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Demonstration of NPSB and *Rhizobium* Inoculation on Chickpea yield and Profitability in Hatsebo (Laelay Maychew)

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Authors' contributions

This work was carried out in collaboration among all authors. All authors read and approved the final manuscript.

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Original Research Article

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ABSTRACT

Justification: Chickpea yieldunder farmers condition is far below compared to the research and potential yield. To fill the yield gap demonstration of NPSB (nitrogen phosphorus sulphur and boron), along with *Rhizobium* inoculation was carried out on chickpea in Laelay Maychew District (Hatsebo) which is the potential chickpea growing area in 2019/2020.
Objectives: i) To demonstrate and increase farmers' productivity through combined application of NPSB *Rhizobium* inoculation on chickpea crop. ii) To analyze farmers' perception towards the Blended fertilizer with *Rhizobium* inoculation.
Methodology: 29 volunteer farmers were selected in the demonstration. Yield was measured using Quadrant 1*1m as well as semi-structured questionnaire also used to collect the feedback of the

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respondents towards the improved variety. Descriptive statistics and Likert scale analysis method was used to analyze the data collected perception of the beneficiary farmers. Statistical Analysis software (SAS) used for yield analysis.

Results: The result showed that in the intervention area the improved chickpea variety (Dalota) accompanied with NPSB + *Rhizobium* inoculation (CP-M-41) showed high yield (2226kg ha^{-1}) compared to untreated plots with a yield of 1808kg ha^{-1} which is significantly difference between the practice.It showed23.12% yield advantage over control(untreated check). The perception of respondents is also positive for most of the attributes (preferred by farmers) which was higher than the mean agreement level of mean score (3).

Conclusion: Hence, application of 125 kg ha^{-1} along with 500 g ha^{-1}could improve chickpea productivty in the area and similar site specific NPSB recommendation. It needs to be popularizd to a number of farmers in soils deficient in NPSB and low *Rhizobium* .population(CP-M-41) to increase chickpea productivity so as to improve livelihood of farmers.

Keywords: Demonstration; chickpea; NPSB; Rhizobium inoculation; yield; profitability.

1. INTRODUCTION

Pulses are essential sources of protein and minerals as they provide 15-40% of protein compared to 6 to 10% for cereals and contain essential amino acid lysine, which is missing in cereals [1]. Pulses supply a cheaper source of protein for smallholders than meat, fish and dairy products. For the 40 percent of Ethiopians who identify as orthodox Christians, pulses are particularly crucial during the fasting season.

Pulses are generally more profitable than cereals, giving smallholders an economic incentive to increase pulse production. It gives up to 20% higher profit compared with Tef and four times higher compared with barley and comparable returns to wheat [2].

Chickpea is among the most important food legume crops widely produced globally next to soya bean and dry bean/haricot bean in area coverage and volume of production. Globally its production is 18,095,248 tons from 14,810,916 hectares of land [3].

In Ethiopia, chickpea production took the third rank in area and volume of production among legumes next to faba bean and haricot bean. From 504,569.99 ha of land 10,706,36.5 ton, from 208,295.03 ha, 367,030.00 tonand 177,546.76 ha, 3,740,36.2 ton were produced infaba bean, haricot bean and chickpea respectively(CSA,2021) [4]. Chickpea is one of the most significant pulse crops in Tigray. Chickpea is widely grown throughout nearly all woredas in the region. Currently, around 35,361 house holds are engaged in the production process with the potential to reach up to 120,000 number of house holds and area covered of 7,556.02 ha. The production and productivity was 1,179.77 ton ha^{-1} and 1.56 ton ha^{-1} respectively and ranked second after faba bean in terms of area coverage and production **[**4]. This indicates the significant importance of chickpea in the region as an excellent source of animal feed and human protein and source of income (high price at both grain and green pod).It is cultivated in rotation with cereals and double cropped wheat, barley, and tef for early harvest. It can fix 60-80% of its nitrogen requirement from the atmosphere [5].

