

Effects of NPS and Bio-organic Fertilizers on Yield and Yield components of Faba bean (*Vicia faba* L.) in Gozamin District, East Gojjam, Ethiopia

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ABSTRACT

Faba bean (Vicia faba L) is the first grain legume in terms of hectareage, total production and foreign exchange earnings in Ethiopia. The current study was designed to evaluate effect of NPS and bio-organic fertilizers on the yield and yield components of faba bean in Debre Markos University research farm. A total of 16 treatments were made from the factorial combination of four levels NPS (0, 50, 100 and 150 kg ha⁻¹) and four levels bio-organic fertilizer (Nil BOF (Bio_(Nil)), rhizobium (Bio_(IR)), 10 t ha⁻¹ FYM (Bio_(FYM)) and FYM+Rhizobium (Bio_(FYM+IR))) in randomized complete block design (RCBD) with three replications. The Walki (EH 96049-2) variety, which is high yielding, moderate disease resistant and water-logging tolerant used as test crop. The result experiment showed that, plot treated with Bio_(FYM+IR)+NPS₁₀₀ treatment gave statically maximum effective number of tillers (2.73), maximum number of pods per plant (20.30), hundred seeds weight (76.11g), grain yield (5.62 t ha⁻¹), biomass yield (10.94 t ha⁻¹) and Harvest index (59.91%) than over other treatments received NPS fertilizer with and without bio-organic fertilizers. Therefore, the combined use of 100kg ha⁻¹ NPS with 10 tha⁻¹ FYM and rhizobium inoculation is superior for optimum production of faba bean in study area.

Key word: Faba Bean, Farmyard Manure (FYM), Nodulation, NPS Fertilizers, Rhizobium, Yield

1. Background

Faba bean is a crop belonging to the genus *Vicia* L., and *Fabaceae* family (Smýkal *et al.*, 2014). It is one of the most important grain legumes as human food and animal feed with high nutritive value and is an excellent nitrogen fixer (Sahile *et al.*, 2008; Rubiales, 2010). Faba bean is the first grain legume in Ethiopia in terms of hectareage, total production and foreign exchange earnings (Yamane and Skjelvg, 2003; IFPRI, 2010). The total area under cultivation of faba bean in Ethiopia is estimated to be 443,074.68 ha of land from which 838,938.38 tons is produced with the average yield of 1.89 t ha⁻¹ (CSA, 2015). Amhara and Oromia regions are the major producer of faba bean. Within the Amhara National Regional State: West Shoa, North Shoa, South Wello and East Gojjam Zones are identified as the major producer of faba bean in area coverage and productivity (Biruk, 2009; CSA, 2015).

Maintaining soil fertility and using plant nutrients in sufficient and balanced amounts is one of the key requirements to increase crop yield (Diacono *et al.*, 2013). The process of N₂-fixation is very sensitive to the availability of nutrient like N and P (Tang *et al.*, 2001). Still, the needs of N as starter (Lafond and Johnston, 2002) and Sulfur nutrients (Jamal *et al.*, 2009) were high in synthesis of amino acid and in synergistic role for nutrient uptake (Randhawa & Arora, 2000).

Rhizobium inoculation is well known bio-organic fertilizers to ensure adequate N of legumes instead of N-fertilizer (Gupta, 2004). Many investigators reported that *Rhizobium* inoculation increases plant growth, yield and chemical composition of legumes crops (Tartoura, 2002; Sara *et al.*, 2013). However, neither inorganic fertilizers nor organic sources alone can result in sustainable productivity of crops (Godara *et al.*, 2012; Zelalem, 2013). The best remedy for soil

fertility management and crop production is, therefore, a combination of inorganic and organic fertilizers, where the organic fertilizer increases soil organic matter and improves soil structure and buffering capacity of the soil (Godara *et al.*, 2012). Combination of FYM (Farm Yard Manure) with inoculation and nitrogen resulted in higher pods and shoot dry weight of pigeon peas (Ahmed, 2008). Likewise, Negi *et al.* (2007) noted that *Rhizobium leguminosarum* (N-fixer) and *Pseudomonas striata* (P-Solubilizer) in combination with FYM+NPK and NPK+lime increase the yield and protein content of garden pea.

