International Journal of Research Studies in Science, Engineering and Technology
Volume 7, Issue 9, 2020, PP 16-21
ISSN 2349-476X

Validation of Soybean (Glycine max. L.) to NP Fertilizer Rates and Plant Population Densities at Jimma, Southwestern Ethiopia

Sisay Gurmu*, Muhidin Biya and Eshetu Yadete

Jimma Agricultural Research Center, Ethiopia

***Corresponding Author:** *Sisay Gurmu, Jimma Agricultural Research Center, Ethiopia*

ABSTRACT

Soybean (Glycine max. L.) is an important crop in the tropical, hot sub-moist agro-ecological zone of south western Ethiopia. However, the yield of the crop is limited due to lack of appropriate plant population density and optimum NP fertilizer rate. Therefore, after three years on farm field study of NP fertilizer rate and plant population further evaluation and validation was conducted to determine optimum NP fertilizer rates and plant population on yield and yield components of soybean at Jimma Zone, Southwestern Ethiopia during 2019 main cropping season. The experiment was laid out in RCBD with factorial arrangement of two different plant population density (333333 plants $ha^{-1}$and 400000 plants ha^{-1}) and two levels of NP fertilizer rate (46/46kg ha^{-1} and 69/69 kg ha^{-1} N/P_2O_5).The combined over locations analysis was done using SAS 9.3 software. There was no significant ($p>0.05$) interaction and main effect of NP fertilizer rates on plant height, number of pod per plant, grain yield, above ground biomass and harvest index. Also the rate of plant population had no significant ($p>0.05$) effect on plant height, number of pod per plant and harvest index, but it had significant ($p<0.05$) effect on grain yield and above ground biomass. It was observed that an increase in plant population increased grain yield and above ground biomass and vice versa. Significantly the highest mean grain yield (3570 kg ha^{-1}) was obtained from plant population of 400,000plants ha-1 with the highest net benefit of 46,855 Ethiopian Birr ha^{-1}. Therefore, it is advisable for farmers in the study area and adjacent wored as' with similar agro-ecologies, a plant population density of 400,000 plants ha^{-1} (50 x 5cm) in complement with N/P_2O_5 fertilizer rate of 46/46 kg ha^{-1}.

Keywords: *Plant population, NP fertilizer rate and grain yield*

INTRODUCTION

Soy bean (Glycine max. L.) is one of the most important oilseed crops in the world. It contains 18-22 % oil and 40-42 % protein (Mounts et al., 1987). It is highly industrialized in developed countries, providing more than a quarter of world's food and animal feed requirement in addition to protein .Soybean was first introduced to Ethiopia in 1950's because of its nutritional value, multi-purpose use and wider adaptability in different cropping systems. It is a crop that can play major role as protein source for resource poor farmers of Ethiopia who cannot afford animal products. Besides, it can also be used as oil, crop, animal feed, and poultry meal, for soil fertility improvement and more importantly as income for the country. Soybean can be grown in different parts of Ethiopia, the major areas currently growing the crop are situated in the western and south western parts of the country, notably Benishangul Gumuz, Gambela and parts of Oromia Region.

Entry of large scale commercial farmers, including government sugarcane-soybean intercropping programs, and research in soil fertility rehabilitation have made soybean a favorite crop. According to FAO, cited by Tesfaye, 2015, an average productivity of soybean in Ethiopia was 1.79 t ha^{-1} which is low as compared to world average of 2.5 t ha^{-1}. However, this level is very low compared to its potential, which could go up to 4 tons per hectare if improved crop management is used. This low yield may be attributed to the combination of several production constraints among which poor soil fertility, periodic moisture stress, diseases and insect-pests, weeds, non-optimum plant population, un-NP fertilizer rate and untimely field operations play a major role. Perhaps the three years experiment of NP fertilizer rate and plant population density was performed from 2016 up to 2018 and the further evaluation and validation was needed. Therefore, the objective of this study was to validate the response of soya bean to plant population density and NP fertilizer rates on growth parameters, yield and yield components.

