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Irrigation Frequency and Plant Density Affect Phenology and Crop Growth of Haricot Bean (*Phaseolus vulgaris* L.)

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ABSTRACT

A field study was conducted involving a factorial combination of two haricot bean (*Phaseolus vulgaris* L.) varieties 'Roba-1' and 'Mexican-142' with three irrigation frequencies at 60, 90 and 120 mm cumulative pan evaporation (CPE) using an IW/CPE ratio thereby fixing the depth of irrigation water (IW) to 60 mm and three planting density levels (150000, 250000, 350000 plants/ha) to investigate their effects on phenology and crop growth at Tony farm, Dire Dawa during winter (*bega*). A split plot design was laid out with irrigation frequency as the main plot while a combination of planting density and variety served as sub-plots with three replications each. Days to maturity and crop growth parameters of haricot bean increased as irrigation frequency increased from 120 to 90 then to 60 mm CPE. Variety significantly influenced phenological stage, specifically days to flowering and days to maturity. Plant height and leaf number were significantly higher for 'Mexican-142', with a 17.7 and 29.0% increase, respectively. As plant density increased, it significantly ($P < 0.05$) decreased leaf area and leaf number, and increased the leaf area index of beans. The highest seed yield/plant was recorded with the minimum plant density (150000 plants/ha) and lowest seed yield/plant with the highest plant density (350000 plants/ha). The increased irrigation frequency from 120 to 60 mm CPE significantly increased seed yield/plant from 38.22 to 59.94 g.

Keywords: crop growth, haricot bean, irrigation frequency, phenology, plant density

INTRODUCTION

Plant proteins provide nearly 65% of the world protein supply, with 45-50% coming from legumes and cereals, to the population of developing countries and vegetarians of industrialized nations (Mahe *et al*. 1994). In view of this, legumes are recognized as important sources of proteins in the diet of the population of many countries around the world. Grain legumes, also called pulses, currently of importance to world agriculture, include pea (*Pisum sativum* L.), chick pea (*Cicer arientinum* L.), faba bean (*Vicia faba* L.), lentil (*Lens culinaris* Medic.), common or haricot bean (*Phaseolus vulgaris* L.), lima bean (*Phaseolus lunatus* L.), mung bean (*Vigna radiata* L.), cow pea (*Vigna unguiculata* L.), pigeon pea (*Cajanus cajan* L.), lupin (*Lupinus* spp.), soy bean (*Glycine max* L.) and ground nut (*Arachis hypogea* L.) with the last two also valuable as oil seed crops (Önder and Babaougu 2001; Simane *et al*. 1998; EEPA 2004).

In addition to this, legumes are complementary to cereal foods regarding their amino acid balance, with lysine and tryptophan being higher in legumes than in cereals. Besides, studies of Kneer *et al*. (1999) and Hoeck *et al*. (2000) have also shown that the seeds of grain legumes also contain isoflavones, which are now considered to be cancer-preventing compounds through their phyto-oestrogenic activities based on the inhibition of tyrosine kinases and/or inhibition of DNA topoisomerase II. In East Africa, beans are mostly grown for their dried seed as a field crop (Acland 1971; Kay 1979). However, according to Tindall (1968), leaves are also edible and seeds are sometimes fried in oil.

In spite of the importance of haricot bean in Ethiopia, the average yield ranged from 800 to 900 Kg/ha, which is far lower than its potential yield, mainly owing to different environmental, biological and socio-economic production constraints (Simane *et al.* 1998). Among the stated constraints, moisture stress is the most important limiting factor in semi-arid regions (Fischer and Turner 1978; Simane and Struik 1993; Bationo *et al*. 2006; Abebe *et al*. 2010). The importance of this factor arose from its recurrent occurrence and wide coverage (Tesfaye *et al.* 2008) by affecting every aspect of plant growth and the overall loss in yield. On this account it probably exceeded the losses from all other causes combined (Kramer 1980).

