Journal of Natural Sciences Research
ISSN 2224-3186 (Paper) ISSN 2225-0921 (Online)
Vol.5, No.15, 2015

Effect of Intra-Row Spacing on Haricot Bean (Phaseolus vulgaris L.) Production in humid Tropics of Southern Ethiopia.

Yacob Alemayehu* Mieso Kaweti Ararsa Boki
Department of Plant Science, College Agriculture and Natural Resource, Dilla University. P.O. Box 419, Dilla, Ethiopia

ABSTRACT
Field experiment was conducted at the research farm of Dilla University in 2015 main cropping season, with the objective of determining the optimum plant spacing for better productivity of haricot bean under the humid conditions of Dilla, southern Ethiopia. A well-adapted haricot bean variety namely, Hawassa-Dume, was tested at 5, 10, 15 and 20 cm intra-row spacing with 40 cm inter-row spacing for each treatment. The analysis of variance (ANOVA) revealed that plant height, number of branch plant^{-1}, pod plant^{-1}, total biomass and grain yield were significantly ($p < 0.05$) influenced by varying intra-row spacing. In contrary, number of leaves plant^{-1}, seed pod^{-1} and thousand seed weight were insignificant in all intra-row spacing. Increasing the intra-row spacing beyond 10 cm resulted in significant reduction in grain and biomass yields, but consistent increase in number of branches plant^{-1} and pod plant^{-1}. Compared with the grain yield obtained at widest intra-row spacing (20 cm), increase in the grain yield was recorded at 5 cm and 10 cm intra-row spacing that were 22.9% and 33.2%, respectively. In general, the result suggests that narrow intra-row spacing at 10 cm which corresponds to plant population density of 266,667 plants ha^{-1} was better for achieving optimum grain yield under humid environment. To confirm this, similar investigations should repeated in multi- locations and years.
Keywords: Yield, yield components, Haricot bean, Intra-row spacing

1. INTRODUCTION

Haricot bean (*Phaseolus vulgaris* L.) is one of the major legume crops produced in various parts of Ethiopia. The total area and production estimated to be 366,876.94 ha and 46,300.9 tons respectively (CSA, 2013). Haricot bean is grown highly for consumption as a food crop (an important source of protein) (MoARD, 2009), and consumed highly in traditional dishes: such as *nefro* (boiled grain mixed with maize), and *wet* (local soup). Despite its tremendous importance, the current national average yield of haricot bean is low 1.26 t ha^{-1} (CSA, 2013), which is far lower than its yield potential, mainly owing to various production constraints. Among the constraints, lack of well adapted varieties, fertilizers levels, planting date, row spacing (population density), weed and disease control and weather conditions are important factors determining the productivity and quality of bean crops (Chemeda, 1997; Solomon, 2003; Essubalew *et al*., 2014; Gebremedhin, 2015).

The grain yield of haricot bean is highly affected as a result of many complex morphological and physiological processes occurring during the growth of the crop, which ultimately influence the yield and yield components. Based on climatic conditions, several researchers obtained different response of haricot bean in relation to spacing. Solomon (2003) observed seed yield increase from 42.44 to 56.89 g plant^{-1} with increasing 7 x 40 and 16 x 40 cm intra-row spacing. Results obtained by the same author indicated that grain yield was highest (778.2 kg ha^{-1}) at 10 cm intra-row spacing. Similarly, Essubalew *et al*. (2014) reported that pod yield [of green been] increased consistently from 3473 kg ha^{-1} to 2574 kg ha^{-1} with an increase in intra-row spacing ranging from 7 x 40 - 15 x 40 cm. On the other hand, Bakry *et al*. (2011) and Mtaita and Mutetwa (2014) indicated that seed yield and biomass tends to decrease in wider row spacing (row spacing of 7, 10 cm). Mehmud *et al.* (1997) indicated that increased row spacing manifested increase in the seed weight/plant, pod weight/plant, and 1000 seed weight, but decreased plant height and seed yield/unit area. Kumar *et al*. (1997) and Mureithi *et al*. (2012) obtained the highest seed yield (1.09 t ha^{-1}) and plant dry weight (15 g) with plant spacing of 15 cm and 20 cm, respectively. However, Mishra and Mishra (1995) concluded that seed yield was not affected by row spacing.

