

Effects of Intra and Inter-Row Spacing on Yield and Yield Components of Mung Bean (Vigna radiate L.)

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Abstract
Maintaining optimum planting space spacing is the most important agronomic practice for determining effective population density to increase growth and yield of Mungbean crop. A field trial was conducted to establish the proper intra and inter-row spacing of Mungbean (*Vigna radiate* L.) at Gozamin District, North-western Ethiopia in 2015 main cropping season. Rasa mung bean variety (N-26) was used as a test crop. Factorial combinations of three intra row spacing (5, 10 and 15 cm) and four inter row spacing (25, 30, 35 and 40 cm) were laid out in a randomized complete block design with three replications. The analysis of variance indicated highly significant differences ($p < 0.01$) among all agronomic traits in response to the different intra and inters row spacing's. Based on the result of this study, application of 5cm intra-row spacing exhibited maximum values on Mungbean growth, yield and yield related traits over the rest two levels. Similarly among four inter-row spacing's the use of 25cm is superior in most of Mungbean agronomic traits such as days to emergence, days to physiological maturity, plant height, pod number per plant, number of kernels per pod, thousand kernel weight, grain yield, biomass yield, straw yield and harvest index than 30, 35 and 40cm.The maximum numbers of pods were recorded in treatment with 5cm intra-row and 15cm inter-row spacing. The tallest plants were observed in the plots with similar spacing, while the smallest plants were recorded in the treatment with 15cm intra-row and 40cm inter-row spacing. Maximum grain yield and harvest index were also recorded in plots with 5cm intra-row and 25cm inter-row spacing. Consequently 5cm intra-row and 25cm inter-row spacing's were concluded as optimum for Mungbean production in the study area.
Keywords: Mungbean, *Vigna radiate* L., plant spacing, Grain yield, seed per pod.

1. INTRODUCTION

Mung bean (*Vigna radiate*) commonly known as green gram is an ancient and well-known pulse crop that belongs to family Papilionoideae and originated from south East Asia (Mogotsi, 2006). The crop is the most important pulse crop in the world. Mung beans are mainly grown for human food, in the form of boiled dry beans, stew, flour, sprouts and immature pods as a vegetable. The dry beans are sometimes used for animal food, mainly poultry; when they are either roasted or boiled while its biomass used as fodder (Winch, 2006). Thus, it has great value as food and fodder. It is a cheap source of protein for human consumption. According to the chemical content study conducted by Dainavizadeh & Mehranzadeh (2013) Displayed that seed of mung bean contains 20-24% protein, 2.1% oil, 1-2% fats and carbohydrates and a fair amount of vitamin A and B. On the other hand, the same source indicated that mung bean fixing atmospheric N_2 and enriches the soil with N nutrient for the growth of succeeding crops. Moreover, the crop can be successfully grown on marginal lands where other crops perform poorly and most suitable for green manure use (Ghafoor *et al*., 2003; Dainavizadeh & Mehranzadeh, 2013).

Mung bean is a main short-duration grain legume crop with wide adaptability, low input requirements and the ability to meliorate the soil by fixing atmospheric nitrogen. It is a warm season annual grain legume that requires a mean annual temperature of 27 to 30 °C and 350 - 450 mm rainfall for its optimum growth (Imrie, 1998; Gebre, 2015). Mung bean is a quick or very early maturing crop, which requires 75–90 days to mature. The crop is also drought resistant (Kidane, 2010; MoA, 2015; Gebre, 2015).

In Ethiopia it is mostly produced by small scale farmers of Amhara National Regional State particularly in some areas of North Shewa and south Wollo as well as in some districts of Benishangul Gumuz Regional State. The crop is also produced in moisture stress areas of country (Gofa, Konso, south Omo zone and Konta) have been growing mung bean (Asrat *et al*., 2012; Gebre, 2015). According to Kidane (2010) report, mung bean has special features such as its earliness in maturity, supply good yield, drought resilient property makes highly responsive in scanty rainfall and its ability to stimulate striga without being parasitized. Moreover, the same source disclosed that mung bean is the most suitable crop to put under crop rotation with cereals and relay cropping systems through its compatible feature of effectiveness in residual soil moisture usage. On the other hand, the crop has good nutritive value and reasonable cost for the consumers (Asrat *et al*., 2012; Gebre, 2015). In spite of its importance as food and feed, very little attention has been paid to its quantitative and qualitative improvement in Ethiopia.

