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Response of Mungbean [*Vigna radiata* (L.)Wilczek] Varieties to Plant Spacing under Irrigation at Gewane, Northeastern Ethiopia

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Abstract. An experiment was conducted to determine the effect of inter-row and intra-row spacing on growth, yield components and yield of mungbean varieties under irrigation. The treatments consisted of factorial combinations of three inter-row spacing (30, 40, and 50 cm), three-intra-row spacing (5, 10 and 15 cm) and two mungbean varieties (N-26 and MH-97) laid out in Randomized Complete Block Design with three replications. Effect of varieties, inter-row spacing and intra-row spacing was highly significant and significant on plant height, and secondary branch. The longest plant height (41.71 cm) was for variety MH-97 and from 5 cm intra-row spacing, respectively and maximum number of secondary branch was recorded for variety MH-97 (8.91) and from 15cm intra-row and 50cm inter-row spacing, respectively. The interaction effect of the variety, inter and intra-row spacing was highly significant on number of primary branch per plant, number of pod per plant and crop stand count percentage where the highest number of primary branches (7.00) was recorded from variety MH-97 at 50 cm inter-row spacing and highest number pods per plant (30.15) were recorded for variety MH-97 at 40 cm inter-row and (31.34) at 15cm intra-row spacing. Where the highest crop stand count at harvest were recorded from variety MH-97 (97.00%) at 40 cm inter-row spacing. Effect of inter-row spacing and intra-row spacing were highly significant and significant on above ground dry biomass and the highest above ground dry biomass at inter-row spacing of 30 cm (5968.8 kg ha^{-1}) and intra-row spacing 5cm 6145.9 kg ha^{-1}). Effect of variety, inter-row and intra-row spacing were highly significant on harvest index and grain yield where the highest harvest index was from variety MH-97 (20.91%), inter-row spacing of 40 cm which give (21.18%) and intra-row spacing 10 cm which give (20.30%) and the highest grain yield from Variety MH-97 (1117.94 kg ha^{-1}), inter-row spacing 40 cm (1213.75 kg ha^{-1}) and intra-row spacing 10 cm which give (1151.67 kg ha^{-1}).
Keywords: dry biomass, harvest index, mungbean varieties, row spacing, seed yield

INTRODUCTION

Mungbean is one of the most important pulse crops, grown from the tropical to sub-tropical areas around the world (Kumari *et al.*, 2012). It is an important wide spreading, herbaceous and annual legume pulse crop cultivated mostly by traditional farmers (Ali *et al*., 2010). In Ethiopia, mungbean is mostly grown by smallholder farmers under the dryer marginal environmental conditions and the production capacity is lower than other pulse. Poor farmers in Ethiopia, mungbean are mainly used as food, but growing it for income generation can also be important. A recent addition to the Ethiopian pulse production, it is grown in few areas of north showa zone and currently becoming popular in other parts of the country especially as export crop. Its production has increased in Ethiopia from 14,562.00 ha with average seed yield of 966 kg ha^{-1} in 2014/15 cropping season (CSA, 2015) to 24,038.85 hectares with average productivity of 1.003 t ha^{-1} in 2015/16 cropping season (CSA, 2016). Among legumes, mungbean is noted for its protein and lysine-rich grain, which supplements cereal-based diets (Minh, 2014).

Mungbean has good potential for crop rotation system, for crops in drier farmland cultivation areas (Ashraf *et al.*, 2003) and the ability to grow on dry and irrigated conditions (Rahim *et al*., 2010). Sowing of mungbean mainly occurs during summer when sufficient rain is available for growth but it is sensitive to waterlogging. It is grown in several types of cultivation systems, including sole cropping, intercropping, multiple cropping and relay

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cropping, where it is planted after cereals using residual moisture (Rehman *et al*., 2009).

Plant density effects early ground cover, competitive ability of crops with weed, soil surface evaporation, light interception, lodging and development of an optimum number of fruiting sites in a crop canopy. It also affects canopy development, plant architecture, and distribution of pods (Matthews *et al*., 2008). However, optimum plant density varies depending on crop species or varietals differences in vigor, height and branching, time of sowing, and the nature of the season (Anderson *et al*., 2004). This can also depend on soil type, management practices, soil moisture, seasonal rainfall etc. (Matthews *et al.*, 2008). The number of seeds/pod was not increased by irrigation levels. It was also noted that water stress reduced mungbean yield regardless of whether the stress was imposed when plant were in vegetative or reproductive stage (Raza et al., 2012).