According to Davi *et al.* (1995) seed yield of haricot bean increases as plant density increases (narrow spacing), but high plant densities can lead to low aeration, high humidity and prolonged periods of dampness. These are ideal conditions for the development of white mold (Sclerotinia). The environment within a canopy of given plant density will be affected both by plant and row spacing. As seed is a major input cost for dry bean production, optimum plant density should maximize yield while minimizing seed cost.

In Ethiopia, a standard spacing of 40 cm x 10 cm has been adopted; irrespective of the growing conditions and locations which was not clear how this spacing was considered as the standard spacing without having planting density study. In Dilla area, production of haricot bean covers about 334.91 ha (15%) of the total area of land for pulses (2,209.9 ha) under cultivation, with annual production of 3303.27qt (CSA, 2013). However, most farmers are not sure of the appropriate planting density to use. They either use very high or very low plant density, which consequently results in poor grain yield in quality and quantity. Hence, optimization of plant density for high yielding genotypes with suitable inter- as well as intra-row spacing is crucial in order to increase haricot bean productivity per unit area. This study was, therefore, conducted with the objectives of determining optimum plant spacing for better productivity of haricot bean under humid tropical condition of Dilla area, Southern Ethiopia.

2. MATERIALS AND METHOD

2.1. Description of the Study Area

Field experiment was carried out at the research site of Dilla University in 2015 main cropping season. The site is located at Gedeo zone in southern Ethiopia (about 365 km south of the capital, Addis Ababa); between latitude 6^0 25' 06.9"N and longitude 38^0 16' 52"E, at an altitude of 1,439 meters above sea level. Dilla area receives an average annual rainfall of 1245 mm with monthly maximum and minimum temperatures of 21.5 and 12.6 ^{0}C, respectively (Fig. 1) (World weather online, 2015). The area falls within warm humid agro-ecological zone (NRRD, 1998). The experiment growing period was between April and June, and the total rainfall for the growing period was 458 mm. The soil of the area is classified as Nitisols, which is well drained, deep, and reddish with clay loam texture…...

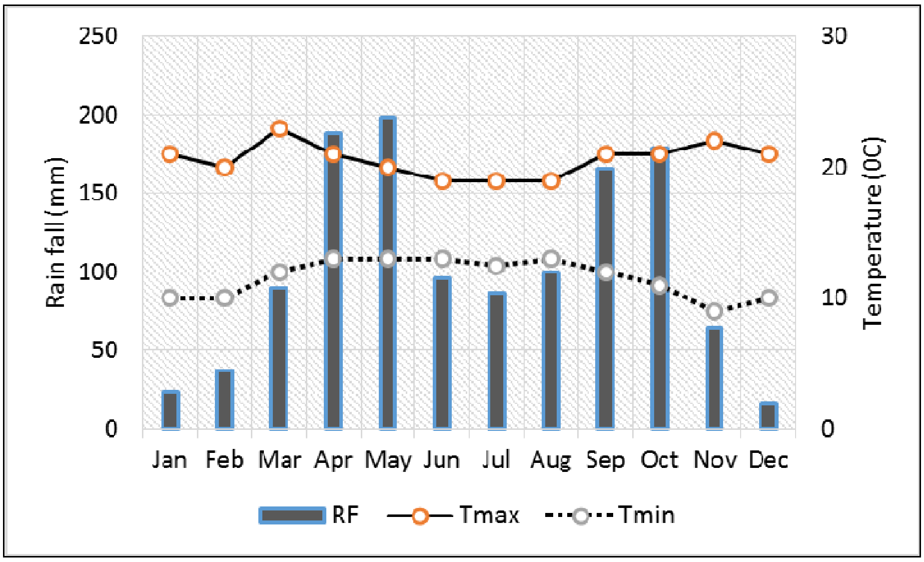

Figure 1. Monthly mean maximum and minimum temperature, and rain fall of the study area (2000-2014).

