African Journal of Basic & Applied Sciences 14 (1): 01-07, 2022
ISSN 2079-2034

DOI: 10.5829/idosi.ajbas.2022.01.07

Enhancing Mung Bean Productivity Through Crop and Fertilizer Management Practices in Ethiopia: A Review

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Abstract: Mung bean is a recent introduction in Ethiopia and is grown in some areas of the North Shewa lowlands and the South Wollo (Kallu) areas of Amhara Regional State. It is currently advancing to Oromia, the Southern, Tigray and Benishangul Gumuz regions. It has low local consumption yet has high international demand. As a result, mung beans are a relatively higher-priced crop than lowland pulses. Recently, the Ethiopian Commodity Exchange (ECX) installed Mung beans as the sixth commodity to be traded, following Coffee, Sesame, White Pea Beans, Maize and Wheat. However, despite its importance as a cash crop, food and feed crop, very little attention has been given to its quantitative and qualitative improvement in the country. Although plant density and fertilization influence plant establishment, growth, grain yield and the profitability of a crop, there is limited published information on the optimum spacing and/or sowing rate and fertilizer rate for mung bean production in Ethiopia. Therefore, this paper reviews the status of spacing/plant density and fertilizer recommendations in Ethiopia in relation to global perspective.

Key words: Agro-Climate · Optimum · Recommendations · Seed Yield · Spacing

INTRODUCTION

Mung bean (*Vigna radiata* (L.) Wilczek), commonly known as 'masho' in Amharic, is a legume cultivated for its edible seeds and sprouts but can also be used as a green manure crop and as forage for livestock. It is thought to have originated from the Indian subcontinent, where it was domesticated as early as 1500 BC. Cultivated mung beans were introduced to southern and eastern Asia, Africa, Australia, the Americas and the West Indies. It is now found throughout the Tropics, from sea level to 1850 meters in the Himalayas [1]. It is a recent introduction to Ethiopian pulse production and is grown in a few areas of the North Shewa lowlands and the South Wollo (Kallu) areas of Amhara Regional State. It is currently also taking root in the Oromia, Southern, Tigray and Benishangul Gumuz Regions [2, 3]. Mung beans are high in protein (20-30%) and easy to digest, with a high starch content (> 45%), a low lipid content (2%) and variable but generally low fiber levels (crude fiber of 6.5% on average). Furthermore, the amino acid profile of mung beans is comparable to that of soybeans [4]. Locally boiled seeds ('nifro') are consumed in a mixture with maize, sorghum, or common beans around the Shewarobit areas in northern Ethiopia.

It is often grown with limited rainfall, by utilizing residual moisture in the soil, or as the main crop with a short rainy season and on a wide range of soil types. Mung beans are quick crops, requiring 75–90 days to mature. It is a useful crop in drier areas and has good potential for crop rotation and relay cropping with cereals. Smallholder farmers in drier marginal environments in Ethiopia grow mung beans. In the Shewarobit areas, it is grown by the majority of smallholder farmers in "belg" (the short rainy season from February to June) and "meher" (the long rainy season from July to September). Mung beans occupied an area of 48, 022.34 hectares and produced 51568.66 tons of grain in the 2020/21 crop season and the national average is estimated to be 1.07 tons/ha [5]. Green mung bean is one of the products that has low local consumption yet has high international demand. Hence, it is expected to have a positive impact on the country's export earnings and bring considerable foreign currency exchange. Accordingly, the Ethiopian

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Commodity Exchange (ECX) installed mung beans as the sixth commodity to be traded, following coffee, sesame, white pea beans, maize and wheat [2].

Despite increases in the potential export market, its production at the country level has no considerable improvement in quantity as well as the quality of production to provide it for the central market with the help of the Ethiopian commodity exchange (ECX) [6]. So far, a blanket recommendations of 25 cm row-to-row spacing x 10 cm plant-to-plant spacing for short rainy season and 30 – 40 cm row-to-row spacing and 5 cm plant-to-plant spacing for main rainy season, respectively, or a seed rate of 20 – 40 kg/ha depending on seed size together with DAP fertilizer at the rate of 100 kg/ha, has been practiced [7]. However, this blanket recommendation may not represent each locality. Therefore, this paper is intended to review the status of crop and soil fertility management recommendations made so far.