Appropriate varieties and plant spacing are among the most important agronomic practices which contribute substantially to the seed yield of mungbean. The full yield potential of an individual plant exploited when sown at appropriate spacing. Yield per plant decreases gradually as plant population per unit area increases. As plant density increases the amount of dry matter in vegetative parts also increases. Both the biological and economic yield increase with increasing plant population up to certain point and subsequently, no addition in biological yield can be obtained and economic yield decreases. Therefore, the optimum plant population of the individual crop should be worked out under suitable environment conditions (Singh and Singh, 2002).Yield response of different plant cultivars to plant spacing under irrigated condition need to be known for practical purposes, as planting density is a major management variable used in matching crop requirements to the environmental offer of resources. According to Gewane woreda, the yield of mungbean recorded from farmers' field ranged from 600-900 kg ha^{-1} under irrigated condition. However, this yield is lower than the national average yield (966 kg ha^{-1}) (CSA, 2015) and the potential yield of the crop 800-1500 kg (MoARD, 2011).

One of the major constraints that limit the production of mungbean is a lack of optimum plant populations related to mungbean cultivars. Different mungbean cultivars have different morphological characteristics and traditional indeterminate mungbean varieties had long growth duration (90 to 110 days) and required multiple harvests. As a number of factors such as fertility status of the soil, moisture availability, growth pattern of the varieties and cultural practices influence both inter-row and intra-row spacing, optimum planting density should be determined to specific area and to specific mungbean varieties through conducting location or agro-ecology based experiment. The application of liquid biological fertilizer significantly increases the growth and yield of shallots (Purba et al., 2020).

Therefore, the objective of this study was to assess the effect of inter and intra-row spacing on growth, yield components and yield of mungbean varieties under irrigation.

METHODS

Description of the study area

The experiment was conducted at Gewane Agricultural Technical and Vocational Training College demonstration site, Afar Regional State during 2019 cropping season. It is located in Gewane Woreda at 10°10' N latitude, 40°32' E longitude, and 356 km North East from Addis Ababa. The altitude of the site is about 626 meters above sea levels. The experimental area is characterized as a semi-arid climatic zone with an average annual rainfall of about 400 mm. The rainfall is erratic and low due to which crop production is not possible under rain-fed condition. The mean annual temperature of the experimental site is about 30 °C with 39°C maximum and 22.5°C minimum (ESRDF, 2003).

Treatments and Experimental Design

The treatments consisted of factorial combinations of two mung varieties (MH-97 and N-26) with three inter-row spacing (30 cm, 40 cm and 50 cm) and three intra-row spacing (5 cm, 10 cm and 15 cm). The experiment was laid out in Randomized Complete Block Design (RCBD) and replicated three times per treatment in factorial combination with a total of eighteen treatments.

Experimental Procedure and Crop Management

The experimental field was plowed with a tractor to a depth of 25-30 cm. After laying out as per the specification, each plot was leveled and ridges were made manually. Each plot was an area of 3.6 m x 3.0 m (10.8 m^2). The spacing between plots and between blocks was 0.8 m and 1 m, respectively.Treatments were assigned to each plot randomly. Seven, nine and twelve rows were accommodated per plot for 50 cm, 40 cm, 30 cm row spacing, respectively. Each row had 60, 30 and 20 plants spaced at 5, 10 and 15 cm apart, respectively. The one outer most row from each side and one plant from both ends of each row were considered as a border and one row was used for destructive sampling. Thinning was done as required to maintain the target population densities 10 days after emergence.

Phenological parameters

Days to 50% emergence was recorded as the number of days from sowing to when 50% of the plants emerged in each plot. Similarly, days to 50% flowering was recorded as the number of days from planting to when 50% of the plants produced first flower and 90% physiological maturity was recorded as the number of days from planting to when 90% of the plants showed yellowing of pods.

Growth and nodulation parameters

Total number of nodules: It was determined by counting taking a destructive sample of ten plants from a net plot at flowering. Roots were carefully exposed with the bulk of root mass and nodules. The nodules were separated from the soil, washed and the total number of nodules was determined by counting. Then, effective and non-effective nodules were separated by their colors where a cross section of an effective nodule made with a pocket knife show a pink to dark-red color, whereas a green color indicates in effective nodulation. **Plant height:** It was measured as the height of 10 randomly taken plants from the ground level to the apex of each plant at the time of physiological maturity from the net plot area. **Number of primary branches: It was** determined by counting the number of primary branches on the main stem from randomly selected 10 plants from the net plot area. **Number of secondary branches: It** was determined by counting of secondary branches on the primary branches from randomly selected 10 plants from the net plot area.

