EFFECT OF PLANT DENSITY AND TIME OF WEEDING ON THE PERFORMANCE OF MUNGBEAN (*Vigna radiata* L.)

By

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Dedicated to

My

Beloved Parents

CERTIFICATE

This is to certify that thesis entitled, **"EFFECT OF PLANT DENSITY AND TIME OF WEEDING ON THE PERFORMANCE OF MUNGBEAN (*Vigna radiata* L.)"** submitted to the Faculty of Agriculture, Sher-e-Bangla Agricultural University, Dhaka, in partial fulfilment of the requirements for the degree of **MASTER OF SCIENCE** in **AGRONOMY**, embodies the result of a piece of bona fide research work carried out by **Ashick Ahmed**, Registration No. **27538/00711** 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 of during the course of this investigation has duly been acknowledged.

Dated: 30/12/07
Place: Dhaka, Bangladesh

(Prof. Md. Sadrul Anam Sardar)
Supervisor

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The Author

EFFECT OF PLANT DENSITY AND TIME OF WEEDING ON THE PERFORMANCE OF MUNGBEAN (*Vigna radiata* L.)

ABSTRACT

An experiment was carried out to investigate the effect of plant density and time of weeding on the performance of mungbean cv. BARI Mung-6 at the field laboratory of Sher-e-Bangla Agricultural University, Dhaka-1207.The experiment comprised three plant densities viz. 33 plants m^{-2}(D_1), 40 plants m^{-2}(D_2), 66 plants m^{-2} (D_3) and four levels of weeding viz. no weeding (W_1), weeding at 15 DAE (W_2), weeding at 30 DAE (W_3) and weeding at 45 DAE (W_4). The experiment was laid out in a randomized complete block design (factorial) with 3 replications. Results revealed that both plant density and time of weeding significantly influenced yield and yield contributing characters of mungbean. Among the 17 weed species identified during crop duration, *Cyperus rotundus* (28%) was the most dominant both in weeded and unweeded plots. In the case of plant density, highest grain yield (899.2 kg ha^{-1}) was recorded from 66 plants m^{-2} density. Among the four levels of weeding the second level i.e. weeding at 15 DAE performed the best in obtaining the highest values in almost all the parameters such as number of nodes $plant^{-1}$ (9.57), number of pods $plant^{-1}$ (15.17), number of seeds pod^{-1} (11.08), plant height (60.81 cm), number of branches $plant^{-1}$ (3.73), weight of 1000- seed (29.80 g.) and seed yield (898.3 kg ha^{-1}).The highest yield (1220 kg ha^{-1}) of mungbean was obtained from plots of 66 plants m^{-2} weeded at 15 DAE and the lowest yield (230.7 kgha^{-1}) in plots of 33 plants m^{-2} that remained unweeded. Delay in weeding decreased seed yield, yield attributes and dry biomass of mungbean but increased dry biomass of weed. The critical period of weed control appeared to be between 15 and 30 DAE. Unrestricted growth of weed reduced mungbean seed yield by 43-61%. Linear regression model indicated that for one kg ha^{-1} of weed growth, mungbean seed yield is reduced by one kg ha^{-1}.

LIST OF CONTENTS

CONTENTS (Contd.)

CONTENTS (Contd.)

CONTENTS (Contd.)

LIST OF TABLES

LIST OF FIGURES

LIST OF APPENDICES

LIST OF ACRONYMS

Abbreviation	Full Word
AEZ	Agro-Ecological Zone
BARI	Bangladesh Agricultural Research Institute
°C	Degree Celsius
cm	Centi-meter
CV	Coefficient of Variance
DAE	Days After Emergence
et al.	And others
g	Gram (s)
ha	Hectare (s)
Kg	Kilogram (s)
LSD	Least Significant Difference
L/ha	Liter per hectare
M^2	Meter square
No.	Number
SA	Surface Area
Var.	Variety

Chapter 1

Introduction

Chapter 1

INTRODUCTION

Mungbean (*Vigna radiata* L.) is one of the most important pulse crops in Bangladesh. It has good digestibility, flavor, and high protein content. Being a short duration crop it fits well into the intensive cropping system. However, it is one of the least cared crops. Mungbean is cultivated with minimum land preparation and without fertilizer application and insect, diseases or weed control. All these factors are responsible for low yield of mungbean. Average yield of mungbean is 514 kg ha^{-1} in Bangladesh (BBS, 1991).

Plant density is one of the most important yield contributing characters which can be manipulated to maximize yield (Babu and Mitra, 1989). Plant density plays an important role in the dominance and suppression during the process of competition of two or more species having similar life forms (Hashem, 1991). Ahmed *et al.* (1992) obtained greater yield of mungbean at higher density grown during early Kharif. Information on the effect of mungbean plant density on competition with weed grown during late Kharif is lacking in Bangladesh.

Weed is one of the most important factors responsible for low yield or crops (Islam *et al.*, 1989). Mungbean is not very competitive against weed and therefore weed control is essential for mungbean production (Moody, 1978). Yield losses due to uncontrolled weed growth in mungbean range from 27 to 100% (Madrid and Vega, 1971; AVRDC, 1976).

Dry weight of weed increases as the duration of weed competition increased in wheat (Islam *et al.*, 1989). All crops have a stage during their life cycle when they are particularly sensitive to weed competition. In general, it ranges up to first 25 to 50% of the life time of crops. Critical period of weed competition is the range within which a crop must be weeded to save the crop from ravages of weeds (Islam *et al.*, 1989). The critical period of weed competition in mungbean and time of weed control for maximum yield is not yet known in Bangladesh.

The rate of dry matter production in many crops is proportional to the intercepted radiation. The growth of crop is therefore, often analyzed in terms of intercepted radiation and the efficiency of conversion of solar radiation to dry weight (Gallagher and Biscoe, 1978). However, such relationship may be changed for a crop which is in competition with weed for solar radiation. The development of leaf area of mungbean may be modified by competition with weeds. Therefore, this experiment was conducted

1) to examine the effect of plant density and time of weeding on the plant characters, yield and yield attributes of mungbean
2) to quantify the relationship of mungbean seed yield to mungbean plant biomass and weed biomass
3) to study the combined effect of plant density and weed growth on the performance of mungbean
4) to compare the efficiency of different time of weeding on the performance of mungbean

Chapter 2

Review of literature

Chapter 2

REVIEW OF LITERATURE

Many studies addressed the effect of plant density and time of weed control on the performance of mungbean (*Vigna radiata* L.) and other crops. Results of such studies indicate that plant population density and weed interference have profound influence on yield, yield attributes, and biomass of crops. Some of the works that are relevant to the present study are reviewed here.

Plant density and mungbean performance

Griepentrog *et al.* (2000) also found that increasing wheat seed rates from 200-660 m^{-2} greatly increased weed suppression. However, sowing in a cross pattern at 12-8cm, compared with a normal row pattern at the same width, suppressed weed biomass by a further 30%. Yield also increased by 60% over normal row pattern at 400 seeds m^{-2}.

Provisional Scottish results indicate that row width of about 16cm gives better weed suppression than narrower or wider row widths, but these trials are being repeated over two further seasons (Davies and Hoad, 2000).

Researchers in Arkansas, Louisiana, and Texas summarized 21 field experiments conducted over 14 yr to determine the effect of row spacing on seed

Yield in soyabean (Bowers *et al.*, 2000). For all environments tested, narrow rows ($\leq$ 40 cm) yielded equal to or greater than wider rows.These researchers concluded that narrow rows should be used to optimize yields in soyabean in the Midsouthern USA.

Research under many conditions and locations throughout the USA has investigated adjusting plant populations and row spacing to achieve suitable vegetative growth and increase yield (Bullock *et al.*, 1998)

Boquet (1998) found that planting date and cultivars selection were the most important factors for increasing yields in Louisiana while row spacing was less significant.

Low planting density due to wide spacing has been identified as one of the reasons responsible for low yield of garlic (Abubakar, 1998).

Bodnar *et al.* (1998) reported that widely spaced garlic plants tend to grow more vegetatively and bear more leaves plant^{-1}.

Highest bulb yield was obtained from 10 cm intra-row spacing while 20 cm intra-row spacing gave the lowest bulb yield of onions (John, 1997).

The positive increase in bulb yield of garlic at closer spacing might be ascribed to increase plant population per unit land area while the decrease in bulb yield at wider intra-raw spacing could be associated with decreased plant population per unit land area. It can thus be seen that, the total yield per unit area depends not only on the performance of individual plants but also on the number of plants per unit area (Babaji, 1996; Abubakar,1997).

Ahmed *et al.* (1992) found that 50 plants m^{-2} of mungbean gave higher yield than 33 plants m^{-2} in early kharif.

Hamid (1989) found that mungbean grown at very high density failed to produce yield because of high rate of mortality.

Plant density is achieved by varying the row spacing. Seed yield of soybean was significantly higher with high population in narrow rows than in the wide rows (Ethredge *et al.*, 1989).

Plant density is the most important yield contributing character, which can maximize yield (Babu and Mitra, 1989).

Plant density has considerable effect on the suppression of weeds. Plant density, species proportion, and spatial arrangements are important considerations, that mediate the influence of environmental and biological factors (Radosevich, 1987).

Yield per hectare and number of seeds pod^{-1} increased with increasing plant density whereas yield per plant and number of pods $plant^{-1}$ decreased with increasing plant density in mungbean (Panwar and Sirohi, 1987).

In Arkansas, Beatty and Aulakh (1982) adjusted plant population with row spacing and found that April plantings in 18-cm rows with 60 seeds m^{-2} and 48-cm rows with 46 seeds m^{-2} yielded more than May or June plantings at any row spacing.

High yield of good quality pod can be obtained from increased plant density and weed free environment in *vigna unguiculata* (Brathwaite, 1982).

Per plant dry matter yield decreased progressively with increasing density. Grain yield plant^{-1} decreased with increasing density but the yield density function constructed based on grain yield/unit area followed a quadratic relationship. Increased plant density resulted in plants bearing less pod and seed in *Vicia fava* L. (Zahab *et al.*, 1981).

Increase in the planted density of crops is expected to suppress weed growth (Radosevich, 1987; Martin *et al.*, 1987). The use of crop to compete against weeds and suppress them is a weed control techniques that is often overlooked (Moody, 1978).

One approach of elevating the seed yield of mungbean by Asian Vegetables Research and Development center (AVRDC) is to increase yield by increasing plant density (Mackenzie *et al.*, 1975).

The yield of mungbean does not increase linearly with increase in density as it does in soybean. The number of pods per plant of mungbean decreases as density increases unlike soybean (MacKenzie *et al.*, 1975).

Time of weed control and mungbean performance

Weeds remain one of the most significant agronomic problems associated with organic arable crop production. It is recognised that a low weed population can be beneficial to the crop as it provides food and habitat for a range of beneficial organisms (Aebischer and Fuller, 1998).

Ahmed *et al.* (1992) found that one hand weeding at 10 or 20 DAE produced higher yield than unweeded plots in mungbean during early kharif.

Ahmed *et al.* (1992) also observed highest grain yield of mungbean when weeded at 10 DAE.

The critical weed-free period represents the time interval between two separated measured components: the maximum weed-infested period or the length of time that weeds which have emerged with the crop can remain before they begin to interfere with crop growth; and the minimum weed free period or the length of time a crop must be free of weeds after planting in order to prevent yield loss (Weaver *et al.*, 1992).

Bulb yield losses of about 79 - 89% due to weed infestation have been reported (Ahmed, 1991).

Weeds can significantly reduce crop yield and quality in conventional and organic (Bulson, 1991) crops.

Maximum seed yield was obtained when weeds were removed 20 days after sowing. In competition study, 20 % yield reduction in soybean occurred if weed control measure was not taken prior to 5weeks after emegence (Crook and Renner, 1990; Marwat and Nafziger, 1990).

The critical period of crop/weed competition was determined in mungbean (Kumar and Kairon, 1990; in cotton (Bryson, 1990); in wheat (Islam *et al.*, 1989) and in mustard (Dashora *et al.*, 1990).

Critical period of weed competition is the minimum weed free period essential during the life cycle of a crop to prevent yield loss. The critical period of weed control in interference study is the period up to which the weeds would be allowed without significant yield losses of crops (Bryson, 1990).

Every crop has a stage during its life cycle when it is particularly sensitive to weed competition (Islam *et al.*, 1989).

Kumar and Kairon (1988) found that weed biomass increased and mungbean yield decreased with delay in weeding. However, delay in weeding did not affect the number of seeds pod^{-1}.

Dry matter was maximum under weed free condition followed by weed removal at 30 and 40 days after sowing (Kumar and Kairon, 1988).

Higher yield of mungbean was observed in the early-weeded plots compared to late/unweeded plots (Singh *et al.*, 1988).

Pascua (1988) determined the critical period of weed control and competition on mungbean yield. The treatments that gave lower fresh weight of weed had higher number of seeds pod^{-1}. Higher percent yield reduction was recorded when the mungbean plants were exposed to longer weed competition.

Karim *et al.* (1986), found that critical period of weed competition was in between 20 and 30 days after sowing in jute. The critical period of crop/weed competition was determined in direct seeded Aus rice (Mamun *et al.*, 1986), transplanted Aus rice (Ahmed *et al.*, 1986).

Sarker and Mondal (1985) observed that weeding at different dates after sowing affected some yield contributing characters and yield of mungbean. Grain yield was reduced by 49 to 55% when weeds were not removed at all.

Variable number of weedings in mungbean have been suggested viz., one weeding at 2 weeks after emergence (Sarker and Mondal, 1985), two weedings during early growth stage (Madrid and Vega, 1984).

Removal of weeds at 10, 20 or 30 days after sowing produced higher yields of mungbean than weedy check (Yadav *et al.*, 1983).

The harmful effect of weed infestation does not begin just after emergence of seedling, rather the competition between the weeds and crop is the most severe at a particular stage of crop growth which is known as critical period of crop-weed competition (Shahota and Govinda, 1982).

Soybean seed weight, seeds pod^{-1}, pods $plant^{-1}$ was reduced due to long duration of wild oat competition (Rathmann and Miller, 1981).

The knowledge of critical period of weed competition is a pre-requisite for a good harvest. Panwar and Singh (1980) reported that weeding of mungbean at 20 DAE could effectively produce yields twice than that of unweeded plots.

Mungbean is not very competitive against weeds and, therefore, weed control is essential for mungbean production (Moody, 1978).

The yield loss of barley grain due to weed infestation ranges from 10-35% (Gupta and Lamb, 1978), it may even range upto 100% (Mann and Barnes, 1977).

The yield loss of mungbean was 95% during dry season in Philippines (Madrid and Vega, 1971). Yield losses due to uncontrolled weed growth in mungbean range from 27% to 100% (AVRDC, 1976; Vats and Sidhu, 1976; Madrid and Manimtim, 1977).

Vats and Sidhu (1976) reported that weeding in greengram two weeks after sowing was significantly superior to weeding four or eight weeks after sowing.

The magnitude of yield loss due to weed depends on environmental condition and weed growth. Yield loss was 60% during spring and 27% during the summer in Taiwan (AVRDC, 1976).

Enyi (1973) reported that weeding up to 8weeks after sowing is reported for optimum yield of mungbean.

Enyi (1973) also reported that weed competition causes reduction in the number of pods plant^{-1}.

The longer the weeds are allowed to compete with crops, the lower is the yield of crop. Madrid and Vega (1971) reported that mungbean needs to be weeded for the first 5 weeks during wet season and only for 3 weeks during the dry season.

Weed is one of the major constraints to high production of this crop during the kharif season (Mian *et al.*, 1970).

Chapter 3

Materials and Methods

Chapter 3
MATERIALS AND METHODS

The experiment was carried out during the period from April to June 2007 at the Agricultural Field Laboratory, Sher-e-Bangla Agricultural University, Dhaka. The experiment was designed to study the performance of mungbean under different treatments of plant densities and time of weeding.

3.1 Description of the experimental site

3.1.1 Site and soil

The experiment was conducted at the Field Laboratory, Sher-e-Bangla Agricultural University, Sher-e-Bangla Nagar, Dhaka-1207 that lies between $90^0 22'$ E longitude and $23^0 41'$ N latitude at an altitude of 8.6 meters above the sea level. The land was in Agro-ecological region of "Madhupur Tract" (AEZ No. 28). It was Deep Red Brown Terrace soil and belonged to "Nodda" cultivated series. The soil was sandy loam in texture having pH 5.47 - 5.63. The physical and chemical characteristics of the field soil have been presented in Appendix I.

3.1.2 Climate and weather

The climate of the locality is sub tropical. The climate is characterized by high temperature and heavy rainfall during kharif-I season (April to June) and scanty rainfall during rest of the year. The prevailing weather data during the study period have been presented in Appendix II.

3.2 Planting Materials

The variety BARI Mung-6 was used as the test crop. The seeds were collected from the Pulse Research Station of Bangladesh Agricultural Research Institute, Joydevpur, Gazipur. BARI Mung-6 is a recommended variety of mungbean, which was developed by the Pulse Research Center (PRC). It grows both in kharif and late rabi season. . Life cycle of this variety ranges from 55 to 6o days. The variety is tolerant to diseases, insects and pest attack.