The Effect of Plant Density on Crop Growth, Yield Components and Yield: Al-Suhaibani *et al*. [8] defined plant density as the number of plants per square meter, which in turn determines the area available to the individual plant. For most crops, plant density has a major influence on biomass, crop yield and economic profitability [9]. For example, as plant density increases, both biological and economic yields increase with an increasing plant population up to a certain point and subsequently, no addition in biological yield can be obtained and economic yield decreases [10]. On the other hand, yield per plant decreases gradually as plant density per unit area increases. However, the yield per unit area is increased up to a certain level of plant density due to the utilization of growth factors. Hence, an optimum plant population is essential for high yields and a net return [11]. That is, a very high population can result in excessive plant competition for resources and excessive seed costs. On the other hand, a below-optimal plant population can result in inefficient use of resources and thus lower yields and a lower net return. Thus, the optimal density or plant population for any given situation results in mature plants that are sufficiently crowded to use resources such as water, nutrients and sunlight efficiently [12, 13]. At this population, production from the entire field is optimized, although any individual plant might produce less than what would have occurred with unlimited space [12, 14]. Schonbeck [15] also indicated that plants spaced close enough together compete effectively with weeds, but not so close that the plants restrict each other's growth. This is because the closer together crop plants stand, the narrower the open niches in space for weeds and the faster they get shaded over by the crop canopy. A healthy plant population also aids in the prevention of insect pests and disease transmission from one plant to the next [9].

According to Mondal *et al*. [11], there are two general concepts to describe the relationship between plant density and seed yield. Firstly, plant density must be such that the crop develops a canopy able to intercept more than 95% of the incoming solar radiation during reproductive growth; and secondly, a nearly equidistant plant arrangement minimizes interplant competition and produces maximum seed yield. In the case of higher density, the individual plant gets a narrow space, leading to competition for growth factors (such as water, light and nutrients, which are in interaction) between plants, resulting in a reduction of yield per plant. Increasing density causes the crop to compete against itself, resulting in loss of yield, quality, or both [15, 16]. In general, plant density is one of the important and effective factors in the fixation of crop yield and is not stable for one variety in different climatic conditions [17, 16].

Factors Influencing Plant Density: López-Bellido *et al*. [18], noted that for most crops, including grain legumes, the choice of sowing rate is an important agronomic practice that influences plant density and crop establishment. According to Lyon [12], many factors influence the optimum plant population for a crop: availability of water, nutrients, sunlight, length of the growing season, potential plant size and the plant's capacity to change its form in response to varying environmental conditions (morphological plasticity). One example of this is tillering, which allows small grain crops like wheat to produce the same number of heads and final grain yield in a given area over a wide range of plant densities. Islam *et al*. [19] reported that plant population or seed rate is influenced by row width, crop species, soil, climatic variables and crop use. The space available for individual plants growing in the field affects the yield and quality of products and hence, proper spacing is one of the key factors resulting in the proper and healthy growth of a crop. In general, both genetic and environmental factors affect plant density [20].

The Effect of Fertilization on Crop Growth, Yield Components and Yield of Mung Bean: According to the review by Yin *et al*. [21], nitrogen (N), phosphorus (P) and potassium (K) are essential elements present in high levels in mung bean and play an important role in its growth, development and high yield and significantly affect many mung bean traits. As per this review report, when soil N levels are low (total N content $< 0.05\%$), the application of a small amount of N fertilizer induces rhizobia formation and promotes the growth of strong mung bean seedlings. During the early growth stages before the branches develop, mung bean cannot efficiently fix atmospheric N because it has few or no rhizobia. Hence, increasing the application of N fertilizer during the early growth period promotes vegetative growth and creates conditions favoring high yield. As the plant grows, the rhizobia increase and its ability to fix atmospheric N improves. However, during the late growth period, rhizobia activity is inhibited if excess N fertilizer is applied. In this situation, flower bud differentiation and yield formation are impeded. Yin *et al*. [21] also noted that P fertilizer promotes root growth, disease resistance, drought tolerance and enhances nutrient and water absorption in the seedlings after they have depleted their endosperm reserves. On the other hand, K fertilizer improves sugar metabolism, enhances osmotic cell concentration, maintains stomatal guard cell turgor, helps regulate stomatal opening, participates in photosynthesis, enhances drought resistance and increases yield [21]. Hence, appropriate use of fertilizers is of great importance to crop growth and productivity.