Ethiopian dry lands covers about 75 percent of the total land mass of the country and found in arid, semi arid and dry sub-humid agro-ecologies. They are geographically located in the north, east and central areas of the rift valley, also south and southeastern parts of the country, including a very wide and with diversified ranges of agricultural systems. On the other hand, most portions of the dry lands are categorized under semi-arid agroecology that characterized by most suitable area for mung bean production due to short growing cycle of the crop (Kidane, 2010). Therefore, mung bean is the most suitable and recommended pulse crop to improve the nation's food insecurity problem and enhance soil fertility in the Ethiopian low lands. Gebre (2015) suggested that an adoption and expansion of mung bean production on moisture stressed areas is crucial to solve food insecurity problem in Ethiopia. Now a day, these areas faced a challenge of producing long maturing crops. Although, the above mentioned facts deduced that the country has great potential for the crop; mung bean is produced on small patches of land (annually on about 10,000 ha).

Reports indicated that numerous biotic and abiotic factors are responsible for low coverage and productivity of mung bean in Ethiopia (MoA, 2015 and Gebre , 2015). Among the factors lack of improved varieties, disease and pest attack, current climate change, limited information about an optimum spacing, seed rate and fertilizer application. In Ethiopian 2014/2015 cropping season nationally 14,562.00hectare of land was covered with mungbean and 14067.654ton yield produced. This is far below its potential yield achieved from field trials. While in Amhara national Regional State 11,281.69hectare of land cultivated by the crop and 11982.848ton grain produced in same season and the region was leader producer of mungbean in Ethiopia (CSA, 2015).

Several research works in the world indicated that maintaining proper space between plants and between rows allows increasing mung bean yield (Ansari *et al*., 2000; Ihasanullah, 2002; Mohsen and Jahanfar, 2012). According to Ihsanullah *et al.* (2002), he found that planting mung bean with intra-row of 10 cm and inter-row of 30 cm is optimum spacing under commercial cultivation to obtained 320,000 plant per ha^{-1}. In the other hand, planting the crop on various inter-row spacing (20, 30 and 43 cm) have showed different yield responses (921, 818.8 and 727 kg ha^{-1}), respectively (Bashir, 1994). Moreover; Kabir and. Sarkar (2008) found that planting of the crop in 30 cm × 10 cm space for BARI and Mung-2 variety in *Kharif*- I season was showed good yield response and more suitable for the cultivation of mung bean. Among crop management practices seeding densities or plant population greatly affect crop growth and yield (Jan *et al.,* 2000).

During 2015cropping season the area coverage and total production of mung bean in Gozamin district was 1400 ha and 21000 quintal respectively. The impact or yield loss due to using old cultivars that have low productivity and susceptible to disease (not using improved varieties), inappropriate sowing method and intra and inter row spacing were identified as the bottle neck for maximization of its production and productivity in the study area (GDAO, 2015). However, sufficient research was not conducted and meagre information is available about the optimum spacing of the crop to increase mung bean production in Ethiopia, particularly in the study area. Hence, this study is designed to determine the appropriate intra and inter row spacing for mung bean production. Therefore this study was initiated with the following objectives:

- To evaluate the effects of intra-row spacing and inter-row spacing on the crop yield and yield components of mung bean and
- To determine the optimum intra-row and inter-row spacing for mung bean of the study area.