The dry land areas of Ethiopia account for more than 50-75% of the total land mass, however contributing to less than 30% of the country's total agricultural production (Reddy and Kidane 1993; Jama and Zeila 2005; Kidane *et al*. 2010). According to CSA (1998), the irrigation potential of the country is more than 5 million ha of which only 4.5% is currently exploited. The traditional rainfed agricultural activity, mainly located in the highlands, seemed to shoulder the responsibility of feeding a human population exceeding 80 million and which is growing at a rate of 2.6% each year (World Bank 2009). In order to mitigate the food insecurity problem with its roots in the high population growth rate and low food crop production level mainly attributed to insufficient soil moisture, it is imperative to bring large areas of the arid, semi-arid and sub-humid regions with uneven rainfall distribution under irrigation and other appropriate technological interventions (Cirelli *et al.* 2009). Therefore, reducing the effect of drought, through rationalised application of irrigation water, would provide a satisfactory elucidation of irrigation frequency that must be applied for optimizing bean production.

Apart from irrigation, other important factors determining the productivity and quality of bean crop include choice of an adapted variety, selection of suitable land, fertilizers levels, planting date, row spacing, cropping system, weed control, weather, outbreak of insects and diseases. The two most important cultural practices, the choice of appropriate variety and optimum between-row spacing and variations either in row widths or within row spacings, are reported to have an effect on plant yield and other characters to

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Table 1 Description of treatments used in the study.

Treatments		Description
Varieties	'Roba-1'	Determinate (growth habit I), cream colored, medium sized, food been
	'Mexican-142'	Indeterminate (growth habit III), white colored, small size, export bean
Planting density	150,000 plants/ha	40 cm × 16 cm
	250,000 plants/ha	40 cm × 10 cm
	350,000 plants/ha	40 cm × 7 cm
Irrigation frequency	Irrigation at 60 mm CPE*	60 mm of irrigation water was applied at 60 mm CPE
	Irrigation at 90 mm CPE	60 mm of irrigation water was applied at 90 mm CPE
	Irrigation at 120 mm CPE	60 mm irrigation water was applied at 120 mm CPE

*CPE, cumulative pan evaporation

Table 2 Description of dates for irrigation frequency treatment.

Irrigation frequency treatment	Date of irrigation			
	First irrigation	Second irrigation	Third irrigation	Fourth irrigation
60 mm CPE	Jan. 30, 2002	Feb. 09, 2002	Feb. 17, 2002	Feb. 28, 2002
90 mm CPE	Feb. 4, 2002	Feb. 12, 2002	Feb. 27, 2002	-
120 mm CPE	Feb. 5, 2002	Feb. 27, 2002	-	-

varying degrees (Johnson and Harris 1967; Norman *et al.* 1984).

However, such valuable information of bean varieties with respect to varying growth habits is lacking in Ethiopia at large and in the Eastern part of the country, in particular. This information is important at this point of time when many agricultural investors in the country are producing beans for export (EARO 1999). In view of the existing knowledge gap, the present study was envisaged with the specific objectives to determine the effects of irrigation frequency and planting density on growth, yield components and yield of determinate and indeterminate haricot bean varieties.

MATERIALS AND METHODS

The experiment was carried out during 2001/2002 dry ('Bega') season at the research field of Alemaya University located at Tony farm in Dire Dawa. The experimental site is located on the eastern escarpment of the Rift Valley at 41° 51' E longitude, 9° 31' N latitude and at an altitude of 1160 m.a.s.l (AUA 1998). The soil of the experimental site is predominantly loamy sand to sandy loam of alluvial origin with pH ranging from 7.8 to 8.4. The mean annual rainfall of the region is 500 mm and the mean annual maximum and minimum temperatures are 34 and 18°C, respectively.