Achievements in Spacing and/or Seed Rate Research: In Ethiopia, traditionally, farmers are accustomed to using broadcast sowing for most crops, including mung beans. However, recently, some spacing recommendations have been made in different parts of the country. For example, Mebrate *et al*. [22] experimented to assess the effects of inter-row spacing on two varieties of mung bean at different localities in the Jema valley and Shewarobit areas in central Ethiopia and recommended production of both varieties (the local and the improved variety "*Rasa*") at Jema valley and variety "*Rasa*" at Shewarobit areas at a row-to-row spacing of 20 to 30 cm and plant-to-plant spacing of 5 cm. Abayneh [23] reported maximum grain yield from a treatment combination of 5 cm intra-row spacing and 25 cm inter-row spacing in the Gozamin district, north-western Ethiopia (Table 1). From a similar experiment conducted in the North Gondar Zone, in Ethiopia, economically optimum yield was obtained at a spacing of 40 cm x 15 cm inter-row spacing and intra-row spacing, respectively [24]. Gebrelibanos and Fiseha [25] also reported maximum grain yield at inter-row spacing and intra-row spacing of 30 cm and 5 cm, respectively (Table 2) at Humera, Northern Ethiopia. Similarly, the combination of 10 cm intra-row spacing and 30 cm inter-row spacing significantly increased the grain yield of variety "Rasa" at Jile Timuga District, North-Eastern Ethiopia (Table 3) [26].

Table 1: Effect of intra- and inter-row spacing on yield of mung bean at Gozamin district in 2015 main cropping season

Treatments	Biological yield (t/ha)	Grain yield (t/ha)	Straw yield (t/ha)
Intra-row spacing (cm)			
5	3.62	1.03	2.59
10	3.46	0.95	2.51
15	3.31	0.87	2.44
Significance level	**	***	***
Inter-row spacing (cm)			
25	4.14	1.25	2.88
30	3.69	1.05	2.64
35	3.24	0.85	2.39
40	2.79	0.64	2.15
Significance level	*	***	**
CV (%)	2.09	2.62	0.69

Source: Abayneh [23]

Table 2: Interaction effect of inter and intra-row spacing on grain yield (kg/ha) of mung bean

	Intra-row spacing (cm)			
Inter-row spacing (cm)	5	10	15	20
20	2.21^{a-e}	1.80b-f	1.56fg	1.60fg
25	2.34^{abc}	1.92a-f	1.81b-f	1.75cdef
30	2.46a	2.38ab	1.71ef	1.50fg
35	2.33abcd	1.89a-f	1.54fg	1.72def
40	1.74cdef	1.64ef	1.56fg	1.02g
CV (%)		10.20		

Source: Gebrelibanos and Fiseha [25]

Table 3: Effect of intra-row- and inter-row spacing on grain yield (kg/ha) of mung bean

	Intra-row spacing (cm)		
Inter-row spacing (cm)	5	10	15
25	0.57^{k}	0.64j	0.97f
30	0.78h	1.34a	1.16cd
35	0.85g	1.25b	1.20c
40	0.71i	1.05e	1.13d

Source: Mohammed *et al*. [26]

In similar experiments, several spacing recommendations have been reported in different countries depending on the climatic and growth conditions of mung beans. For example, Mansoor *et al*. [27] reported the highest grain yield from the combination of a seed rate of 40 kg/ha with a row spacing of 30 cm in the Pakistan Dera Ismail Khan areas, which could be the result of optimum space between rows that resulted in efficient light interception and photosynthetic activity. In another experiment, Jan *et al*. [28] reported a lack of significant interaction among five cultivars of mung bean (NM-92, NM-19-19, NM-121-