2. MATERIALS AND METHOS

2.1. Description of the Study Area

The experiment was conducted at Dessa Enessie kebelie in Gozamin district, East Gojjam Zone of Amhara National Regional State during the 2015 main cropping season. Gozamin district is located at 1002' - 10°8' N" latitude and 37°3' - 38°1'E" longitude with an altitude ranges between 1050 to 4200 m above sea level (m.a.s.l). It has a hot and humid climate with an average maximum and minimum temperature of 22.4 and 10.63°C respectively, and average annual precipitation of about 1327.5 mm regarding the land features, 50% of the district is plain with gentle to flat slopes, 43% is mountainous with undulating to steep slopes and the remaining 7% constitutes valley relief. The dominant type of soil in the district areas are Nitrosol.

2.2. Materials Used for Experiments

2.2.1. Planting materials

Rasa variety of mungbean was used as a test crop and sown using 3 intra-rows and 4 inter-row spacing's in the experimental site with uniform application of N, P, S nutrients for all plots.

2.2.2. Fertilizer materials

The recommended fertilizer rate of 100 kg/ha NPS (19% N, 38% P_2O_5 and7% S) used for the experiment. The three nutrients were applied in the form of NPS in band application at the time of sowing based on the recommended rates of fertilizers for the study area by the regional bureau of Agriculture.

2.3. Treatments and Experimental Design

The treatments were arranged in factorial combinations of three levels of intra-row spacing (5, 10 and 15 cm) and four levels of inter-row spacing (25, 30, 35 and 40 cm). Therefore, the experiment consists of 12 treatment combinations. The experiment laid out as randomized complete block design in factorial arrangement and replicated three times. Gross plot sizes have 1.6 m width and 2 m length ($3.2m^2$). Net plot size was determined by excluding the border row from each side and 0.5 m row length at both ends to prevent the border effect. The space between blocks and plots were 1 m and 0.5 m, respectively.

2.4. Experiment procedures

The experimental field was tilled three times for fine seed bed preparation using oxen-drawn local plough (*Maresha*) and then followed by manual bed preparation for field layout. The treatments were randomly allotted to each plot. The seeds were planted at 3 cm depth according to the predetermined spacing of each treatment at the beginning of summer rainfall. The whole doses of the fertilizer will be applied during crop planting in band. All recommended cultural practices for mung bean production were adopted and employed for the management of this experiment.

2.5. Data Collection and Measurements

2.5.1. Phonological and growth parameters

1. **Days of plants emergency:** was determined by counting the number of days from sowing to the time when 50% of the plants started to emerge the tip of panicles through visual observation.
2. **Days of physiological maturity:** it was recorded when 90% of the plants in each plot reaches physiological maturity.
3. **Plant height :** The average height of ten plants which are selected randomly measured in centimeters from the base to tip of a plant from the net plot area of each plot excluding owns at harvest using a meter scale. Average plant height for each plot was calculated.

2.5.2. Yield and yield components

1. **Pod number:** The total numbers of pods from two randomly selected 0.5m length of each plot were counted from each plot.
2. **Kernel number:** The number of grains per pod was counted at the inner rows of each plot by threshing the ten randomly selected plants pods from each treatment. Then the mean kernel number was taken.
3. **Thousand kernel weights:** It is the weight of 1000 seeds from a random sample of seeds harvested per plot. Samples of thousand grains were taken at random from each plot.
4. **Biomass yield:** Total biomass or biological yield was measured by weighing the sun dried total above ground plant biomass (straw + grain) of the net plot.
5. **Grain yield :** was measured by taking the weight of the grains threshed from the net plot area and then converted to kilograms per hectare after adjusting the grain moisture content to 12.5%.
6. **Straw Yield:** Straw yield was determined after mung bean bundles of each plot were threshed and straw yield recorded by subtracting grain yield from total above ground biomass in kg per plot and then converted into kg per ha.
7. **Harvest Index :** is the weight of grain divided by the total weight of above ground biomass (straw + grain)of each plot expressed as percentage, and calculated by using the following formula:

$$HI = \frac{Grain\ yield\ (Kg/ha)}{\text{Biological yield (Kg/ha)}} \text{x100}$$

2.6. Statistical data analysis

1. The value of each character understudy was summarized and subjected to analysis of variance procedures which were recommended to randomize complete block design (RCBD) by using SAS version 9.3.1 with a general linear model procedure (SAS,2003).
2. **Mean separation** (mean differences comparison) was undertaken by Duncan's Multiple Range Test (Duncan, 1955) at 5 percent level of probability.
3. **Correlation analyses:** was carried out by calculating simple correlation coefficients between yields and yield components.

