World Journal of Agricultural Sciences 15 (4): 261-268, 2019
ISSN 1817-3047

DOI: 10.5829/idosi.wjas.2019.261.268

Review on Effect of Plant Density and Planting Arrangement on Faba Bean Production

Almaz M. Gezahegn

Ethiopian Institute of Agricultural Research, 2003, Addis Abeba, Ethiopia

Abstract: Increasing productivity per unit area through agronomic management is one of the important strategies to increase production of faba bean. Keeping this in view, an attempt was carried out to review the work done on the effect of plant density and planting arrangement on resource utilization, growth, disease and pest and yield and yield components of faba bean. In faba bean, the effect of plant density and planting arrangement is well documented. From the review, it is understood that seed yield per unit area is the product of seed yield per plant and number of plants per unit area. At low densities, seed yield has limited by the number of plants, whereas at higher densities it declines due to increase in number of aborted pods and barren stalks. Therefore, finding the optimum densities that produce the maximum yield per unit area under different environmental condition has been the major concern in many investigations.

Key words: Faba Bean · Growth · Plant Density · Yield

INTRODUCTION

Faba bean is the fourth important pulse crop in the world. Plant population is one of the factors that affect growth and yield. It also affect canopy architecture, light conversion efficiency, duration of vegetative growth, dry matter production, seed yield and ultimately, the economic productivity of faba bean [1]. High plant population adversely affects plant growth and development, while suboptimal plant population results in high yield per plant but lower yield per unit area [2]. This might be due to high plant density lead to competitive shading within the leaf canopy architecture [3] thereby limiting interception of radiation by the middle and lower stem leaves particularly during poding time [4,5] accelerating leaf senescence [6] reducing photosynthesis and net assimilation of individual plants. Increasing plant density enhances intra-plant competition, decreases the growth of single-plant crops [7].

Optimum plant density (i.e. the population that produces maximum yield and suitable plant arrangement per unit area) allows crop to exploit resources optimally and produce high yields [8]. It has been reported that the optimum plant density to get high productivity for different faba bean crop varieties can range from 10 to 100 plants m^2 [9]. These indicated that the faba bean crop has the ability to alter plant size and canopy structure in response to changes in plant density. Therefore the aim of this article is to give a brief review of the literature related to the effects of plant density and planting arrangement on resource utilization, growth, disease and pest and yield and yield component of faba bean.

Concepts of Plant Density and Planting Arrangement: For sole cropping, the different aspects of plant density and spatial arrangement are well understood. Plant density defines the number of plant per unit area, which determines the size of the area available to the individual plant. Willey and Osiru [10] stated that an essential component of plant density is a spatial arrangement. Spatial arrangement is defined as the pattern of plants over the ground, which determines the shape of the area available to the individual plant [11]. It has been indicated that three components of plant arrangement have the potential to influence yield which include: (a) a square grid, (b) regularity of distribution and (c) the direction of rows either north-south or east-west. Willey and Osiru [10] indicated that an ideal spatial arrangement is a square grid or equidistant between plants which is often used in perennial tree crops. Particularly in annual or row crops

Corresponding Author: Almaz M. Gezahegn, Ethiopian Institute of Agricultural Research, 2003, Addis Abeba, Ethiopia.

the arrangement is rectangular in which the between row spacing is greater than the with-in row spacing [12]. Planting arrangement in the field is very important and plays a significant role in determining plant growth and development. Arrangement of a population is altered by changing row spacing, planting seeds singly or in groups, or changing row direction [13]. Plant spacing should be thought of as existing in two directions, within row spacing and between row spacing. At a given plant density, as row spacing decreases, the plant spacing within the row increases and results in a more equidistant plant spacing. At a fixed row width, plant density increase the plant spacing within the row decreases and inter plant competition increases. Obviously, both factors can be adjusted to give ideal plant spacing and typically plant density increases as row spacing decreases [14].

