

# Effect of Plant Density on Yield Components and Yield of Faba Bean (*Vicia Faba L.*) Varieties at Wolaita Sodo, Southern Ethiopia

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## Abstract

Faba bean is one of the most popular pulse crops with manifold merits in the economy of the farming communities in the highlands and semi-highlands of Ethiopia. On the other hand, crop yield is functions of different growth and management factors of which optimum plant density is one of the paramount important. Basically, optimum plant density varies with genotypes, ecology, time of planting, production objective, cultural practices, water availability, and nutrients status of the soil. In this context, a field experiment was conducted during 2016 main cropping season at Wolaita Sodo Agricultural Technical Vocational Education and Training College farm in southern Ethiopia with objective of evaluating the effect of plant densities on performance of faba bean varieties. Treatments consisted in three faba bean varieties (Hachalu, Moti and Tumisa) and six level of plant densities (166,666, 222,222, 250,000, 333,333, 500,000 and 666,666 plants/ha) were combined in factorial and laid out in a randomized complete design (RCBD) with three replications. The longest days to flowering and physiological maturity were recorded for variety Tumisa at plant density of 166 666 plant/ha and both parameters were shortest for variety Moti at plant density of 666 666 plants/ha. The tallest plant height was obtained from the highest plant density and the shortest plants from the lowest plant density. The highest number of pods per plant, seeds per pod and HSW were recorded at plant density of 166 666 plants/ha and all parameters were lowest at the highest plant density. Grain yield increased for all varieties with increasing plant densities up to 250 000 plants/ha and then declined for further increase in plant density above it with the highest grain yield was recorded for variety Tumisa at plant density of 250 000 plants/ha followed by variety Moti at the same plant density. This finding revealed that all the varieties had the highest grain yield at plant density of 250 000 plants/ha where the variety Tumisa out yielded and followed by variety Moti. Varieties Tumisa and Moti at plant density 250 000 or 222 222 plants/ha could the best options for faba bean production.

**Keywords:** faba bean, grain yield, yield components, density, varieties

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## 1. Introduction

Faba bean (*Vicia faba L.*) is a legume crop belonging to *Fabaceae* family has a multi-use. It is the fourth most important pulse crop in the world with total average annual production of 4.316.371 tons (Anon, 2010). Major producers of faba bean in the world are China (1.65 Mt), Ethiopia (0.61 Mt), France (0.44 Mt), Egypt (0.29 Mt) and Australia (0.19 Mt) (FAOSTAT, 2009; Sitou and Mywish, 2011). Faba bean is widely cultivated and consumed as a source of protein both in human and animal nutrition, either fresh or dried. It contains a large amount of protein, carbohydrate, B-group vitamins and minerals where its protein content is 29.57-31.83 %, carbohydrate 52.96-54.60%, ash 3.37-3.47%, fat 0.81-1.24% and fiber 10.88-11.96% depending on varieties (Sarah *et al.*, 2009).

Ethiopia is one of the largest faba bean producing countries in the world next to China and accounts for about 12% of the world area and production (Mussa and Gemechu, 2006). Thus, the country is considered to be secondary center of diversity and one of the nine major agro-geographical production regions of the crop (Asfaw *et al.*, 1994; Hailu *et al.*, 2014). Faba bean is cultivated as a field crop at highlands in between the altitudes of 1800 and 3000 m above sea level and mainly grown under rain-fed conditions (Asfaw, 1985). It the most important cool-season food legume crop in Ethiopia in terms of area coverage, production, foreign exchange earnings, protein source, soil amelioration and cropping system (Tafere *et al.*, 2012) and reduces poverty by 3% (Getachew and Rezene, 2006; ICARDA, 2008).