3. RESULT AND DISCUSSION

3.1. Weather Condition of the Experimental Site

The experimental site received an annual rainfall of 1196.8mm during the cropping season (June - December, 2015) which was lower than the mean annual rainfall of the twenty nine years (1987-2015). Mean monthly maximum and minimum temperatures recorded for the experimental site during the cropping season were 23.28^{o}C and 11.17^{o}C respectively. There was highly increased rain fall during July, August and September of the cropping season in which the highest amount (238.6, 243.6 & 271.4mm respectively) was received in these months. During October 54.8mm rainfall was obtained, while in June 133.1 mm rainfall was received. So there was no moisture constraint for the normal crop husbandry and timely application of inputs and agronomic practices. The weather condition of the experimental site during the cropping season was suitable for Mungbean production.

4.1. Phenological and Growth Parameters

4.1.1. Days to 50% emergence

Analysis of variance of the data revealed that days to 50% seedling emergence was significantly ($p<0.05$) affected by both intra and inter-row spacing's, but their interaction effects didn't show a significant difference. The highest days to emergence or late emergence was recorded for 5cm intra-row spacing and 40 cm inter-row spacing. While early emergence was exhibited by 15 and 35, intra and inter-row spacing's respectively. This significant difference in days to emergence by the effect of intra-row spacing may be due to the strong competition to resources for germination. The same result was reported by Rasul *et al*. (2012) who concluded that days to emergence of Mungbean was significantly affected by intra and inter-row spacing's.

4.1.2. Days to 90% physiological maturity

Days to 90% physiological maturity showed significant response to Spacing. Both intra and inter-row spacing had very highly significant ($P<0.001$) effect on physiological maturity of mungbean (Table 3.1). However, their interaction effect did not show significant effect on days to 90% physiological maturity. When Increasing inter-row spacing from 25cm to 40cm days to 90% maturity increased by 10 days, and as intra-row spacing increased from 5cm to 15cm days to physiological maturity increased from 70.5 to 72.75days (Table 3.1). The minimum intra and inter-row spacing associated with early maturity might be due to plant competition for available resources in narrow spacing's. This result was in agreement with the finding of Rasul *et al.* (2012) who revealed that days to physiological maturity was significantly ($P<0.005$) influenced by inter-row spacing.

4.1.3. Plant height

The analysis of variance indicated that both intra and inter-row spacing had significant ($P<0.05$) effect on Mungbean plant height. Whereas, their interaction didn't show any significant effect on the crop plant height. The shortest plant was observed at a planting density of 15 cm × 40 cm while the longest at 5cm x 25cm. As intra-row increased from the least (5cm) to the highest (15cm), the height of the plant correspondingly decreased from 32.57 to 31.55cm, similarly as row spacing increased from 25 cm to 40 cm plant height decreased from 33.32 to 31.52 (Table 4.1). Long plant heights in narrow row spacing might be due to the presence of increased competition for light as the plant population becomes denser and also probably due to lack of enough space for lateral growth then plants grew vertically resulting in to taller plants. This research finding was in line with the finding of Rasul *et al*. (2012) who showed that the plant height was significantly affected by inter-row spacing.

Table 4.1: Effect of Intra and inter-row spacing on Phenological and growth parameters of Mungbean at Gozamin in 2015 main cropping season

Treatments	DPE(days)	DPM(days)	PH(cm)
Intra-row Spacing(cm)			
5	6.00	70.50	32.57
10	5.83	71.50	32.10
15	5.00	72.75	31.55
Sign. Difference	**	***	*
Inter-row Spacing			
25	5.78	66.67	33.32
30	5.33	70.00	31.88
35	5.11	73.00	31.57
40	6.22	76.67	31.52
Sign. Difference	*	***	***
CV (%)	13.4	1.44	2.36

Means with the same letter(s) in the same column and row of each trait are not significantly different at 5% probability level, * , **, *** & ns indicates significant difference at 5% , 1% 0.1% probability level, and non-significant difference respectively. While CV (%) = coefficient of variation in percent, DPE = Days of plants emergence, DPM = days to 90% physiological maturity and PH= plant height.