Effect of Plant Density on Resources Utilization: Plants show extreme plasticity, responding remarkably in size and form to environmental conditions. One of the most potent of these external forces is the presence of competing neighbors, which may reduce a plant to diminutive size. The factors for which competition may occur among plants are water, nutrient, light, oxygen and carbon dioxide and in the reproductive phase, agents of pollination and dispersal. Water, nutrients and light are the factors most commonly deficient. When the immediate supply of a single necessary factor falls below the combined demand of the plants, competition begins [15].

For a low density of plants of a single species increasing the density increases yield per unit area and intraspecific competition becomes more intense, because greater number of individuals compete for the same common limiting resources. In pure stands, increase in the intensity of competition manifests itself by the reduction of the performance of the individual, e.g. biomass of single plant and/or reduction of grain weight per plant [16]. According to Reddy [11] both too narrow and too wide spacing do affect grain yields through competition and due to the effect of shading. In the case of too wide spacing, yield reduction can occur due to in efficient utilization of the growth factors. Normally, as density increases yield also increases proportionally but after a certain level, it declines [17].

Establishment of optimum density per unit area is essential to get maximum yield [18]. Under conditions of sufficient soil moisture and nutrients, higher density is necessary to utilize all the growth factors efficiently. Each growth factor for which the plant competes has limitation to support a crop beyond the optimum plant density level per unit area. The level of plant density should be such that maximum solar radiation is utilized. The full yield potential of an individual plant is fully exploited when sown at wider spacing [18]. Equidistant spacing of inter and intra rows produces an earlier and more complete soil cover than other spacing. As a result, more sunlight is intercepted by the foliage. The more complete soil cover also intercepts more rainfall and may reduce runoff and soil erosion [13]. In theory, plants arranged in a square should make more efficient use resources than those in rectangle [11]. Singh and Singh [18] reported that the crop plants should cover the soil as early as possible to intercept maximum sun light to produce higher dry matter as the intercepted solar radiation and dry matter production are directly related. Closely spaced and quick-growing crops like soybean which can intercept more light within a short period gives higher yield as compared to wider spaced crop. As such for the proper light interception at various growth stages, optimum plant density is necessary. The greater interception increases photosynthesis and reduces evaporation of water from the soil [13]. Similarly, competition for soil resources is greater with the more crowded row systems in wide rows.

Planting arrangement alters both the spatial and temporal pattern of interception or retrieval of the limiting resource, especially in dry land cropping where the soil water is rarely adequate throughout the growing season. In such cases, inter and intra row spacing is normally a matter of compromise [19]. Closely spaced plants had increased root elongation and hence continued to extract available moisture between the rows later in the season for grain production. Plant density must be adjusted to available soil moisture levels, either with in rows or between rows.

Effect of Plant Density on Growth and Development: Plant density highly influences faba bean growth and development. The degree of the influence generally depends up on the availability and / or scarcity of environmental resources for which plants compete with each other and the growth pattern and morphological characteristics of the competing plants [20]. High plant density brings out certain changes in the growth of plants e.g. increase in plant height, reduction in leaf thickness, alteration in leaf orientation, and leaves become erect, narrow and are arranged at longer vertical intervals to intercept more sun light [18]. According to Fasoula and

Tollenaar [21] as plant density increases, competition between plants becomes more intense, affecting the growth, development and production of each plant. Yalemtesfa *et al*. [22] reported that increased intra-row spacing decreased the number of branches plant. This is due to more nutrient, moisture and space become available for the other vegetative growth than branches.

Turk *et al*. [23] who worked on lentil, reported that high plant density promotes phenological development; with flowering occurring 14 days earlier in the high plant density. Ahmad *et al*. [24] also reported that row spacing had significant effect on number of days to flower and maximum days (56) were taken to flower at 60 cm row spacing, while crop sown at 30 cm rows took minimum days (52) to flower. In Australia, Loss *et al*. [1] observed that high sowing rates resulted in significantly earlier canopy closure, larger green area indices, more radiation absorption and dry matter accumulation particularly during the early vegetative stages than in treatments where a low plant density was established in faba bean. Parvez *et al*. [25] also indicated that with increasing plant density, there was an increase in plant height, while branching and node development decreased. This is because in narrow spacing plants compete more for available resources especially for light and thus result in more height than widely spaced plants [18]. On the other hand, Nwofia *et al*. [26] reported that highest population density (80,000 plants/ ha) gave highest number of leaves plant of cowpea.