25, N-41 and local) with a seed rate of 10, 20, 30 and 40 kg/ha. However, a seed rate of 20 kg/ha seems optimum for the production of mung bean varieties under the dryland conditions of the Karak areas in Pakistan. On the other hand, mung bean variety BINA moog7 interacted favorably with a seed rate of 30 kg/ha to produce the highest grain yield in the Mymensingh areas of Bangladesh [29]. Similarly, Rasul *et al*. [30] reported the interaction of variety NM-98 with 30 cm row spacing that exhibited significantly higher yield than other treatments and was recommended for the agro-climatic conditions of Faisalabad. In another experiment, variety BARIMung-2 planted at 30 cm x 10 cm spacing yielded the highest seed yield in the Mymensingh areas of Bangladesh [31]. Ahamed *et al*. [32] also reported the highest grain yield at a spacing of 20 cm x 10 cm for the variety BARI mung-2 at Dehaka, Bangladesh.

Also, Singh *et al*. [33] recommended 25 cm x 10 cm and 50 cm x 10 cm row-to-row and plant-to-plant spacing in India for loamy sand soil and in Taiwan for sandy loam soil, respectively. Ihsanullah *et al*. [34] also suggested 20 cm row-to-row spacing with 15 cm plant-to-plant spacing for an irrigated condition to get a higher grain yield. On the other hand, Dainavizadeh and Mehranzadeh [35] reported higher yields from a seed rate of 20 kg/ha for irrigated dryland areas of Quetta in Khuzestan, Iran. AVRDC [36] noted that sowing summer mung bean on a raised bed (67.5cm) with three rows at 20 cm spacing gives a better yield than flatbeds with row-to-row spacing. According to Gentry [37], mung beans have been successfully grown using a wide range of planting equipment and row spacing ranging from 18 cm to one meter (1 meter) in Australia. The available planting equipment at the time and the farm layout will largely influence the final decision on the row spacing and planting configuration. The recent trend is toward an increasingly higher percentage of the mung bean crop being grown in wider rows of 50 to 100 cm. This is mainly due to the greater number of row crop planters now available, controlled traffic and the adoption of shielded and band spraying. Gentry also noted that lodging could be a problem when plant populations exceed 40 plants per square meter, especially on wider row spacing. According to him, if the emerged plant population is less than 10 plants per square meter, consideration of re-sowing is important.

Achievements in Fertilizer Management Research: Depending on the experimental results, Mota *et al*. [38] found that the growing of improved variety N-26 with the drill application of NPS fertilizer at the rate of 100 kg/ha was the most suitable treatment combination to improve the income of farmers and increase the productivity of mung beans at Humbo district in Wolaita Zone, Southern Ethiopia. In another experiment, Dikr and Garkebo [39] obtained the highest yield from the highest rate of phosphorus (60 kg P_2O_5/ha) combined with 40 cm x 10 cm row spacing of mung beans at Adamitulu Jido Kombolcha district in southern Oromia Zone, Ethiopia. Several similar research findings have been reported by different scholars in different countries. For example, Varma *et al*. [40] suggested the use of NPK fertilizer at the rate of 20:40:20 kg/ha (N_2: P_2O_5:K_2O) and 200 kg lime/ha to neutralize the soil acidity and increase mung bean productivity in the Vindhyan region of India. Sadeghipour *et al*. [41] recommended an application of 90 kg N/ha and 120 kg P_2O_5/ha for mung bean production in the Tehran areas of Iran. The study in Subukia, Kenya, recommended spacing of 45 cm x 15 cm and application of DAP at a rate of 100 kg/ha for improved growth and grain yields of mung beans [42]. In an experiment conducted in a low-nutrient environment, the application of 60 kg N/ha recorded 14.2 g per plant, which was a 48% increase over control [43]. Sheoran *et al*. [44] indicated that the supply of 12.5 kg N + 40 kg P_2O_5/ha to mung beans leads to an increase in seed yield by 4.3 percent over no fertilizer application under rainfed conditions. Application of vermicompost at the rate of 5 t/ha gave an almost 16-17% higher seed yield in mung bean compared to control [45]. In another study, Malik *et al*. [46] reported that the combined application of 25 kg N and 75 kg P_2O_5/ha results in a higher seed yield of mung bean. The experiment conducted by Sharma *et al*. [47] revealed that the increasing rates of N and P up to 20 and 60 kg/ha, respectively, increased the seed yield in mung bean. In another experiment, the application of 30 kg N/ha with a combination of 60 kg P_2O_5/ha significantly recorded a higher seed yield of mung bean [48]. Similarly, application of biochar at the rate of 25 tons/ha in combination with FYM and mineral nitrogen at the rates of 10 tons/ha and 30 kg N/ha, respectively, is recommended for improving mung bean productivity while using 60 kg P/ha as a basal application at Peshawar, Pakistan [49]. From the pot experiment conducted to determine the phosphorus requirement of mung bean (Vigna radiata) using sorption isotherms, a solution P concentration level of 0.2 µg/g equivalent to 8.38 kg/ha gave the best grain yield in the soils of Bende, South Eastern Nigeria, as well as a concentration of 0.3 µg/g equivalent to 26.5 kg/ha gave the best grain yield in the soils of Amaeke, South Eastern Nigeria [50].