4.2. Yield and Yield Components

4.2.1. Pod number

The statistical analysis results revealed that pod number of Mungbean was high significantly ($P<0.001$) affected by both intra and inter-row spacing. On the other hand, their interaction had non-significant ($p>0.05$) effect on pod number (Table 4.2). The maximum pod number was recorded at 5cm and 25cm intra and inter-row spacing's respectively. While the minimum pod number was obtained from 15 and 40cm intra and inter-row spacing's. As intra-row increased from the least (5cm) to the highest (15cm), the pod number negatively decreased from 17.05 to 15.00cm, similarly as inter-row spacing increased from 25 cm to 40 cm pod number decreased from 18.34 to

16.27 (Table 4.2). This might be due to more free space between plants at the lower inter-row spacing's and less intra-plant competition for available resources that resulted in higher pod number. The current result is in agreement with the finding conducted by Kabir and Sarkar (2008) who reported that pod number was significantly affected by both intra and inter-row spacing's and the lowest number of pods were produced at 40 cm × 30 cm inter & intra-row spacing's.

4.2.2. Number of kernels per Pod

Data recorded on number of kernels per pod indicated that it was high significantly ($P<0.001$) influenced by the main effects of intra and inter-row spacing. However, their interaction showed non-significant ($p>0.05$) effect on number of kernels per pod (Table 4.2). Maximum number of kernels per pod (9.91) was obtained from 5cm intra-row spacing and minimum number of kernels per pod (9.43) recorded from 15cm intra-row spacing. Similarly highest number of kernels per pod was obtained from the 25cm inter-row spacing while the least from 40cm inter-row spacing (Table 4.2). Grains per pod is purely an inherent character of Mungbean that greatly affected by row spacing and the high number of kernels per pod in closer row spacing may be due to high plant population in these treatments. This result was in line with the finding of Ihsanullah *et al.* (2002) who stated that significant difference was observed in number of kernels per pod by the effects of both intra and inter-row spacing.

Table 4.2: Effect of Intra and Inter-row row spacing on Yield and yield components of Mungbean at Gozamin in 2015 main cropping season

Treatments	PN	NKP	TKW
Intra-row Spacing(cm)			
5	17.05	9.91	49.81
10	16.74	9.64	50.20
15	16.27	9.43	50.47
Sign. Difference	**	***	***
Inter-row Spacing			
25	18.34	10.76	48.58
30	17.22	10.02	49.70
35	16.19	9.26	50.76
40	15.00	8.61	51.61
Sign. Difference	*	***	**
CV (%)	2.09	2.62	0.69

Means with the same letter(s) in the same column and row of each trait are not significantly different at 5% probability level, * , **, *** & ns indicates significant difference at 5% , 1% 0.1% probability level, and non-significant difference respectively. While CV (%) = coefficient of variation in percent, PN = Pod Number, NKP = Number of Kernels per pod and TKW= Thousand Kernel Weight.

4.1.1. Thousand kernel weight

The analysis of variance revealed that both seeding rate and row spacing had highly significant ($p<0.01$) effect on thousand kernel weight. However, the interaction effect of intra and inter-row spacing did not influence significantly ($p>0.05$) thousand kernels weight of Mungbean (Table 4.2). The highest thousand kernels weights (35.44 g) were recorded for seeds sown at the intra and inter row spacing of 15cm and 40cm respectively, whereas the lowest thousand kernel weights (33.04 g) were recorded at the intra and inter row spacing of 5cm and 25cm respectively. This might be due to the strong competition for moisture, light and soil nutrients in closer row spacing's. This research result was in conformity with the previous finding of Kabir and Sarkar (2008) who reported that there is a significant difference in thousand kernel weight of Mungbean by the effect of row spacing.

