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Research Article

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Combined application of macro and micro nutrients and Rhizobium inoculation to nodulation and yield response of chickpea (*Cicer Arietinum* L.) at Halaba Woreda, Southern Ethiopia

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ABSTRACT

The effects of combining the application of recently introduced blended fertilizer with Rhizobium inoculation on chickpea nodulation and productivity are not being studied in Halaba special woreda. Hence, the application of blended fertilizer and rhizobium inoculation for chickpea production under rain-fed conditions at Halaba Special District, Southern Ethiopia is crucial. Factorial combination of eight fertilizers (Control, NP, NPS, NPSB, NPSB+K, NPS+Zn, NPSB+Zn and NPSB+K+Zn) and inoculation and without inoculation of rhizobium biofertilizer was used as an experimental factor laid out in a randomized complete block design with three replications. Fertilizer application significantly influenced crop phenology, nodulation, growth parameters, yield and yield components, except number of seeds pod^{-1} and harvest index. Maximum days to 50% flowering (48.33) and 95% physiological maturity (112.3) were obtained on NPSB+K and without fertilizer treatment respectively. The Highest number of nodules (23.25), nodules dry weight (0.13 g), number of branches $plant^{-1}$ (17.64) and plant height (43.34 cm) were recorded on NPSB, NPSB+K+Zn, NPSB+Zn and NPS+Zn respectively. Similarly, the higher number of pods $plant^{-1}$(61.6), and hundred seed weight (28.0 g) were observed for blended fertilizer treatments of NPSB+K and NPS+Zn respectively. Maximum grain yield (1.85 ton ha^{-1}) was obtained for blended fertilizer of NPSB+K application with an increment 57.9% over control treatment. Rhizobium inoculation increased the number of nodules $plant^{-1}$ (23.29), nodules dry weight (0.11 g), number of branches $plant^{-1}$ (17.70), number of pods $plant^{-1}$ (59), number of seeds pod^{-1} (1.17) and hundred seed weight (27.7 g). Maximum grain yield (1.84 ton ha^{-1}) was recorded on rhizobium inoculated and it increased chickpea grain yield by 33.3% over uninoculated. Regarding the economic feasibility of fertilizers greater net benefits with acceptable MRR 1802, 866 and 257 were recorded for blended fertilizers of NPS, NPS+Zn and NPSB, respectively. Given the fact that the three fertilizers had statistically similar grain yields, the blended fertilizer NPS is a better choice among the three alternatives. Similarly, a higher net benefit with acceptable MRR (4189%) was recorded for Rhizobium inoculation. Therefore, blended fertilizer; NPS and Rhizobium inoculation were found to be relevant and recommended for chickpea production in the study area.

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INTRODUCTION

The chickpea (*Cicer arietinum* L.), a member of the genus Cicer, tribe Cicereae, family Fabaceae, and subfamily Papilionaceae, is one of the most significant and commonly cultivated pulse crops in the world. It is an annual herbaceous plant that branches from the root (Joshi *et al.*, 2001). It is a cool-season annual pulse crop produced in the world in temperate, subtropical, and tropical climates (Muehlbauer & Tulu, 1997). Chickpeas are the third-most significant pulse crop produced extensively in Ethiopia with 4,441,459.26 qt produced per year on an area of 225,607.53 hectares of land (CSA, 2017). Amhara, Oromia, Tigray, as well as other zones, certain unique Woredas, in the Southern Nations, Nationalities, and Peoples Regional State (SNNPRS), are some of the regions of the country where chickpea is currently grown. Chickpeas are prized for their nutrient-dense seeds, which have high protein content (25.3-28.9%), carbohydrate, fiber, Vitamin B9, folate, and magnesium Hulse (1991). Due to their ability to biologically fix nitrogen, chickpeas can increase soil fertility, and their straw is used as animal feed (Pundir & Mengesha, 1995).

The lack of soil N, P, and micronutrients are widespread in many African nations, as it is in many tropical and subtropical countries. This is because continuous farming without the addition of outside agricultural inputs has resulted in low soil fertility and high rates of soil nutrient depletion. Due to topsoil erosion, soil acidity, nutrient and organic matter depletion, and soil salinity, Ethiopia suffers from a variety of soil fertility issues (Zeleke *et al.*, 2010). For effective agriculture, the human population of the world is dependent on synthetic fertilizers. However, compared to developed and emerging countries, sub-Saharan Africa continues to use little inorganic fertilizer. This is because most mineral fertilizer used in Africa is imported, which results in their high cost, lack of availability, and poor marketing infrastructures (Chianu *et al.*, 2011). These obstacles prevent subsistence and small-scale farmers in Africa from using fertilizers, although there is an increasing need for fertilizers in many Sub-Saharan African nations to boost crop productivity and feed the world's expanding population (Mentsiro *et al.*, 2011). The use of chemical fertilizers in Ethiopia has greatly expanded since the 1980s, but it is still quite low (Zeleke *et al.*, 2010).

To balance high production with long-term economic, environmental, and social sustainability, it may also be beneficial to optimize the combined use of inorganic and organic fertilizers. The symbiosis between rhizobial bacteria and legumes is often a more effective and cost-effective agronomic technique than adding fertilizer-N to ensure an adequate supply of N for the growth of legume-based crops and pastures. In symbiosis with legumes, rhizobium bacteria have the ability to fix N from the air (N2). Thus, the symbiotic relationship enables the huge natural source of N from the air to be absorbed, which reduces or eliminates the need to apply N mineral fertilizer to the field (Abbas *et al.*, 2011). Rhizobium inoculation starts the root growth and boosts the above-ground biomass of faba beans, according to Al-Ani and Adhab (2013). A pulse crop with rhizobium inoculation yields 10-15% more grain than a crop without inoculation (Fatima *et al.*, 2008).

Phosphorus is one of the most important nutrients for plants, and chickpea types profit substantially from its use. Phosphate fertilization of chickpeas promotes growth and nodulation, which raises output. According to Kumar *et al.* (2016), phosphorus is essential for the shoot's toughness, improves grain quality, regulates photosynthesis, and regulates physical-biochemical processes, all of which support nitrogen fixation. Phosphorus increases rhizobial activity, encourages the growth of root nodules, and helps root nodules fix more atmospheric nitrogen either as seed coats or as granular fertilizer applied into the soil. Potassium promotes root development and plant vigor, aids in preventing lodging, and increases crop resilience to pests and diseases. Potassium is highly effective at promoting nodulation in pulse crops, which enhances seed output by improving nitrogen fixation (Rajput, 2018). According to statistics from Ethiopia's national soil survey, in addition to the macronutrients, some micronutrients including zinc, boron, and copper have been depleted from the soil in the country's main crop-producing regions because of long-year farming. The greatest way to reduce the risk of nutrient losses to the environment is through balanced fertilization, which also ensures optimal crop production, better food quality, and benefits for the growers. When added at a reasonable cost to new fertilizer formulations and targeted at soils with deficiencies, nutrients like Zn, B, S, and K can significantly increase fertilizer usage efficiency and crop profitability (John *et al.*, 2000). Ethiopian soil lacks around seven nutrients, including N, P, K, S, Cu, Zn, and B, according to a soil fertility map created over 150 districts (Ethio SIS, 2013). Ethiopian producers of grains and pulse crops have recently been encouraged to use blended fertilizers rather than the more conventional compound or straight fertilizers. However, it is unclear how these fertilizers would affect crops, particularly pulse crops, and what their comparative advantages will be. However, there is a dearth of information on blended fertilizers and studies on Rhizobium inoculation concerning the production of chickpeas in the study region. According to a personal conversation, the farmers in Halaba frequently follow the general fertilizer requirement of 100 kg NP ha^{-1}. Therefore, a study on different fertilizer kinds and Rhizobium inoculation are necessary to develop pertinent suggestions that would aid farmers in increasing their output. Therefore this study was conducted to; - Investigate the effect of different types of blended fertilizers and Rhizobium inoculation on yield, yield components and its economic feasibility of chickpeas at Halaba Special Woreda.

MATERIALS AND METHODS

Description of the Experimental Site

The experiment was carried out on a farmer's field at Halaba Special Woreda during the main cropping season of 2016. Halaba Woreda is located 315 kilometers south of Addis Abeba and 85 kilometers southwest of Hawassa, the capital city of the SNNPR region. Its elevation ranges from 1554 to 2149 meters above sea level. The annual mean temperature ranges from 17 °C to 20 °C with a mean value of 18 °C, and the annual mean rainfall ranges from 857 to 1085 mm. The region experiences bimodal rainfall, with the smallest amounts falling between March and April and the heaviest amounts falling between July and September during the Meher season (from June-September), crops like maize, teff, wheat, pepper, haricot beans, sorghum, and millet are cultivated in the region.

