NODULATION, SEED YIELD AND ITS RELATED TRAITS RESPONSE OF COMMON BEAN (*PHASEOLUS VULGARIS* L.) CULTIVARS TO NPS FERTILIZER UNDER ACIDIC SOIL

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ABSTRACT

This study was aimed to evaluate the response of common bean cultivars to NPS fertilizer. Results revealed that the main effect of NPS rates, and cultivars highly significantly affected 50% days to flowering, number of primary branches per plant, pods per plant, hundred seeds weight, above-ground dry matter biomass, and grain yield. Nasir cv. provided highest for all the studie parameters, among NPS rate, 100 kg ha^{-1} recorded the highest results for the 50% days to flowering, the number of primary branches per plant, pods per plant, hundred seeds weight, above-ground dry matter biomass, and seeds yield. The interaction effects of NPS rate and cultivars highly significantly influenced days to 90% physiological maturity, plant height, total and effective nodule number, and the number of seeds per pod. Thus, cultivar Nasir interaction with 100 kg ha^{-1} NPS rate resulted in higher total and effective nodule number, seeds per pod, and the less for plant height which was recorded highest result for Red Wolaita with 100 kg ha^{-1} NPS rate. This study was revealed that cultivar Nasir with the optimum amount of NPS fertilizer application, the common bean can produce a more effective nodule that is capable of fixing atmospheric nitrogen for plant nourishment under acidic soil..It can be concluded as the combined use of 100 kg ha^{-1} NPS with cultivar Nasir results in higher grain yield and soil fertility improvement through nitrogen fixation for succeeding crops.

Keywords: common bean, Hawassa Dume, Nasir, Nitrogen fixation, NPS fertilizer, Red Wolaita

العقد وحاصل البذور والصفت التي لها علاقة لاستجابة اصناف من الفاصولياء (*PHASEOLUS VULGARIS* L.) على سماد NPS في الترب الحامضية

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المستخلص

تهدف الدراسة إلى تقييم استجابة أصناف الفاصوليا الشائعة للأسمدة NPS. أوضحت النتائج أن معدلات NPS والأصناف أثرت معنوياً على 50٪ يوم من الإزهار، عدد الأفرع الأولية للنبات، القرون لكل نبات، وزن مائة بذرة، الكتلة الحيوية للمادة الجافة فوق الأرض، وحاصل البذور. تم الحصول على أعلى نتائج لجميع الصفات المدروسة، لمعدل NPS، سجلت 100 كجم هكتارمن السماد أعلى النتائج خلال 50٪ أيام من الإزهار، وعدد الأفرع الأولية لكل نبات، والقرون لكل نبات، ووزن مائة بذرة، والمادة الجافة فوق الأرض الكتلة الحيوية، وحاصل البذور. كانت التأثيرات التداخلية لمعدل NPS والأصناف بشكل كبير على أيام النضج الفسيولوجي بنسبة 90٪، وارتفاع النبات، وعدد العقد الكلية والفعالة، وعدد البذور لكل قرنة. وبالتالي، فإن تداخل الصنف ناصر مع معدل 100 كجم / هكتار NPS أدى إلى ارتفاع عدد العقد الكلية والفعالة، والبذور لكل غرام، وأقل ارتفاع النبات سجل للصنف Red Wolaita بمعدل 100 كجم/ هكتار من NPS. أوضحت هذه الدراسة أن الصنف ناصر مع 100كغم من السماد NPS انتجت عقد أكثر فاعلية قادرة على تثبيت النيتروجين من الغلاف الجوي لتغذية النبات تحت التربة الحامضية يمكن الاستنتاج على أن استعمال . 100 كغم/ هكتار NPS مع الصنف ناصر يؤدي إلى زيادة حاصل البذور وتحسين خصوبة التربة من خلال تثبيت النيتروجين للمحاصيل التالية.