Plant density is directly correlated with growth and yield parameters of faba bean. Indeed, growth and yield parameters of faba bean like plant height, number of branches, number of pods, pods yield, number of seeds, seed yield, hundred seed weight, biological yield and the overall yield of the crop can be affected considerably (Bakry *et al.*, 2011; Malekmeiki *et al.*, 2012; Yucel, 2013, Derogar *et al.*, 2014). Higher plant density above optimum has a significant effect on growth, yield components and yield of most pulse crops including faba bean (Mokhtar, 2001). High plant density may lead to certain morphological modifications on the growth and development of faba bean crop such as increase in plant height, reduction in branching, reduction in number of pods per plant, alteration

in leaf orientation (Yucel, 2013; Derogar and Mojaddam, 2014). At higher plant densities faba bean plants develop weak stems liable to various climatic and biotic factors that can affect the overall performance of the crop (ICARDA, 2008). Different researchers reported that at higher plant densities intensify interplant competition for growth factors such as sunlight, moisture, air and essential nutrients in the soil (Yucel, 2013, Dergar *et al.*, 2014; Tekle *et al.*, 2015; Wakweya and Meleta, 2016). Moreover, higher plant densities exert significant influence on individual plant morphology of faba bean crop (Khalil *et al.*, 2010; Yucel, 2013). Thus, determining optimum plant density is one of a pre-requisite to increase production and productivity in faba bean (Bakry *et al.*, 2011; Biswas *et al.*, 2012; Wakweya and Meleta, 2016). Hence, this study was initiated with objective to determine the optimum plant density for faba bean varieties.

## 2. Materials and methods

### 2.1 Experimental Site

Field experiment was conducted during 2016/17 main cropping season at Wolaita Sodo Agricultural Technical Vocational Education and Training (ATVET) College demonstration field in Southern Ethiopia. An approximate geographical coordinates of the site is 6°34' N latitude and 37°43' E longitude having an altitude of 1950 m.a.s.l, (Shiferaw, 2008). The area is characterized with a bimodal rainfall distribution pattern with average annual rainfall of 1150 mm. The average minimum and maximum air temperatures are 13.5 and 23 °C, respectively. The soil of the experimental field is of nitosoil and classified as clay loam textural class (Solomon, 2009).

### 2.2 Treatments and Experimental Design

Treatments consisted in three faba bean varieties (Hachalu, Moti and Tumisa) and six level of plant densities (166,666, 222,222, 250,000, 333,333, 500,000 and 666,666 plants/ha). The respective row and plant spacing to maintain the proposed plant densities were 40 x15 cm for 166,666, 30 x15 cm for 222,222, 40 x10 cm for 250,000, 30 x10 cm for 333,333, 40 x5 cm for 500,000 and 30 x5 cm for 666,666 plants/ha. The treatments were combined in factorial and laid out in a randomized complete design (RCBD) with three replications. Each plot was 2.4 m wide and 2 m long with total growth area of 4.8 m<sup>2</sup>. Seeds were hand planted by putting two seeds per hill and thinned after germination to maintain the proposed plant densities per plot. The experimental field was oxen ploughed twice and leveled to get smooth seed bed. Recommended amount of phosphorus was applied in the form of DAP at the rate of 20 kg/ha and nitrogen in the form of urea at rate of 16.4 kg/ha was applied at planting. All management practices such as cultivation, weeding etc, were done uniformly for all treatments as desired. Disease incidence and insect pests were visually monitored.

### 2.3. Data Collection and Measurements

Plant parameters recorded were days to flowering, physiological maturity, plant height, leaf area index (LAI), number of pods per plant, seeds per pod, hundred seed weight (HSW), biomass, grain yield and harvest index (HI). Days to flowering was recorded as the number of days from planting to 50% of the plants exhibit flowering per plot. Days to physiological maturity was recorded when 50% of plants in the plot lose green color of pod. Plant height, LAI, pods per plant and seeds per pod were taken from ten randomly selected plants per plot. Hundred seed weight (HSW) was measured by counting a hundred seeds with a seed counter and weighing it with sensitive balance. Grain yield was harvested from central rows by avoiding border effects and converted to kg/ha after adjusting moisture content at 10%. Biomass was determined as the sum of straw weighed and total grain yield. Harvest index (HI) is the ratio of grain to the total biomass and estimated as:

$$HI = \frac{\text{Grain yield}}{\text{Biomass yield}}$$

All collected data were subjected to analysis of variance (ANOVA) using SAS version 9.20 (SAS, 2008) statistical computer software and interpretations were made following the procedure described by Gomez and Gomez (1984). Whenever the effects of the treatments were found to be significant, the means were compared using the Least Significant Differences (LSD) test at 5% probability level.

## 3. Results and discussion

### 3.1. Days to flowering and physiological maturity

Analysis of variance showed that faba bean varieties were significantly differed with respect to days flowering and physiological maturity (Table 1). Variety Tumisa took the longest days to flowering (54.1) and physiological maturity (115.8) followed by variety Hachalu with mean days to flowering of 53.6 and physiological maturity of 112.3. The shortest days to flowering (45.0) and physiological maturity (108.5) were recorded for variety Moti. The difference of 9.1 days to flowering and 7.3 days to physiological maturity were observed between the longest and shortest days to flowering and physiological maturity. Similarly, plant density had significant effect on days to flowering and physiological maturity (Table 1). Both parameters were shortened as plant density increased. The highest plant density resulted in shortest days to flowering and physiological maturity and vice versa.

Significant differences were detected due to effect of varieties by plant densities interaction on days to flowering and physiological maturity (Table 1). Generally days flowering and physiological maturity tended to shorten for all varieties as plant densities increased. The longest days to flowering (57.3) was recorded for variety Tumisa at plant density of 166 666 plant/ha followed by Hachalu with mean days to flowering of 57.0. The shortest days to flowering (43.0) was seen for variety Moti at plant density of 666 666 plants/ha. The difference of 6 days for Hachalu, 3 days for Moti and 5.7 days for Tumisa were recorded between at the lowest and highest plant densities for varieties. This result suggests that variety Moti relatively earlier to flowering as compared Hachalu and Tumisa where as the two varieties response to change in plant densities were relatively similar. The differences in response of varieties to variable plant densities might be attributed to their inheritance variations. Similar findings were reported by Khalil *et al.* (2011), Tafere *et al.* (2012), Rehab and El-Rahman (2014) and Tewdros *et al.* (2015) that faba bean varieties responded differently to variable plant densities for days to flowering. Regarding days to physiological maturity, the longest days to maturity (125.0) was observed for Tumisa at plant density of 166 666 plants/ha followed by the same variety at plant density of 222 222 plants/ha with mean days to maturity of 122.3. The shortest days to maturity (101.3) was recorded for variety Moti at plant density of 666 666 plants/ha. The difference of 14.7 for variety Hachalu, 12.7 for Moti and 19.4 days were recorded for varieties at the lowest and highest plant densities. This finding probably suggests that days to physiological maturity was more variable for Tumisa and least for Moti while Hachalu is somewhat intermediate in response to plant density. The differences days to maturity of varieties with respect to variable plant densities were likely due to genetic differences among the cultivars. This result is in agreement with the findings of Abdalla *et al.* (2000), Rehab and El-Rahman (2014) and Ashenafi and Mekuria (2015) reported variations on days of maturity of faba bean varieties in response to different plant densities. However, contradictory finding was reported by Almaz *et al.* (2016) that at higher plant densities days to physiological maturity delayed for faba bean varieties.