Yield is a quantitative trait that is influenced by genetic and environmental factors among which nutrients have basic functions in biological processes, growth, and development. Therefore, yield is a cumulative effect of different nutrient constituents and variety of which each has its influence in an increasing or decreasing magnitude. Inspit of the significant increment of chickpea yield through combined application of NPSB and *Rhizobium* inoculant(CP-M-41)compared to untreated check(control) at Hatsebo research station [6].

However, the productivity, acceptance and profotability of these technologies has not yet tested under the farmers' condition in a large plot area. Therefore this study was initiatedi) to demonstrate the Blended fertilizers (NPSB) along with *Rhizobium* inoculation on farmers' fields.ii) To analyze farmers' perception towards Blended fertilizer with *Rhizobium* inoculant (CP-M-41).iii) To increase farmers' productivity and production through Blended fertilizer with *Rhizobium* inoculation of chickpea.

2. MATERIALS AND METHODS

2.1 Description of the Study Area

The the demonstration was carried out in in La'elay Maychew district at Hatsebo peasant association in 2019/2020 main cropping season. It is the potential for chickpea growing and the trial was conducted for 2 years on a research station based on the site Specific fertilizer recommendation [7] prior to the demonstration. It is situated in a geographical location of 14°6'46"N to 38°46'3" E at an altitude of 2084 meter above sea level (m.a.s.l) which can be classified as $SM_2 5D_2$(sub-moist mid-highland**).**

The major farming system is a mixed cereal/ legumes-livestock system. Teff, chickpea, wheat and grass pea are commonly grown in the area. The area receives a mono modal rainy season 300 mm to 800 mm rainfall per annum concentrated in the months of July to September. The soil type of the area is clay dominated soil (vertisol).

2.2 Sample Size, Sampling Technique and Procedures

Demonstration of Blended fertilizer rate (NPSB) along with *Rhizobium* inoculation on improved chickpea variety (Dalota) has been conducted in 2019/ 2020 cropping season. Site and participant farmers (Beneficiary farmers) selected in collaboration with DAs and Woreda Extension workers.

Twenty nine (29) farmers were selected and grouped as Farmers Research Group (FRG). The demonstration comprises 2 treatments (125kgNPSB with *Rhizobium* inoculation /CP-M-41/ and farmers own experience(untreated with any fertilizer or inoculant). Each farmer was allocated 20mx20m plot area for each treatment. 400m^2 used to for the research output and the other 400m^2 used for planting farmers own practices. Training was organized and delivered to farmers, DAs and Extension workers with practical application of *Rhizobium* inoculation.

The only commercial inoculant manufacturer in Ethiopia, inoculants Menagesha Biotech Industry PLC, Addis Ababa, was the source of the that were purchased. The inoculant contained chickpea *Meso Rhizobium* strains (CP-M-41) and lignite as a carrier. The strain have been evaluated in Ethiopia throughout a broad spectrum of ecological circumstances [5,8]. Using a sugar solution as a sticker, 5 g of inoculant per kg of seed was used to inoculate the seeds. Before planting, the inoculated seed was allowed to air dry for a few minutes after being injected under shade. To prevent cross-contamination, uninoculated treatment plots were sowed first on all farms.