CONCLUSIONS

In Ethiopia, mung bean production is getting attention in the lowland areas, especially in the Amhara region (North Shewa lowlands and South Wollo at Kallu areas), in Oromia (some areas), the Southern Regional State (in two zones), Tigray (Western Zone) and Benishangul Gumuz Regional States. It is also produced on a large scale on some private and state farms. In the Shewarobit areas, it is being produced both in the short rainy season (*belg*) and the main season. Its consumption is not well known locally, but around Shewarobit areas, boiled seeds are being used as "*Nifro*, " mixed with maize and bean seeds. On the other hand, the export option to Asian countries could be used as an opportunity to scale up its production. Accordingly, it has been considered as a commodity crop for foreign exchange and its price is getting higher, though market accessibility is a big challenge for the producers. Its production also remained low due to the low attention given to improving its production and productivity. Furthermore, mung bean crop grain yield is a function of the cumulative effect of various yield components, which are influenced by the genetic make-up of the variety, various agronomic practices and environmental conditions. The various findings suggested that the management of nutrients in an integrated manner and the adjustment of plant spacing and density improved both the yield-attributing traits and the final yield of mung bean. As indicated above, plant density is one of the important factors in the fixation of crop yield and is not stable for similar varieties in different climatic conditions. The review of research results covered in this paper supports the above statement by reporting different spacing recommendations within Ethiopia using a similar variety called "*Rasa*" (N-26). Similarly, in different countries, different recommendations have been made using plant spacing and/or seed rate and fertilization, confirming the above statement.

In conclusion, for deciding plant density or seed rate, the growing season, cropping system, average seed size (100-seed weight) and the vigor of genotype, soil type and environmental conditions are the major factors. Low plant populations always give poor yields and excessive plant populations are disadvantageous and uneconomical.