Table 1. Days flowering and physiological maturity as affected by varieties and plant densities

| Variety            | Plant density (Ha) | Days to flowering | Days to maturity |
|--------------------|--------------------|-------------------|------------------|
| Hachalu            | 166 666            | 57.0a             | 120.0bc          |
|                    | 222 222            | 56.3a             | 118.3c           |
|                    | 250 000            | 55.0b             | 113.3d           |
|                    | 333 333            | 51.0d             | 110.0d           |
|                    | 500 000            | 51.3d             | 106.6f           |
|                    | 666 666            | 51.0d             | 105.3f           |
| Moti               | 166 666            | 46.0ef            | 114.0d           |
|                    | 222 222            | 45.6ef            | 113.0d           |
|                    | 250 000            | 45.3e             | 110.0e           |
|                    | 333 333            | 45.0fg            | 106.3f           |
|                    | 500 000            | 44.0h             | 106.3f           |
|                    | 666 666            | 43.0h             | 101.3g           |
| Tumisa             | 166 666            | 57.3a             | 125.0a           |
|                    | 222 222            | 56.3a             | 120.0bc          |
|                    | 250 000            | 54.6b             | 122.3ab          |
|                    | 333 333            | 53.0c             | 115.0d           |
|                    | 500 000            | 51.6d             | 106.6f           |
|                    | 666 666            | 51.6d             | 105.6f           |
|                    | LSD                | 1.1               | 2.6              |
| Variety mean       | Hachalu            | 53.6b             | 112.3b           |
|                    | Moti               | 45.0c             | 108.5c           |
|                    | Tumisa             | 54.1a             | 115.8a           |
|                    | LSD                | 0.48              | 1.1              |
| Plant density mean | 166 666            | 53.6a             | 119.7a           |
|                    | 222 222            | 52.3b             | 116.1b           |
|                    | 250 000            | 52.0b             | 116.2b           |
|                    | 333 333            | 50.0c             | 110.4c           |
|                    | 500 000            | 49.0d             | 106.5d           |
|                    | 666 666            | 48.5d             | 104.1e           |
|                    | LSD                | 0.68              | 1.55             |
|                    | CV (%)             | 1.4               | 3.4              |

Means followed by the different letters within columns are significantly different at 5% probability level, NS = not significant

### 3.2. Plant height, pods per plant, seeds per pod and hundred seed weight

Analysis of variance indicated that varieties exhibited significant differences on plant heights, pods per plant, seeds per pod and HSW (Table 2). The tallest plant heights (130.2 cm) and the highest HSW (95.78 g) were recorded for variety Tumisa followed by Hachalu with mean plant heights of 129.6 cm and HSW of 94.28 g. The shortest plant height (126.8 cm) and lowest HSW (93.89 g) were seen for variety Moti. The differences in plant height among varieties could be attributed to the difference in their genetic makeup. This result is in agreement with findings of Peksen *et al.* (2006), Bakry *et al.* (2011), Yucel (2013) and Abd El-azeem *et al.* (2014) that there were plant height variations for faba bean cultivars. With respect to number of pods per plant and seeds per pod, the greatest number of pods per plant (17.19) was obtained from variety Hachalu and seeds per pod (3.19) from Tumisa. The least number of pods per plant (13.84) and seeds per pod (3.10) were achieved from variety Moti (Table 2).

