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Effect of Deficit Irrigations and Sowing Methods on Mung Bean Productivity

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ABSTRACT

A field experiment was designed to study the response of Mungbean to deficit irrigation levels and sowing methods. Randomized Complete Block Design (RCBD) with split plot arrangement replicated three times. Water treatments were controlled at I_0 (zero percent irrigation), I_{33} (33% of full irrigation), I_{67} (67% of full irrigation) and I_{100} (full irrigation). Full irrigation was determined on the basis of 65% management allowed deficit (MAD). Results shows that I_{67} and I_{100} not significant for pods plant^{-1} while these were highly significant for the sowing methods. The pods per plant are highly significant for I_0 and I_{33} levels. The sowing methods and irrigation levels both have significant impact on grain yield and biological yield. The biological yields continuously and consistently increase with the increase in irrigation levels. The harvest index of Mungbean and its water productivity both increase in irrigation levels certain level. The maximum irrigation applied at 65% MAD substantially decreases the Mungbean water productivity when compared to the harvest index. It was concluded that Mungbean MAD in semi-arid region of Peshawar may be exploited further; more moisture contents may be further extracted before applying next irrigation in raised bed technique in special and as usual in flat beds.

Keywords: Deficit irrigation, Irrigation levels, Sowing method, Growth attributes, Mung bean.

INTRODUCTION

Mungbean Vigna radiata L. also termed as green gram is a tropical legume. It belongs to the leguminaceae family, with a sub-family of papilionaceae. In Pakistan it is one of the important pulse crops. The leading countries in Mungbean production are Pakistan, Thailand and India (Khalil and Jan 2002). In those areas where diet mostly depends on cereals e.g. South east and South Asia, Mungbean is a primary source of protein. All over Pakistan Mungbean is cultivated as Rabi as well as Kharif crop. The main problem in Mungbean production is considered to be poor stand establishment (Rahmianna et al. 2000).

Agricultural sector has been given top priority by Government of Pakistan; however, the main problem in Mungbean production is due to poor institutional interest in the growing of mungbean crop (Rashid et al. 2004). In early summer the variation in the rainfalls coupled with an increased temperatures are the main problem in production of Mungbean in Peshawar region of Pakistan. Seed germination and early vigour was lowered due to increased temperature of soil which caused drought by evaporating moisture of soil at planting due to less rainfall. Sensitivity to extreme drought conditions and salinity are Mungbean serious problems (Bradford et al. 1993).

The adoption of these systems continues to expand as growers seek to increase water use efficiency and cropping flexibility. Permanent raised beds are the recommended irrigation design to achieve high yields in many irrigated crops on heavy clay soils, including maize, soybean, and fababean, canola and winter cereals. The incorporation of lateral (i.e. placed across the main slope of the field) raised beds into a bank less channel style design provides the opportunity to produce selected crops in sequence on raised beds within an unaltered irrigation design (Beecher et al. 2005).

The main problem which affects yield of Mungbean is its poor stand establishment. This problem is due to variable rainfall in summer monsoon period along with high temperature. Hence it is important to consider and incorporate their effects as well. In the water scarced region of the region, the whole study is an optimally tested model in a controlled environment for this specific Mungbean crop. However it is not possible to test this crop in these environments provided with such experimental setup in a locally grown field crop under intermittent supply from the source. The best alternative from the study among others has been selected to use less water for more production.

Objectives

- To study the effect of different irrigation on mungbean yield and yield component.
- To compare mungbean yield under raised bed and flat bed.
- To find water productivity of mungbean crop.

MATERIALS AND METHODS

The experiment was conducted at The University of Agriculture New Developmental Agriculture Research Farm, Peshawar situated at 34° 1'19.37"-34° 1'16.35"N and 71°28'5.07"-71°28'6.09"E during the season of Mungbean crop 2012.

Experimental Design

Randomized complete block design (RCBD) with split plot arrangement having three replications was used. This design contains two factorial study including sowing methods of Flat and Raised bed (Factor A) to which four Irrigation levels of 100%, 67%, 33% and 0 % (Factor B) have been applied during the whole growing season of mungbean crop.

Factor A sowing methods

The flat bed (FB) is the smooth plain surface on natural surface of the field which is surrounded by its boundaries in the shape of a simple plot. The full width of the raised bed (RB) at the bed level between two furrows was kept as 125 cm which on its upper level remains only to a top width of 90 cm. The height of the raised bed between furrows remains at 25 cm from the natural terrain.