4.1.2. Biomass yield

Biomass yield represents overall growth performance of the plant as well as the crop and is considered to be the essential yield parameter to get useful information about overall growth of the crop. Biomass yield is highly inclined by crop nutrition and planting distance. Analysis of variance showed that the main effect of seeding rate had highly significant ($P < 0.001$) effect on the above ground dry biomass yield. However, the interaction effect of seeding rate and row spacing was found non significant. Highest biomass yield (3615.33kg ha-1) was observed at the intra-row spacing of 5cm while lowest biomass yield (3312.00kg ha-1) was obtained at the intra-row spacing of 15cm (Table 4.3). The increase in biomass production at narrow spacing's might be attributed to the increased plant population due to many numbers of rows.

Inter-row spacing also had prominent effect on biomass yield of Mungbean Maximum biomass yield (4136.44kg ha-1) was observed at 25cm inter-row spacing followed by 30cm row spacing (3688.67kg ha-1) while lowest biomass yield (2786.44kg ha-1) was recorded at 40cm row spacing (Table 3.3). In this study, higher biomass yield was obtained at the narrower row spacing than wider row spacing this might be due to better resource utilization in narrow rows than wider rows. This finding is in conformity with the finding of Ihsanullah *et al.* (2002) who reported that more biomass was produced at narrow row spacing than wider spacing. Similarly, Chen *et al.* (2008) reported that narrower row spacing produced higher biomass yield than wider row spacing in rice.

4.1.3. Grain yield

Analysis of variance showed that the main effect intra and inter row spacing had highly significant (P < 0.01) effect on grain yield of Mungbean. However, their interaction effect showed non- significant (p>0.05) effect on its grain yield (Table 4.3). The highest grain yield (1025.67kg ha-1) was obtained at the intra-row spacing of 5cm and the lowest grain yield (869.83kg ha-1) was obtained at 15cm. Intra-row spacing of 5cm resulted in increasing yield by 17.92% over the highest intra-row spacing.

Table 4.3 Effect of Intra and Inter-row row spacing on Yield and yield components of Mungbean at Gozamin in 2015 main cropping season

Treatments	BY	GY	SY	HI
Intra-row Spacing(cm)				
5	3615.33	1025.67	2589.67	0.28
10	3459.50	946.42	2513.08	0.26
15	3312.00	869.83	2442.17	0.25
Sign. Difference	**	***	***	
Inter-row Spacing				
25	4136.44	1251.56	2884.89	0.30
30	3688.67	1050.89	2637.78	0.28
35	3237.56	848.89	2388.67	0.26
40	2786.44	637.89	2148.56	0.23
Sign. Difference	*	***	**	
CV (%)	2.09	2.62	0.69	

Means with the same letter(s) in the same column and row of each trait are not significantly different at 5% probability level, * , **, *** & ns indicates significant difference at 5% , 1% 0.1% probability level, and non-significant difference respectively. While CV (%) = coefficient of variation in percent, BY = Biomass Yield, GY = Grain Yield, ST = Straw Yield and HI= Harvest Index.

The data presented in Table 4.3 showed that inter-row spacing of 25 cm produced maximum (1251.56kg ha-1) Mungbean grain yield followed by 30cm (1050.89kg ha-1) as against the minimum (637.89kg ha-1) with 40 cm inter-row spacing. Closer row spacing of 25 cm recorded significantly higher yield than wider inter-row spacing of 40 cm. The increase in grain yield due to narrow row spacing was 96.2% higher than wider spacing. The maximum grain yield obtained from the use of narrow intra and inter row spacing's might be due to high density of plants in rows and increased number of branches per rows as a result increased pod number in rows and then number of grains per pod. Based on this result average number of plants were reduced in the wider rows than narrow rows this is might be due to increased competition for resources as the seeds were placed closer together in the wide rows and ultimately may also have been related to reduction in grain yield. This result was in line with Ihsanullah *et al.* (2002) who found that both intra and inter row spacing had significant effect on grain yield of Mungbean. Frizzell *et al*. (2006) also reported that grain yield of cereals increased in response to decreasing the spacing between rows.