A total of 18 treatment combinations (**Table 1**) were adopted for the study comprising of two haricot bean varieties ('Roba-1' and 'Mexican-142'), three plant densities, and three irrigation frequencies. The seed source of the two varieties for a study was the Pulse Improvement Program of Alemaya University. A split plot design with three replications having three irrigation frequencies as main plot and the combination of three plant densities and two varieties as sub-plot treatments was used. The two haricot bean varieties under plant densities viz., 150000, 250000 and 350000 plants/ha were raised on 10 m^2 (5 m × 2 m) plots, each having 5 rows. The sowing of the crop was carried out on January 01, 2002. The seeds were over sown in each row beyond the treatment levels. After 15 days, plants were thinned to the respective treatment levels on row basis (30 plants/row, 50 plants/row and 70 plants/row). For all the treatments, a uniform inter-row spacing of 40 cm was adopted. Immediately after sowing, in all the treatments one common irrigation of 60 mm was given to ensure satisfactory seed germination and crop establishment. Thereafter, irrigations were given as per treatments. The dates of irrigation are given in **Table 2**. Other cultural practices such as weeding and cultivation were done as and when needed. Harvesting of the experiment was done on April 10, 2002. For the irrigation frequency treatments three levels of IW/CPE ratio were used (1, 0.67 and 0.5) and IW (irrigation water) was fixed at 60 mm CPE (cumulative pan evaporation).

Data on days to 50% flowering and maturity, plant height, leaf area, LAI, leaf number and yield per plant were recorded.

Statistical procedures

All the measured variables were subjected to analysis of variance (ANOVA) (Gomez and Gomez 1984) using MSTATC computer program (Michigan State University, Crop and Soil Science Department (MSTAT-C 1991). Least Significant Difference (LSD) was used to separate the means.

RESULTS AND DISCUSSION

Days to 50% flowering

ANOVA on days to 50% flowering revealed that main effects of varieties and plant density as well as interaction between irrigation frequency and plant density; and plant density and variety significantly influenced days to 50% flowering (**Table 6**). Plant density of 250,000 plants/ha significantly hastened flowering when compared with other densities. This finding however did not agree with the earlier results of Singh *et al.* (2011) who reported that the number of days to flowering increased with increasing planting density in mungbean; and Kueneman and Wallace (1979), where date of flowering was not significantly affected by increasing and/or decreasing plant density. The determinate variety, 'Roba-1' flowered earlier than the indeterminate variety, 'Mexican-142' at planting density of 250,000 plants/ha (**Table 3**). Irrigation frequency had no effect on days to flowering (**Table 3**). However, report of El-Aal *et al.* (2011) on common bean revealed the presence of significant variation in days to flowering, where they explained delay of flowering with more irrigation. The interaction between plant density and variety (**Table 4**) demonstrated significantly earlier flowering with increased plant density of 'Roba-1'. On the contrary, there was no significant difference in days to 50% flowering of 'Mexican-142' at the lowest (150,000 plants/ha) and the highest (350,000 plants/ha) plant densities. This variety behaved intermediate in days to flowering at the mid plant density (250,000 plants/ha). This result was in agreement with the findings of Kueneman and Wallace (1979).

Irrespective of the main effect of planting density, interaction of irrigation frequency and planting density showed similar number of days to 50% flowering for I2 (90 mm CPE) and I3 (120 mm CPE). However, when irrigation is more frequent at I1 (60 mm CPE), flowering was delayed under the influence of the lowest plant density (150,000 plants/ha) while it was hastened significantly due to 250,000 plants/ha and it was again delayed at 350,000 plants/ha (**Fig. 1**). This significant variation with regard to days to 50% flowering observed at more frequent irrigation could be attributed to the effect of moisture and plant densities on availability of growth factors required for completion of the crop growth.

Table 3 Main effects of variety, plant density and irrigation frequency on the crop phonological aspects of haricot bean.

Treatment	Days to 50% flowering	Days to maturity
Variety		
'Roba-1'	58.7	92.4
'Mexican-142'	60.5	94.6
$LSD_{0.01}$	1.2	0.8
Plant density (plants/ha)		
150,000	60.3	93.4
250,000	58.7	93.7
350,000	59.7	93.4
$LSD_{0.05}$	1.5	Ns
Irrigation frequency		
60 CPE	59.7	94.8
90 CPE	59.3	93.2
120 CPE	59.7	92.4
$LSD_{0.05}$	Ns	0.7
CV%	2.59	1.17

*Ns, Non significant

Table 4 Days to 50% flowering, 50% maturity and yield of 'Roba-1' and 'Mexican-142' as affected by plant density.