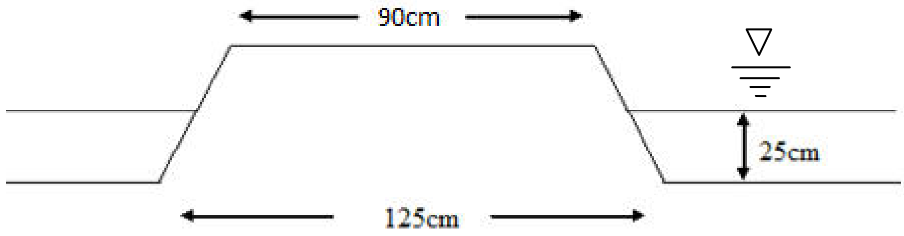

Figure 1. Sketch of raised bed

Irrigation levels (Factor B)

The different irrigation levels are Io (rainfed), I_{33} (33% of full irrigation), I_{67} (67% of full irrigation) and I_{100} (100% or full irrigation at the depletion level of 65% MAD).

Warsak Gravity canal water was used as source of irrigation. The cutthroat flume was used for measuring the flow rate to the experimental plots. This was installed in the channel before the inlet at certain distance from the plot inlet to avoid the fluctuation. Each plot was duly irrigated separately for the application of required amount of water, including the seepage losses in the channel from the point of installation of the cut-throat flume to the inlet of the plot. Full irrigation was given on the basis of 65% MAD. At a week interval the soil moisture was estimated at the root zone of the tentative plot using Gravimetric method. The soil sample for soil moisture contents estimation was collected at three different depths in the plot at 0-30, 30-60, and 60-100 cm. The reduced amount of 33% and 67% was applied after estimating the full irrigation at 65% MAD. The fourth level of moisture contents $I_{0,}$ a controlled one was determined from the effective rainfall through rain gauge or soil moisture sampling.

Seed bed Preparation

The experimental field having a size of 60 m × 18 m (1080 m^2) was divided into 24 sub plots with an area of 7.5 m × 5 m (37.5 m^2) each. The five meter strip on the two sides of the whole field was provided to protect it against irrelevant activities and situations. One meter wide space among sub plots was also kept for data collection and observations before sowing of crop. The other unnecessary plants were removed from the whole field time by time to provide ideal and neat environment to the plant growth. The whole field was given a pre-irrigation which was measured separately. After pre-irrigation sub plots were laid down according to the designed layout. Before layout all requirements like farm yard manure, fertilizer including nitrogen, phosphorus penta oxide (P_2O_5) and potassium oxide (K_2O) were applied according to the needs as basal dozes.

Sowing

The sowing period for Mungbean in Khyber Pakhtunkhwa is always in the month of July. For the present study the seeds in the field were sown in the first week of July. The depth of the seeds was 3-4 cm; keeping row to row distance of 30-34 cm. The plant to plant distance was 10 cm. The seed rate per acre was kept as 7-8 kg.

Irrigation water Management

The seasonal crop water demand for Mungbean is generally 400mm for a period ranging from 60-75 days. Irrigation is normally limited to supplement rainfall. Generally the flowering, pod formation and filling are sensitive to water shortages. The irrigation was applied when the required depletion of 65% or more is extracted from the soil. The replacement of the required amount was fulfilled as per strategies adopted in factor (A) of the experimental design.

In order to reach the required depletion level in each sub plot, the status of moisture content was maintained by the amount of irrigation estimated with respect to the full irrigation. For this purpose it was utmost important to initially determine the three basic parameters of field capacity, permanent wilting point and bulk density from three different depths of the sample field. The overall field capacity, permanent wilting point and bulk density were determined as the critical moisture depletions 30%, 18%, and 1.44 gm $cm^{-3.}$

For a given maximum allowable depletion of 65% MAD for Mungbean the critical moisture percentage on volume basis was 22.9%. Whereas 21.36% and 19.68% for 67% and 33% of full irrigation respectively for the soil nature has a field capacity 32% and a permanent wilting point of 18%.

Soil Moisture Content Determination

The moisture content of the soil samples was determined through gravimetric method. The first soil sample for moisture estimation was collected for assessment at the time of crop sowing. Moisture sample were collected after all irrigations at an interval of 7 to 10 days until harvest of the crop. Before and after irrigation the soil moisture sampling were carried out for the verification of depletion of soil moisture at the given stress level created by the deficit irrigation.

