GROWTH AND YIELD OF SOYBEAN AS AFFECTED BY IRRIGATION AND WEED CONTROL METHOD

By

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CERTIFICATE

This is to certify that the thesis entitled, **"GROWTH AND YIELD OF SOYBEAN AS AFFECTED BY IRRIGATION AND WEED CONTROL METHOD"** submitted to the Faculty of Agriculture Sher-e-Bangla Agricultural University, Dhaka, in the partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE (M.S.) IN AGRONOMY,** embodies the result of a piece of *bona fide* research work carried out by **JANNATUL FERDOUS,** Registration No.**08-2707** under my supervision and guidance. No part of the thesis has been submitted for any other degree or diploma.

I further certify that such help or source of information, as has been availed during the course of this investigation has been duly acknowledged and style of this thesis have been approved and recommended for submission.

Dated: 23.2.16

Place: Dhaka, Bangladesh

(Prof. Dr. Md. Hazrat Ali)

Research Supervisor

DEDICATED TO
MY
BELOVED PARENTS

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GROWTH AND YIELD OF SOYBEAN AS AFFECTED BY IRRIGATION AND WEED CONTROL METHOD

ABSTRACT

A field experiment was conducted at Sher-e-Bangla Agricultural University, Dhaka during December, 2013 to March,2014 with a view to find out the influence of irrigation and weed control method on the growth and yield of Soybean cv. BARI Soybean 6.The experiment was carried out with four(4) irrigation treatments viz. no irrigation (control), one time(at 20 DAS,two times (at 20 and 40 DAS), three times (at 20, 40, and 60 DAS), and four weed management treatments i.e., no weeding (control), one time hand weeding(at 20 DAS), two times hand weeding (at 20 and 40 DAS) and chemical control by Whip Super® (Fenoxaprop-p-ethyl)@75g ha^{-1} at 20 DAS. Results showed different types of weed werefound to infest experimental fields, among them *Echinochloa colonum* (72.19%), *Lindernia procumbens* (28.28%) and *Cynodon dactylon* (14.25%) had the highest relative density. It is also noticed that *Lindernia procumbens* created dominancy throughout the crop growth period even at the later stage of crop. Three times irrigation (I_3) gave the highest (1.628 t ha^{-1}) seed yield on the other hand two times hand weeding (W_2) gave the highest (1.556 t ha^{-1}) seed yield. Interaction effects showed the highest (1.917 t ha^{-1}) seed yield from the combination of three times irrigation andtwo times hand weeding (I_3W_2). This was also observed that herbicide Whip Super® showed better performance to control grass weeds but failed to control *Lindernia procumbens*. However, crop plants treated with herbicide became mature one week earlier than other treated crop plants. Considering weed control method of herbicide Whip Super®may be most economic for cultivation of soybean.

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LIST OF ACCRONYMS 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
SRDI	Soil Resource Development Institute
CV	Coefficient of Variance
DAS	Days after sowing
Environ.	Environmental
et al.	And others
etc.	Etcetra
@	At the rate
g	Gram (s)
^0C	Degree centigrade
Sci.	Science
pod^{-1}	Per pod
i.e.	*id est* (L), that is
Res.	Research
HI	Harvest index
cv.	Cultivar
j.	Journal
kg	Kilogram (s)
df	Degrees of freedom
m^2	Meter squares
M.S	Master of Science
DMRT	Duncan's Multiple Range Test
SAU	Sher-e-Bangla Agricultural University
t ha^{-1}	Ton per hectare
viz	Namely
%	Percentage

Chapter 1

INTRODUCTION

CHAPTER 1

INTRODUCTION

Soybean occupies a unique position in agriculture, in addition of being a crop with enormous uses. Soybean is grown in almost all parts of the world for human consumption, industry and animal feed (Boydak *et al.*, 2002). Soybean [*Glycine max* (L.) Merrill] is a leguminous crop and belongs to the family Fabaceae and sub-family Faboideae. 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). Soybean seed contains 40-45% protein, 20-22% oil, 20-26% carbohydrate and a high amount of Ca, P and vitamins (Rahman *et al.,* 2011). Soybean has 3% lesithine which is helpful for brain development. It accounts for approximately 50% of the total production of oil crops in the world. It has become the leading source of edible oils and fats, composing of about 20% of the world supply and more than any other single source of this essential food constituent (Singh *et al.*, 1989). 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.

Therefore, soybean has huge potential as healthy food. Due to its high nutritional value there is an increasing demand of soya 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 plant has great importance for enriching soil. It improves the soil fertility and productivity. Soybean, like other legumes, has the ability to fix atmospheric N though root nodule bacteria (*Bradyrhizobium japonicum*) and thus enrich the soil fertility

(Mahabal, 1986). It fixes about 270 kg N ha^{-1} compared to 58 to 157 kg N ha^{-1} by other pulses (Hoque, 1978). This can compensate around 80-90% demand for nitrogen by the crops.

Soybean can be cultivated under a wide range of climatic and soil condition. Soil moisture demand of the crop is not high. As such, it can be grown under rainfed condition in the kharif-2 season as well as in the Rabi season with supplementary irrigation. The world production of soybean as estimated in 2008 was 231.27 million ton from an area of hectare (FAO, 2009). The production of soybean is very negligible (around only 3000MT per year) compared to its demand. Bangladesh has to import soybean cooking oil with US $180 million and soybean meal about US$ 25.51 million per year.

Soybeans are a relatively drought-tolerant crop but can respond well to irrigation. Soybeans respond well to irrigation during later growth stages where water stress may lead to decrease in yield. Water stress imposed during pre-flowering and flowering stage reduced yield of soybean by 28% and 24% respectively (Gunton and Evenson, 1980). Similarly various soybean cultivars show varying sensitivity to drought at their different developmental stages (Momen *et al.,* 1979).

Weeds grow in the crop fields throughout the world. It is often said, "Crop production is a fight against weeds" (Mukhopadhyay and Ghosh, 1981). The prevailing climatic and edaphic conditions are highly favorable for luxuriant growth of numerous species of weeds which offer a keen competition with soybean crop. Soybean are not strong competitors in the early part of the season, therefore weeds that germinate 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 as this duration is the critical period for weed competition in soybeans (Jannink *et. al.,* 2000).

Losses in both yield and quality of crops due to weeds, as well as costs of weed control, constitute an enormous economic problem in all agricultural areas. 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, Kurchania *et al.,* 2001 and Tiwari & Kurchania, 1990). 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). Weed infestation removed 21.4 kg N and 3.4 kg P ha^{-1} in soybean (Pandya *et al.*, 2005).

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). Two hand hoeings are recommended for effective weed control in soybean (Jain *et al.*, 2000; Rakesh & Shirvastava, 2002 Ahmed *et al.* 2001; Galal, 2003; Singh & Jolly, 2004).

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 irrigation and weed control methods on growth, yield and yield contributing characters of soybean with the following objectives:

Objectives

1. Determination of irrigation requirement for achieving higher yield of soybean
2. Determine of the effective weed control method for soybean cultivation, and
3. Evaluation of the interaction effect of weed control method and irrigation requirement on yield of soybean.

Chapter 2

REVIEW OF LITERATURE

CHAPTER 2

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 in the tropical and subtropical regions. Researches on irrigation of soybean with weed control method have been carried out by a large number of researchers throughout the world. In Bangladesh, researches on irrigation and weed control method of soybean are very scanty. However, some important findings have been reviewed in this chapter under the following headings.

2.1. Effect of irrigation on growth and yield of soybean

2.1.1. Effect of irrigation on growth parameters

Rabbani *et al.* (2004) studied 3 genotypes of soybean under different irrigation frequencies during November 2000 to February 2001 at Mymensingh, Bangladesh. The growth and yield parameters were evaluated from 30 to 90 DAS at 15 days intervals. Plant height , leaf area index ,crop growth rate, shoot dry weight, number of filled pods plant^{-1}, number of seeds plant^{-1}, seed yield and harvest index were highest with irrigation at 20,40 and 60 DAS. The highest numbers of branches were obtained with irrigation at 20, 40, 60 DAS and 20, 40, 60 and 80 DAS. The chlorophyll content increased whereas the number of empty pods decreased with increasing irrigation frequency.

Hao *et al.* (2003) conducted experiments to find out effects of irrigation on soybean cv. Bei during 1992-98 and 2000 in Heilongjing, China. They found that the effects of irrigation varied among the levels of fertilizer application and vice versa. The pods per plant, seeds per pod and 100 seed weight had positive correlation with soybean yield. Leaf area index and dry matter accumulation significantly increased with irrigation application.

Kazi *et al.* (2002) conducted an experiment to study the impact of irrigation frequencies on growth and yield of soybean cv. Bragg. The irrigation frequencies were 2, 3, 4, 5 and 6 irrigations. It was observed that the growth and yield components were significantly affected by irrigation frequencies. Maximum plant height, more branches plant^{-1}, pods plant^{-1}, harvest index and seed yield were found superior with the application of 6 irrigations followed by 5 irrigations, whereas, lowest number of irrigation decreased all the traits adversely.

Tokoyoda *et al.* (1999) conducted experiments and observed that plant height and number of tillers were generally greatest with normal irrigation and lowest in dry land conditions. Total plant dry weights at 86 days after sowing were highest with normal irrigation on soybean.

2.1.1. Effect of irrigation on yield and yield contributing characters

Irrigation is one of the most important factor that influenced yield and quality of soybean to a great extent. Soybean yield was reported to be increased when irrigation was scheduled throughout the whole growth period followed in order by irrigation at germination and flowering compared with irrigated control (Lago *et al.*, 1981). It was reported that maximum seed yield was obtained in Lee–74 and improved Pelican variety of soybean with one irrigation after 30 or 45 days of sowing (Khair and Israil, 1977).

Constable and Hearn (1980) reported that irrigations during late flower and pod filling in soybean were necessary to ensure maximum seed yield (up to 305 t ha^{-1}).

Martin *et al.* (1979) reported that yield of soybean cv. Ransom with irrigation after flowering and pod set began stages were 2.12 and 1.69 t ha^{-1}, respectively.

Shahidullah *et al.* (1979) reported that pod plant $^{-1}$ and seed yield plot^{-1} were higher with single irrigation applied after 30 days of sowing.

Sweeney *et al.* (2003) carried out experiment to determine the effect of a single irrigation at different reproductive growth stages on yield and quality of soybean (*Glycine max* L.) from 1991 to 1994. They found that yields from a single irrigation at R1, R5 or R6 were similar and averaged approximately 20% .They added that irrigation at R 4 increased seeds plant^{-1} whereas R 3 and R 6 irrigations increased seed weight -.Irrigation had minimal effect on seed protein and variable effect on oil content.

Sabev *et al.* (2003) reported that the optimum irrigation regimes with 40 and 20% reduced irrigation rates resulted in an increase of energy efficiency by 16.1 and 15.3% respectively, compared to non-irrigated treatment. Under disturbed irrigated regime, the coefficient of energy efficiency was highest for the treatment without first watering compared to the optimum one (1.3), followed by the treatments with application only of third, second and first watering . The energy difference had the highest values for the treatments with the optimum irrigation regimes with 20 and 40% reduced irrigation rates (24.28 and 23.87 MJ), followed by the treatments without first and second watering compared to the optimum treatment (17.97 and 16.24 MJ, respectively).

Kazi *et al* . (2002) stated that where irrigation frequencies were 2,3,4,5 and 6 irrigations, the growth yield components and oil content were significantly affected by irrigation frequencies. Maximum plant height, more branches plant^{-1}, pods plant^{-1}, seed index, seed yield (t ha^{-1}) and oil content (%) were found superior with the application of 6 irrigations followed by 5 irrigations . Whereas, lowest numbers of irrigations decreased all the traits adversely.

Sabbe and Delong (1998) conducted field traits with soybean at Marianna, Arkansas, USA in 1995, 97 and 1998. They used two irrigation treatments viz- no irrigation and irrigation and found drought in 1995 reduced un irrigated yields from 17.2 to 27.0 bushels acre^{-1} compared with 35.0 to 54.7 bushels acre^{-1} for irrigated crops. Corresponding yields for 1997 and 1998 were 27.9 -48.5 and 49.0-57.4 bushels acre^{-1} and 18.5 to 33.9 and 50.0-60.7 bushels acre^{-1}, respectively.

Sabbe and Delong (1996) observed that seed yields of the irrigated crops were 2 and 3 times greater than the rainfed craps at Marianna and Rohwer, respectively.

Gretzmacher and Wolfsberger (1991) reported that when irrigation given at flowering and pod set stages the average yields increase was 68 % from 1982 to 1989 with a maximum harvest of 3900 kg ha^{-1}. Rao and Reddy (1990) stated that irrigation at vegetative phase, vegetative +flowering stages , vegetative +flowering + pod formation stages or , vegetative +flowering + pod formation+seed development stages gave seed yields of 1.09, 1.15, 1.21 and 1.17 t ha^{-1}, resprctively.

Klik and Cepuder (1991) reported that a single irrigation either at flowering or 4 days later at the beginning of pod development gave a 14 % increase of yields over control. They also found 23 % increase of yields 3.38 t ha^{-1} with irrigation applied 4 times over non irrigation control.

Svoboda (1988) stated that at irrigation applied before flowering and after flowering or without irrigation, seed yields were 20.96% higher in 1980 and 9.2% % higher in 1981 with irrigation compared to without irrigation. He also observed that irrigation increased seed weight $plant^{-1}$, 1000 seed weight, seed weight pod^{-1}, Number of seed pod^{-1}.

Vasiliu (1988) reported that soybean seed yields ranged from 1.30 t $ha^{-1}$with no irrigation to 3.00 t $ha^{-1}$with irrigation to 50 % field capacity up to the maturity of the last pods.

Moraru *et al.*(1988). reported that soybean seed yields were lowest with no irrigation and highest with irrigation at 70% of field capacity at 0-80 cm depth or at 50% of field capacity before and at flowering and or at 50% of field capacity at 0-80 cm depth.

Stutte and Weiland (1981) stated that when soybean irrigated at late vegetative, flowering and early pod filling stages, seed yields of cv. Davis and Forrest were increased.

Matheny and Hunt (1981) reported that when soybean irrigated at late flowering stage, irrigation increased yields by 86% compared with control plants and maximum seed yield was recorded 3.10 t ha^{-1} in this treatment.

Yazdi and Saadati (1978) stated that seed yield was 1.25 t ha^{-1} with one irrigation before flowering and upto (4.21 t ha^{-1}) with extra irrigation before and after flowering. Irrigation at the vegetative stage was important and at the end of flowering most important in increasing seed yields of soybean.

When to start and stop irrigation in soybean

Irrigation should not commence too early – thus during vegetative growth the plants can be stressed a bit otherwise a shallow root system and tall plants that fall over easily will develop (Specht, 2002). He also stated that soybean yield do not respond to irrigation during vegetative and early flowering stages, and that irrigation during these growth stages could lead to the plant being more susceptible to diseases. Irrigation in the early stages can be postponed if there was water stored in the soil profile before plant. He claims that in 15 years research, heavy irrigation (bringing the soil back to no less than 75% of field capacity on a weekly basis) at pod elongation has always resulted in a positive yield response. After this the irrigation can be reduced to 50% of field capacity on a weekly basis, but should not stop until all the beans have fully enlarged. Hodges and Heatherly (1983) also advise that soybean should be irrigated until seeds have reached their full size before irrigation should be stopped. Constable and Hearn (1980) found that plant available water should be kept above 60% during pod fill but could be depleted below 60% during the vegetative growth stage.

Eck *et al.* (1987) subjected soybeans to water stress during different reproductive stages. This resulted in a 9-13% reduction in seed yield when stresses initiated during R1/R2 were extended to R3. When this stress was extended further to R4.5, the yield reduced by 46%, while if the stress only started at R3 to R4.5, the yield reduction was only 19%. When stress started at R5 but was relieved at R6 the yield decrease was between 15 and 46% over two seasons, while stressing it from R5 throughout R6 (5 weeks total) increased the yield decrease to between 45 and 88% for the two seasons. When the stress was only applied throughout R6 (3 weeks total) the yield decrease was between 21 and 65% for the two seasons. The main difference between the seasons was that the first received a higher rainfall than the second season. This answers the question as to when to stop irrigating. If producers stop too early, it can have a substantial effect on the final yield. This is supported by Specht (2002) whichstated that if irrigation is stopped too early, ithastens maturity and results in lower yields as the individual seeds cannot reach their maximum potential (size).

Irrigating soybean according to growth stage

Klocke *et al.* (1989) did a trial with indeterminate soybean cultivars in Nebraska. They advocate that soybean should be irrigated according to growth stages. In doing so, one need to give attention to the soil water holding capacity, climatic factors and the irrigation system itself. They recommend that in the warmer and dryer production areas, irrigation to meet evaporative demand should be applied from the beginning of the season (thus vegetative growth stage), while in moist areas, it can be delayed until the flowering stage. But even in the latter case the soil should have a good water holding capacity and be filled to field capacity before planting. This is similar to what Specht (2002) has suggested. Their research, however, indicated that rainfall supplemented with irrigation from flowering in most cases resulted in better yields than waiting till pod fill. In these cases, irrigation at flowering often resulted in similar yields than where full irrigation from start to end of season was applied.