كلمات مفتاحية: السماد الكيمياوي، عقد جذرية وعددالتفرعات/نبات، وزن البذور

Received:22/6/2021, Accepted:19/9/2021

INTRODUCTION

Common bean (*Phaseolus vulgaris* L.) is one of the most important grain legumes to provide calorie and protein sources for human beings. The domestication of common beans occurred independently in South America and Central America/Mexico; leading to two different domesticated gene pools, the Andean and Mesoamerican, respectively (16). Common bean is currently estimated to be one of the most important sources of nutrients for more than 300 million people in parts of Eastern Africa and Latin America, representing 65% of total protein consumed, 32% of energy (10). Besides, legume production has been showing an upward trend during the past 13 years, ranging from 1.10 million tons in 2000/01 to 2.75 million tons in 2012/13. The role that Ethiopia now plays in the international grain legumes market can also be attributed to significant growth rates in seed legumes production over the last nearly 20 years.(7) Legumes also hold vital importance in improving food and nutrition security, generation of income, soil fertility improvement, providing livestock feed, soil erosion control and water conservation, and as a source of fuel.(27). Legumes have nitrogen-fixing properties that can reduce fertilizer usage for cereals in the next season by up to 60% (46) ,fall during crop legume development in the nodulated roots is also reported to contain up to 40 kg nitrogen ha^{-1} to benefit subsequent crops (32), using grain legumes in the agricultural system increases organic matter and improves soil structure (42), Even though grain legumes are critical to smallholder livelihoods in the country, the current production and productivity of legumes fall significantly below the potential. Low input usage, limited availability of seed and limited familiarity with the variety of existing legumes, and limited usage of modern agronomic practices, market problems, and poor extension services are the major constraints accounting for this low production and productivity (27). The main causes of low productivity at farmer fields are a poor technology level, utilization of low agricultural input, and cropping in low fertility soils, especially with low N content (2, 3, 9). Soil factors such as nutrient deficiency like low soil nitrogen and phosphorus and acidic soil conditions are important limitations for common bean production in most of the common bean growing areas (23). In common beans, symbiotic N fixation rates, seed protein level, and tolerance to phosphorus deficiency are low in comparison to other legumes (11) Among nutrients, nitrogen is the critical limiting element for the growth of most plants including common beans due to its unavailability and poor fixation of the crop (49) Nitrogen at moderate rates led to significant enhancements in yield components and seeds yield, (43). Deficiency of phosphorus results in stunted growth of the plant with a thin stem and shortened internodes, small, dark-green upper leaves, and few pods form and contain only a small number of seeds (37). Nodule number and biomass were significantly diminished by the low P treatment. However, the intrinsic characteristics of the nodules (individual biomass and size, P concentration, and efficiency of N fixation) did not depend on P availability (29). In nodulated legumes, sulfur supply is positively linked to symbiotic nitrogen fixation (SNF) and sulfur starvation causes three additional major effects: decrease of nodulation, inhibition of SNF, and slowing down of nodule metabolism (8). The limitation of S can reduce N_2 fixation by affecting nodule development and function. The present report deals with the influence of S on yield formation and N_2 fixation of legumes and tries to explain the lower yield formation and reduced N_2 fixation of S-starved legumes , (5). Sulfur fertilization allows significant increases in common bean seeds yield in the average of six cultivars and must be considered in cropping systems aiming at high yields (35). Also Sulfur plays a vital role in improving vegetative structure for nutrient absorption, strong sink strength through the development of reproductive structure, and production of assimilates to fill economically important sink (39) Sulfur nutrition of beans and other plants is important since its application not only increases growth rate but also improves the quality of the seed (14).

MATERIALS AND METHODS

Description of the study area

This study was conducted at Boloso Bombe Woreda, Wolaita Zone, Southern Nations Nationalities and Peoples Regional State (SNNPRS) The experimental site is located 325 km south of Addis Ababa and 55 km away from Zonal town Sodo towards the west. The geographical location of the study area is 7°8'31" N latitude, 37°34' 85" E longitude, and at an altitude of 1542 meters above sea level. It receives a mean annual rainfall of 1420 mm in a bi-modal pattern with an extended rainy season from March to September. The annual average temperature is 26.4°C. The monthly total rainfall and average maximum temperature during the experimental time (July-October) were 491.2mm and 25.3°C, respectively.

Experimental materials

The experimental materials used for this study were common bean cultivars (Hawassa Dume, Red Wolaita, and Nasir) (Table 1), and NPS fertilizer rates (0,100 and 200 kg/ha). The source of common bean genotypes and NPS fertilizer was Areka agricultural research center, and Boloso Bombe Woreda Agricultural Office, respectively.