Leaf size and shape have an important bearing on the amount of light intercepted and both of these leaf characters vary greatly according to plant density and inter- and intra-row spacing [9]. Increasing density enhanced, and shading retarded both leaf senescence and seed maturation. Research conducted in Australia has shown faba bean plants have a capacity to produce many stems and a large amount of biomass under abundant space, so that under wide rows, populations can be reduced to 20 plants/m^2 [27]. A significant increase in nodes per unit area with increasing plant density was reported by James and Singh [28]. However, increase in plant density leading to a significant curvilinear reduction in branches/plant and nodes/branch was observed. Bennet *et al.* [29] observed only linear reductions in branches/plant and no change in number of nodes on branches as plant density increased from 17 to 63 plants/m^2. Total plant nitrogen fixation during growth affected by the relative successes of nodulation and the longevity of symbiotically active nodule population. These factors were influenced by plant density due to inter and intra plant competition for water and mineral nutrition. Plant densities have statistically significant effect on faba bean nodulation [30]. Similarly, Joachim *et al.* [31] reported that plant growth and symbiotic performance of cow pea was decrease by high plant density.

Effects of Plant Density on Yield and Yield Components: The spatial distribution of plants in a crop community is an important determinant of yield [32] and many experiments have been conducted to determine the spacing between rows and between plants within the row that maximizes yield. Two general concepts are frequently used to explain the relationship between row spacing, plant density and yield. First, maximum yield could be obtained only if the plant community produced enough leaf area to provide maximum light interception during reproductive growth. Secondly, equidistant spacing between plants affected interplant competition [33]. Hence, it will be imperative to adjust the spatial distribution of the recommended population in order to have maximum yield.

Seed yield in faba bean is the product of several components which include number of pods per plant, number of seed per pod and 100 seed weight [34]. As plant density increases (i.e. narrow spacing) intensity of interplant competition increases and reduce many parameters (i.e. number of pods/plant, number of seeds/pod, 100 seed weight and seed yield /plant) in the individual plants of faba bean, although seed yield per unit area, total dry matter and harvest index of lentils (*Lens culnaris medic*), chickpeas (*Cicer arietinum*), peas (*Pisum sativum*) and faba beans increased as the plant populations increased [35]. Similarly, Wendimu [36] reported that grain yield increased for all tested faba bean 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. The reduction of crop yield components by increasing plant population after a certain level is due to greater inter-plant competition for incident light, soil nutrition and soil water in high plant density than low plant density [18].

Similarly, Al-Abduselam and Abdai [30] reported that the reduction in pods per plant, number of seed per pod,100 seed weight and yield per plant in higher densities could be attributed to changes in the canopy structure, due to changes in density and hence in the light interception by the crop. Ahmed *et al*. [37] also reported that increasing plant distance or decrease plant population have increased the total dry matter production per plant.

According to Gezahegn *et al.* [38] the number of pods per plant in faba bean was greatly reduced as plant density increased. In response to plant density, number of pods per plant decreased, while the number of seeds per plant remained constant due to number of seed per pod is a relatively stable character in faba bean [39]. However, Abdel Latif [40] indicated that number of seed per pod increased with the increase in plant density. Similar report indicates that faba bean plants are capable of compensating for low plant density by producing more branches and more pods per plant [1]. They also reported that high sowing rates produced tall plants with the lowest pods farther from the soil surface than those at low plant density, and hence mechanical harvesting was easier. According to Lopez-Bellido *et al.* [41] a given plant density is considered optimum, when it provides the maximum number of podding nodes per square meter.