2.2. Treatments, experimental design and procedures

Four intra-row spacing: 5, 10, 15 and 20 cm which corresponds to the plant density of 533,333.3, 266,666.7, 160,000.0 and 133,333.3 plants ha^{-1}, respectively. The experiment was laid out in randomized complete block design (RCBD) with three replications of each treatment. The inter-row spacing was set at 40 cm in all the plots. A 1.5 m^2 (1 x 1.5 m) plot area was used as experimental unit, accommodating 4 rows of each 1.5 m length. Haricot bean *Hawassa-dume* variety was used as a test crop, a well-adapted variety to the agro-ecology. Two seeds per hill were planted and thinned to one plant per hill at two weeks after sowing. Other agronomic practices including hoeing, weeding, pest and disease control were kept similar manner to all the plots during the experimental period.

2.3. Data Collection and Analysis

Data Collection: Crop phenology data *viz.* days to flowering and physiological maturity were recorded when 50% of the plants in a plot were flowered and 85% of the plants attained yellow coloration, respectively. The growth parameters: leaf number plant^{-1}, branches plant^{-1}, plant height were measured from eight randomly selected plants at the central rows in each plot. Plant height was measured from the base of the plant to the upper most leaves, whereas number of functional leaves plant^{-1} was determined by visual count when the plant attains flowering stage, and branches plant^{-1} was measured during harvesting the crop. Pod number plant^{-1} and seeds plot^{-1} were measured from eight randomly selected plants. Thousand seed weight was obtained from four samples in each plot. Grain yield and biomass yield were determined from the net plot area and expressed as tone per hectare basis. Grain yield was measured using electronic balance and then adjusted to 12.5% moisture content. Harvest index (%) was calculated as the ratio of grain yield to total biomass yield.

Data Analysis: The data collected for each parameter was subjected to Analysis of Variance (ANOVA) procedures using SAS 9.2 software (SAS, 2002). Differences among the treatment means were compared using

Least Significant Difference (LSD) test at 0.05 probability level.

3. RESULTS AND DISCUSSION

3.1. Crop phenology and growth attributes

Days to flowering and physiological maturity of haricot bean were not significantly ($p > 0.05$) influenced by intra-row spacing (Table 1). On average, the crop took about 38 and 78 days to set flower and attain its physiological maturity in each plot, respectively.

Significant differences ($p < 0.05$) in plant height among treatments were observed (Table 1), and plant height decreased significantly with increasing intra-row spacing (Table 2). Maximum plant height (49 cm) was produced in 5 cm intra-row spacing followed by 48.7 cm in 10 cm intra-row spacing, whereas minimum plant height (40.6 cm) was recorded from 20 cm intra-row spacing (Table 2). Both narrow intra-row spacing (5 and 10 cm) significantly enhanced the plant height over the others. Higher plant height at narrow spacing could be explained that when the plants are sown closely, their stems are shaded from light resulting in accumulation of auxin (a growth hormone) that stimulates cell division and elongation of internodes, thereby increase in height. While, in widely spaced plants, auxin destruction by light occurs resulting in plants being shorter in height (Mureithi *et al*., 2012). In line with this, Kumar *et al*. (2007) and Pawar *et al*. (2007) also reported increase in plant height in densely planted French beans. Contrary to our results, the study by Solomon (2003) indicated that plant height was not significantly affected by intra-row spacing. Decrease in plant height at wider spacing might also be due to excessive branching, and this tends to encourage lateral growth while suppressing apical growth.

Table 1. Summary of ANOVA for phenology, growth, yield and yield related attributes of haricot bean as influenced by intra-row spacing.