Table 1. Description of the varieties used for the study

Cultivars	Altitude (m) range	Seed size	Seed color	Days to maturity	Yield on station (t ha^{-1})	Yield on farm (t ha^{-1})	Year of release
Hawassa Dume	1100-1750	Small	Dark red	85-90	3.017	1.97	2008
Nasir	1200-1800	Small	Red	86-88	2.0-3.2	2.3	2003
Red Wolaita	1400-2250	Small	Red	110	2.2-2.4	1.9	1974

Source: (MoARD, 2008).

Soil sampling and analysis

Pre-sowing soil samples of the experimental site were collected from 10 spots in a crisscross design from the profundity of 0-30 cm. One kilogram of composite soil sample was taken to the laboratory. The samples were air-dried, ground employing a pestle and a mortar, and permitted to pass through a 2 mm sifter within the Wolaita Sodo soil testing laboratory. Working samples were gotten from each submitted sample and analyzed for natural matter, add up to N, soil pH, accessible phosphorus, cation exchange capacity (CEC), and textural investigation utilizing standard laboratory methods in Wolaita Sodo soil laboratory. Hence, organic matter content was determined by the volumetric method, (48), total nitrogen was analyzed by the Micro-Kjeldahl digestion method with sulphuric acid The cation exchange capacity (CEC) was measured after saturating the soil with 1N ammonium acetate (NH_4OAc) and displacing it with 1N NaOAc (13) available phosphorus was determined by the Olsen's method using a spectrophotometer (38), soil pH was measured in water at the soil to water ratio of 1:2.5 (45), and soil textural analysis was performed by Bouyoucous hydrometer method (15).

Treatments and the xperimental design: The experiment was done in a factorial combination of three cultivars of common bean (Hawassa Dume, Nasir, and Red Wolaita), and three levels of blended NPS fertilizer (0, 100, 200 kg ha^{-1}) using a randomized complete block design (RCBD) with three replications. Total numbers of treatments were nine (0kg NPS-RW, 100kg NPS-RW, 200kg NPS-RW, 0kg NPS-HD, 100kg NPS-HD, 200kg NPS-HD, 0kg NPS-NA, 100kg NPS-NA, 200kg NPS-NA). Blended NPS fertilizer contained (19% N, 38% P_2O_5, and 7% S). The gross plot size was (2.8 m × 3 m = 8.4 m^2) which contained 7 rows totally and the net plot size was (1.6 × 3 m =4.8 m^2) which contained 4 rows and one row was left for destructive sampling and two border rows were left as a border effect. The spacing between blocks and plots was 1 m and 0.6 m, respectively.

Experimental procedures and management

The soil was cleared from all unwanted materials and plant residues, plowed by oxen, leveled and the field layout was prepared. The field was divided into three blocks and nine plots in each block. The row spacing was 40 cm and the spacing between plants was 10 cm. assigning of the experimental treatment in the plots was carried out through lottery method randomization. After land preparation, the sowing hole was prepared in the depth of 5 cm and two seeds per hill were sown. NPS fertilizer was applied between two seeds at the time of sowing based on the treatment combination. After seedling establishment, one plant was thinned per plot throughout the plots. All necessary agronomic management was carried out properly starting from field preparation to harvesting uniformly.

Data collected

Phenological parameters: Days to 50% flowering was recorded as the number of days from planting to the date when 50% of the plants in each plot produced a flower, and days to physiological maturity was recorded as the number of days from sowing to when 90% of the plants in each plot showed yellowing of pods.

Growth parameters

Plant height was measured as the height of 10 randomly taken plants per plot from the ground level to the apex of each plant at the time of physiological maturity from the net plot area. The number of primary branches per plant was determined by counting primary branches on the main stem from randomly taken 10 plants per plot from the net plot area. The total number of nodules was determined by counting from five plants per plot at 50% flowering. Roots were carefully exposed with the bulk of root mass and nodules. The nodules were separated from the soil by washing and the total numbers of nodules were determined by counting. Effective nodules were separated by their colors were a cross-section of an effective nodule showed a pink to dark red color.