MATERIALS AND METHODS

Description of the Experimental Site

The study was conducted at Jimma Zone, Karsa and Omonada woreda district, in Oromia region at the southwestern part of Ethiopia, during the main cropping season of 2019. The Kersa site was located on latitude 7º42' N and longitude 36º 59'E and laid at an altitude of 1750 m.a.s.l. The average minimum and maximum temperature is 6ºC and 25.5ºC respectively and reliably receives good rains 1712 mm per annum during cropping season. The Omonada site was located on 7º46' N and 36º 00'E and laid at an altitude of up to 1753 m.a.s.l. with soil type of the area is Upland: Chromic Nitosol and Combisol. The average maximum and minimum temperature are 9ºC and 28ºC respectively and reliably receive good rains 1561 mm per annum cropping season. The farming system of the study site is coffee and cereal crops dominated with coffee, maize, teff and sorghum also has warm and cold climate, also convenient topography is very suitable for all agricultural practices. It was situated in the tepid to cool humid-mid highlands of southwestern Ethiopia. The soil type of the experimental area was Eutric-nitisols (reddish brown).

Soil Physico-Chemical Properties

The soil of the experimental field was characterized by selected physico-chemical properties before the application of the treatments (Table 1). The average soil pH of the trial sites ranges from 5.06 to 5.14 across locations, which was strongly acidic (Batjes, 1995) and ideal for the production of most field crops. The pH of the soil affects maize growth by suppressing the root development and reducing availability of macronutrients to plants especially phosphorus (Brady and Weil, 2008). The soil total N ranges from 0.16 to 0.19% and SOM from 3.08 to 3.55% which were medium rate for crop growth and development for both nutrients (Berhanu, 1980). For all locations the average Bray II extractable available P ranges from 4.48 to 11.82 mg kg^{-1} which was below the critical level (8 mg kg^{-1}) for most crops as described by Tekalign and Haque (1991) at Kersa woreda and above critical level at Omonada woreda.

Table1. *Selected physico-chemical properties of the soil of the experimental sites before planting*

Soil characters	Location	
	Kersa	Omonada
pH(1:2.5)	5.06	5.14
Av P(mg kg^{-1})	4.48	11.82
TN (%)	0.16	0.19
OC (%)	1.79	2.06
SOM (%)	3.08	3.55
C:N ratio	10.97	10.86

Where pH= hydrogen power, OC=Organic carbon, TN=Total Nitrogen, Av P=Available Phosphorous, SOM=Soil Organic Matter. Values are the means of duplicated samples.

Source: *Jimma Agricultural Research Center soil and plant laboratory*

Experimental Procedure and Field Management

The land was ploughed, disked, and harrowed by oxen and one seed was planted per hole at the specified intra and inter row spacing from 11^{the} June up to 13^{the} June, 2019. Harvesting was done manually when the crop reached harvest maturity and the pods were picked from the net plots and allowed to air and sundry for six days then trashed. Grain yield was calculated over all harvestable plants in the net plot.

Experimental Design and Treatments

A field experiment was conducted on farmer's field of Jimma Zone Omonada and Kersa woreda. The trial was carried out on five farmers field at both woreda's for 2019 main cropping season. The plot size of each treatment was $48m^2$(10m x 4.8 m).

Released Soybean variety (Clark 63k) was used. The experiment was laid out in RCBD with factorial arrangement of two different plant population density (333,333 plants ha^{-1} and 400,000 plants ha^{-1}) and two levels of N/P_2O_5 fertilizer rate (46/46 kg $ha^{-1}$and 69/69 kg ha^{-1}).

To increase the nitrogen use efficiency, it was split in two equal rates and applied at planting time and at four leaf initiation stages.All other cultural practices were given based on available recommendations for Soya bean growing woreda of south western part of the country.

Data Collected

Plant Height (Cm)

It was measured by centimeters from the ground level to the top of the plant at 50% flowering from 5 randomly selected plants from each plot.