Variables	Sources of variation			F values for treatment	
	MSB (2)	MST (3)	MSE (6)	F	*Pr> F*
Days to flowering	0.583	0.750	0.25	3.00ns	0.11
Days to maturity	0.750	0.083	0.08	1.03ns	0.45
Plant height (cm)	30.63	85.28	16.85	5.06*	0.044
Number of leaves plant^{-1}	37.17	72.17	42.73	1.69ns	0.267
Number of branches plant^{-1}	0.261	1.53	0.053	28.52***	0.0006
Number of pods plant^{-1}	3.075	124.49	6.88	11.04**	0.006
Number of seeds pod^{-1}	0.017	0.0039	0.064	0.06ns	0.978
1000seed weight(g)	1794.81	14.80.02	2395.69	0.62ns	0.62
Seed yield (t ha^{-1})	0.04	2.77	0.51	5.42*	0.038
Total biomass yield (t ha^{-1})	0.1262	8.673	1.452	5.97*	0.031
Harvest index	0.00037	0.0001	0.001	0.56ns	0.66

*MSB=Mean squares of block; MST=Mean squares of treatment; MSE=Mean squares of error; *, **, ***: Significant at 0.05, 0.01 and ≤0.001 probability levels respectively; ns: non- significant; Values in parenthesis indicates the degrees of freedom.*

Table 2. Mean values of crop phenology and growth parameters of haricot bean as affected by intra-row arrangement.

Intra-row spacing (cm)†	Days to flowering	Days to Maturity	Plant height (cm)*	Leaf No plant^{-1}	Branch No plant^{-1}
5 (533,333 plants ha^{-1})	37.67	77.66	49.00a	38.5	1.95b
10 (266,667 plants ha^{-1})	37.67	77.66	48.67a	43.0	2.40b
15 (160,000 plants ha^{-1})	38.67	79.00	40.92b	36.0	3.33a
20 (133,333 plants ha^{-1})	37.33	77.66	40.58b	31.3	3.37a
LSD (0.05)	ns	ns	6.2017	ns	0.4629
CV (%)	2.31	1.37	9.27	17.51	8.31

† Values in the bracket indicates plant density for each intra-row spacing set at 40 cm row spacing.
*Means within a column followed by the same letter(s) are not significantly different at p <0.05 (LSD). *Plant height was recorded at maturity; ns: non- significant.*

As the ANOVA result indicated in Table 1, intra-row spacing had no significant effect ($p > 0.05$) on number of leaves plant^{-1}. Though there was no statistical differences, an increase in spacing showed a tendency of decrease in number of leaves plant^{-1}, ranging between 31.3 and 43 (Table 2). On the other hand, the number of branches plant^{-1} was significantly ($p < 0.001$) influenced by intra-row spacing (Table 1), which was consistently increased with increasing intra-row spacing (fig. 2a). Maximum number of branches plant^{-1} (3.37) was recorded under 20 cm intra-row spacing; followed by 3.33 obtained from 15 cm intra-row spacing (Table 2). Higher number of branches with increasing spacing could possibly be due to less competition between plants in the wider plant spacing for soil nutrients and moisture. Besides, higher number of branches with increasing intra-row spacing reflects that wider plant spacing encouraged lateral growth (branching) but not apical growth, and the vice versa. In line with this, Mtaita and Mutetwa (2014) reported that lower plant population of 125,000 plants ha^{-1} had the highest number of branches $plant^{-1}$ than higher population of 320,000 plants ha^{-1}. This result is in agreement with the works of Pawar *et al*. (2007) and Mureithi *et al*. (2012) who reported an increased in branches per plant at increased spacing in haricot bean and French bean, respectively.

3.2. Grain yield and yield related attributes

The analysis of variance (ANOVA) revealed that the effect of treatments was significant ($P < 0.05$) for number of pods $plant^{-1}$, grain yield and total biomass yield, whereas the number of seeds pod^{-1}, thousand seed weight and harvest index were not significant (Table 1).