Yield components and yield

The number of pods per plant was determined by counting the number of pods per plant of 10 randomly taken plants from each net plot area at harvest, the number of seeds per pod was recorded from 10 randomly taken pods from each net plot at harvest, and hundred seeds weight (g) was determined by taking the weight of 100 randomly sampled seeds from the total harvest from each net plot area and adjusted to 10% moisture level. Total above-ground dry biomass (kg ha^{-1}) was measured from the destructive rows. The above-ground dry biomass of randomly taken ten plants was measured after sun drying till constant weight. For obtaining the total aboveground dry biomass, the dried biomass per plant was multiplied by the total number of plants per net plot and converted into kg ha^{-1}. This was used to calculate the harvest index also. Seeds yield (kg ha^{-1}) was determined after threshing the seeds harvested from each net plot. The seeds yield was adjusted to 10% moisture level and converted to kg ha^{-1}.

Statistical data analysis

All measured parameters were subjected to analysis of variance (ANOVA) appropriate to factorial experiment in RCBD using the GenStat version 15 (GenStat, 2012) and interpretations were made following the procedures described by (22) Whenever the effects of the factors were found to be significant, the means were compared using the Least Significant Differences (LSD) test at a 5 % level of significance.

RESULTS AND DISCUSSION

Soil physico-chemical properties of the experimental site The soil analysis result of experimental site was revealed that the soil is acidic and sandy loam where cultivation of haricot bean is possible (Table 2).

Table 2. Selected physicochemical properties of the experimental site soil before planting

Soil characters	Value	Rating	Reference
Particle size distribution			
Sand (%)	55		
Silt (%)	30		
Clay (%)	15		
Textural class		Sandy loam	(Gupta 2003)
Chemical analysis			
Soil pH	6.1	Slightly acidic	(Dragun 1998)
Organic carbon (%)	0.893	Low	(Walkley and Black 1934)
Total nitrogen (%)	0.1126	Low	(Bruce and Rayment 1982)
Available phosphorus (mg/kg)	3.58	Very low	(Hazelton and Murphy 2016)
CEC (cmol(+)/kg)	21.42	Medium	(Chapman 1965)

Phenological Parameters of Common bean

Days to 50% flowering: The number of days to 50% flowering was highly significantly ($P< 0.01$) affected by the main effect of the cultivar. Cultivars Nasir and Hawassa Dume were early flowering which required 41 and 41.33 days than Red Wolaita was flowered on 43.78 days after planting, this might be due to genetic differences as common bean has very high diversity in such phenological characters. In conformity to this result, (36) ,also reported significant differences in the number of days required to reach 50% flowering among 20 common bean genotypes that ranged from 26.67 to 45.

Days to physiological maturity

The number of days to physiological maturity was highly significantly (P<0.01) affected by the main effect of NPS and cultivars, and their interaction effect. Cultivar Red Wolaita with the NPS rate of 100 kg ha^{-1} required the longest (98.67) days to physiological mature while Hawassa Dume with control recorded the shortest (75.00) days to physiological mature (Table 3). This might be due to the cultivar that has a vigorous plant to germinate and flower attains early physiological maturity. This might be genetically controlled or environmentally derived due to drought stress that adversely affects the plant to perform the normal physiology. In line with this finding, the interaction effects of cultivars and P rates also significantly influenced days to 50% flowering, days to 90% physiological maturity (1).

Table 3. Physiological maturity influenced by the interaction effect of cultivars and the NPS rate

	NPS rate (kg ha^{-1})		
Cultivars	**0**	**100**	**200**
Hawassa Dume	**75.00^{f}**	**78.67^{d}**	**76.00^{e}**
Nasir	**73.67^{g}**	**78.00^{d}**	**76.00^{e}**
Red Wolaita	**88.00^{c}**	**98.67^{a}**	**93.00^{b}**
LSD (0.05)		**0.7900**	
CV (%)		**0.6**	

Growth parameters of common bean

Plant height (cm): Analysis of variance showed that the main effect of NPS rate and cultivars was highly significant (P<0.01), and the interaction effect of NPS rate with cultivar was significant on plant height. The highest plant height (107.87cm), and the lowest plant height (53.43cm) and (54.40cm) were observed at the NPS rate of 100 kg ha^{-1} with cultivar Red Wolaita, and NPS rate 0 kg ha^{-1} with cultivar Nasir and Hawassa Dume, respectively (Table 4). In line with this result, the promotion effect of high phosphorus in NPS fertilizer level and balanced NPS supply on plant height may be due to better development of the root system and nutrient absorption, (26) . In contrast, Turuko and Mohammed (44) reported that phosphorus rate had no significant effect on the plant height of the common bean.