3.3 Treatments under study

Factor-1 (Plant density):

1. $30 \times 10\ cm^2 = 33$ plants $m^{-2} = D_1$
2. $25 \times 10\ cm^2 = 40$ plants $m^{-2} = D_2$
3. $30 \times 5\ cm^2 = 66$ plants $m^{-2} = D_3$

Factor-2 (Time of weeding):

1. No weeding (Control)= W_1
2. Weeding at 15 days after emergence (DAE)=W_2
3. Weeding at 30 days after emergence (DAE)=W_3
4. Weeding at 45days after emergence (DAE)= W_4

Combination of the treatment:

1. No weeding + 33 plants m^{-2} (W_1D_1)
2. No weeding + 40 plants m^{-2} (W_1D_2)
3. No weeding + 66 plants m^{-2} (W_1D_3)
4. Weeding at 15 DAE + 33 plants m^{-2} (W_2D_1)
5. Weeding at 15 DAE + 40 plants m^{-2} (W_2D_2)
6. Weeding at 15 DAE + 66 plants m^{-2} (W_2D_3)
7. Weeding at 30 DAE + 33 plants m^{-2} (W_3D_1)
8. Weeding at 30 DAE + 40 plants m^{-2} (W_3D_2)
9. Weeding at 30 DAE + 66 plants m^{-2} (W_3D_3)
10. Weeding at 45 DAE + 33 plants m^{-2} (W_4D_1)
11. Weeding at 45 DAE + 40 plants m^{-2} (W_4D_2)
12. Weeding at 45 DAE + 66 plants m^{-2} (W_4D_3)

3.4 Experimental design and layout

The experiment was laid out in a randomized completely block design (RCBD) (factorial) with three replications on 18 April, 2007. There were 36 plots. The size of each unit plot was 3mx2m, and distance between unit plots was 1m. Each replication was separated from another by 0.75 meter.

3.5 Land preparation

The land was ploughed with a rotary plough and power tiller. Ploughed soil was then brought into desirable fine tilth and leveled by four ploughing operations and repeated laddering. The land was fallow, so the weeds of fallow land were cleaned properly. The final ploughing and land preparation were done on April 14, 2007. The plots were laid out as per design in the field on 18 April, 2007.

3.6 Application of fertilizer

The experimental area was fertilized with 20-40-25 N_2, P_2O_5 and K_2O Kg ha^{-1} in the form of Urea, Triple Super Phosphate (TSP) and Muriate of potash (MP). All the fertilizers were incorporated into soil before sowing seeds.

3.7 Germination test

Before sowing the germination test of seed was done in Petri dish in laboratory condition and percentage of seed germination was found 98%.

3.8 Sowing and seed rate

The seeds were sown at the rate of 25 kg ha^{-1} by hand on 18 April, 2007. The seeds were soaked in water for four hours prior to sowing. Two to three seeds per hill were sown in rows 30 cm apart line with 10 cm, 25 cm apart line with 10 cm and 30 cm apart line with 5 cm between seeds within row for obtaining 33 plants m^{-2}, 40 plants m^{-2} and 66 plants m^{-2} respectively.

3.9 Intercultural operations

3.9.1 Thinning and weeding

The seeds emerged on 20 April, 2007.The plants were thinned to one per hill at 12 and 13 DAE. All treatments were weeded once except unweeded plots.

3.9.2 Irrigation and drainage

The experimental plots were irrigated with check-basin irrigation at 14, 36, and 43 DAE. Drainage operation for draining out of rain water was done as and when required for proper growth and development of crop.

3.9.3 Pest management and plant protection

Necessary plant protection measures against insects and diseases were taken. Dimecron was sprayed @ 3 l ha^{-1} on 5, 14 and 20 DAE to control flee beetle. Sumithion was sprayed on 35, and 50 DAE @ 3 l ha^{-1} to control pod borer. To control downey mildew, Diathane M-45 was applied @ 3 kg ha^{-1}.

3.10 Harvesting and threshing

The crop was harvested at 60 & 64 DAE. The crop was harvested plot-wise when about 80% of the pods became mature. Samples were collected from different places of each plot leaving undisturbed one meter square in the centre. The harvested crops were tied into bundles and carried to the threshing floor. The crop bundles were sun dried by spreading those on the threshing floor. The seeds were separated, cleaned and dried in the sun for 3 to 4 consecutive days for achieving safe moisture of seed.

3.11 Drying and weighing

The seeds thus collected were dried into 6-8 % moisture contents. Dried seeds and stovers (Oven dry basis) of each plot was weighed and subsequently converted into yield kg ha^{-1}.

3.12 Sampling and collection of experimental data

Data were collected from ten randomly selected plants from each unit plot on the following yield and yield attributes parameters.

3.12.1 Plant height (cm)

The height of each sample plant was measured unit plot wise from the base of the plant to the tip at harvest and mean plant height was determined in cm.

3.12.2 Plant population, biomass of mungbean and weed

Plants were destructively sampled at 29 DAE from $1m^2$ area. Plant number and dry matter of mungbean were recorded. Weeds removed from plots were washed in water and dried in oven at 70^0C and dry biomass of weed was recorded. For no-weeding treatment, weed biomass was recorded during crop duration. Final dry weight of weeding plots is the sum of dry weed weights of successive harvests including that of final harvest.

3.12.3 Number of branches per plant

The number of branches per plant was counted from total branches of ten sampled plants and then averaged.

3.12.4 Number of nodes per plant

The number of nodes per plant was counted from ten sampled plants and then averaged.

3.12.5 Number of pods per plant

All the pods borne on all ten sample plants of each unit plot were counted to determine the average number of pods per plant.

3.12.6 Number of seeds per pod

From each sample plant of each unit plot, 5 pods were randomly selected and all the seeds of them were counted, the number of seeds per pod was determined by averaging the data.

3.12.7 Weight of 1000 seeds (g)

A composite sample was taken from the yield of ten tagged plants. 1000 seeds of each plot were counted and weighed with a fine electric digital balance. The 1000 seed weight was recorded in g.

3.12.8 Seed yield (t/ha)

$1m \times 1m = 1m^2$ areas were selected in middle points of each plot for recording seed yield per hectare. The total produce from the net area of each plot was cleaned and weighed and computed the seed yield in kg per hectare.

3.12.9 Percent of maximum mungbean biomass and biomass loss

Percent of maximum biomass for plant density was determined by the following formula:

$$\text{Maximum biomass (\%)} = \frac{\text{Biomass recorded at individual plant density}}{\text{Maximum biomass}} \times 100$$

Percent of maximum biomass in case of time of weeding was calculated followed by above formula.

Percent of mungbean biomass loss for plant density was determined by the following formula:

Mungbean biomass loss (%)

$$= \frac{\text{Maximum biomass - Biomass recorded at individual plant density}}{\text{Maximum biomass}} \times 100$$

Percent of mungbean biomass loss in case of time of weeding was determined followed by above formula.

3.12.10 Percent of maximum yield and yield loss

Percent of maximum yield for plant density was determined by the following formula:

$$\text{Maximum yield (\%)} = \frac{\text{Yield recorded at individual plant density}}{\text{Maximum yield}} \times 100$$

Percent of maximum yield in case of time of weeding was calculated followed by above formula.

Percent of mungbean yield loss for plant density was determined by the following formula:

Mungbean yield loss (%)

$$= \frac{\text{Maximum yield - Yield recorded at individual plant density}}{\text{Maximum yield}} \times 100$$

Percent of mungbean yield loss in case of time of weeding was determined followed by above formula.

3.13 Data analysis

Analyses of variance (ANOVA) were performed on plant characters, yield and yield attributes. The means were separated and compared by LSD at 0.05% level of significance. Linear regression models were developed on the relationship of yield with weed biomass and mungbean biomass. Correlation was performed on some characteristics. All analyses were done by MSTAT.

Chapter 4

Results and Discussion

Chapter 4

RESULTS AND DISCUSSION

The experiment was conducted to evaluate the effect of plant density and time of weeding on plant characters, yield and yield attributes of mungbean. The parameters studied were plant height(cm), number of branches plant^{-1}, number of nodes plant^{-1}, plant population(no. m^{-2}), number of pods plant^{-1}, number of seeds pod^{-1},1000 seed-weight, yield(kg ha^{-1}),mungbean biomass (g.m^{-2}), weed biomass (g.m^{-2}), percent of maximum biomass, mungbean biomass loss(%), maximum seed yield(%), loss of seed yield(%).

The results obtained from this study are presented in Tables1 through 7 and Figures1 through 20. The experimental site under this study has been presented in Appendix I. The layout of the experimental plot has been presented in appendix II. The prevailing temperature and total rainfalls for each month during the period of study are presented in Appendix III. The mean square values in respect of the above parameters together with the source of variation and their corresponding degrees of freedom have been presented in the appendix V, VI and VII. Mungbean does not grow if temperature falls below 20^0C. The minimum temperature during the growing season (April to June, 2007) of mungbean in this study was >24^0C.The results have been presented and discussed as below

4.1 Floristic composition of weed species

As many as 17 different weed species are found to infest the mungbean experimental plots. Among them the dominant weed species are *Cyperus rotundus, Cynodon dactylon, Echinochloa colonum, Leucas aspera spreng, Digitaria sanguinalis, Eclipta prostata, Enhydra flactuans, Paspalum commersonii. Cyperus rotundus* was the most dominant (28%) weed species on mungbean followed by *Cynodon dactylon* (21%), *Echinochloa colonum* (19.6%) and so on (Table1). Other nine weed species viz. *Amaranthus viridis, Cyperus diformis, Euphorbia thymefolia, Leptochola chinensis, Cyperus miliacea, Jussia limifolia, Physalis heterophylla, Solanum torvum and Portulaca oleracea, were* sporadically observed.

The weed count of all the species was higher in unweeded plots than in the weeded plots where the weed counts for unweeded plots m^{-2} were 70.22, 50.28, 48.37, 25.57 and 17.57 respectively for the weed species of *Cyperus rotundus, Cynodon dactylon, Echinochloa colonum, Leucas aspera spreng,* and *Digitaria sanguinalis* while the weed counts for the corresponding weeded plots m^{-2} of the same species were 20.82, 17.54, 15.76, 3.55 and 2.55. On average the weed counts in the unweeded plots was four to five times higher than the weeded plots.

The weed count was also affected by mungbean density. It revealed from the table1 that there was a gradual reduction in weed count from the lower to higher of mungbean plants viz. in case of the weed species of *Cyperus rotundus*, the number of weed m^{-2} while at density of 33 m^{-2} was 35.52, but at 40 m^{-2} and at 66 plant m^{-2} it was 32.28 and 25.23 respectively that is on average there was 25 to 30% reduction in weed counts from the higher density (66 plants m^{-2}). This amount of weed suppression due to high population density might have an influence in regulating future population of weed species.

Table 1. Floristic composition of weed species as recorded at final harvest in weeded and unweeded plots at 33 plants m^{-2}, 40 plants m^{-2} and 66 plants m^{-2} densities of mungbean

Name of weed species	No. of weed plants m^{-2}		Average total weed plants (No. m^{-2})	% of average total weed plants	No. of weed plants m^{-2} at		
	Weeded	Unweeded			33 plants m^{-2}	40 plants m^{-2}	66 plants m^{-2}
Cyperus rotundus L.	20.82	70.22	45.52	27.77	35.32	32.28	25.23
Cynodon dactylon L.	17.54	50.28	33.91	20.69	27.37	25.27	18.87
Echnichloa colonum	15.76	48.37	32.065	19.56	23.22	21.78	15.44
Leucas aspera spreng	3.55	25.57	14.56	8.89	5.56	4.45	3.25
Paspulum commersonii	5.27	18.78	12.025	7.33	9.56	10.56	6.67
Digitaria sanguinalis	2.55	17.57	10.06	6.13	3.88	3.29	1.88
Enhydra flactuans	3.73	15.15	9.443	5.76	3.27	2.98	2.22
Eclipta prostata	2.11	10.58	6.33	3.87	7.22	3.22	2.76
Total	71.33	256.56	163.945	100	115.4	103.83	76.42

Plant characters of mungbean

4.2 Plant height

4.2.1 Effect of plant density

There was significant influence of plant density on the plant height of mungbean (Appendix V and Table 2). Plant density of 33 plants m^{-2} maintained the tallest plant of 58.80 cm, which was significantly different from others. The second highest (57.76 cm) was from the plant density of 66 plants m^{-2}. Though there was significant variation of plant height due to variation in plant density but apparently from numerical point of view, it was negligible. However the lowest plant density i.e. widest spacing produced the tallest plant.

4.2.2 Effect of time of weeding

Time of weeding kept significant influence on plant height of mungbean (Appendix V Table 3). Weeding at 15 DAE (W_2) produced the tallest plant of 60.81 cm height. Weeding at 30 DAE produced the shortest plant of 51.40 cm height. Of course no weeding (W_1) produced the second highest tall plants of 59.90 cm height. Results indicated that early weeding operation favoured the mungbean plants to have better growth and produced the tallest plants.

4.2.3 Combined effect of plant density and time of weeding

Interaction effect of plant density and weeding time had a significant effect on the plant height of mungbean crops under study (Appendix V Table 4). The interaction effect of plant density of 66 plants m^{-2} and weeding at 15 DAE produced the tallest plant of 64.58 cm height, which was significantly different from other plant height. The second highest plant (60.45 cm) which was identical to 60.37 cm obtained from the interaction treatment of D_3W_4 i.e. interaction of plant density of 66 plants m^{-2} × 45 DAE weeding while 60.37cm was obtained from D_3W_1 i.e. Plant density of 66 plants m^{-2} × no weeding. The results revealed that density of 66 plants m^{-2} also in the interaction effect plays significant role in producing the tallest plant of mungbean. Second highest density of mungbean plants i.e. 40 plants m^{-2} in combination with weeding operation time of both control and 45 DAE recorded the 3rd highest plant height of 59.76 cm and 59.47 cm respectively, which are similar to each other. With the declination of plant density of mungbean plant height of the mungbean plants decreased showing irrespective effect of weeding time in interaction.

Table 2. Response of mungbean crop to some plant characters as influenced by plant density

Treatment	Plant height (cm)	No. of branches plant^{-1}	No. of nodes plant^{-1}
33 p m^{-2} (D_1)	58.80 a	3.14 a	9.18 a
40 p m^{-2} (D_2)	57.21 c	2.90 c	8.52 b
66 p m^{-2} (D_3)	57.76 b	3.07 b	7.87 c
$LSD_{0.05}$	0.179	0.065	0.053
CV (%)	0.37	2.60	0.74

In a column the means bearing similar letter (s) are identical and those having dissimilar letter (s) differ significantly (as per MSTAT)

Table 3. Response of mungbean crop to some plant characters as influenced by time of weeding

Treatment	Plant height (cm)	No. of branches plant^{-1}	No. of nodes plant^{-1}
W_1 = No weeding	59.99 b	2.69 c	7.78 d
W_2 = 15 DAE	60.81 a	3.73 a	9.56 a
W_3 = 30 DAE	51.40 d	2.76 c	8.75 b
W_4 = 45 DAE	59.50 c	2.97 b	7.98 c
$LSD_{0.05}$	0.207	0.075	0.061
CV (%)	0.37	2.60	0.74

In a column the means bearing similar letter (s) are identical and those having dissimilar letter (s) differ significantly (as per MSTAT)

4.3 Number of branches plant^{-1}

4.3.1 Effect of plant density

The three different densities of mungbean plants viz. 33, 40 and 66 plants m^{-2} showed significant variation in influencing number of branches plant^{-1} (Appendix V & Table 2). The lowest plant density i.e. 33 plants m^{-2} recoded significantly the highest number of branches plant^{-1} (3.14). The second highest (3.08) which was statistically different from the third highest or lowest number of branches plant^{-1} (2.90) was observed from the plant density of 40 plants m^{-2} (W_2). It is apparent from the results that widest spacing recorded more number of branches plant^{-1} compared to shorter spacing. This means that the plants in wider spacing provided more space for producing branches compared to shorter spacing. These findings were in agreement with Bodnar *et al.* (1998).

4.3.2 Effect of time of weeding

Weeding time influenced significantly on the plant characters of number of branches plant^{-1}(Appendix V). Weeding at 15 DAE produced the highest number of branches plant^{-1} (3.73) while weeding at 45 DAE produced the 2nd highest number of branches plant^{-1} (2.97). Weeding at 30DAE and no weeding produced the identical number of branches plant^{-1} such as 2.77 and 2.70 respectively (Table 3). Early weeding provided better environment for producing branches plant^{-1} compared to other weeding activities.