Number of Pods Per Plant

The number of pods was counted from five randomly selected plants of harvestable rows at the time of harvesting from each plot and their averages were recorded.

Grain Yield (Kg/Ha)

It was measured from each plot using electronic balance and then adjusted to 7.0% moisture and converted to hectare basis.

Above Ground Biomass (Ton Ha^{-1})

All above ground biomass was harvested from net plot and weighted, sample plants were selected dried till get uniform weight.

Harvest Index

It was expressed as the ratio of economic yield per plant to the total above ground biomass (Donald, 1962).

$$HI(\%) = \frac{Economic\ yield\ (kg/ha)}{Total\ biological\ yield\ (kg/ha)} x100$$

Data Analysis

The collected data were subjected to analysis of variance (ANOVA) appropriate to factorial experiment in RCBD using SAS software 9.3 versions. The interpretations were made following the procedure described by Gomez and Gomez (1984). The means were compared using the least significant differences (LSD) test at 5 % level of significance.

Partial Budget Analysis

Partial budget analysis was performed to investigate the economic feasibility of the treatments

and assess the costs and benefits associated with different treatments of chemical fertilizers and the seed rates. The partial budget technique as described by CIMMYT (1988) was applied. The partial budget analysis was done using the prevailing market prices for inputs at planting and for outputs at the time the crop was harvested. All costs and benefits were calculated on hectare basis in Ethiopian Birr (ETB). The inputs and/or concepts used in the partial budget analysis were the mean grain yield of each treatment, the gross field benefit (GFB) ha^{-1} (the product of field price and the mean yield for each treatment), the field price of chemical fertilizers and urea kg^{-1} (the nutrient cost plus the cost of transportation from the point of sale to the farm), cost of labor spent on seed purchase and planting, the total costs that varied (TVC) which included the sum of field costs of fertilizers and their application, and seed purchase and planting.

Results and Discussions

After three years experiment of NP fertilizer rates and plant population density on soybean, further evaluation and validation was done at five farmers' sites during 2019 main cropping season at Jimma zone Omonada and Kersa woreda.

The homogeneity test of the error variances for locations indicated that the error variance was homogenous and hence combined analysis of variance was conducted. Over locations combined analysis indicates the interaction effect, main effect of NP fertilizer rates and plant population density didn't show significant ($P > 0.05$) difference on plant height, number of pod per plant and harvest index. Concerning main effect of plant population density, it was highly significantly ($P \leq 0.01$) affects grain yield and significantly ($P \leq 0.05$) affects aboveground biomass. Whereas, both grain yield and above ground biomass was not significantly ($P > 0.05$) affected by NP fertilizer rates and plant population density (Table 2).

Grain Yield

The grain yields per hectare obtained from the experiment are presented in Table 3. Grain yield varied from 3030 to 3570 kg ha^{-1} for plant population density rates with the lowest grain yield with lowest plant population density (333,333 plants ha^{-1}) and highest grain yield with highest plant population density (400000 plants ha^{-1}). The significant difference between the lowest and the highest grain yield was 540 kg ha^{-1}. As a result, 400,000 plants ha^{-1} plant population density produced 17.8% higher grain yield than 333,333 plants ha^{-1}. An increase in grain yield per hectare in response to plant density is due to increased number of plant per unit area. Christmas (2002), Berglund and Helms (2003) and Yilmaz (2003) have also reported parallel results. In soybean one of the benefits of higher plant density is contribution to earlier canopy closure which makes weed control easier by increasing competition between the crop and weeds. Yield increase to emanating from plant density in unit area was mainly due to increased number of grain per area rather than increased yield per plant. These results are supported by Edwards and Purcell, (2005) who showed that as soybean population increases, yield increases rapidly until it becomes asymptotic per plants.