Table 4. Plant height (cm) influenced by the interaction effect of cultivars with NPS rate

	NPS rate (kg ha^{-1})		
Cultivars	**0**	**100**	**200**
Hawassa Dume	**54.40^{h}**	**105.50^{b}**	**87.43^{e}**
Nasir	**53.43^{h}**	**102.27^{c}**	**79.87^{f}**
Red Wolaita	**58.17^{g}**	**107.87^{a}**	**91.93^{d}**
LSD (0.05)		**2.321**	
CV (%)		**1.6**	

Means in the table followed by the same letter(s) are not significantly different to each other at 5% level of significance, LSD (0.05)=Least significant difference at 5%; and CV (%) =coefficient of variation

Number of primary branches per plant

The main effect of cultivars and NPS rate was highly significant (P<0.01) on the number of primary branches per plant. The highest number of primary branches (4.567) was observed at cultivar Nasir which is statistically similar to Hawassa Dume (4.361) while the lowest number (3.80) was recorded for Red Wolaita, this can be attributed to genetic characteristics of common been as the crop has much diversity. Meanwhile, 100 NPS kg ha^{-1} rate resulted in the highest numbers of primary branches per plant (5.089) while the lowest (3.156) was recorded for control (Table 5). Low primary branches at 200 kg NPS kg ha^{-1} rate compared to 100 kg NPS kg ha^{-1} might be due to nutrient imbalance and excess SO_4^{-2} interferes with PO_4^{-3} uptake. The increment in the number of primary branches per plant might also be due to the importance of P in NPS fertilizer for cell division activity, leading to the increase of plant height and number of branches and consequently increased the plant dry weight and importance of S in NPS for growth and physiological functioning of plants. Also, sulfur plays a vital role in promoting nodule formation in legumes, chlorophyll formation, the formation of nitrogenase, controls certain soil-borne diseases, and tolerance to heavy metal toxicity in plants. Similarly (43) reported the highest number of branches per plant (5.67) at 20 kg P_2O_5 ha^{-1}. Likewise (6) reported the maximum number of primary branches per plant (6.6) due to the application of recommended rate of NP fertilizer (46 kg ha^{-1} of P_2O_5 and 41 kg ha^{-1} of N).

Table 5. Number of primary branches as influenced by the main effects of NPS rate and Nodulation

Cultivars	Number of primary branch per plant
Hawassa Dume	4.361[a]
Nasir	4.567[a]
Red Wolaita	3.800[b]
LSD (0.05)	0.3301
NPS rate (kg ha^{-1})	
0	3.156[c]
100	5.089[a]
200	4.483[b]
LSD (0.05)	0.331
CV (%)	7.8

Means in the table followed by the same letter(s) are not significantly different to each other at 5% level of significance; LSD (0.05) =Least significant difference at 5%; and CV (%) =coefficient of variation