Yield components and yield

Crop stand count: The plants from the net plot area were counted after thinning and at crop harvesting to determine the change in stand count in percent. **Number of pods per plant:** It was recorded based on ten randomly pre tagged plants in each net plot area and the average was taken as number of pods per plant. **Number of seeds per pod:** The total number of seeds in ten randomly taken pods from the net plot was counted and divided by total number of pods to find the number of seeds per pod. **Hundred seed weight (g)** was determined by taking the weight of hundred randomly sampled seeds from the total harvest from each net plot area and adjusted to 10% moisture level. **Above ground dry biomass (kg ha^{-1}):** At physiological maturity, from the destructive rows the above ground dry biomass of randomly ten plants was taken and measured

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after drying till a constant weight. For obtaining the total above ground dry biomass, the dry biomass per plant thus obtained was multiplied by the total number of plants per net plot and was converted into kg ha^{-1}. This was used to calculate the harvest index. **Seed yield (kg ha^{-1})**: This was recorded from net plot area of each plot after sun drying for 10 days. The grain yield was adjusted to the designated moisture content of 10%. **Harvest index (HI): It** was computed as the ratio of seed yield (kg ha^{-1}) to the total above ground dry biomass.

Statistical Analysis

All the measured parameters were subjected to analysis of variance (ANOVA) appropriate to factorial experiment in RCBD according to the Generalized Linear Model (GLM) of SAS 9.0 (SAS, 2004) and interpretations were made following the procedure described by Gomez and Gomez (1984). Whenever the effects of the factors were found to be significant, the means were compared using the Least Significant Differences (LSD) test at 5% level of significance.

RESULTS AND DISCUSSION

Crop Phenology and Growth Parameters

Days to 50% flowering

The main effects of variety, inter and intra-row spacing and their all interactions were not significant on days to 50% flowering. Variety 'MH-97'with indeterminate erect growth habit was earlier to flower (40.10 days) than variety 'N-26' with determinate bush growth habit took the highest number of days (42.42) to flower (Table 1). In agreement with this result, Wedajo (2015) showed that the main effect of mungbean varieties on days to 50% flowering was not significant.

Table 1. The main effect of variety, intra-row spacing and inter-row spacing on days to 50% flowering, days to 90% physiological maturity and plant height of mungbean.

Treatment	Days to 50% flowering	Days to 90% physiological maturity	Plant height (cm)
Variety			
MH-97	40.10	74.49^{b}	41.72
N-26	42.42	79.86^{a}	41.33
LSD(0.05)	NS	1.93	NS
Intra-row spacing (cm)			
5	41.96	76.41	44.06^{a}
10	42.17	77.35	41.38^{ab}
15	42.64	77.77	39.13^{b}
LSD(0.05)	NS	NS	3.89
Inter-row spacing (cm)			
30	42.18	76.25	43.54
40	42..23	76.70	41.50
50	42.36	78.583	39.53
LSD(0.05)	NS	NS	NS
CV%	4.20	4.53	13.84

LSD (0.05) = Least Significant Difference at 5% level; CV= coefficient of variation; NS= Non- Significant. Means in a column followed by the same letter(s) are not significantly different at 5% level of significance according to LSD test.

Days to 90% physiological maturity

The main effect of variety showed highly significant (P<0.01) effect on the days to 90% physiological maturity while the main effect of

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inter and intra-row spacing and all the interactions were not significant. Variety MH-97 matured significantly earlier (74.49 days) than variety N-26 (79.86 days (Table 1). The possible reason for the difference between the varieties might be determinate cultivars produce additional nodes after initial flowering. varietal characteristics, which is genetically controlled and individual varieties have different growing habit, flowering and maturity days. Previous reports also showed that who obtained significant difference variety MH-97 to be earlier than varieties N-26 (MoARD, 2008). Similarly Wedajo (2015) reported that MH-97 was earlier in days to flowering and days to maturity.

Plant height

The main effects of variety and inter-row spacing as well as any of the interactions revealed no significant effect on plant height at maturity, while the main effect of intra-row spacing had a significant effect on plant height. Variety MH-97 was taller (41.72 cm) than variety N-26 (Table 4). This result was in agreement with Wedajo (2015) who reported no significant difference in plant height between variety MH-97 and N-26.