Table2. *Mean square values of NP fertilizer rates and plant population density on growth, yield components and yield of soybean*

Parameter	Mean square for source of variation			
	NP (1)	Plant population density (1)	NP x Plant population density (1)	Error (12)
Plant height(cm)	7.938^{ns}	2.738^{ns}	6.05^{ns}	21.655
Number of pod per plant	2.888^{ns}	145.80^{ns}	7.20^{ns}	50.98
Grain yield (kg ha^{-1})	297.2^{ns}	1446520.7^{**}	33105.4^{ns}	188013.1
AGB (t ha^{-1})	0.133^{ns}	16.65^{*}	0.036^{ns}	3.1459
Harvest index	0.000005^{ns}	0.00013^{ns}	0.0004^{ns}	0.000599

**Numbers in parenthesis = Degrees of freedom; *= Significant ($P \leq 0.05$); ** = highly significant ($p \leq 0.01$) difference; NS= non significant; AGB= Above ground biomass; ha = Hectare*

Above Ground Biomass

Numerically the highest above ground dry biomass (13.84 ton ha^{-1}) was recorded at the highest plant population density of 400,000 plants ha^{-1}, while the lowest above ground dry biomass yield (12.02 ton ha^{-1}) was recorded from the lowest plant population density 333,333 plants ha^{-1} (Table 3). The result indicates that as plant population increased from 400,000 plants ha^{-1} to 333,333 plants ha^{-1} the above ground dry biomass increased by 15%; which might be due to the higher number crop stand count at narrower spacing than wider spacing. The biological yield was increased by increasing plant density due to high grain yield. These results were in agreement with Bullock et al., (1998) who reported that narrow row spacing (high plant population) made more efficient use of available light and shaded the surface soil more completely during the early part of the growing season while the soil is still moist and therefore, high plant population density are more effective in producing biomass. Getachew et al., (2006) also reported increased dry biomass of faba bean with increased plant population density.

Table3. *Over location effect of plant population densities and NP fertilizer rate on growth, yield and yield components of soybean at Kersa and Omonada Jimma Zone during 2019 main cropping season*

Plant population density ha^{-1}	Over location				
	Plant height (cm)	No. of pod $plant^{-1}$	Grain yield (ton ha^{-1})	AGB (ton ha^{-1})	HI
400000 (50*5cm)	74.9	44.5	3.57a	13.84a	0.26
333333 (60*5cm)	75.6	49.9	3.03b	12.02b	0.26
F-test	NS	NS	**	*	NS
NP fertilizer rates kg ha^{-1}					
46/46	74.6	46.9	3.30	12.85	0.26
69/69	75.9	47.6	3.31	13.01	0.26
LSD (0.05)	4.53	6.96	0.42	1.73	0.024
CV (%)	6.2	15.11	13.13	13.7	9.43
F-test	NS	NS	NS	NS	NS

LSD= Least significant difference; CV=Coefficient of variation; NS=Non significant; HI= Harvest index; AGB=Above ground biomass; Values followed by the same letter within a column are not significantly different at P>0.05.

Economic Analysis

Analysis of variance (Table 2) showed that NP fertilizer rates and plant population density had a significant ($P \leq 0.01$) effect on the soybean grain yield. The economic analysis was performed using partial budget analysis following the procedure described by CIMMYT (1988) in which prevailing market prices for inputs at planting and for outputs at harvesting were used. All costs and benefits were calculated on hectare basis in Ethiopian Birr (ETB). The concepts used in the partial budget analysis were the mean grain yield of each treatment, the field price of soya bean grain, and the gross field benefit (GFB) ha^{-1} (the product of field price and the mean yield for each treatment).The net benefit (NB) was calculated as the difference between the gross benefit and the total cost. The average yield obtained from experimental plot was adjusted by 10% for management difference to reflect the difference between the experimental yield and the yield that farmers could expect from the same treatment (Getachew and Taye, 2005, CIMMYT, 1988). The total costs of NP fertilizer (13.5 ETB kg^{-1}) and urea = 10 ETB kg^{-1} were calculated based on store sale prices of both woreda's farmers' Cooperative in May, 2019 and sale of grain soya bean at both woreda's open market average price (15 ETB kg^{-1}) in December, 2019.