Significant differences were detected due to effect of plant densities on plant height, pods per plant, seeds per pod and HSW (Table 2). Generally, plant height tended to increase with increasing plant densities. The tallest plant height (139.0 cm) was obtained from the highest plant density followed by plant density of 500 000 plants/ha with mean plant height of 133.1 cm. The shortest plant height (121.1 cm) was achieved from plant density of 166 666 plants/ha. Higher plant densities resulted in taller plant heights whereas lower plant densities resulted in shorter plants. The tallest plant height at a high plant density was likely due to the elongation of internodes ('etiolation' – as a result of insufficient radiation penetration, over shading and self shading). When plants are placed in close proximity of each other as a result of increased plant density, the internode length and stems become elongated due to a phototropism reaction of plants in response to light stimulus (Mason *et al.*, 1974; Leopold and Kreidemann, 1975; Park *et al.*, 1989). This was also confirmed by Ogunlella *et al.* (2005) and Amanullah *et al.* (2010) indicated that plants were taller with increased plant density in reaction to an enhanced competition among plants for light. Conversely, varieties by plant densities interactions did not have significant effect on plant height. On the other hand, number of pods per plant, seeds per pod and HSW showed the tendency of declining as plant densities increased (Table 2). The highest number of pods per plant (21.28), seeds per pod (3.51) and HSW (98.22 g) were recorded at plant density of 166 666 plants/ha followed by plant density of 222 222 plants/ha with mean number of pods per plant 17.23, seeds per pod of 3.22 and HSW of 97.22 g. All parameters were lowest at the highest plant density. In line with this, varieties by plant densities interactions resulted in significant differences on number of pods per plant (Table 2). Number of pods per plant showed tendency of decreasing for all varieties as plant densities increased. The greatest number of pods per plant (24.46) was observed for variety Tumisa at plant density of 166 666 plants/ha followed by variety Hachalu at the same plant density with mean number of pods per plant of 21.38. The lowest number of pods per plant (9.50) was seen for variety Moti at plant density of 666 666 plants/ha. The result is in accordance with the works of Dahmardeh *et al.* (2010), Osman *et al.* (2010), Bakry *et al.* (2011) and Tekle *et al.* (2015) indicated that faba bean varieties differ in yielding number of pods per plant. Moreover, Shad *et al.* (2010), Derogar and Mojaddam (2014) and Almaz *et al.* (2016) showed that increasing plant densities may lead to a decrease in the number of pods per plant in faba bean is due to a reduction in the number of pod bearing branches per plant. Conversely, varieties by plant densities interactions did not result in significant differences on plant height, seeds per pod and HSW.

Table 2. Plant height, pods per plant, seeds per pod and HSW as affected by varieties and plant densities

| Variety | Plant density (Ha) | Plant height (cm) | Pods/plant           | Seeds/pod | HSW (g) |
|---------|--------------------|-------------------|----------------------|-----------|---------|
| Hachalu | 166 666            | 120.6             | 21.38 <sup>b</sup>   | 3.19      | 97.33   |
|         | 222 222            | 128.1             | 20.00 <sup>bc</sup>  | 3.00      | 96.66   |
|         | 250 000            | 125.5             | 16.96 <sup>d-f</sup> | 2.96      | 96.00   |
|         | 333 333            | 132.9             | 16.50 <sup>d-f</sup> | 2.62      | 91.66   |
|         | 500 000            | 130.2             | 15.13 <sup>fg</sup>  | 2.71      | 93.66   |
|         | 666 666            | 140.3             | 13.17 <sup>gh</sup>  | 2.62      | 90.33   |
| Moti    | 166 666            | 120.8             | 18.00 <sup>c-e</sup> | 3.50      | 97.33   |
|         | 222 222            | 121.2             | 16.09 <sup>ef</sup>  | 3.21      | 96.66   |
|         | 250 000            | 122.1             | 14.54 <sup>f-h</sup> | 3.25      | 95.00   |
|         | 333 333            | 132.7             | 12.63 <sup>g-i</sup> | 2.92      | 90.66   |
|         | 500 000            | 127.1             | 12.25 <sup>h-j</sup> | 2.96      | 93.33   |
|         | 666 666            | 137.1             | 9.50 <sup>j</sup>    | 2.75      | 90.33   |
| Tumisa  | 166 666            | 121.8             | 24.46 <sup>a</sup>   | 3.75      | 100.00  |
|         | 222 222            | 127.0             | 19.13 <sup>b-d</sup> | 3.46      | 98.33   |
|         | 250 000            | 133.3             | 16.50 <sup>d-f</sup> | 3.25      | 98.33   |
|         | 333 333            | 125.6             | 13.21 <sup>gh</sup>  | 2.88      | 92.66   |
|         | 500 000            | 133.7             | 12.25 <sup>h-j</sup> | 2.96      | 95.33   |
|         | 666 666            | 139.7             | 10.21 <sup>ij</sup>  | 2.83      | 90.00   |
|         | LSD                | NS                | 2.8                  | NS        | NS      |