Variety	Days to 50% flowering		
	150000 plants/ha	**250000 plants/ha**	**350000 plants/ha**
'Roba-1'	60.1	58.0	57.9
'Mexican-142'	60.6	59.4	61.4
$LSD_{0.05}$	10.3		
	Days to 50% maturity		
'Roba-1'	93.0	92.6	91.7
'Mexican-142'	96.6	93.9	93.2
$LSD_{0.05}$	1.4		

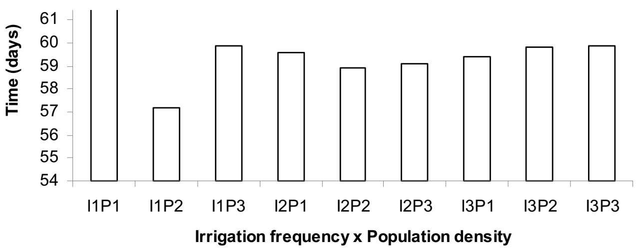

Fig. 1 Irrigation frequency vs. population density on days to 50% flowering. $LSD_{0.01}$ = 2.45. n = 54.

Days to maturity

The determinate variety 'Roba-1' matured earlier (92.4 days after planting) than the indeterminate variety 'Mexican-142' (93.7 days to planting) (**Table 3**). The less number of irrigation frequency (two irrigation) given at 120 mm CPE enhanced the maturity (92.4 days after planting) while the increased irrigation frequency (four irrigation) given at 60 mm CPE delayed the maturity (94.8 days after planting) (**Table 3**). In this case, it is possible that more water application leading to higher plant water status might have delayed the physiological maturity and continued vegetative growth.

'Roba-1' at a plant density of 350,000 plants/ha, which is statistically at par with the other two plant densities (250,000 plants/ha and 150,000 plants/ha), matured significantly earlier (91.7 days after planting) than any other interaction treatments of 'Mexican-142' (**Table 4**). Similarly findings of Gan *et al.* (2003) showed that increased planting density accelerated maturity in Chickpea. In the case of mung bean, there was no marked difference in days to maturity with variable plant densities (Singh *et al.* 2011). The interactions between plant density and irrigation frequency as well as variety × plant density × irrigation frequency however were non significant for this parameter (**Table 6**).

Plant height

ANOVA (**Table 6**) revealed that the plant height was highly significantly ($P < 0.01$) affected by varieties and irrigation frequencies. The plant height of 'Mexican-142' ranged from 70.9 cm to 79.9 cm, while that of 'Roba-1' ranged from 55.6 cm to 70.6 cm. The indeterminate variety, 'Mexican-142' recorded significantly higher values of height than the determinate variety, 'Roba-1' (**Table 5**) suggesting higher growth potential of 'Mexican-142'. Similar study carried out on soybean by Parvez *et al.* (1989) corroborated these findings that plant height was significantly higher for indeterminate varieties than determinate ones.

Lower irrigation frequency (120 mm CPE) decreased the plant height when compared with more frequent irrigation made at 90 and 60 mm CPE. The maximum plant height (71.9 cm) was recorded under highest irrigation frequency (60 mm CPE), while the lowest value (64.6 cm) was with the lowest irrigation frequency (120 mm CPE). This increase of plant height with frequent irrigations suggested favorable effect of water on growth parameters which corroborated the findings of Markhart (1985) and Nunez-Barrious (1991) who described the direct effect of water stress on plant height of beans (*P. vulgaris*), and Bafeel and Moftah (2008) who explained the adverse effect of water stress on the whole growth parameters of eggplant. Similarly, Castonguay and Markhart (1991) explained the reason for decreased plant height with low irrigation as resulted from a reduction in plant photosynthetic efficiency.