Table4. *Partial budget analysis of NP fertilizer rates and plant population density on grain yield of soybean at Kersa and Omonada woreda during 2019 cropping season*

Plant population density ha^{-1}	GY (ton ha^{-1})	Adj.GY (ton ha^{-1})	GFB (ETB ha^{-1})	TVC (ETB ha^{-1})	NB (ETB ha^{-1})
400000 (50*5cm)	3.57	3.213	48195	1340.0	46855.0
333333 (60*5cm)	3.03	2.727	40905	1120.0	39785.0
NP fertilizer rates kg ha^{-1}					
46/46	3.30	2.970	44550	2305.9	42244.1
69/69	3.31	2.979	44685	3466.0	41219.0

**GY= Grain yield; GFB = Gross field benefit; TVC = Total variable cost; NB = Net benefit; ETB = Ethiopian Birr; Price of chemical fertilizer = 13.5birr kg^{-1}; Price of Urea = 10 birr kg^{-1}; Wage rate = 40 Birr man-day^{-1}; Retail price of grain = 15 birr kg^{-1}.*

Thus, upon sale of grain soya bean at Kersa and Omonada woreda open market, the highest plant population density (400,000 plants ha^{-1}) gave highest net benefit 46,855 ETB ha^{-1} with an increase of 17.8% (7070 ETB ha^{-1}) net benefit over the lowest plant population density 333,333 plants ha^{-1} Regarding NP fertilizer rates, 46/46 kg ha^{-1} N/P_2O_5) gave the highest net benefit 42244.1 ETB ha^{-1}(Table 4).

The farmers' perceptions were collected at harvest period. Evaluation criteria were set by farmers to select best plant population density and optimal fertilizer application. Accordingly, soybean growth rate, number of pod/plant, seed size and yield potential were found the most important evaluation criteria.

Further, based on evaluation criteria's that was set by farmers (Table 5) 33% of them chosen NP fertilizer application of 46/46 Kg ha^{-1} NP_2O_5 AND plant population of 400,000 plants ha^{-1}.

Table5. *Farmers perception on optimal NP fertilizer application and medium maturing maize varieties at Jimma zone during 2019 cropping*

Farmers Evaluation Criteria	NP fertilizer rates			
	46/46 NP_2O_5 (Kg ha^{-1})		69/69 NP_2O_5 (Kg ha^{-1})	
	Plant population density plants ha^{-1}			
	333,333	400,000	333,333	400,000
Weeding Frequency	Medium	Medium	Medium	Medium
Growth rate	Medium	High	Medium	High
Number of pod/plant	Higher	Medium	Higher	Medium
Seed size	Bigger	Medium	Bigger	Medium
Yield potential	Medium	Higher	Medium	Higher
choice in Percentage	23%	33%	19%	25%

Summary and Conclusions

The study was conducted to validate and determine the response of soya bean to plant population density and NP fertilizer rates on growth parameters, yield and yield components in Jimma area south west Ethiopia. The experiment was laid out in RCBD with factorial arrangement of two different plant populations (333333 plants ha^{-1} and 400000 plants ha^{-1})

and two levels of NP fertilizer rate (46/46 and 69/69 kg ha^{-1} N/P_2O_5). The combined Analysis was done across locations for growth, yield and yield components of the crop. It was observed that increase in plant population density significantly increased grain yield and above ground biomass. The NP fertilizer rate was no effect on the plant height, number of pod per plant, grain yield, above ground biomass and harvest index. There was no interaction effect observed among plant population densities and NP fertilizer rate across location.

Over location data analysis showed that the significant highest plant population density (400,000 plants ha^{-1}) gave higher mean grain yield 3570 kg ha^{-1} and above ground biomass 13.84 ton ha^{-1}. To concluded that narrower inter row space (50 cm with intra row 5 cm) resulting in density 400,000 plants per hectare and 46/46 kg ha^{-1} NP_2O_5 were determined for optimum productivity of soya bean in Jimma area and similar agro ecologies.