|                    |                |        |        |        |        |
|--------------------|----------------|--------|--------|--------|--------|
| Variety mean       | <i>Hachalu</i> | 129.6a | 17.19a | 2.87c  | 94.28b |
|                    | <i>Moti</i>    | 126.8b | 13.84c | 3.10b  | 93.89b |
|                    | <i>Tumisa</i>  | 130.2a | 15.96b | 3.19a  | 95.78a |
|                    | <i>LSD</i>     | 1.30   | 1.14   | 0.06   | 1.37   |
| Plant density mean | 166 666        | 121.1e | 21.28a | 3.51a  | 98.22a |
|                    | 222 222        | 124.8d | 17.23b | 3.22b  | 97.22a |
|                    | 250 000        | 125.0d | 17.01b | 3.15b  | 96.44a |
|                    | 333 333        | 130.1c | 14.14c | 2.87c  | 94.11b |
|                    | 500 000        | 133.1b | 13.33c | 2.81cd | 91.66c |
|                    | 666 666        | 139.0a | 10.95d | 2.74d  | 90.22c |
|                    | <i>LSD</i>     | 1.9    | 1.62   | 0.09   | 1.94   |
|                    | <i>CV (%)</i>  | 1.5    | 10.8   | 3.1    | 2.1    |

Means followed by the different letters within columns are significantly different at 5% probability level, NS = not significant

### 3.3. Biomass, grain yield, harvest index and plant lodging

Analysis of variance revealed that varieties showed significant differences on biomass yield, grain yield, HI (Table 3). The greatest biomass production (12260 kg/ha) was found from variety *Moti* followed by variety *Hachalu* with mean biomass yield of 11970 kg/ha. The lowest biomass yield (11710 kg/ha) was obtained from variety *Tumisa*. Biomass is a function of numerous interacting environmental and genetic factors and its production is directly related to potential growth and development factors such as solar radiation, water supply, availability of mineral nutrients and crop management practices. Thus, the differences in biomass yield among varieties might be due to the genetic variability on the performance of varieties in response to the growing environment. With respect to grain yield and HI, both parameters were highest for variety *Tumisa* and followed by *Moti*. The lowest grain yield (3559 kg/ha) was obtained from variety *Hachalu*. Similarly, biomass, grain yield and HI were significantly differed due to effect plant densities (Table 3). Biomass yield as affected by plant density ranged from 10450 to 13820 kg/ha. The highest biomass yield (13820 kg/ha) recorded at plant density of 500 000 plants/ha followed by plant density of 333 333 plants/ha with mean biomass yield of 13120 kg/ha. The lowest biomass yield (10450 kg/ha) was obtained from plant density of 166 666 plants/ha (Table 3). This illustrated that subjecting plants to high plant density increased the ability of plants for capturing resources which was reflected as evident in their increased biomass production. Bullock *et al.* (1998) proved that high plant densities (narrow row spacings) made more efficient use of available light and shaded the soil surface to a greater degree during the early part of the growing season while the soil is still moist and therefore, higher plant densities are more effective in producing biomass. Regarding grain yield, it increased with increasing plant density up to 250 000 plants/ha and then declined with further increment of plant density above that optimum level. The highest grain yield (4202 kg/ha) was achieved from plant density of 250 000 plants/ha followed by plant density of 222 222 plants/ha with mean grain yield of 4045 kg/ha. The lowest grain yield (3032 kg/ha) was recorded at plant density of 666 666 plants/ha. Regarding the HI, it was greatest at the lowest plant density and lowest at the highest plant density.