Table 4. Response of mungbean crop to some plant characters as influenced by the interaction of plant density and time of weeding

Treatment combination	Plant height (cm)	No. of branches plant^{-1}	No. of nodes plant^{-1}
$W_1D_1 = T_1$	59.84 c	2.67 g	8.23 d
$W_1D_2 = T_2$	59.76 c	2.35 h	7.89 c
$W_1D_3 = T_3$	60.37 b	3.06 cd	7.22 h
$W_2D_1 = T_4$	58.92 d	3.94 a	10.17 a
$W_2D_2 = T_5$	58.93 d	3.57 b	9.65 b
$W_2D_3 = T_6$	64.58 a	3.66 b	8.87 c
$W_3D_1 = T_7$	57.87 e	2.97 de	9.55 b
$W_3D_2 = T_8$	50.69 f	2.86 ef	8.86 c
$W_3D_3 = T_9$	45.63 g	2.47 h	7.84 e
$W_4D_1 = T_{10}$	58.58 d	2.96 de	8.76 c
$W_4D_2 = T_{11}$	59.47 c	2.82 f	7.66 f
$W_4D_3 = T_{12}$	60.45 b	3.11 c	7.52 g
$LSD_{0.05}$	0.359	0.131	0.107
CV (%)	0.37	2.60	0.74

In a column the means bearing similar letter (s) are identical and those having dissimilar letter (s) differ significantly (as per MSTAT)

4.3.3 Combined effect of plant density and time of weeding

Interaction effect of plant density and weeding time showed significant influence on number of branches plant^{-1} (Appendix V and Table 4). The interaction effect of plant density of 33 plants m^{-2} and weeding at 15 DAE (D_1W_2) was found to maintain highest number of branches plant^{-1} (3.94) which was significantly different from others. The second highest number of branches plant^{-1} obtained from plant density of 66 plant m^{-2} × weeding at 15 DAE (D_3W_2) was 3.67 which was followed by 3.58 obtained from the interaction treatment of plant density 40 plant m^{-2} × weeding at 15 DAE (D_2W_2). From the results depicted it revealed that early weeding with any plant density performed better in producing branches plant^{-1} compared to late and no weeding. Of course the highest number of branches plant^{-1} (3.94) was found to be obtained from early weeding (15DAE) coupled with sparse plant density 33 plants m^{-2}. The combined effect of early weeding and lowest plant density provided weed free as well as sufficient space for the formation of branches. No weeding coupled with plant density of medium and sparse performed worst in respect of producing number of branches plant^{-1}.

4.4 Number of nodes plant^{-1}

4.4.1 Effect of plant density

Number of nodes plant^{-1} was significantly influenced by density of mungbean (Appendix V and Table 2). The highest number of nodes plant^{-1} (9.18) was recorded from the treatment of plant density of 33 plants m^{-2} while the second highest (8.52) was found from the treatment of plant density of 40 plants m^{-2}. The lowest number of nodes plant^{-1} (7.87) was produced from the plant density of 66 plants m^{-2}. It is evident from the results that increasing plant density caused decreasing the number of nodes plant^{-1}. Similar results were also found in mungbean by Singh *et al.* (1990).

4.4.2 Effect of time of weeding

Time of weeding also showed significant effect on number of nodes plant^{-1} (Appendix V Table 3). The highest number of nodes plant^{-1} (9.57) was found in the plant weeded at 15 DAE. The plants weeded at 30 DAE had produced the second highest (8.76) number of nodes plant^{-1}. The lowest number of nodes plant^{-1} (7.78) was found in the control plants. However, if weeds were allowed to compete beyond 30 DAE, number of nodes plant^{-1} was reduced.

4.4.3 Combined effect of plant density and time of weeding

Interaction effect of plant density and time of weeding significantly influenced number of nodes plant^{-1} (Appendix V and Table 4). The highest number of nodes plant^{-1} (10.17) was found at 33 plants m^{-2} when weeded at 15 DAE and lowest number of nodes plant^{-1} (7.23) was found at high-density i.e. 66 plants m^{-2} that remained unweeded. Generally number of nodes plant^{-1} at 33 plants m^{-2} and 40 plants m^{-2} was higher when weeded at 15 DAE and 30 DAE than plants at high-density i.e. 66 plants m^{-2}. Effect of plant density on number of nodes plant^{-1} was diminished if plants were not weeded at all.

Yield and yield attributes of mungbean

4.5 Plant population

4.5.1 Effect of plant density

Mungbean plant density i.e. plant spacing showed significant effect on mungbean plant population (Appendix V and Table 5).

Among the 3 spacing, the spacing of 30 × 5 cm^2 i.e. the plant density of 66 plants m^2 (D_3) showed significantly the highest plant population of mungbean (57.25). The second highest plant population (34.25) was obtained from the plant spacing of 25 × 10 cm^2 i.e. 40 plants m^{-2} (D_2) spacing while significantly the lowest plant population (29.17) was observed from the plant density of 33 plants m^{-2} spacing. The results indicated that the higher the plant density higher was the mungbean plant population. The similar findings were also reported by Abubakar (1997), Babaji (1996), Ethredge *et al.* (1989), Hossain and Gill (1974).

4.5.2 Effect of time of weeding

Plant population also varied significantly with the variation of time of weeding (Appendix V Table 6). Weeding at 15 DAE (W_2) maintained highest plant population (44.00) in mungbean which was significantly different from 41.33, 39.22 and 36.33, the number of plant population recorded respectively from weeding at 30 DAE (W_3), 45 DAE (W_4) and from control (W_1). Unweeded plots maintained lowest number of plant population as the plants of those plots faced severe competition with different weed species. Weeding at 30 DAE maintained second highest plant population (41.33) which was significantly higher than the 3rd highest (39.22) as well as than the lowest plant populations (36.33) recorded from the control. It reveals from the results that early weeding maintained higher plant population compared to late weeding. These findings supported the findings of Sarkar and Mondal (1985).

4.5.3 Combined effect of plant density and time of weeding

Interaction effect of weeding of mungbean and plant density influenced the plant population of mungbean m^{-2} (Appendix V Table 7).The highest plant population of mungbean (62.00) was observed in the combined effect of plant density of 66 plants m^{-2} and weeding at 15 DAE (D_3W_3). The second highest plant population m^{-2} (54.00) was found with both the interaction effect of D_3W_1 (Plant density of 66 plant m^{-2} + no weeding) and D_3W_4 (Plant density of 66 plants m^{-2} + weeding at 45 DAE). These findings indicated that highest plant density 66 plants m^{-2} of mungbean showed a dominant role in the interaction effect with weeding time on the mungbean plant population. The 4^{th} highest plant population m^{-2} (37.00) was found from the interaction treatment of D_1W_1.There was a gradual decrease of plant population in the interaction effect with the decrease of plant density in combination with weeding time showing 15DAE of weeding with 66 plants m^{-2} was the most effective.

Table 5. Effect of plant density on yield and yield attributes of mungbean

Plant density	Plant population (No. m^{-2})	No. of pods $plant^{-1}$	No. of seeds pod^{-1}	1000 seed weight (g)	Yield (kg ha^{-1})
33 p m^{-2} (D_1)	29.17 c	12.81 a	10.76 a	28.60 a	486.3 c
40 p m^{-2} (D_2)	34.25 b	12.45 b	10.457 b	27.94 b	605.5 b
66 p m^{-2} (D_3)	57.25 a	11.14 c	9.822 c	26.42 c	899.2 a
$LSD_{0.05}$	0.858	0.128	0.070	0.080	12.19
CV (%)	2.52	1.24	0.79	0.34	2.17

In a column the means bearing similar letter (s) are identical and those having dissimilar letter (s) differ significantly (as per MSTAT)

Table 6. Effect of time of weeding on yield and yield attributes of mungbean

Time of weeding	Plant population (No. m^{-2})	No. of pods $plant^{-1}$	No. of seeds pod^{-1}	1000 seed weight (g)	Yield (kg ha^{-1})
W_1 = No weeding	36.33 d	7.98 d	9.69 c	27.00 c	413.9 d
W_2 = 15 DAE	44.00 a	15.17 a	11.08 a	29.79 a	898.3 a
W_3 = 30 DAE	41.33 b	13.95 b	10.86 b	27.59 b	789.7 b
W_4 = 45 DAE	39.22 c	11.44 c	9.74 c	26.24 d	552.7 c
$LSD_{0.05}$	0.991	0.148	0.081	0.092	14.07
CV (%)	2.52	1.24	0.79	0.34	2.17

In a column the means bearing similar letter (s) are identical and those having dissimilar letter (s) differ significantly (as per MSTAT)

4.6 Number of pods plant^{-1}

4.6.1 Effect of plant density

Three different plant densities showed significantly different number of pods plant^{-1} (Appendix V and Table 5). Smallest plant density (33 plants m^{-2}) produced the highest number of pods plant^{-1} (12.81) while the highest plant density (66 plants m^{-2}) produced the lowest number of pods plant^{-1} (11.14) and medium plant density (40 plants m^{-2}) produced the medium number of pods plant^{-1} (12.45). Correlation exists between number of branches plant^{-1} and number of pods plant^{-1}, sparse plant density and plant population, more plants and more branches, and as a result more pods. Panwar and Sirohi (1987) also reported that number of pods plant^{-1} decreased with increasing plant density in mungbean.

4.6.2 Effect of time of weeding

Four different weeding times also showed four distinctly different number of pods in mungbean crops (Table 6). Significantly the highest number of pods plant^{-1} (15.17) was found to be recorded from early weeding i.e. weeding at 15 DAE and the medium (30 DAE) and late (45 DAE) weeding produced respectively 13.95 and 11.44 number of pods plant^{-1} while the last one was significantly the lowest number of pods plant^{-1} (7.98) was produced by no weeding i.e. the control treatment. The results indicated that weeding at early stage showed beneficial effect in producing pods due to maintain almost weed free situation. On the other hand, no weeding and late weeding failed to address the weed infestation problem and resultantly there was reduction in number of pods plant^{-1}. These findings were in conformity with those of Enyi (1973), Madrid and Vega (1971) and Moody (1978).

4.6.3 Combined effect of plant density and time of weeding

Number of pods plant^{-1} in mungbean plant under study was also significantly influenced by the combined effect of plant density and weeding time (Appendix V). As revealed from the table 7. it was observed that early and medium period weeding i.e. 15 and 30 DAE in combination with lowest/medium plant density i.e. 33/40 plants m^{-2} were able to produce more number of pods plant^{-1} compared to the interaction of late/no weeding with dense population i.e. 66 plants m^{-2}. The highest number of pods plant^{-1} (15.77), which was statistically similar to 15.54, was recorded from the treatment combination of W_2D_1 while the later value (15.54) was obtained from W_2D_2. These two values of number of pods plant^{-1} though were similar to each other; each of them was significantly superior to the other values of pods plant^{-1} obtained by the rest interactions. The second highest values of pods plant^{-1} were 14.94 and 14.76 which were similar to each other but were significantly higher than those of the other values. These two values (14.94 and 14.76) were respectively produced by the treatment combination of medium time weeding i.e. at 30 DAE with lowest medium density population. The interaction of late weeding/no weeding with dense plant density (D_3) caused reduction in the number of pods plant^{-1} and as such the lowest number of pods plant^{-1} was found to be obtained from the interaction treatment of W_1 D_3 (No weeding × 66 plants m^{-2}).

Table 7. Interaction effect of plant density and time of weeding on yield and yield attributes of mungbean

Treatment Combination	Plant population (No. m^{-2})	No. of pods $plant^{-1}$	No. of seeds pod^{-1}	1000 seed weight (g)	Yield (kg ha^{-1})
$W_1D_1 = T_1$	25.00 h	8.227 g	10.42 f	27.51d	230.7 k
$W_1D_2 = T_2$	30.00 g	8.157 g	9457 h	27.23 e	318.0 j
$W_1D_3 = T_3$	54.00 c	7.557 h	9.22 i	26.25 g	693.0 e
$W_2D_1 = T_4$	33.00 f	15.77 a	11.66 a	30.43 a	651.7 f
$W_2D_2 = T_5$	37.00 d	15.54 a	10.88 c	30.37 a	823.7 c
$W_2D_3 = T_6$	62.00 a	14.19 c	10.69 de	28.58 b	1220 a
$W_3D_1 = T_7$	30.00 g	14.94 b	10.75 cd	28.61 b	621.7 g
$W_3D_2 = T_8$	35.00 e	14.76 b	11.24 b	27.56 d	806.0 c
$W_3D_3 = T_9$	54.00 b	12.15 d	10.59 e	26.58 f	941.3 b
$W_4D_1 = T_{10}$	28.67 g	12.32 d	10.20 g	27.86 c	441.0 i
$W_4D_2 = T_{11}$	35.00 e	11.34 e	10.25 g	26.58 f	474.3 h
$W_4D_3 = T_{12}$	54.00 c	10.97 f	8.793 j	24.27 h	742.7 d
$LSD_{0.05}$	1.717	0.256	0.141	0.160	24.37
CV (%)	2.52	1.24	0.79	0.34	2.17

In a column the means bearing similar letter (s) are identical and those having dissimilar letter (s) differ significantly (as per MSTAT)

4.7 Number of seeds pod^{-1}

4.7.1 Effect of plant density

The response of plant density to number of seeds pod^{-1} in mungbean was significantly affected (Appendix V and Table 5). Seeds pod^{-1} was the highest in number (10.76) in response to the lowest plant density (33 plants m^{-2}) while 2nd (10.45) and 3rd (9.82) highest number of seeds pod^{-1} were respectively observed in mungbean plants in response to medium plant density (40 plants m^{-2}) and highest plant density (66 plants m^{-2}). It is obvious from the above findings that widest spacing produced highest number of seeds pod^{-1} and closest spacing the lowest number of seeds pod^{-1} i.e. mungbean plants facing less competition for resources themselves produced more number of pods plant^{-1} as well as more number of seeds pod^{-1}. Zahab *et al.* (1981) also reported that increasing plant density resulted in plants bearing less pod and seed.

4.7.2 Effect of time of weeding

Weeding time also exerted significant effect on number of seeds pod^{-1}(Appendix V and Table 6). Early weeding also produced significantly the highest number of seeds pod^{-1} (11.08) and the late and no weeding produced respectively 9.75 and 9.70 number of seeds pod^{-1} while these two values were identical to each other but were significantly lower than the second highest number of seeds pod^{-1} (10.86) produced by medium period weeding (weeding at 30 DAE). Enyi (1973) and Pascua (1988) reported that the treatments that gave lower fresh weight of weed had higher number of seeds pod^{-1}.

4.7.3 Combined effect of plant density and time of weeding

Interaction effect of plant density and weeding time showed significant influence on number of seeds pod^{-1} (Appendix V). From the table 7 it was observed that early and medium period weeding in combination with sparse and medium plant density showed better performance in respect of producing number of seeds pod^{-1} compared to the combined effect of late/no weeding with dense plant density. The highest number of seeds pod^{-1} (11.66) was recorded from the combination of W_2D_1 i.e. weeding at 15 DAE × 33 plants m^{-2} and the lowest (8.80) was from the treatment combination of W_4D_3 i.e. 45 DAE weeding × 66 plants m^{-2} while the medium number of seeds pod^{-1} were obtained from the combined effect of weeding (W_3D_2) at 30 DAE × 66 plants pod^{-1} of plant density.

4.8 Weight of 1000-seed

4.8.1 Effect of plant density

Weight of 1000-seed varied significantly with the variation of plant density (Appendix V and Table 5). Plant density of 33 plants m^{-2} provided favourable environment for the growth and development of mungbean plants which resulted in the formation of biggest size of seeds and highest weight of 1000-seed (28.60 g). The second highest weight of 1000-seed (27.94 g) was from medium plant density of 40 plants m^{-2} and significantly the lowest weight of 1000-seed (26.42 g) was from the highest plant density (66plants m^{-2}). Plants in the closest spacing suffered from the competition for growth resources among themselves, which resulted in the development of small size of seeds and eventually the lower and lowest weight of 1000-seed.

4.8.2 Effect of time of weeding

Weeding time also kept significant influence on the weight of 1000-seed /seed size (Appendix V and Table 6). Weeding in the early stage of crops provided weed free or less weed problem environment on the field, which helped in the development of optimum size of seeds that ultimately resulted in higher weight of 1000-seed compared to treatments, experienced later stage weeding. For this reason it reveals from the table 6 that the highest weight of 1000-seed (29.79 g) was recorded from the weeding at 15 DAE and the lowest size seeds/lowest 1000-seed weight from weeding at 45 DAE.

4.8.3 Combined effect of plant density and time of weeding

Weeding at early stage of crops in the plots of optimum plant density/lower plant density caused to produce bigger size of seeds which resulted in the higher weight of 1000-seed compared to late weeding/no weeding in the plots of higher plant density that resulted in the lower weight of 1000-seed. The two statistically similar seed sized seeds/ weight of 1000-seed 30.43 g and 30.37 g were obtained respectively from the treatment combination of W_2D_1 (weeding at 15 DAE + 33 plants m^{-2}) and W_2D_2 (weeding at 15 DAE + 40 plants m^{-2}) were significantly higher than the weight of 1000-seed of the remaining treatment combinations.

The combination of late weeding/no weeding with higher plant density caused to form smaller sized seeds and that resulted in achieving higher 1000-seed weight. The lower 1000-seed weights/smaller sized seeds 26.58 g and 24.27 g were found to be obtained from the combinations of W_4D_2 (weeding at 45 DAE × 40 plants m^{-2}) and W_4D_3 (weeding at 45 DAE × 66 plants m^{-2}). Medium size seeds/medium 1000-seed weights revealed from the table 7 were 28.61 g and 28.58 g, which were obtained from the treatment combination of W_3D_1 and W_2D_3.