Pod number $plant^{-1}$ increased consistently and significantly ($p < 0.05$) with increasing intra-row spacing (Table 3). The maximum number of pods $plant^{-1}$ (29.34) was obtained when haricot beans were sown at a wider spacing (20 cm); while the lowest pods $plant^{-1}$ (15.96) was obtained from the narrow intra-row spacing (5 cm). Higher number of pods $plant^{-1}$ observed might be due to higher number of branches $plant^{-1}$ at wider plant spacing (Fig. 2a) as higher number of branches benefits to more sites for flower development, which attributed to a prolific pod production. This result is in conformity with the works of Mtaita and Mutetwa (2014) who reported an increased pod number and dry weight of haricot bean at the wider intra-row spacing (30 cm), as compared to closer spacing (22 cm). Also, higher values of pod number was reported in a green bean sowed at the lower planting densities as compared to higher planting density. However, this result contradicted the findings of Khalil *et al*. (2010) and Solomon (2003) and who reported that pod number $plant^{-1}$ is significantly reduced with the increase in plant densities.

Grain yield is the end result of many complex morphological and physiological processes occurring during the growth and development of the crop. Grain yield tends to increase with increasing intra-row spacing up to 10 cm, beyond which it was significantly ($p < 0.05$) decreased (Table 2; Fig. 2b). The highest grain yield (9.058 t ha^{-1}) was observed from the narrower intra-row spacing (10 cm), which was statistically at par with the yield of 5 cm intra-row spacing (Table 3). The lowest (6.799 t ha^{-1}) was recorded with the widest intra-row spacing (20 cm). Compared with the grain yield obtained at widest intra-row spacing, increase in the grain yield recorded at 5 cm and 10 cm intra-row spacing were 22.9% and 33.2%, respectively. This result agrees with the work of Essubalew *et al*. (2014) and Mtaita and Mutetwa (2014) who reported that bean yields increased linearly as the spacing reduced due to superior yield in the case of high plant populations over that of low plant population of beans. Grain yield followed opposite trend exhibited by the number of branches and pods per plant. This indicates the number of plants per unit area seems to be more critical than number of branches and/or pods per plant, in influencing grain yield.

Total biomass yield shown a slight increase with increased intra-row spacing up to 10 cm, beyond which it significantly decreased (Fig. 2b), following the trend exhibited by grain yield. Total biomass yield was maximum (17.94 t ha^{-1}) at 10 cm intra-row spacing, whereas the lowest biomass yield (14.13 t ha^{-1}) was at 20 cm intra-row spacing (Table 3). The two top narrow intra-row spacing (5 and 10 cm) were at par among each other and they were significantly different from the other two treatments. Such a marked response of biomass yield to intra-row spacing [in this study] is in agreement with results from Bakry *et al*. (2011) and Mtaita and Mutetwa (2014) who observed that there was increase in biomass yield with decrease in the row spacing because of higher populations per unit area. Mureithi *et al*. (2012) obtained the highest plant dry weight (15 g) with intra-row spacing of 20 cm.

Table 3. Mean values of pod plant, seed per pod, thousand seed weight, seed yield, total biomass and harvest index as affected by intra-row arrangement.

Intra-row spacing (cm)†	Pod $plant^{-1}$	Seed pod^{-1}	1000 Seed weight (g)	Grain yield	Total biomass	Harvest Index
				-------t ha^{-1}---------		
5 (533,333 plants ha^{-1})	15.96c	4.05	594.0	8.356a	17.286a	0.483
10 (266,667 plants ha^{-1})	18.55b	4.05	555.6	9.058a	17.940a	0.507
15 (160,000 plants ha^{-1})	26.92a	4.00	604.2	7.709ab	15.720ab	0.493
20 (133,333 plants ha^{-1})	29.34a	3.98	599.5	6.799b	14.136b	0.483
LSD (0.05)	5.240	ns	ns	1.428	2.4078	ns
CV (%)	11.55	6.3	8.32	8.96	9.83	3.9

† Values in the bracket indicates plant density for each intra-row spacing set at 40 cm row spacing.
Means within a column followed by the same letter(s) are not significantly different at p < 0.05 (LSD).