Experimental Design and Treatments

A factorial, randomized complete block design with three replications was used to arrange two Rhizobium inoculations; uninoculated (-I) and inoculated (+I) with eight nutrient combinations (control, NP, NPS, NPSB, NPSBK, NPSZn, NPSBZn, and NPKSBZn). There were sixteen plots (2.1 m x 2.1 m) in each replication, one for each of the sixteen treatment combinations. Plots and blocks were separated by 1 and 0.5 meters, respectively. Each plot was given treatment randomly within the block. A space of 30 cm between rows and 10 cm within rows was used for sowing the seed. In addition to borax (11 B) and zinc sulfate (23Zn and 10S), two newly introduced blended fertilizers, NPS (19N-38P_2O_5-7S) and NPSB (18.1N-36.1P_2O_5-6.7S-0.71B), were used as sources of nutrients (Urea (46 N), TSP (46 P_2O_5), Muriate of Potash (60 K_2O), and NP (18 N - 46 P_2O_5)). One treatment was the 100 kg NP rate for chickpeas that was nationally recommended (18N-46P). To bring the macro- and micronutrient levels of the blended fertilizers to the levels suggested for chickpea, urea, TSP, borax, KCl, and zinc sulfate were added to the fertilizers. Table 1 lists the specific nutritional combinations that were employed in the experiment.

Using sugar solution as a sticker, seeds were infected at a rate of 5 g of inoculant per kilogram of seeds (Belete *et al.*, 2019). The seed was infected in a shaded area and allowed to air dry for a short while before being sown. To prevent cross-contamination, plots designated for uninoculated treatments were seeded first. Regardless of the treatments, all recommended crop husbandry practices for chickpea were consistently applied to all plots. Each plot was harvested at the end of the growing season, with just one border row left on each edge.

Soil Sampling and Analysis

Before planting, a single representative composite sample was obtained using an auger at a depth of 0-20 cm from randomly chosen sites diagonally across the experimental area. The sample was mashed in a pestle and mortar and allowed to pass through a 2 mm sieve after being air-dried. Working samples were taken from the sample that was provided, and they were examined for several physicochemical characteristics, total nitrogen, available phosphorus, potassium, sulfur, boron, and zinc (as well as soil texture, pH, organic matter, cation exchange capacity, and carbon to nitrogen ratio). Mehlich (1978a) employed the Mehlich 3 soil testing method to obtain as many crucial plant nutrients as feasible.

Nodulation

Five randomly selected plants from each plot were used to measure nodulation at the mid-flowering development stage,

Table 1: Composition of fertilizer treatment for the experiment

Nutrient combinations	Nutrient composition					
	N	P_2O_5	S	$ZnSO_4$	Borax	K_2O
NP	18	46				
NPS	9.5	19	3.5		0.835	
NPSB	23	46	7		0.835	41
NPKSB	23	46	7			
NPSZn	23	46	8.5	3		
NPSBZn	46	69	11.5	1.5	1.67	
NPKSBZn	23	46	10	3	1.67	41

and the mean value was calculated. The number of nodules Plant^{-1} was counted after the plants were properly uprooted and cleaned. Counted nodules were oven dried at 50°C, and plant-1 nodule dry weight was recorded.

Phenology, Growth and Yield-Related Data

By counting the number of days from plant emergence until 50% and 95% of the plants on the plot produce flowers and pods become yellow, days to flowering and physiological maturity were recorded respectively. Five randomly selected plants were used to calculate the height, number of seeds per pod, and number of branches per plant. From 100 randomly chosen seeds from each plot, the weight of one hundred seeds (g) was calculated and adjusted to a 10% moisture level. After removing the single border row from each plot's edge and harvesting the plants from each plot, the above-ground dry biomass, and grain yield (ton ha^{-1}) were measured. The harvest index was determined as the percentage of above-ground dry biomass to grain yield (Unkovich *et al.*, 2010).

Partial Budget Analysis

A study of the experiment's economic feasibility was conducted using economic analysis. Marginal and partial budget assessments were used. The average grain yield was reduced by 15% to reflect the discrepancy between the experimental output and the yield farmers can expect from the same treatment. The average open market price (30.00 Birr kg^{-1}) for chickpea crop, the official prices of NP (14.10 Birr kg^{-1}), TSP(12.00 Birr kg^{-1}), Urea (10.69 Birr kg^{-1}), NPS (14.10 Birr kg^{-1}), NPSB (16.00 Birr kg^{-1}), Zinc sulfate (17.98 Birr kg^{-1}), KCl (11.00 Birr kg^{-1}), Borax (12.00 Birr kg^{-1}) and Rhizobium inoculant (1.60 Birr kg^{-1}) were used for analysis. According to CIMMYT (1988), a treatment was supposed worth, while for farmers when it's minimum acceptable rate of return (MAR) was between 50% and 100%. This makes it possible to use marginal analysis to give farmers suggestions.

Statistical Analysis

Statistical analysis systems (SAS Version 9.2) were used to analyze the variance of the data. At 5% levels of significance, Fisher's least significant (LSD) test was used to separate the means. Between yield, yield components, and other important factors, a correlation study was done.

RESULTS AND DISCUSSION

Soil Physico-chemical Properties of the Experimental Site

The study area of the soil test was clay loam texture in a composite soil sample test (Table 2). The soil's pH was 6.88, which is considered neutral (EthioSIS, 2014). According to Mahler *et al.* (1988) the ideal pH range for chickpea is 5.7 to

7.2. This suggests that the experimental site's soil reaction is suitable for promoting the best possible chickpea growth and yield. According to Mehlich (1978a, b) available potassium (228.46 mg kg^{-1}) was high while available sulfur (6.80 mg kg^{-1}) and total nitrogen (0.09%) were very low. Available boron (0.73 mg kg^{-1} (ppm)), zink (1.42 mg kg^{-1} (ppm)), and organic matter (2.22 mg kg^{-1}) were low, While, the ideal phosphorus concentration, the carbon to nitrogen ratio, and cation exchange capacity were 31.94 mg kg^{-1}, 16.75% and 19.73 Meq^{-1} 100 g, were optimum respectively Mehlich (1978a).

Weather Conditions during the Experimental Period

The total amount of monthly rainfall and maximum temperature observed during the experiment was presented in Figures 1 and 2. During the growth season, a mean maximum temperature of 29.175 °C was recorded. The same statistics also showed that rain precipitation significantly dropped and eventually stopped altogether later in the growing season. In September, October, November, and December, the crop received 123.4, 58.6, 50, 4, and 0 mm of precipitation, respectively.

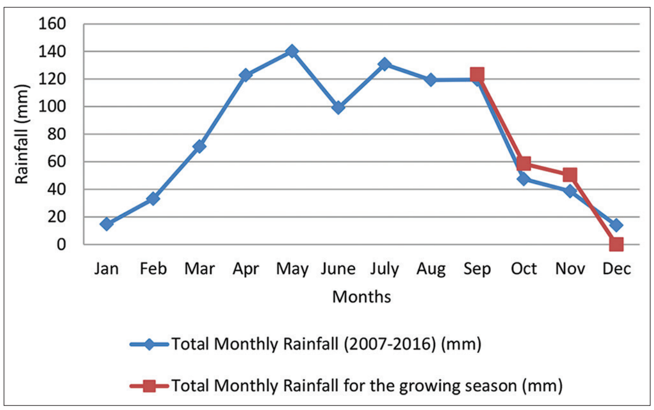

Figure 1: Total monthly rainfall during the crop growth season, September to December, 2016 at Halaba Special Woreda

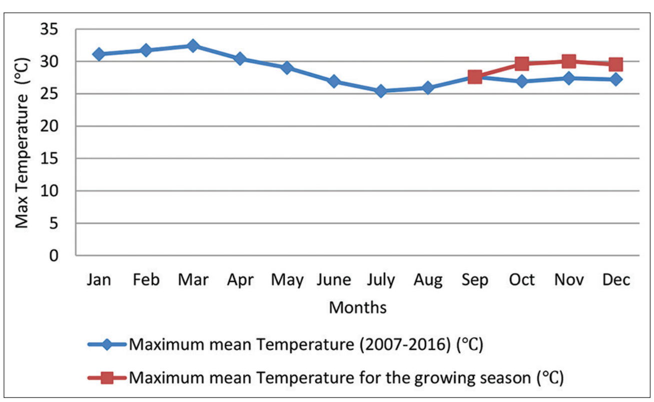

Figure 2: Mean temperature during the crop growth season, September to December 2016 at Halaba Special Woreda

