_1	2.19 b-d	2.57 b-d	4.76 cd	46.01 ab
S_3W_2	1.92 d-f	2.33 d-g	4.26 ef	45.07 ab
S_3W_3	2.20 b-d	2.54 b-e	4.74 cd	46.41 ab
S_4W_0	1.20 h	1.70 h	2.90 i	41.38 ab
S_4W_1	1.86 e-g	2.41 c-f	4.27 ef	43.56 ab
S_4W_2	1.63 g	1.93 gh	3.55gh	45.92 ab
S_4W_3	1.85 e-g	2.11 e-h	3.96 fg	46.72 a
SE	0.089	0.135	0.146	2.136
CV (%)	8.05	9.70	5.83	8.36

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

S_1=18th December, S_2=2nd January, S_3=17th January, S_4=1st February. W_0=No weeding, W_1= Hand weeding at 20 and 40 DAS, W_2= Hand hoe weeding at 20 and 40 DAS, W_3= Whip Super 9 EC (Fenoxaprop-P-ethyl)

Chapter 5

Summary and conclusion

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was conducted at the Agronomy field of Sher-e-Bangla Agricultural University (SAU), Dhaka during the period from December, 2012 to June, 2013 to investigate the influence of different sowing date and weed control methods on growth and yield of soybean under the Modhupur Tract (AEZ-28). Two factor experiment included 4 sowing dates viz. 18 December (S_1), 2 January (S_2), 17 January (S_3), 1 February (S_4); and 4 weed control methods viz. no weeding (Control), hand weeding at 20 DAS and 40 DAS (W_1), hand hoe weeding at 20 DAS and 40 DAS (W_2), Whip Super 9 EC (Fenoxaprop-P-ethyl) (W_3) was outlined in split plot design with three replications. The size of the individual plot was 4.0 m x 2.5 m and total numbers of plots were 48. There were 16 treatment combinations. Sowing date treatments were placed at the main plots and weed control method treatments were placed at the sub plots.

The data on weed parameters such as infested weed species, relative weed density (%), weed biomass (g m^{-2}) and weed control efficiency (%) were examined. The data on crop growth characters like plant height, number of branches $plant^{-1}$, dry weight $plant^{-1}$ were recorded at different growth stages. Yield and yield contributing parameters like, number of plants m^{-2}, number of pods $plant^{-1}$, pod length, number of seeds pod^{-1}, 1000-seed weight, seed yield, stover yield, biological yield and harvest index were recorded after harvest. Data were analyzed using MSTAT-C computerized package program. The mean differences among the treatments were compared by Duncan's Multiple Range Test (DMRT) at 5% level of significance.

About twenty weed species infested the experimental plots belonging to eleven families. The most important weeds of the experimental plots were *Lindernia procumbens, Echinochloa colonum, Vicia sativa* and *Cynodon dactylon,* respectively. Relative weed density, weed biomass and weed control efficiency were significantly influenced by the weed control treatments. The highest weed biomass was observed in the no weeding treatment throughout the growing period and the lowest was found in the hand weeding (20 and 40 DAS) treatment. The best weed control efficiency was found from hand weeding (20 and 40 DAS) and lowest efficiency was obtained from hand hoe weeding (20 and 40 DAS). In case of treatment combination, the maximum amount of weed dry weight was obtained from sowing date 1st February with no weeding (control) treatment at 20, 40 and 60 DAS. Sowing at 2nd January with hand weeding (20 and 40 DAS) treatment combination produced the lowest amount of weed dry matter at 40 and 60 DAS. The highest weed control efficiency was showed by the treatment combination sowing at 2nd January with hand weeding (20 and 40 DAS).

Results showed that sowing dates of soybean had significant effect on most of the growth, yield and yield contributing parameters except dry weight plant^{-1} (80 DAS, at harvest), pod length and harvest index. Sowing at 2nd January performed best results in case of plant height, number of branches plant^{-1}, dry weight plant^{-1} in all the growth stages, number of plants m^{-2}, number of pods plant^{-1}, pod length, number of seeds pod^{-1}, 1000-seed weight, seed yield, stover yield, biological yield and harvest index of BARI Soybean-6. Delay sowing (1st February) of BARI Soybean-6 adversely affect the growth, yield and yield contributing characters which showed the lowest plant height, number of branches plant^{-1}, dry weight plant^{-1}, number of plants m^{-2}, number of pods plant^{-1}, pod length, number of seeds pod^{-1}, 1000-seed weight, seed yield, stover yield and biological yield. Sowing at 17th January showed the lowest harvest index of soybean.