Similar to the report of Dahmardeh *et al.* (2010) on fababean tested in Iran, the influence of planting density on plant height was not significant (**Table 6**), but the trend confirmed an increase of plant height with increase in planting density, which could be, as indicated by Doss and Thurlow (1974) and Parvez *et al.* (1989) for haricot bean, Abdel-Aziz *et al.* (1999) and Dahmardeh *et al.* (2010) for faba bean, Heath *et al.* (1991) for pea, and Edwards and Purcell (2005) for soybean, due to lower amount of light intercepted by a single plant at high plant density resulting in to increased the inter node length. In contrast to this, the results of the studies by Kueneman and Wallace (1979) and Shahein *et al.* (1995) who studied for broad bean, and Kabir and Sarkar (2008) for mung bean indicated that increased competition for growth limiting factors at the highest plant density might have resulted in reduced growth (including stem elongation).

Interaction effects between irrigation frequency, plant density and variety did not have any significant effects on plant height (**Table 6**).

Leaf area

ANOVA on leaf area revealed that main effects of irrigation frequency and plant density significantly influenced the leaf area (**Table 6**). Increasing irrigation frequency significantly increased the leaf area. Highest leaf area (824.1 cm^2) was recorded at the highest irrigation frequency (60 mm CPE) followed by 710.0 and 621.8 cm^2 at intermediate (90 mm CPE) and lowest (120 mm CPE) irrigation frequencies, respectively (**Table 5**). The reason for this could be attributed to the abscission of lower leaves, being larger in size and hence; their loss caused significant reduction in the total leaf area at lower irrigation frequency levels, or according to Pardossi *el al.* (1994), the decrease in the leaf area under low levels of irrigation regimes may be ascribed to the decrease in the leaf water content, which in turn reduces the turgor pressure in leaf cells, thereby inhibiting cell division and elongation. This observation confirms that of Lenka (1991), who pointed out that moisture stress caused by reduced irrigation frequency, reduced the leaf area, size, volume and division of cells. Similar findings have also been reported by Siniot and Kramer (1977) on soybean, Markhart (1985) on two phaseolus species and Bafeel and Moftah (2008) on eggplant, where leaf areas of studied plants were reduced with water stress.

Table 5 Main effect of variety, plant density and irrigation frequency on crop growth parameters.

Treatment	Plant height	Leaf area	Leaf area index	Leaf number	Yield/plant
Variety					
'Roba-1'	62.6	715.1	1.95	54.2	51.41
'Mexican-142'	73.7	755.1	1.85	69.9	48.85
$LSD_{0.01}$	3.7	Ns	Ns	8.1	Ns
Plant density					
150,000	66.6	788.7	1.63	67.2	56.89a
250,000	68.9	722.8	1.72	61.5	51.06b
350,000	68.9	644.3	2.35	57.3	42.44c
$LSD_{0.05}$	Ns	95.9	0.48	7.4	4.06
Irrigation frequency					
60 CPE	71.9	824.1	2.1	64.7	59.94a
90 CPE	67.9	710.0	1.9	62.7	52.22b
120 CPE	64.6	621.8	1.7	58.7	38.22c
$LSD_{0.05}$	3.4	96.0	0.4	Ns	4.05
CV%	7.3	19.6	27.2	17.5	20.65

Table 6 ANOVA for growth, yield component and yield of haricot bean.

Source	Df	Phenological parameters		Growth parameters				Yield/plant
		Date of flowering	Date of maturity	Plant height	Leaf area	Leaf area index	Leaf number	
Replication	2	4.21	1.1	3.96	1.36	2.47	2.30	20.8
Irrigation	2	1.19	25.4**	8.12*	8.35*	5.81*	1.91	2182.1**
Error	4	1.30	2.7	1.10	1.15	0.60	0.34	355.3
Plant density	2	11.80*	0.1	1.38	4.73*	10.47*	3.80*	950.1**
Irrigation × plant density	4	9.94**	2.3	0.48	0.30	1.54	0.92	388.2*
Variety	1	44.46**	62.3**	68.36**	0.03	0.59	28.00**	88.2
Irrigation × variety	2	0.07	6.7**	2.17	0.07	0.64	0.22	167.7
Plant density × variety	2	11.36*	1.7	2.16	2.18	1.45	0.10	115.2
Irrigation × plant density × variety	4	3.21	2.1	0.11	0.84	0.32	0.20	218.6
Error	30	2.39	1.2	8.9	1.25	2.51	1.06	107.2
CV		2.59	25.4	7.29	19.61	27.17	17.48	20.65

df, degree of freedom; **,* significant at 1% and 5% levels respectively.