REFERENCES

1. Lambrides, C.J. and I.D. Godwin, 2006. Mung bean. In: Chittarajan, K., Genome Mapping and Molecular Breeding in Plants, 3:69-90.
2. Seyoum, H., 2014. Mung Beans Become Sixth Commodity on Ethiopia's Exchange Floor Fortune Staff Writer, 14(717).
3. MOA (Ministry of Agriculture), 2014. Agricultural Transformation Agency (ATA) and Ethiopian Institute of Agricultural Research EIAR), Technology Package for Pulse Crops, Addis Ababa, Ethiopia.
4. Heuzé, V., G. Tran, D. Bastianelli and F. Lebas, 2013. Mung bean (*Vigna radiata*). Feedipedia.org. A program by INRA, CIRAD, AFZ and FAO. http://www.feedipedia.org/node/235, last updated on August 13, 2013, 21: 41.
5. CSA (Central Statistical Agency), 2021. The Federal Democratic Republic of Ethiopia Central Statistical Agency Agricultural Sample Survey 2020/21 (2013 E.C.); Report on Area and Production of Major Crops. Volume I, Statistical Bulletin, pp: 590.
6. Mohammed, A., S. Muhammed and M. Said, 2017. Marketing practices and challenges of Mung Bean in Ethiopia Amhara Regional State: North Shewa Zone in focus. African Journal of Marketing Management, 9(4): 35-45.
7. MoA (Ministry of Agriculture), 2014. Technology Package for Pulse Crops. In collaboration with Agricultural Transformation Agency (ATA) and Ethiopian Institute of Agricultural Research EIAR), Addis Ababa, Ethiopia.
8. 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.
9. Singh, D.B., R.K.M. Malhi and G.S. Kiran, 2015. Assessing the impact of agronomic spacing conditions on biophysical and biochemical parameters along with yield and yield components in cotton. International Journal of Agronomy and Agricultural Research, 6(1): 36-44.
10. Singh, N.P. and R.A. Singh, 2002. Scientific Crop Production, 1st edition, X press Graphics, Delhi-28, India.
11. Mondal, M.M.A., A.B. Puteh, M.A. Kashem and M.M. Hasan, 2014. Effect of plant density on canopy structure and dry matter partitioning into plant parts of soybean (*Glycin max*). Life Science Journal, 11(3): 67-74.
12. Lyon, D.J., 2009. "How Do Plant Populations Affect Yield?" Press Releases from Panhandle Research and Extension Center, Paper No. 19. Retrieved March 20, 2022, from http://digitalcommons.unl.edu/panpressrel/19.

13. Sabo, M.U., M.A. Wailare, M. Aliyu, S. Jari and Y.M. Shuaibu, 2013. Effect of NPK Fertilizer and spacing on growth and yield of watermelon (*Citrullus lanatus* L.) in Kaltungo Local Government area of Gombe State, Nigeria. Scholarly Journal of Agricultural Science, 3(8): 325-330.
14. Khalil, S.K., A. Wahab, A. Rehman, M. Fida, S. Wahab, A.Z. Khan, M. Zubair, M.K. Shah, I.H. Khalil and R. Amin, 2010. Density and planting date influence phonological development assimilate partitioning and dry matter production of faba bean. Pakistan Journal of Botany, 42(6): 3831-3838.
15. Schonbeck, M., 2013. Grow Vigorous, Competitive Crops - the First Line of Defense Against Weeds. Extension: America's Research-based Learning Network, eOrganic 2497. Retrieved April 10, 2022, from http://www.extension.org/pages/18533/.
16. Yucel, D.O., 2013. Optimal intra-row spacing for production of local faba bean (*Vicia faba* L. major) cultivars in the Mediterranean conditions. Pakistan Journal of Botany, 45(6): 1933-1938.