Effects of Fertilizer Application and Inoculation on Phenology of Chickpea

Days to flowering

Days to 50% flowering were significantly different on blended fertilizer application while inoculation of Rhizobium and the interaction between the two factors were not significantly different at ($P < 0.05$). The maximum days (50.17) to 50% flowering was obtained with no fertilizer application which is an insignificant difference with NP application, while the lowest (48.17) days to flowering were recorded on the blended fertilizer application with insignificant differences among them (Table 3). These findings are consistent with those of Fageria *et al.* (2002), who found a beneficial relationship between B, K, and N fertilizers and the lengthening of flowering days. Chimdessa (2016) also noted a similar result. On days to 50% blooming, rhizobium inoculation had no significant impact on chickpea growth. Similar to this, Verghis *et al.* (1993) found, no variation in days to blooming of rhizobium inoculation. In contrast to these, Verma *et al.* (2013) reported that rhizobium inoculation for chickpeas delayed the days to flowering.

Days to physiological maturity

The applied fertilizer treatments had a substantial (P 0.05) impact on days to 95% physiological maturity, while Rhizobium inoculation and the interaction of the experimental factors had no effect. On control treatments, the greatest number of days (112.17) to 95% physiological maturity was noted with insignificant variation with NP. The minimum (110.17) days were found in NPS and an insignificant difference with the other blended fertilizers (NPS+Zn, NPSB, NPSB+K, NPSB+K+Zn, and NPSB+Zn) (Table 3). Under these, Chimdessa (2016) discovered that the use of blended fertilizers, maize mature early. Rhizobium inoculation did not affect days to maturity. However, Bejandi *et al.* (2012) found that, in comparison to treatments without inoculation, inoculation of seeds decreased days to physiological maturity in chickpeas.

Number of Nodule plant^{-1}

Number of nodules $plant^{-1}$ was significantly influenced by blended fertilizer treatment and Rhizobium inoculation (Table 4). The NPKSB treatments had a higher number of nodules $plant^{-1}$ (23.25), while the control treatments had the fewest nodules (7.87). There were no statistically significant differences among the other blended fertilizer (NPSB+K, NPS+Zn, NPSB+Zn, NPSB+K+Zn) treatments. These findings might point out the effect of nitrogen and phosphorus application on nodule number $plant^{-1}$. According to Surendra and Katiyar (2010), the number of nodules $plant^{-1}$ (21.13) in mungbean increased noticeably after the application of 40 kg S ha^{-1}. Nelson *et al.* (1978), noted potassium affects root growth, which affects crop growth and nodule development. Researchers

Table 2: Physical and chemical properties of experimental soil

Soil characters	Values	Rating †
pH $_{(H20)}$	6.88	Neutral
Total N (%)	0.09	Very low
Mehlich *P* (mg kg^{-1})	31.94	Optimum
Mehlich K (mg kg^{-1})	228.46	High
Mehlich S (mg kg^{-1})	6.80	Very low
Mehlich B (mg kg^{-1})	0.73	Low
Mehlich Zn (mg kg^{-1})	1.42	Low
Organic matter (%)	2.22	Low
Carbon to nitrogen ratio (%)	16.75	Optimum
Cation exchange capacity (Meq^{-1} 100 g)	19.73	Optimum

†Based on EthioSIS (2014)

Table 3: Main effects of fertilizers and *Rhizobium* inoculation on phenology of chickpea

Treatments	Days to flowering	Days to maturity
Control	50.17^{a}	112.3^{a}
NP	49.50^{a}	112.17^{a}
NPS	48.17^{b}	110.17^{b}
NPSB	48.17^{b}	110.50^{b}
NPSB+K	48.33^{b}	110.50^{b}
NPS+Zn	48.17^{b}	110.33^{b}
NPSB+Zn	48.17^{b}	110.83^{b}
NPSB+K+Zn	48.17^{b}	110.50^{b}
LSD$_{0.05}$	0.76	0.67
Inoculation		
Inoculated	48.79^{a}	110.54^{a}
Non-inoculated	48.42^{a}	110.30^{a}
LSD	0.38	0.33
CV%	1.33	0.51

Means within a column followed by the same letters are significantly similar at 5% probability level

Table 4: Effects of fertilizers and *Rhizobium* inoculation on nodulation and growth of chickpea

Treatments	Nodule No. plant^{-1}	Nodule dry Weight plant^{-1}	No. of Branch plant^{-1}	Plant height
Control	7.87^{b}	0.04^{c}	12.12^{c}	35.97^{b}
NP	12.57^{b}	0.05^{c}	13.02^{bc}	36.17^{b}
NPS	20.26^{a}	0.12^{ab}	15.60^{a}	42.22^{a}
NPSB	23.25^{a}	0.10^{ab}	15.16^{ab}	41.68^{a}
NPSB+K	19.92^{a}	0.11^{ab}	15.73^{a}	42.99^{a}
NPS+Zn	21.33^{a}	0.09^{b}	16.42^{a}	43.34^{a}
NPSB+Zn	19.12^{a}	0.12^{ab}	17.64^{a}	40.32^{ab}
NPSB+K+Zn	21.55^{a}	0.13^{a}	17.10^{a}	40.21^{ab}
LSD$_{0.05}$	6.23	0.03	2.50	4.70
Inoculation				
Inoculated	23.29^{a}	0.11^{a}	17.70^{a}	41.59^{a}
Non-inoculated	13.18^{b}	0.08^{b}	12.99^{b}	39.38^{a}
LSD	3.11	0.015	1.25	2.35
CV%	28.96	26.93	13.80	9.85

Means within a column followed by the same letters are significantly similar at 5% probability level

Mathan *et al.* (1996) and Reddy (1998) discovered that applying zinc to plants improves nodulation, nitrogen fixation, and plant development. Similarly to this, Misra *et al.* (2002) found that adding 20 mg of zinc per kilogram of soil increased root nodulation by 55%. The biological nitrogen fixation is enhanced by the use of Zn, either alone or in combination with other nutrients.

Similar to blended fertilizer treatments, inoculated and un-inoculated treatments showed significant variation for nodules number plant^{-1} (Table 4). A minimum number of nodules plant^{-1} (13.18) was obtained on un-inoculated treatments. In comparison inoculated Rhizobium increased the number of chickpea nodules by 43.4% compared to the un-inoculated treatment, which may have been due to the inoculated bacteria's better ability to induce nodules in response to indigenous rhizobium populations in the soil. Native Rhizobium's lessened competitiveness with the inoculated. To increase root nodulation and crop output in soils lacking native rhizobia, chickpea seeds can be artificially inoculated (Muhammad *et al.*, 2010). According to Gul *et al.* (2014), more inoculated plants (10.86 nodules plant^{-1}) were found than uninoculated plants (7.86 nodules plant^{-1}). Nodules in un-inoculated treatments are a sign that there is an indigenous rhizobial population present in the soil.

Nodules dry weight

The application of macro and micronutrients and Rhizobium inoculation considerably affected nodules' dry weight, but their interaction had no substantial effect (Table 4). On control treatments, the lowest nodule dry weight (0.04 g) was noted, with no significant variation with NP. The nodule with the highest dry weight (0.13g) was found on NPSB+K+Zn (Table 4). This result is consistent with Ahlawat *et al.* (2007) showing fertilization with Zn and B improved root growth, nodulation, and nodules dry weight in chickpeas. The positive effects of S on nodulation and nodule activity are also consistent with those of Tomar *et al.* (1995).

The nodules' dry weight of chickpeas improved significantly after Rhizobium inoculation. Inoculated treatments produced a higher (0.11 g) nodule dry weight plant^{-1} than non-inoculated treatments (0.08 g). This rise in nodule dry weight may be the result of the nodules' increased size and quantity as a result of the inoculated chickpea crop. Different authors found that Nodule number and dry weight were higher in the inoculated treatment than in the uninoculated treatment, Argaw (2012), Beshir *et al.* (2015), and Bhuiyan *et al.* (2008) reported a similar result.