Nowadays, faba bean cultivation and production is continuously declining due to the yield instability, devastating diseases, low soil fertility and lack of effective and compatible strain of *Rhizobium* in the soil (Habtemichael *et al.*, 2007; Gresta *et al.*, 2009). Blanket application of 100 kg DAP (Di-ammonium phosphate) ha⁻¹ or no application of any fertilizers for legume crop is also the most common problem in study area (EGZAD, 2016). Furthermore, there was meager information on data regarding interaction effect of NPS, FYM and *Rhizobium* inoculation on legume crops. Based on the EthioSIS (Ethiopian soil Information System) 2013 report, soil of Gozamin (soil of study area) lacks N, P and S soil nutrients. Therefore, this study was initiated and designed to evaluate effect of integrated use of NPS and bio-organic fertilizers on the yield and yield components of faba bean.

2. MATERIALS AND METHODS

2.1. Description of the Study Area

The experiment was conducted in Debre Markos University research farm during the main cropping season of 2016. It is located 10°20'N latitude and 37°43'E longitude with an altitude of 2446 m.a.s.l, while the soil of study area was dominated by nitosol (Table 1). The mean seasonal and annual rainfall of the area during 2016 was 1197 mm, and for 30 the year (1987-2016) was 1334 mm per year with minima and maxima temperature of 15°C and 25 °C respective.

2.2. Experimental Design and Treatments

The experiment was conducted using factorial experiment in randomized complete block design (RCBD) arrangement with three replications and two factors consisting of four levels in each. Which is bio-organic fertilizers (Nil BOF (Bio_(Nil)), *Rhizobium* inoculums (Bio_(IR)), FYM (Bio_(FYM)), and FYM+*Rhizobium* (Bio_(FYM+IR))) and blended-NPS (19-38-7) fertilizer (0, 50, 100 and 150 NPS kg ha⁻¹) which constitute a total of 16 treatments. The gross plot size was 2.8 m by 1.5 m (4.2 m²) and net area was 2 m*1.1 m* (2.2 m²). The space between each plot and block were 0.50 m and 1.50 m respectively while, inter and intra row spacing 40 cm and 10 cm were used. The average 10 t ha⁻¹ of FYM, which was prepared from mixer of cow dung and some waste feeds, was incorporated into soil 15 days prior to sowing and fertilizations. The “Walki (EH 96049-2)” which is high yielding, exporting type, moderate disease resistant and water-logging tolerant, variety of faba bean EIAR (2016), seeds were sown at depth of 8 cm in each plot after inoculation with *R. leguminosarum biovar viceae* inoculums following the rhizobia-based bio-fertilizer guidelines for smallholder farmers in Ethiopia recommend by (EIAR, 2014). Harvesting of faba bean was carried following their full maturity period with respect to their treatments mainly begin at 133 day after sowing. Then, it was subjected to sun drying to standardize the seed moisture content. The net plots of 2.4mx1.1m were harvested leaving border rows to test different parameters needed per plot of faba bean according to recommended agronomic practices.

2.3. Data Collection and Measurements

2.3.1. Growth and phonological parameter

Number of effective Nodule per plant (NENP):- Average effective number of root nodules per root were counted at 50% of flowing stage from five randomly selected plants of net plot area after gently washing is with clean water. The color was used to separate effective nodule number (Pinkish and reddish color) from ineffective (green to white color) indicating *Rhizobium* infection of the roots from total nodules (Lindstrom *et al.*, 2010; Aruna and Vishnu, 2016).

Plant height (PH):- The average height of ten randomly selected plants from the net plot area of each plot was measured from the soil surface up to the tip of the stem.

2.3.2 Yield component and yield parameters

Pod length (PL):- The pod length was measured in cm from ten plants those are randomly selected and the mean length was recorded on each plot.

Pod number per plant (PNP):- The total number of pods per plant from ten randomly selected plants was counted from each plot and the mean number was taken for analysis of variance.

Seed number per pod (SNP):- Number of seeds per pod was counted from ten randomly selected plants from net plot area and the mean seed number was taken.

Hundred-seed weight (HSW):- The seed was being harvested and sundried for three day and hundred seed was counted and weighed that had been taken from the composited seeds at each plot.

Biomass yield (BMV):- At maturity, the whole plant parts of above ground, from the net plot area was harvested and after drying for three days, the total biomass was measured.

Grain yield (GY):- Grain yield (economic yield) was measured by taking the weight of the grains from the net plot area converted to kilograms per hectare.

Straw yield (SY):- Straw yield was determined by subtracting the grain yield from total above ground biomass yield (BMV).

Harvest index (HI):- It is the ratio of economic yields to biological yield (Shah *et al.*, 2009).

2.4. Soil Sampling and Analysis

Table 1: Nutrient composition of FYM and physico-chemical properties of soil in experimental site.