The plant height was decreased with the increase in the intra-row spacing where the highest plant height of 44.06 cm was recorded at 5 cm and the lowest height (39.13 cm) was from the 15cm intra-row spacing (Table 1). Increase in plant height with decreasing intra-row spacing might be due to intra-specific competition for the sunlight resulting in taller plants. This trend explains that as the number of plants increased in a given area, the competition among the plants for nutrients uptake and sunlight interception also increased. In agreement with this result, Taj *et al*. (2002) found that competition for light in narrow spacing that resulted in taller plants of mungbean while at wider spacing light distribution was normal. Similarly, Shamsi and Kobraee (2009) on soybean observed that increasing the density of plants of soybean led to significant increases in plant height.

Number of primary branches

Analysis of variance revealed that main effects of inter-row spacing, intra-row spacing and the interaction effect of variety and inter-row spacing were highly significant (P < 0.01) on the number of primary branches per plant while the main effect of variety, the interaction effect of varieties and intra-row spacing, inter and intra-row spacing and three way interaction had no significant effects on the number of primary branches per plant.

Variety ‘MH-97’ at 50 cm inter-row spacing gave significantly highest number of primary branches (7.00) while variety ‘N-26’ at 30cm inter-row spacing gave the lowest number of the primary branch (5.30) (Table 2). This is indicated the plasticity response of plants to various plant spacing, that is increased in plant population is associated with a progressive decline in number of branches whereas, plants at higher inter and intra-row spacing produce higher number of branches.

Mahama (2011) reported that soybean variety and row spacing showed a significant effect on the number of primary branches per plant and reported a higher number of primary branches at wider inter-row spacing (60 cm and 50 cm) than narrow inter-row spacing (40 cm and 30 cm).

Number of secondary branches

The main effect of inter-row spacing and intra-row spacing had highly significant (P < 0.01) effects on the number of secondary branches while the main effect of variety and the interactions had no significant effect on a number of secondary branches.

Secondary branches per plant were increased with increase in inter and intra-row spacing. The highest mean number of secondary branches (9.30) and (8.25) were produced at the highest inter-row spacing of 50 cm and at intra-row spacing of 15 cm, respectively (Table 3) which might be because in wide plant spacing there was a low competition among plants for growth factors such as moisture, nutrients, and light, which in turn increased potentiality of mungbean plants in producing more branches. Loss *et al*. (1998) reported similar findings wherein, faba bean, soybean, and common vetch, respectively, reduced the number of branches with increased plant population. In contrast this result, Rasul *et al*. (2012) obtained more number of fruit bearing branches (6.24) on mungbean in inter-row spacing of 30 cm the lowest number of branches per plant (5.93) from an inter-row spacing of 60 cm

Table 2. Interaction effect of variety and inter-row spacing on a number of primary branches per plant of mungbean.

	Inter-row spacing (cm)		
Variety	30	40	50
MH-97	4.80^{d}	5.28^{bc}	7.00^{a}
N-26	5.30^{dc}	5.55^{bc}	5.68^{b}
LSD (0.05)	0.73		
CV%	19.8		

Means in columns and rows followed by the same letter(s) are not significantly different at 5% level of significance; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of variation.

Number of total and effective nodules

The total and effective number of nodules per plant revealed no significance difference due to the main effects of varieties, inter and intra-row spacing and in all two way and three-way interactions. Lack of response in nodulation parameters might be due to higher total nitrogen percentage in the experimental soil (Table 3) of the study area, which may limit nitrogen-fixing ability of the crop. In general, the number of nodules recorded per plant was very low which might be due to the high soil temperature which might not be suitable for the *Rhizobium* bacteria. In line with this result, Rasul *et al*. (2012) reported non-significant effect of inter-row spacing of plants did not significantly affect the nodulation process on mungbean. Mahama (2012) also reported no significant difference in row spacing on a total number of nodule per plant. Similarly, Daniel *et al.* (2012) reported no significant effect of plant densities and varieties of soybean on a total number of nodules per plant.

This result was in line with that of Rasul *et al*. (2012) inter-row spacing did not significantly affect the nodulation process and likewise, the interaction among varieties and inter-row spacing also could not affect the number of nodules on mungbean.

Yield Components and Yield

Crop stand count

Analysis of variance revealed the main effects of inter-row spacing, intra-row spacing and the interaction effect of variety and inter-row spacing were highly significant ($P < 0.01$) on the number of primary branches per plant. while the main effect of variety, the interaction effect of varieties and intra-row spacing, inter and intra-row spacing and three way interaction had no significant effects onon stand count at harvest as compared to an initial count.