Hence continuous gravimetric soil sampling assessment after sowing was carried out till reached usual targeted moisture content percentage. For this purpose Soil samples were taken at 0-30, 30-60, 60-100cm depths from each treatment of the block. Samples were dried in oven at 105^0 for 24 hr. Percent moisture contents were calculated on a dry weight basis (by mass) by using the following formula:

$$\theta m = \frac{Ww - Wd}{Wd} * 10 \quad \ldots\ldots 1$$

Where, θm is the soil moisture content on a dry weight basis in percent Ww is the Wet weight of soil in gm, and Wd is the oven dry weight of soil in gm.

The percent soil moisture content on a volume basis from equation (2) was calculated by using the following relationships:

$$\theta v = \rho b * \frac{\theta m}{\rho w} \quad \ldots\ldots (2)$$

Where θv is the Soil moisture content on volume basis in percent ρw is the density of water in gm/cm3, and ρb is the Bulk density of the soil in gm/cm3.

Maximum allowable deficit or depletion (MAD), the ratio of readily available water to the available water is determined. The irrigation was applied at soil moisture depletion of 65%. Subsequent irrigation was applied to the respective plots as with an interval of one or two weeks each. The moisture level on volume basis was computed making use of the following relationship.

$$MAD = \frac{RAW}{AW} \times 100 \quad \ldots\ldots (3)$$

Where, MAD is the Management allowed deficit in percent, AW is the Available water in cm, and RAW is the readily available water in cm.

Available water is the total amount of water when the soil water is depleted to extreme limit of permanent welting point in the above mentioned example. The total amount comes to 14 cm when a root zone depth of 100 cm is considered. The equation 4 is the general representation of the available water determination.

$$AW = \frac{Drz\,(FC - PWP)}{100} \quad \ldots\ldots (4)$$

Where Drz is the depth of root zone in cm FC is field capacity in percent by volume, and PWP Permanent wilting point in percent by volume.

The readily available water is the amount of water, when water is extracted up to the limit of plant survival or critical or optimum growth and yield. It is shown by the following relation.

$$RAW = \frac{Drz\,(FC - \theta c)}{100} \quad \ldots\ldots (5)$$

Where, θc is Critical soil moisture content in percent by volume. In order to determine the θc, the following relation is derived by combining equation 4 and 5.

Combining equation 3 and 5 then we get;

$$\theta c = Fc - MAD(Fc - Pwp) \quad \ldots\ldots (6)$$

The depth of irrigation to be applied to each plot was calculated since per-irrigation from soil moisture collected for each irrigation level.

$$dw - \frac{Drz(FC - \theta i)}{100} \quad \ldots\ldots (7)$$

$$dw_{0-30} = \frac{Drz\{Fc - (\theta i)_1\}}{100} \quad \ldots\ldots \mathbf{(7a)}$$

$$dw_{30-60} = \frac{Drz\{Fc - (\theta i)_2\}}{100} \quad \text{.............................(7b)}$$

$$dw_{60-100} = \frac{Drz\{Fc - (\theta i)_3\}}{100} \quad \text{.............................(7c)}$$

Total depth of soil moisture is physically achieved from the algebric sum of all the depths collected from the three samples determined by using the equation 7(7(a), 7(b), 7(c)). The total depth of water required is as shown following.

$$dw = dw_{0-30} + dw_{30-60} + dw_{60-100} \text{...(8)}$$

where dw is the total depth of water to be applied in cm or soil moisture deficit from 0-100cm. θi is the Soil moisture contents before next irrigation in percent by volume at three different depths. The total depth of water (dw) is actually the net irrigation requirement (NIR). Hence

$$GIR = \frac{NIR}{Ea} \quad \text{.......................... (8)}$$

Where NIR is the total depth of water applied to the plant GIR is the Gross irrigation requirement (mm), and Ea is application efficiency (%).

Time required to obtain the desired depth of irrigation for each plot was calculated as suggested by Jensen (1998). Irrigation water was applied when the soil under the crop is reached to the depletion level maintained at different stress levels and as mentioned earlier in the experimental design. The irrigation application time t (hours) was computed from equation 9.

$$t = \frac{A \times dw}{Q} \quad \text{....................................... (9)}$$

Where t is time required to irrigate (s), A is area of subplot (m^2), dw depth of water applied (mm), and Q is the discharge from the watercourse (l/s).