Weight of thousand seeds and harvest index were not significantly ($p > 0.01$) affected by intra-row spacing (Table 1). Although there was no statistical differences, reduced weight of thousand seeds observed at narrow plant spacing might have resulted due to decreased pod width at narrow plant spacing which indirectly affects the size or the weight of seeds.

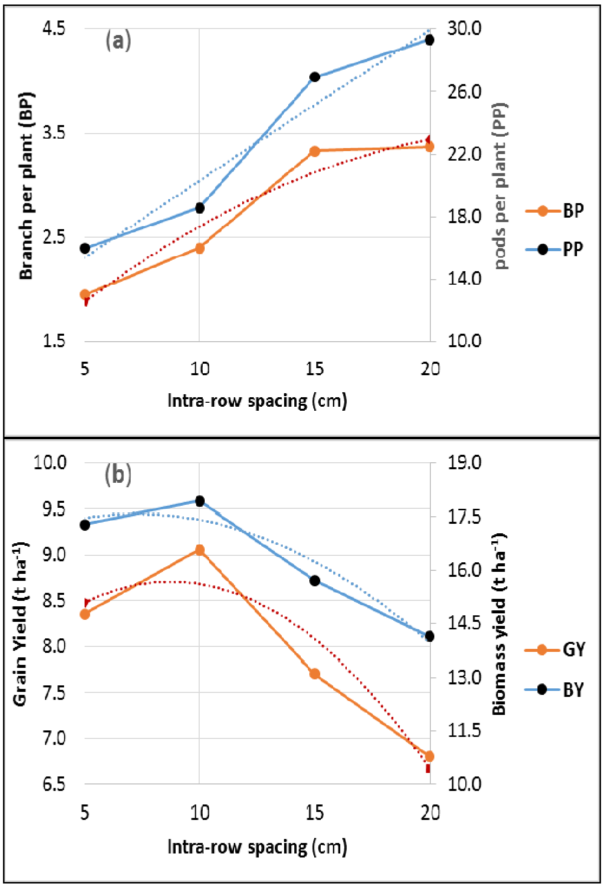

Figure 2: Relationship between intra-row spacing and (**a**) number of branches plant^{-1} and number of pods plant^{-1} (**b**) grain yield (GY) and biomass yield (BY).

CONCLUSION

Increasing crop productivity per unit area through appropriate management strategies should be given due emphasis in order to meet the ever-increasing demands of human population. In view of this, the study was conducted with the objectives of determining optimum intra-row spacing for better productivity of haricot bean under Dilla University condition. The result indicated that increased intra-row spacing manifested increase in the number of branches and number pods per plant, but decreased plant height and grain yield per unit area. This indicates that the number of plants per unit area seems to be more critical than number of branches and/or pods per plant, for influencing grain yield. On the other hand, higher number of branches and pods per plant with increasing spacing could possibly be due to less competition between plants in the wider plant spacing for soil nutrients and moisture. The result suggested that narrow intra-row spacing less than 10 cm which corresponds to plant population density 266,667 plants ha^{-1} gave optimum grain yield haricot bean. Similar investigations should be conducted in multi-locations and years to confirm the present findings.

ACKNOWLEDGEMENTS

The authors would like to thank the anonymous field assistants and staff members of the Department of Plant Science, Dilla University, particularly Kebene Getahun and Tsige Timer, for their unreserved assistance in data collection.

REFERENCE

Bakry, B.A., T.A. Elewa, M. F. El-Karamany, M. S. Zeidan, and M. M. Tawfik. 2011. Effect of row spacing on yield and its components of some bean varieties under newly reclaimed sand soil condition. World J. Agri. Sci.7: 68-72.