The highest final percent stand count (97.00%) was recorded from variety MH-97 at inter-row spacing 40 cm. while the lowest final percent stand count (70.57%) was recorded from variety N-26 at inter-row spacing 30 cm (Table 4) (Construct one-way tables as the interaction is NS).

The high percent mortality with relatively higher population density might be due to crowding effect. There may be possibilities that at narrower inter-row spacing plants became

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crowded and died due to intense competition for growth resources. Hence, at narrow inter-row and intra-row spacing, there was a decrease in the survival rate of the plants than at a wider spacing. At lower plant population comparatively, the availability of more space might have resulted in less competition for resources (nutrients, moisture, and light).

In agreement with this result, Almaz et al. (2016) reported increased plant mortality rate as density of plant increased for faba bean variety in which the wider inter-row spacing (50 cm) had the maximum (93.3%) final stand count percentage as compared to 40 cm (91.0%) and 30 cm (90.1%) inter-row spacing. Similarly, Abdel (2008) reported reduced plant competition and plant mortality at lower plant population of faba bean than higher plant population where wider plant spacing (30cm) gave higher percentage of crop stand count (91.9%) as compared to narrower plant spacing (10 cm) which gave lower percentage of crop stand count (85.5%).

Table 3. The main effects of variety, intra-row spacing and inter-row spacing numbers of the total nodules, effective nodules and secondary branches per plant of mungbean.

Treatment	Number of total nodules	Number of effective nodules	Number of secondary branches
Variety			
MH-97	6.16	2.19	8.91
N-26	5.99	2.18	8.83
LSD(0.05)	NS	NS	NS
Intra-row spacing (cm)			
5	6.53	2.07	8.33[b]
10	6.35	2.29	8.75[b]
15	5.35	2.20	9.53[a]
LSD(0.05)	NS	NS	0.73
Inter-row spacing (cm)			
30	6.47	2.27	8.25[b]
40	6.23	2.28	9.05[a]
50	5.52	2.00	9.30[a]
LSD(0.05)	NS	NS	0.73
CV (%)	30.22	27.32	12.21

LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of Variation; NS= Non-Significant. Means in a column followed by the same letters are not significantly different at 5% level of significance.

In contrast Rasul *et al*. (2012), also reported plant population was significantly affected by varying inter-row spacing, 30 cm gave the maximum plant population per unit area (37.56 %) which was significantly different from 45 cm inter-row spacing (28.78 %) and 60 cm (19.44%).

In conformity with results of this study, Abdolreza (2016) reported a significant difference due to seed rate, maximum number of pods per plant (8.81) was recorded at 25 kg ha^{-1} and the minimum number of pods per plant (4.53) was recorded at 75 kg ha^{-1} of mungbean. Rasul *et al*. (2012) also reported that the interaction of varieties at inter-row spacing significantly affected the number of pods per plant. Variety NM-98 sown at inter-row spacing of 30 cm produced maximum

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number of pods per plant (17.09) and variety V3 M-1 at inter-row spacing of 45 cm produced the minimum number of pods per plant (15.76). Similarly, Yadav *et al*. (2014) reported a significant differences due to the main effects of plant spacing where the maximum number of pod per plant was observed at 30 cm × 10 cm spacing (34) followed by 40 cm x 10 cm spacing and minimum number of pods per plant was observed at 20 cm ×10 cm (30) on mungbean.

Table 4. Interaction effect of variety and inter-row spacing on percent stand count of mungbean at harvest.

	Inter-row spacing(cm)		
Variety	30	40	50
MH-97	89.96[a]	97.00[a]	89.44[a]
N-26	70.57[b]	90.51[a]	73.14[b]
LSD(0.05)	59.83		
CV (%)	9.05		

LSD (0.05) = Least Significant Difference at 5% level;CV= Coefficient of Variation;NS= Non- Significant. Means in a column followed by the same letters are not significantly different at 5% level of significance.

Abdolreza (2016) also reported a significant differences due to the main effects of seed rate, seed at 25 kg ha^{-1} gave the maximum number of pods (8.82) whereas seed of 50 kg ha^{-1} gave the minimum number of pods (6.52).The decreasing trend of number of pods per plant with increasing seed rate could be attributed to the competition existing between the populated crops for the sake of nutrients uptake.