Crop Water Productivity

The sample data for Mungbean was collected at the end of the season. The relative volume of water supplied to the given command area was calculated from the measured discharges for the specific time of irrigations. Crop water productivity was determined by using the following relation

$$CWP_{(Water\ Applied)} = \frac{Crop\ \text{Yield}}{\text{SWA}} \quad \text{................ (10)}$$

Where, SWA is the combination of seasonal irrigation water including effective rainfall and CWP is the crop water productivity in Kg m^{-3}.

Agronomic parameters

Pods per plant

Number of pods per plant was recorded by counting the number of pods of randomly selected four plants from central two rows in each sub plot average pods $plant^{-1}$ was calculated accordingly.

Grains per pod

Ten pods were selected from each treatment and were counted after drying, threshing and averaged.

Yield Parameters

1000 Grain weight (g)

Fro Thousand-grain weight thousand grains were taken from each subplot and were weighed (grams) in the laboratory on electronic balance.

Grain yield (kg/ha)

Grain yield for each treatment was determined with the help of spring balance, selecting two central rows for a length of four meter with 75cm row to row distance in each subplot and were converted into Kg ha^{-1}.

$$Grain\ Yield\ (Kg/ha) = \frac{\text{Grain Yield of 2 rows} \times 1000}{\text{No of rows} \times \text{row to row distance} \times \text{row length}} \text{..............11}$$

Biological yield (kg/ha)

For biological yield two central rows were harvested, dried in sun and then weighted and converted into kg ha^{-1} as grain yield.

$$Biological\ yield = \frac{\text{biological yield per plot}}{\text{plot area harvested} \times 10\,000.}$$

………………..... (13)

Statistical procedure

The data collected on different parameters were statistically analysed using analysis of variance (ANOVA) appropriate of randomized complete block design with split plot. Means were compared using LSD test at 0.05 level of probability, where the F-test was significant. (Steel and Torrie, 1980).

RESULTS AND DISCUSSIONS

Crop Water Productivity

Table I shows that crop water productivity of Mung bean was significantly affected by all stressed irrigations or deficit irrigations $I_{o,}$ I_{33} and I_{67}. However the sowing methods at 5% level of probability are not significantly different. As much as the interactions (sowing methods with a given irrigation) are concerned all the sowing methods at 5% probability level are significant except the full irrigation (I_{100}). Maximum crop water productivity (CWP) was recorded at the deficit irrigation level of I_{67} as compare to minimum CWP at the rain fed condition (I_0). The minimum CWP and its values at full irrigation are approximately closer to each other whereas I_{33} and I_{67} are prominently different than the situation of full irrigation and 33% irrigation supply.

Agronomic parameters

Number of pods plant^{-1}

The study showed maximum number of pods plant^{-1} (29) for I_{67} followed by $I_{33,}$ I_{100} and I_0 (27, 24 and 23 pod plant^{-1}). Analysis of variance showed that effect of irrigation treatment was significant at 5% level of probability whereas sowing methods also showed significant effect on pods plant^{-1}. (Table-2) demonstrated that the highest numbers of pods (28) were available under raised bed conditions. The flat bed gave minimum number of (25) pods plant^{-1}. The interaction was found non-significant where the maximum number of pods were (32) at an irrigation level of I_{67} under raised bed conditions. The minimum numbers of pods plant^{-1} were showed at I_0 under flat bed conditions.

Number of pods per plant significantly increased by the stress applied due to deficit irrigation as given in Table-2. Flat and raised bed for any irrigation level had significant effect on number of pods; however interaction between the two variables when irrigation level is changed along with the sowing method was not significant.

Number of pods per plant increased with the optimal application (I_{67}) of water for the raised bed. There was significant difference in the results of different irrigations. At 5% level of probability for irrigation level of I_{67} having raised bed showed good results than the other levels of irrigation on flat bed.

Number of Grains Pod^{-1}

The study shows that the number of seeds pod^{-1} increased with increase in quantity of water applied up to an optimal limit of I_{67}. The highest number of grains per pod were recorded at irrigation level of I_{67} (11 grains) followed by I_{100}, I_{33} and rainfed (I_0) (10, 10 and 7) number grains per pod respectively (Figure 4.5). The sowing methods also show significant effect at 5% level of probability on number of grains pod^{-1}. The raised bed gave 10 and flat bed gave 9 numbers of grains while the highest value for the interaction of sowing method and irrigations was recorded for irrigation level of I_{67} to raised bed 12. However, the lowest value was for flat bed under non irrigated conditions (8) (Table-2). Hence it is concluded that deficit irrigation upto 67% of full irrigation and raised bed practice gave more grains as compare to other levels of irrigation and sowing methods.