17. Dahmardeh, M., M. Ramroodi and J. Valizadeh, 2010. Effect of plant density and cultivars on growth, yield and yield components of faba bean (*Vicia faba* L.). African Journal of Biotechnology, 9(50): 8643-8647.
18. López-Bellido, F.J., L. López-Bellido and R.J. López-Bellido, 2005. Competition, growth and yield of faba bean (*Vicia faba* L.). European Journal of Agronomy, 23: 359-378.
19. Islam, M., S. Saha, M.H. Akand and M.A. Rahim, 2011. Effect of spacing on the growth and yield of sweet pepper (*Capsicum annuum* L.). Journal of Central European Agriculture, 12(2): 328-335.
20. Shirtliffe, S.J., W.E. May and C.E. Willenborg, 2007. The effect of oat seed size on tame oat competition with wild oat, Abstract to Weed Science Society of America (WSSA).
21. Yin. Z., W. Guo, H. Xiao, J. Liang, X. Hao, N. Dong, T. Leng, Y. Wang, Q. Wang and F. Yin, 2018. Nitrogen, phosphorus and potassium fertilization to achieve expected yield and improve yield components of mung bean. PloS one, 13(10): e0206285.
22. Mebrate Tamrat, Daniel Admasu, Fikadu Tewolde and Bereket Ali, 2017. Effect of Row Spacing on Yield and Yield Components of Mungbean (*Vigna radiata* (L.) Wilczek) in North Shewa Lowlands, pp: 177-198. Alemayehu Assefa, Baye Berihanu, Ermias Abate and Mulugeta Alemayehu (Eds.). Proceedings of the 8th Annual Regional Conference on Completed Crop Research Activities, 13-20 February 2014, Amhara Regional Agricultural Research Institute, Bahir Dar, Ethiopia.
23. Wubetu, A., 2018. Effects of Intra and Inter-Row Spacing on Yield and Yield Components of Mung Bean (*Vigna radiate* L.) Debre Markos Seed Laboratory. Journal of Biology, Agriculture and Healthcare, 8(12): 1-9.
24. Birhanu, A., T. Tadesse and D. Tadesse, 2018. Effect of inter-raw spacing and intra-row spacing on yield and yield components of mung bean (*Vigna radiata* L.) under rain-fed condition at Metema District, northwestern Ethiopia. Agriculture & Food Security, 7(84): 1-7.
25. Gebremariam, G. and F. Baraki, 2018. Effect of Inter Row and Intra Row Spacing on Yield and Yield Components of Mung Bean (*Vigna radiata* L.) in Northern Ethiopia. International Journal of Engineering Development and Research, 6(1): 348-352.
26. Mohammed, S., A. Mekonnen and K. Mulatu, 2020. Effects of Spacing on Yield of Mung Bean (*Vigna* radiata L.) In Jile Timuga District, North-Eastern Ethiopia. Global Scientific Journals, 8(9): 1020-1033.
27. Mansoor, M., H. Khan, M. Ayaz, M. Zubair and M. A. Nadim, 2010. Effect of different planting densities on some physiological parameters of Mung bean. Gomal University Journal of Research, 26(2): 1-8.
28. Jan, A., S.A. Kaleem, F.H. Taj and H. Khan, 2000. Response of Mung bean Cultivars to different Seeding Densities at Dry Land Conditions. Pakistan Journal of Biological Sciences, 3(12): 2030-2032.
29. Begum, M.S.T.N., M. Begum, A.S. Juraimi and M.D.P. Anwar, 2009. Optimizing seed rate for summer mung bean varieties. Journal of Agriculture & Social Sciences, 5: 114-118.
30. Rasul, F., M.A. Cheema, A. Sattar, M.F. Saleem and M.A. Wahid, 2012. Evaluating the performance of three Mung bean varieties grown under varying inter-row spacing. The Journal of Animal & Plant Sciences, 22(4): 1030-1035.
31. Kabir, M.H. and M.A.R. Sarkar, 2008. Seed yield of Mung bean as affected by variety and plant spacing in Kharif-I season. J. Bangladesh Agril. Univ., 6(2): 239-244.

