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Response of Chickpea (*Cicier Arietinium* L.) to *Rhizobium* Inoculation and Blended fertilizer Rates in Laelay Maichew, Central Zone of Tigray, Northern Ethiopia

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Abstract

Low soil fertility is one of the limiting factor for low productivity of chickpea in Central zone of Tigray, Northern Ethiopia. Field experiment was therefore, conducted for two consecutive years (2016-2017) in Laelay Maichew (Hatsebo) to evaluate the effects of NPSB fertilizer and rhizobium inoculation on yield and yield components of chickpea. The experiment was laid out in a split plot design with three replications. Rhizobium inoculation was assigned to the main plots with two levels (with and without *rhizobium* inoculation) and NPSB fertilizer rates in sub plot with seven levels (0, 25, 50, 75, 100, 125 and 150 kg ha^{-1} NPSB). Data collected were subjected to the analysis of variance (ANOVA) using SAS software. A combined analysis of variance showed a significant interaction effects of NPSB and *rhizobium* inoculation on chickpea yield and yield components ($P<0.05$) across the two years. The highest number of pods per plant (76.8) was recorded from 125 kg ha^{-1} NPSB along with *rhizobium* inoculation and the highest grain yields were obtained from 150 kg ha^{-1} (3609 kg ha^{-1}) and 125 kg ha^{-1} NPSB (3514 kg ha^{-1}) along with *rhizobium* inoculation. Maximum marginal rate of return (4106.68%) was gained when chickpea was inoculated with *rhizobium* and 125 kg ha^{-1} NPSB application. From the present results it could be concluded that 125 kg ha^{-1} NPSB along with *rhizobium* inoculation seeds would be the optimum treatment combination for enhancing chickpea yield and better profitability in soils with low level of available plant nutrients (NPSB).

Keywords: Chickpea, marginal rate of return, NPSB, rhizobium inoculation, yield

1. Introduction

In Ethiopia pulses are among the various crops produced in all the regions of the country after cereals (CSA, 2018). In 2017/18 pulses were cultivated in about 1.6 x 10^6 ha with annual estimated production of 2,978,588 tons (CSA, 2018). Among the pulses crops, chickpea is an important annual crop. It is only cultivated species of genus *Cicer*. Chickpea is the world's third most important food legume next to haricot bean and soybean (Namvar and Sharifi 2011). Globally it was cultivated on area of 13.65 million ha with production of 13.10 million tons (FAOSTAT, 2016). It is grown in 35 countries of the world. India, Turkey, Pakistan, Iran, Mexico, Myanmar, Ethiopia, Australia, Spain, Canada and USA are top ten chickpea producing countries. Ethiopia contributed around 3% of the global chickpea production. In Africa, Ethiopia is the leading chickpea producer and ranked third in its production next to faba bean and haricot bean (FAOSTAT, 2012).

Chickpea is a relatively cheap source of protein (20–23% in the grain), energy (carbohydrates, 40%), oil (3–6%) (Gil etal.,1996) and minerals (Mg, K, P, Fe, Zn, and Mn (Ibrikci et al 2003) and β-carotene (Milan etal., 2006) in the developing world. Chickpea contributes significantly to sustainability of cereal-legume cropping systems, increasing the yield of cereals through enhancing the soil nitrogen and breaking the disease cycles of important cereal pathogens (Pande et al.,2011). However its productivity is low (1630 kg ha^{-1}) in Tigray compared to the national average (2053 kg ha^{-1}) in Ethiopia (CSA, 2018) and very much below the potential of the crop.

Moisture stress (drought) mainly terminal drought, decline in soil fertility, diseases (dry root rot, wilt) insect pests (pod borer and cut worm) are the major constraints for low productivity of chickpea. Declining in soil fertility is one of the constraints contributing for low chickpea production and productivity. Many of the soils in Ethiopia are deficient in N, P, K, S (EthioSIS, 2014). Moreover, soil fertility declining is aggravetaed due to intensive cropping and unbalanced use of fertilizers by the farmers. Therefore, balanced fertilization is needed for optimum growth and production of crops including chickpea.