The main effect of NPS rate, cultivars, and the interaction effect of NPS rate with cultivar on the number of effective nodules per plant, as well as the total number of nodules, was highly significant (P<0.01). The interaction effect of NPS rate of 100 kg ha^{-1} with cultivar Nasir produced the highest number of total nodules (68.53) and effective nodules (20.97), while variety Red Wolaita with 0 kg NPS rate produced the lowest number of total nodules (22.87h) and effective nodules (7.3) per plant (Table 6). This may be due to the cultivar's ability to establish a symbiotic relationship with *Rhizobium* bacteria, which allows the plant to form more nodules in its root. Similarly, differences exist among common bean cultivars in their respective abilities to form nodules and fix nitrogen, (30) . And, phosphorus is known to promote early root formation and the formation of lateral, fibrous, and healthy roots, which play an important role in N_2 fixation, nutrient, and water uptake. Thereby phosphorus is known to initiate nodule formation, increasing the number of nodules and essential for the development and function of the nodules. Also, sulfur plays an essential role in controlling certain soil-borne diseases and nitrogenase formation which are used in nitrogen fixation. The reduction of nodule for NPS rate of 200 kg ha^{-1} might be, as the application of easily available inorganic fertilizer weakens the symbiotic interaction and reduces the ability of nitrogen fixation for legume crops. Thus common bean needs the optimum rate of inorganic fertilizer for starting nodule formation and nitrogen fixation. In line with this result, (6) , reported the highest number of nodules per plant (15.3) for cultivar Nasir, (21) reported that nodule number per plant was significantly increased with increasing levels of phosphorus where the highest value (31.85) was obtained from the application of 20 kg P_2O_5 ha^{-1}. Nodule number and biomass were significantly diminished by the low P treatment (29), bean plants were well nodulated only when soil P concentrations were adequate (4), application of 26 kg P ha^{-1} and 8-16 kg N ha^{-1} fertilizer dramatically increased the number of root nodules and increased 48-51 %N derived from N_2-fixation of *Phaseolus vulgaris* (20) interaction effects of cultivars and P rates also significantly influenced root length, number of nodules, nodule dry weight (1). The total number of nodules and active nodules significantly increased with the application of sulfur only up to 20 kg S ha^{-1} but beyond the 20 S kg ha^{-1}, the mean nodule production reached a plateau and did not increase further (18) , similarly concluded as the limitation of S can reduce N_2 fixation by affecting nodule development and function (6)

Table 6. Interaction effect of cultivars and NPS rate on total and effective nodule number per plant

	Total nodule number NPS rate (kg ha^{-1})			Effective nodule number NPS rate (kg ha^{-1})		
Cultivars	0	100	200	0	100	200
Hawassa Dume	25.00^{g}	62.20^{b}	40.07^{d}	7.53^{f}	20.03^{b}	14.00^{cd}
Nasir	28.00^{f}	68.53^{a}	40.60^{d}	9.33^{e}	20.97^{a}	13.93^{cd}
Red Wolaita	22.87^{h}	47.53^{c}	38.47^{e}	7.30^{f}	14.300^{c}	13.57^{d}
LSD(0.05)		1.565			0.5779	
CV (%)		2.2			2.5	

Means in the table followed by the same letter(s) are not significantly different to each other at 5% level of significance, LSD(0.05) =Least significant difference at 5%; and CV(%) =coefficient of variation

Yield components and yield of common bean: Number of pods per plant : The main effect of NPS rates was highly significant and the main effect of cultivar was significant on numbers of pods per plant, while the interaction effect was non-significant. The number of pods per plant was highest (14.57) for cultivar Nasir while the lowest number of pods per plant (12.57) was recorded for cultivar Red Wolaita (Table 8), this might be due to hereditary disparity of cultivars to produce dry matter accumulating organs that further improvement in grain yield. In agreement with this result; (33) found substantial differences in the number of pods per plant among haricot bean varieties. Variety Hawassa Dume with a smaller seed size had a higher number of pods per plant than variety Ibbado with a larger seed size. Concerning the NPS rate, the highest number of pods per plant (18.64) was recorded by the NPS rate of 100 kg ha^{-1} while the lowest number (8.96) was from the control (Table 8). Increased number of pods with phosphorus application might be due to optimum availability and utilization of N, P, and S and other important nutrients for reproductive development. Much more fertilizer application is not necessary for the improvement of plant performance as it faces many fates. Following this finding, (46) stated that phosphorus application increased nutrient levels, causing the plants to produce more pods per plant because phosphorus promotes flowering and pod production. (44) found that applying phosphorus at a rate of 20 kg P ha^{-1} resulted in a higher number of pods per plant (48.16) of common bean. Besides, (21), reported that the application of phosphorus at 40 kg P_2O_5 ha^{-1} produced the maximum significant number of pods per plant (19.011).