Increase in plant density significantly ($P < 0.05$) decreased leaf area of bean crop and the largest leaf area (788.7 cm^2) was observed at a plant density of 150,000 plants/ha followed by (722.8 cm^2) at 250,000 plants/ha and 644.3 cm^2 at 350,000 plants/ha, respectively. This was contradicted with the findings of Pawar *et al*. (2007) who reported non-significant result. There was no significant ($P < 0.05$) varietal difference for leaf area in spite of difference in their growth habits. The trend of data, however, indicated that leaf area was relatively higher in 'Mexican-142' than in 'Roba-1' (**Table 5**).

Leaf Area Index (LAI)

The main effects of plant density and irrigation frequency on LAI were significant (**Table 6**). Bean crop raised under irrigation frequency of 60 mm CPE showed a significantly higher LAI than grown at 90 mm CPE and 120 mm CPE for both varieties with mean values 2.1, 1.9 and 1.7, respectively. This result was not in agreement with the works of Mburu *et al*. (1999) and Simmonds *et al*. (1999) who explained the non-significant effect of irrigation on LAI.

LAI of both the varieties was significantly ($P < 0.05$) reduced due to decreased plant density. This result is in conformity with Kueneman and Wallace (1979), and Ghadiri and Bayat (2004) who reported a decreased LAI of dry and pinto beans with increase in row and plant spacing, respectively. A similar experiment on field beans (*Vicia faba*) also indicated higher LAI at higher plant density than at lower ones (Diaz and Manrique 1995). However, this finding was in contrary with Naim and Jabereldar (2010) who found that LAI tends to decrease with increasing plant densities of cowpea from 30,000 to 120,000 plants ha^{-1}.

Leaf number

The determinate variety 'Roba-1' had significantly less number of leaves than the indeterminate variety 'Mexican-142' with their respective mean leaf numbers of 54.2 and 69.9 (**Table 5**). This result agreed with the findings of Kueneman and Wallace (1979) who reported existence of variation in leaf number between different growth types of dry beans. The reduction in plant density increased the leaf number of bean crop significantly ($P < 0.05$). The highest number of leaves (67.2) was produced with 150,000 plants/ha. These results are in agreement with the previous findings reported by many workers (Weber *et al.* 1966 on soybean; and Alege and Mustapha 2007; Naim and Jabereldar 2010 on cowpea). They showed that increased plant densities reduced the number of leaf bearing branches/plant, thereby reduced leaf number.

Reducing the irrigation frequency caused a slight but non-significant decrease in leaf number of the two varieties. Non-significant effect of irrigation on the number of leaves was also reported by Nunez-Barrios (1991) and Mburu *et al.* (1999). There was no significant interaction effect between plant density and irrigation frequency in both the varieties.

Bean yield/plant

Variance data of yield per plant (**Table 6**) showed that the main effects of irrigation frequency and plant density as well as interaction between irrigation frequency and plant density significantly influenced the yield/plant.

The increased plant density decreased the seed yield/plant. The highest seed yield/plant (56.89 g) was recorded with 150,000 plants/ha plant density and lowest seed yield/plant (42.44 g) with 350000 plants/ha density (**Table 5**). This result is in agreement with the research findings of Biswas *et al*. (1997) who reported inverse relationship of plant density and bean yield $plant^{-1}$ on cowpea. In addition, Hoggard *et al*. (1978) from studies on determinate soybean found that maximum yield per plant of cultivars was reached at lower plant density than the higher plant density. For soybean, Hinson and Hanson (1962), Timmons *et al.* (1967), Ball *et al.* (2001) and Mehmet (2008); and for sun-