The increase in a number of pods per plant at wider inter and intra-row spacing might be due to the highest number of primary branches at a wider spacing which may contribute to producing higher number of pods per plant or as the result of higher net assimilation rates and reduction of competition in wider spacing. The decrease in the number of pods per plant with increased plant density might be due to increased plant density that might have induced competition between the former and later emerged flowers that could lead to flower abortion. However, the growth factors (nutrient, moisture, and light) for individual plants might be easily accessible that retained more flowers and supported the development of lateral branches.

Number of pods per plant

The main effect of variety, inter, intra-row spacing and the interactions effect of variety with inter-row spacing and variety with intra-row spacing had highly significant ($P < 0.01$) effect on the number of pods per plant while, the interaction effect of inter and intra-row spacing and the three way interactions were not significant.

The highest mean number of pods per plant (30.15) was recorded for variety 'MH-97' at 40 cm inter-row spacing and 15cm intra-row spacing (30.34) and the lowest number of pods per plant (21.67) was recorded for variety 'N-26' at 30 cm inter-row spacing and the lowest number of pods per plant (22.55) was recorded for variety 'N-26'at 5cm intra-row spacing 9 (Table 5). According to Purba et al. (2018), the spacing has a very significant effect on the total number of pods per plant with the use of a distance of 40 x 20 cm which is 50.78 pods.

The increase in number of pods per plant at low density (wider inter and intra-row spacing) might be due to the highest number of primary branches at a wider spacing which may contribute to producing higher number of pods per plant or as the result of higher net

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assimilation rates and reduction of competition in wider spacing.

Table 5. Interaction effect of variety and intra-row spacing on a number of pod per plant of mungbean.

Variety	Intra-row spacing (cm)			Inter-row spacing (cm)		
	5	10	15	30	40	50
MH-97	22.55^{b}	23.11^{b}	31.34^{a}	89.96^{a}	97.00^{a}	89.44^{a}
N-26	16.98^{c}	18.77^{c}	18.89^{c}	70.57^{b}	90.51^{a}	73.14^{b}
LSD(0.05)	3.2			59.83		
CV (%)	14.73			9.05		

LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of Variation; NS= Non- Significant. Means in a column followed by the same letters are not significantly different at 5% level of Significance.

Hundred Seeds weight

The main effect of inter and intra-row spacing and all the interaction effect of variety, inter and intra-row spacing had no significant effect on hundred grains weight of mungbean. While the main effect of variety had highly significant ($P < 0.01$) effect (Appendix Table 3).

Significantly higher hundred seed weight was observed for variety MH-97 (6.78 g) and the lowest was obtained for variety 'N-26' (6.35 g) (Table 6). The significant difference on hundred seed weight might be due to seed size of different varieties. This result was in line with the study by Wedajo (2015) who obtained significantly higher seed weight for variety MH-97 (9.1 g) and variety N-26 (5.6 g) on hundred-seed weight.

Even though the difference was not significant, with increased inter and intra-row spacing , hundred seed weight increased where the highest hundred seed weight (6.73 g) was recorded at the highest inter and intra-row spacing of 50 cm and 15 cm. The highest hundred seed weight with with increased spacing might be with the decreased inter plant competition that leads to increased plant capacity, for utilizing the environmental inputs in building great amount of metabolites to be used in developing new tissues and increasing its yield components. In wider spaced plants, improved supply of assimilates to be stored in the seed, hence, increased the weight of hundred seeds. In agreement with this result, Abdolreza (2016) reported non-significant effect of seed rate on 1000-seed weight, but numerically a maximum 1000-seed weight (58.73 g) was obtained in seed rate of 15 kg ha^{-1} followed by 20 kg ha^{-1} (57.69 g). Similarly, Lemlem (2011) obtained non-significant effect of plant density on hundred seed weight of soybean.

Aboveground dry biomass

The main effects of inter-row spacing had highly significant ($P<0.01$) effect on the aboveground dry biomass (kg ha^{-1}) while intra-row spacing had a significant ($P<0.05$) effect. However, the main effects variety and all two way and the three way interactions were not significant. Variety N-26 gave higher aboveground dry biomass (5740.2 kg ha^{-1}) than variety MH-97 (5468.5 kg ha^{-1}) which might be due to the bush type nature growth of variety N-26.

Intra-row spacing of 5 cm gave significantly highest dry biomass (6145.9 kg ha$^{-1)}$ than 15 cm inter-row spacing (4924.2 kg ha^{-1}). Likewise, the highest dry biomass of (5968.8 kg ha^{-1}) was recorded at 30 cm (Table 7). In general, as both the intra-row and inter-row spacing decreased the dry biomass per ha was increased.