4.9 Grain yield (kg ha^{-1})

4.9.1 Effect of plant density

Significant influence was also observed in per hectare yield of mungbean due to variation in plant density (Appendix VI and Table 5). Plant density had diverse effects on grain yield of mungbean compared to that on yield attributes of the same. In yield attributes of mungbean such as number of pods $plant^{-1}$, number of seeds $plant^{-1}$ and weight of 1000-seed everywhere lowest plant density (33 plants m^{-2}) recorded the highest values but in per hectare yield of mungbean the highest plant density (66 plants m^{-2}) showed the highest grain yield ha^{-1} (899 kg) and the lowest grain yield ha^{-1} (486.30 kg) was found to be obtained from the lowest plant density (33 plants m^{-2}). The diverse effect of plant density on grain yield of mungbean might be attributed to the attainment of remarkable higher plant population m^{-2} by the highest plant density (66 plants m^{-2}) compared to the attainment of plant populations by the other plant densities.

Similar findings were obtained from the reports of Babu and Mitra (1989), Mackenzie *et al.* (1975), Ahmed *et al.* (1992), Abubakar (1997), Babaji (1996) and Ethredge *et al.* (1989).

4.9.2 Effect of time of weeding

Time of weeding also had a significant effect on grain yield of mungbean (Appendix VI and Table 6). Like its effect on yield attributes of mungbean, early weeding (15 DAE) showed the highest grain yield ha^{-1} (898.30 kg) and lowest grain yield ha^{-1} (413.90 kg) was from no weeding (control). Weeding at medium period (30 DAE) obtained per hectare yield as 789.70 kg, which was significantly lower than the yield ha^{-1} obtained at 15 DAE but was significantly higher than the yield ha^{-1} obtained at 45 DAE and control. Similar effect of time of weeding on grain yield was also observed by Yadav *et al.* (1983), Rathmann and Miller (1981), Kumar and Kairon (1988), Ahmed *et al.* (1992), Panwar and Singh (1980).

4.9.3 Combined effect of plant density and time of weeding

In the interaction effect the closest spacing i.e. the highest plant density (66 plant m^{-2}) in combination with early weeding (weeding at 15 DAE) was able to maintain the highest grain yield ha^{-1} (1220.00 kg), the second highest yield ha^{-1} (941.30 kg) due to interaction was also observed from the combination of the closest spacing (66 plants m^{-2}) with the weeding at 30 DAE and the third highest yield ha^{-1} (823.70 kg) was obtained from the combination of medium plant density (40 plants m^{-2}) and weeding at 15 DAE while the lowest yield ha^{-1} (230.70 kg) was obtained from the interaction of sparse density (33 plants m^{-2}) and no weeding (Table 7). The interaction effect on yields ha^{-1} revealed that there was a significant effect of plant density in influencing the interaction effect on grain yield ha^{-1}.

4.10 Biomass of mungbean

4.10.1 Effect of plant density

Plant density had significant influence on biomass of mungbean (Appendix VI and Fig.1). Mungbean biomass was the highest (293 g m^{-2}) at the plant density of 66 plants m^{-2} because of the highest number of plant population obtained in those plots. Significantly the lowest mungbean biomass (262 g m^{-2}) was found from the lower plant density i.e. 33 plants m^{-2} density and the medium valued biomass (277.8 g m^{-2}) was obtained at plant density of 40 plants m^{-2}. These findings supported the findings of Babu and Mitra (1989).

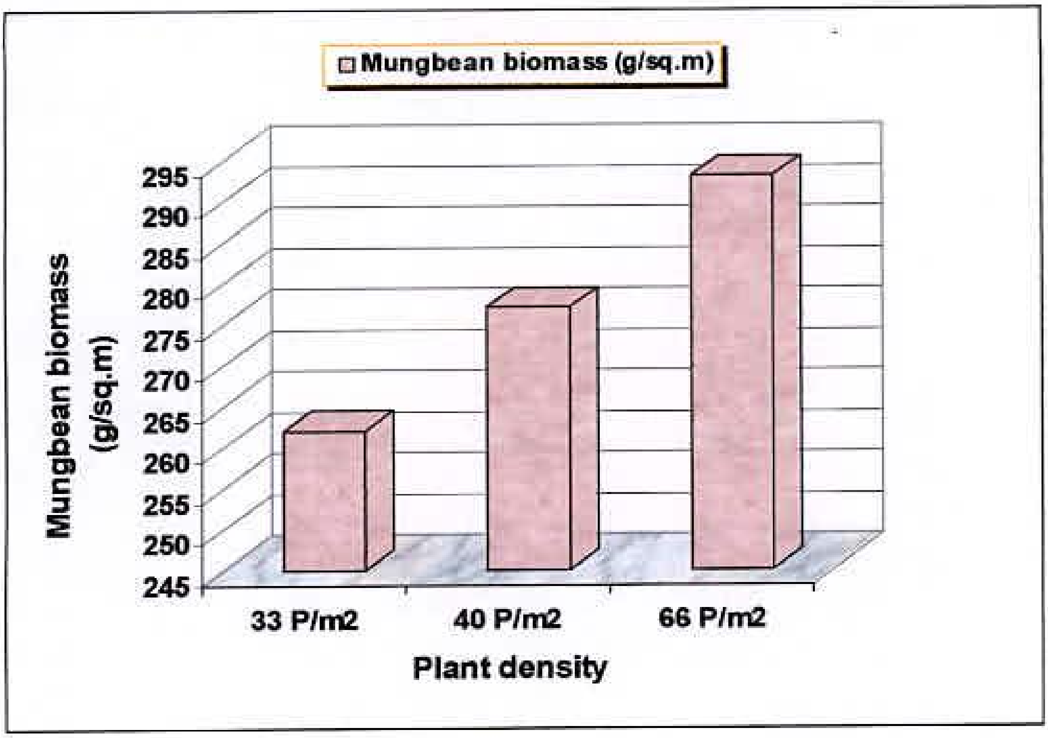

Fig. 1 Effect of plant density on the dry biomass of mungbean at harvest (LSD $_{0.05}$ = 8.114)

4.10.2 Effect of time of weeding

Time of weeding also significantly influenced on mungbean biomass (Appendix VI and Fig. 2). The highest value of mungbean biomass (327.3 g m^{-2}) was found from the treatment weeded at 15 DAE while the second highest (285 g m^{-2}) from the plots weeded at 30 DAE. Unweeded plots produced the lowest value (237 g m^{-2}) of mungbean biomass.This result demonstrated that delay in weeding reduced crop biomass. Kumar and Kairon (1988) also obtained maximum biomass under weed free condition.

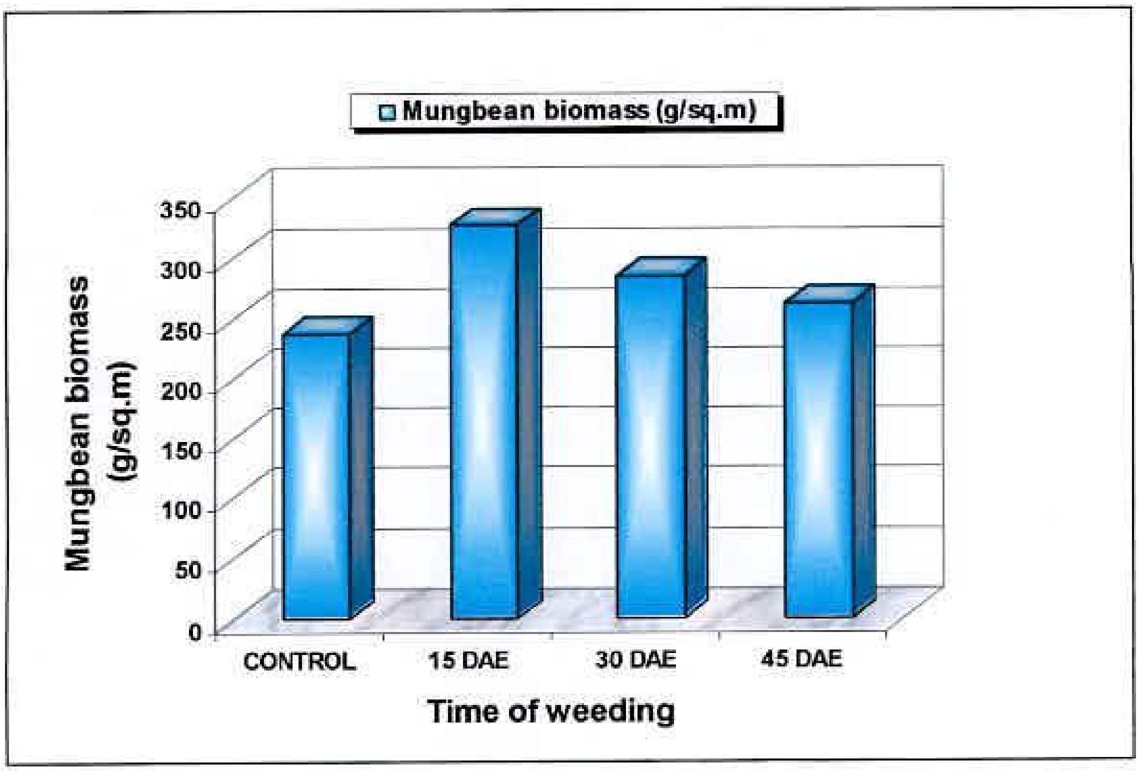

Fig. 2 Effect of time of weeding on the dry biomass of mungbean at harvest (LSD $_{0.05}$ = 9.369)

4.10.3 Combined effect of plant density and time of weeding

The interaction of crop density and time of weeding under study showed significant variation on biomass of mungbean (Appendix VI and Fig. 3). The highest mungbean biomass (338 g m^{-2}) was obtained from the treatment combination of 66 plants m^{-2} when weeded at 15 DAE. On the other hand, the lowest value (224 g m^{-2} was found from the plots of 33 plants m^{-2} density when remained unweeded.

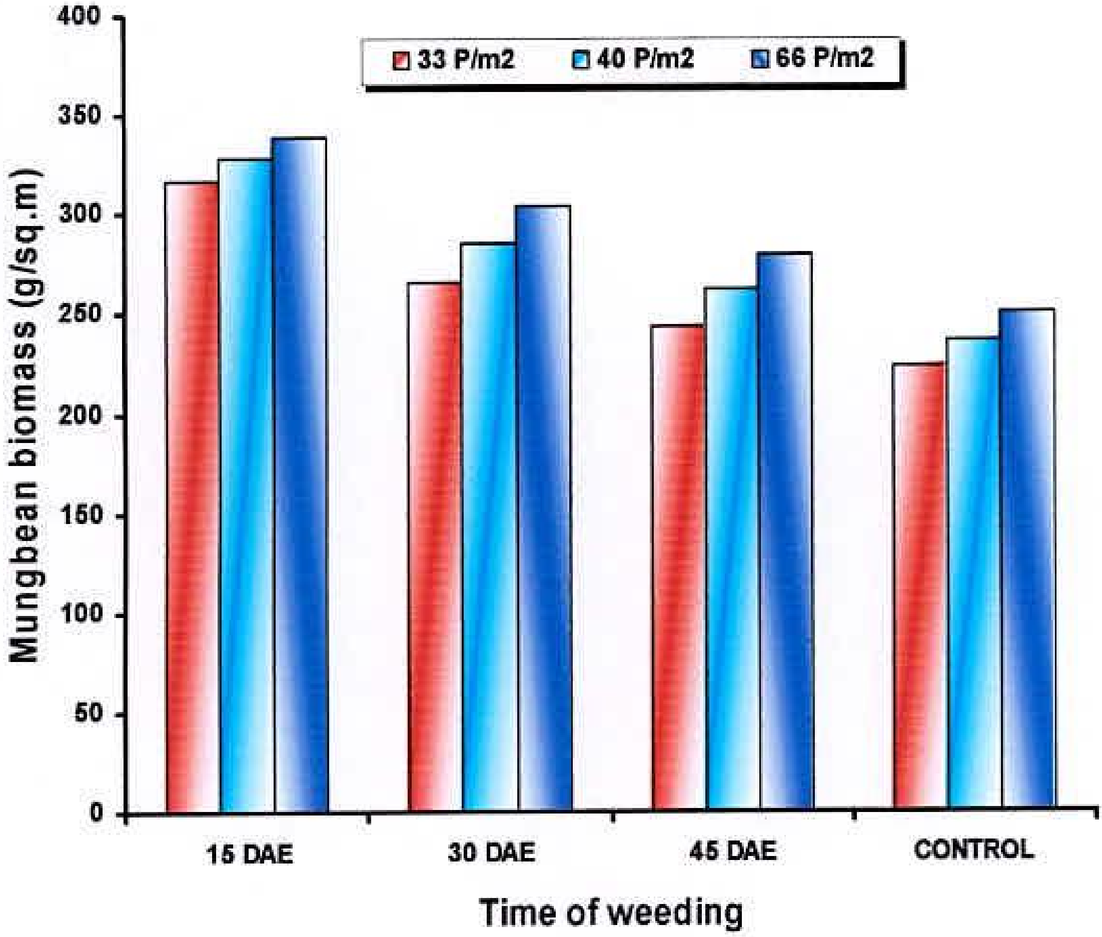

Fig. 3 Interaction effect of plant density and time of weeding on the dry biomass of mungbean at harvest ($LSD_{0.05}$ = 16.23)

4.11 Biomass of weed

4.11.1 Effect of plant density

There was a significant influence in plant density on biomass of weed (Appendix VI and Fig. 4). The highest weed biomass (133 g m^{-2}) was found from the plant population of 33 plants m^{-2} while the second highest (125.3 g m^{-2}) was found from the 40 plants m^{-2} density. The plant density of 66 plants m^{-2} produced the lowest (118 g m^{-2}) weed biomass. So it is appeared that plant density was indirectly proportional/reciprocal to biomass of weed. Radosevich (1987) and Moody *et al.* (1978) also reported that plant density has considerable effect on the suppression of weeds.

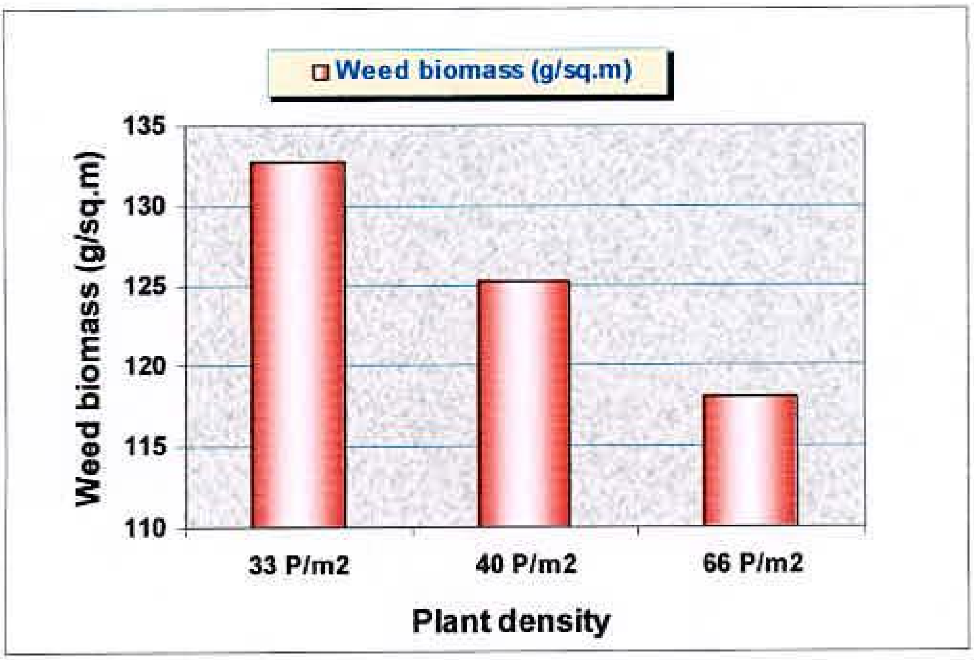

Fig. 4 Effect of plant density on cumulative total dry biomass of weed ($LSD_{0.05}$ = 6.443)

4.11.2 Effect of time of weeding

Time of weeding also showed significant influence on weed biomass (Appendix VI and Fig. 5). The highest weed biomass (178 g m^{-2}) was obviously found from the unweeded plots. Weeding at 45 DAE produced the second highest (157 g m^{-2}) weed biomass which was statistically different from the unweeded plots. The lowest weed biomass (61 g m^{-2}) was found from the treatment weeded at 15 DAE followed by 30 DAE (105.3 g m^{-2}). It is evident from the results that weed biomass increased as weeding was delayed. Kumar and Kairon (1988) found that weed biomass increased with delay in weeding.