Thousand grain weight

Weight of one thousand grains under I_{67} irrigation level was much heavier than those of I_{100}, I_{33} and I_0 (Rainfed). Irrigation levels and sowing methods at 5% level of probability shows significant effect on thousand grains weight. The irrigation level of I_{67} gave the highest value of 48 grams per thousand grains which is followed by other levels of irrigation of I_{100}, I_{33} and I_0 with their values of 47, 43, and 36 grams per thousand grains respectively (Table-3). The Table-3 shows the significant effect for sowing methods. The maximum values for raised bed 45gm was obtained while for flat bed (42 grams) a minimum value was obtained. However the interaction for irrigation levels and sowing method was not much significant as indicated from the statistical analysis. Hence the higher value for interaction was recorded as 50 grams per 1000 grains for raised bed which for flat bed was 46 grams at I_{67} irrigation level. The minimum value obtained were 38.10 grams per thousand grains and 34.50 grams per thousand grains for raised and flat bed at I_0 irrigation (Table-3). Hence it is concluded that the raised bed grains were heavier when compared to the flat bed but if one applies the optimal amount of water then the crop will give good results on lesser water.

Biological Yield

Table-4 shows data on biological yield (kg ha^{-1}) for Mung bean crop. The maximum biological yield of 5653 kg ha^{-1} was obtained at 100% irrigation followed by I_{67}, I_{33} and I_0 (5368, 4321 and 3771 kg ha^{-1}) respectively. The raised and flat bed also gave significant effect on biological yield the maximum yield was (4870 kg ha^{-1}) obtained on raised bed while flat bed gives comparatively (4687 kg ha^{-1}) lesser one. The ANOVA shows that interaction is non-significant. However the highest rate in the interaction was 5706 kg ha^{-1} under raised bed technique at 100% irrigation where the smallest rate was 3653 kg ha^{-1} at I_0 under flat bed conditions. It is concluded that the raised bed at I_{100} gave best results.

The effects of irrigations and the sowing methods were significant at 5% level of probability. Both the factors, however, were independent of each other in their effect as their interaction was not significant. Decrease in water application had a negative effect on biological yield as it declined with the decrease in irrigation.

Grain Yield

Grain yield or economic yield is an important factor. In the present study the grain yield has significantly been affected both by irrigations and sowing method as shown in Table-5. The analysis shows that maximum grain yield (1429 kg/ha) was obtained from I_{67} irrigation level followed by (1343, 1084, and 687 kg ha^{-1}). The irrigations level of I_{100}, I_{33} and I_0 respectively. All the differences among the four levels of irrigation were significant from each other at 5% level of probability (Table-5).

The highest yield 1169 kg ha^{-1} was given by raised bed while the flat bed gives only 1102 kg ha^{-1}. Hence the interaction was non-significant although at the irrigation level I_{67} it shows significant effect. The highest value 1475 kg ha^{-1} was recorded under raised bed on I_{67} while the lowest value was of 645 Kg ha^{-1} under flat bed on rainfed (I_0) condition (Table-V)

Similarly maximum grain yield of 1436 Kg ha^{-1} was achieved from plots at the same site. The yield decreased with decrease in the quantity of water applied but it doesn't means that the yield will be increasing with increase in irrigation or water to the Mungbean crop. Differences in grain yield of the different irrigation levels were significantly different from each other at 5% level of probability. Plots with the lowest yield was produced by flat bed I_0 of irrigation level which upto a certain level of irrigation got increased but at full irrigation level of I_{100} again its yield has decreased. As a result the average of the two treatments indicated at I_{67} irrigation level which further increased under raised bed sowing method.