32. Ahamed, K.U., K. Nahar, N.M. Rahmatullah, G. Faruq and M.D.A. Alamgir, 2011. Yield components and yield of different mung bean varieties as affected by row spacing. American-Eurasian Journal of Agronomy, 4(1): 01-05.
33. Singh, G., H.S. Sekhon, G. Singh, J.S. Bar, T.S. Bains and S. Shanmugasundaram, 2011. Effect of Plant Density on the Growth and Yield of Mung bean (*Vigna radiata* (L.) Wilczek) Genotypes under Different Environments in India and Taiwan. International Journal of Agricultural Research, 6(7): 573-583.
34. Ihsanullah, F., H. Taj, H. Akbar, A. Basir and N. Ullah, 2002. Effect of Row Spacing on Agronomic Traits and Yield of Mung bean (*Vigna radiate* L. Wilczek). Asian Journal of Plant Sciences, 1(4): 328-329.
35. Dainavizadeh, P. and M. Mehranzadeh, 2013. Effect of Seed Rate on Growth, Yield Components and Yield of Mung bean Grown under Irrigated Conditions in The North of Khuzestan. International Journal of Agriculture and Crop Sciences, 5(20): 2359-2364.
36. AVRDC, 2006. AVRDC-Mung bean project report (year two, April 2006–September 2006): "Popularization of extra short duration mung bean 40 Short Duration Mung bean: A New Success in South Asia cultivars for poverty alleviation and improved nutrition in Bihar, Rajasthan and Jharkhand, India, Based on Punjab model, " pp: 1-79.
37. Gentry, J., 2010. Mung bean Management Guide 2nd edition, In Collaboration with Sectors of the Australian Mung bean Industry, the State of Queensland (Department of Agriculture and Fisheries) 2010-2015, Queensland Government.
38. Mota, F.M., D.S. Balla and M.B. Doda, 2021. Response of Mung Bean Varieties (*Vigna radiata* L.) to Application Rates and Methods of Blended NPS Fertilizer at Humbo. Hindawi, International Journal of Agronomy, Vol. 2021, Article ID 3786720, 10 pages, Retrieved April 25, 2022, from https://doi.org/10.1155/2021/3786720.
39. Dikr, W. and H. Garkebo, 2022. Evaluation of the Agronomic Traits and Grain Yield of Mung bean (*Vigna radiata* L.) by Different Levels of Phosphorus Fertilizer with Row Spacings at Abine Germama Kebele in Adamitulu Jido kombolchaWereda. Journal of Biology, Agriculture and Healthcare, 12(7): 25-36.
40. Varma, D., R.S. Meena and S. Kumar, 2017. Response of mung bean to fertility and lime levels under soil acidity in an alley cropping system of Vindhyan Region, India. International Journal of Chemical Studies, 5(4): 1558-1560.
41. Sadeghipour, O., R. Monem and A.A. Tajali, 2010. Production of Mungbean (*Vigna radiata* L.) as Affected by Nitrogen and Phosphorus Fertilizer Application. Journal of Applied Sciences, 10(10): 843-847.
42. Muchira B., P. Kamau and D. Mushimiyimana, 2018. Effects of Spacing and Fertilization on Growth and Grain Yields of Mung Beans (*Vigna radiata* (L.) Wilckzeck) in Dry Areas of Subukia, Kenya. International Journal of Advanced Research and Publications, 2(7): 30-44.
43. Razzaque M., M. Haque and M. Karim, 2017. Effect of nitrogen on growth and yield on mung bean in low nutrient soil. Bangladesh Journal of Agricultural Research, 42(1): 77-85.
44. Sheoran, P., V. Sardana and S. Singh, 2008. Effect of nutrient levels on the productivity of mung bean genotypes under sub-humid rainfed condition of Punjab. Journal of Food Legume, 21(2): 117-118.
45. Kumar, S., R.C. Singh and V.S. Kadian, 2003. Performance of mung bean as influenced by seed inoculation with Rhizobium and levels of inorganic sources of nutrients. Indian Journal of Pulses Research, 16(1): 67-68.
46. Malik, M.A., M.F. Saleem, A. Asghar and M. Ijaz, 2003. Effect of nitrogen and phosphorus application on growth, yield and quality of mung bean (*Vigna radiata* L.) Pakistan Journal of Agricultural Sciences, 40(3 and 4): 133-136.
47. Sharma, S., R.S. Upadhyay and C.R. Sharma, 2003. Response of various levels of nitrogen and phosphorus application on growth, physiological parameters and yield of *Vigna radiata* (L.) Wilczek under rainfed and mid hill conditions of Himachal Pradesh. Indian Journal of Agricultural Research, 37(1): 52-55.
48. Nadeem, M.A., R. Ahmad and M.S. Ahmad, 2004. Effect of seed inoculation and different fertilizer levels on the growth and yield of mung bean (*Vigna radiata*). Journal of Agronomy, 3(1): 40-42.
49. Hussain, Z., N. Khan, S. Ullah, A. Liaqat, F. Nawaz, A.U.R. Khalil, J.A. Shah, M. Junaid and M. Ali, 2017. Response of Mung bean to Various Levels of Biochar, Farmyard Manure and Nitrogen. World Journal of Agricultural Sciences, 13(1): 26-33.
50. Umoh, F.O. and V.E. Osodeke, 2016. Estimation of Phosphorus Requirement of Mungbean (*Vigna radiata* L.) Wilezek in the Acid Soils of South Eastern Nigerian Using P-Sorption Isotherm. American-Eurasian J. Agric. & Environ. Sci., 16(3): 487-493.