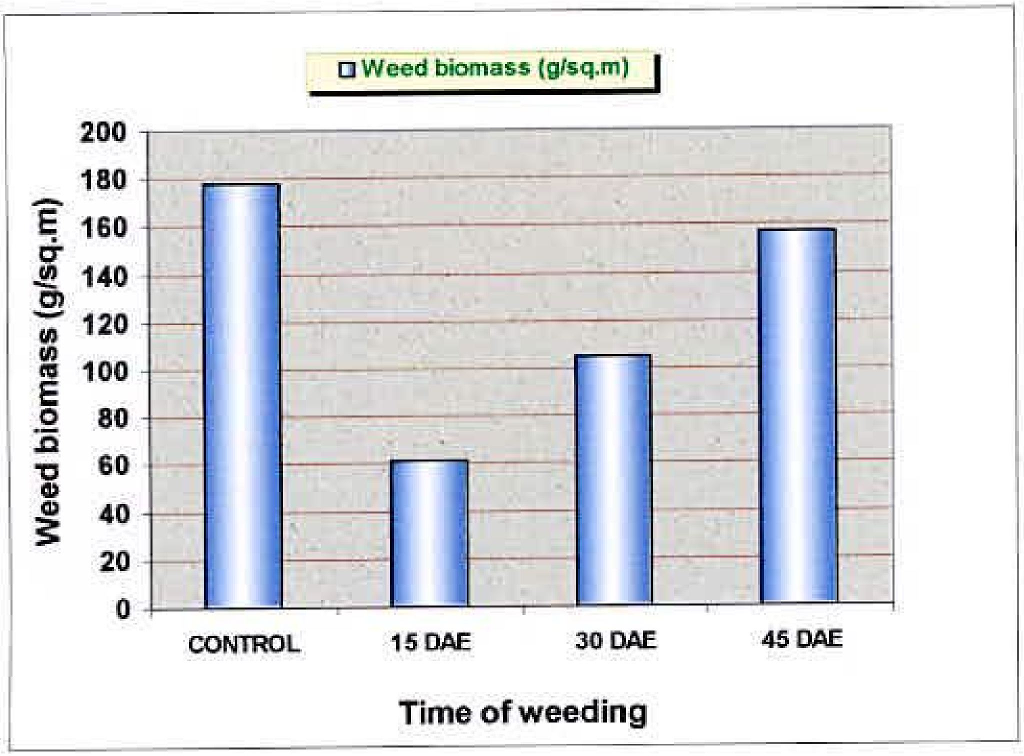

Fig. 5 Effect of time of weeding on cumulative total dry biomass of weed ($LSD_{0.05}$ = 7.440)

4.11.3 Combined effect of plant density and time of weeding

Plant density and time of weed control interacted to affect weed biomass. The highest weed dry weight 186 g m^{-2} and 178 g m^{-2} was obtained at 33 plants m^{-2} and 40 plants m^{-2} when weeding was delayed up to 45 DAE and the lowest 55 g m^{-2} at 66 plant m^{-2} when weeded at 15 DAE of crop (Fig. 6). The higher weed biomass at lower density means that increased plant population, could suppress weed biomass better than optimum density. From agronomic point of view, crop density could serve as a measure of weed control (Moody *et al.*, 1978). The incremental trend of biomass for all 3 densities up to 30 DAE was more or less similar. The rate of increase in weed biomass was rapid for 33 plants m^{-2} and 40 plants m^{-2} density. This was probably due to mortality and slower growth of weeds in high density caused by the mutual shading and competition for resources. The weed biomass removed at 15 DAE in all the densities were lower than those recorded at 30 or 45 DAE. This could probably be attributed to earlier and faster rate of mortality and subsequent decomposition of weeds in unweeded plots.

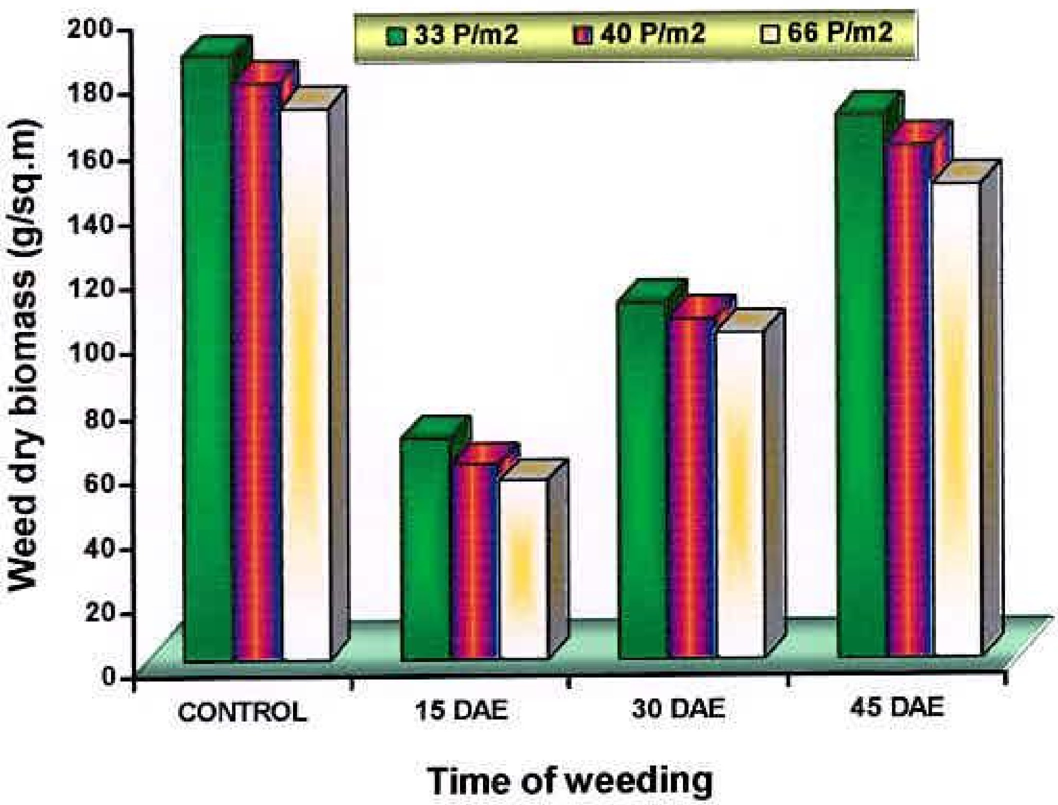

Fig. 6 Interaction effect of mungbean density and time of weeding on cumulative total dry biomass of weed ($LSD_{0.05}$ = 12.89)

4.12 Percentage of maximum biomass

4.12.1 Effect of plant density

The relative (percentage of maximum biomass) mungbean biomass (RMB) was significantly influenced by the plant density (Appendix VI and Fig. 7). From the figure it was demonstrated that increasing plant density increased the RMB. The highest RMB (99%) was found from the plots at 66 plants m^{-2} and the second highest RMB was obtained from the 40 plants m^{-2} density (95%). The lowest RMB was found the plots of 33 plants m^{-2} density.

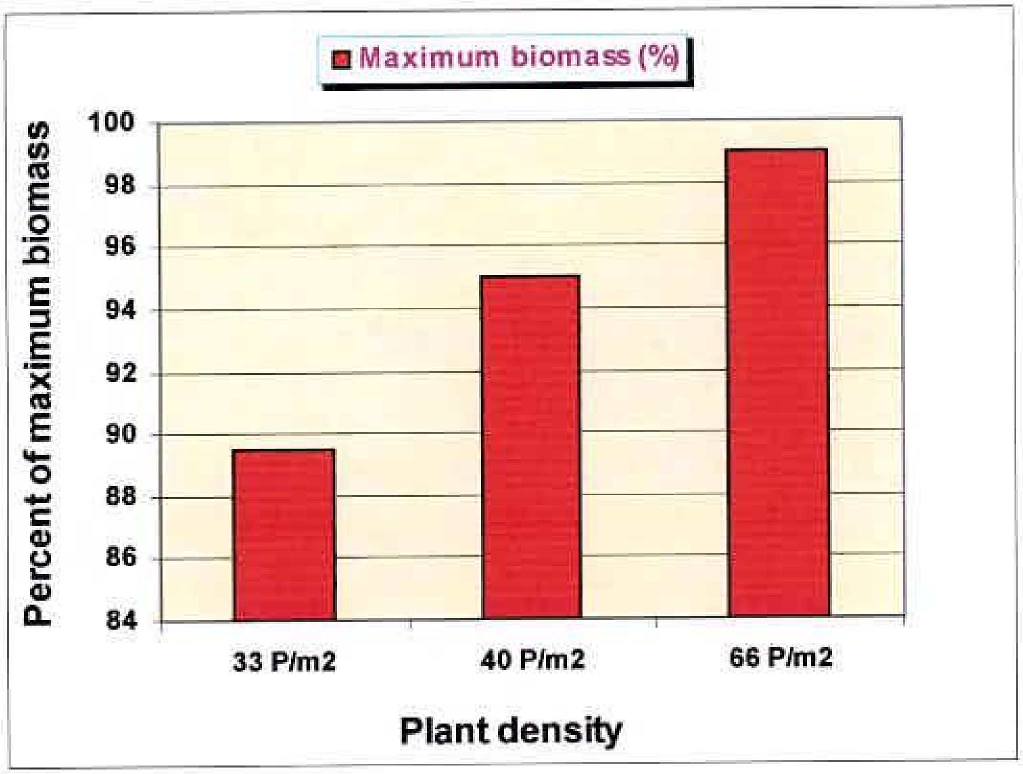

Fig. 7 Effect of mungbean density on mungbean dry biomass relative to the maximum dry biomass of mungbean ($LSD_{0.05} = 3.594$)

4.12.2 Effect of time of weeding

Time of weeding also showed significant effect on RMB (Appendix VI and Fig. 8). Weeding at 15 DAE produced the highest RMB (99%) followed by 30 DAE (87%) and the lowest RMB were found from the plots remained unweeded (72%). This result demonstrated that delay in weeding reduced crop biomass. A reduction in RMB was proportionate to increase in weed biomass with delay in weeding.

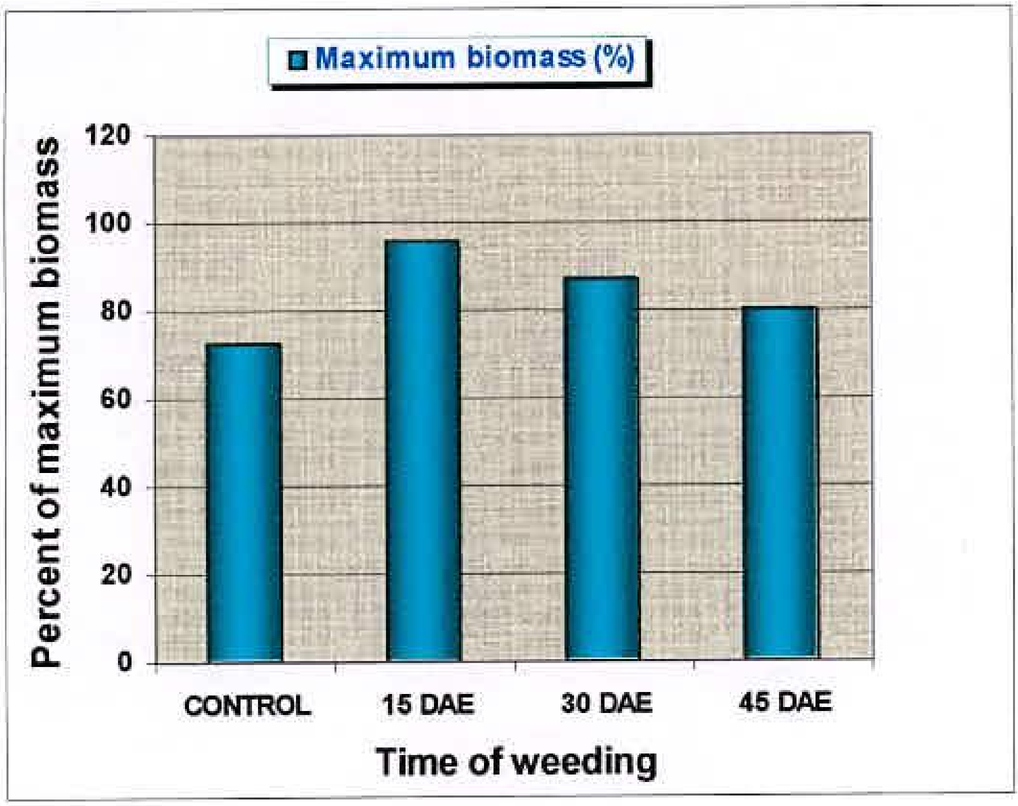

Fig. 8 Effect of time of weeding on mungbean dry biomass relative to the maximum dry biomass of mungbean ($LSD_{0.05}$ = 4.150)

4.12.3 Combined effect of plant density and time of weeding

The combination effect of plant density and time of weeding showed significant influence on RMB (Appendix VI and Fig. 9). The highest value of RMB was found from the plant density at 66 plants m^{-2} density (99%) which was statistically similar to the plant densities of 40 plants m^{-2} (98.43%) and 33 plants m^{-2} density (98%) weeded at 15 DAE and the lowest RMB (71%) was found from the treatment combination of 33 plants m^{-2} density in unweeded plots which was also similar to the treatment combination of 40 plants m^{-2} density when remained unweeded.

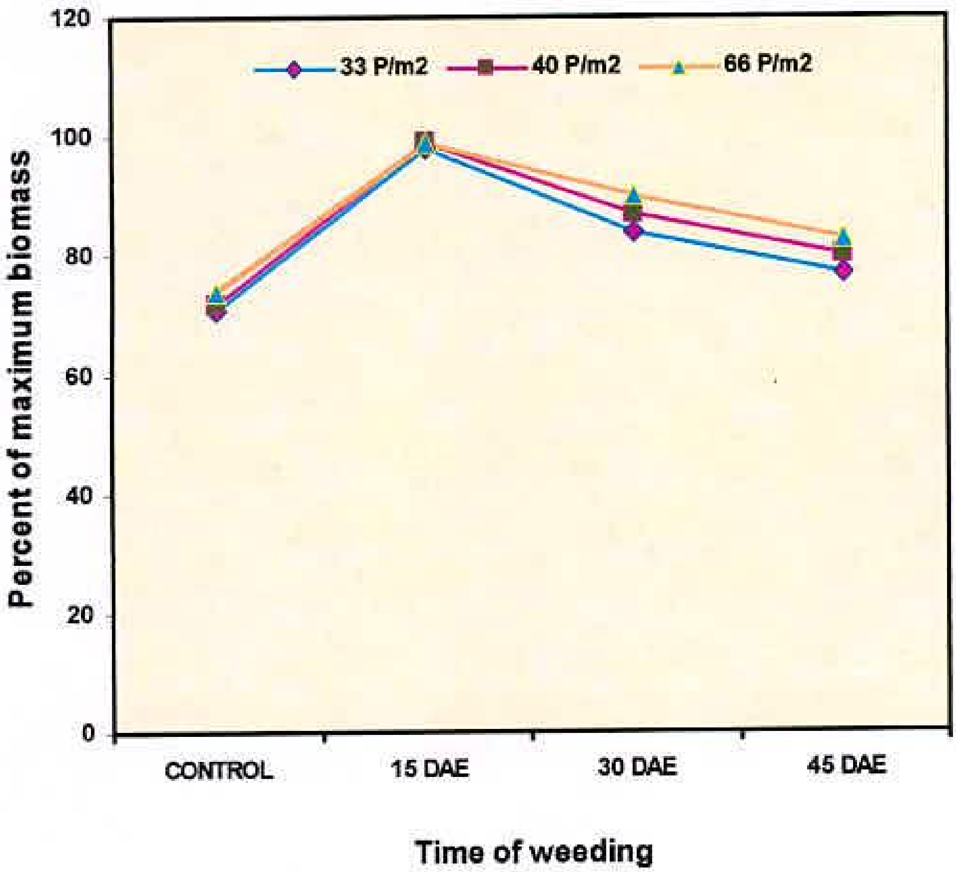

Fig. 9 Interaction effect of mungbean density and time of weeding on the dry biomass of mungbean relative to the maximum dry biomass of mungbean ($LSD_{0.05}$ = 7.189)

4.13 Percentage of mungbean biomass loss

4.13.1 Effect of plant density

Plant density showed significant influenced on mungbean biomass loss (Appendix VI and Fig.10). Percentage of mungbean biomass loss was found highest (11%) at 33 plants m^{-2} density and the lowest (0.50%) at 66 plants m^{-2}. It is evident that increasing plant density-decreasing loss of mungbean biomass.