In a trial with a determinate and indeterminate cultivar, both responded the best in terms of yield when irrigation was applied during both flowering and pod growth or only during pod fill stage (Schulze, 1986). Where the plants only received water during the flowering stage and nothing during vegetative nor pod fill, the yield was reduced. With more water applied, yield, number of pods per plant, LA and LAI increased, while maturity was delayed. The literature cited by Schulze (1986), in general agree that irrigation improved yields while irrigation during flowering and/or pod fill is important for good yields. Kanemasu (1981) reported a reduction in yield due to irrigation during vegetative and flowering stages. Griffin *et al.* (1981) reported that irrigation during pod fill only, resulted in lower yields while irrigation during flowering and pod fill increased yields.

Kadhem *et al.* (1985a; 1985b) evaluated 16 soybean cultivars (determinate and indeterminate) in terms of sensitivity to drought at seven growth stages ranging from vegetative growth through to seed fill stage. The control only receiving rainfall, while a fully irrigated treatment was also included. From this study it was concluded that soybean yields in general reacted best to irrigation applied between growth stages R3.5 to R4.5, thus during the mid to late pod elongation stages.

Korte *et al.* (1983a; 1983b) also used different soybean cultivars and irrigated them during R1 to R2 flowering (F), R3 to R4 pod elongation (P), or R5 to R6 seed enlargement (S). Plants irrigated during any of the reproductive stages resulted in less flower and pod abortion, 5 while irrigation later in the ontogeny resulted in fewer ovules being aborted. However, more flowers and pods did not significantly increase the seed yield, while fewer aborted ovules did. Irrigation during F, resulted in lowest yield due to lower 100 seed mass, while the 100 seed mass of P and S plants were not affected or increased respectively, leading to higher seed yields, but with S plants showing the highest seed yield increase.

Sweeney and Granade (2002) reported an increased in yield with applying irrigation during R1 to R2 (beginning to full bloom), at R4 (full pod), or at R6 (full seed). They stated that while R1/R2 or R4 irrigations had a positive effect on number of seeds, irrigation at R6 in addition increased individual seed mass.

Sweeney *et al.* (2003) and Specht *et al.* (1989) compared an irrigated versus none irrigated soybean crop as well as irrigating it during certain growth stages (R4, R5 or R6). The irrigated crops on average yielded 20% (Sweeney *et al.*, 2003) to 50% (Specht *et al.*, 1989) more than the none irrigated crop.

Shaw and Laing (1966); Shipley and Regier (1970); Dusek *et al.* (1971); Doss *et al.* (1974); Sionit and Kramer (1977); Constable and Hearn (1980); Korte *et al.* (1983a, 1983b); and Stegman *et al.* (1990) all stated that soybean seed yield is least sensitive to water deficits during the vegetative stage, more sensitive during flowering and pod set, and most sensitive during pod fill. Krote *et al.* (1983); Westgate and Peterson (1993); and Liu *et al.* (2003) all reported more pod abortion if the plants are stressed during flowering and early pod growth, leading to lower yields.

Demirtas *et al.* (2010) withhold water during six growth stages (during vegetative growth V5 (fifth trifoliate), flowering (R2), podding (R4), seed fill (R6), full bloom + podding (R2 + R4), and podding + seed fill (R2 + R6)), with a fully irrigated and a dryland treatment included as controls. Their data (averaged over two years) indicated a decrease in yield from 3.79 t ha-1 for the well irrigated control to 2.81 t ha-1 for the treatment stressed during pod growth and seed fill (R2 + R6). As expected, water use efficiency (WUE) under dryland conditions (T8) was the best for all the treatments while it decreased with between 0.14 and 0.11 kg m-3 when the plants did not receive water during R6 (T5), R2 + R4 (T6) and R2 + R6 (T7). Irrigation water use efficiency was also severely negatively affected by withholding irrigation during R6 (T5) and R2 + R6 (T7).

Dogan *et al.* (2007) applied full irrigation during the vegetative stages where after the soybean plants were either not stress (control) or stressed at various reproductive stages (R1-R2; R3; R4; R5 and R6). The result of the stress was a reduction in yield for all the stressed treatments, with the highest reduction reported for stress at R6.

Sutherland and Danileson (1980) showed that water stress during flowering followed by full irrigations increases yield. Water stress imposed on soybeans throughout the growing stages reduces vegetative growth and affects flowering and yield (Boyer *et al.*, 1980; Hodges and Heatherly, 1983).

Water stress during reproductive development often decreases the seed size in soybean (Sionet and Kramer, 1977; Momen *et al.*, 1979; Kadhem *et al.*, 1985a; 1985b). Meckel *et al.* (1984) ascribe this to a shortening in the length of the seed filling period, rather than reduced seed growth rate.

Most of the observations made in this section can be explained by the results from Malek *et al.* (2012). They investigated absolute growth rate (AGR), LA and LAI of field grown soybean and reported that for all the genotypes tested, the growth rate was slowest during the vegetative phase leading to a smaller portion of total dry mass produced before flower initiation, and the bulk thereafter. Due to the plants reaching maximum LA and LAI during the pod fill stage, AGR was at its maximum. Taking this into account, it could explain why yield reacted more positively to irrigation during the reproductive than vegetative growth stages. They observed that irrigation at R4 increased the number of seeds, while irrigation at the other two stages increased the seed mass.

De Costa and Shanmugathasan (2002) measured numerous growth related characteristics of the soybean plant in relation to its response to withholding of irrigation during certain growth stages. By withholding water during V1 – R1, R1 – R4 and R4 –R8, the following was reported. LAI, radiation interception and biomass increased with more growth stages being irrigated, but the singular growth stage showing the highest positive reaction to this was the vegetative growth stage. Radiation use efficiency was most positively affected by irrigation during flowering and pod fill stages, while for pod number, and harvest index it was at the flowering stage. Mean pod growth rate during pod filling exceeded corresponding overall crop growth rate of all treatments indicating translocation of reserves.

2.2. Effect of weed control method on growth and yield of soybean

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.

Weed dry matter

Hassan (2013) showed that the favorite weed control treatments were hoeing (twice) followed by trifurlin and diphenamid in 1^{st} and 2^{nd} 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).

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.

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.

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.

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.

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.

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.

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.

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 3

MATERIALS AND METHOD

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 2013 to June 2014. Geographically the experimental field is located at 23°46' N latitude and 90° 22' E longitude (Google maps, 2015) 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:

Factor A: Irrigation

a) I_0 = No irrigation

b) I_1= One irrigation at 20 DAS

c) I_2= Two irrigation at 20 DAS and 40 DAS

d) I_3= Three irrigation at 20 DAS and 40 DAS and 60DAS

Factor B: Weed control method

a) W_0 = no weeding (control)
b) W_1 = hand weeding at 20 DAS
c) W_2= hand weeding at 20 DAS and 40 DAS
d) W_3 = chemical control by ® Whip Super @ 75g ha^{-1} herbicide application at 20 DAE

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 at 20 DAS

iii) Hand weeding at 20 DAS and 40 DAS: Two hand 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 **2 m × 2m** and total numbers of plots were 48. There were 16 treatment combinations. Each block was divided into 16 unit plots. Irrigation was placed along the main plot and weeding treatments were placed in the sub plot. Layout of the experiment was done on December 27, 2013 with inter plot spacing of 0.50 m and inter block spacing of 0.75 m. A layout of the experimental plot is given on Plate 1.

3.8. Land preparation

The land of the experimental field was first opened on December 10, 2013 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 stubble were removed from the experimental field.

3.9. Fertilizer application

All the fertilizers were applied at BARI recommended dose as 60, 175, 120 and 115 kg ha^{-1} of Urea, TSP, MOP and Gypsum respectively (BARI Krish Projucti Hatboi). The elemental dose of Urea, TSP, MOP and Gypsum fertilizers as 27.6, 28, 57.6 and 20.7kg ha^{-1} respectively. 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

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

3.12.2. Weeding

Weed control method are followed as per treatments as mentioned in section 3.5.

3.12.3. Irrigation

Irrigation were applied as per treatments as mentioned in section 3.5. Proper drainage system was also provided 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, 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

Three sample plants were collected randomly from each plot. These 3 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 on 29 April, 2014. 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

Three plants in each plot were selected and tagged. All the growth data (except dry weight) were recorded from those three 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})

B. Crop growth parameters

i. Plant height (cm) at 30, 45, 60, 75, 90 and 105 DAS.
ii. Leaf area index at 30, 45, 60, 75, 90 and 105 DAS.
iii. Number of Nodules plant^{-1} 30, 60, 90 and 120 DAS.
iv. Fresh weight of plant^{-1} at 30, 60, 90 DAS.
v. Dry weight of plant^{-1} at 30, 60, 90 DAS.

C. Yield contributing characters

i. Number of pods plants^{-1}
ii. Filled pod
iii. Pod length (cm)
iv. Number of seeds plant^{-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. Method 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 80 DAS at 20 days interval. A plant quadrate of 1.0 m^2 was placed atone spots of 4 m^2 of the plot. The middle quadrate was remained undisturbed for yield data. The infesting species of weeds within quadrate were identified and their number was counted species wise at 20, 40, 60 and 80 DAS.

ii. Relative weed density (%)

Relative weed density was calculated by using the following formula:

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

iii. Weed dry matter

The weeds inside the quadrate for density count were uprooted and counted sample are 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}.

B. Crop growth parameters

i) Plant height (cm)

The height of the soybean plants was recorded at 30, 45, 60, 75, 90 and 105 DAS. The heights of 3 pre-selected sample plants were measured from the ground level to the tip of the shoot. Then the data was averaged and expressed in cm.

ii) Leaf area index (LAI)

Total leaf area index was taken at 30, 45, 60, 75, 90 and 105 DAS. All the leaf area present on 3 pre-selected sample plants were counted and averaged them to have leaf area. Leaf area index were estimated measuring the length and width of leaf and multiplying by a factor of 0.75 followed by Yoshida (1981). (This correction factor usually use in case of rice and maize crops. But there is no information about soybean crop correction factor. So leaf area index of soybean measure by 0.75 correction factor.)

ii) Fresh weight of plant^{-1}

The fresh weight of soybean plants was recorded at 30, 60, 90 DAS. Three plants were collected randomly from the inner rows of each plot. The fresh 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}.

iii) Dry weight of plant^{-1}

The dry weight of soybean plants was recorded at 30, 60 and 90 DAS. Three 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}.

iv) Number of Nodules plant^{-1}

Number of nodules of soybean plants was recorded at 30, 60, 90 and 120 DAS. Three plants were collected randomly from the inner rows of each plot. Then count carefully the number of nodules per plant.

C. Yield contributing characters

i. Filled pods plants^{-1}

All the pods of the pre-selected 3 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 was taken from sample plants were measured. Mean data was expressed in centimeter (cm).

iv. Number of seeds plant^{-1}

Number of total seeds of three sample plants from each plot was noted and the mean number was expressed per plant 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 4

RESULTS AND DISCUSSION

This chapter comprises presentation and discussion of the results obtained from a study to investigate the influence of irrigation 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 irrigation and weed control treatments have been presented and discussed in this chapter.

4.1. Weed parameters

Twenty one weed species belonging to twelve 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 sixteen 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, Oryza sativa* 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 acrusgalli, 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):

SL No.	Local name	Common name	Scientific name	Family	Types
1	Bathua	Lambs quarter	*Chenopodium album*	Chenopodiaceae	Broad Leaf
2	Mutha	Nutgrass	*Cyperus rotundus*	Cyperaceae	Sedge
3	Durba	Bermuda grass	*Cynodon dactylon*	Poaceae	Grass
4	Ban masur	Wild lentil	*Vicia sativa*	Fabaceae	Broad Leaf
5	Chapra	Indian goosegrass	*Eleusine indica*	Poacease	Grass
6	Hatishur	Wild clary	*Heliotropium indicum*	Boraginaceae	Broad Leaf
7	Ban mula	Wild raddish	*Raphanus raphanistrum*	Brassicaceae	Broad Leaf
8	Ban sarisha	Wild mustard	*Brassica kaber*	Brassicaceae	Broad Leaf
9	Shetlomi	Common cudweed	*Gnaphalium luteoalbum*	Asteraceae	Broad Leaf
10	Khet papri	Prostate false pimpernel	*Lindernia procumbens*	Scrophulariaceae	Broad Leaf
11	Chanchi	Sessile joyweed	*Alternanthera sessilis*	Amaranthaceae	Broad Leaf
12	Khude shama	Jungle rice	*Echinochloa colonum*	Poaceae	Grass
13	Kanta begun	Horse nettle	*Solanum carolinense*	Solanaceae	Broad Leaf
14	Foska begun	Foska begun	*Physalis heterophylla*	Solanaceae	Broad Leaf
15	Malanch	Alligator weed	*Alternanthera philoxeroides*	Amaranthaceae	Broad Leaf
16	Keshuti	White eclipta	*Eclipta prostrata*	Compositea	Broad leaf
17	Angulee Ghash	Scrab grass	*Digitaria sanguinalis*	Gramineae	Grass
18	Araich	Tora weed	*Cassia tora*	Leguminosae	Broad leaf
19	Shusni shak	4-leaved water clover	*Marsilia quadrifolia*	Marsileaceae	Broad leaf
20	Helencha	Harkuch	*Enhydra fluctuans*	Compositea	Broad leaf
21	Dhan	Rice	*Oryza sativa*	Gramineae	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 stage (Table 2). This may 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 20 DAS *Echinochloa colonum* **(56.91%)**, *Lindernia procumbens* **(25.07%)**, *Cynodon dactylon* **(14.25%)** dominated the experimental field. In case of 40DAS, 60DAS, 80DAS respectively *Echinochloa colonum* (64.99%, **72.19%, 74.23%)**, *Lindernia procumbens* **(28.28%, 19.94%, 14.69%)**, *Cynodon dactylon* **(1.42%, 0.39%, 0.69%).** 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 infested the experimental area

ommon name	Scientific name	Family	Types	Relative density (%)			
				20 DAS	40 DAS	60 DAS	80 DAS
1. Lambs quarter	*Chenopodium album*	Chenopodiaceae	Broad Leaf	2.01	0.43	0	0.08
2. Nutgrass	*Cyperus rotundus*	Cyperaceae	Sedge	0	0	0.55	0
3. Bermuda grass	*Cynodon dactylon*	Poaceae	Grass	**14.25**	**1.42**	**0.39**	**0.69**
4. Wild lentil	*Vicia sativa*	Fabaceae	Broad Leaf	0.32	0.78	0.55	0.22
5. Indian goose grass	*Eleusine indica*	Poacease	Grass	0	0	0	0.69
6. Wild clary	*Heliotropium indicum*	Boraginaceae	Broad Leaf	0.40	1.06	1.57	1.15
7. Wild raddish	*Raphanus raphanistrum*	Brassicaceae	Broad Leaf	0	0.92	0.94	0.61
8. Wild mustard	*Brassica kaber*	Brassicaceae	Broad Leaf	0.24	1.06	0.79	0.08
9. Common cudweed	*Gnaphalium luteoalbum*	Asteraceae	Broad Leaf	0	0	0.16	0.38
10. Prostate false pimpernel	*Lindernia procumbens*	Scrophulariacea e	Broad Leaf	**25.07**	**28.28**	**19.94**	**14.69**
11. Sessile joyweed	*Alternanthera sessilis*	Amaranthaceae	Broad Leaf	0	0	0.47	0.08
12. Jungle rice	*Echinochloa colonum*	Poaceae	Grass	**56.91**	**64.99**	**72.19**	**74.23**
13. Horse nettle	*Solanum carolinense*	Solanaceae	Broad Leaf	0.08	0.5	0.31	0.38
14. Foska begun	*Physalis heterophylla*	Solanaceae	Broad Leaf	0.16	0	0	0.08
15. Alligator weed	*Alternanthera philoxeroides*	Amaranthaceae	Broad Leaf	0.08	0	0.31	0.08
16. White eclipta	*Eclipta prostrata*	Compositea	Broad leaf	0	0	0	0.08
17. Scrab grass	*Digitaria sanguinalis*	Gramineae	Grass	0	0	1.26	4.05
18. Tora weed	*Cassia tora*	Leguminosae	Broad leaf	0	0	0	0.08
19. 4-leaved water clover	*Marsilia quadrifolia*	Marsileaceae	Fern	0.24	0.14	0.16	0.08
20. Harkuch	*Enhydra fluctuans*	Compositea	Broad leaf	0.08	0	0	0
21. Rice	*Oryza sativa*	Gramineae	Broad leaf	0.16	0.42	0.39	2.29

4.1.3. Weed dry matter

4.1.3.1. Effect of Irrigation:

The significant effect on weed dry weight was found due to different irrigation 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 highest weed 9 (gm) dry matter was produced by I_2 (1.486 g m^{-2}) and the lowest was found from I_1 (1.100 g m^{-2}). At 40 DAS, I_3 produced the highest amount of weed dry weight (12.010 g m^{-2}) and lowest was produced by I_0 (8.291 g m^{-2}). At 60 DAS, the maximum amount of dry matter was obtained from I_3 (15.730 g m^{-2}) and minimum was from I_0 (11.640 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. Three irrigation showed maximum amount of dry matter, so the total dry weight in soybean was less than that of one irrigation plot. The results are consistent with the findings of Kouchaki (1994).