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The highest total dry biomass at the lowest inters and intra-row spacing might be due to more plants per unit area. Dry matter production per unit area increases with increases in plant density up to a limit in biological yield. When plants are, widely spaced vegetative dry matter yields will at first tend to increase with inversing plant density. This indicates that no appreciable competition is occurring between neighboring plants. Plant numbers compensate almost exactly for a reduction in the production of individual plant.

This result was in line with the study of Abdolreza (2016) who reported a significant differences due to seed rate where maximum mungbean dry biomass was recorded at 50 kg ha^{-1} which give (2273 kg ha^{-1}) and the minimum dry biomass was recorded at seed rate of 25 kg ha^{-1} (2045 kg ha^{-1}). Simlarly, Rasul *et al*. (2012) reported that the inter-row spacing of 30 cm and 45 cm produced dry biomass of 4131 and 4003.5 kg ha^{-1} while wider spacing of 60 cm gave minimum dry biomass (3328.9 kg ha^{-1}).

Table 6. The main effect of variety, intra-row and inter-row spacing on number of seeds per pod and hundred seeds weight of mungbean

Treatment	No. of seeds per pod	Hundred Seeds weight (g)
Variety		
MH-97	10.08[a]	6.78[a]
N-26	9.41[b]	6.35[b]
LSD(0.05)	0.65	0.28
Intra-row spacing (cm)		
5	9.42	6.39
10	9.79	6.57
15	10.02	6.73
LSD(0.05)	NS	NS
Inter-row spacing (cm)		
30	9.57	6.46
40	9.73	6.48
50	9.92	6.73
LSD(0.05)	NS	NS
CV(%)	9.92	7.82

LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of Variation; NS= Non- Significant. Means in a column followed by the same letters are not significantly different at 5% level of Significance.

Grain yield

The main effect of variety, inter-row spacing and intra-row spacing had highly significant ($P < 0.01$) effect on grain yield while the two and three way interaction of variety, inter-row and intra-row spacing, had no significant effect on grain yield (kg ha^{-1}) of mungbean.

Variety 'MH-97' gave significantly higher grain yield (1117.94 kg ha^{-1}) than variety 'N-26' (935.14 kg ha^{-1}) (Table 7). The higher yield for variety MH-97 might be due to higher 100 grain weight, higher number of primary branches and number of pod per plant and higher crop stand count percentage at harvest.

The highest grain yield (1213.74 kg ha^{-1}) was recorded at 40 cm inter-row spacing and the lowest grain yield (864.56 kg ha^{-1}) was recorded at 50cm inter-row spacing. Similarly, the highest grain yield (1151.67 kg ha^{-1}) was recorded at 10 cm intra-row spacing and the lowest grain yield (961.14 kg ha^{-1}).was recorded at 5cm intra-row spacing.

For both varieties of mungbean grain yield was highest at 40 cm inter-row spacing and below and above 40 cm inter-row spacing the yield was decreased. Similarly, the intra-row spacing of 10 cm gand below and above 10 cm intra-row spacing the grain yield decreased (Table 11). The yield reduction at the narrow inter aave highest grain yield and below and above 40 cm intra-row spacing the yield was decreased. This might be due to intense interplant competition for resources such as nutrients, water and solar radiation at the narrowest spacing. On the other hand, lower yield at the widest spacing could be due to sub-optimal population that might not sufficiently exploit the growth resources.

The result of this study was in agreement with Abdolreza (2016) who reported a significant differences due to seed rate where the maximum mungbean seed yield (2273 kg ha^{-1}) was recorded at 25 kg ha^{-1} and the minimum seed yield (1600 kg ha^{1}) was recorded at seed rate of 75 kg ha^{-1}. Simllarly, Yadav *et al.* (2014) reported a significant differences due to the main effects of plant spacing where the maximum mungbean seed yield (1259 kg ha^{-1}) was observed at 30 cm × 10 cm spacing while the minimum seed yield (1135 kg ha^{-1}) was at spacing of 20 cm × 10 cm. Kabir1 and Sarkar (2008) also reported a significant differences in grain yield among different mungbean varieties and plant density where variety BARIMung-2 gave higher yield (843.70 kg ha^{-1}) than variety BARIMung-3 (783.80 kg ha^{-1}). Moroever, they reported that 30 cm ×10 cm gave higher yield (1046.00 kg ha^{-1}) and 20 cm × 20 cm gave lower yield (750.50 kg ha^{-1}).