In the study area, use of fertilizer was focused mainly on the use of nitrogen (urea) and phosphorous (di-ammonium phosphate-DAP) for almost all crops. Such unbalanced application of plant nutrients might have aggravated the depletion of nutrient elements in soils including the recently identified S and micronutrient (B). Hence, the yield gap in pulses in general and chickpea in particular could be fulfilled through combined application of biofertilizers (rhizobium inoculants) and blended fertilizers along with improved varieties. There is also a need to consider the relative cost and profitability of these technologies with the respect to their adoption by small-holder farmers. This study was therefore initiated with to evaluate the sole and comined rhizobium and blended (NPSB) fertilizer application on yield and yield components chickpea. It was hypothesized that application of optimum NPSB fertilizer rates combined with rhizobium inoculation would improve yield and agronomic traits of chickpea in the study area.

2. Materials and Methods

2.1 Description of The Study Site

The experiment was conducted at *Hatsebo* experimental site of Axum Agricultural Research Center. The experimental site is located 5 km East from Axum town of Tigray regional state, Northern Ethiopia at 14°6’46”N and 38°46’3” E and attitude of 2084 meter above sea level. It has a Vertisols dominated clay soil type. It is situated in the northern semi-arid tropical belt of Ethiopia where teff, chickpea, wheat and faba bean are commonly grown. Chickpea is an important crop in the area both economically and ecologically. The rainy season is mono modal concentrated in one season from July to September and receives from 400 to 800 mm rainfall per annum.

2.2 Experimental Design, Treatments and Procedures

The experiment was carried out for two consecutive years (2016– 2017) during the rain fed conditions. The experiment was conducted in a split plot design with three replications at Axum Agricultural Research Station (*Hatsebo* site) and sown at mid August. The main factor was rhizobium inoculation with two levels (inoculated and uninoculated). The sub-plots factor was blended fertilizer rates with seven treatments (0, 25, 50, and 75,100,125,150 kg NPSB ha^{-1}). The experiment was conducted in a plot size of 3 m length by 2.4 m width with spacings of 0.10 m, 0.30 m, 0.50 m, 1 m and 1.5 m between plants, rows, sub plots, main plots and replications, respectively.

Popular and predominant grown improved chickpea variety (*Arerti*) was used for the trial. The recommended biofertilier level 500 g ha^{-1} was used for chickpea inoculation. Rhizobium chickpea strain CP-M-41 was obtained from Menagesha Biotech industry P.L.C, Addis Ababa, Ethiopia. It is popular strain across the country in enhancing chickpea yield and yield components. The inoculants were prepared based on the recommended rate of 10g kg^{-1} seeds for inoculation. Before planting, 1.5 kg of Chickpea (*Arerti*) seeds was prepared for inoculation. Seeds were soaked in water for 30 minutes. Then excess water was removed from the seeds by placing in a sack. There after sugar was applied as adhesive material to stick the inoculums in to the seeds. Finally the inoculants was applied to the seeds and dressed until the seeds showed a black color in a shade to avoid direct sun light so as to maintain the viability of the inoculums.

Blended fertilizer (NPSB) at rates of 0, 25, 50, 75,100,125,150 kg ha^{-1} were applied at the center of the row and covered with soil to avoid contact with the inoculated seeds. At seed sowing, daily laborers were grouped into two before planting was started. One group planted the inoculated seed on the other hand the other group planted the non inoculated seeds. Finally, plots planted with inoculated seeds were immediately covered with soil to avoid direct sun light.