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 highest weed dry matter was produced by W_3 (1.54 g m^{-2}) and lowest was found from W_1 (0.9667 g m^{-2}). At 40 DAS, the maximum amount of dry matter was obtained from W_0 (25.260 g m^{-2}) and minimum was from W_1 (3.892 g m^{-2}). At 60 DAS, W_0 produced the highest amount of weed dry weight (36.430 g m^{-2}) and lowest was produced by W_2 (3.367 g m^{-2}).

Table 3. Effect of irrigation and weed control method with their combination effect on weed biomass

Treatments	At 20 DAS (gm)	At 40 DAS (gm)	At 60 DAS (gm)
Effect of irrigation			
I_0	1.119 a	8.291 c	11.640 c
I_1	1.100 a	9.322 bc	13.570 bc
I_2	1.486 a	10.73 ab	13.750 b
I_3	1.470 a	12.01 a	15.730 a
SE	0.139	0.525	0.665
Effect of weed control method			
W_0	1.508 a	25.26 a	36.430 a
W_1	0.966 b	3.892 c	7.542 b
W_2	1.158 ab	6.633 b	3.367 c
W_3	1.542 a	4.567 c	7.348 b
SE	0.139	0.525	0.665
Interaction effect of date of irrigation and weed control method			
I_0W_0	2.000 a	19.960 c	28.870 b
I_0W_1	0.366 f	3.900 e	7.733 cd
I_0W_2	0.733 ef	4.867 e	3.467 de
I_0W_3	1.377 a-e	4.433 e	6.493 c-e
I_1W_0	1.000 b-f	23.320 b	37.700 a
I_1W_1	0.900 c-f	2.800 e	7.267 cd
I_1W_2	0.800 d-f	6.367 de	2.233 e
I_1W_3	1.700 a-d	4.800 e	7.067 cd
I_2W_0	1.800 a-c	27.710 a	37.870 a
I_2W_1	1.367 a-e	4.433 e	6.567 c-e
I_2W_2	1.600 a-e	6.267 de	3.333 de
I_2W_3	1.177 a-f	4.50 e	7.233 cd
I_3W_0	1.233 a-f	30.030 a	41.300 a
I_3W_1	1.233 a-f	4.433 e	8.600 c
I_3W_2	1.500 a-e	9.033 d	4.433 c-e
I_3W_3	1.913 ab	4.533 e	8.600 c
SE	0.279	1.050	1.330
CV (%)	37.36	18.04	16.85

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

I_0 = No irrigation, **I_1**= One irrigation at 20 DAS.**I_2**= Two irrigation at 20 DAS and 40 DAS, **I_3**= Three irrigation at 20 DAS and 40 DAS and 60DAS.

W_0 = no weeding (control), **W_1** = hand weeding at 20 DAS, **W_2**= hand weeding at 20 DAS and 40 DAS, **W3** = chemical control by Whip Super® @ 75g ha^{-1} herbicide application at 20 DAE.

4.1.3.3. Interaction effect of Irrigation and weed control method

Weed dry weight significantly influenced by the combination of different irrigation and weed control method at 20, 40, 60 DAS. At 20 DAS, numerically the highest amount of dry matter (2.000 g m^{-2}) was found from I_0W_0 treatment combinations and the lowest was obtained from I_0W_1 (0.3667 g m^{-2}). At 40 and 60 DAS, I_3W_0 produced the highest amount of weed dry matter (30.030 gm^{-2} and 41.30 g m^{-2}, respectively) and the lowest was found from I_1W_1 (2.800 gm^{-2})at 40 DAS and at 60 DAS the lowest was found from I_1W_2 (2.230g m^{-2}).

4.2. Crop growth parameters

4.2.1. Plant height

4.2.1.1. Effect of Irrigation:

The significant result was found in plant height of soybean by the irrigation at different growth stages (Appendix V and Fig. 1). Plant height of the soybean was measured at 30, 45, 60, 75, 90 and 105DAS. It was evident from (Fig. 1) that the height of the plant was influenced by irrigation. At 30 DAS I_3 produced the tallest plant (13.180 cm) and I_0 produced (12.250 cm). At 105 DAS I_3 produce tallest plant (52.190 cm) and I_0 produce shortest plant height (44.920 cm). Kazi *et al.* (2002) conducted an experiment to study the impact of irrigation frequencies and observed that the growth and yield components were significantly affected by irrigation frequencies. Maximum plant height and more branches $plant^{-1}$ were found with the application of 6 irrigations followed by 5 irrigations, whereas, lowest number of irrigation decreased the traits adversely.

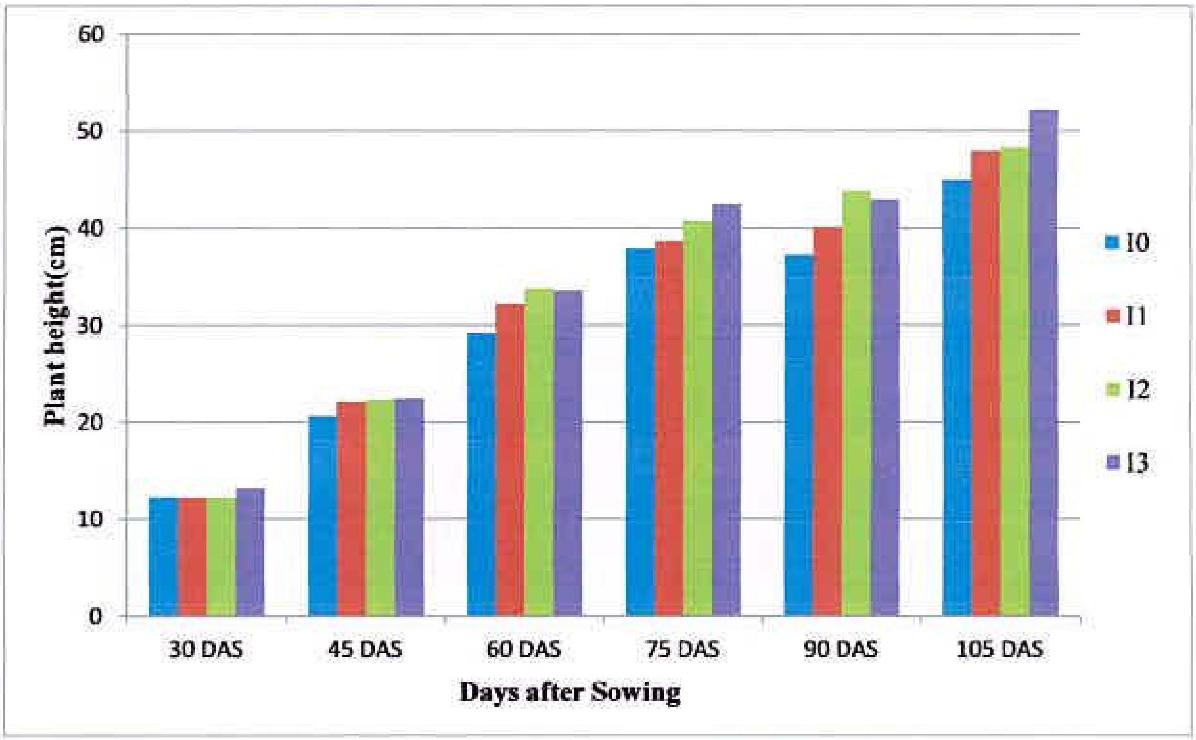

Figure 1. Effect of irrigation on plant height (cm) of soybean at different days after sowing (SE = 0.3364, 0.7221, 0.8727, 1.311, 1.365 and 4.332 at 30, 45, 60, 75, 90 and 105 DAS respectively)

I_0 = No irrigation, I_1= One irrigation at 20 DAS. I_2= Two irrigation at 20 DAS and 40 DAS, I_3= Three irrigation at 20 DAS and 40 DAS and 60 DAS

4.2.1.2. Effect of weed control method

Weed control method had significant effect on plant height of soybean at 30, 45, 60, 75, 90 and 105 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 harvest irrespective of all weed control method. It can be deduced from the figure that weed control method W_3 showed the taller plant (12.730, 23.290, 34.390, 41.39 and 48.56 cm) and W_0 produced the shortest plant (12.010, 20.600, 29.900, 36.800, 37.780and 45.220 cm) for sampling dates of 30, 45, 60, 75, 90 and 105 DAS respectively.

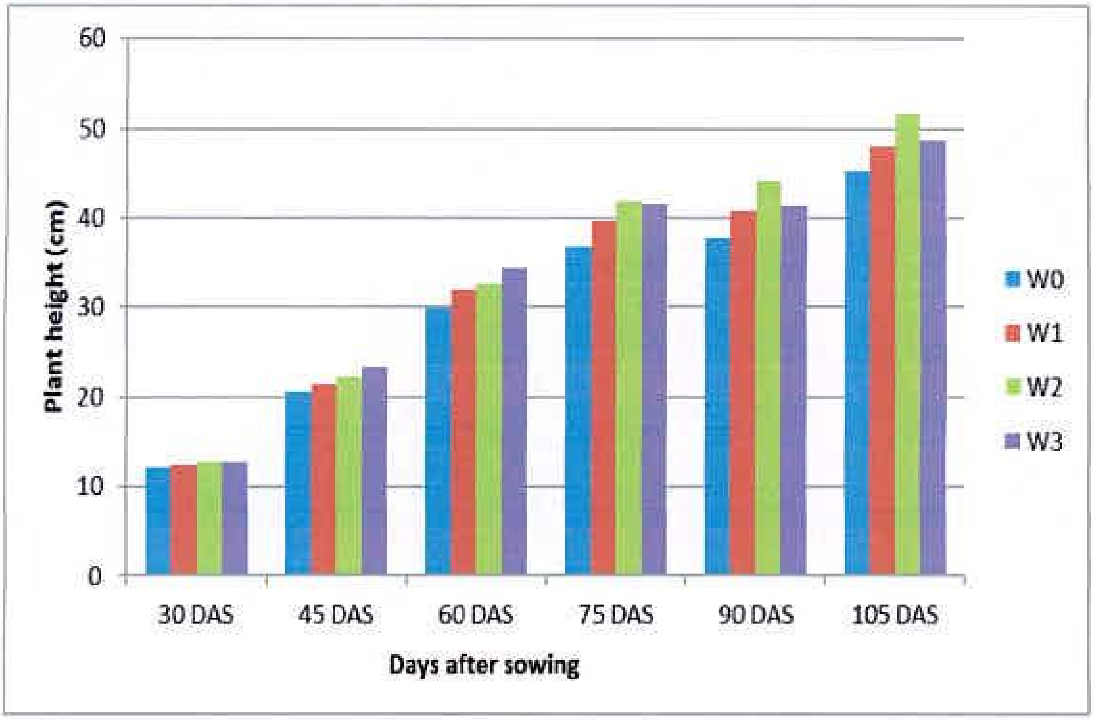

Figure 2. Effect of weed control method on plant height (cm) of soybean at different days after sowing (SE = 0.3364, 0.7221, 0.8727, 1.311, 1.365 and 4.332 at 30, 45, 60, 75, 90 and 105 DAS respectively)

W_0 = no weeding (control), W_1 = hand weeding at 20 DAS, W_2= hand weeding at 20 DAS and 40 DAS, W_3 = chemical control by Whip Super® @ 75g ha^{-1} herbicide application at 20 DAE

4.2.1.3. Interaction effect of Irrigation and Weed control method

Due to interaction effect of irrigation and weed control method plant height of soybean was significantly affected at different growth stages expect 30 DAS (Appendix V and Table 4). At 30 DAS, numerically the tallest plant was observed from I_3W_3 (13.460 cm) which was statistically similar with all other plot and the shortest was obtained from I_2W_1 (11.190cm). At 45 DAS, the tallest plant was observed from I_1W_3 (24.250 cm), the shortest was obtained from I_0W_0 (18.880 cm). At 60 DAS, the longest plant was observed from I_3W_3 (36.660cm) which, the shortest was obtained from I_0W_0 (25.770 cm). At 75

DAS, the tallest plant was observed from I_3W_3 (44.550cm) which was statistically similar with I_3W_2, I_3W_1, I_2W_3, I_2W_2 and I_1W_2 whereas, the smallest was obtained from I_1W_0 (32.890 cm). At 90DAS, the tallest plant was observed from I_1W_2 (47.000 cm) which was statistically similar with I_2W_2 whereas, the shortest was obtained from I_1W_0 (33.660 cm). At 105 DAS, the tallest plant was observed from I_3W_2 (54.340 cm) and the shortest was obtained from I_0W_0 (41.670 cm).

Table 4. Interaction effect of irrigation and weed control method on plant height (cm) of soybean at different days after sowing

Treatment combination	Plant height at					
	30DAS	45DAS	60DAS	75DAS	90DAS	105DAS
I_0W_0	11.740	18.880 b	25.770 d	36.330 ab	36.110 bc	41.670 c
I_0W_1	12.030	20.140 ab	29.440 cd	37.220 ab	36.550 bc	44.670 a-c
I_0W_2	12.610	21.000 ab	29.770 cd	38.000 ab	38.220 a-c	46.440 a-c
I_0W_3	12.620	22.470 ab	31.990 a-c	40.220 ab	38.110 a-c	46.890 a-c
I_1W_0	11.540	21.240 ab	31.830 a-c	32.890 b	33.660 c	44.670 a-c
I_1W_1	13.200	21.450 ab	32.050 a-c	38.440 ab	39.770 a-c	46.450 a-c
I_1W_2	11.770	21.700 ab	32.170 a-c	44.220 a	47.000 a	53.890 a
I_1W_3	12.280	24.250 a	32.890 a-c	39.220 ab	40.000 a-c	46.780 a-c
I_2W_0	12.230	21.950 ab	31.330 a-d	37.440 ab	41.780 a-c	43.220 bc
I_2W_1	11.190	22.020 ab	33.220 a-c	40.890 ab	43.550 ab	49.000 a-c
I_2W_2	13.000	22.610 ab	34.770 a-c	42.550 a	46.000 a	51.890 ab
I_2W_3	12.550	22.710 ab	36.000 ab	42.110 a	44.000 ab	49.330 a-c
I_3W_0	12.530	20.330 ab	30.670 b-d	40.550 ab	39.550 a-c	51.330 a-c
I_3W_1	13.310	22.100 ab	33.270 a-c	42.110 a	43.220 ab	51.890 ab
I_3W_2	13.420	23.510 ab	33.440 a-c	42.770 a	45.440 ab	54.340 a
I_3W_3	13.460	23.730 ab	36.660 a	44.550 a	43.440 ab	51.220 a-c
SE	NS	1.4440	1.745	2.622	2.730	2.968
CV (%)	9.350	11.430	9.390	11.360	11.520	10.630

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

I_0 = No irrigation, I_1= One irrigation at 20 DAS. I_2= Two irrigation at 20 DAS and 40 DAS, I_3= Three irrigation at 20 DAS and 40 DAS and 60 DAS.

W_0 = no weeding (control), W_1 = hand weeding at 20 DAS, W_2= hand weeding at 20 DAS and 40 DAS, W_3 = chemical control by Whip Super® @ 75g ha^{-1} herbicide application at 20 DAE.

4.2.2. Leaf Area Index

4.2.2.1. Effect of irrigation

Leaf area or the surface area of green leaves produced by soybean plants per unit area of land was taken as an index of leaf area development. The leaf area of plant is one of the major determinants of its growth. The leaf area (LA) was affected by irrigation (I). Leaf area index of soybean varied significantly due to irrigation treatments at different days after sowing (Figure 3). The highest (5.910) leaf area index was obtained from the treatment of three irrigation (I_3) at 90 DAS. At 90 DAS, the lowest (5.100) leaf area index was recorded from the control (I_0). This result agrees well with Hao *et al.* (2003) who reported that the leaf area index significantly increased with irrigation application.