4.1.4. Straw yield

The main effect of intra and inter row spacing's high significantly (P < 0.001) affected straw yield Mungbean whereas their interaction effect didn't show significant (p>0.05) effect on straw yield of Mungbean (Table 4.3). The highest (2589.67kg ha-1) straw yield was observed at intra-row spacing of 15 cm while the lowest (2442.17kg ha-1) straw yield was recorded with row spacing of 40cm. There was a linear increase in straw yield as the intra-row was decreased (Table 4.3).

Maximum straw yield (2884.89 kg ha-1) was exhibited from the plots where 25cm inter-row spacing was used and this might be due to the fact that narrow inter-rows result in more plant population and greater plant height due to strong competition for light which resulted in higher straw yield. This result is in harmony with the finding of Kabir and Sarkar (2008) who reported that the highest Stover yield was observed at narrow intra and inter row spacing's which may be mainly due to higher number of branches plant^{-1} and the lowest one was observed at wider intra and inter-row spacing's.

4.1.5. Harvest index

The ability of a cultivar to convert the dry matter into economic yield is indicated by its harvest index. The higher the harvest index value, the greater the physiological potential of the crop for the converting dry matter to grain yield. The analysis of variance showed that harvest index was statistically high significantly (p<0.01) affected by intra and inter row spacing's. However, the interaction effect of intra and inter row spacing was found insignificant. The highest harvest index (0.28) was calculated at intra-row spacing of 5cm, while lowest (0.25) harvest index was recorded at the intra-row spacing of 15cm (Table 4.3).

Maximum harvest index (0.30) was observed at inter-row spacing of 25 cm while minimum harvest index (0.23) was recorded at inter-row spacing of 40 cm (Table 4.3). This result is in line with the findings of Yadav *et al.* (2014) who stated that there was maximum harvest index at narrow row spacing while minimum harvest index was recorded at wider row spacing of Mungbean. Harvest index had interrelationship with grain yield and above ground biomass yield that the highest harvest index was the result of greater grain yield. Lowest harvest index was mainly due to increased biomass yield rather than grain yield which lead to decrease of harvest index.

4.2. Correlation Analysis

Grain yield had strong significant positive correlations with plant height (r=0.81**), pod number (r=0.99**), number of kernels per pod (r= 0.99**), biomass yield (r=0.99**) straw yield and harvest index (r=0.98**), but negatively correlated with traits of days to physiological maturity (r= -0.99**) and thousand kernel weight (r= -0.99**), and had non-significant negative correlation with days to emergence (r= -0.01ns). These indicated that the yield increase is attributed to an increase in plant height, number of kernels per pod, pod number, biomass yield, straw yield and harvest index. Similar result was reported by Canci and Toker (2014) who conclude that grain yield was significantly and positively correlated with the biological yield (r = 0.688), pods per plant (r = 0.682), plant height (r = 0.602), branches per plant (r= 0.585), straw yield (r = 581), grains per pod (r = 0.574), and pod number (r = 0.510) of Mungbean.

The study showed that most of the traits were positively correlated with each other while some others are in a negative correlation. Number of kernels per pod (r= 0.99**) had significant positive correlation with plant height (r=0.81**), pod number (r=0.99**), biomass yield (r=0.99**), grain yield (r=0.99**), straw yield (r=0.99**) and harvest index (r=0.97**), and also showed positive non-significant correlation with days to emergence and negative correlation with days to physiological maturity (r= -0.99**). These positive correlations among growth and yield related parameters elucidated that all of them had a cumulative contribution for increasing the grain yield in Mungbean which leads to the conclusion that an increase in those growth and yield related parameters simultaneously increased the total yield and vice versa.