According to different research findings, the plant density of 50 or 75 plants /m^2 resulted in significantly lower 100 seed weight than those of 100 plants /m^2. At this low density faba bean have a large number of sinks because of the large number of pods and seeds per plant. Consequently seed could not receive all the photosynthetic assimilates produced by the crop canopy [30]. A research conducted by Amare [42] at Holleta revealed that both the seed and total biological yields of faba bean were favorably increased from 30 to 50 plants/m^2 and dropped with further increases to 60 plants/m^2. However, Lopez Bellido *et al*. [43] reported that increasing seeding rates from 20 to 50 plants/m^2 in early sown faba bean resulted in a reduction in yield, presumably due to excessive growth, lodging, inefficient pod set and increased disease. On the other hand, spacing trials conducted at Kulumsa revealed that the best seed yields in faba bean were obtained from a spacing of 20 cm between rows and 5 cm between plants although it resulted in high lodging and reduced 100 seed weight. Foysalkabir and Quamruzzaman [44] also reported minimum 1000 grain weight at high plant density or lower inter and intra (20 x 10 cm) spacing.

In contrast, Gezahen *et al*. [38] reported that plant density had no significant effect on 100-seed weight of faba bean. Maobe *et al*. [45] also reported non-significant effect of 1000 grain weight due to increased or decreased plant density. Similarly, Tollenaar *et al*. [46] in their research finding indicated that a moderate increase in plant-spacing variability does not influence yield at the canopy level because reductions in grain yield of plants that experience enhanced crowding stress is compensated, in part, by increased yield of plants that experience reduced crowding stress.

It is worth mentioning that decreasing row spacing has socio economic implications: high plant population densities means upward adjustment of the amount of agro inputs used (Seed rate and fertilizer). Manual weeding, harvesting and other agronomic maintenance operations would take more labour and time, as it is difficult working through the dense crop stand [47]. Gezahegn *et al*. [38] reported that 30 cm inter-row and 8 cm intra-row spacing (42 plants/m^2) gave highest net benefit with high B:C ratio and a MRR. Similarly, Kebure *et al.* [48] reported that the highest net benefits of faba bean at high plant density (44 plants m^2) under vertisol. In contrast, Al-Suhaibani *et al*. [9] found a higher profit of faba bean from lower seed rate under different soil (Sandy soil).

Effect of Plant Density on Disease and Pest Development: Disease incidence and severity tended to increase with increased plant spacing in susceptible cultivars [49]. Muchaw [50] indicated that higher planting density would ensure greater stability against losses in plant stand caused by *Fusarium* wilt and increased yield of stem for fuel wood. Tala and Shalaldeh [51] reported that lowering plant density reduced the risk and pressure of diseases such as Chocolate spot (*Botrytis fabae*) and Ascochyta blight (*Ascochyta fabae*).

Sharaan *et al*. [52] reported that Chocolate-spot infection (%) increased by decreasing intra–plant distance. In other word, level of infection has been increased by enhancing plant density. The value of 26.7plants/m^2 surpassed that of 44.4plants/m^2. These results were in agreement with that early reported by Sharaan *et al.* [52] who suggested that chocolate-spot disease was more damaging in the relatively dense faba bean population. Also, Khalil *et al*. [53] found that the level of infection/m^2 increased by increasing plant density from 16 to 33 plants/m^2. However, experiments have shown that an increase in disease incidence due to increased plant density could be compensated by a yield increase as in the case with chocolate spot and rust in faba bean [54].

On the other hand, dense planting changes crop growth, development, and microclimate, which in turn have an effect on pests and their natural enemies. Tebkew and Mekasha [55] reported that aphid population on pea icreased as the seed rate was increased. The tendency of aphid population increment with seed rate might be attributed to the availability of more food or to the creation of micro-environment suitable to aphids when the seed rate was high [55]. The influence of plant densities on the incidence of pod-borer on chickpea increased with the increase in plant density, whereas cut worm incidence was more prevalent at low plant density [56].

Beside disease and pest, sparse planting encourages weeds. According to Tolera and Dhaba [57] an optimum plant density helps to counter the effects of early weed competition. Similarly, Loss *et al.* [1] showed that early canopy closure and greater dry matter production under high sowing rates of faba bean caused greater suppression of weeds and aphids. However, Nathan *et al.* [58] reported that weed emergence was not affected by seeding rate or planting arrangement but weed biomass decreased with increased seeding rate.