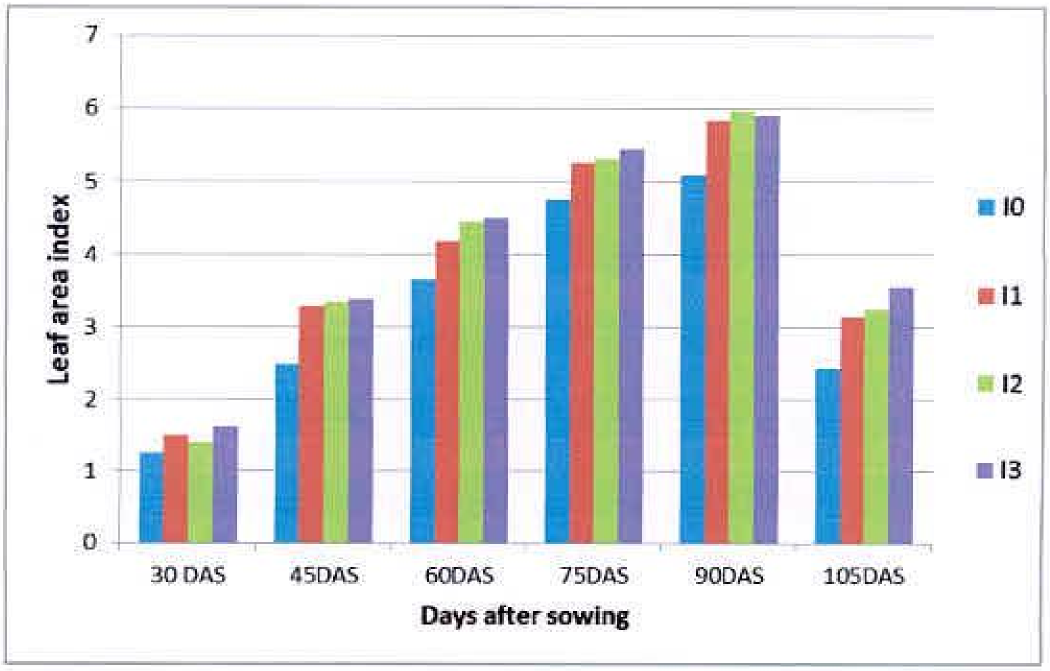

Figure 3. Effect of irrigation on leaf area index of soybean at different days after sowing (SE = 0.08165, 0.08466, 0.1012, 0.09037, 0.07360 and 0.1155at 30, 45, 60, 75, 90 and 105 DAS respectively)

I_0 = No irrigation, I_1= One irrigation at 20 DAS. I_2= Two irrigation at 20 DAS and 40 DAS, I_3= Three irrigation at 20 DAS and 40 DAS and 60 DAS.

4.2.2.2. Effect of weed control method

Weed control method had significant influence on the leaf area index of different days after sowing (Appendix VI and Figure 4). The highest (6.092) leaf area index was obtained from the treatment W_3 at 90 DAS. At 90 DAS, the lowest (5.192) leaf area index was recorded in control (W_0).

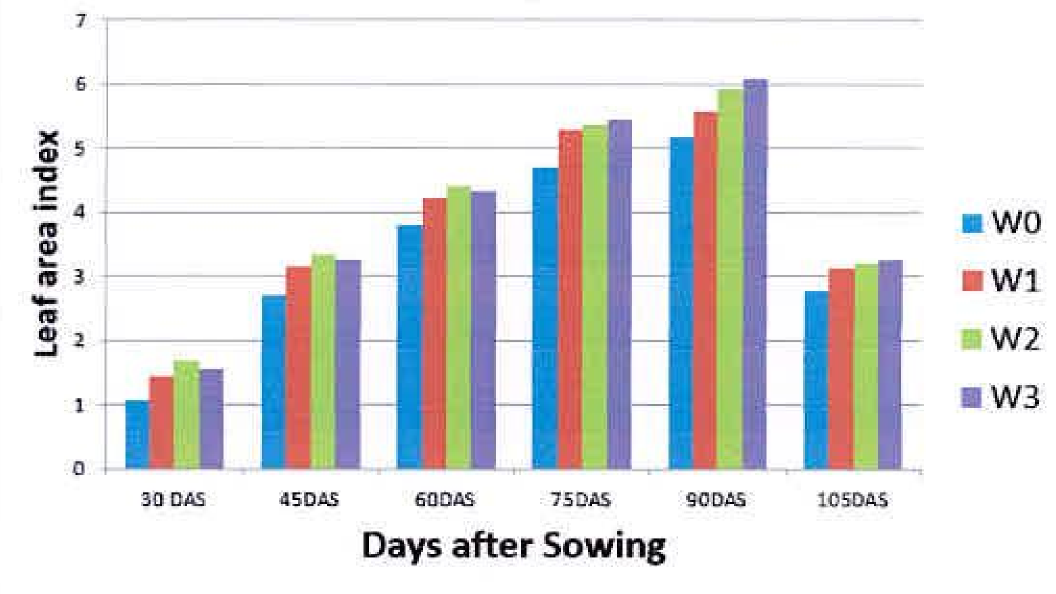

Figure 4. Effect of weed control method on leaf area index of soybean at different days after sowing (SE = 0.08165, 0.08466, 0.1012, 0.09037, 0.07360 and 0.1155 at 30, 45, 60, 75, 90 and 105 DAS respectively)

W_0 = no weeding (control), **W_1** = hand weeding at 20 DAS, **W_2**= hand weeding at 20 DAS and 40 DAS, **W_3** = chemical control by ® Whip Super @ 75g ha^{-1} herbicide application at 20 DAE

4.2.2.3. Interaction effect of irrigation and weed control method

Different treatment combinations of irrigation and weed control method had no significant influence on the leaf area index of soybean at different days after sowing (Table 5). Numerically, the highest (6.433) leaf area index was recorded in the treatment combination of I_2W_3 at 90 DAS. At 90 DAS the lowest (4.2) leaf area index was recorded from I_0W_0.

Table 5. Interaction effect of irrigation and weed control method on leaf area index of soybean at different days after sowing

Treatment Combination	leaf area index					
	30DAS	45DAS	60DAS	75DAS	90DAS	105DAS
I_0W_0	0.800 e	2.233 e	3.167 e	4.100 g	4.200 f	2.100 f
I_0W_1	1.200 b-e	2.467 de	3.567 de	4.900 ef	4.933 e	2.467 ef
I_0W_2	1.633 a-c	2.567 de	3.967 a-d	5.033 c-f	5.467 d	2.633 c-f
I_0W_3	1.367 a-d	2.667 de	3.933 b-d	5.000 d-f	5.767 b-d	2.567 d-f
I_1W_0	1.000 de	2.833 cd	3.733 c-e	5.100 b-f	5.533 d	2.900 a-e
I_1W_1	1.600 a-c	3.233 abc	4.367 a-c	5.333 a-f	5.800 b-d	3.167 a-e
I_1W_2	1.700 a-c	3.433 ab	4.500 ab	5.300 a-f	5.933 b-d	3.200 a-e
I_1W_3	1.700 a-c	3.600 a	4.133 a-d	5.333 a-f	6.067 a-c	3.333 a-d
I_2W_0	1.167 c-e	2.967 bcd	4.067 a-d	4.733 f	5.533 d	2.767 b-f
I_2W_1	1.300 a-e	3.433 ab	4.467 ab	5.333 a-f	5.700 cd	3.333 a-d
I_2W_2	1.733 ab	3.700 a	4.600 ab	5.467 a-e	6.200 ab	3.367 a-c
I_2W_3	1.400 a-d	3.300 a-c	4.633 a	5.700 ab	6.433 a	3.500 ab
I_3W_0	1.300 a-e	2.767 c-e	4.267 a-c	4.867 ef	5.500 d	3.367 a-c
I_3W_1	1.700 a-c	3.533 a	4.500 ab	5.567 a-d	5.900 b-d	3.500 ab
I_3W_2	1.733 ab	3.667 a	4.600 ab	5.633 a-c	6.133 a-c	3.667 a
I_3W_3	1.767 a	3.533 a	4.600 ab	5.733 a	6.100 a-c	3.667 a
SE	0.163	0.169	0.203	0.181	0.147	0.231
CV (%)	19.570	9.380	8.350	6.040	4.460	12.940

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

I_0 = No irrigation, **I_1**= One irrigation at 20 DAS. **I_2** = Two irrigation at 20 DAS and 40 DAS, **I_3**= Three irrigation at 20 DAS and 40 DAS and 60 DAS.

W_0 = no weeding (control), **W_1** = hand weeding at 20 DAS, **W_2**= hand weeding at 20 DAS and 40 DAS, **W_3** = chemical control by Whip Super® @ 75g ha^{-1} herbicide application at 20 DAE.

4.2.3. Nodule production

4.2.3.1. Effect of irrigation

At 90 DAS number of nodule was increased at the highest pick. Again during harvest time (90 DAS) it reduces to the starting level. In 30 DAS highest nodule number I_2 (3.310) which was similar to I_3, I_1 and lowest nodule number in I_0 (2.025). In 90 DAS nodule number with I_3 was (9.107) and lowest nodule number I_0 was (6.358). (Appendix VII)

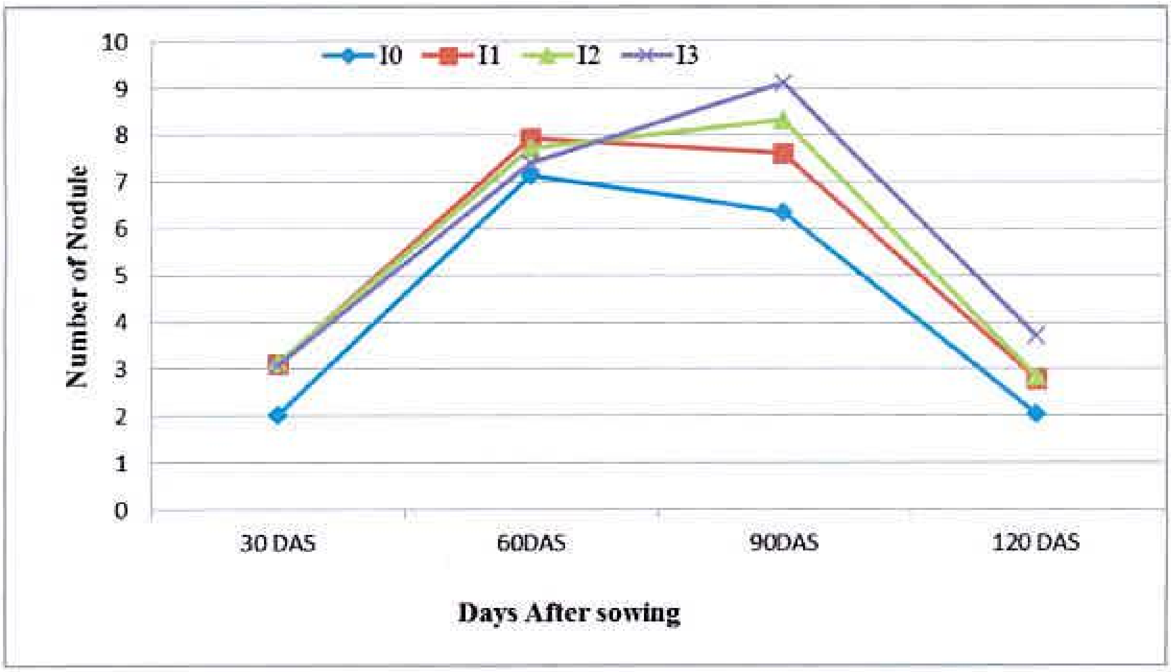

Figure 5. Effect of irrigation on nodule production of soybean at different days after sowing (SE = 0.304, 0.694, 0.678, 0.328 at 30, 60, 90 and 120 DAS, respectively).

I_0 = No irrigation, **I_1**= One irrigation at 20 DAS. **I_2** = Two irrigation at 20 DAS and 40 DAS, **I_3**= Three irrigation at 20 DAS and 40 DAS and 60 DAS.

4.2.3.2. Effect of weed control:

At 90 DAS number of nodule was increased at the pick. Again during harvest time (90 DAS) it reduces to the starting level. In 30 DAS the highest nodule number was W_2 (3.359) which were statistically similar with W_3 and W_1 and lowest nodule number in W_0 (1.886). In 90 DAS nodule number was W_3

(9.386) which were statistically similar to W_1 and lowest nodule number W_0 (5.940).

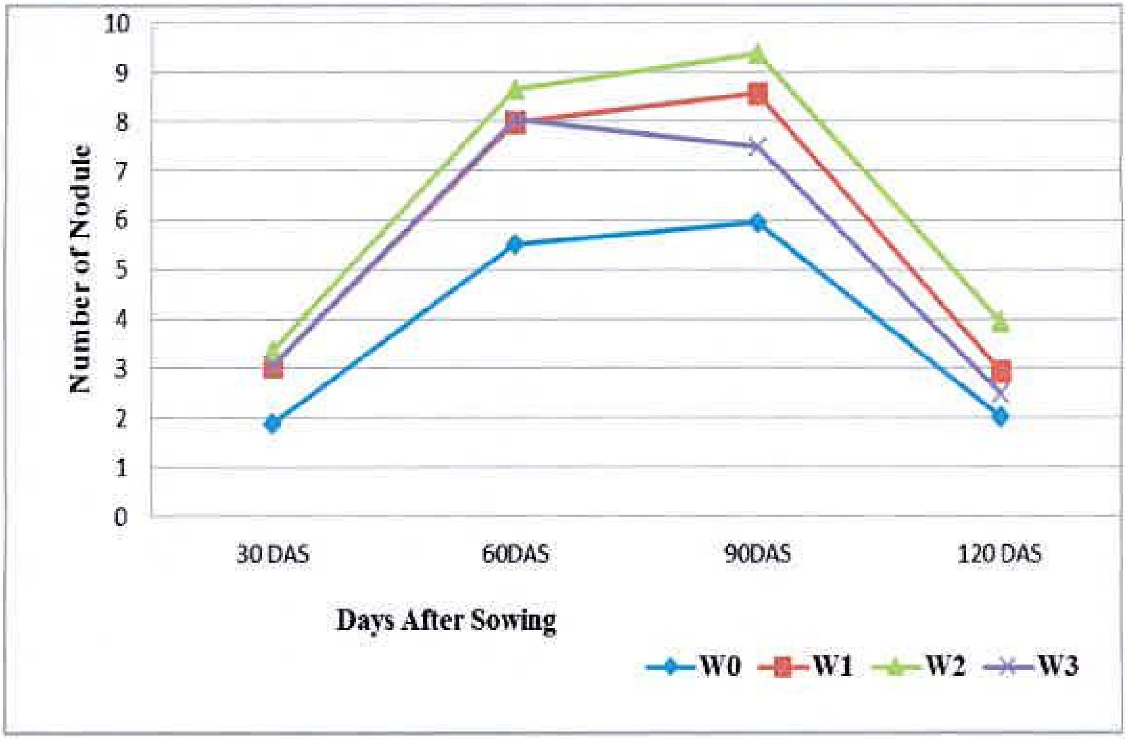

Figure 6. Effect of weed control method on nodule production of soybean at different days after sowing (SE = 0.304, 0.694, 0.677, 0.328 at 30, 60, 90 and 120 DAS, respectively).

W_0 = no weeding (control), **W_1** = hand weeding at 20 DAS, **W_2**= hand weeding at 20 DAS and 40 DAS, **W_3** = chemical control by Whip Super® @ 75g ha^{-1} herbicide application at 20 DAE.

4.2.3.3. Interaction effect of Irrigation and weed control method

Different treatment combinations of irrigation and weed control method had significant influence on the nodule production of soybean at different days after sowing (Table 6). Numerically, the highest nodule production (10.550) was recorded in the treatment combination of I_3W_1 at 90 DAS. At 90 DAS the lowest nodule production (5.220) was recorded from I_0W_0.

Table 6. Interaction effect of irrigation and weed control method on nodule production of soybean at different days after sowing

Treatment	Nodule production			
	30DAS	60DAS	90DAS	120DAS
I_0W_0	1.443 c	5.217 b	5.220 c	1.663 b
I_0W_1	2.443 a-c	6.550 ab	6.550 a-c	2.107 b
I_0W_2	2.440 a-c	10.220 a	7.663 a-c	2.663 b
I_0W_3	1.773 bc	6.550 ab	5.997 a-c	1.777 b
I_1W_0	2.330 a-c	5.440 b	6.217 a-c	1.660 b
I_1W_1	2.667 a-c	9.530 ab	7.997 a-c	3.440 b
I_1W_2	3.887 a	9.107 ab	10.000 ab	3.660 b
I_1W_3	3.553 ab	7.663 ab	6.217 a-c	2.440 b
I_2W_0	2.440 a-c	5.997 ab	6.660 a-c	2.110 b
I_2W_1	3.553 ab	8.220 ab	9.220 a-c	2.997 b
I_2W_2	3.000 a-c	8.883 ab	9.550 a-c	3.550 b
I_2W_3	3.540 ab	7.777 ab	7.887 a-c	2.663 b
I_3W_0	1.330 c	5.330 b	5.663 bc	2.663 b
I_3W_1	3.550 ab	7.663 ab	10.550 a	3.217 b
I_3W_2	4.110 a	6.443 ab	10.330 a	5.887 a
I_3W_3	3.330 a-c	10.220 a	9.883 ab	3.110 b
SE	0.6080	1.387	1.355	1.913
CV (%)	37.120	31.820	29.890	39.830

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

I_0 = No irrigation, **I_1**= One irrigation at 20 DAS, **I_2**= Two irrigation at 20 DAS and 40 DAS, **I_3**= Three irrigation at 20 DAS and 40 DAS and 60 DAS.

W_0 = no weeding (control), **W_1** = hand weeding at 20 DAS, **W_2**= hand weeding at 20 DAS and 40 DAS, **W_3** = chemical control by Whip Super® @ 75g ha^{-1} herbicide application at 20 DAE.