Number of seeds per pod

The number of seeds per pod was highly significantly (P<0.01) affected by the main effects of NPS rate and cultivars, and their interaction effect. Considerably highest number of seeds per pod (7.5) was observed from the interaction effect of NPS rate at 100 kg ha^{-1} with variety Nasir while the lowest number of seeds per pod (5.73, 5.70, and 5.83) was recorded for the interaction of variety Red Wolaita, Hawassa Dume, and Nasir with NPS rate of 0 kg ha^{-1}, respectively (Table 7). The increase in seeds per pod with NPS fertilizer application up to the optimum level could mean that the NPS fertilizer contains ample nutrients for nodule formation, protein synthesis, fruiting, and seed formation. In line with this result, (44) found that at a P rate of 20 kg ha^{-1}, the maximum number of seeds per pod (5.85) was obtained.

Table 7. Seeds per pod influenced by interaction effect of cultivars and NPS rate

	NPS rate (kg ha^{-1})		
Cultivars	0	100	200
Hawassa Dume	5.733^{f}	7.233^{b}	6.333^{d}
Nasir	5.833^{f}	7.500^{a}	6.200^{de}
Red Wolaita	5.700^{f}	6.600^{c}	6.167^{e}
LSD (0.05)		0.1442	
CV (%)		1.3	

Means in the table followed by the same letter(s) are not significantly different to each other at 5% level of significance, LSD (0.05) =Least significant difference at 5%; and CV(%) =coefficient of variation

Hundred seeds weight (g)

The main effect of NPS rate and cultivars was highly significant, while the interaction effect was non-significant. Concerning the main effect of varieties, Nasir gave the highest 100 seed weight (30.01 g) followed by Hawassa

Dume (28.84 g) while Red Wolaita gave the lowest 100 seed weight (27.42 g) (Table 8). The deviation in seed weight among the cultivars might be genetic makeup, nutrients uptake and utilization, and dry matter translocation efficiency. Similar to other parameters, the NPS fertilizer rate of 100 kg ha^{-1} resulted in the highest hundred seed weight (32.57g) whereas 0 kg NPS ha^{-1} recorded the lowest hundred seed weight (25.00g) (Table 8). In line with this result, (32) reported that phosphorous fertilized crops were better filled with heavier seeds. Meanwhile, increased pods per plant and grains pod, as well as heavier seeds, can account for the increased yield under the Sulphur application (40).

Above ground dry biomass

The main effect of NPS rate and cultivars was highly significant on the above-ground dry-biomass yield, while the interaction effect was not significant. Among the cultivars, Nasir resulted in the highest above-ground dry biomass (3403kgha^{-1}) whereas the lowest (2963kgha^{-1}) was recorded from cultivar Red Wolaita (Table 8). Meanwhile, the NPS rate of 100 kg ha^{-1} recorded the highest above-ground dry biomass of (4074kgha^{-1}) while the lowest from control (Table 8). This increment in dry matter yield with an application of NPS fertilizer might be due to the adequate supply of N, P and S could have increased the vegetative canopy of the plant, which in turn increased the surface area for light interception and carbon dioxide absorption. Following this finding, (34) ,found that applying nitrogen and phosphorus fertilizers increased the dry matter yield of common beans significantly. Similarly, (19) ,found that the treatment with 40 kg P ha^{-1} resulted in the highest total biomass (4597 kg ha^{-1}).

Seeds yield

The main effect of NPS rate and cultivars on common bean seeds yield was highly significant ($P<0.01$), while the interaction effect was non-significant. The cultivar Nasir produced the highest grain yield (2233 kg ha^{-1}) and Red Wolaita produced the lowest seeds yield (1875 kg ha^{-1}) (Table 8). The final seeds yield is a cumulative result of improvement in the production of yield-related traits like pod per plant, seed per pod, hundred seed weight, and biological yield as well as the photosynthetic and dry matter translocation efficiency. This might be fevered by the application of the adequate composition and optimum rate of nutrients like phosphorous, nitrogen, and sulfur which are essential for the normal functioning of the plant. The highest grain yield (2627 kg ha^{-1}) was obtained with an NPS rate of 100 kg ha^{-1}, while the lowest grain yield (1389 kg ha^{-1}) was obtained with an NPS rate of 0 kg ha^{-1} (Table 8). The high phosphorus fertilizer dose of 200 kg ha^{-1} causes nutrient interaction, which can affect the availability of other nutrients required for common bean development. The control yielded the lowest grain yield, likely due to lower nitrification rates and P fixation in the acidic soil, which rendered N and P inaccessible to the common bean crop, resulting in low uptake and poor results. Following this result, (21) recorded a substantial increase in yield with rising phosphorus levels, with a maximum yield (2326 kg ha^{-1}) for haricot bean at the rate of 20 kg P2O5 ha^{-1} compared to control and 40 kg P2O5 ha^{-1},(40) reported that the rate of 100 kg NPS ha^{-1} found to be promising for better productivity of N-26 Mung bean cultivar, (1) reported that the interaction effects of cultivars and P significantly influenced the number of pods per plant, number of seeds per pod, pod length, hundred seed weight, dry biomass yield, and seeds yield. However, increasing the phosphorus level above the optimum rate did not result in a substantial increase in grain yield. This may be due to phosphorus interacts with several nutrients, the most common and well-studied antagonistic interaction being with zinc, which decreases its solubility and induces deficiency as a result of its toxic effect, as the toxicity of one nutrient is often followed by a deficiency of another. According to (1) , report the P use efficiency were also significantly affected by the interaction effect of cultivar and P application rate.