Plant Density and Soil Type: Plant density per hectare depends on soil fertility, soil structure, availability of water and tillering capacity of the crop [11]. Similarly, Azam and Squire [17] reported that plant density depends on the soil, climate, and the type of crop planted. For example, under extreme conditions, in poor soils and in semi-arid regions with no irrigation, planting is best done at low population. Otherwise, it resulted in thin and weak plants. Such condition not only produces low yields, but also creates ideal condition for pests and diseases.

Since soils differ considerably in nutrients, the response of plant density should differ from soil to soil due to difference in fertility. Moreover, the effect of space would be reduced with fertilizer application. However, the proportionality between yield per plant and available space is a universal phenomenon observed in all soils under field or pot culture solution [11]. Gezahegn and Kinde [59] reported that the highest faba bean yield was obtained at 25 plants/m^2 under fluvisol. However, Gezahegn *et al.* [38] reported high yield of faba bean at 42 plants/m^2 under vertisol. Further, it was also indicated that broadcasting of 250 kg/ha seed on nitosols and drilling 350 kg/ha seed on cambered vertisols gave the highest yield of faba bean. On the other hand Anderson [60] reported that, experiments in clay loam soils had higher optimum seed rates of wheat crop (52-76 kg/ha, depending on the cultivars used) and in sandy soils, the optimum seed rate was lower (35-60 kg/ha) depending on cultivar and sowing time but higher (67 kg/ha) at higher seasonal rainfall.

CONCLUSION

Based on the review, faba bean growth, yield and yield component, disease and pest and resources utilization are highly depending on plant density. Seed yield per unit area is the product of seed yield per plant and number of plants per unit area. At low densities, seed yield is limited by the number of plants, whereas at higher densities it declines due to increase in number of aborted pods and barren stalks. Therefore, optimum plant density and suitable plant arrangement per unit area allow crops to exploit resource optimally and produce high yield of faba bean.

REFERENCES

1. Loss, S.P., K.H.M. Siddique, L.D. Martin and A. Crombie, 1998. Response of faba bean (*Vicia faba* L.) to sowing rate in south-western Australia II. Canopy development, radiation absorption and dry matter partitioning. Aust. J. Agric. Res., 49: 999-1008.
2. Singh, S.P., N.P. Singh and R.K. Pandey, 1992. Performance of faba bean varieties at different plant densities. FABIS Newsletter, 30: 29-31.
3. Hiyane, R., H. Shinichi, C. Tang and J.S. Boyer, 2010. Sucrose feeding reverses shade-induced kernel losses in maize. Ann. Bot, 106: 395-440.
4. Christopher, R.B., B.S. Judith, M. Tollenaar and J.V. Tony, 2009. Maize morphophysio-logical responses to intense crowding and low nitrogen availability: an analysis and review. Agronomy Journal, 101: 1426-1452.
5. Li, S.K. and C.T. Wang, 2010. Innovation and Diffusion of Corn Production Technology. Beijing: Science Press.
6. Antonietta, M., D.D. Fanelloa, H.A. Acciaresib and J.J. Guiamet, 2014. Senescence and yield responses to plant density in stay green and earlier-senescing maize hybrids from Argentina. Field Crop Research, 155: 111-119.