2.3 Soil Sampling, Preparation and Analysis

Pre-sowing surface soil samples were collected at 0-30 cm depth diagonally from 20 spots in the experimental field using an Auger. Sub samples were composited and processed for soil analysis before sowing. Composite soil samples were analyzed for organic carbon (OC), total N (Kjeldahl method) and available soil P (Olsen method). Particle size was determined following the hydrometer method. Cation exchange capacity, EC and soil pH were also measured using standard laboratory procedures followed by Shire Soil Research Center.

2.4 Agronomic Data Collection

Days to 90% maturity was recorded for all the plots when 90% of the plot was ready for harvesting when the foliage color becomes yellowish, lower pods starting shedding pods and seeds harden. At harvesting time, plant height and number of pods $plant^{-1}$ were estimated from randomly tagged six plant samples in each plot. Harvesting was done from the central six rows Threshing was done manually after a week. Grain yield of the six inner 6 rows was measured by using sensitive balance and converted kg ha^{-1}. Grain yield of each plot was adjusted to 12% seed moisture content. Finally 100 seed data were weighed by counting 100 seeds from each plot by using sensitive balance.

2.5 Statistical Analysis

All collected data were subjected to the analysis of variance (ANOVA) using the SAS computer program, version 9.1 (SAS, 2002). Error variance of the individual years was tested for homogeneity. Treatment means were compared using least significant difference at 5% probability level (Petersen, 1994).

2.6 Partial Budget Analysis

Partial budget analysis of the rhizobium and blended (NPSZnB) fertilizer treatments were performed on the basis of prevailing market prices (CIMMYT,1988). The partial budget analysis was performed to assess treatment combinations that would give acceptable returns at low risk to farmers. All costs and benefits were calculated on hectare basis in Ethiopian birr (ETB). Variable costs (fertilizer and *Rhizobium*, Application and transport costs) were considered for partial budget analysis. Mean grain yield of the two years result were used for partial budget analysis. The average grain yield was adjusted to 10% downwards to reflect the difference between the experimental yield and the yield farmers will expect from the same treatment.

3. Results and Discussion

3.1 Experimental Soil Selected Physical and Chemical Properties

Selected soil physical and chemical properties of the experimental site before planting are indicated in Table 1. The soil textural class is clay. The soil pH was neutral and non-saline (EthioSIS, 2014). The soil pH is in optimal pH range for most plants. Soil organic carbon and total nitrogen were low according to the rating of Tekalign et al. (1991). Available P was in the marginal level while cation exchange capacity was high according to the rating of Landon (1991).

Table 1. Physico-chemical properties of the experimental site soil before planting (0-30cm)

Soil characters	Values
Clay (%)	66
Sand (%)	12
Silt (%)	22
Textural class	Clay
Soil pH	7.2
OC (%)	0.67
Total N (%)	0.06
Available P (mg kg^{-1})	10.28
CEC (meq100 g^{-1} soil)	58.4
EC (dS m^{-1})	0.986

Notes: CEC: cation exchange capacity; EC: electrical conductivity; N: nitrogen; P: phosphorus; OC: organic

3.2 Effects on Yield and Yield Components

The interaction effects are presented and discussed as most of the parameters are significantly affected by the combination effects of rhizobium and NPSB application in chickpea (Tables 2, 3 and 4). Analysis of variance result showed that significant differences among the majority of yield and yield components of chickpea for the interaction effect of NPSB and rhizobium inoculation.

There was significant ($p<0.05$) interaction effects of rhizobium inoculation along with NPSB application on 90% days to maturity in a separate year and combined over years. A significant and increasing trend was observed in 90% days to maturity with increasing among the rhizobium NPSB fertilizer levels. The shortest days to maturity (108.33) was recorded in the untreated check. On the contrary, the longest days to maturity (113) was observed in the maximum fertilizer doses and inoculation across the two years (Table 4). This could be attributed to the high nitrogen due to the increased N-in the higher fertilizer rates and able to fix of atmospheric nitrogen due to rhizobium inoculation. Abdula (2013) reported that the delay in maturity recorded at the maximum fertilizer dose combined with rhizobium inoculation.