Weed control methods also significantly influenced the growth, yield and yield contributing attributes except plant height at 40 DAS. Plant height, number of branches plant^{-1}, dry weight plant^{-1}, number of plants m^{-2}, number of pods plant^{-1}, pod length, number of seeds pod^{-1}, 1000-seed weight, seed yield, stover yield, biological yield and harvest index was maximum at hand weeding (20 and 40 DAS) and chemical control showed the almost similar result in most of the growth and yield parameters. Among the weed control methods minimum result was found from the control treatment where no weeding was done and weed was granted to grow without disturbance.

Interaction effect of sowing date and weed control methods also significantly influenced growth, yield and yield contributing characters. The tallest plant at 40, 60 DAS and at harvest was obtained from the combination of sowing date 2nd January with hand weeding (20 and 40 DAS) treatments. Combination of sowing date 1st February with no weeding (control) treatments produced the shortest plant at 40, 60, 80 DAS and at harvest. Sowing at 18th January with hand weeding (20 and 40 DAS) treatment combinations produced the maximum number of branches plant^{-1} at 60, 80 DAS and at harvest. 1st February with no weeding (control) treatment combination produced the lowest number of branches plant^{-1} at 80 DAS and at harvest. Maximum amount of dry weight plant^{-1} was accumulated from sowing date 2nd January along with hand weeding (20 and 40 DAS) treatment combinations at 40, 80 DAS and at harvest. Sowing at 1st February with no weeding (control) treatment combination produced the minimum amount of dry matter plant^{-1}. Highest number of plants m^{-2}, number of pods plant^{-1}, number of seeds pod^{-1}, 1000-seed weight, seed yield, stover yield and biological yield was obtained from sowing time 2nd January with hand weeding (20 and 40 DAS) treatment combinations. Sowing at 1st February with no weeding (control) treatment combination produced the lowest number of plants m^{-2}, number of seeds pod^{-1}, 1000-seed weight, seed yield, stover yield and biological yield. Treatment combination of sowing at 1st February with herbicide Whip Super 9 EC (Fenoxaprop-P-ethyl) produced the maximum harvest index and 17th January with no weeding (control) treatment combination showed the minimum harvest index.

Considering the results of the present experiment, it may concluded that growth, yield and yield contributing parameters of soybean decreased with delay planting. Early sowing favored the growth and yield of BARI soybean-6. On the other hand, hand weeding at 20 and 40 DAS was the best weed control practice. So, on the basis of above mentioned discussion, 2nd January and hand weeding (20 and 40 DAS) showed better performance compared to those of other treatments.