Table 8. Seeds yield, hundred seed weight, pod per plant, and above-ground dry biomass as influenced by the main effect of NPS rates and cultivars

Cultivars	Yield related traits			
	GY (kg ha^{-1})	HSW (g)	PPP	AGDBM (kg ha^{-1})
Hawassa Dume	2106^{b}	28.84^{b}	13.91^{b}	3218^{b}
Nasir	2233^{a}	30.01^{a}	14.57^{a}	3403^{a}
Red Wolaita	1875^{c}	27.42^{c}	12.57^{c}	2963^{c}
LSD (0.05)	171.4	1.198	1.096	194.8
NPS rate (kg ha^{-1})				
0	1389^{c}	25.00^{c}	8.96^{c}	2037^{c}
100	2627^{a}	32.57^{a}	18.64^{a}	4074^{a}
200	2199^{b}	28.71^{b}	13.44^{b}	3472^{b}
LSD (0.05)	171.4	1.198	1.096	337.5
CV (%)	8.3	4.2	8.0	6.1

Where, GY = grain yield; HSW= hundred seed weight; PPP= pod per plant; AGDBM= above ground dry biomass; LSD (0.05) =Least significant difference at 5%; and CV (%) = coefficient of variation.

CONCLUSION

Major constraints which limit the common bean cultivation in the study area were poor agronomic practices, soil acidity, poor soil fertility, and fertilizer management. The nutrient deficiency and inadequate amount of fertilization affect the notable ability of pulses like nodulation and biological nitrogen fixation. Supplying an adequate amount of well-balanced blended NPS fertilizer is very important to avail the essential nutrients like phosphorous, nitrogen, and Sulphur for maintaining the normal growth, nitrogen fixation, and productivity of crops. Due to this, the current research was aimed to assess the response of common bean cultivars to blended NPS fertilizer. Results revealed that the main effect of NPS rates, and cultivars highly significantly affected 50% days to flowering, number of primary branches per plant, pods per plant, hundred seed weight, above-ground dry matter biomass, and grain yield. Cultivar Nasir result higher for all the measured parameters, and among NPS rate 100 kg ha^{-1} recorded the highest result for the parameters like 50% days to flowering, the number of primary branches per plant, pods per plant, hundred seed weight, above-ground dry matter biomass, and grain yield. The interaction effect of NPS rate and cultivars highly significantly influenced days to 90% physiological maturity, plant height, total and effective nodule number, and the number of seeds per pod. Thus, cultivar Nasir interaction with 100 kg ha^{-1} NPS rate resulted in higher results for parameters like total and effective nodule number, seed per pod, and the less for plant height which was recorded highest result for Red Wolaita with 100 kg ha^{-1} NPS rate. Cultivar Nasir revealed that with the optimum amount of NPS application, the common bean can produce a more effective nodule that is capable of fixing atmospheric nitrogen for plant nourishment under acidic soil. Thereby it results in higher yield-related traits and grain yield among the three tested common bean cultivars. Thus, the use of the combination of 100 kg ha^{-1} NPS with Nasir cultivar result in the best performance for soil fertility improvement through nitrogen fixation for succeeding crops and it can be concluded tentatively.

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