4.2.4. Fresh weight

4.2.4.1. Effect of irrigation:

Effect of irrigation method had significant influence on the fresh weight at different days after sowing (Appendix VIII and Figure 7). The highest fresh weight (89.990 gm) was obtained from the treatment I_2 at 90 DAS. At 90 DAS, the lowest fresh weight (63.650 gm) was recorded in I_1.

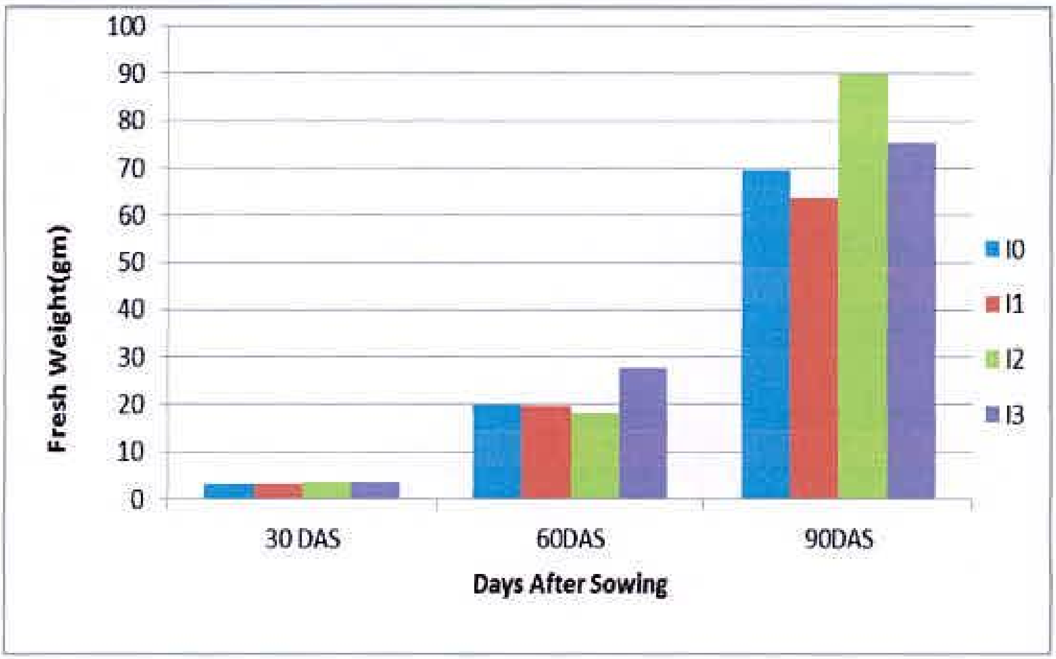

Figure 7. Effect of irrigation on fresh weight (g) of soybean at different days after sowing (SE = 0.219, 2.087, 6.865 at 30, 60 and 90 DAS, respectively).

I_0 = No irrigation, I_1= One irrigation at 20 DAS, I_2 = Two irrigation at 20 DAS and 40 DAS, I_3= Three irrigation at 20 DAS and 40 DAS and 60 DAS.

4.2.4.2. Effect of weed control

Weed control method had significant influence on the fresh weight at different days after sowing (Figure 8). The highest fresh weight (92.040 gm) was obtained from the treatment W_2 at 90 DAS. At 90 DAS, the lowest fresh weight (57.480 gm) was recorded in control (W_0).

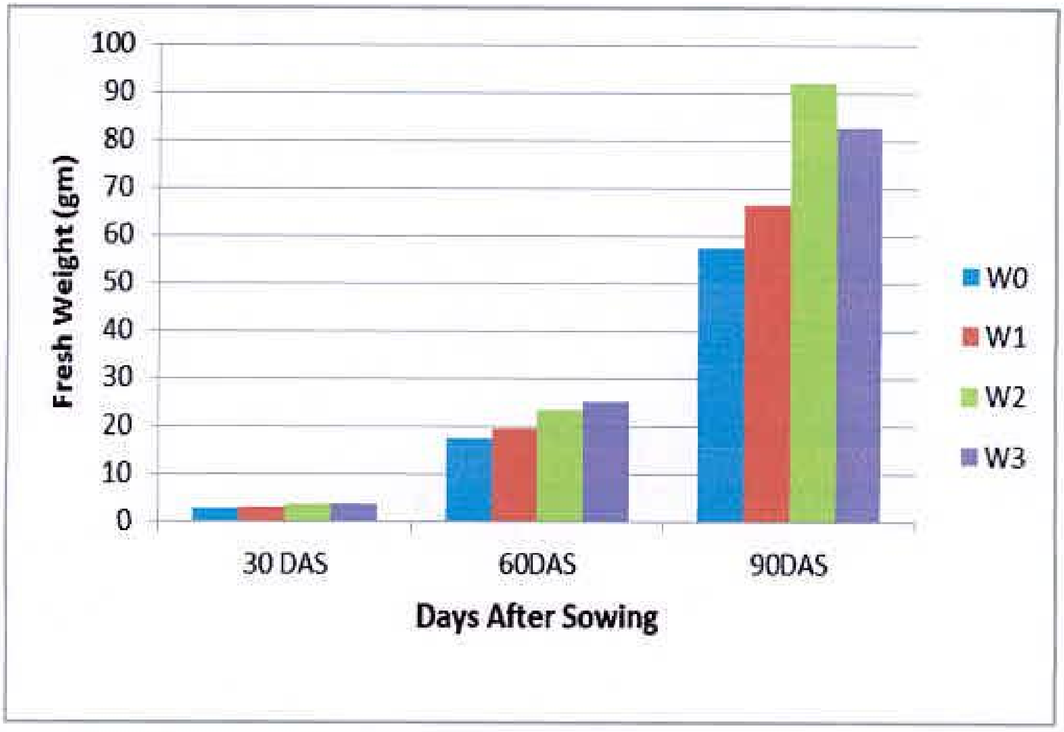

Figure 8. Effect of weed control method on fresh weight (g) of soybean at different days after sowing (SE = 0.2191, 2.087, 6.865 at 30, 60 and 90 DAS, respectively)

W_0 = no weeding (control), **W_1** = hand weeding at 20 DAS, **W_2**= hand weeding at 20 DAS and 40 DAS, **W_3** = chemical control by Whip Super® @ 75g ha^{-1} herbicide application at 20 DAE.

4.2.4.3. Interaction effect of irrigation and weed control method

Different treatment combinations of irrigation and weed control method had significant influence on the fresh weight of soybean at different days after sowing (Table 7). Numerically, the highest fresh weight (126.600gm) was recorded in the treatment combination of I_2W_2 at 90 DAS. At 90 DAS the lowest fresh weight (49.500gm) was recorded from I_1W_0.

Table 7. Interaction effect of irrigation and weed control method on fresh weight (g) of soybean at different days after sowing

Treatment	Fresh weight (g)		
	30DAS	60DAS	90DAS
I_0W_0	2.733 bc	16.330 b	61.730 bc
I_0W_1	2.800 bc	17.670 b	65.330 bc
I_0W_2	3.300 a-c	21.000 ab	78.230 bc
I_0W_3	3.667 a-c	24.330 ab	72.500 bc
I_1W_0	2.600 c	14.000 b	49.500 c
I_1W_1	3.100 a-c	19.000 b	57.500 bc
I_1W_2	3.533 a-c	21.000 ab	76.370 bc
I_1W_3	4.167 ab	24.000 ab	71.230 bc
I_2W_0	2.900 a-c	17.330 b	59.070 bc
I_2W_1	3.067 a-c	18.000 b	71.800 bc
I_2W_2	4.333 a	18.670 b	126.600 a
I_2W_3	3.267 a-c	18.670 b	102.500 ab
I_3W_0	3.033 a-c	21.670 ab	59.630 bc
I_3W_1	3.267 a-c	22.330 ab	70.200 bc
I_3W_2	3.500 a-c	33.000 a	86.970 a-c
I_3W_3	3.767 a-c	33.330 a	84.770 a-c
SE	0.438	4.174	13.730
CV (%)	22.900	33.990	31.870

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

I_0 = No irrigation, **I_1**= One irrigation at 20 DAS, **I_2**= Two irrigation at 20 DAS and 40 DAS, **I_3**= Three irrigation at 20 DAS and 40 DAS and 60 DAS.

W_0 = no weeding (control), **W_1** = hand weeding at 20 DAS, **W_2**= hand weeding at 20 DAS and 40 DAS, **W_3** = chemical control by Whip Super® @ 75g ha^{-1} herbicide application at 20 DAE.

4.2.5. Total dry matter production

4.2.5.1. Effect of irrigation

Dry matter is the material which was dried to a constant weight. Total dry matter (TDM) production indicates the production potential of a crop. A high TDM production is the first perquisite for high yield. Figure 9 shows that at 90 DAS I_3 produced higher amount of dry matter of (29.500 g) and lower amount of dry matter production (20.670 g) in I_0 treatment. Hao *et al* (2003) conducted experiments to find out effects of irrigation and found that dry matter accumulation significantly increased with irrigation application.

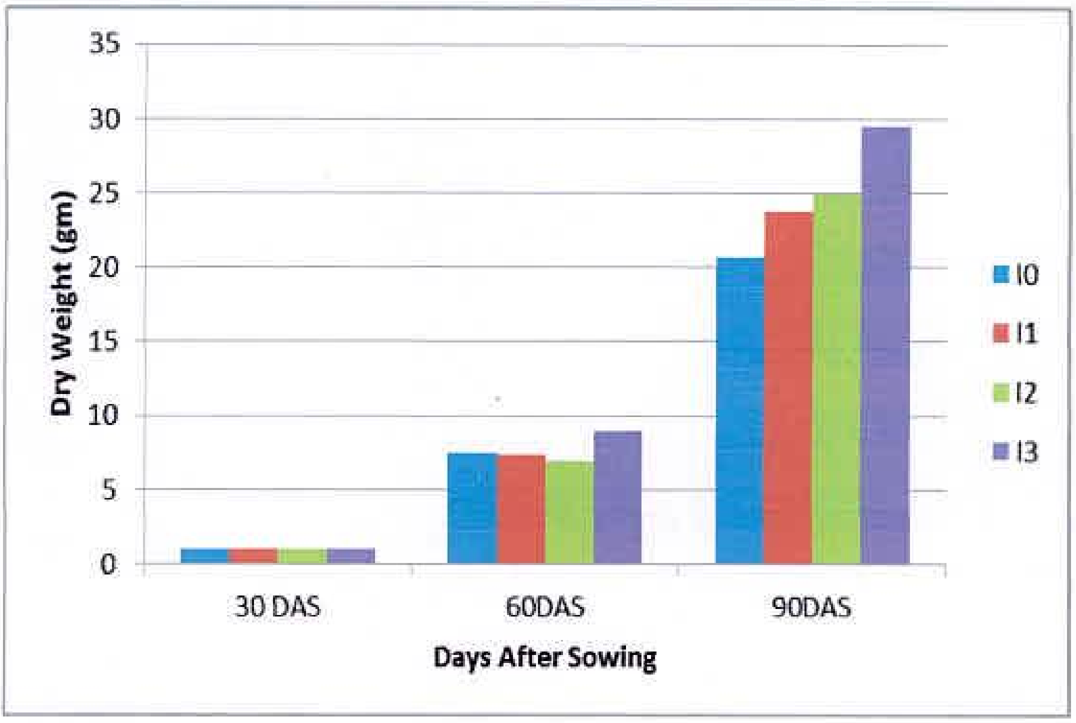

Figure 9. Effect of irrigation on total dry weight (g plant^{-1}) of soybean at different days after sowing (SE = 0.0592, 0.619, 2.306 at 30, 60 and 90 DAS respectively).

I_0 = No irrigation, I_1= One irrigation at 20 DAS. I_2= Two irrigation at 20 DAS and 40 DAS, I_3= Three irrigation at 20 DAS and 40 DAS and 60 DAS.

4.2.5.2. Effect of weed control method

Weed control method showed significant effect on dry weight plant^{-1} of soybean at different date after sowing (Appendix IX and Fig. 10). The figure show 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 30 DAS, after that dry weight increased steadily upto harvest irrespective of all weed control method. The figure indicated that weed control method W_2 showed the highest dry weight plant^{-1} (1.122, 8.560, 30.17 g plant^{-1}) and W_0 showed the lowest weight (0.9242, 6.525, 19.00g) for sampling dates of 30, 60, 90 DAS, respectively. Van Acker *et al.* (1993) stated that weed interference caused a significant decrease in soybean total aboveground dry weight.

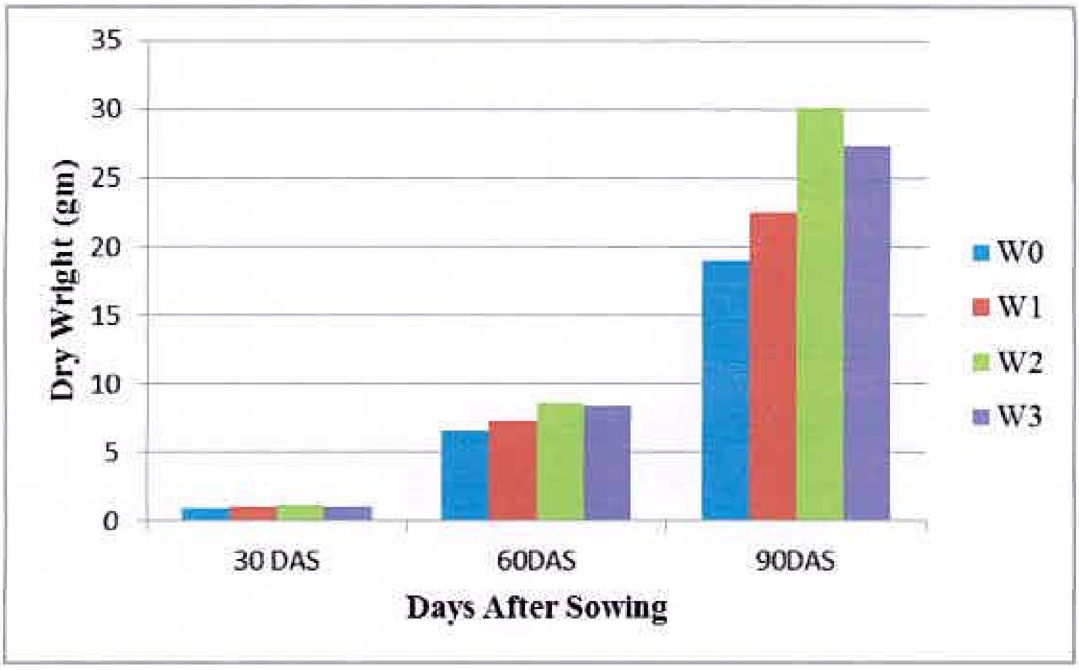

Figure 10. Effect of weed control method on total dry weight (g plant^{-1}) of soybean at different days after sowing (SE = 0.05916, 0.6199, 2.306 at 30, 60 and 90 DAS respectively).

W_0 = no weeding (control), **W_1** = hand weeding at 20 DAS, **W_2**= hand weeding at 20 DAS and 40 DAS, **W_3** = chemical control by Whip Super® @ 75g ha^{-1} herbicide application at 20 DAE.

4.2.5.3. Interaction effect of irrigation and weed control method

Different treatment combinations of irrigation and weed control method had significant influence on the total dry matter production of soybean at different days after sowing except 30 DAS (Table 8). At 60 DAS, the maximum dry weight plant^{-1} was observed from I_3W_2 (11.130 gm) and the lowest was obtained from I_1W_0 (5.670 gm). At 90 DAS, the highest dry weight plant^{-1} was observed from I_3W_2 (42.000 gm) and the lowest was obtained from I_0W_0 (16.670 gm).

Table 8. Interaction effect of irrigation and weed control method on total dry weight (g) of soybean at different days after sowing

Treatments	Dry weight plant^{-1} (g)		
	30 DAS	60 DAS	90DAS
I_0W_0	0.8900	6.837 b	16.670 c
I_0W_1	0.9867	7.053 ab	19.330 bc
I_0W_2	1.033	7.237 ab	24.000 bc
I_0W_3	1.007	8.750 ab	22.670 bc
I_1W_0	0.910	5.670 b	20.000 bc
I_1W_1	0.940	7.283 ab	24.000 bc
I_1W_2	1.177	8.790 ab	26.000 bc
I_1W_3	0.990	7.700 ab	25.330 bc
I_2W_0	1.000	6.557 b	19.330 bc
I_2W_1	1.020	6.900 ab	23.330 bc
I_2W_2	1.197	7.080 ab	28.670 a-c
I_2W_3	1.063	7.447 ab	28.670 a-c
I_3W_0	0.897	7.037 ab	20.000 bc
I_3W_1	1.003	8.000 ab	23.330 bc
I_3W_2	1.083	11.130 a	42.000 a
I_3W_3	1.190	9.717 ab	32.670 ab
SE	NS	1.240	4.612
CV (%)	19.950	27.890	32.270

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

I_0 = No irrigation, I_1= One irrigation at 20 DAS, I_2 = Two irrigation at 20 DAS and 40 DAS, I_3= Three irrigation at 20 DAS and 40 DAS and 60 DAS.