Table 2. Effect of inoculation and NPSB application on Chickpea Yield and Yield Components in L/maichew (Hatsebo), 2016

Ino*NPSB (kg ha^{-1})	90% DTM	PH (cm)	NPPL	GY (kg ha^{-1})	HSW (g)
0*0	104e	33.8e	52e	1625.7f	25e
0*25	106bcd	35.93cde	55.2de	1779.8ef	25.5de
0*50	105.67cde	36.53cde	53.5de	2075.8de	25.13e
0*75	105de	37.2bcd	65.47b-d	1821.3ef	25.7cde
0*100	106.67a-d	36.97bcd	73.33a-d	2653.8c	26.87ab
0*125	106.33bcd	38.27abc	77.6abc	2256.9cd	27.07ab
0*150	107.33abc	37.87b	75.2abc	2522.1c	26.73abc
1*0	105de	34.47de	61.37cde	1670.2ef	25.8cde
1*25	105de	36cde	63.6cde	2284.7cd	25.4e
1*50	105.33de	37.07cd	69.4b-e	2397.9cd	26.53bcd
1*75	106.67a-d	37.73bc	75.6abc	3349.8b	26.6bc
1*100	107.67ab	38.73abc	92.7a	3210.9b	27.27ab
1*125	107.33abc	39.07ab	85.2ab	3626.7ab	27.37ab
1*150	108.33a	40.99a	78.6abc	3785.1a	27.67a
Grand mean	106.17	37.19	69.91	10.01	26.33
LSD (5%)	1.67	2.93	19.98	419.3	1.04
CV (%)	0.94	4.7	17.09	10.01	2.96

Ino indicates for Rhzobium inoculantion; 0= uninoculated, 1= inoculated with rhizobium; DM= days to maturity; PH= plant height; NPPL= number of pods per plant; GY=grain yield; HSW=hundred seed weight. Means followed by the same letter(s) with in a column are not significantly different at P = 0.05

With regard to the plant height the analysis of variance test showed a significant statistical difference ($P<0.05$) among the interaction effect of rhizobium inoculation and NPSB application in the single year as well as over years. The highest plant height (40.40 cm) was obtained from the interaction effect of rhizobium inoculation and NPSB application over the two years (Table 4) and the shortest plant height (32 cm) was recorded from the untreated check. This could be attributed to the high nitrogen source obtained from the fixed N- due to inoculation rhizobium inoculants as well as maximum vegetative growth of the plants under higher N availability from the higher NPSB levels.

Number of pods per plant significantly ($P \leq 0.05$) influenced by combine effect of rhizobium inoculation and NPSB levels in the separate years as well as across the two years (Tables 2,3 and 4). Significantly highest number of pods per plant was counted from the combine effect of rhizobium inoculation and 125 kg NPSB ha-1 (65.13) compared to the control (37.67) over the two years (Table 4). This result revealed that the combined application rhizobium and NPSB could be the optimum levels to obtain the higher number of pods per plant.

Table 3. Chickpea Yield and Yield Components as influenced by inoculation and NPSB application in Laelay maichew (Hatsebo), 2017

Ino*NPSB (kg ha^{-1})	DTM	PH (cm)	NPPL	GY (kg ha^{-1})	HSW (g)
0*0	112.67a	32e	37.67d	1357.3f	24.97b
0*25	113.33a	33.4de	44.27cd	1483.2ef	25.4ab
0*50	114ab	34.33cde	45.9bcd	1851.7d	25.37ab
0*75	115ab	34.87cde	47.8bcd	1937.6d	25.5ab
0*100	114.67abc	34.27cde	46.6bcd	2013.9d	25.7ab
0*125	113.67bc	37.2abc	55.33abc	2029d	25.3ab
0*150	115bcd	36.8abc	53.33abc	2711.7c	25.17b
1*0	114bcd	34.47cde	46.2bcd	1451.1ef	25.13b
1*25	114bcd	36bcd	51.93bc	1729.4de	25.47ab
1*50	115bcd	35.27cd	52.73abc	2980.7bc	25.83ab
1*75	114cd	36.47bcd	56.3abc	3151.6ab	26.46a
1*100	115.67bcd	38.4ab	57.9ab	3332.2a	26.03ab
1*125	116.33bcd	38.6ab	65.13a	3401.9a	25.77ab