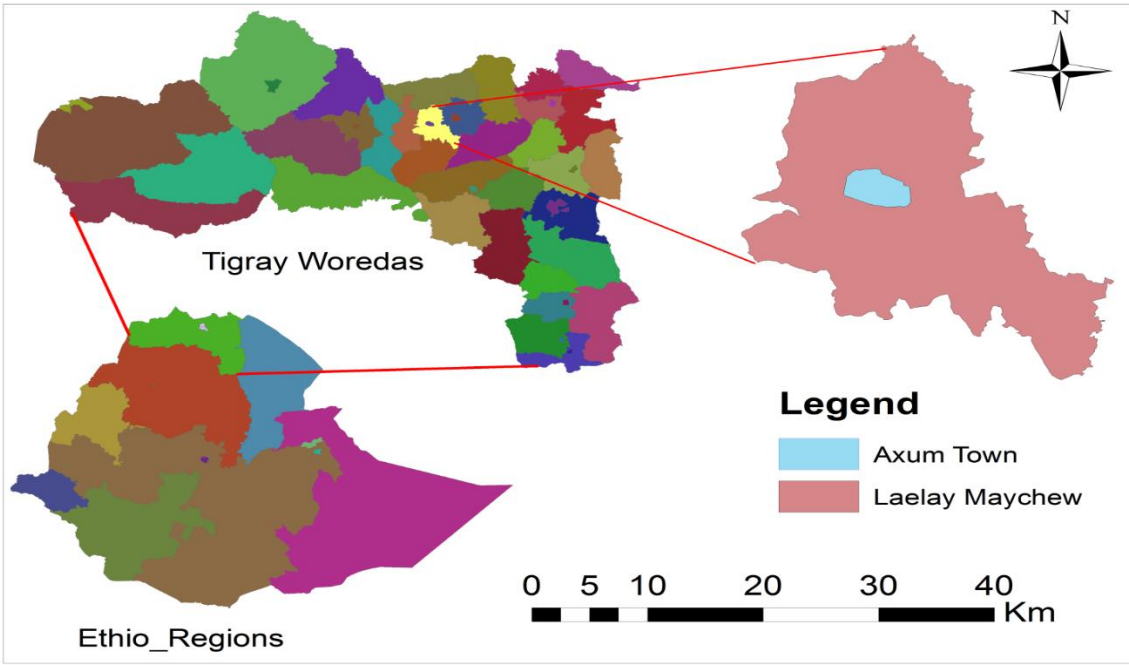

Fig. 1. Map of the study woreda (district)

2.3 Data Collected

Yield data were collected from 1mx1m sample area from eleven (11) farmers for yield analysis at Hatsebo (Laelay Maychew district) in 2019/2020.Moreover, Questionnaire was prepared to collect demographic characteristics and Economic profile of the household, Farmers' perception on technology attributes i.e., before harvest and post-harvest *i.e.,* vegetative, productivity, marketability, product quality, taste and palatability data collected during the follow-up and the field days and conducted survey.

2.4 Data Analysis

Yield data was anlyzed by using the Statistical analysis software [9] using independent samples T-test method.As well as descriptive statistical (mean, minimum, maximum and standard deviation) and Perception data were analysed by SPSS software [10] using Likert scale(1-5). 1 indicates for strongly diagree, 2=diagree, 3=no change, 4=agree and 5= strongly agree.

Partial budget analysis of the *Rhizobium* and blended (NPSB) fertilizer treatments were performed on the basis of prevailing market prices [11]. 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 chickpea in 2019/2020 was used for partial budget analysis.

Net benefits for each treatment were calculated by subtracting the variable costs from the gross income. And the marginal rate of return(MRR) was calculated by comparing the marginal (extra) cost with the marginal net benefit. Because higher net benefit may not be accepted if they are attained at higher costs.Marginal analysis was calculated by using the net benefit and variable cost values. Final recommendations (correct evaluation of alternative technologies) to farmers were given on the basis of marginal rate of return, which was calculated by the following formula [11].