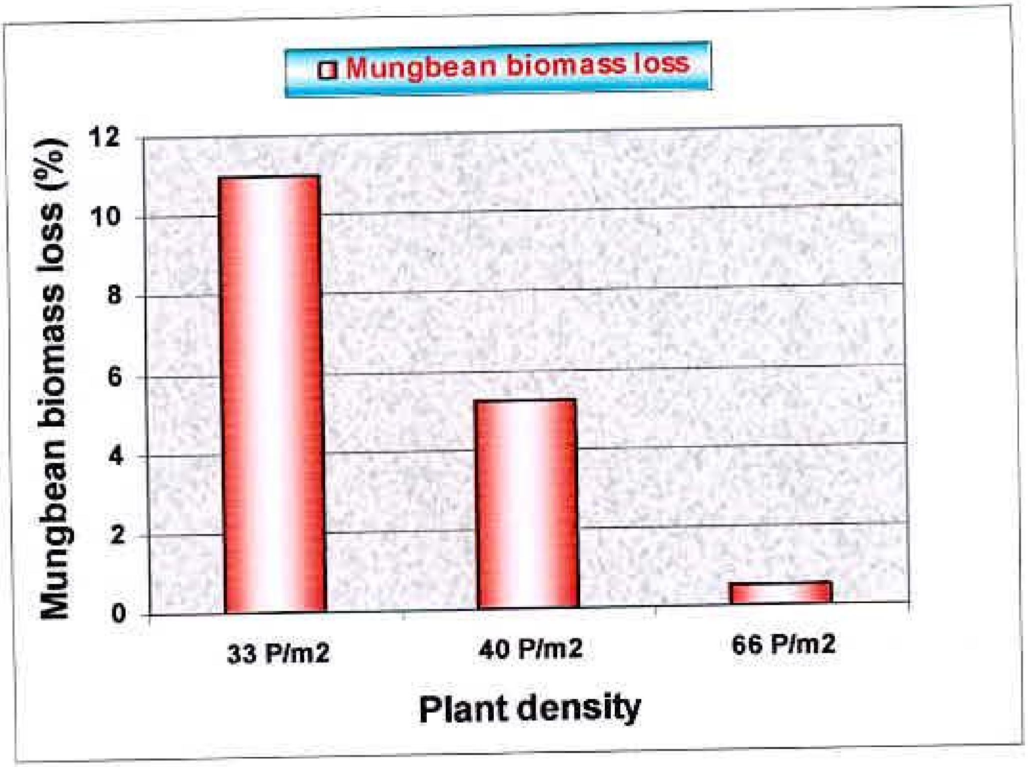

Fig. 10 Percent loss in mungbean dry biomass as affected by mungbean plant density compared to maximum dry biomass of mungbean ($LSD_{0.05}$ = 1.633)

4.13.2 Effect of time of weeding

Time of weeding also showed significant effect on mungbean biomass loss (Appendix VI and Fig. 11). Percentage of mungbean biomass loss was found highest (28%) in unweeded plots and the second highest was 20% which was observed in the plots weeded at 45 DAE. The third highest was 13% found in the plots weeded at 30 DAE while the negligible mungbean biomass loss was observed in the plots weeded at 15 DAE.

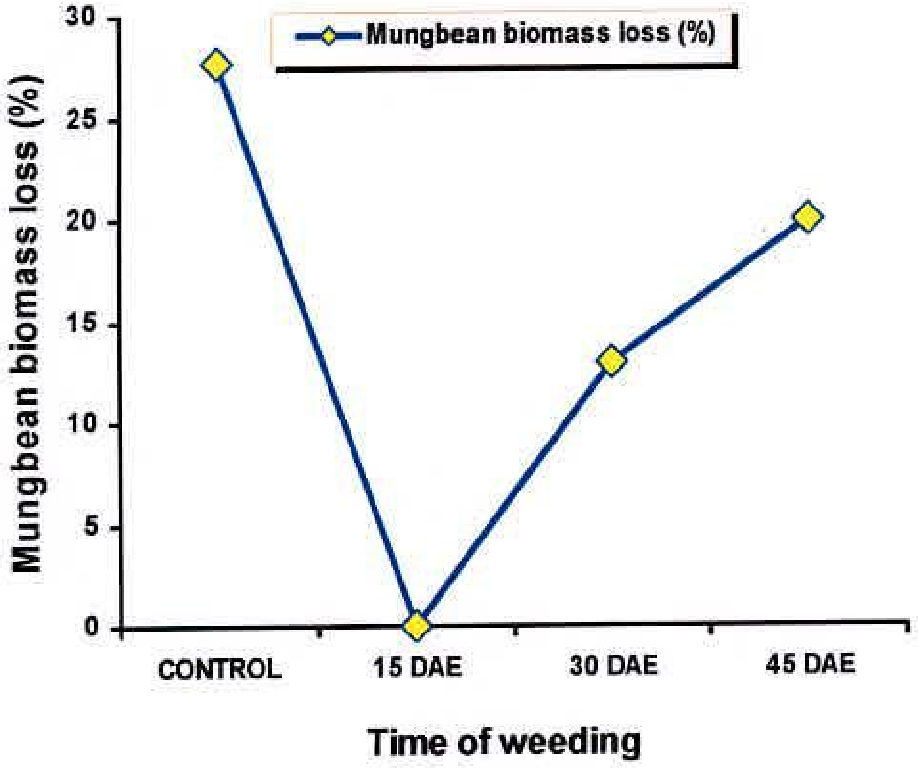

Fig. 11 Percent loss in mungbean dry biomass as affected by time of weeding compared to maximum dry biomass of mungbean ($LSD_{0.05}$ = 1.886)

4.13.3 Combined effect of plant density and time of weeding

Biomass loss of mungbean understudy was also significantly influenced by the combined effect of crop density and weeding time (Appendix VI and Fig. 12).Percentage of the highest mungbean biomass loss (29%) was found in the treatment combination of 33 plants m^{-2} density with the control treatment which was statistically similar (28%) to the treatment combination of 40 plants m^{-2} density with the control treatment. The plots weeded at 15 DAE in all three-plant densities showed negligible loss in mungbean biomass.

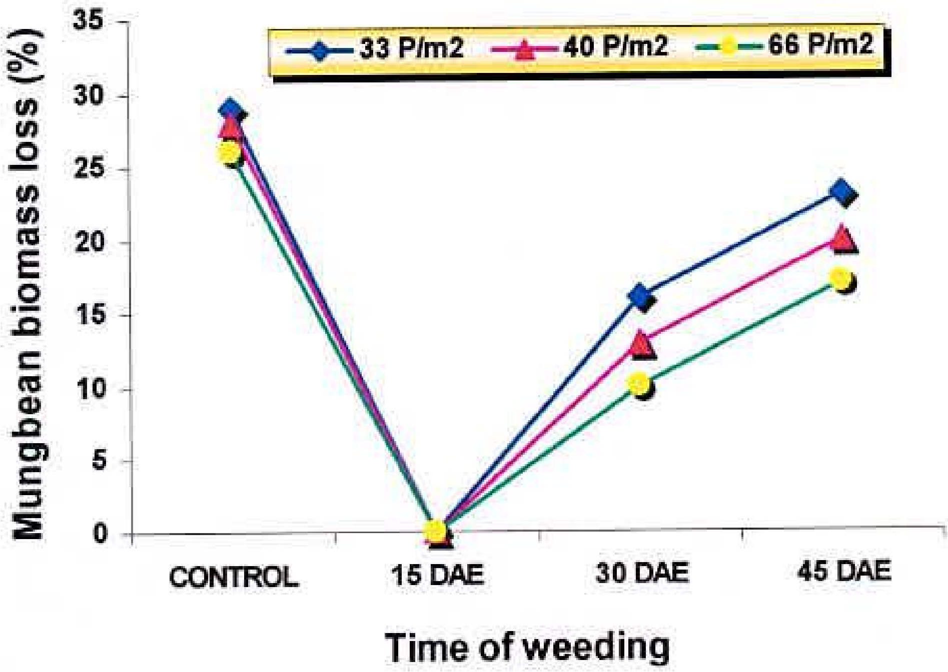

Fig. 12 Interaction effect of mungbean crop density and time of weeding on percent loss in mungbean dry biomass compared to maximum dry biomass of mungbean ($LSD_{0.05}$ = 3.266)

4.14 Percentage of maximum yield of mungbean

4.14.1 Effect of plant density

The effect on percentage of maximum yield significantly influenced by crop density (Appendix VII and Fig. 13). The highest percentage of maximum yield (99%) was recorded from the treatment of 66 plants m^{-2} density which was significantly different from the percentage of maximum yield of 67% and 54% obtained from the treatment of D_2 (40 plants m^{-2} density) and D_1(33 plants m^{-2} density) while the last one was the lowest. From the result it appears that percentage of maximum yield increased with the increasing trend of crop density.These findings were in agreement with those of Babu and Mitra (1989), Mackenzie *et al.* (1975), Babaji (1996), Abubakar (1997) and Ethredge *et al.* (1989).

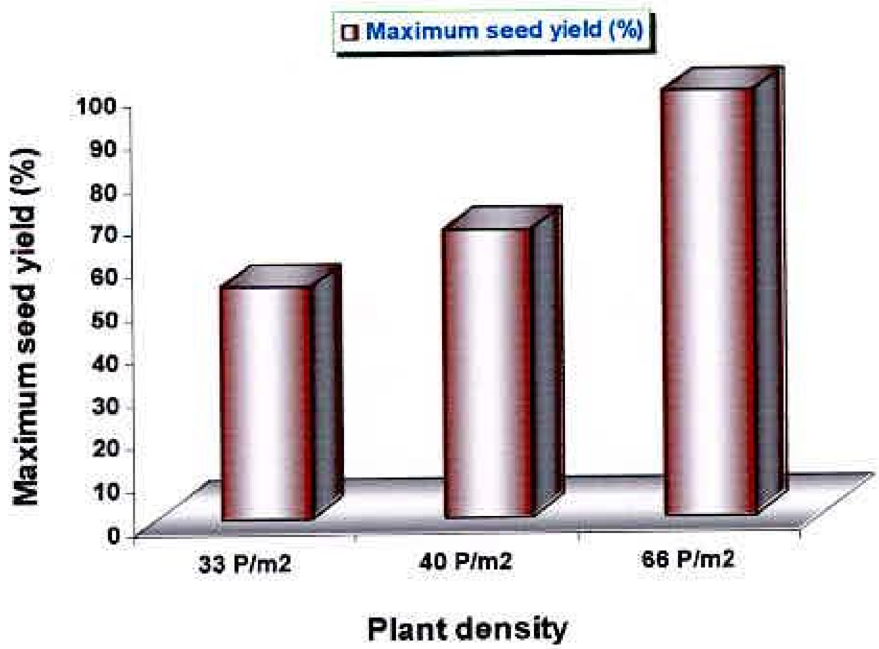

Fig. 13 Effect of plant density on the mungbean seed yield relative to the maximum seed yield of mungbean ($LSD_{0.05}$ = 2.191)

4.14.2 Effect of time of weeding

Time of weeding had a significant effect on the percentage of maximum yield (Appendix VII and Fig. 14). Weeding at 15 DAE was found to give the highest percentage of maximum yield (99%) while weeding at 30 DAE gave 89% which was statistically different from the treatment of 15 DAE. Percentage of maximum yield was the lowest (45%) observed in unweeded plots. So, it is demonstrated that delay in weeding declined percentage of maximum yield. Similar effect of time of weeding on the percentage of maximum yield was also observed by Yadav *et al*. (1983) and Ahmed *et al*. (1992).

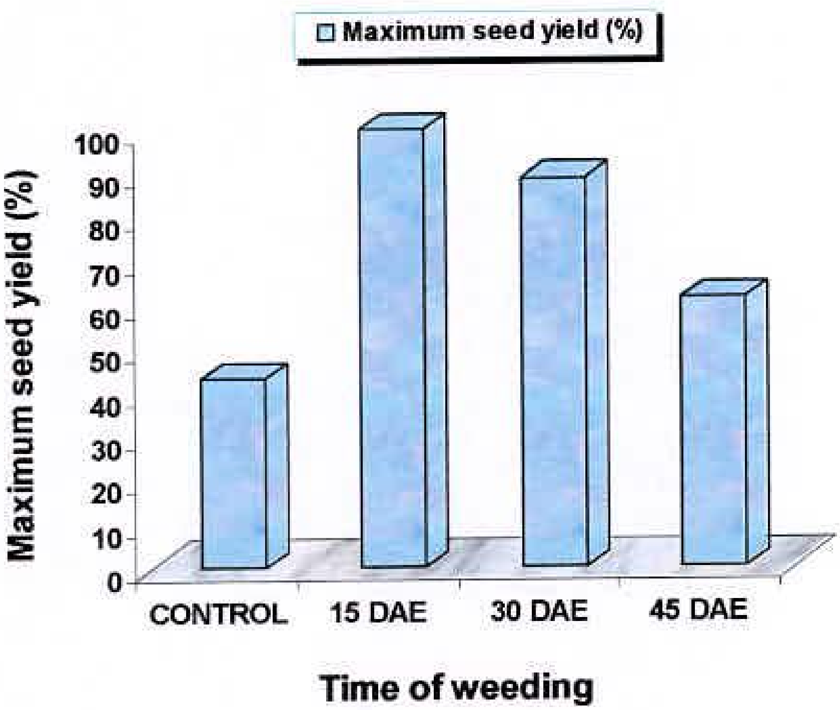

Fig. 14 Effect of time of weeding on the mungbean seed yield relative to the maximum seed yield of mungbean ($LSD_{0.05}$ = 2.530)

4.14.3 Combined effect of plant density and time of weeding

Percentage of maximum yield also significantly varied with the variation in the interaction effect of crop density and time of weeding in the experiment (Appendix VII and Fig. 15). The highest percentage of maximum yield (98%) was obtained from the treatment combination of W_2D_1 (weeding at 15 DAE + 33 plants m^{-2} density) which was statistically similar to the percentage of maximum yield 97.75%, 97.32% and 96.74% respectively obtained from W_2D_2, W_2D_3 and W_3D_2 treatments combination and the second highest (92%) was found from the treatment combination of W_3D_1. The lowest percentage of maximum yield was obtained from the W_1D_1 (control + 33 plants m^{-2} density) treatment.

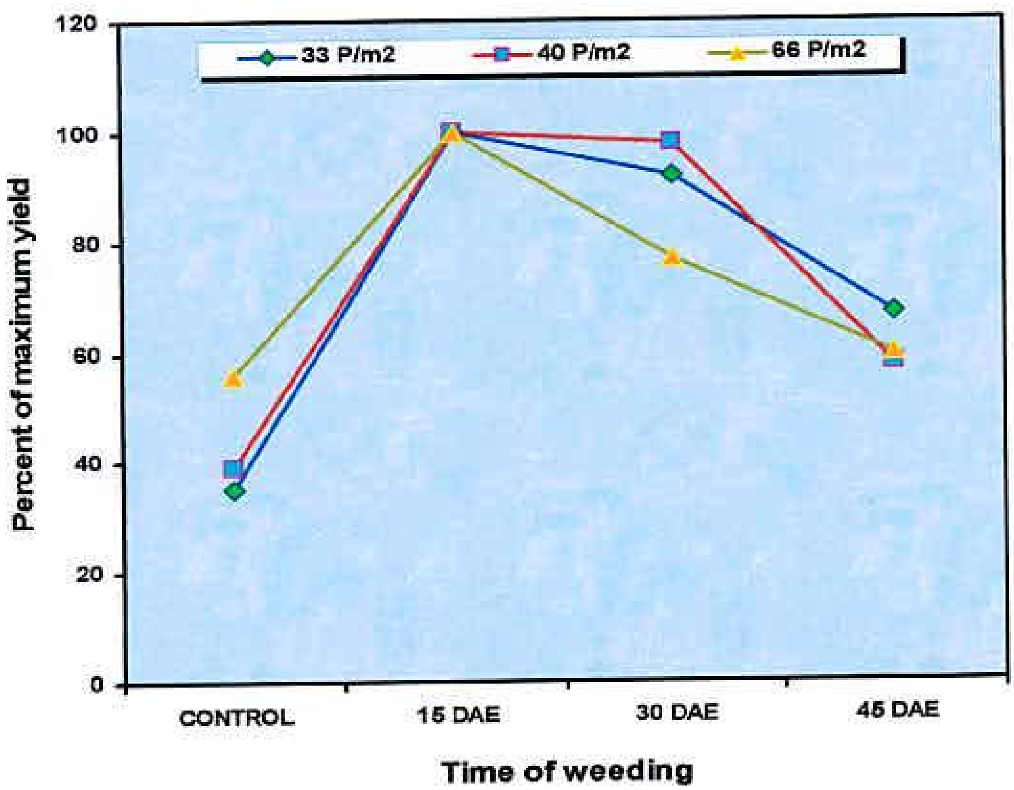

Fig. 15 **Interaction effect of plant density and time of weeding on the dry biomass of mungbean seed yield relative to the maximum seed yield of mungbean ($LSD_{0.05}$ = 4.382)**

4.15 Percentage of yield loss of mungbean

4.15.1 Effect of plant density

Plant density significantly influenced on percentage of yield loss of mungbean (Appendix VII and Fig. 16). Percentage of yield loss was the highest (46%) at 33 plants m^{-2} density and the second highest was 33% obtained at 40 plants m^{-2} density (33%), which was statistically different from D_1 treatment and the lowest was observed (2%) at 66 plants m^{-2} density. So, it is evident from the result that increasing plant density reduced yield loss. These findings were in agreement with Hamid (1989) and Mackenzie (1975).