Number of branches

The effects of blended fertilizer and rhizobium inoculation on the number of branches plant-1 were significant (Table 4). The NPSB+Zn blended fertilizers produced the highest number of branches plant^{-1} (17.64), whereas the control treatment produced the fewest (12.12) branches. The branch count increased by 34.84% over the control after the application of blended fertilizer. The increased number of primary branches in blended fertilizer is a result of P fertilizer's significance for cell division activity, which in turn leads to an increase in branch count. The presence of S also suggests that S is important for plant growth and physiological function. These findings are consistent with Khampariva (1996) discovery that Zn^{2+} contributed to the number of branches in soybeans. Additionally, the application of boron had a significant impact on the number of primary branches plant^{-1}, with the highest number (4.93) seen at 3 kg B ha^{-1} and the lowest (4.24) at the control treatment of 0 kg B ha^{-1} (Alam *et al.*, 2017). Goud *et al.* (2012) found that the number of branches per plant grew noticeably when potash levels gradually increased up to 40 kg K_2O ha^{-1}.

Rhizobium inoculation also significantly influenced the number of branches of plant^{-1}. The highest number of branch plant^{-1} (17.7) was obtained from inoculated treatment. It increased the number of branches by 36.23% compared to un-inoculated treatments. According to Ali *et al.* (2011), Rhizobium inoculation raised the number of primary branches by 8.50%. Similarly to this, Rudresh *et al.* (2005) and Togay *et al.* (2008) reported the highest branches of plant^{-1} were obtained on inoculated Rhizobium.

Plant height (cm)

The application of fertilizer had a substantial impact on plant height, while rhizobium inoculation and the interaction of the two components had no significant impact (Table 4). The treatments that received mixed fertilizers (NPS+Zn) had longer plant heights (43.34 cm), with insignificant differences from the other blended fertilizers, whereas the treatments that received no fertilizer recorded the shortest heights (35.97 cm). Therefore, compared to the control (without) fertilizer treatment, the average increase in plant height following the application of blended fertilizers was 17%. The current findings show that application of a balanced fertilizer plan could increase agricultural yield since the availability of nutrients has an impact on crop growth. The present findings are found to be consistent with Rawal and Yadav (1986) observation that zinc shortage considerably lowered plant height. Ceyhan *et al.* (2007) also found that fertilization with B has a beneficial effect. Through its effects on regulating transpiration and water intake, potassium helps plants grow taller. To maximize crop output in rain-fed systems, sulfur, boron, and zink must be applied in addition to phosphorus and nitrogen to degraded semi-arid tropical soils. Common bean plants increased taller after boron application compared to fertilizer sources without boron additions (Sharma *et al.*, 2013). Chickpea and soybean plants grew higher when their Nitrogen fertilizer was increased Caliskan *et al.* (2008). Data on variance analysis revealed that rhizobium inoculation had no significant effect on chickpea plant height. This result is consistent with Rudresh *et al.* (2005) observation that Rhizobium inoculation did not significantly alter plant height.

Effects of blended fertilizers and Rhizobium inoculation on yield component of Chickpea

Number of pods per plant

Rhizobium inoculation and the use of blended fertilizer had a substantial impact on the number of pod plants^{-1} (Table 5). For the number of pods, there was no statistically significant interaction between blended fertilizer and rhizobium inoculation. The application of NPSB+K obtained the maximum number of pods plant^{-1} (61.6), and there was no significant difference with the other blended fertilizers (Table 5). On NP, the fewest pods plant^{-1} (30.62) were counted without significantly differing from the control (33.44). Accordingly, Ali *et al.* (2007) and Patel *et al.* (2013) reported that potassium and sulfur contributed to the increase in the number of pods plant-1 Alam *et al.* (2017) noted that 3 kg ha^{-1} boron application showed the highest total pod plant^{-1} count (49.52) while the control treatment showed the lowest total pod plant^{-1} (36.52). Khampariva (1996) also found that Zn^{2+} plays a larger role in the number of soybean pods per plant.

Table 5: Effects of fertilizers and *Rhizobium* inoculation on yield component of chickpea

Treatments	NPPP	NSPP	HSW (g)
Control	33.4^{b}	1.19	24.3^{d}
NP	30.6^{b}	1.18	25.2^{dc}
NPS	56.8^{a}	1.11	25.9^{bc}
NPSB	54.2^{a}	1.13	27.5^{a}
NPSB+K	61.6^{a}	1.11	26.9^{ab}
NPS+Zn	60.0^{a}	1.19	28.0^{a}
NPSB+Zn	54.1^{a}	1.12	26.9^{ab}
NPSB+K+Zn	56.7^{a}	1.14	26.8^{ab}
$LSD_{0.05}$	16.2	0.14^{ns}	1.5
Inoculation			
Inoculated	59^{a}	1.17^{a}	27.7^{a}
Non-inoculated	42.8^{b}	1.10^{b}	25.1^{b}
LSD	8.1	0.07	0.7
CV%	26.9	10.33	4.8

Means within a column followed by the same letters are significantly similar at 5% probability level
NPPP=number of pod plant$_{-1}$, NSPP= number of seed pod$_{-1}$,
HSW= hundred seed weight

A statistically significant difference was found between the inoculation and uninoculated treatments for the number of pod plant^{-1} (Table 5). A higher number of pods plant^{-1} (59.01) was recorded for inoculated treatments. Togay *et al.* (2008) observed that the number of pods plant^{-1} was affected by Rhizobium inoculation in chickpeas. According to Desta *et al.* (2015), faba bean rhizobium strain inoculation considerably increases nodule number. Both Albayrak *et al.* (2006) and Malik *et al.* (2006) also reported similar results.

Number of seeds per pod

Rhizobium inoculation had a substantial impact on the number of seed pods, although the effects of blended fertilizer application and their interactions were not significant. The inoculated treatment recorded the highest number of seed pod^{-1} (1.17) whereas the un-inoculated treatment found the lowest number (1.10). Similarly, Solaiman and Hossain (2006) noted that Rhizobium inoculation on chickpeas and lentils produced a larger number of seeds plant^{-1}. This outcome is consistent with research by Ali *et al.* (2011) who found that Rhizobium bacteria inoculation had the highest impact on the number of grains plant^{-1}.

Hundred seed weight

The application of blended fertilizer and rhizobium inoculation had a significant effect on hundred seed weight, but their interactions had no effect. On NPS+Zn, the hundred seed weight reached a maximum of 28.0, whereas the control treatment had the lowest hundred seed weight (24.3) (Table 5). In comparison to control treatments, the application of mixed fertilizers NPS+Zn enhanced the weight of 100 seeds by 13.21%. Among the mixed fertilizers, adding Zn and B to N and S notably increases the weight of the hundred seeds. In general, these increases in seed weight may be attributed to the blended fertilizer's higher plant nutritional content, which comprises both macro and micronutrients. Due to the presence of phosphorus in the blended fertilizer, increased cell division, and production of fat resulted in to increase in the weight of 100 seeds. This finding was in line with that of Jadeja *et al.* (2016), who noted that application of 40kg S ha^{-1} resulted in a significantly greater 100-seed weight (23.60 g). Valenciano *et al.* (2010), also studied applying of zinc improved the 100 seed weight of chickpeas. Similarly to this, fertilizer treatments that also include boron in addition to NPS result in an increased 1000-seed weight Samiullah and Khan (2003).

Rhizobium inoculation had a significant impact on hundred seed weight. The inoculated treatment obtained the highest hundred seed weight (27.7 g), whereas the non-inoculated treatment scored the lowest hundred seed weight (25.1 g) (Table 5). The weight difference gained from this work could be attributed to the effect of the grain-filling ability of nitrogen through nitrogen biological fixation. Gedamu *et al.* (2021) reported that inoculation of faba bean with rhizobial strain alone could increase 100 seed weight. Contrary to this result, Bolland *et al.* (2000) stated that inoculation of faba bean rhizobium strains didn't bring significant seed weight difference.