Marginal rate of return (%)=

$$\frac{\text{Change in net benefit}(\Delta \text{I})}{\text{Change in variable cost}(\Delta \text{C})} \text{x}100$$

3. RESULTS AND DISCUSSION

3.1 Grain Yield Response of Chickpea to NPSB and *Rhizobium* Inoculation

The result of NPSB and *Rhizobium* inoculation compared to control (existing practice) on chickpea yield are presented in Table 1. It was originally hypothesized that application of NPSB (Nitrogen Phosphorus, sulfur and Boron) combined with effective Rhizobium inoculation could significantly increase chickpea yield. The result also agrees with the stated hypothesis. The results of data collected from the NPSB along with *Rhizobium* inoculation suggested that there was significant difference (P=0.017) between the combined application of NPSB +I (*Rhizobium* inoculated) and control(I0) for grain yield. This could be due to the synergistic effectof phosphorus (36% in the form of P_2O_5 compared to 19%N in the NPSB) and Rhizobium inoculation, contributed to high number of pods per plant. Phosphorus improves root development, which in turn supports more effective *Rhizobium* colonization and nitrogen fixation. Inaddition to this Nitrogen could be used as a starter until the crop starts to fix atmospheric nitrogen. This result agrees with the findings of Wolde-meskel et al*.* [12] who reported that combined application of Phosphorus fertilizer along with effective Rhizobium inoculation significantly increased yield of chickpea across smallholder farms in Ethiopia. Wolday & Teklu [6] also reported significantly higher chickpea grain yield from the combination of NPSB and *Rhizobium* innoculated plot than the control (existing practice).

The analysis result showed application of NPSB and *Rhizobium* inoculation on the improved variety (Dalota) gave an average 2226 kg ha^{-1} while from the control plot obtained 1808 kg ha^{-1} (Table 1). Yield difference of 418 kg ha^{-1} was recorded between the combined application of NPSB along with *Rhizobium* inoculation and the cotrol on chickpea (dalota) variety. Yeld increment of 23.12% obtained with the combined application of NPSB + *Rhizobium* inoculation (I) from the control plot(I0).The result coincides with the findings of Tirfessa et al. [13] who reported that application of blended fertilizers to innoculated common bean variety increased yield by 112% over the control (untreated check) in acidic soil, western Ethiopia. Furthermore, inoculation of *Rhizobium etli* strain along with application of NPSB at the rate of 100 kg ha^{-1} found to be the suitable treatment combination at

Sodo Zuria in Southern Ethiopia [14,15]. Others research findings also confirmed that application of site specific blended fertilizer or ionrganic fertilizers combined with *Rhizobium* inoculation has significantly increased yield in faba bean and common bean [16,17,18].

The shortest days to maturity was observed from the combined application of NPSB along with *Rhizobium* application from the control plots(data not shown). Hence, the expected result secured against to the proposed action. This could be due to the high proportion levels of P_2O_5 (36%), as phosphorus fertilier has significant effect for early maturing of crops.

Higher mariginal rate of return (499%) was obtained by the combine application of NPSB along with effective *Rhizobium* inoculation(CP-M-41) on the popular chickpea variety (Dalota) at Hatsebo (Table 2). This indidates by investing 1 birr to the NPSB and *Rhizobium* innoculant a 4.99 birr return could be obtained. CIMMYT mannual partial budget of analysis indicates tha an increase in output will always rise profit as long as the marginal rate of return (MRR) is higher than the minimum rate of return *i.e.* 100% [11]. Similar result was reported by Wolde-meskel et al. [12] who reported that by the combined application of phosphorus fertilizer and *Rhizobium* inoculation the benefit of farmers increased across smallholder farms in Ethiopia. Bam [19] also concluded and reported that application of biofertilizers in combination with organic or inorganic fertilizers could incresea mungbean yield and financial viability compared to the untreated check.