Analysis of variance revealed that significant differences were detected due to the effect of varieties by plant density interactions on grain yield and HI (Table 3). Generally, grain yield increased for all varieties with increasing plant densities up to 250 000 plants/ha and then declined for further increase in plant density above it. The highest grain yield (4330 kg/ha) was recorded for variety *Tumisa* at plant density of 250 000 plants/ha followed by variety *Moti* at the same plant density with mean grain yield of 4188 kg/ha. The lowest grain yield (3003 kg/ha) was seen for variety *Moti* at plant density of 666 666 plants/ha. Thus, plant density 250 000 plants/ha seems to be optimum for all varieties. Decreasing plant density from 250 000 to 222 222 plants/ha resulted in yield loss 3.1% for *Hachalu*, 3.7% for *Moti* and 4.8% for variety *Tumisa*. In line with this, increasing plant density from 250 000 to 333 333 plants led to a yield loss 25.9% for *Hachalu*, 37.6% for *Moti* and 6.3% for *Tumisa*. This suggests that varieties were more sensitive to yield reduction for plant densities above the optimum than reduction below the optimum. With respect to HI, all varieties had the highest HI at the lowest plant density and lowest HI at the highest plant density. This result is in conformity with findings of Gebremeskel *et al.* (2011), Abdalla *et al.* (2015) and Ashenafi and Mekuria (2015) reported that HI varies for different faba bean varieties at different plant densities. In line with this, AL-Rifae *et al.* (2004), Mahmoud (2014) and Tekle *et al.* (2015) indicated that low plant density results higher HI as compared to higher plant densities.

Crop yield is a function of a number of factors and processes such as amount of light intercepted by the canopy, metabolic efficiency of plants and the translocation efficiency of photosynthates from leaves to economic parts. These processes are affected by crop cultivars and plant densities. Differences in plant densities in of this study caused a profound impact on faba bean grain yield by affecting yield and yield components. Plant density exerts a strong influence on faba bean growth and yield as a result of the competitive ability of plants at variable densities (Singh and Chaudhary, 2008). Balanced growth and development of plants need an optimum plant

density because optimum density enable plants' efficient utilization of available nutrients, soil water and better light interception coupled with other growth factors. Increasing plant density above an optimum level intensifies competition for solar radiation, soil nutrients and soil moisture. Moreover, high plant density can cause lodging, less light penetration in the crop canopy leading reduced photosynthetic efficiency of the plants resulting in drastic yield reduction (Lemerle *et al.*, 2004; Lemerle *et al.*, 2006; and Shad *et al.*, 2010). On the other hand, plant density lower than optimum exhibited lower grain yield per unit area which might attributed to a lower number of plants per unit area. Reduction of plant density below an optimum resulted in a negative impact on grain yield primarily due to underutilization of resources. The same impact was reported by Hashemi- Dezfouli & Herbert (1992) and Echarte *et al.* (2000) that plant density below the optimum led to decreased use efficiency of available resources. In contrast, varieties by plant densities interactions did not result in significant differences on biomass yield.

Plant lodging was significantly differed due to interaction effect of varieties by plant densities (Table 3). A variable number of lodged plants were recorded in response of varieties to pant densities. For all varieties the highest plant lodging was observed at the highest plant densities. At plant density above 250 000 plants/ha variety Hachalu was more liable to lodging while the remaining two varieties more or less similar with respect to tolerance to lodging at higher plant densities. At higher plant densities (PD  $\geq$  250 000 plants/ha) plant lodging might be the result of weak stems and shallow root development due to overcrowding of plants per unit area. The tendency of plant lodging at increased plant density is also associated with a disorganized light profile in dense plant densities according to Sangoi and Salvador (1996). Rajcan & Swanton (2001) suggested that when plants grow in a dense canopy, they tend to receive a different quality of light radiation, enriched with far red (FR) and impoverished in red (R) radiation where this high FR/R ratio triggers many morphological changes in plant architecture, stimulating stem elongation, favouring apical dominance and reducing stem diameter. Such changes make plant stalks more susceptible to stem breakage and root lodging before seeds attain physiological maturity.