Effects of Fertilizers and Rhizobium Inoculation on yield (ton ha^{-1}) of Chickpea

Total biomass

The major effects of fertilizer application and rhizobium inoculation had a considerable impact on total biomass, but their interaction had no significant effect. The highest overall biomass output (3.86 tons ha^{-1}) was seen when blended fertilizers NPSB+K were used (Table 6), whereas the lowest biomass yield (2.09 tons ha^{-1}) was attained when no fertilizer was used. This result demonstrates that the application of Boron, Sulfur, and potassium nutrients with Nitrogen and Phosphorus nutrients boosts the total biomass of chickpea crops because Nitrogen, Phosphorus, and Sulfur may have increased the number of branches per plant and leaf area which in turn increased photosynthetic area and number of pods per plant, thereby dry matter accumulation. The blended fertilizers application on total biomass recorded a 77% yield advantage over without fertilizer application. By promoting cell division, elongation, expansion, and chlorophyll biosynthesis and the statue had a significant physiological impact by rising assimilate production and increasing crop yield. These findings concur with those of Farooqui *et al.* (2009), Zaman *et al.* (2011), and Assefa *et al.* (2015), who found that the use of NPS fertilizer encourages chickpea growth and development. More dry matter accumulated as a result of an increase in potash levels (Mansur *et al.* 2010). Due to an increase in the dry weight of pods including seeds, the application of boron led to a larger production of dry matter (Valenciano *et al.*, 2010). Similarly, Choudhary & Muhammad (1990) reported, total dry matter was significantly affected after $ZnSO_4$ application.

Table 6: Effects of blended fertilizers and *Rhizobium* inoculation on yield of chickpea

Treatments	TB (ton ha^{-1})	GY (ton ha^{-1})	HI
Control	2.09^{b}	1.10^{c}	0.47
NP	2.16^{b}	1.17^{bc}	0.54
NPS	3.73^{a}	1.76^{a}	0.48
NPSB	3.51^{a}	1.82^{a}	0.54
NPSB+K	3.86^{a}	1.85^{a}	0.49
NPS+Zn	3.57^{a}	1.77^{a}	0.51
NPSB+Zn	3.75^{a}	1.62^{ab}	0.42
NPSB+K+Zn	3.54^{a}	1.77^{a}	0.48
$LSD_{0.05}$	0.87	0.49	0.14^{ns}
Inoculation			
Inoculated	3.59^{a}	1.84^{a}	0.51
Non-inoculated	2.97^{b}	1.38^{b}	0.47
$LSD_{0.05}$	0.43	0.25	0.07^{ns}
CV (%)	22.43	26.12	23.8

Means within a column followed by the same letters are significantly similar at 5% probability level
NB;-TB=Total biomass, GY=Grain yield, SY=straw yield and HI=Harvest index

Total biomass per hectare has a substantial impact on rhizobium inoculation. Rhizobium inoculation produced the highest biomass output (3.59 tons per hectare), whereas un-inoculated treatments produced the lowest total biomass production (2.97 tons per hectare). It demonstrates that rhizobium inoculation increased total biomass by 21% in comparison to treatments that were not inoculated. Alam and Haider (2006) reported a similar result. Al-Ani and Adhab (2013) have noted that rhizobium inoculation starts the root growth and boosts the above-ground biomass of faba beans. Additionally, nitrogen raises shoot dry matter, which has a favorable correlation with grain output in both legumes and cereals (Fageria *et al.*, 2008).

Grain yield

The combined Application of macro and micronutrient and Rhizobium inoculation had a significant effect on the grain output of chickpea crops (Table 6). The interaction of the two main factors was not significant. The NPSB+K treatment produced the maximum seed output of 1.85 tons per hectare, whereas the plots that received no fertilizer application produced the lowest seed yield of 1.1 tons per hectare. In comparison to NP and without fertilizer application, mixed fertilizer application increases seed production by 48.6 and 57.9%, respectively. The combined application of macro and micro nutrients has synergistic effects. Chickpeas produced more grain when other nutrients were added to the nitrogen and phosphorus. These findings were in agreement with those of Kambale *et al.* (2012) noted that potassium application greatly influences chickpea grain output, with the greatest grain yield increment of 2.41 tons per hectare. The yield of chickpeas was also boosted by 18 to 20% by applying 17 to 50 kg K ha^{-1} (Thakur *et al.*, 1990). Additionally, according to El-Shafie and

El-Gamaily (2002), sulfur and nitrogen stimulate enzymatic reactions and the production of chlorophyll, which encourage plant growth and development and result in a high yield. The presence of boron, which is essential for hormone synthesis and translocation, glucose metabolism, and DNA synthesis, is also credited with contributing to an increase in grain yield (Roy *et al.*, 2006). In general, balanced fertilizer application led to a higher seed yield than nutrient application alone.

The yield of grains was significantly influenced by rhizobium inoculation. Rhizobium inoculation boosted chickpea grain yield by 33.3% when compared to un-inoculated, yielding a maximum of 1.84 tons ha^{-1}. This can be explained by the fact that the inoculations of Rhizobia enhance symbiotic Nitrogen fixation and N nutrition, which in turn improve assimilate production, thereby promoting growth, which can then be re-translocated for the formation of yield components like increasing the number of seeds per pod. Our findings are consistent with those of Romdhane *et al.* (2008), who claimed that competitive rhizobia inoculation can boost chickpea seed yield and is particularly inexpensive promising to expand chickpea production. In addition to this different author, noted that the effect of inoculation on seed yield in chickpea increases significantly (Tellawi *et al.*, 2007; Bhuiyan *et al.*, 2008; Akhtar *et al.*, 2013).

Harvest index

Both the major effects of fertilizer treatment and Rhizobium inoculation had no statistically significant effect on the harvest index (Table 7). Similar to the interaction effects, there was no noticeable difference between them. These findings support the findings of Boru *et al.* (2017) who claimed that the application of phosphorus to wheat did not significantly alter the harvest index. According to Zare *et al.* (2013), the application of potassium had no significant influence on the harvest index. Al-Amery *et al.* (2011) discovered that the application of boron did not result in any noticeable differences. The harvest index was not statistically different for zinc application in rice, Hakoomat *et al.* (2014). The majority of the growth and yield-contributing features increased as a result of rhizobium inoculation, which ultimately resulted in a large rise in grain and Stover yields.

Correlation among yield and yield related traits

The estimates of the correlation coefficients among measured parameters of chickpea influenced by blended fertilizers and Rhizobium inoculation. The association of the number of pods per plant was positively and significantly correlated with the number of branches plant^{-1} (r = 0.6***), grain yield (r = 0.6***), and total biomass (r = 0.7***) (Table 7). The correlation of the number of pods plant^{-1} with the number of branches, grain yield, and total biomass is in agreement with the previous work of Mallu *et al.* (2015). Above ground biomass significantly correlated with straw yield (r = 0.9***), grain yield (r = 0.8***), hundred seed weight (r = 0.5***), number of branches plant^{-1} (r = 0.6***) and plant height (r = 0.4**). Our result stands in line with the findings of Nihal and Sait (2012). Moreover, grain yield correlated positively and significantly with the number of pods plant^{-1} (r = 0.6***), hundred seed weight (r = 0.5***), and total biomass (r = 0.8***) these indicated that grain yield increased due to application of blended fertilizer and Rhizobium inoculation is contributed through an increase in total growth and yield components. Similar results were also reported by Nihal and Sait (2012) and Mallu *et al.* (2015).

Partial budget analysis

According to the results of the partial budget analysis for fertilizer, the NP, NPSB+Zn, NPSB+K, and NPSB+K+Zn were favored (Table 8). This led to an analysis of the marginal rates of return for the three non-dominated blended fertilizers (NPS, NPS+Zn, and NPSB). As a result, the MRR for NPS, NPS+Zn, and NPSB fertilizers, respectively, were 1801.7%, 866.4%, and 256.8% (Table 8). Accordingly, farmers can anticipate receiving 18.01, 8.66, and 2.56 more Birr for every 1.00 Birr they invest in fertilizer application, respectively. The marginal rates of return obtained by NPS, NPS+Zn, and NPSB exceeded the minimum acceptable rate of return set by CIMMYT in 1988, which ranged from 50 to 100%. The treatment with the largest net benefit and a respectable MRR is approved as a suggestion, according to CIMMYT (1988). Therefore, the acceptable domain of treatments for the study region is taken to include the blended fertilizers NPS, NPS+Zn, and NPSB that showed higher net

Table 7: Simple correlation coefficients among parameters (n=48)