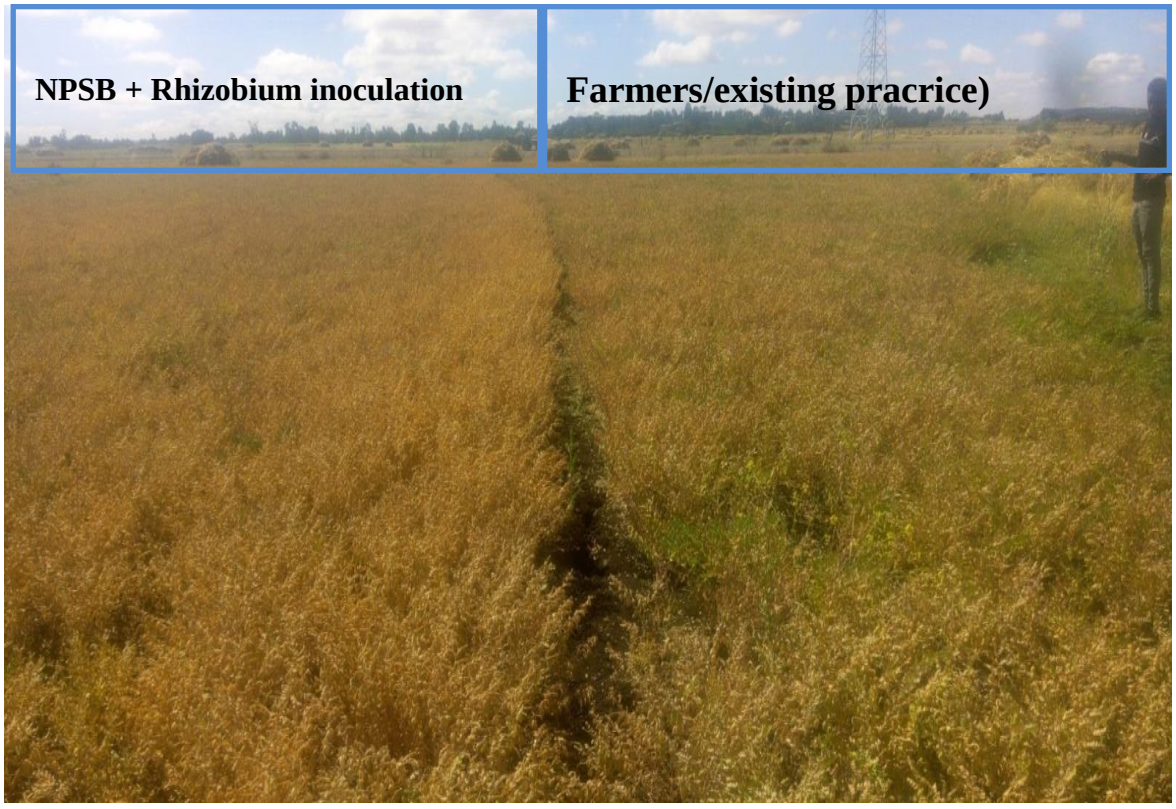

Fig. 2. Photo showing Performance of chickpea-at maturity stage at farmers field (Hatsebo)

Table 1. Average grain yield (kg ha^{-1}) of chickpea (Dalota) with NPSB and *Rhizobium* inoculation Vs the existing practice in L/Maychew District,2019/2020

Treatments	N	Min	Max	Mean	Sd	t-value	p-value
NPSB +I	29	1759	2717	2226	328.2	2.661	0.017
Untreated check (control)	29	1353.5	2348	1808	337.2		

N.B: I=Inoculant; Sd= standard deviation

Table 2. Partial budget Analysis of NPSB and *Rhizobium* inoculation, 2019/20

Variables costs	Control (Farmers actual practice)	NPSB + I(inoculation)
Average yield (kg ha^{-1})	1808	2226
Gross Benefit (Eth birr ha^{-1})	37.33*1808=67493	37.33*2226=83096.58
Cost of NPSB (Eth birr ha^{-1})	0	125*15.6517=1956.4625
Cost of CP-M-41(Eth birr ha^{-1})	0	160
NPSB application+ Inoculation	0	600
Total Variable cost (Eth birr ha^{-1})	0	2716.4625
Net benefit (Eth birr ha^{-1})	67493	81061.58
MRR(%)	**499**	