W_0 = no weeding (control), W_1 = hand weeding at 20 DAS, W_2= hand weeding at 20 DAS and 40 DAS, W_3 = chemical control by Whip Super® @ 75g ha^{-1} herbicide application at 20 DAE.

4.3. Yield contributing characters

4.3.1. Number of filled pod plant^{-1}

4.3.1.1. Effect of irrigation

Irrigation had significant effect on number of filled pod plant^{-1} of soybean (Appendix X and Table 9). The highest number of filled pod plant^{-1} (20.970) was observed from I_3 and the lowest was found from I_0 (12.330).

4.3.1.2. Effect of weed control method

The filled pod plant^{-1} of soybean affected significantly by weed control method (Appendix X and Table 9). The highest number of filled pod plant^{-1} was observed from W_2 (24.94) and the lowest was found from W_0 (11.41).

Table 9. Effect of irrigation and weed control method on yield contributing characters of soybean

Treatment	Filled pods plant^{-1} (no.)	Length of pod (cm)	Seed plant^{-1} (no.)	1000-seed weight (gm)
Effect of irrigation				
I_0	12.330 b	3.017 a	15.830 b	99.640 a
I_1	14.970 b	3.032 a	18.500 b	102.300 a
I_2	18.360 a	3.127 a	28.860 a	102.800 a
I_3	20.970 a	3.005 a	33.300 a	105.900 a
SE	1.078	0.105^{NS}	1.856	3.535^{NS}
CV%	46.780	22.460	48.380	13.200
Effect of weed control				
W_0	11.410 c	2.842 b	13.050 c	92.850 c
W_1	14.410 bc	3.047 ab	18.890 b	99.500 bc
W_2	24.940 a	3.303 a	41.970 a	111.700 a
W_3	15.860 b	2.989 ab	22.580 b	106.600 ab
SE	1.078	0.1045	1.856	3.535
CV (%)	22.420	11.90	26.660	11.930

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

I_0 = No irrigation, I_1= One irrigation at 20 DAS, I_2= Two irrigation at 20 DAS and 40 DAS, I_3= Three irrigation at 20 DAS and 40 DAS and 60 DAS.

W_0 = no weeding (control), W_1 = hand weeding at 20 DAS, W_2= hand weeding at 20 DAS and 40 DAS, W_3 = chemical control by Whip Super® @ 75g ha^{-1} herbicide application at 20 DAE.

4.3.1.3. Interaction effect of irrigation and weed control method

Interaction of irrigation and weed control method had significant effect on filled pod plant^{-1} of soybean (Appendix X and Table 10). The highest filled pod plant^{-1} (33.440) was observed from I_3W_2 and whereas, the lowest was obtained from I_0W_0 (8.220) which was statistically similar with I_0W_1, I_1W_0.

4.3.2. Length of pod

4.3.2.1. Effect of irrigation

The pod length varied due to irrigation shown in (Table 9). It was observed that treatments were non-significant.

4.3.3.2. Effect of weed control method

The pod length of soybean affected significantly by weed control method (Appendix x and Table 9). The largest pod length was found from W_2 (3.303 cm) and the lowest was observed from W_0 (2.842 cm).

4.3.3.3. Interaction effect of sowing date and weed control method

Interaction of irrigation and weed control method showed significant effect on pod length of soybean (Appendix x and Table 10). The largest pod length was found from I_2W_2 (3.530 cm) and the smallest was obtained from I_3W_0 (2.557 cm).

4.3.3. Number of seeds plant^{-1}

4.3.3.1. Effect of irrigation

Number of seed per plant was influenced by irrigation (Table 9). The maximum number of seed pod^{-1} (33.300) was found from I_3 treatment which was statistically similar with I_2 treatment and the minimum number of seed plant^{-1} (15.830) was produced from I_0 treatment.

4.3.3.2. Effect of weed control method

The number of seeds plant^{-1}of soybean affected significantly by weed control method (Appendix X and Table 9). The maximum seeds plant^{-1} was observed from W_2 (41.970), the lowest was observed from W_0 (13.050).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).

4.3.3.3. Interaction effect of irrigation and weed control method

Interaction of irrigation and weed control method had significant effect on number of seeds plant^{-1} of soybean (Appendix X and Table 10). The maximum number of seeds plant^{-1} was observed from I_3W_2 (57.110), the lowest was obtained from I_1W_0 (6.440).

4.3.4. 1000-seed weight (g)

4.3.4.1. Effect of irrigation

Weight of 1000 seed weight was influenced by irrigation. The maximum 1000 seed weight (105.900 gm) was found from I_3 treatment and the minimum 1000 seed weight (99.640gm) was produced from I_0 treatment (Table 9).

4.3.4.2. Effect of weed control method

The 1000-seed weight of soybean affected significantly by weed control method (Appendix x and Table 9). The highest 1000-seed weight was observed from W_2 (111.700 gm) and the lowest was found from W_0 (92.850 gm).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).

4.3.4.3. Interaction effect of irrigation and weed control method

Interaction of irrigation and weed control method showed significant effect on 1000-seed weight of soybean (Appendix x and Table 10). The highest 1000-seed weight was observed from I_3W_2 (118.700 g) and the lowest was obtained from I_0W_0 (81.670g).

Table.10 Interaction effect of irrigation and weed control method on yield contributing characters of soybean

Treatment	Filled pods plant^{-1}	Length of pod (cm)	No. of seed plant^{-1}	1000-seed weight (gm)
Interaction effect of irrigation and weed control method				
I_0W_0	8.220 f	3.163 a-c	8.220 gh	81.670 c
I_0W_1	8.440 f	2.927 a-c	9.663 f-h	104.500 a-c
I_0W_2	21.220 b-d	3.063 a-c	32.550 b-d	107.300 ab
I_0W_3	11.440 ef	2.917 a-c	12.890 f-h	105.100 a-c
I_1W_0	8.220 f	2.790 bc	6.440 h	100.500 a-c
I_1W_1	14.110 d-f	2.877 a-c	10.550 f-h	102.000 a-c
I_1W_2	23.440 b	3.383 ab	36.330 bc	103.300 a-c
I_1W_3	14.110 d-f	3.077 a-c	20.660 d-f	103.300 a-c
I_2W_0	17.660 b-e	2.777 bc	20.330 d-g	90.930 bc
I_2W_1	16.000 c-e	3.423 ab	26.110 c-e	91.110 bc
I_2W_2	21.660 bc	3.530 a	41.890 b	117.300 a
I_2W_3	18.110 b-e	2.777 bc	27.110 c-e	111.800 ab
I_3W_0	11.550 ef	2.640 c	17.220 e-h	98.330 a-c
I_3W_1	19.110 b-d	2.960 a-c	29.220 c-e	100.400 a-c
I_3W_2	33.440 a	3.233 a-c	57.110 a	118.700 a
I_3W_3	19.770 b-d	3.187 a-c	29.660 cd	106.200 ab
SE	2.156	0.209	3.713	7.070
CV (%)	22.420	11.900	26.660	11.930

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

I_0 = No irrigation, I_1= One irrigation at 20 DAS, I_2= Two irrigation at 20 DAS and 40 DAS, I_3= Three irrigation at 20 DAS and 40 DAS and 60 DAS.

W_0 = no weeding (control), **W_1** = hand weeding at 20 DAS, **W_2**= hand weeding at 20 DAS and 40 DAS, **W_3** = chemical control by Whip Super® @ 75g ha^{-1} herbicide application at 20 DAE.

4.4. Yield and harvest index

4.4.1. Seed yield

4.4.1.1. Effect of irrigation

Seed yield was influenced by irrigation. The maximum yield of soybean (1.628 t ha^{-1}) was found from I_3 treatment and the minimum yield of soybean (1.067 t ha^{-1}) was produced from I_0 treatment (fig. 11). Kazi *et al.* (2002) also reported that the maximum seed yield was found superior with the application of 6 irrigations followed by 5 irrigations, whereas, lowest number of irrigation decreased all the traits adversely. Constable and Heam (1980) reported that irrigations during late flowering and pod filling in soybean were necessary to ensure maximum seed yield (up to 305 t ha^{-1}).

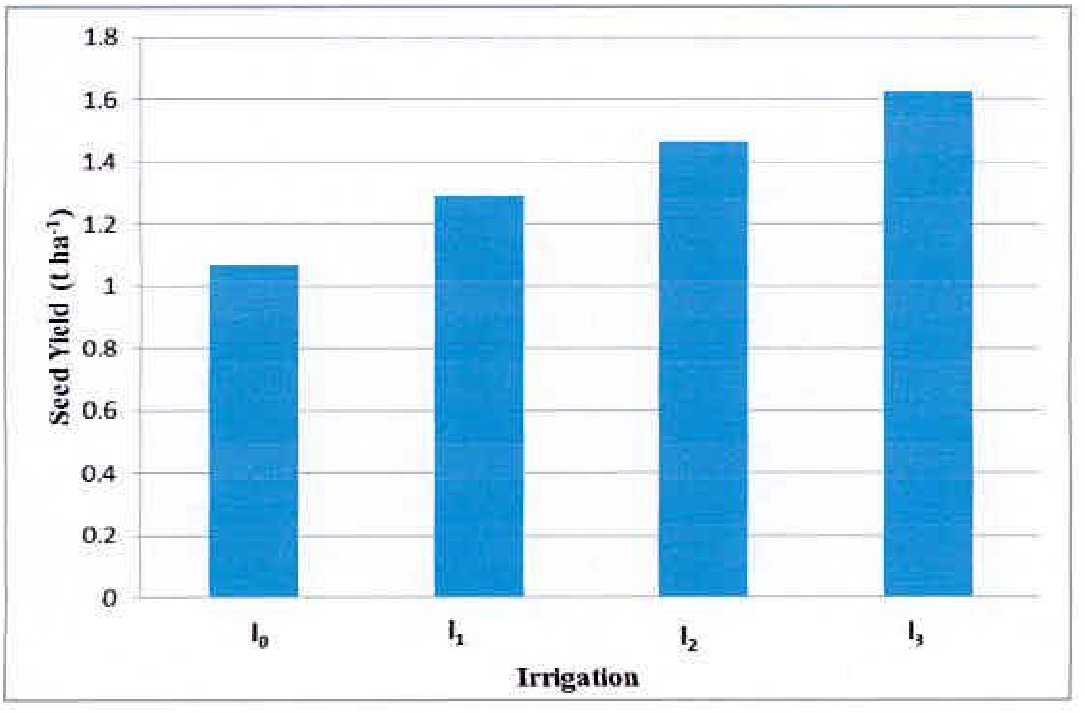

Figure 11. Effect of irrigation on seed yield (t ha^{-1}) of soybean (SE = 0.061 at harvest time).

I_0 = No irrigation, **I_1**= One irrigation at 20 DAS, **I_2** = Two irrigation at 20 DAS and 40 DAS, **I_3**= Three irrigation at 20 DAS and 40 DAS and 60 DAS.

4.4.1.2. Effect of weed control method

Weed control method exerted significant effect on seed yield of soybean (Appendix XI and Figure 12). The highest seed yield was observed from W_2 (1.556 tha^{-1}) and the lowest was found from W_0 (1.182 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.

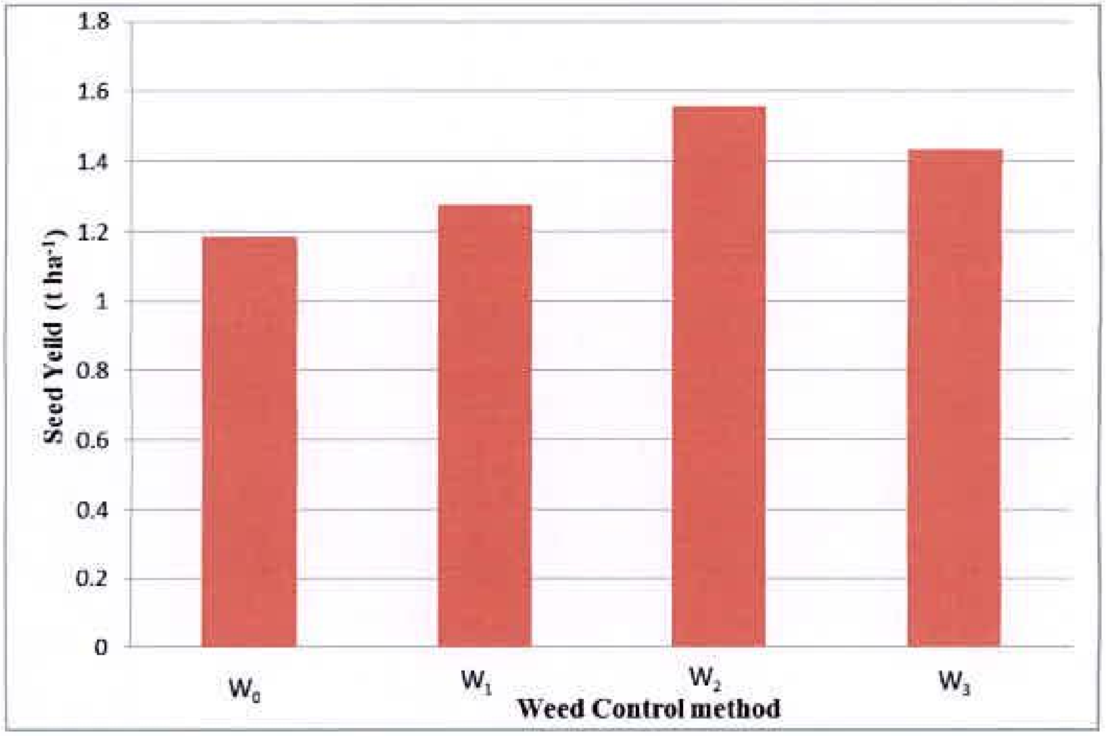

Figure 12. Effect of weed control on seed yield (t ha^{-1}) of soybean (SE = 0.061 at harvest time)

W_0 = no weeding (control), **W_1** = hand weeding at 20 DAS, **W_2**= hand weeding at 20 DAS and 40 DAS, **W_3** = chemical control by Whip Super® @ 75g ha^{-1} herbicide application at 20 DAE.

4.4.1.3. Interaction effect of irrigation and weed control method

Interaction of irrigation and weed control method had significant effect on seed yield of soybean (Appendix XI and Table 11). The highest seed yield was observed from I_3W_2 (1.917 t ha^{-1}) which was statistically similar with I_3W_3 whereas, the lowest was obtained from I_0W_0 (0.960 t ha^{-1}) which was statistically similar with I_0W_1 and I_0W_3. 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 co-existed with weeds throughout their cycle, which agrees with this experiment.

Table 11. Yield and harvest index of soybean as influenced by the interaction of irrigation and weed control method

Treatments	Seed yield (t ha^{-1})	Stover yield (t ha^{-1})	Biological yield (t ha^{-1})	Harvest index (%)
I_0W_0	0.960 d	1.510 c	2.470 f	38.840 d
I_0W_1	0.973 d	1.527 c	2.500 f	38.910 d
I_0W_2	1.247 cd	1.553 c	2.800 c-f	44.100 b-d
I_0W_3	1.090 d	1.540 c	2.630 ef	41.370 cd
I_1W_0	1.230 cd	1.527 c	2.757 d-f	44.570 bc
I_1W_1	1.257 cd	1.567 c	2.823 c-f	44.290 bc
I_1W_2	1.350 b-d	1.613 bc	2.963 c-f	44.970 a-c
I_1W_3	1.313 b-d	1.550 c	2.863 c-f	45.720 a-c
I_2W_0	1.267 cd	1.540 c	2.807 c-f	45.000 a-c
I_2W_1	1.337 b-d	1.547 c	2.883 c-f	46.350 a-c
I_2W_2	1.710 ab	1.693 bc	3.403 a-c	50.260 a
I_2W_3	1.540 a-c	1.590 bc	3.130 b-e	49.230 ab
I_3W_0	1.270 cd	1.567 c	2.837 c-f	44.720 a-c
I_3W_1	1.537 a-c	1.717 bc	3.257 b-d	46.770 a-c
I_3W_2	1.917 a	1.953 a	3.873 a	49.500 ab
I_3W_3	1.790 a	1.817 ab	3.607 ab	49.520 ab
SE	0.123	0.0730	0.183	1.662
CV (%)	15.620	7.890	10.630	6.360

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

I_0 = No irrigation, I_1= One irrigation at 20 DAS. I_2= Two irrigation at 20 DAS and 40 DAS, I_3= Three irrigation at 20 DAS and 40 DAS and 60 DAS.

W_0 = no weeding (control), W_1 = hand weeding at 20 DAS, W_2= hand weeding at 20 DAS and 40 DAS, W_3 = chemical control by Whip Super® @ 75g ha^{-1} herbicide application at 20 DAE.

4.4.2. Stover yield

4.4.2.1. Effect of irrigation

Irrigation had significant effect on stover yield of soybean (Appendix XI and Figure 13). The highest stover yield was obtained from I_3 (1.763 t ha^{-1}) whereas, the lowest was observed from I_0 (1.533t ha^{-1}) which was statistically similar with I_1 (1.564t ha^{-1}) and I_2 (1.592 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.