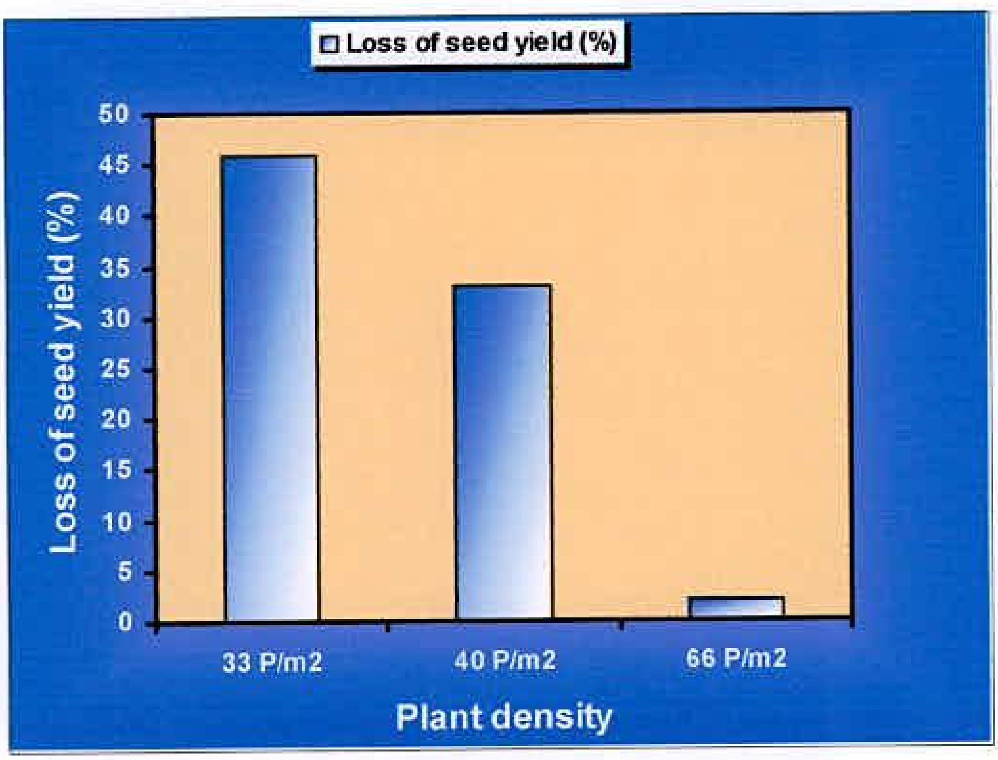

Fig. 16 Percent loss in mungbean seed yield as affected by mungbean plant density compared to maximum seed yield of mungbean ($LSD_{0.05}$ = 1.839)

4.15.2 Effect of time of weeding

Time of weeding also showed significant influence on percentage of yield loss (Appendix VII and Fig. 17).The plots remained unweeded showed the highest yield loss (54%) of mungbean while the second highest value (38%) was obtained from the plots weeded at 45 DAE. The percentage of yield loss was the lowest (2.43%) for the treatment weeding at 15 DAE. When the weeds were allowed to compete with the crop at 15 DAE, there was minimum loss in yield from those in the weed free plots. From the results it is demonstrated that there was no need for weeding in mungbean up to 15 DAE. A significant reduction in yield was observed when weeding was done at 30 DAE. It is evident that the critical period of weed competition lies between 15 and 30 DAE. Mungbean must be weeded during first 5 weeks after sowing during wet season and up to 3 weeks during the dry season (Madrid and Vega, 1971). Sarkar and Mondal (1985) found that one weeding two weeks after emergence was enough for optimum mungbean yield. Such findings were observed in the reports of AVRDC (1976), Madrid and Vega (1971), Vats and Sidhu (1976), Madrid and Manimtim (1977), Ahmed (1991), Gupta and Lamb (1978) and Mann and Barnes (1977).

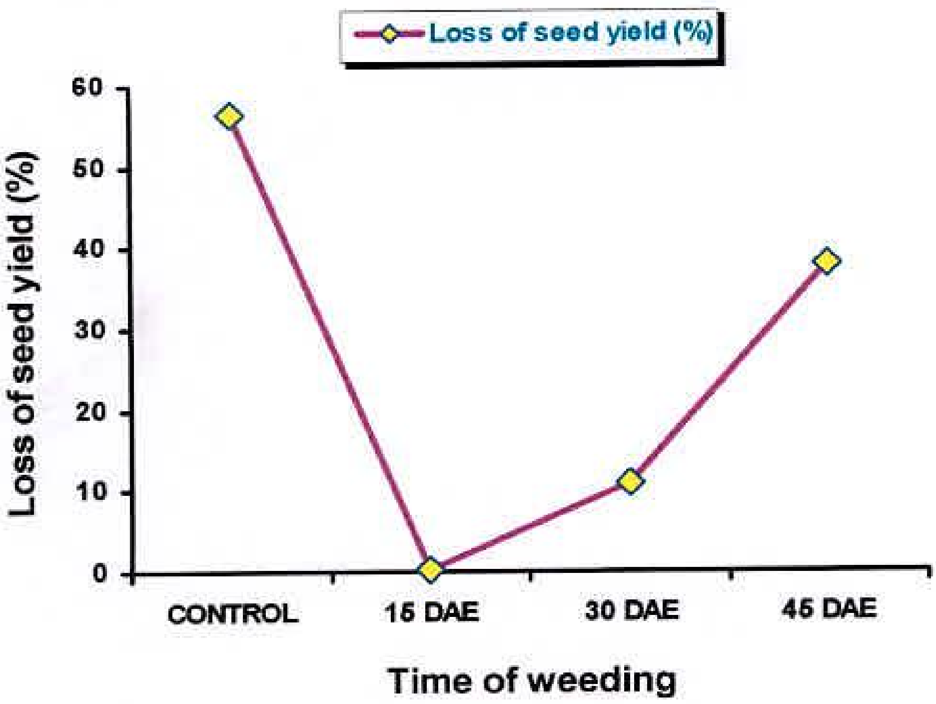

Fig. 17 Percent loss in mungbean seed yield as affected by time of weeding compared to maximum seed yield of mungbean ($LSD_{0.05}$ = 2.123)

4.15.3 Combined effect of plant density and time of weeding

Crop density and time of weeding interacted to affect yield loss (Appendix VII and Fig. 18). The highest yield loss (65%) was found from the treatment combination of 33 plants m^{-2} density when remained unweeded. It is appeared from the fig. 18 that 40 plants m^{-2} and 66 plants m^{-2} densities when weeded at 15 DAE produced negligible yield loss. So, it was evident that at lower density more weed infestation reduced seed yield.

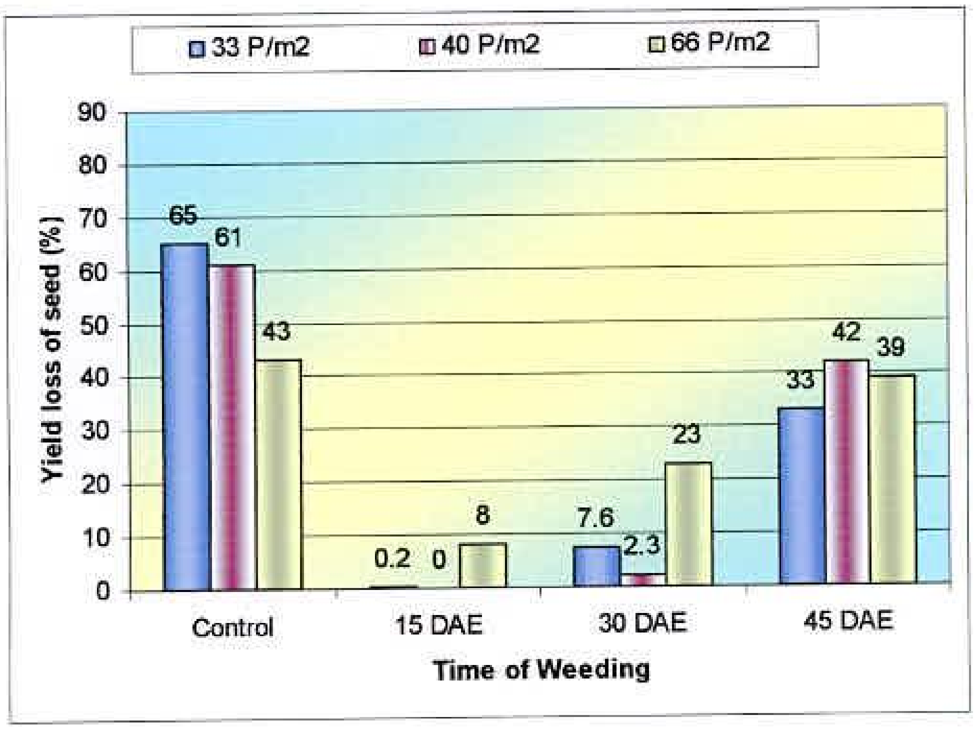

Fig. 18 Interaction effect of mungbean plant density and time of weeding on percent loss in mungbean seed yield compared to maximum seed yield of mungbean ($LSD_{0.05}$ = 3.678)

4.16 Relationship between seed yield and mungbean biomass

Linear regression models were developed to predict yield of mungbean seed by biomass of mungbean. In the regression equation Y = -2937.4 + 1.2952X (Fig. 19), Y is the predicted yield of mungbean seed and X is the biomass of mungbean. The constant 1.2952 is the slope of regression equation explaining the rate of change in seed yield due to unit in mungbean biomass. The intercept -2937.4 was insignificant i.e. the intercept was not different from 0. This means that when mungbean biomass is 0, its yield is also zero. The slope indicates that for one kg yield increase by 1.2952 kg biomass within the linear part of their relationships. The R^2 explains that 97% of the total variation in yield of mungbean was explained by the mungbean biomass.

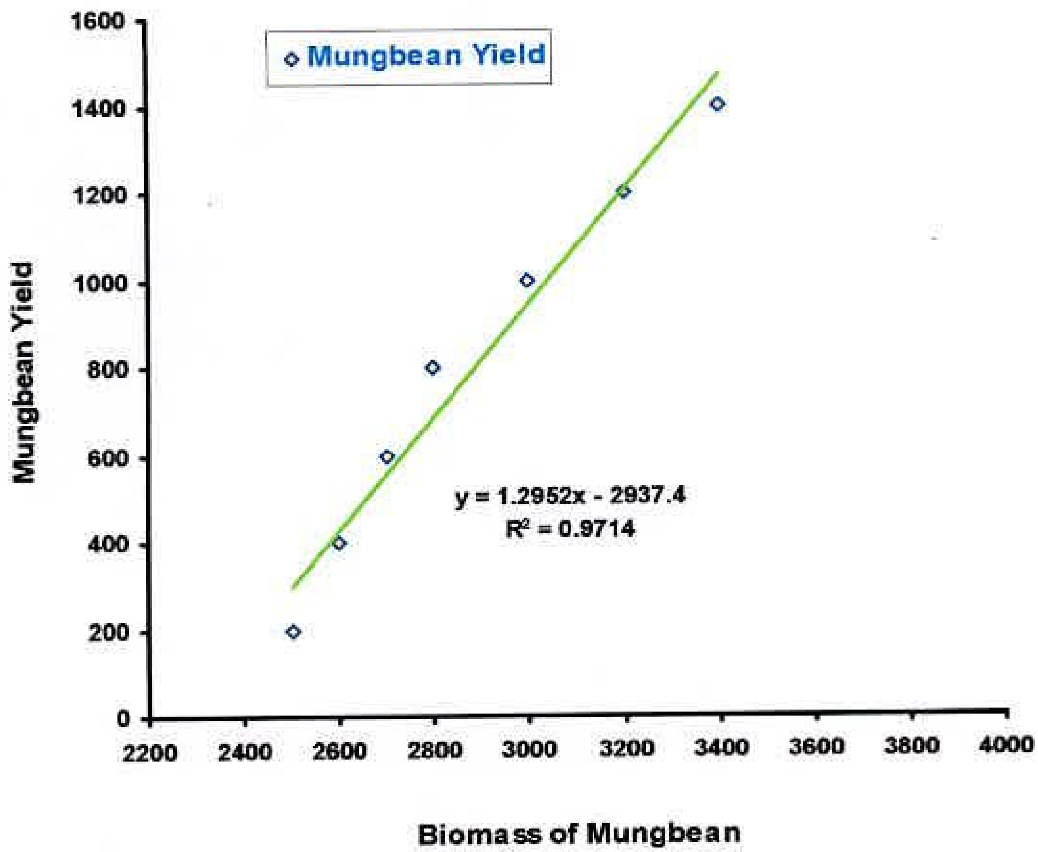

Fig. 19 Relationship of seed yield (kg ha^{-1}) of mungbean to its total final dry biomass (kg ha^{-1})

4.17 Relationship between seed yield and weed biomass

The regression equation Y = 1900 – x (R^2 = 1) (Fig. 20) expresses the relationship between dry weed biomass and seed yield of mungbean. The significant intercept 1900 indicates the yield of mungbean should be 1900 kg ha^{-1} if there is no weed in the field. The slope -1 indicates that for 1 kg ha^{-1} increase in weed biomass, the mungbean yield would decrease by 1 kg ha^{-1}. The

R^2 demonstrates that 100% of total variation in seed yield was explained by dry weed biomass alone.

Both the regression equations were powerful in predicting the yield of mungbean. However, the slopes of the equations are limited to the set of data that fall within the range of data of this study.

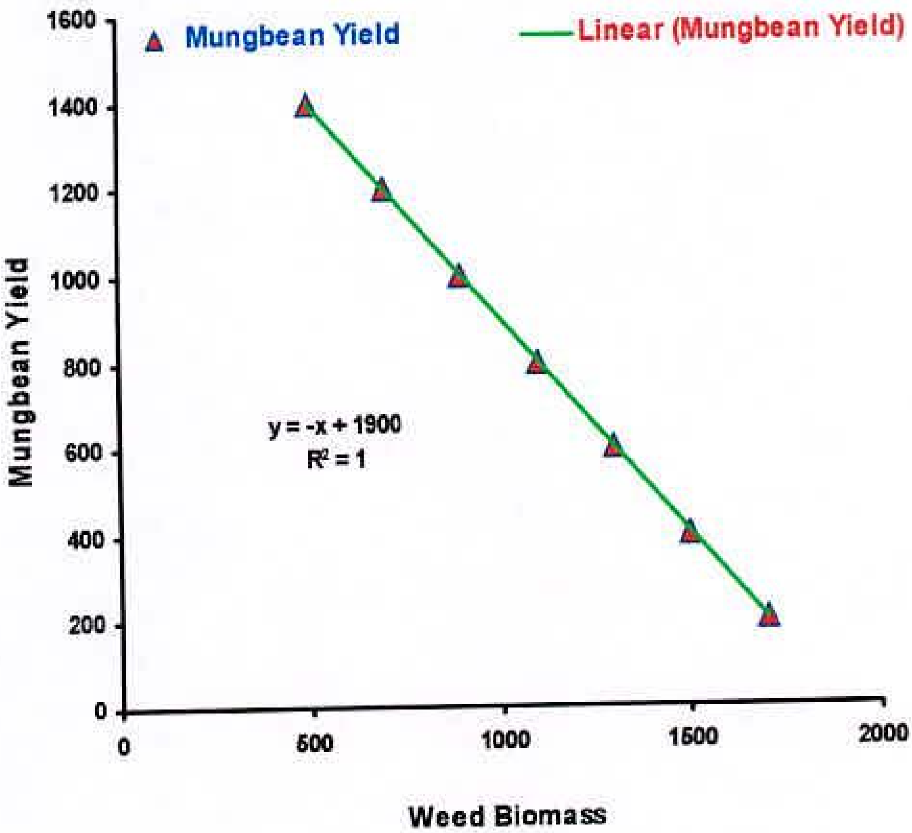

Fig. 20 Relationship of seed yield (kg ha^{-1}) of mungbean to the cumulative total final dry biomass of weeds (kg ha^{-1})

Chapter 5

Summary and Conclusion

Chapter 5

SUMMARY AND CONCLUSION

A field experiment was conducted at the experimental field of SAU, Dhaka-1207 during the Kharif-1 season (April – June, 2007) to examine the effect of plant density of mungbean and time of weeding on some plant characters, yield and yield attributes of mungbean. Plant densities at 3 levels (33 plants m^{-2}, 40 plants m^{-2} and 66 plants m^{-2}) and weeding at 4 times (15, 30, 45 DAE and no-weeding) were arranged in a RCBD (factorial) design. Each unit plot was replicated three times. Seeds were sown on 18 April, 2007 and seedling emerged on 28 April, 2007. Dry matter weights were measured by destructive sampling at 29 DAE. At maturity, yield and yield attributes were measured. At each time of weeding, dry weights of weeds removed were recorded. At maturity, the weed species of each plot were identified and individual of each species counted. Final weed dry weight was the cumulative total dry weight of weeds including those at harvest.