Table 3. Participants (farmers') perception on the chickpea variety attributes

Positive attribute sentences	Perception level (n= 11)					Mean score	Sd
	Strongly agree (5)	Agree (4)	No change (3)	Disagree (2)	Strongly disagreed (1)		
Vegetative	2 (18.18)	5 (45.45)	3 (27.27)	1 (9.1)	0	3.73	3.73
Early mature	0	8 (72.72)	2 (18.18)	1 (9.1)	0	3.64	3.64
Resistant disease	0	1 (9.1)	9 (81.81)	1 (9.1)	0	3	3.00
Good Pod size	0	6 (54.54)	5 (45.45)	0	0	3.55	3.55
Product quality	2(18.23)	3 (27.27)	6 (54.54)	0	0	3.6	3.33
Productivity	0	6 (54.5)	3 (27.3)	2(18.18)	0	3.36	3.33
Profitability	0	8 (72.72)	2 (18.18)	1 (9.1)	0	3.7	3.70
Average weight	-	-	-	-	-	3.5	3.47
Proportion %	-	-	-	-	-		70

Sd= standard deviation

3.2 Respondents' Perception towards the NPSB with *Rhizobium* Inoculation on Chickpea

The response of respondents shows that there wsa a difference in perception in most of the pre- and post-harvest towards the characteristics of combined application of NPSB and Rhizobium inoculation. The respondents agreed on the attribute like vegetative ability, early maturity, pod size, productivity and yield quality. The mean average of the agreement level of the respondent shown that is high (3.5) above the mean score (3.0) against the farmers practiced. Generally, most of the respondents evaluated the new application of input is a positive change (high) in majority of the criteria's set compared to the existing farmers practice. Similar positive response of respondents reported by Hando and Gemayda [15], who reported that field performance of maize crop under new rate (100 NPSB + 260 Urea) kg ha^{-1} of blended fertilizer was more preferred to the existing extension practices.

4. CONCLUSION

Site specific blended fertilizer (NPSB) application along with *Rhizobium* inoculation was increased the yield of chickpea demonstrated on the popular variety of chickpea (Dalota) in La'elay Maychew district at Hatsebopeasant association on 29 farmers (beneficares) in 2019/20, production year. In the intervention area the improved chickpea variety (Dalota) that received technology packages (125 hgha^{-1}NPSB and *Rhizobium* inoculation (CP-M-41) gave yield advantage of 23.12% over theuntreated check (control). Besides, The maximum net benefit (81061.58 Eth birr) and acceptable mariginal rate of return (499%) was achieved by the combined application of NPSB and Rhizobium inoculation compare to the control. In addition to this,By the combine application of 125 kg ha^{-1}with effective *Rhizobium* innoculant on chickpea brought about income of 29.84 times a unit total cost of NPSB + *Rhizobium* innoculat.

The perception of respondents is also positive for most of the attributes preferred by farmers. Respondents mean score of agreement shows that vegetative (3.73), early maturity (3.64), product quality (3.6), pod size (3.55) and profitability is (3.7) which is higher than the mean agreement level of mean score (3). Therefore, productivity of chickpea could be improve through combined application of blended fertilizers and effective *Rhizobium* inoculant

(technology package). Therfore, productivity and profitability of chickpea in the intervention area and in similar site specific blended fertilizer recommendation(NPSB) areas could be improved through the combined application of 125 $kgha^{-1}$ NPSB and 500 g ha^{-1} (5 g kg^{-1}) *Rhizobium* innoculant (CP-M-41) to achieve sustainable chickpea production and productivity.

DISCLAIMER (ARTIFICIAL INTELLIGENCE)

Author (s) hereby declare that NO generative AI technologies such as Large Language Models (ChatGPT, COPILOT, etc) and text-to-image generators have been used during writing or editing of this manuscript.

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COMPETING INTERESTS

Authors have declared that no competing interests exist.

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