1*150	117.67bcd	39.8a	57.2abc	3433.1a	25.97ab
Grand.mean	114.64	35.84	51.31	2347.46	25.57
LSD (5%)	2.62	3.08	13.19	308.07	1.18
CV (%)	1.36	5.14	15.37	7.84	2.75

Ino indicates for Rhzobium inoculantion; 0= uninoculated, 1= inoculated with rhizobium; DM= days to maturity; PH= plant height; NPPL= number of pods per plant; GY=grain yield; HSW=hundred seed weight. Means followed by the same letter(s) with in a column are not significantly different at P $\leq$ 0.05

In relation to grain yield analysis of variance revealed that statistical significant difference (P<0.05) among the combined application of rhizobium and NPSB. Application of NPSB and rhizobium inoculants at the same time had synergistic effect on the yield of chickpea thus increased the yield. All the treatments gave higher number of pods per plant over the control. Application of 125 kg/ha NPSB along with rhizobium inoculation had resulted 134**%** yield inncrea than the untreated check (control). Synergetic and positive response of rhizobium inoculation and di-amonium phsphate was reported in *Birhanu and Pant (2012)* in chickpea grain yield at shoa robit area.

Hundred seed weight (HSW) analysis of variance test showed a significant statistical difference (P≤0.05) among the combination of rhizobium inoculation and NPSB application (Table 4). The highest hundred seed weight (26.46 g) was recorded with inoculation rhizobium inoculants along with 75 kg NPSB ha^{-1}, followed by *rhizobium inoculation* along with 100 kg NPSB ha^{-1} which were significantly higher than control.

Table 4. Combined mean value of Chickpea Yield and Yield components as influenced by the application of Rhizobium inoculation and NPSB in Laelay maichew (Hatsebo) 2016-2017

Ino*NPSB (kg ha^{-1})	90% DTM	PH (cm)	NPPL	GY (kg ha^{-1})	HSW (g)
0 *0	108.33	32.9f	43.5f	1501e	24.98e
0 *25	109.67	34.67ef	49.73ef	1631.5de	25.45cde
0 *50	109.83	35.43cde	49.70c-f	1903.7cde	25.25de
0 *75	110	36.03ed	56.63c-f	1956.7cd	25.6bcde
0 *100	110.67	35.62de	59.97b-e	2191.8bc	26.28abc
0 *125	110	37.73bc	66.47a-e	2261.3bc	26.18a-d
0 *150	111.17	37.33bcd	64.27def	2616.9e	25.95a-d
1 *0	109.5	34.47ef	51.95def	1517.6e	25.47cde
1 *25	109.5	36cde	57.77c-f	1640.4de	25.43cde
1 *50	110.17	36.17cde	58.73b-f	1910.7cde	26.18a-d
1*75	110.33	37.1bcd	65.95a-d	2200.7c	26.53ab
1*100	111.67	38.57ab	70.18abc	2489.9b	26.65a
1*125	111.83	38.83ab	76.8a	3514.3a	26.57a
1 *150	113	40.40a	73.83ab	3609.1a	26.82a
Grand.mean	110.4	36.53	60.39	2210.39	25.95
LSD (5%)	NS	2.11	15.31	437.94	0.94
CV (%)	4.4	5.01	22.2	17.21	3.16