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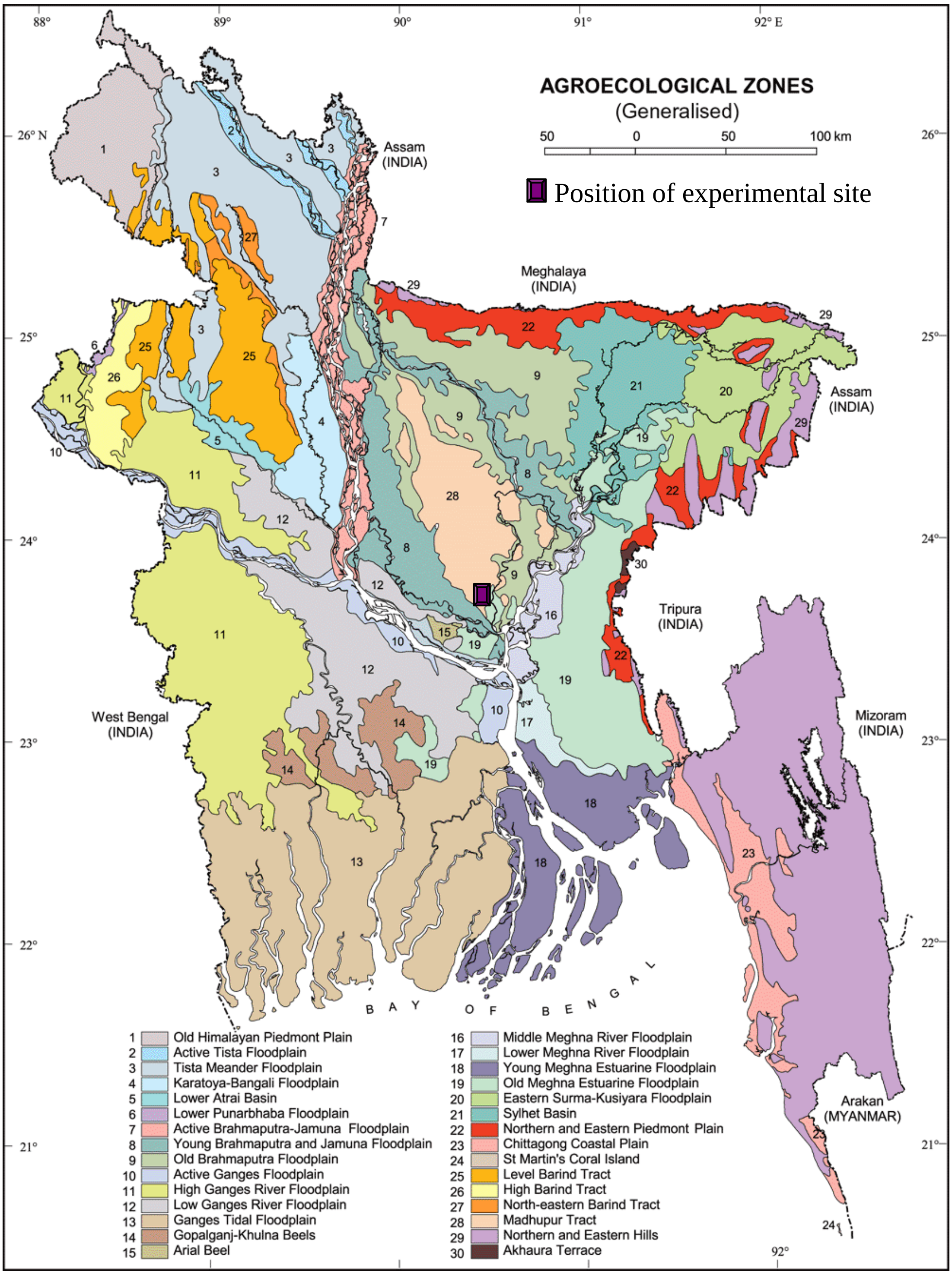
Appendices

APPENDICES

Appendix I. Map showing the experimental site under study



Appendix II. The morphological, physical and chemical properties of the experimental land

A. Morphological properties of the soil

Morphology	Characteristics
Location	Agronomy field, SAU, Dhaka
Agro-ecological zone	Madhupur Tract (AEZ- 28)
General Soil Type	Slightly acidic in reaction with low organic matter content
Parent material	Madhupur Terrace
Topography	Fairly level
Soil colour	Dark grey
Drainage	Well drained
Flood level	Above flood level

B. Physical properties of the soil

Physical properties	Value
Sand (%)	17.60
Silt (%)	47.40
Clay (%)	35.00
Porosity (%)	44.5
Texture	Silty Clay Loam
Bulk density (g/cc)	1.48
Particle density (g/cc)	2.52

C. Chemical composition of the initial soil (0-15 cm depth)

Chemical properties	Value
Soil pH	5.8
Organic Carbon (%)	0.89
Total N (%)	0.063
Available P (mg kg^{-1} soil)	14.90
Exchangeable K (meq/100 g soil)	0.12
Available S (mg kg^{-1})	11.0

Appendix III. Weather data, 2012-2013, Dhaka

Month	Average Relative Humidity (%)	Average Temperature ($^{\circ}C$)		Total Rainfall (mm)
		Minimum	Maximum	
December	78.58	14.54	23.93	5
January	65.39	12.09	24.55	14
February	47.16	16.5	27.86	34
March	43.8	23.3	31.6	43.4
April	38.6	34.55	24.5	45.2