	DF	DPM	NN	NDW	NPPP	NSPP	PH	NB	HSW	TBM	SY	GY
DF	1											
DPM	0.8***	1										
NN	-0.6***	-0.7***	1									
NDW	-0.6***	-0.6***	0.5***	1								
NPPP	-0.5***	-0.7***	0.6***	0.5***	1							
NSPP	0.15***	-0.15^{ns}	-0.2^{ns}	-0.3^{ns}	-0.2^{ns}	1						
PH	-0.5***	-0.6***	0.4**	0.4**	0.6***	-0.15^{ns}	1					
NB	-0.5***	-0.5***	0.7***	0.6***	0.6***	-0.3*	0.4**	1				
HSW	-0.6***	-0.6***	0.6***	0.5***	0.5***	-0.3^{ns}	0.5*	0.7***	1			
TBM	-0.6***	-0.7***	0.7***	0.5***	0.7***	0.1^{ns}	0.4**	0.6***	0.5***	1		
SY	-0.6***	-0.6***	0.5***	0.5**	0.6***	0.0^{ns}	0.3*	0.4**	0.3*	0.9***	1	
GY	-0.5***	-0.6***	0.7***	0.4**	0.6**	-0.2^{ns}	0.4**	0.3***	0.5***	0.8***	0.5***	1

*, **, ***; indicates that significantly different at $P<0.05$, $P<0.01$, 0.001 probability level, respectively. ns=non significant
DF: days to flowering; DPM: days to physiological maturity; NN: number of nodules; NDW: nodules dry weight; NPPP: number of pods per plant;
NSPP: number of seeds per pod; PH: plant height; NB: number of branches; HSW: hundred seed weight; TBM: total biomass; SY: straw yield and GY: grain yield.

Table 8: Partial budget analysis on chickpea grain yield as influenced by fertilizers and *Rhizobium* inoculation

Treatment Fertilization	Adjusted grain yield (ton/ha)	Gross field benefit (Birr/ha)	Variable cost (Birr/ha)	Net benefit (Birr/ha)	Change in net benefit (Birr/ha)	MRR (%)
Control	0.935	28050	0	28050		
NPS	1.496	44880	885	43995	15945	1801.7
DAP	0.994	29820	1590	28230d		
NPS+Zn	1.505	45150	1750.79	43399.2	15169.2	866.4
NPSB+Zn	1.377	41310	1874.22	39435.8d		
NPSB	1.547	46410	1954.95	44455.1	5020	256.8
NPSB+K	1.573	47190	2738.5	44451.5d		
NPSB+K+Zn	1.505	45150	3297.79	41852.2d		
Inoculation						
Un inoculated	1.173	35190	280	34910		
Inoculated	1.564	46920	280	46640	11730	4189.3

benefits along with an acceptable MRR (Table 8). Given that the three solutions produced statistically comparable grain yields, the combined fertilizer NPS is the preferable option.

Additionally, the results of a partial budget analysis for the inoculation of Rhizobium revealed that inoculated treatments were not dominant. As a result, the MRR obtained with inoculation treatments was 4189.3%. Accordingly, farmers can anticipate receiving an additional 41.89 Birr for every 1.00 Birr spent on Rhizobium inoculants in addition to recovering their initial investment of 1.00 Birr. The treatment with the largest net benefit and a respectable MRR is approved as a suggestion, according to CIMMYT's (1988) findings. As a result, the Rhizobium inoculation that produced the best grain yield, the largest net benefit, and an acceptable MRR (Table 8) is considered to be both profitable and appropriate for the research area.

CONCLUSION

The results of this study revealed that the application of fertilizers significantly influenced most of the parameters tested and yield and yield-related traits of chickpeas except the number of seeds pod^{-1} and harvest index. Blended fertilizer application improved chickpea grain yield (1.73 ton ha^{-1}) by 48.35% and 57.9% as compared to NP and control. If only macronutrients are applied to the crop, the shortage of some additional secondary macro and micro-nutrients will emerge in different crops. Hence, those sources of nutrients are supposed to apply which possess various nutrients. This will tower crop yields and maintain soil health for a longer period. Accordingly, all the studied blended fertilizers' effects on chickpea yield and yield components showed that the application of blended fertilizers would be promising to grow chickpeas in the study area. The Native Rhizobium population of chickpeas in most of the farmers' fields is less than what is required for the optimum symbiotic association. The maximum number of nodules (23.29), nodules dry weight (0.11 g), growth, and yield component parameters were recorded for inoculated treatments, and treating the seed with Rhizobium inoculation improved chickpea grain yield by 33.3% (1.84 ton ha^{-1}) compared to the control. Thus, Rhizobium inoculation can be considered necessary for better production of chickpeas in the experimental area. The partial budget analysis indicated that blended fertilizers; NPS, NPS+Zn, and NPSB gave the greater net benefits of 43,995, 43399, and 44,455 Ethiopian Birr ha^{-1}, respectively. These treatments all had acceptable MRRs of 1802, 866, and 257. Rhizobium inoculation resulted in a higher net benefit of 46,640 Birr ha^{-1} with an acceptable MRR of 4189. Based on the result of this study it can be concluded that application of blended fertilizer: NPS and Rhizobium inoculation are recommended for chickpea production in the study area.

REFERENCES

Abbas, G., Abbas, Z., Aslam, M., Malik, A. U., Ishaque, M., & Hussain, F. (2011). Effects of organic and inorganic fertilizers on Mungbean (*Vigna radiata* (L.) yield under arid climate. *International Research Journal of Plant Science, 2*(4), 094- 098.

Ahlawat, I. P. S., Gangaiah, B., & Zahid, M. A. (2007). Nutrient management in chickpea. In S. S. Yadav, R. Redden, W. Chen & B. Sharma (Eds.), *Chickpea Breeding and Management* (pp. 213-223) Wallingford, UK: CAB International. https://doi.org/10.1079/9781845932138.010

Akhtar, N., Arshad, I., Shakir, M. A., Qureshi, J., Sehrish, M., & Ali, L. (2013). Co-inoculation with *Rhizobium* and bacillus sp to improve the phosphorus availability and yield of wheat (*Triticum aestivum* L.). *Journal of Animal and Plant Sciences, 23*(1), 190-197.

Alam, M. S., Ali, K. J., & Hoque, A. (2017). Yield and yield component of chickpea as affected by boron application. *Journal of Experimental Agriculture International, 15*(2), 1-9. https://doi.org/10.9734/JEAI/2017/8944

Alam, M. Z., & Haider, S. A. (2006). Growth attributes of barley (*Hordeum Vulgare* L.) cultivars in relation to different doses of nitrogen fertilizer. *Journal of Life and Earth Sciences, 1*(2), 77-82.

Al-Amery, M. M., Hamza, J. H., & Fuller, M. P. (2011). Effect of boron foliar application on reproductive growth of sunflower (*Helianthus annuus* L.). *International Journal of Agronomy, 2011*, 230712. https://doi.org/10.1155/2011/230712

Al-Ani, R. A., & Adhab, M. A. (2013). Bean yellow mosaic virus (BYMV) on broadbean: Characterization and resistance induced by *Rhizobium leguminosarum*. *Journal of Pure and Applied Microbiology, 7*(1), 135-142.

Albayrak, S., Sevimay, C. S., & Tongel, O. (2006). Effect of inoculation with *Rhizobium* on seed yield and yield components of common vetch (*Vicia sativa* L.). *Turkish Journal of Agricultural and Forestry, 30*(1), 31-37.

Ali, A., Ndeem, M. A., Tahir, A. T. M., & Hussain, M. (2007). Effect of different potash levels on the growth, yield and contents of chickpea (*Cicer artinium* L.). *Pakistan Journal of Botany, 39*(2), 523-527.

Ali, N., Raouf, S. S., & Teymur K., (2011). Growth analysis and yield of chickpea (*Cicer arietinum* L.) in relation to organic and inorganic nitrogen fertilization. *Ekologija, 57*(3), 97-108. https://doi.org/10.6001/ekologija.v57i3.1915

Argaw, A. (2012). Characterization of symbiotic effectiveness of *Rhizobia* nodulating Faba bean (*Vicia faba* L.) isolated from Central Ethiopia.

Research Journal of Microbiology, 7(6), 280-296.

Assefa, A., Mesgina, G., & Abrha, Y. (2015). Effect of inorganic and organic fertilizers on the growth and yield of garlic crop (*Allium sativum* L.) in Northern Ethiopia. *Journal of Agricultural Science, 7*(4), 80-86. https://doi.org/10.5539/jas.v7n4p80

Bejandi, T. K., Sharifii, R. S., Sedghi, M., & Navmar, A. (2012). Effects of plant density, *Rhizobium* inoculation and microelements on nodulation, chlorophyll content and yield of chickpea (*Cicer arietinum* L.). *Annals of Biological Research, 3*(2), 951-958.