CONCLUSIONS

- The sowing methods and irrigation levels both have significant impact on grain and biological yields. With the increases in the amount of irrigation in both methods the biological yields significantly increase by which process there are significant decreases in the grain yields.
- In terms of grains $pods^{-1}$ the irrigation level of I_0 and I_{33} are mutually non significant. The same is the case with I_{67} and I_{100}. However these groups of irrigation levels are mutually highly significant. As the 1000 grains weight of irrigation levels are concerned from lowest irrigation level of I_0 to higher irrigation levels it goes on increase while further increase to I_{100} shows decline for the sowing methods in relation to grains per pod and 1000 grain weight. The raised bed has highly significant value than flat bed in all treatments.
- The deficit irrigation upto 67% of full irrigation for the raised bed sowing method gives maximum number of pod $plant^{-1}$.
- The harvest index as a physiological impact efficiency and Mungbean water productivity as water use efficiency both significantly increase with the increase in irrigation upto a certain optimal limit of I_{67}. The further increase in irrigation upto I_{100} irrigation level drastically decreases Mungbean water productivity in particular while in general it significantly decreases the harvest index as well. However the sowing methods for Mung bean crop are not so much significant for both the harvest index and crop water productivity.

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Table- I. Crop Water Productivity (Kg m^{-3}) of Mungbean as Affected by Different Irrigation Levels and Sowing Methods

Irrigations	Sowing methods		Mean
	Raised bed	Flat bed	
I_0	0.24	0.21	**0.23d**
I_{33}	0.28	0.26	**0.27b**
I_{67}	0.30	0.28	**0.29a**
Controlled I_{100}	0.24	0.24	**0.24c**
Mean	**0.27a**	**0.25a**	

LSD value for Irrigations (I) at 5% level of probability = 0.01
LSD value for BxI at 5% level of probability = 0.01 LSD value for sowing method = 0.03

Table-2 Pods plant^{-1} of Mungbean as affected by different irrigation levels and sowing methods

Irrigations	Sowing methods		Mean
	Raised bed	Flat bed	
I_0	22.93	18.95	**20.94b**
I_{33}	26.92	25.58	**26.25ab**
I_{67}	32.25	27.67	**29.96a**
I_{100}	27.83	26.17	**27.00a**
Mean	**27.48a**	**24.59b**	

LSD value for Beds (B) at 5% level of probability = 1.70
LSD value for Irrigations (I) at 5% level of probability = 1.96
LSD values for irrigation B×I at 5% level of probability= 8.30

Table- 3 Grains per pod of Mungbean as affected by different irrigation levels and sowing methods

Irrigations	Sowing methods		Mean
	Raised bed	Flat bed	
I_0	8.52	8.32	**8.42b**
I_{33}	9.64	9.50	**9.57ab**
I_{67}	11.72	10.08	**10.90a**
I_{100}	10.33	9.42	**9.88a**
Mean	**10.05a**	**9.33b**	

LSD value for Beds (B) at 5% level of probability = 0.46
LSD value for Irrigations (I) at 5% level of probability = 1.33

Table- 4 Thousand grain weight (g) of Mungbean as affected by different irrigation levels and sowing methods

Irrigations	Sowing methods		Mean
	Raised bed	Flat bed	
I_0	38.10	34.50	**36.30d**
I_{33}	44.13	41.97	**43.05c**
I_{67}	50.27	45.63	**47.95a**
I_{100}	47.57	45.87	**46.72b**
Mean	**45.02a**	**41.99b**	

LSD value for Beds (B) at 5% level of probability = 1.06
LSD value for Irrigations (I) at 5% level of probability = 1.14

Table- 5 Biological yield (kg ha^{-1}) of Mungbean as affected by different irrigation levels and sowing methods

irrigations	Sowing methods		Mean
	Raised bed	Flat bed	
I_0	3889	3652	**3771d**
I_{33}	4381	4261	**4321c**
I_{67}	5502	5234	**5368b**
I_{100}	5706	5600	**5653a**
Mean	**4870a**	**4687b**	

LSD value for Beds (B) at 5% level of probability = 78.15
LSD value for Irrigations (I) at 5% level of probability = 116.61

Table-6 Grains yield of Mung bean as affected by different irrigation levels and sowing methods

Irrigations	Sowing methods		Mean
	Raised bed	Flat bed	
I_0	8.52	8.32	**8.42b**
I_{33}	9.64	9.50	**9.57ab**
I_{67}	11.72	10.08	**10.90a**
I_{100}	10.33	9.42	**9.88a**
Mean	**10.05a**	**9.33b**	

LSD value for Beds (B) at 5% level of probability = 34.61
LSD value for Irrigations (I) at 5% level of probability = 37.34
LSD value for Irrigations (B×I) at 5% level of probability = 54.81