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

Appendix IV. Mean square values for weed dry weight and weed control efficiency of soybean at different days after sowing

Sources of variation	Degrees of freedom	Mean Square				
		Weed dry matter (g m^{-2})			Weed control efficiency (%)	
		20 DAS	40 DAS	60 DAS	40 DAS	60 DAS
Replication	2	0.072	2.715	0.973	30.322	5.514
Sowing date (S)	3	0.010^{NS}	41.274**	56.095**	19.124*	7.467^{NS}
Error (a)	6	0.080	1.135	2.251	5.927	4.857
Weed control methods (W)	3	0.025^{NS}	1224.742**	2796.996**	19983.633**	21155.738**
Interaction (S×W)	9	0.007^{NS}	11.342**	16.728**	9.773*	37.151**
Error (b)	24	0.063	0.702	0.915	7.584	5.398

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability NS: Non significant

Appendix V. Mean square values for plant height of soybean at different days after sowing

Sources of variation	Degrees of freedom	Mean Square				
		Plant height				
		20 DAS	40 DAS	60 DAS	80 DAS	At harvest
Replication	2	1.291	11.415	161.198	255.712	278.369
Sowing date (S)	3	16.438**	202.608**	1163.869**	566.302*	55.838*
Error (a)	6	0.741	4.691	23.873	57.523	11.033
Weed control methods (W)	3	1.338*	3.211*	48.272*	87.371*	69.316*
Interaction (S×W)	9	0.226*	0.288*	4.655*	5.975*	4.062*
Error (b)	24	0.491	3.040	16.702	29.809	25.577

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability

Appendix VI. Mean square values for number of branches plant^{-1} of soybean at different days after sowing

Sources of variation	Degrees of freedom	Mean Square		
		Number of branches plant^{-1}		
		60 DAS	80 DAS	At harvest
Replication	2	0.075	0.080	0.089
Sowing date (S)	3	0.347*	0.179*	0.224*
Error (a)	6	0.058	0.197	0.303
Weed control methods (W)	3	0.419**	0.264*	0.229*
Interaction (S×W)	9	0.037*	0.024*	0.043*
Error (b)	24	0.046	0.088	0.056

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability

Appendix VII. Mean square values for dry weight plant^{-1} of soybean at different days after sowing

Sources of variation	Degrees of freedom	Mean Square				
		Dry weight plant^{-1} (g)				
		20 DAS	40 DAS	60 DAS	80 DAS	At harvest
Replication	2	0.004	0.068	7.134	2.972	41.565
Sowing date (S)	3	0.121*	5.692**	13.470*	5.803*	52.031*
Error (a)	6	0.016	0.049	2.053	11.700	18.988
Weed control methods (W)	3	0.037*	0.545**	4.545*	75.851**	181.612**
Interaction (S×W)	9	0.004*	0.044*	1.165*	2.233*	15.726*
Error (b)	24	0.007	0.028	1.674	7.105	11.801

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability

Appendix VIII. Mean square values for number of plants m^{-2}, number of pods plant^{-1}, pod length, number of seeds pod^{-1}, 1000-seed weight of soybean