Belete, S., Bezabih, M., Abdulkadir, B., Tolera, A., Mekonnen, K., & Wolde-Meskel, E. (2019). Inoculation and phosphorus fertilizer improve food-feed traits of grain legumes in mixed crop-livestock systems of Ethiopia. *Agriculture, Ecosystems & Environment*, *279*, 58-64. https://doi.org/10.1016/j.agee.2019.04.014

Beshir, H. M., Walley, F. L., Bueckert, R., & Tar'an, B. (2015). Response of snap bean cultivars to *Rhizobium* inoculation under dryland agriculture in Ethiopia. *Agronomy, 5*(3), 291-308. https://doi.org/10.3390/agronomy5030291

Bhuiyan, M. A. H., Khanam, D., Hossain, M. F., & Ahmed, M. S. (2008). Effect of *Rhizobium* inoculation on nodulation and yield of chickpea in Calcareous soil. *Bangladesh Journal of Agricultural Research, 33*(4), 549-554. https://doi.org/10.3329/bjar.v33i4.2287

Bolland, M. D. A., Siddique, K. H. M., & Brennan, R. F. (2000). Grain yield responses of faba bean (*Vicia faba* L.) to applications of fertiliser phosphorus and zinc. *Australian Journal of Experimental Agriculture, 40*(6), 849-857. https://doi.org/10.1071/EA99164

Boru, M., Tsadik, W. K., & Tana T. (2017). Effects of application of farmyard manure and inorganic phosphorus on tuberous root yield and yield related traits of sweet potato (*Ipomoea batatas* L.) at Assosa, Western Ethiopia. *Advances in Crop Science and Technology, 5*, 302. https://doi.org/10.4172/2329-8863.1000302

Caliskan, S., Ozkaya, I., Caliskan, M. E., & Arslan, M. (2008). The effects of nitrogen and iron fertilization on growth, yield and fertilizer use efficiency of soybean in a Mediterranean-type soil. *Field Crops Research, 108*(2), 126-132. https://doi.org/10.1016/j.fcr.2008.04.005

Ceyhan, E., Önder, M., Harmankaya, M., Hamurcu, M., & Gezgin, S. (2007). Response of chickpea cultivars to application of boron in boron deficient calcareous soils. *Communications in Soil Science and Plant Analysis, 38*(17-18), 2381-2399. https://doi.org/10.1080/00103620701588734

Chianu, J. N., Nkonya, E. M., Mairura, F. S., Chianu, J. N., & Akinnifesi, F. K. (2011). Biological nitrogen fixation and socioeconomic factors for legume production in sub-Saharan Africa: a review. *Agronomy for Sustainable Development, 31*, 139-154. https://doi.org/10.1051/agro/2010004

Chimdessa, D. (2016). Blended Fertilizers Effects on Maize Yield and Yield Components of Western Oromia, Ethiopia. *Agriculture, Forestry & Fisheries, 5*(5), 151-162. https://doi.org/10.11648/j.aff.20160505.13

Choudhary, A. U., & Muhammad, N. (1990). Effect of micronutrients on nodulation and seed yield of chickpea (*Cicer arietinum* L.). *Journal of Agricultural Research, 28*, 139-147.

CIMMYT. (1988). *From agronomic data to farmer recommendations: Economics training manual*. CIMMYT, Mexico.

CSA. (2017). *Agricultural sample survey: Report on area and production for major crops* (private peasant holdings, Meher season), 2016/2017 (2009 E.C.), Volume I, Statistical Bulletin 584. Central Statistical Agency (CSA), Addis Ababa.

Desta, Y., Habtegebrial, K., & Weldu, Y. (2015). Innoculation, Phosphorus and zinc fertilizer rates on nodulation, yield and nutrient uptake of faba bean (*Vica faba* L.) grown on Calcaric Cambi soil of semiarid Ethiopia. *Journal of Soil Science and Environmental Management, 6*(1), 9-15. https://doi.org/10.5897/JSSEM2013.0406

El-Shafie, F., & El-Gamaily, E. (2002). Effect of organic manure, sulfur and microelements on growth, bulb yield storability and chemical composition of onion plants. *Minufiya Journal of Agricultural Research, 27*(2), 407-424.

EthioSIS. (2013). Ethiopian Soil Information System. *Soil analysis report, Agricultural Transformation Agency* (Unpublished).

Fageria, N. K., Baligar, V. C., & Clark, R. B. (2002). Micronutrients in crop production. *Advances in Agronomy, 77*, 185-268. https://doi.org/10.1016/S0065-2113(02)77015-6

Fageria, N. K., Baligar, V. C., & Li, Y. C. (2008). The role of nutrient efficient plants in improving crop yields in the twenty first century. *Journal of Plant Nutrition*, *31*(6), 1121-1157. https://doi.org/10.1080/01904160802116068

Fatima, Z., Bano, A., Sial, R., & Aslam, M. (2008). Response of chickpea to plant growth regulators on nitrogen fixation and yield. *Pakistan Journal of Botany, 40*(5), 2005-2013.

Gedamu, S. A., Tsegaye, E. A., & Beyene, T. F. (2021). Effect of rhizobial inoculants on yield and yield components of faba bean (*Vicia fabae* L.) on vertisol of Wereillu District, South Wollo, Ethiopia. *CABI Agricultural and Bioscience, 2*, 8. https://doi.org/10.1186/s43170-021-00025-y

Goud, V. V., Konde, N. M., Mohod, P. V., & Kharche, V. K. (2012). Response of chickpea to potassium fertilization on yield, quality, soil fertility and economic in vertisoils. *Legume Research – An International Journal, 37*(3), 311-315. https://doi.org/10.5958/j.0976-0571.37.3.047

Gul, R., Khan, H., Khan, N. U., & Fahim, U. K. (2014). Characterization of chickpea germplasm for nodulation and effect of *Rhizobium* inoculation on nodules number and seed yield. *The Journal of Animal & Plant Sciences, 24*(5), 1421-1429.

Hakoomat, A., Hasnain, Z., Shahzad, A. N., Sarwar, N., Qureshi, M. K., Khaliq, S., & Qayyum, M. F. (2014). Nitrogen and zinc interaction improves yield and quality of submerged basmati rice (*Oryza sativa* L.). *Notulae Botanicae Horti Agrobotanici Cluj-Napoca*, *42*(2), 372-379.

Hulse, J. H. (1991). Nature, composition and utilization of grain legumes. In Uses of tropical Legumes: ICRISAT Center. Proceedings of a consultants meeting (pp. 11-27).

Jadeja, A. S., Rajani, A. V., Foram, C., Kaneriy, A. S. C., & Kavar, N. R. (2016). Soil application of potassium and sulfur and effect on growth and yield components of chickpea (*Cicer arietinum* L.) under south Saurashtr region of Gujarat. *International Journal of Science, Environment and Technology, 5*(5), 3172-3176. https://doi.org/10.13140/RG.2.2.22889.44649

Kambale, R. D., Jadhav, J. D., Andhale, R. P., & Pawar, P. B. (2012). Sowing dates and potash levels influences on yield of chickpea. *Advanced Research Journal of Crop Improvement, 3*(2), 148-153.

Khampariva, N. K. (1996). Yield and yield attributing characters of soybean as affected by levels of phosphorous and zinc and their interactions on vertisoil. *Crop Research Hisar, 12*, 275-282.

Kumar, S., Tripathi, D. K., Bharose, R., Kumar, M., & Kumar, R. (2016). Effect of different fertility level and micronutrients on nodulation and nutrient uptake by chickpea. *An Asian Journal of Soil Science, 11*(1), 62-66. https://doi.org/10.15740/HAS/AJSS/11.1/62-66

Mahler, R. L., Saxena M. C., & Aeschllmann J. (1988). Soil fertility requirements of pea, lentil, chickpea and faba bean. In R. J. Summerfield (Eds.), *World crops* (Vol. 5, pp. 279-289) Dordrecht, Netherlands: Kluwer Academic Publishers. https://doi.org/10.1007/978-94-009-2764-3_27

Malik, M. A., Cheema, M. A., Khan, H. Z., & Wahid, M. A. (2006). Growth and yield response of soybean (*Glycine max* L.*)* to seed inoculation and varying phosphorus levels. *Journal of Agricultural Research, 44*, 47-53.

Mallu, T. S., Nyende, A. B., Rao, N. V. P. R. G., Odeny, D. A., & Mwangi, S. G. (2015). Assessment of Interrelationship among Agronomic and Yield Characters of Chickpea. *International Journal of Agriculture and Crop Sciences, 8*(2), 128-135.