As many as 17 weed species were found in the experimental plots. Among these, *Cyperus rotundus* L. was the most dominant (28%) weed species followed by *Cynodon dactylon* (21%), *Echinochloa colonum* (19.6%), *Leucas aspera spreng* (8.9%) and *Paspalum commersonii* (7.33%) and so on. The richness of weed in unweeded plot was 3 times greater than weeded plots. The weed count was 36% less in high density of 66 plants m^{-2} than in 40 plants m^{-2} and 51% less than in 33 plants m^{-2} density but wed biomass was 6% and 12.5% lower in high density (66 plants m^{-2}) than in medium & lower density (40 plants m^{-2} and 33 plants m^{-2}).Some plant characters, yield and most of the yield attributes were affected by density of mungbean. The highest number of plant height (58.80 cm), number of branches plant^{-1} (3.14), number of nodes plant^{-1} (9.18), number of pods plant^{-1} (12.81), number of seeds pod^{-1} (10.76), and 1000-seed weight (28.60 g) were obtained from the plant density of 33 plants m^{-2} but the highest grain yield (899.20 kg ha^{-1}) was found from the treatment of 66 plants m^{-2} density. It might be attributed to the attainment of remarkable higher plant population m^{-2} by the highest plant density (66 plants m^{-2}) compared to the attainment of plant populations by the other densities. The treatment W_2 (weeding at 15 DAE) showed the highest values of all the studied parameters such as number of plant population m^{-2} (44), number of nodes plant^{-1}(9.57), number of pods plant (15.17), number of seeds pod^{-1} (11.08), plant height (60.81 cm), number of branches plant^{-1} (3.73), weight of 1000-seed (29.79 gm) and grain yield (898.30 kg ha^{-1}). The lowest corresponding values of the above parameters obtained from the control treatment (W_1) were 36.33 number m^{-2} plant populations, 7.79 numbers of nodes plant^{-1}, 7.98 numbers of pods plant^{-1} and 413.90 kg ha^{-1} grain yield.

Delay in time of weeding i.e. increases in the duration of crop/weed competition beyond 15 DAE, progressively reduced 54% seed yield than at 15 DAE. Delay in weeding reduced number of nodes plant^{-1}, number of pods plant^{-1}, number of seeds pod^{-1} and seed size of mungbean.

The critical period of crop/weed competition appeared to be between 15 and 30 DAE. Delay in time of weeding reduced mungbean biomass and increased biomass of weed. Unrestricted (no-weeding) growth of weed through out the crop cycle reduced seed yield by 65 & 61% in 33 plant m^{-2} and 40 plants m^{-2} respectively but 43% in 66 plants m^{-2} density and mungbean biomass by 27% but increased weed biomass by about 3 times compared to weeding at emergence.

Interaction of crop density and time of weeding showed that highest mungbean yield 1220 kg ha^{-1} was obtained when plants were weeded at 15 DAE in 66 plants m^{-2} plots and the lowest 230.7 kg ha^{-1} was obtained from no weeding plots of 33 plants m^{-2} density. Linear regression model demonstrated that the yield of mungbean could be as high as 1900 kg/ha and for every kg ha^{-1} of increased dry matter weed biomass, the seed yield of mungbean would be decreased by 1 kg ha^{-1}.

On the basis of the above findings of the experiment, it may be concluded that weeding at 15 DAE in combination with crop density of 66 plants m^{-2} is suggested to be followed in mungbean production for obtaining higher yield. It is clear that weeds compete with mungbean for resources and reduce yield. So, mungbean must be weeded to get optimum yield.

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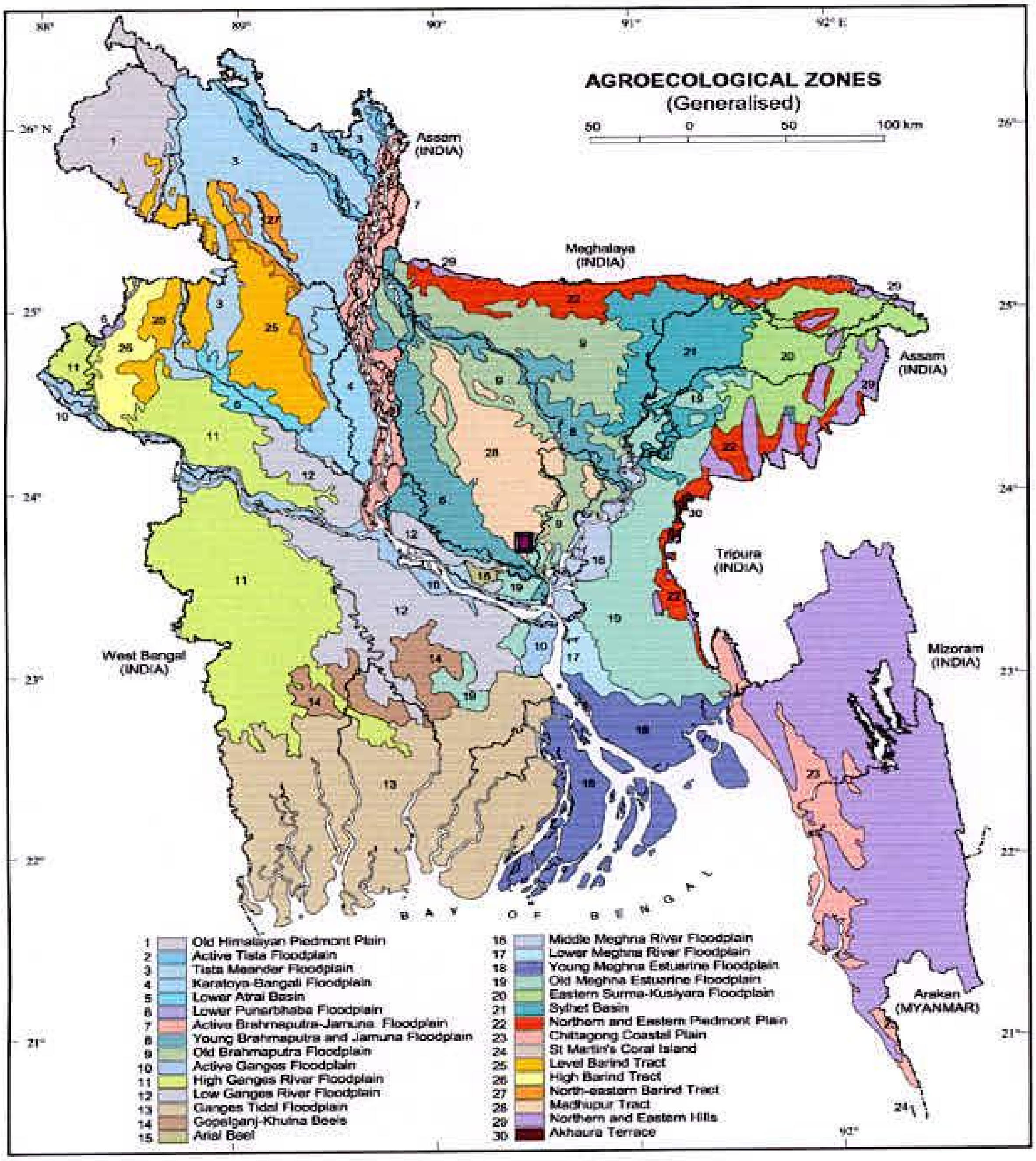
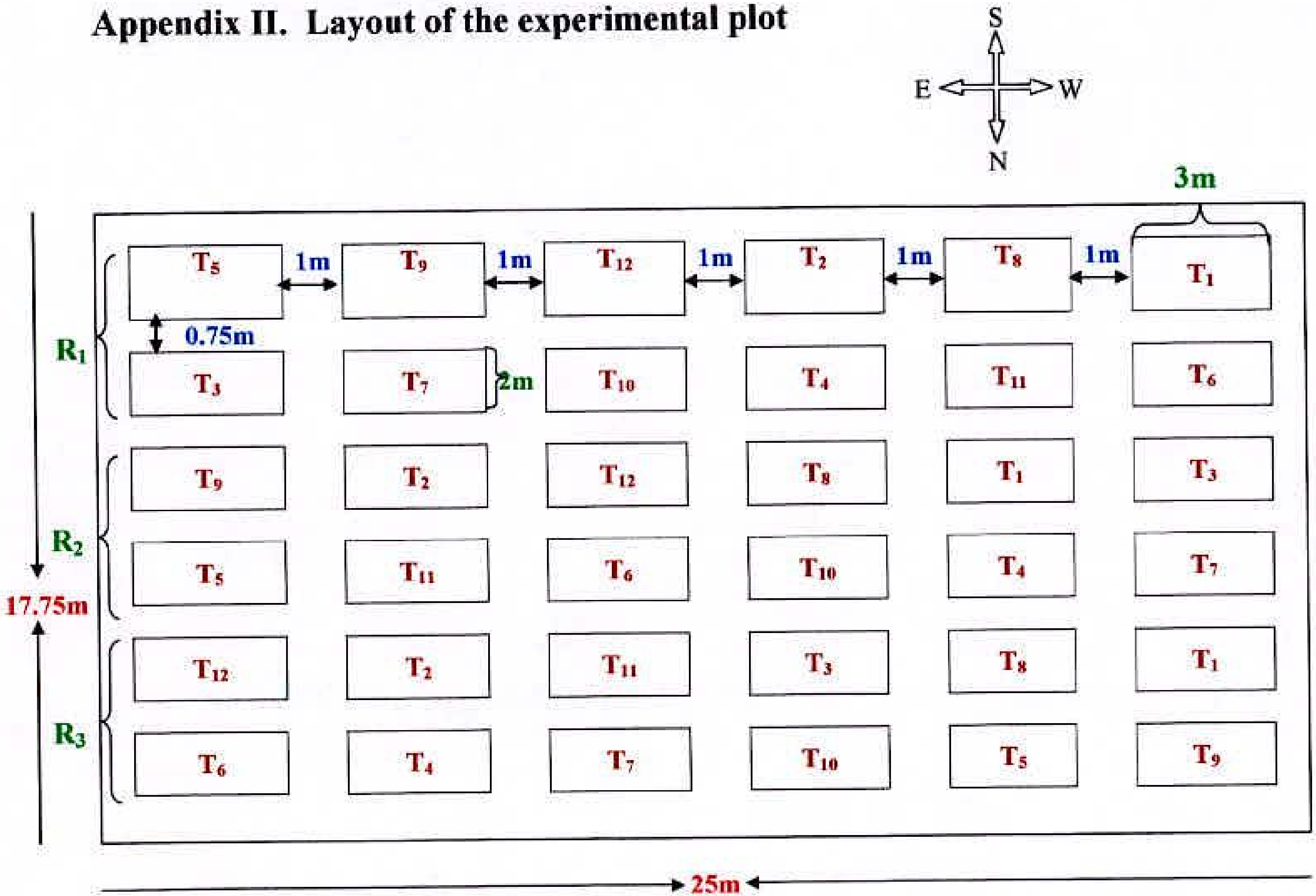
APPENDICES

Appendix I. Map showing the experimental site under study

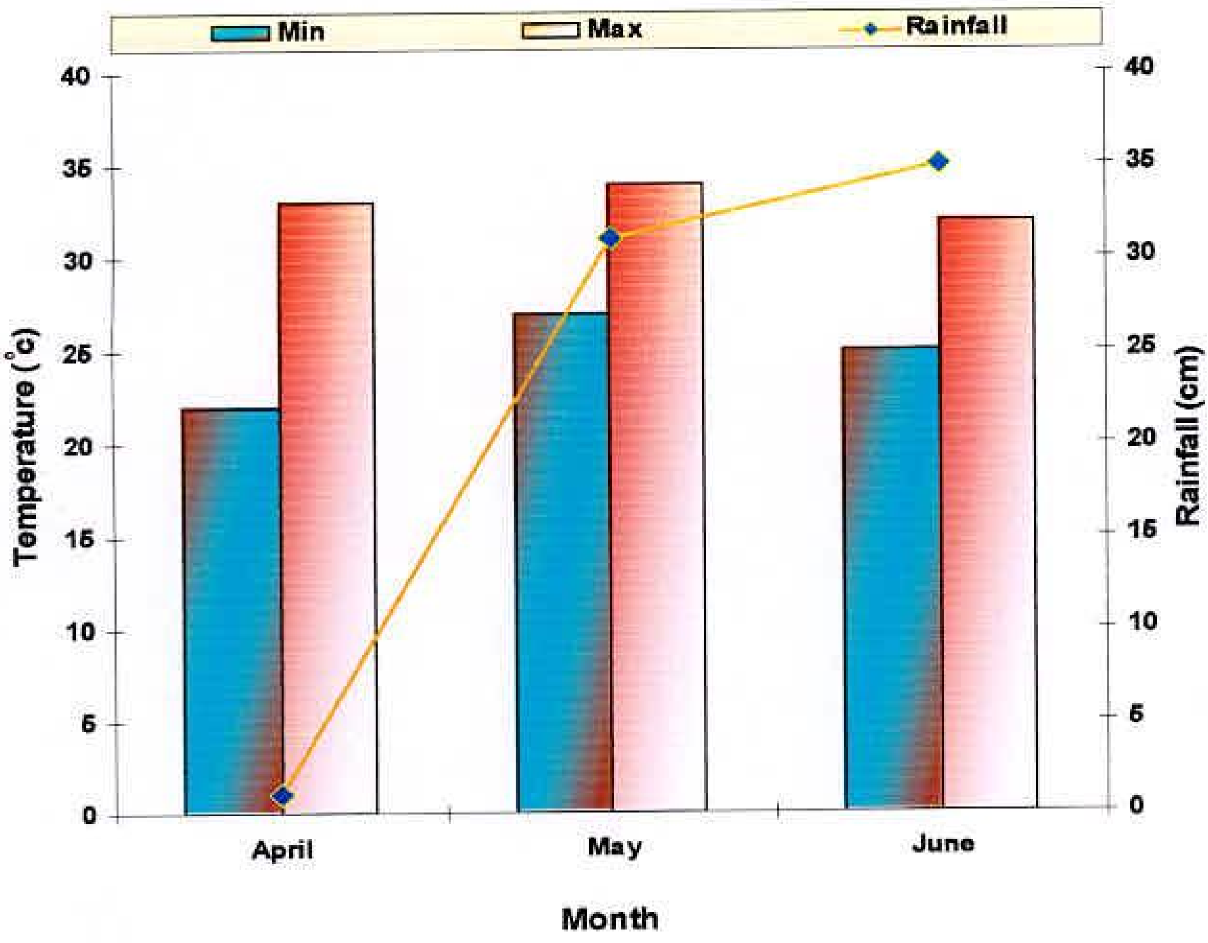


The experimental site under study

Appendix II. Layout of the experimental plot



Appendix III. Monthly record of average air temperature and total rainfall of the experimental site during the period from April 2007 to June 2007



Source: Bangladesh Meteorological Department, Dhaka-1212

Appendix IV: Morphological, physical and chemical characteristics of initial soil (0-15 cm depth)

A. Physical composition of the soil

Soil separates	(%)	Methods employed
Sand	36.90	Hydrometer method (Day, 1995)
Silt	26.40	-do-
Clay	36.66	-do-
Texture class	Clay loam	-do-

B. Chemical composition of the soil

Sl. No.	Soil characteristics	Analytical data	Methods employed
1	Organic carbon (%)	0.82	Walkley and Black, 1947
2	Total N (kg/ha)	1790.00	Bremner & Mulvaney, 1965
3	Total S (ppm)	225.00	Bardsley and Lancster, 1965
4	Total P (ppm)	840.00	Olsen and Sommers, 1982
5	Available N (kg/ha)	54.00	Bremner , 1965
6	Available P (kg/ha)	69.00	Olsen and Dean, 1965
7	Exchangeable K (kg/ha)	89.50	Pratt ,1965
8	Available S (ppm)	16.00	Hunter, 1984
9	PH (1:2.5 soil to water)	5.55	Jackson, 1958
10	CEC	11.23	Chapman, 1965

Source:SRDI

Appendix V. Mean square values for growth and yield components of mungbean

Sources of variation	Degrees of freedom	Mean square values						
		Plant population (no.)	Plant height (cm)	Number of branches plant^{-1}	Number of pods plant^{-1}	Number of seeds pod^{-1}	1000-seed weight (g)	Number of nodes plant^{-1}
Replication	2	1.028	0.004	0.002	0.001	0.000	0.003	0.006
Plant density	2	2687.02*	7.841*	0.178*	9.280*	2.747*	14.99*	5.181*
Time of weeding	3	94.88*	173.01*	2.017*	90.70*	4.726*	21.07*	5.930*
Plant density × Time of weeding	6	5.806*	46.84*	0.194*	0.897*	0.553*	0.885*	0.167*
Error	22	1.028	0.045	0.006	0.023	0.007	0.009	0.004

*Significant at 5% level

Appendix VI. Mean square values for yield and yield components of mungbean

Sources of variation	Degrees of freedom	Mean square values				
		Yield (kg ha^{-1})	Mungbean biomass	Weed biomass	%Maximum biomass	%Mungbean Biomass loss
Replication	2	35.36	36.75	147.0	126.75	0.083
Plant density	2	541921.69*	2883.2*	652.75*	68.25	42.25*
Time of weeding	3	436963.13*	13358.2*	24946.0*	890.91*	1243.0*
Plant density × Time of weeding	6	17630.36*	52.25	20.75	21.91	6.250
Error	22	207.21	91.41	57.90	18.02	3.720

*Significant at 5% level

Appendix VII. Mean square values for yield and yield components of mungbean

Sources of variation	Degrees of freedom	%Maximum yield	% Yield loss
Replication	2	8.333	6.307
Plant density	2	0.750	0.293
Time of weeding	3	5977.6*	5865.5*
Plant density × Time of weeding	6	263.41*	273.97*
Error	22	6.697	4.717

*Significant at 5% level