Biological yield had strong positive correlation with plant height (r=0.8**), pod number (r=0.99**), number of kernels per pod (r= 0.99**), straw yield (r=0.99**) and harvest index (r=0.98**), but negatively correlated with days to physiological maturity and thousand kernels weight. This exhibited that plant height, pod number, number of kernels per pod, straw yield and harvest index had interchangeable contribution with the biomass production during the physiological process of biochemical translocation. Similar finding was reported by Canci and Toker (2014) who elucidated that the biological yield of Mungbean was strongly and positively associated with straw yield (r = 0.989), plant height (r = 0.834), kernels per pod (r = 0.690) and pods number (r =0.479).

Table 4.4 Pearson Correlation coefficient

	DTE	DPM	PH	PN	NKP	TKW	BY	GY	SY	HI
DTE	1.00	0.06ns	0.38ns	-0.03ns	0.002ns	-0.007ns	-0.03ns	-0.01ns	-0.04ns	-0.08ns
DPM		1.00	-0.75**	-0.99**	-0.98**	0.98**	-0.99**	-0.99**	-0.99	-0.98
PH			1.00	0.79**	0.81**	-0.83**	0.8**	0.81**	0.79**	0.75**
PN				1.00	0.99**	-0.99**	0.99**	0.997**	0.996**	0.99**
NKP					1.00	-0.99**	0.99**	0.997**	0.997**	0.977**
TKW						1.00	-0.99**	-0.99**	-0.99**	-0.97**
BY							1.00	0.999**	0.999**	0.986**
GY								1.00**	0.997**	0.989**
SY									1.00	0.98**
HI										1.00

ns = not significant ($P > 0.05$), * and ** correlation is significant at 0.05 ($P < 0.05$) and 0.01 ($P < 0.01$) probability levels respectively. **DPE** = Days of plants emergence, **DPM** = days to 90% physiological maturity, **PH**= plant height, ***PN* =** Pod Number**,** ***NKP* =** Number of Kernels per pod**,** ***TKW*=** Thousand Kernel Weight**,** ***BY*** = Biomass Yield**,** ***GY*** = Grain Yield**,** ***ST*** = Straw Yield and ***HI*=** Harvest Index**.**

4. SUMMARY AND CONCLUSION

The results of the finding also indicated significant variations ($p < 0.05$) in all agronomic traits in response to the different intra-row spacing's. Mungbean is an important crop in Ethiopia. However, poor soil fertility, especially low levels of nitrogen and phosphorus, has been demonstrated to be a major constraint to the production of the crop in the country. The study was conducted in Oromia zone of Amhara National Regional State, north-eastern Ethiopia to investigate the effect of intra and inter row spacing on yield and yield components of Mungbean. Randomized Complete Block Design (RCBD) with three replications was used to lay the experiment. The treatments consisted of three and four levels of intra and inter row spacing's respectively and each arranged in a factorial fashion.

From the present study it is possible to conclude that both intra and inter row spacing affect almost all of growth, yield and yield related traits of Mungbean. The data indicated highly significant differences ($p < 0.01$) in all agronomic traits in response to the different intra and inter row spacing's. Based on the result of this study, application of 5cm intra-row spacing exhibited maximum values on Mungbean growth, yield and yield related traits over the rest two levels. Among them, days to emergence, days to physiological maturity, plant height, pod number per plant, number of kernels per pod, thousand kernel weight, grain yield, biomass yield, straw yield and harvest index were the major agronomic traits highly influenced by the intra-row spacing. Grain yield was increased within narrow intra-row spacing as far as this work is considered. Among intra-row spacing's in this experiment 5cm intra-row spacing produced higher grain yield (1025.67kg ha-1) as compared to 10 and 15cm row spacing's.

Similarly among four inter-row spacing's the use of 25cm is superior in most of Mungbean agronomic traits such as days to emergence, days to physiological maturity, plant height, pod number per plant, number of kernels per pod, thousand kernel weight, grain yield, biomass yield, straw yield and harvest index than 30, 35 and 40cm.Therefore, this study investigated and concluded that inter-row spacing of 15cm performed better and gave higher grain yield (1251.56kg ha-1) and has 82.47 % grain yield advantage on average over the remaining three inter-row spacing's. Whereas all yield and yield components of Mungbean were not affected by the interaction effect of seeding rate and row spacing.

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