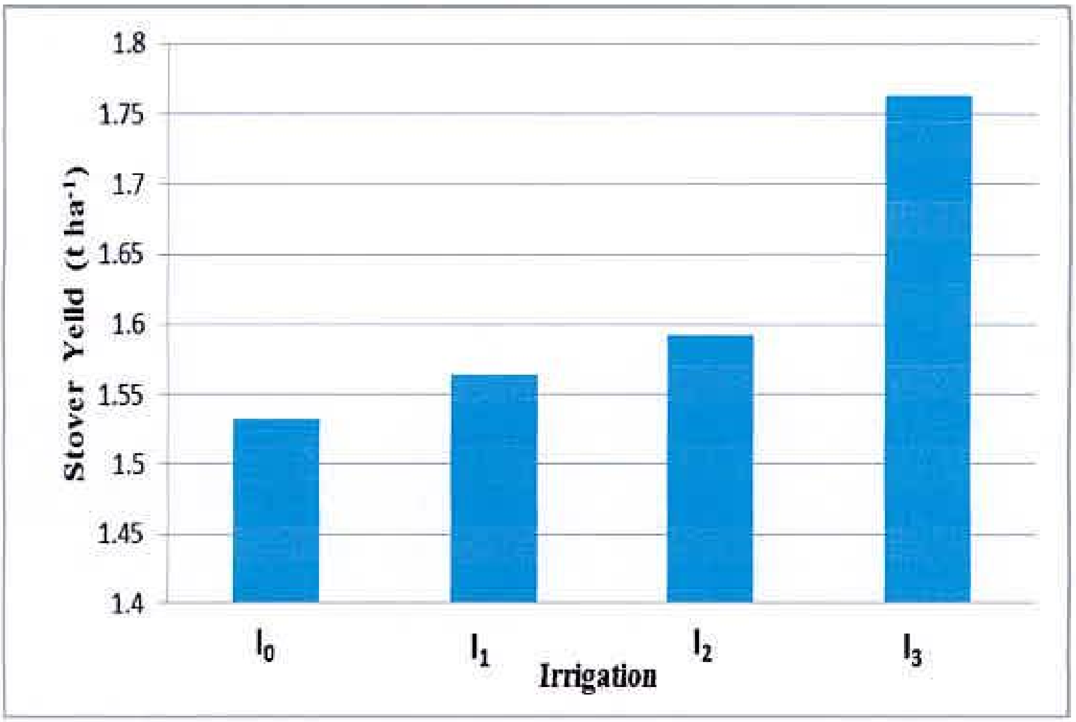

Figure 13. Effect of irrigation on stover yield (t ha^{-1}) of soybean (SE = 0.037 at harvest)

I_0 = No irrigation, **I_1**= One irrigation at 20 DAS, **I_2**= Two irrigation at 20 DAS and 40 DAS, **I_3**= Three irrigation at 20 DAS and 40 DAS and 60 DAS.

4.4.2.2. Effect of weed control method

Weed control method had significant effect on stover yield of soybean (Appendix XI and Fig. 14). The maximum stover yield was obtained from W_2 (1.703 tha^{-1}) and the lowest was observed from W_0 (1.536 t ha^{-1}) which was statistically similar with W_1 (1.589 tha^{-1}). Peer *et al.* (2013) seen superior stover yield in different weed control treatment especially weed free treatment.

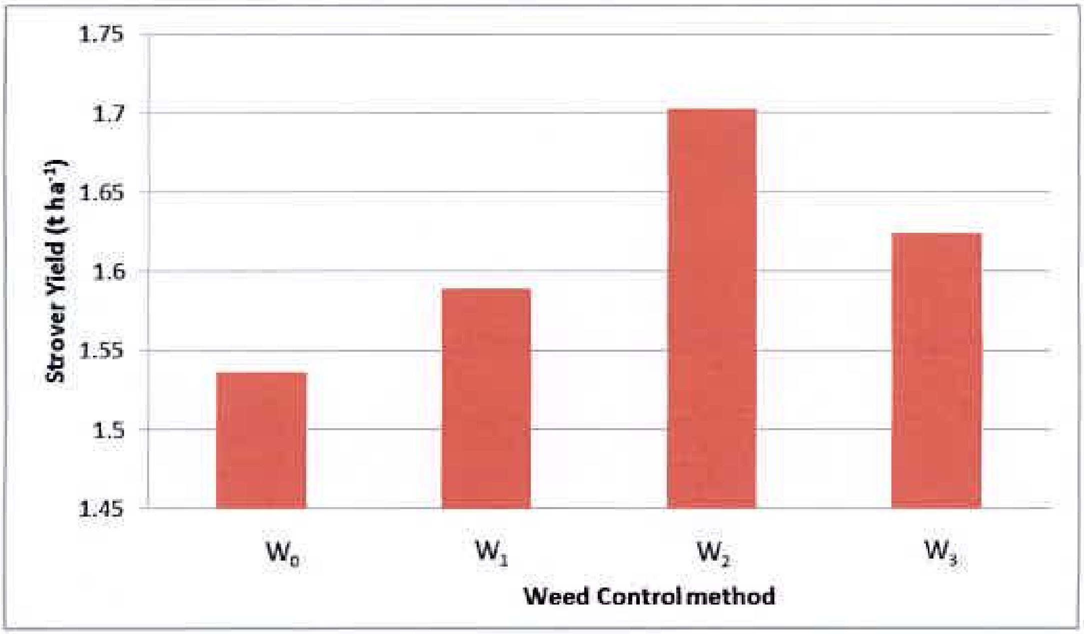

Figure 14. Effect of weed control stover yield (t ha^{-1}) of soybean (SE = 0.037 at harvest)

W_0 = no weeding (control), **W_1** = hand weeding at 20 DAS, **W_2**= hand weeding at 20 DAS and 40 DAS, **W_3** = chemical control by Whip Super® @ 75g ha^{-1} herbicide application at 20 DAE.

4.4.2.3. Interaction effect of irrigation and weed control method

Interaction of irrigation and weed control method showed significant effect on stover yield of soybean (Appendix XI and Table 11). However the highest stover yield was obtained from I_3W_2 (1.953 tha^{-1}), the lowest was obtained from I_0W_0 (1.510 t ha^{-1}) which was statistically similar with I_0W_1, I_0W_2, I_0W_3, I_1W_0, I_1W_1, I_2W_0, I_2W_1 and I_3W_0.

4.4.3. Biological yield

4.4.3.1. Effect of irrigation

Irrigation had significant effect on biological yield of soybean (Appendix XI and Figure 15). The highest biological yield was found from I_3 (3.393 t ha^{-1}) and the lowest was obtained from I_0 (2.600 t ha^{-1}).

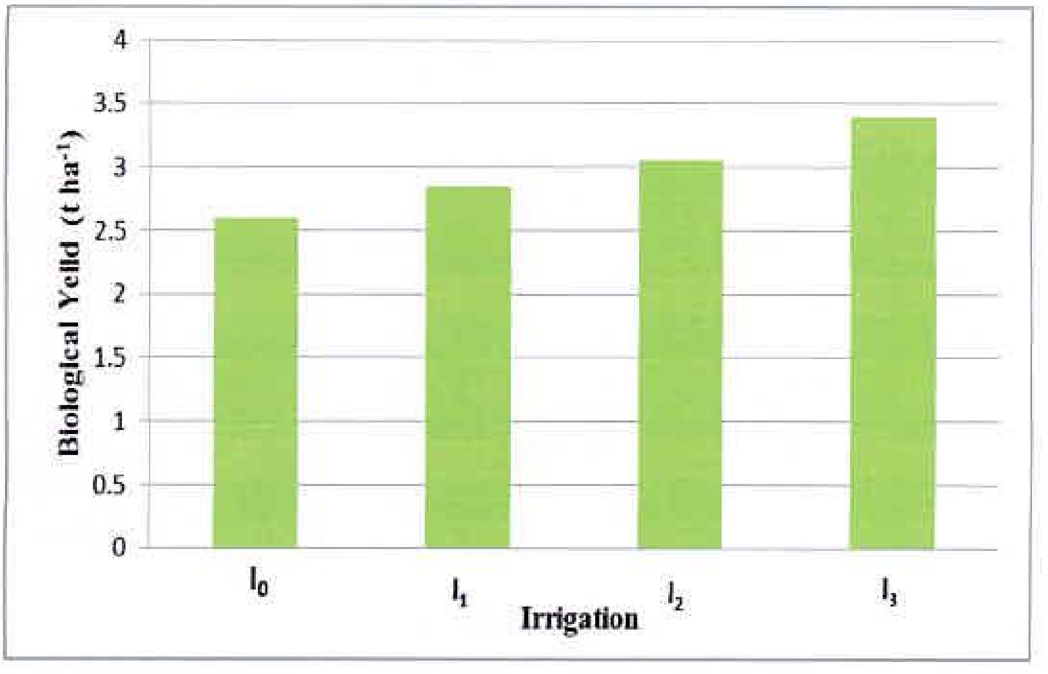

Figure 15. Effect of irrigation on biological yield (t ha^{-1}) of soybean (SE = 0.091 at harvest time.)

I_0 = No irrigation, **I_1**= One irrigation at 20 DAS, **I_2**= Two irrigation at 20 DAS and 40 DAS, **I_3**= Three irrigation at 20 DAS and 40 DAS and 60 DAS.

4.4.3.2. Effect of weed control method

Weed control method had significant effect on biological yield of soybean (Appendix XI and Figure 16). The highest biological yield was found from W_2 (3.260 t ha^{-1}) and the lowest was observed from W_0 (2.717 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.

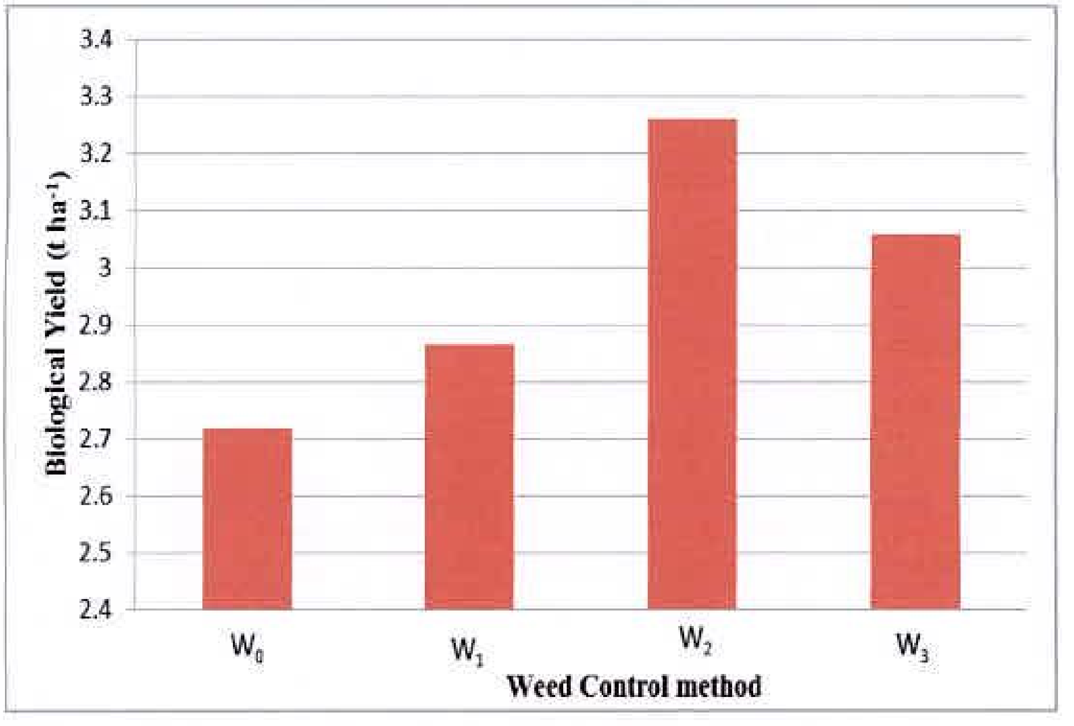

Figure 16. Effect of weed control biological yield (t ha^{-1}) of soybean (SE = 0.091 at harvest time.)

W_0 = no weeding (control), **W_1** = hand weeding at 20 DAS, **W_2**= hand weeding at 20 DAS and 40 DAS, **W_3** = chemical control by Whip Super® @ 75g ha^{-1} herbicide application at 20 DAE.

4.4.3.3. Interaction effect of irrigation and weed control method

Interaction of irrigation and weed control method showed significant effect on biological yield of soybean (Appendix XI and Table 11). The highest biological yield was found from I_3W_2 (3.873 t ha^{-1}), the lowest was obtained from I_0W_0 (2.470 t ha^{-1}) which was statistically similar with I_0W_1.

4.4.4. Harvest index

4.4.4.1. Effect of irrigation

Irrigation showed significant effect on harvest index of soybean (Appendix XI and Figure17). The highest harvest index was observed from I_2 (47.710 %)

which is statistically similar with I_3 and the lowest was found from I_0 (40.810%).

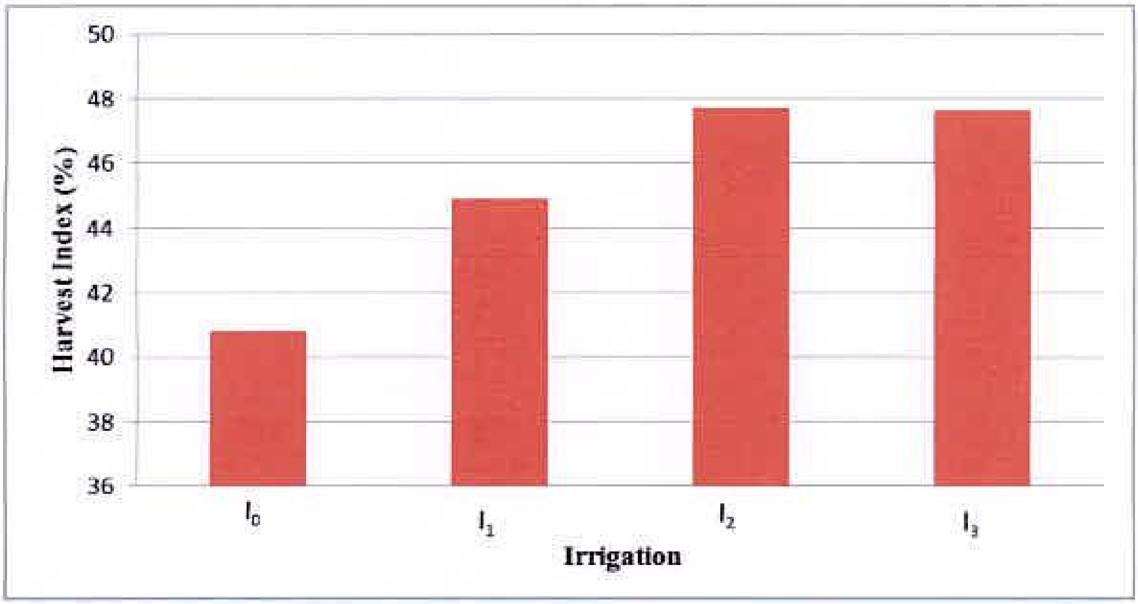

Figure 17. Effect of irrigation on harvest index (%) of soybean (SE = 0.831 at harvest time.)

I_0 = No irrigation, I_1= One irrigation at 20 DAS, I_2 = Two irrigation at 20 DAS and 40 DAS, I_3= Three irrigation at 20 DAS and 40 DAS and 60 DAS.

4.4.4.2. Effect of weed control method

Weed control method showed significant effect on harvest index of soybean (Appendix XI and Figure 18). The highest harvest index was observed from W_2 (47.210 %), the lowest was observed from W_0 (43.280 %). Bhandiwaddar and Itnal (1998) reported superiority of various weed control method with respect to harvest index of soybean over unweeded control.

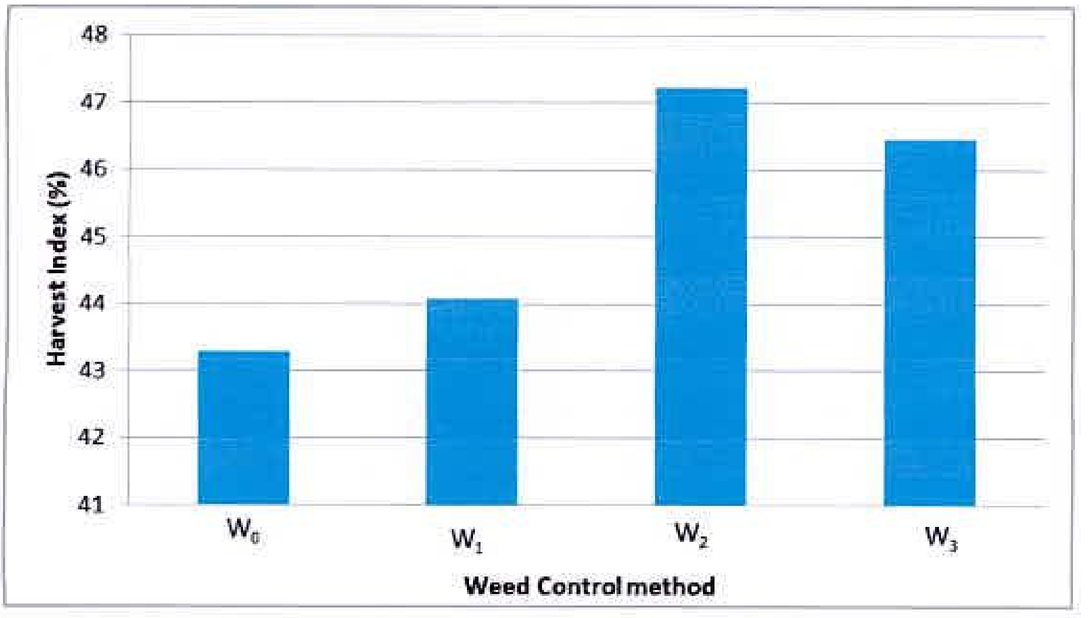

Figure 18. Effect of weed control harvest index (%) of soybean (SE = 0.831 at harvest time.)