7. Yan, Y., C.S. Liao, F.S. Zhang and J.C. Li, 2010. The causal relationship of the decreased shoot and root growth of maize plants under higher plant density. Plant Nutr. Fert. Sci., 16: 257-265.
8. Squire, G.R., 1993. The Physiology of tropical crops (Tropical agriculture Science), pp: 120-280.
9. Al-Suhaibani, N.S. El-Hendawy and U. Schmidhalter, 2013. Influence of varied plant density on growth, yield and economic return of drip irrigated faba bean (*Vicia faba* L.). Turkish Journal of Field Crops, 18(2: 185-197.
10. Willey, R.W. and D.S. Osiru, 1972. Studies in mixture of dwarf sorghum and beans (Phaseolus vulgaris) with particular reference to plant population. Journal of Agricultural Science, 79: 531-540.
11. Reddy, R.S., 2000. Principle of Crop Production. Kalyani Publishers, New Delhi-110 002, India, pp: 45-47.
12. David, R.K., A.A. Bruce and W.M. Richard, 1983. Does optimizing plant arrangements reduce interference or improve the utilization of space? Agricultural Systems, 12(1): 13-36.
13. Robinson, R.G., J.H. Ford, W.E. Lueschen, D.L. Rabas, D.D. Warnes and J.V. Wiersma, 2002. Sunflower Plant Population and Its Arrangement. Communication and Educational Technology Services, University of Minnesota Extension.
14. Pedersen, P., 2008. Soyabean plant population. In Soyabean extension and research program. Iowa State University.
15. Norman, A.G., 1963. The influence of density on the plant. Advances in Agronomy, 15: 17-26.
16. Sobkowicz, P. and M.L. Podgorska, 2007. Experments with crop mixture: interactions, designes and interpertation. Department of Soil Management and Plant Cultivation, Wrocław University of Environmental and Life Sciences, Poland.
17. Azam-Ali, S.N. and G.R. Squire, 2002. Principles of Tropical Agronomy, CABI Publishing, CAB International, UK.
18. Singh, N.P and R.A. Singh, 2002. Scientific crop production. Press Graphics, Delhi-28, India.
19. Bora, K.K., K. Singh and A. Kumar, 2001. Stress and Environmental Physiology. Pointer Publishers, Jaipur, Rajasthan, India.
20. Matthews, P.W., D.J. Carpenter, A. Smith and N. Fettell, 2001. Faba bean seeding rates for central and southern NSW. Proceedings of the 10th Australian Agronomy. Conference, Hobart. Australian Society of Agronomy, Australia.
21. Fasoula, V.A. and M. Tollenaar, 2005. The impact of plant population density on crop yield and response to selection in maize (No. CIMMYT).
22. Yalemtesfa Firew Guade, 2017. Effect of Intra-Row Spacing on Growth and Development ofTomato (*Solanum lycopersicum* L.) Variety Roma-VF under the Irrigated Conditions of East Gojjam Zone, Ethiopia. American-Eurasian J. Agric. & Environ. Sci., 17(2): 174-178.
23. Turk, M.A, A.M. Tawaha and M.K.J. El-shatnawi, 2003. Reponse of lentil (*Lensculinaris medk*) to plant density, sowing date, phosphorus fertilization and ethaphon application in the absence of moisture stress. J. Agri. Crop Science, 189: 1-6.
24. Ahmad, R., T. Mahmood, M.S. Farrukh and S. Ahmad, 2002. Comparative performance of two sesame (*Sesamum indicum* L.) varieties under different row spacing. Asian J. Plant Sci., 1(5): 546-547.
25. Parvez, A.Q., F.P. Gardner and K.J. Boote, 1989. Density and sowing depth effects on yield components of grain legumes. Crop Sci., 29: 150-157.
26. Nwofia G.E., M.C. Nwanebu and E.U. Mbah, 2014. Yield and Yield Component Responses of Some Cowpea Varieties to Population DensityStructures under Rainfed Conditions in Lowland Tropics of Southeast Nigeria. World Journal of Agricultural Sciences, 10(2): 68-75.
27. Matthews, P. and H. Marcellos, 2003. Faba bean. Research Agronomist, Tamworth. Auatralia, 2: 42-47.
28. James, N. and S.P. Singh, 1985. Effects of location and plant density on yield and architectural traits in dry beans. Crop Sci., pp: 579-584.
29. Bennet, J.P., M.W. Adams and C. Burga, 1977. Pod yield component variation and intercorrelation in *Phaseolus vulgaris* L. as affected by planting density. Crop Sci., 17: 73-75.
30. Al-Abduselam, M.A. and K.S. Abdai, 1995. Effect of plant density and certain pesticides on growth, yield and rhizobial nodulation of faba bean. J. King Saudi University, Agric. Sci., 7: 249-257.
31. Joachim H.J., R. Makoi, B.M. Chimphango and F.D. Dakora, 2008. Effect of legume plant density and mixed culture on symbiotic N_2 fixation in five cowpea (*Vigna unguiculata* L. Walp.) genotypes in South Africa. Biomedical and Life Science Journal, 48: 57-67.
32. Egli, D.B., 1988. Plant density and soybean yield. Crop Sci., 28: 977-980.