Mansur, C. P., Palled, Y. B., Halikatti, S. I., Chetti, M. B., & Salimathn P. M. (2010). Effect of date of sowing and irrigation levels on growth, yield parameters and yield of Kabuli chickpea. *Karnataka Journal of Agricultural Sciences, 23*(3), 461-463.

Mathan, K. K., Flancis, N. J., & Ramanathan, S. P. (1996). Response of blackgram to fertilization and *Rhizobium* inoculation. *Indian Journal of Agronomy, 41*(1), 74-77.

Mehlich, A. (1978a). New extractant for soil test evaluation of phosphorus, potassium, magnesium, calcium, sodium, manganese and zinc. *Communications in Soil Science and Plant Analysis, 9*(6), 477-492. https://doi.org/10.1080/00103627809366824

Mehlich, A. (1978b). Influence of fluoride, sulfate, and acidity on extractable phosphorus, calcium, magnesium and potassium. *Communications in Soil Science and Plant Analysis, 9*(6), 455-476. https://doi.org/10.1080/00103627809366823

Mentsiro, A. A. (2011). *Soil Fertility Management and Nutrient Balance in Southwest Ethiopia* (pp. 13-64) Latvia, Germany: VDM Verlag.

Mishra, R. K, Alston, A. M., & Dexter, A. R. (1988). Role of root hairs in phosphorus depletion from a Macro structured soil. *Plant and Soil, 107*, 11-18. https://doi.org/10.1007/BF02371538

Muehlbauer, F. J., & Tullu, A. (1997). *Cicer arietinum L. New Crop Fact sheet*. Center for New Crops and Plant Products. West Lafayette, Indiana: Purdue University.

Nelson, D. W., Swearingin, M. L., & Beckham, L. S. (1978). Response of soybeans to cornmerciai soil-applied inoculants. *Agronomy Journal, 70*(3), 517-518. https://doi.org/10.2134/agronj1978.00021962007000030041x

Nihal, K., & Sait, A. M. (2012). Association of some characters with grain yield in chickpea (*Cicer artinium* L.). *Pakistan Journal of Botany, 44*(1), 267-272.

Patel, H. R., Patel, H. F., Maheriya, V. D., & Dodia, I. N., (2013). Response of kharif green gram (*Vigna radiata* L.) to sulfur and phosphorus fertilization with and without bio fertilizer application. *TheBioscan, 8*(1), 149-152.

Pundir, R. P. S., & Mengesha, M. H. (1995). Cross compatibility between chickpea and its wild relative, *Cicer echinospermum* Davis. *Euphytica, 83*, 241-245. https://doi.org/10.1007/BF01678136

Rajput, A. (2018). Potassium application on chickpea crop under irrigated area. *Sarhad Journal of Agriculture, 34*(4), 941-947. https://doi.org/10.17582/journal.sja/2018/34.4.941.947

Rawal, D. R., & Yadava, G. L. (1986). Fertilizer requirement of gram under dryland conditions on cultivars field in Chittargarh District. *Legume Research, 9*(2), 103-105.

Reddy, G. S. (1998). Effect of phosphorus and potassium on dry matter and crude protein of mungbean. *Indian Botanical Reports, 4*(1), 191-192.

Romdhane, S. B., Aouani, M. E., Rabelsi, M., De Lajudie, P., & Mhamdi, R. (2008). Selection of High Nitrogen-Fixing *Rhizobia* Nodulating Chickpea (*Cicer arietinum L.*) for Semi-Arid Tunisia. *Journal of Agronomy & Crop Science, 194*(6), 413-420. https://doi.org/10.1111/j.1439-037X.2008.00328.x

Roy, R. N., Finck, A., Blair, G. J., & Tandon, H. L. S. (2006). *Plant nutrition for food security. A guide for integrated nutrient management*. FAO Fertilizer and Plant Nutrition Bulletin 16. Rome, Italy, Food and Agriculture Organization of the United Nations.

Rudresh, D. L., Shivaprakash, M. K., & Prasad, R. D. (2005). Effect of combined application of *Rhizobium*, phosphate solubilizing bacterium and Trichoderma spp. on growth, nutrient uptake and yield of chick- pea (*Cicer aritenium* L.). *Applied Soil Ecology, 28*(2), 139-146. https://doi.org/10.1016/j.apsoil.2004.07.005

Samiullah, & Khan, N. A. (2003). Physiological investigation on interactive effect of P and K on growth and yield of chickpea. *Indian Journal of Plant Physiology, 8*(2), 165-170.

Sharma, B. K., Kushwah, S. S., Verma, K. S., & Singh, O. P. (2013). Studies on French bean (*Phaseolus vulgaris* L.) varieties under different N, P, K and S levels for growth, yield and economics. *Journal of Horticulture Sciences, 8*(2), 268-270. https://doi.org/10.24154/jhs.v8i2.317

Solaiman, A. R. M., & Hossain, D. (2006). Effectiveness of *bradyrhizobum japanucum* strains on soybean at field condition. Ann. Bangl. Afric. 9:17-18.

Surendra, R., & Katiyar, T. P. S. (2010). Effect of sulfur and zinc on the seed yield and protein content of summer mungbean under arid climate. *Bulletin of the Institute of Tropical Agriculture, Kyushu University, 4*(3), 563-566. https://doi.org/10.11189/bita.29.11

Tellawi, A., Haddad, N., & Hattar, B. (2007). Effect of several *Rhizobium* strains on nodulation, nitrogen uptake and yield of chickpeas (*Cicer arietinum* L.). *Journal of Plant Nutrition & Soil Science, 149*(3), 314-322. https://doi.org/10.1002/jpln.19861490308

Thakur, R. N., & Jadhav, A. S. (1990). Effects of fertilizers and plant densities on the yield of gram. *Journal of Maharashtra Agricultural Universities, 15*(2), 238-239.

Togay, N., Togay, Y., Cimrin, K. M., & Turan, M., (2008). Effect of *Rhizobium* inoculation, sulfur and phosphorus application on yield, yield components and nutrient uptake in chick pea (*Cicer aretinum* L.). *African Journal of Biotechnology, 7*(6), 776- 782.

Tomar, R. K. S., Namdeo, K. N., & Raghu, J. S. (1995). Efficacy of phosphate solubilizing bacteria biofertilizer with phosphorus on growth and yield of gram (*Cicer arietinum* L.). *Indian Journal of Agronomy, 41*, 412-415.

Unkovich, M., Baldock, J., & Forbes, M. (2010). Variability in harvest index of grain crops and potential significance for carbon accounting: examples from Australian agriculture. *Advances in Agronomy, 105*, 173-219.

Valenciano, J. B., Boto, J. A., & Marcelo, V. (2010). Response of chickpea *(Cicer arietinum* L.*)* yield to zinc, boron and molybdenum application under pot conditions. *Spanish Journal of Agricultural Research, 8*(3), 797-807.

Verghis, T. I., Hill, G. D., & McKenzie, B. A. (1993). Effect of sowing date, nitrogen and *Rhizobium* inoculation on flowering and development of yield in chickpeas. Proceedings Agronomy Society of N.Z. (pp. 93-97).

Verma, J. P., Yadav, J., Tiwari, K. N., & Kumar, A. (2013). Effect of indigenous *Mesorhizobium* spp. and plant growth promoting *Rhizobacteria* on yields and nutrients uptake of chickpea (*Cicer arietinum* L.) under sustainable agriculture. *Ecological Engineering, 51*, 282-286. https://doi.org/10.1016/j.ecoleng.2012.12.022

Zaman, M., Hashem, M., Jahiruddin, M., & Rahim, M. (2011). Effect of nitrogen for yield maximization of garlic in old Brahmaputra flood plain soil. *Bangladesh Journal of Agricultural Research, 36*(2), 357-367. https://doi.org/10.3329/bjar.v36i2.9263

Zare, M., Zadehbagheri, M., & Azarpanah, A. (2013). Influence of potassium and boron on some traits in Wheat (*Triticum Aestivum* Cv. Darab2). *The International Journal of Biotechnology, 2*(8), 141-153.

Zeleke, G., Agegnehu, G., Abera, D., & Rashid, S., (2010). Fertilizer and soil fertility potential in Ethiopia: Constraints and opportunities for enhancing the system. Addis Ababa, Ethiopia: IFPRI.