W_0 = no weeding (control), **W_1** = hand weeding at 20 DAS, **W_2**= hand weeding at 20 DAS and 40 DAS, **W_3** = chemical control by Whip Super® @ 75g ha^{-1} herbicide application at 20 DAE.

4.4.4.3. Interaction effect of irrigation and weed control method

Interaction of irrigation and weed control method showed significant effect on harvest index of soybean (Appendix XI and Table 11). The maximum harvest index was found from I_2W_2 (50.260 %), the minimum was obtained from I_0W_1 (38.840 %) which was statistically similar with I_0W_0.

Chapter 5

SUMMARY AND CONCLUSION

CHAPTER V

SUMMARY AND CONCLUSION

The field experiment was conducted at the Agronomy research field, Sher-e-Bangla Agricultural University, Dhaka during the period from December 2013 to June 2014 to investigate the influence of irrigation and weed control method on growth and yield of soybean under the Modhupur Tract (AEZ-28).The experiment was carried out with four(4) irrigation treatments viz. no irrigation (control), one time(at 20 DAS) ,two times (at 20 and 40 DAS), three times (at 20, 40, and 60 D AS),and four weed management method i.e., no weeding (control), one time hand weeding(at 20 DAS), two times hand weeding (at 20 and 40 DAS) and chemical control by Whip Super® (75g/L Fenoxaprop-p-ethyl) @75g ha^{-1} at 20 DAS was outlined in split plot design with three replications. The size of the individual plot was 2 m x 2m and total numbers of plots were 48. There were 16treatment combinations. Irrigation treatments were placed at the main plots and weed control method were placed at the sub plots.

The data on weed parameters such as infested weed species, relative weed density (%), weed biomass (gm^{-2}) and weed control efficiency (%) were examined. The data on crop growth characters like plant height, leaf area index, nodule production, fresh weight and dry weight $plant^{-1}$(gm) were recorded at different growth stages. Yield and yield contributing parameters like, filled pod, number of pods $plant^{-1}$, pod length, number of seeds $plant^{-1}$, 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-one 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 method. In case of first 20 DAS *Echinochloa colonum* (56.91%), *Lindernia procumbens (*25.07%), *Cynodon dactylon* (14.25%) dominated the experimental field. In case of 40DAS, 60DAS, 80DAS respectively *Echinochloa colonum* (64.99%, 72.19%, 74.23%), *Lindernia procumbens (*28.28%, 19.94%, 14.69%), *Cynodon dactylon* (1.42%, 0.39%, 0.69%).Relative density of several weed species decreased at later stages due to their completion of life cycle.

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. In case of treatment combination, the maximum amount of weed dry weight was obtained from zero irrigation with no weeding (control) treatment at 40 and 60 DAS. The highest amount of dry matter (2.000 g m^{-2}) was found from I_0W_0 treatment combinations and the lowest was obtained from I_0W_1 (0.367 g m^{-2}). At 40 and 60 DAS, I_3W_0 produced the highest amount of weed dry matter (30.030g $m^{-2}$and 41.300 g m^{-2}, respectively) and the lowest was found from I_1W_1 (2.800 g m^{-2}) at 40 DAS and at 60 DAS the lowest was found from I_1W_2 (2.230g m^{-2}).

The significant result was found in irrigation effect at different growth stage. At 105 DAS I_3 produce tallest plant (52.190 cm) and I_0 produce shortest plant height (44.920 cm).Weed control method W_3 showed the tallest plant (12.730, 23.290, 34.390, 41.390 and 48.560 cm) and W_0 produced the shortest plant (12.010, 20.600, 29.900, 36.800, 37.780 and 45.220 cm) for sampling dates of 30, 45, 60, 75, 90 and 105 DAS respectively.

At 105 DAS, the longest plant was observed from I_3W_2 (54.340 cm) which was statistically similar with I_1W_2 whereas, the shortest was obtained from I_0W_0 (41.670 cm).

The highest (5.910) leaf area index was obtained from the treatment of three irrigation (I_3) at 90 DAS and (6.092) leaf area index was obtained from the treatment W_3at 90 DAS. The highest (6.433) leaf area index was recorded in the treatment combination of I_2W_3 at 90 DAS. At 90 DAS the lowest (4.2) leaf area index was recorded from I_0W_0.

The highest (10.550) nodule production was recorded in the treatment combination of I_3W_1 at 90 DAS. At 90 DAS the lowest (5.220) nodule production was recorded from I_0W_0. Fresh weight highest was recorded in the treatment combination of I_2W_2(126.600gm) at 90 DAS and the lowest (49.500gm) fresh weight was recorded from I_1W_0. Three irrigation combined with two weed control method (I_3W_2) produced highest total dry matter of plant (42.000 gm).

Yield contributing characters the highest filled pod plant^{-1} (33.440) was observed from I_3W_2 and whereas, the lowest was obtained from I_0W_0 (8.220) which was statistically similar with I_0W_1, I_1W_0.The largest pod length was found from I_2W_2 (3.530 cm) and the smallest was obtained from I_3W_0 (2.557 cm).The maximum number of seeds plant^{-1} was observed from I_3W_2 (57.110), the lowest was obtained from I_1W_0 (6.440).The highest 1000-seed weight was observed from I_3W_2 (118.700 g) which was statistically similar with I_2W_2 whereas, the lowest was obtained from I_0W_0 (81.670g).

Results showed that the highest seed yield was observed from I_3W_2 (1.917 t ha^{-1}) which was statistically similar with I_3W_3 whereas, the lowest was obtained from I_0W_0 (0.960 t ha^{-1}).The maximum stover yield was obtained from W_2 (1.703t ha^{-1}) and the highest stover yield was obtained from I_3 (1.763 t ha^{-1}). Interaction of I_3W_2 produced stover yield of 1.953t ha^{-1}. The highest biological yield was found from I_3 (3.393 t ha^{-1}) and the lowest was obtained from I_0 (2.600 t ha^{-1}). In case of weed control highest biological yield was found from W_2 (3.260 t ha^{-1}) and the lowest was observed from W_0 (2.717 t ha^{-1}).The interaction effect in highest biological yield was found from I_3W_2 (3.873 t ha^{-1}), the lowest was obtained from I_0W_0 (2.470 t ha^{-1}).The maximum harvest index was found from I_2W_2 (50.260 %), the minimum was obtained from I_0W_1 (38.840 %)

Results showed different types of weed were found to infest experimental fields, among them *Echinochloa colonum* (72.19%), *Lindernia procumbens* (28.28%) and *Cynodon dactylon* (14.25%) had the highest relative density. It was also noticed that *Lindernia procumbens* created dominancy throughout the growing period even at later stage of crop. Three times of irrigation gave the highest (1.63 t ha^{-1}) seed yield on the other hand two times hand weeding gave the highest (1.56 t ha^{-1}) seed yield. Interaction effects showed the highest (1.92 t ha^{-1}) seed yield from the combination of three times irrigation and two times hand weeding (I_3W_2) which was statistically identical with I_3W_3.

Considering the results of the present experiment, it may concluded that growth, yield and yield contributing parameters of soybean decreased with zero irrigation and no weed control plot. Three irrigation 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, three irrigation and two times hand weeding (20 and 40 DAS) showed better performance compared to those of other treatments. This was also observed that herbicide Whip Super® showed better performance to control grass weeds but failed to control *Lindernia procumbens*. However, crop plants treated with herbicide became mature one week earlier than other treated crop plants. Considering application of herbicide Whip Super® may be most economic for cultivation of soybean.

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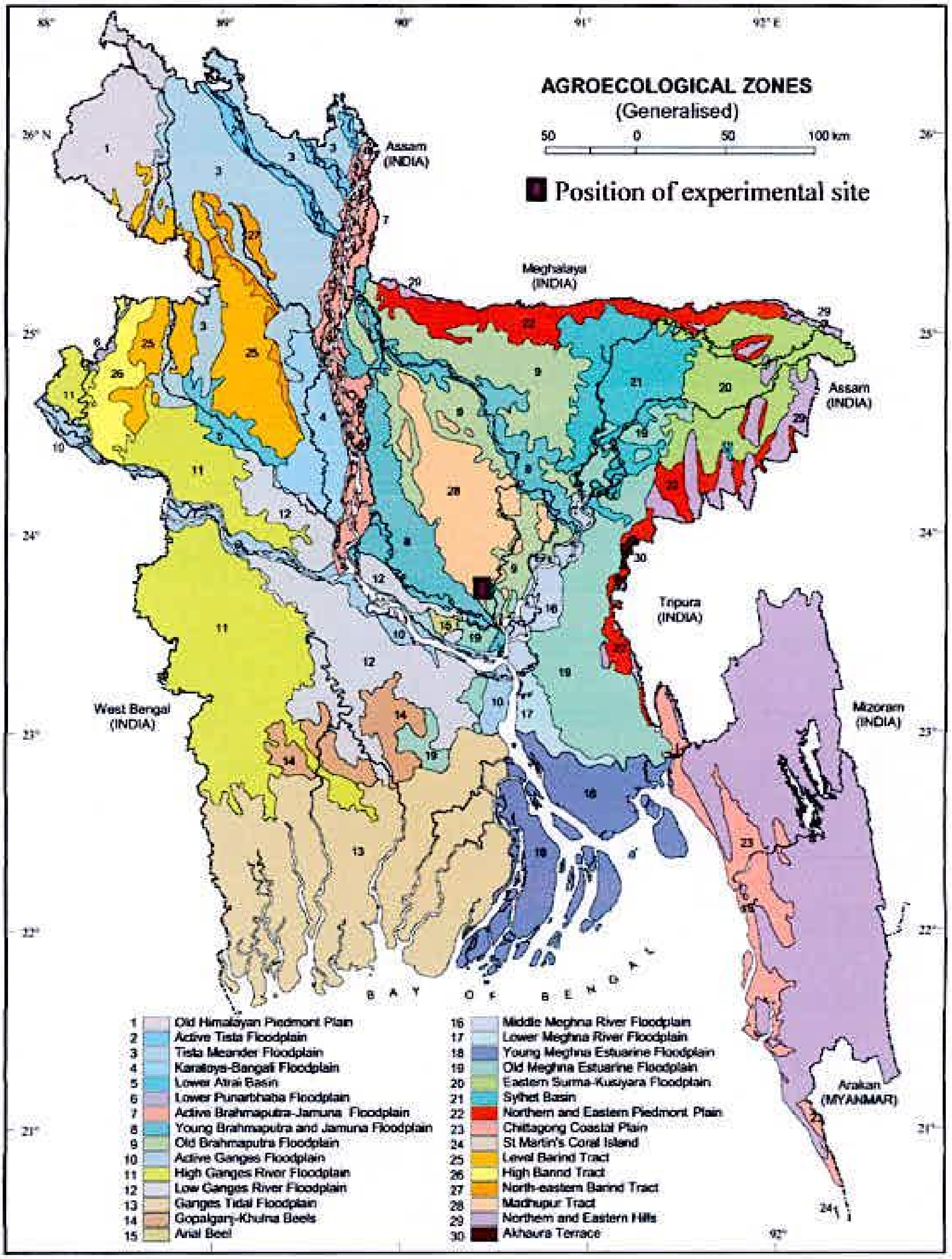
APPENDICES

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, 2013-2014, Dhaka

Month	Average Relative Humidity (%)	Average Temperature (°C)		Total Rainfall (mm)
		Minimum	Maximum	
December	54.30	5.21	25.36	0.21
January	64.02	15.46	21.17	0.00
February	53.07	19.12	24.30	2.34
March	48.66	22.37	29.78	0.12
April	51.02	22.85	33.82	2.19

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

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

Sources of variation	Degrees of freedom	Mean Square		
		20 DAS	40 DAS	60 DAS
Replication	2	0.072	2.715	0.973
Irrigation (I)	3	0.010^{NS}	41.274**	56.095**
Error (a)	6	0.080	1.135	2.251
Weed control methods (W)	3	0.025^{NS}	1224.742**	2796.996**
Interaction (I×W)	9	0.007^{NS}	11.342**	16.728**
Error (b)	24	0.063	0.702	0.915

**: 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					
		30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS
Replication	2	1.291	11.415	161.198	255.712	278.369	399.108
Irrigation (I)	3	16.438**	20.608**	163.869**	66.302*	55.838*	45.832*
Error (a)	6	0.741	4.691	23.873	57.523	11.033	9.33
Weed control method (W)	3	1.338*	3.211*	48.272*	87.371*	69.316*	95.618*
Interaction (I×W)	9	0.226*	0.288*	4.655*	5.975*	4.062*	3.662*
Error (b)	24	1.358	6.258	9.140	20.63	22.35	26.43

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

Appendix VI. Mean square values for leaf area index of soybean at different days after sowing

Sources of variation	Degrees of freedom	Mean Square					
		30 DAS	45 DAS	60 DAS	75 DAS	90 DAS	105 DAS
Replication	2	0.039	0.036	0.057	0.051	0.143	0.009
Irrigation (I)	3	0.302*	2.189*	1.748**	1.095**	2.009*	2.634*
Error (a)	6	0.088	0.257	0.056	0.094	0.044	0.144
Weed control method (W)	3	0.884*	1.007*	0.866*	1.361*	1.919*	0.564**
Interaction (I×W)	9	0.047	0.069	0.057	0.080	0.146	0.027
Error (b)	24	0.080	0.086	0.123	0.098	0.065	0.160

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

Appendix VII. Mean square values for nodule production of soybean at different days after sowing.

Sources of variation	Degrees of freedom	Mean Square			
		30 DAS	60 DAS	90 DAS	120DAS
Replication	2	26.212	245.822	0.506	16.212
Irrigation (I)	3	8.173*	34.171*	3.667*	3.173*
Error (a)	6	3.164	13.384	1.498	2.160
Weed control methods (W)	3	9.935**	78.942**	26.132	8.935**
Interaction (I×W)	9	0.949*	4.554*	2.086*	0.849*
Error (b)	24	1.109	5.773	5.507	1.289

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

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

Sources of variation	Degrees of freedom	Mean Square		
		30 DAS	60 DAS	90 DAS
Replication	2	5.343	138.271	1292.447
Irrigation (I)	3	0.196*	218.743*	1535.814*
Error (a)	6	0.373	7.160	1095.013
Weed control methods (W)	3	2.397*	154.910*	2936.131*
Interaction (I×W)	9	0.353^{NS}	20.947	321.716
Error (b)	24	0.576	52.271	565.561

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

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

Sources of variation	Degrees of freedom	Mean Square		
		30 DAS	60 DAS	90 DAS
Replication	2	0.107	24.782	124.750
Irrigation (I)	3	0.020**	9.125*	160.556*
Error (a)	6	0.029	0.423	107.639
Weed control methods (W)	3	0.090*	11.071*	296.556*
Interaction (I×W)	9	0.011	2.188	38.111
Error (b)	24	0.042	4.612	63.806

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

Appendix X. Mean square values for Filled pod plants^{-1} , pod length, number of seeds plant^{-1}, 1000-seed weight of soybean.

Sources of variation	Degrees of freedom	Mean Square			
		Filled pod plants^{-1}	Pod length	Number of seeds plant^{-1}	1000-seed weight
Replication	2	15.383	0.183	370.051	1303.041
Irrigation (I)	3	72.239*	0.037*	828.377*	79.454*
Error (a)	6	60.718	0.468	136.206	183.743
Weed control methods (W)	3	407.225**	0.442*	1883.441*	811.329*
Interaction (I×W)	9	29.886	0.175	46.786	149.653
Error (b)	24	13.948	0.131	41.355	149.972

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

Appendix XI. 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	Stover yield	Biological yield	Harvest index
Replication	2	0.260	0.113	0.702	18.077
Irrigation (I)	3	0.694*	0.128^{NS}	1.349**	126.341*
Error (a)	6	0.047	0.022	0.115	9.472
Weed control methods (W)	3	0.330*	0.059*	0.665*	42.111*
Interaction (I×W)	9	0.033^{NS}	0.014	0.083	3.973
Error (b)	24	0.045	0.016	0.100	8.285

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

Plate 1. Field view of experiment plot (without irrigation)

Plate 2. At harvest stage of soybean plant.