33. Johnson, R.R., D.E. Green and C.W. Jordan, 1982. What is the best soybean row width: A U.S. Perspective. Crops and Soils, 34(4): 10-13.
34. Pendleton, J.W. and E.E. Hartwing, 1973. Crop Production and Management, 211-237. In: B.E. Caldwell (ed.) Soybeans Improvement, Production and Uses.
35. Ayaz, S., D.L. McNeil, B.A. McKenzie and G.D. Hill, 2001. Density and sowing depth effects on yield components of grain legumes. Agronomy Journal of New Zealands, 29: 9-15.
36. Wendimu Tamerat, 2019. Effect of Plant Density on Yield Components and Yield of Faba Bean (*Vicia faba* L.) Varieties at Wolaita Sodo, Southern Ethiopia, Journals of Natural Science Research, 9(5): 48-55.
37. Ahamed K.U., Kamrun Naher, Mirza Hasanuzz and Golam Faruq, 2011. Growth pattern of Mung bean at different planting distance. Academic Journal of Plant Science, 4(1): 06-1.
38. Gezahegn, A.M., K. Tesfaye, J.J. Sharma and M.D. Belel, 2016. Determination of optimum plant density for faba bean (*Vicia faba* L.) on vertisols at Haramaya, Eastern Ethiopia. Cogent Food & Agriculture, 2(1): 1224485.
39. Salim, S.A. and M.F. El-Massri, 1987. Effect of caltivars, plant density and phosphoric fertilizer levels on seed yield and other Agronomic characters in faba bean. Alex. J.Agric. Res., 31: 127-137.
40. Abdel Latif Y.I., 2008. Effect of Seed Size and Plant Spacing on Yield and Yield Components of Faba Bean (*Vicia faba* L.) Research Journal of Agriculture and Biological Sciences, 4(2): 146-148. University of Zalingei. Sudan.
41. Lopez-Bellido, R.J., L. Lopez-Bellido, F.J. Lopez-Bellido and J.E. Castillo, 2003. Faba bean (*Vicia faba* L.) response to tillage and soil residual nitrogen in a continuous rotation with wheat (Triticum aestivum L.) under rainfed Mediterranean conditions. Agron. J., 95: 1253-1261.
42. Amare Ghizaw and Adamu Molla, 1994. Faba bean and field pea agronomy research. In: Telaye A., G. Bejiga, M.C. Sexana and M.B. Sohl, (eds.): Cool-season food legumes of Ethiopia. Proceedings of the 1st National Cool-season Food Legumes Review Conference, 16-20 December, 1993, Addis Abeba, Ethiopia. ICARDA/IAR. ICARDA: Aleppo, Syria, 199-229.
43. Lopez-Bellido, R.J., L. Lopez-Bellido and F.J. Lopez-Bellido, 2005. Competition, growth and yield of faba bean (*Vicia faba* L). European J. Agron, 23(4): 359-378
44. Foysalkabir, A.K.M. and Md. Quamruzzaman, 2016. Effect of Plant Growth Regulator and Row Spacing on Yield of Mungbean (*Vigna radiate* L.). American-Eurasian J. Agric. & Environ. Sci., 16(4): 814-819.
45. Maobe S.N., Martha K. Nyang'au, E.A. Basweti, A. Getabu, T.J. Mwangi and A.R. Ondicho, 2014. Effect of Plant Density on Growth and Grain Yield of Finger Millet (Eleusine coracana) under High Potential Conditions of Southwest Kenya. World Journal of Agricultural Sciences, 10(6): 261-268.
46. Tollenaar, M., W. Deen, L. Echarte and L. Weidong, 2006. Effect of Crowding Stress on Dry Matter Accumulation and Harvest Index in Maize. Agronomy Journal, 98: 930-937.
47. Onyango, O.C., 2009. Decreased row spacing as an option for increasing maize (*Zea mays* L.) yield in Trans Nzoia district, Kenya. Journal of Plant Breeding and Crop Science, 1(8): 281-283. Kenya.
48. Kubure, T.E., V.R. Cherukuri, C. Arvind and I. Hamza, 2015. Effect of faba bean (*Vicia faba* L.) genotypes, plant densities and phosphous on productivity, nutrients uptake, soil fertility changes and economics in Central high lands o Ethiopia. Int. J. Life Sciences, 3(4): 287-305.
49. Maasa, L.A., K.E. Dashiellb and H.A. Meloukc, 2006. Planting Density Influences Disease Incidence and Severity of Sclerotinia Blight in Peanut. Crop Sciences Journal, 46: 1341-1345. Oklahoma State University, USA.
50. Muchaw, R.C., 1985. Phenology, seed yield and water use of grain legumes grown under different soil water regions in a semi-arid tropical environment. Field Crop Res., 11: 81-97.
51. Talal, T. and G. Shalaldeh, 2006. Effect of planting date on Faba bean Plant nodulation and performance under semi-arid conditions. World Journal of Agricultural Sciences, 2(4): 477-482.
52. Sharaan, A.N., A. Ekram, H. Megawer, H.A. Saber and Z.A. Hemida, 2003. Biological Yield, its related growth criteria and chocolate- spot disease as influenced by cultivar, sowing date and planting distances in Faba bean. Agron. Dept., Fac. Agric. at Fayoum, Cairo Univ. Legumes Sec. Field Crop Res. Ins., ARC. FIPMP, Min. Agric. at Fayoum. Egypt.