Chemeda Fininsa. 1997. Effects of planting pattern, relative planting date and intra-row spacing on a haricot bean/maize intercrop. *African Crop Science Journal, Vol. 5. No.1:15-22.*

CSA (Central Statistical Authority). (2013). Area and Production of crops (Private peasant holdings, Maher season). Statistical Bulletin 532. Issue I. Addis Ababa, Ethiopia. Pp: 10-12.

Davi, D., R. Kumar and A. Khippal. (1995). Effect of different intra-row spacing on the growth of haricot bean and urd bean intercropping. Discovery and Innovation. 9(1-2): 47-51.

Essubalew Getachew, Ali Mohammed, Abush Tesfaye and Amsalu Nebiyu. (2014). Growth and yield response of green beans (Phaseolus vulgaris L.) In relation to time of sowing and plant spacing in the humid tropics of Jimma, southwest Ethiopia. International Journal of Soil and Crop Sciences: 2(5): 61-67.

Gebremedhin Welu. (2015). Effects of Plant Density on the Yield Components of Haricot Bean (Phaseolus vulgaris L.). Journal of Natural Sciences Research. 5(5): 37-41.

Khalil, S.K., A. Wahab, A. Rehman, F. Muhammad, S. Wahab, A. Z. Khan, M. Zubair, M. K. Shah, I. H. Khalil and Amin. 2010. Density and planting date influence phenological development assimilate partitioning and dry matter production of faba bean. Pak. J. Bot. 42: 3831-3838.

Kumar, S.G., Gomathinayajam P. and Rathnaswmy R. 1997. Effect of row spacing on a dry matter accumulation of black gram. Madras Agric. J. 84(3): 160-162.

Mehmud, M., U.F. Chiezey, M.K. Ahmed and I. Rofia. 1997. Effect of different levels of phosphorus fertilizers and intra row spacing on the gram yield, growth and yield components of haricot bean (Vigna mungo L. Hepper). Discovery and Innovation. 9(1-2): 47-51.

Mishra, M. and A. Mishra. 1995. Effect of fertilizers, weed control and row spacing on summer haricot bean. Indian J. Agron. 40(3): 434-438.

MoARD (2009). Animal and Plant Health Regulatory. Directorate Crop Variety Register. Issue No. 12. June, 2009 Addis Ababa, Ethiopia.

Mtaita T. and Mutetwa M. 2014. Effects of Plant Density and Planting Arrangement in Green Bean Seed Production. J. Glob. Innov. Agric. Soc. Sci., 2(4): 152-157.

Mureithi D.M., Onyango M.O., Jeruto P., Gichimu B.M. 2012. Response of French bean (*Phaseolus Vulgaris* L.) to intra-row spacing in Moseno Division, Kenya. Journal of applied science, 12(1): 96-100.

NRRD (Natural Resource Regulatory Department). 1998. Ministry of Agriculture, Addis Ababa, Ethiopia.

Pawar S.U., M. L. Kharwade, M. L. Kharwade, 2007. Effect of Plant Density on Vegetative Growth and Yield Performance of Different Varieties of French bean under Irrigated Condition. Karnataka J. Agric. Sci., 20 (3): 684-685.

SAS Institute Inc (2002). SAS Users Guide. Version 9. SAS Institute Inc., Cary, NC. USA.

Solomon Abate. 2003. Effects of Irrigation Frequency and Plant Population Density on Growth, Yield Components and Yield of Haricot Bean (*Phaseolus Vulgaris* L.) in Dire Dawa Area. MSc Thesis. Alemaya University, Ethiopia.

World weather online. (2015). Dilla Monthly Climate Average, Ethiopia. nID24182-56a0c9e8-ab7b-4597-9f7e-946dd9ea8ea2. Data accessed in18th July, 2015.