#### 4. Conclusion

Grain yield is a function of several factors and processes, such as interception of solar radiation, metabolic efficiency of plants, translocation efficiency of photosynthates from leaves to economic parts, sink strength and genetic make-up of the crop. Thus, sustainable production depends on the correct application of production inputs sustaining both the environment and agriculture. The current investigation clearly showed that all the varieties had the highest grain yield at plant density of 250 000 plants/ha where the variety Tumisa out yielded and followed by variety Moti. Varieties Tumisa and Moti at plant density 250 000 or 222 222 plants/ha could the best options for faba bean production.

Table 3. Biomass, grain yield, HI and plant lodging as affected by varieties and plant densities

| Variety      | Plant density (Ha) | Biomass (kg/ha) | Grain yield (kg/ha) | HI      | Plant lodging (%) |
|--------------|--------------------|-----------------|---------------------|---------|-------------------|
| Hachalu      | 166 666            | 12110           | 3888ef              | 0.33a   | 10.00hi           |
|              | 222 222            | 10410           | 3967de              | 0.30cd  | 16.66g            |
|              | 250 000            | 13100           | 4088c               | 0.29d-f | 18.86fg           |
|              | 333 333            | 10870           | 3246i               | 0.27gh  | 32.77b            |
|              | 500 000            | 13960           | 3113j               | 0.26jg  | 33.50ab           |
|              | 666 666            | 11340           | 3055jk              | 0.26fg  | 35.93a            |
| Moti         | 166 666            | 12250           | 3368h               | 0.34a   | 10.83hi           |
|              | 222 222            | 10640           | 4038cd              | 0.31bc  | 17.92g            |
|              | 250 000            | 13390           | 4188b               | 0.30cd  | 20.55f            |
|              | 333 333            | 11110           | 3043jk              | 0.27gh  | 25.69de           |
|              | 500 000            | 14240           | 3043jk              | 0.26fg  | 26.46de           |
|              | 666 666            | 11920           | 3003k               | 0.25i   | 29.68c            |
| Tumisa       | 166 666            | 12390           | 3501g               | 0.34a   | 8.75i             |
|              | 222 222            | 10300           | 4131bc              | 0.34a   | 11.66h            |
|              | 250 000            | 12820           | 4330a               | 0.32b   | 12.58h            |
|              | 333 333            | 10530           | 4074c               | 0.30cd  | 24.02e            |
|              | 500 000            | 13250           | 3113j               | 0.29ef  | 26.04de           |
|              | 666 666            | 10880           | 3038jk              | 0.27gh  | 28.23ed           |
|              | LSD                | NS              | 97                  | 0.02    | 2.6               |
| Variety mean | Hachalu            | 11970b          | 3559b               | 0.29b   | 24.63a            |
|              | Moti               | 12260a          | 3578b               | 0.29b   | 21.85b            |
|              | Tumisa             | 11710c          | 3698a               | 0.31a   | 18.54c            |
|              | LSD                | 238             | 39                  | 0.01    | 1.06              |
|              |                    | 166 666         | 10450e              | 3371d   | 0.34a             |
|              | 222 222            | 10840d          | 4045a               | 0.32b   | 16.29c            |

|                           |         |        |       |       |        |
|---------------------------|---------|--------|-------|-------|--------|
| <i>Plant density mean</i> | 250 000 | 12250b | 4202a | 0.30c | 16.45c |
|                           | 333 333 | 13120b | 3920b | 0.28d | 27.49b |
|                           | 500 000 | 13820a | 3090e | 0.28d | 28.68b |
|                           | 666 666 | 11380c | 3032f | 0.26d | 31.28a |
|                           | LSD     | 337    | 56    | 0.01  | 1.5    |
|                           | CV (%)  | 12.9   | 11.6  | 12.5  | 7.6    |

Means followed by the different letters within columns are significantly different at 5% probability level, NS = not significant

## 5. References

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