Harvest index

Analysis of variance indicated that the main effects of variety and intra-row spacing had highly significant ($P < 0.01$) effect and the main effect of inter-row spacing had a significant effect ($P<0.05$) on harvest index (Appendix Table 1). However, the two ways and three-way interactions of variety with inter-row and intra-row spacing had no significant effect on harvest index.

Variety 'MH-97'gave significantly higher harvest index (20.91%) than variety N-26 with harvest index of 16.71% (Table 7). Higher harvest index implies higher partitioning of dry matter into grain. The lower harvest index for variety N-26 might be due to its higher above ground dry biomass than the grain as compared to variety 'MH-97' higher harvest index values are usually associated with early maturing cultivars relative to late maturing varieties because different varieties are responded to different plant population.

The harvest indices were higher at inter-row spacing of 40 and 50 cm than 30 cm and higher at intra-row spacing of 10 and15 cm than 5 cm. The highest harvest index at the lower plant density might be due to less interplant competition for resources such as nutrients, water and solar radiation as compared to high plant density that resulted in more assimilate production and partitioning to the grain. This result was in line with the study of Abdolreza (2016) reported that a significant differences due to seed rate, maximum mungbean harvest index was recorded at 25 kg.ha^{-1} and the minimum harvest index was recorded at 50 kg ha^{-1}. Similarly, Kabir and Sarkar (2008) reported that a significant differences in harvest index among different mungbean varieties and plant spacing where variety BARIMung-2 gave higher harvest index (31.38%) than variety BARIMung-3 (29.19%) and 20 cm × 20 cm gave higher harvest index (29.28%) and spacing of 30 cm ×10 cm had lower harvest index (28.43%). Rasul *et al*. (2012) also reported a significant difference among mungbean varieties that ranged from 26.14% to 11.44%. Yadav *et al*. (2014) reported a significant differences due to the main effects of plant spacing where

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maximum harvest index was observed at 30 cm × 10 cm spacing (32%) while the minimum harvest index (30%) was observed at 20 cm ×10 cm. (30 %) on mungbean. Edwards and Purcell (2005) reported that harvest index of soybean decreased with increased plant population and suggested that higher harvest index values are usually associated with early maturing cultivars relative to late maturing varieties because different varieties are responded to different plant population.

Table 7. The main effect of variety, intra and inter-row spacing on aboveground dry biomass (kg ha^{-1}), grain yield (kg ha^{-1}) and harvest index of mungbean

Treatment	ADBM (kg ha^{-1})	GY (kg ha^{-1})	HI (%)
Variety			
MH-97	5468.5	1117.94^{a}	20.91^{a}
N-26	5740.2	935.14^{b}	16.71^{b}
LSD(0.05)	NS	218.48	2.50
Intra-row spacing (cm)			
5	6145.9^{a}	961.14^{b}	16.10^{b}
10	5742.9^{b}	1151.67^{a}	20.30^{a}
15	4924.2^{c}	966.80^{b}	20.02^{a}
LSD(0.05)	493.5	135.87	3.06
Inter-row spacing (cm)			
30	5968.8^{a}	1001.32b	17.46^{b}
40	5836.9^{b}	1213.74a	21.18^{a}
50	5007.3^{b}	864.56c	17.776^{b}
LSD(0.05)	493.5	135.87	3.06
CV (%)	12.99	19.53	24.06

Means in columns followed by the same letter(s) are not significantly different at 5% level of significance; LSD (0.05) = Least Significant Difference at 5% level; CV= Coefficient of Variation; NS =Non-significant. ADBM, GY, and HI = aboveground dry biomass, grain yield and harvest index; respectively.

CONCLUSION

Results showed the main effect of variety had a significant effect on Days to 50% physiological maturity, Number of seeds per pod, Hundred Seeds weight and Harvest index. Whereas Plant height at maturity, Number of primary branches, Number of secondary branches, Number of total and effective nodules, Aboveground dry biomass were not affected. The highest hundred grain weight (6.78 g), number of seeds per pod (10.08), and harvest index (20.91%) were recorded for variety MH-97. above ground dry biomass (5740.2 kg ha^{-1}) were recorded for variety N-26. Thus use of MH-97 mungbean variety with 40 cm and 10 cm inter and intra-row spacing could be considered as a recommendation for the study area for a better mungbean grain yield. However, to reach at conclusive recommendation the experiment has to be repeated across different locations and time since, the study was based on only one season and one location.

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