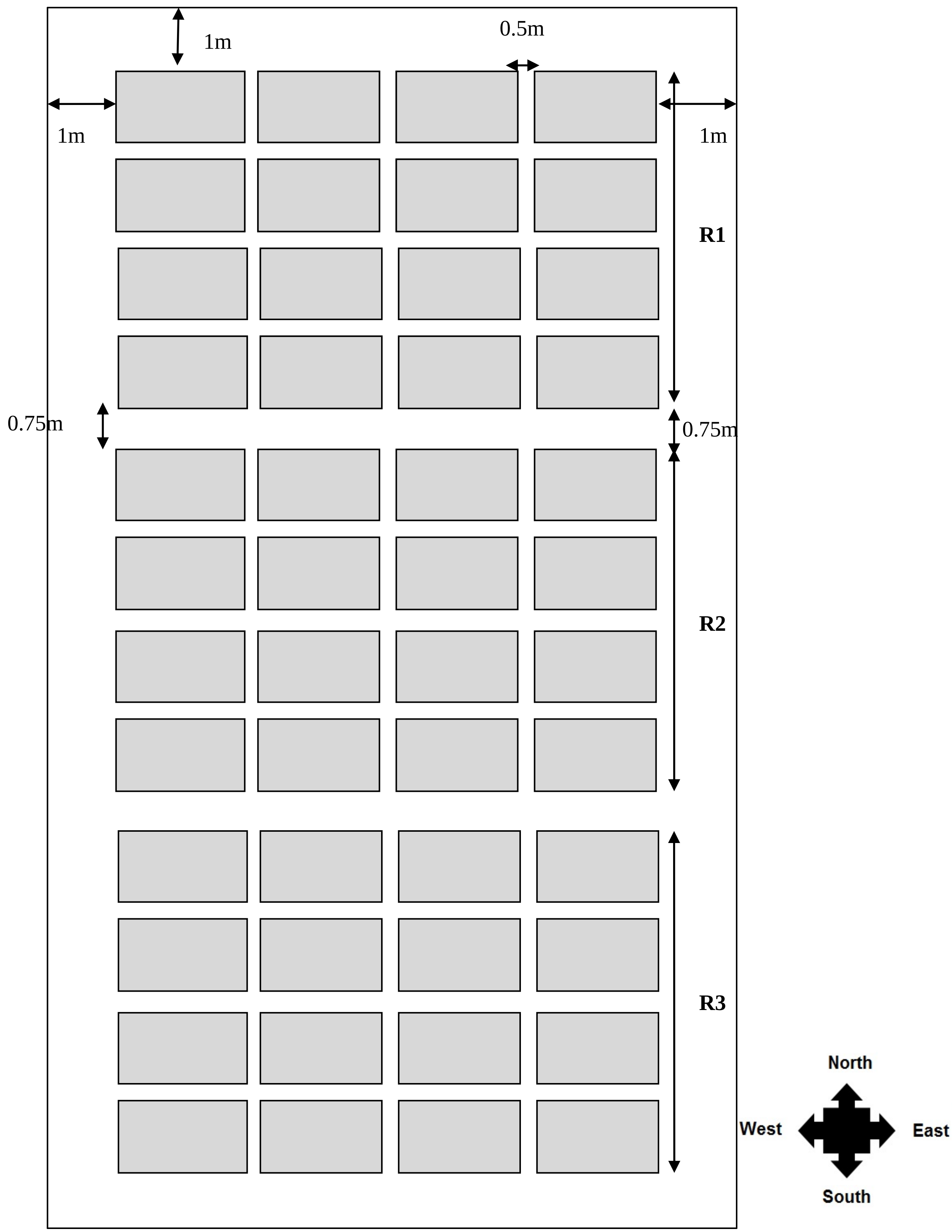
Sources of variation	Degrees of freedom	Mean Square				
		Number of plants m^{-2}	Number of pods plant^{-1}	Pod length (cm)	Number of seeds pod^{-1}	1000-seed weight (g)
Replication	2	40.188	6.813	0.161	0.100	625.536
Sowing date (S)	3	1052.354**	110.722**	0.143^{NS}	0.271**	318.855*
Error (a)	6	69.188	7.368	0.092	0.013	186.440
Weed control methods (W)	3	393.021**	169.722**	0.280*	0.101*	455.141*
Interaction (S×W)	9	35.465*	10.852*	0.074^{NS}	0.003*	10.762*
Error (b)	24	39.104	6.340	0.117	0.024	77.684

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability NS: Non significant

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

Sources of variation	Degrees of freedom	Mean Square			
		Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (%)	Harvest index (%)
Replication	2	0.437	1.884	0.513	541.562
Sowing date (S)	3	0.613*	1.061*	3.280*	2.680^{NS}
Error (a)	6	0.140	0.274	0.286	64.258
Weed control methods (W)	3	1.334**	1.286**	5.212**	28.636^{NS}
Interaction (S×W)	9	0.116*	0.039*	0.133*	27.142*
Error (b)	24	0.052	0.055	0.099	16.355

**: Significant at 0.01 level of probability *: Significant at 0.05 level of probability NS: Non significant



Appendix X. Layout of the experimental field

PLATES

Plate 1: Field view of the experimental plot

Plate 2: Field view showing different sowing dates