REFERENCES

[1] Batjes, N.H., 1995. Aglobal data set of soil pH properties. Technical Paper 27, International Soil Reference and Information Centre (ISRIC), Wageningen.

[2] Berhanu, D., 1980. A survey of studies conducted about soil resources appraisal and evaluation for rural development in Ethiopia, Addis Ababa.70p

[3] Brady, N., Weil R.R., 2008. Nature and Properties of Soils (14th edn.). Prentice Hall, Upper Saddle River. 992p.

[4] Bullock, D., Khan, S., Rayburn A., 1998. Soybean yield responce to narrow rows is largely due to enhanced early growth. Crop Science, 38 (4): 1011-1016.

[5] Berglund, D.R, Helms, T.C., 2003. Soybean Production. NDSU, A-250 Board JE, Harville BG (1996). Growth dynamics during the vegetative period affects yield of narrow-row, late-planted soybean. Agronomy Journal, 88: 567-572.

[6] Christmas, E.P., 2002. Plant populations and seeding rates for soybeans. AY-217. Purdue University Cooperative Extension Service, West Lafayette, Indiana.

[7] CIMMYT, 1988. From Agronomic Data to Farmer Recommendations: An Economics Training Manual. Completely revised edition. Mexico, D.F.79p

[8] Donald, C. M., 1962. In search of yield. Journal of Australian Institute of Agricultural Science, 28(1): 171-178.

[9] Edwards, J.T, Purcell, L.C., 2005. Soybean yield and biomass responses to increasing plant population among diverse maturity groups: I. Agronomic characteristics. Crop Science, 45 (5): 1770-1777.

[10] Getachew, A., Ghizaw, A. and Sinebo, W., 2006. Yield performance and land-use efficiency of barley and faba bean mixed cropping in Ethiopian highlands. European Journal of agronomy, 25(3), pp.202-207.

[11] Getachew, A., and Taye, B., 2005. On-farm integrated soil fertility management in wheat on nitisols of central Ethiopian highlands. Ethiopian Journal of Natural Resources, 7: 141-155.

[12] Gomez, K. A. and Gomez, A. A., 1984. Statistical Procedures for Agricultural Research. 2nd ed. John Wiley and Sons. New York.

[13] Tekalign, M. and Haque, I., 1991. Phosphorus status of some Ethiopian soils, II. Forms and distribution of inorganic phosphates and their relation to available phosphorus. Trop Agric., 68(1): 2-8.

[14] Mounts, T.L, Wolf, W.J, Martinez, W.H., 1987. Processing and utilization. In soybeans: Improvement, production and uses, Second Edition, J.R. Wilcox, Madison, Wisconsin. Norhayati M, Mold SN, Noor S, Chong K, Faizah AW; Herridge DF, Peoples MB, Bergersen FJ (1988). Adaptation of methods for evaluation of N2 fixation in food legumes and legume cover crops. Plant Soil, 108: 143-150.

[15] Tesfaye Fituma, 2015. Effect of Bradyrhizobium Inoculation and Phosphorus Rate on Nodulation, Yield and Yield Related Traits of Soybean Intercropped with Sugarcane in Metahara Sugar Estate, Central Rift Valley of Ethiopia, MSc. Thesis in Soil science, Haramaya University, Ethiopia.

[16] Yilmaz, H.A., 1999. Kahramanmaras ekolojisinde farklı ekim sıklıklarının, iki soya çesidinde verim ve verim unsurlarına etkisi. Turkey Journal of Agriculture, 3: 223-232.

Citation: *Sisay Gurmu, Muhidin Biya and Eshetu Yadete, "Validation of Soybean (Glycine max. L.) to NP Fertilizer Rates and Plant Population Densities at Jimma, Southwestern Ethiopia" International Journal of Research Studies in Science, Engineering and Technology, 7(9), 2020, pp. 16-21.*