53. Khalil, S.A., R.F. Dissouky; M.I. Amer; M.M. El-Hady and M.W.A. Hassan, 1993. Performance of yield and yield components of two faba bean (*Vicia faba* L.) cultivars as affected by two plant densities and foliar disease control in the new reclaimed land. Journal of Agriculture Science, 18(5): 1306-1314.
54. Porta, P.T. Bretag, J. Brovwer, M. Haware, S. Khalil and R. Knight, 2000. Direct and indirect influences of morphological variation on diseases, yield and quality. Proceedings of the Third International Food Legumes Research Conference, Adelaide, Australia, 22-26 Sept, 199-220.
55. Tebkew Damte and Mekash Chichaybelu, 2001. Pea aphid (acythosiphon pisum, Homoptera: Aphididae) management in lentil (Lens culinaries). Paper presented at Nile Vally and Red Sea Reginal Program Regional Coordination Meeting. Food Legume Research Progrm, 23-27 September, Cairo, Egypt.
56. AdARC, 2002. Progress report for the period 2000/01, Adet Agricultural Research Center, Baher Dar, Ethiopia.
57. Tolera Abera and Dhaba Feyissa, 2005. Effect of Seed Rate and Weed Control on Agronomic Performance of Faba Bean (*Vicia faba* L.). Arem, 6: 85-91.
58. Nathan, B.S.,B.B. Eric, S.F. Richard and Y. Ron, 2009. Effect of Seeding Rate and Planting Arrangement on Rye Cover Crop and Weed Growth. Agronomy Journal, 101: 47-51
59. Gezahegn, A.M. and K. Tesfaye, 2017. Optimum inter and intra row spacing for faba bean production under Fluvisols. MAYFEB Journal of Agricultural Science, 4: 10-19.
60. Anderson, W.K., D.L. Sharma, B.J. Shackley and M.F. D'Antuono, 2004. Rainfall, sowing time, soil type and cultivar influence optimum plant density for wheat in Western Australia. Australian Journal of Agricultural Research, 55: 921-930.