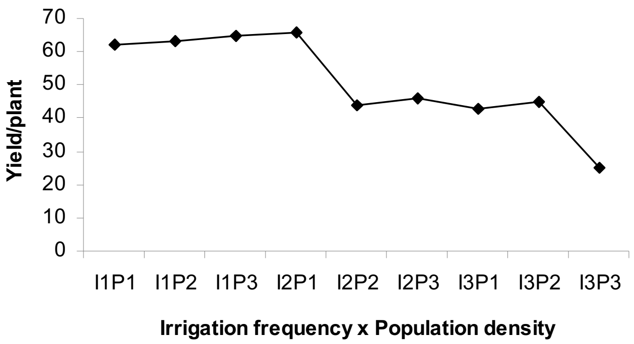

Fig. 2 Effect of irrigation frequency and plant density on bean yield/plant of haricot bean averaged over two varieties. $LSD_{0.05}$ = 12.21. n = 54.

flower, Salih and Bahrani (2000) reported similar results of increase in bean yield with decreased population density. Overcrowding due to competition for resources was mentioned the major reason for lower bean yield per plant in higher densities of pigeon pea (1,000,000 plants/ha) by Rowden *et al*. (1981), soybean (1,200,000) by Rahman and Hossain (2011) and mungbean (500,000 plants/ha) by Singh *et al.* (2011). However, reports of Gan *et al*. (2003) described seed yields of desi and kabuli chickpea increased with increases in plant population density from 20 to 50 plants m^{-2} when the crops were grown on summer fallow.

The increase in irrigation frequency from 120 to 60 mm CPE, significantly increased the seed yield/plant from 38.22 to 59.94 g, respectively (**Table 5**). This trend could be attributed to the fact that seed yield/plant was dictated primarily by the competition with neighboring plants for available water, and is consistent with related works on soybean by Boerma and Ashley (1982); and white bean by Habibi (2011). They reported that water stress reduced yield of the studied species up to 78 and 47.8%, respectively.

Interaction between irrigation frequency and plant density, averaged over the two varieties, pointed out that irrigation at 60 mm CPE frequency with increasing plant density from 150,000 plants/ha to 350,000 plants/ha slightly increased the seed yield/plant (**Fig. 2**). At 90 mm CPE, it was significantly reduced with increase in plant density from 150,000 plants/ha to 250,000 plants/ha and then it was slightly increased at plant density of 350,000 plants/ha. On the other hand, at reduced irrigation frequency (120 mm CPE), increasing the plant density from 150,000 plants/ha to 250,000 plants/ha caused a slight but not significant increase in yield/plant and with further increasing the plant density to 350,000 plants/ha a significant reduction in the trait was observed. The reason for such result on crop yield might attribute to the combined effect of competition between plants for essential nutrients and the deficiency of moisture occurred due to reduced irrigation frequency. This interaction effect result is in consistence with related research report by Doss and Thurlow (1974) who indicated that average soybean yields/plant tended to be higher for the low plant density levels with no irrigation and intermediate irrigation.

SUMMARY AND CONCLUSION

A study was conducted at Tony farm, Dire Dawa, experimental field of Alemaya University, during the 2001/2002 dry ('Bega') season to determine the effect of plant density and irrigation frequency on phenology and crop growth of two haricot bean varieties, 'Roba-1' and 'Mexican-142'. A split plot design with three irrigation frequencies (irrigations at 60, 90 and 120 mm CPE) to main plot and a combination of three plant densities (150,000, 250,000 and 350,000 plants/ha) and two haricot bean varieties ('Roba-1' and 'Mexican-142') to sub plot were assigned with three replications. Days to 50% flowering was significantly affected by the variation in the growth habit and plant density. Variety and irrigation frequency had a significant effect on days to maturity, where by 'Roba-1' matured earlier than 'Mexican-142' and irrigation frequency of 120 mm CPE caused the plant to mature earliest over other irrigation levels. Significant differences in plant height, leaf area and LAI due to the main effects of irrigation frequency were observed. The interaction effects of all the three treatments indicated no significant effect on these parameters. Plant height and leaf number were significantly affected by varietal differences. Increasing plant density from 150,000 to 250,000 plants/ha and to 350,000 plants/ha resulted in a significant reduction in leaf area, LAI and leaf number. The highest seed yield/plant was recorded with the minimum plant density and lowest seed yield/plant with the highest plant density. The increase in irrigation frequency from 120 to 60 mm CPE significantly increased the seed yield/plant from 38.22 to 59.94 g.

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