Ino indicates for Rhzobium inoculantion; 0= uninoculated, 1= inoculated with rhizobium; DM= days to maturity; PH= plant height; NPPL= number of pods per plant; GY=grain yield; HSW=hundred seed weight. Means followed by the same letter(s) with in a column are not significantly different at P = 0.05

Table 5. Net benefit analysis of NPSB application and rhizobium inoculation on chickpea grain yield in Hatsebo (2016-2017)

Ino*NPSB (kg ha^{-1})	Yield (kg ha^{-1})	adj yield	Gross field benefit	Total variable cost	Net benefit
0*0	1501	1350.9	29719.8	0	29719.8
1*0	1517.6	1365.84	30048.48	40	30008.48
0*25	1631.5	1468.35	32303.7	482.19	31821.5125
1*25	1640.4	1476.36	32479.92	522.19	31957.7325
0*50	1903.7	1713.33	37693.26	964.38	36728.885
0*50	1910.7	1719.63	37831.86	1004.38	36827.485
0*75	1956.7	1761.03	38742.66	1446.56	37296.0975
1*75	2200.7	1980.63	43573.86	1486.56	42087.2975
0*100	2191.8	1972.62	43397.64	1928.75	41468.89D
1*100	2489.9	2240.91	49300.02	1968.75	47331.27
0*125	2261.3	2035.17	44773.74	2410.94	42362.8025 D
1*125	3514.3	3162.87	69583.14	2450.94	67132.2025
0*150	2616.9	2355.21	51814.62	2893.13	48921.495D
1*150	3609.1	3248.19	71460.18	2933.13	68527.055

0= inoculated; 1= inoculated; D = Dominated (any treatment that has net benefit less than or equal to that of a treatment with lower cost that vary is dominated)

Partial budget analysis of combine effects of rhizobium inoculation and NPSB fertilizer applied indicated that inoculation with 125 kg NPSB ha^{-1} was the most economical with maximum marginal rate of return (4106.48%) followed by inoculation along with 75 and 100 kg ha^{-1} NPSB respectively (Table 5 & Table 6).

Table 6. Mariginal rate of analysis of NPSB application and rhizobium inoculation on chickpea grain yield in Hatsebo (2016-2017)

Ino*NPSB (kg ha^{-1})	Adjusted yield	Gross field benefit	Total variable cost	Net benefit	MRR%
0 *0	1350.9	29719.8	0	29719.8	_
1*0	1365.84	30048.48	40	30008.48	721.7
0 *25	1468.35	32303.7	482.19	31821.5125	410.01
1 *25	1476.36	32479.92	522.19	31957.7325	340.55
0*50	1713.33	37693.26	964.38	36728.885	1078.99
1*50	1719.63	37831.86	1004.38	36827.485	246.5
1*75	1980.63	43573.86	1486.56	42087.2975	1090.82
1 *100	2240.91	49300.02	1968.75	47331.27	1087.54
1 *125	3162.87	69583.14	2450.94	67132.2025	4106.48
1 *150	3248.19	71460.18	2933.13	68527.055	289.28

0= inoculated; 1= inoculated; Marginal rate of return = Marginal net benefit x 100/Marginal cost; Current Price of chickpea= 22 birr/kg

4. Conclusion

The interaction effect of NPSB and inoculation for most of the parameters were significant in each year and across the two years. The highest grain yield of chickpea was recorded from the inoculated seed planted with the application of 125,150 and 100 kg ha^{-1} blended (NPSB) fertilizers, respectively in decreasing order over the two years at Hatsebo research site in Laelay maichew district. However maximum marginal rate of return were obtained from 125, 75 and 100 kg ha^{-1} NPSB along with rhizobiaum inoculation. Therefore, 125 kg ha^{-1}NPSB along with rhizobiaum inoculation would be the optimum treatment combination for enhancing chickpea grain yield and profitability in soils having low NPSB availability.

Conflict of interest

The authors have not declared any conflict of interest.

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