Sample	Parameter	Value	Rating	Reference	Remark
SOIL	pH	5.3	moderately acidic	Tekalign (1991)	Moderate
	Total N (%)	0.24	Medium	Havlin <i>et al.</i> (1999)	Moderate
	Organic C (%)	1.55	Moderate	Tekalign (1991)	Moderate
	Available P (ppm)	0.59	Very low	Bashour (2007)	Deficient
	Exch. K (Meq/100g)	0.79	Medium	Metson (1961)	Moderate
	CEC (Meq/100g)	22.53	Medium	Landon (1991)	Sufficient
FYM	Total N (%)	0.39	High	Havlin <i>et al.</i> (1999)	Sufficient
	Organic C (%)	6.98	High	Tekalign (1991)	Sufficient
	Available P (ppm)	0.98	Very low	Bashour (2007)	Deficient
	Av. K mg kg ⁻¹	0.3	Low	Metson (1961)	Deficient
	CEC (Meq/100g)	27.53	High	Landon (1991)	Sufficient

NB:CEC=Cation exchange Capacity, Exch. K=Exchangeable potassium, Av.P=available phosphorus.

Table 1 indicates us, the soil of the study area and FYM content in available P and K is too low, while soil total nitrogen is medium for faba bean production. Therefore, the application NPS fertilizer with FYM is paramount important to obtain better yield.

2.5. Statistical Analysis

All the data collected were subjected to the analysis of variance using SAS version 9.1.3 (SAS, 2003). Wherever, the treatment showed a significant effect, Duncan's multiple range test (DMRT) was used for means separation. The treatments were compared for their significance using least significant difference (LSD) values at $p=0.05$.

3. RESULTS AND DISCUSSION

3.1. Effect of Bio-organic and NPS fertilizers on Growth Parameters of Faba bean.

3.1.1. Nodulation of faba bean

The analysis of variance ($p<0.05$) showed that, there was presence of significant differences on number of effective nodules per plant (NENP) due to the main and interaction effect of NPS and BOF (Appendix I). Accordingly, significantly higher NENP (62.53) followed by Bio_(IR+FYM)+NPS₀ (152.2) which was statically par with Bio_(IR)+NPS₀ (150). While, the lowest result from the interaction effect were recorded in those treatments received Bio_(FYM+IR)+NPS₁₅₀ and Bio_(FYM)+NPS₁₅₀ which gave minimum number of NENP Bio_(FYM+IR)+NPS₁₅₀ (76) and Bio_(FYM+IR)+NPS₀ (79.11) and is alike with Bio_(IR)+NPS₁₅₀ and Bio_(Nil)+NPS₁₅₀ (Table 2).

The possible reason might be due to the role of phosphorus that initiates nodule formation as well as influence the efficiency of the *Rhizobium*-legume symbiosis thereby enhancing nitrogen fixation. This result is corroborated with Nile (2011) who suggested that, application of organic manure alone or with *Rhizobium* inoculation plus 20 kg N ha⁻¹ significantly increased groundnuts nodulation and early pod formation over the control. Correspondingly, Bhuiyan *et al.* (2015) found that, the application of *Rhizobium* biofertilizer along with PKSZn chemical fertilizers produced the highest nodule number and nodule weight and the seed yield of lentil. However, more application of NPS chemical fertilizer with BOF the number of effective nodule per plant decreased, thus, treatments like Bio_(Nil)+NPS₁₅₀, Bio_(FYM)+NPS₁₅₀, and Bio_(FYM+IR)+NPS₁₅₀ gave the lowest the number of effective nodules per plant as compared with plants treated lower NPS levels fertilizers with and without BOF (Table 2). This might be due to the inhibitory effect of nitrate (NO₃⁻) that suppress nodulation of legumes, which caused from higher application of N fertilizer. In line with this result, different authors found that high N fertilizer application significantly reduce number of nodules and nodule dry weight per plant due to its inhibitory effects (Pons *et al.*, 2007). Otieno *et al.* (2009) reported that N fertilizer applications reduce the number of nodules per plant in Lablab and common bean but had no significant on green gram and lima bean.

3.1.2. Plant height

The plant height (PH) at 90% maturity reveals highly significant difference ($p<0.01$) due to combined and sole application of bio-organic and inorganic fertilizers (Table 2 & Appendix I). It was clearly observed that interaction effect of BOF and NPS fertilizers produce far superior PH to individual one (Table 2). Thus, statically the tallest plant was recorded from the plot treated with the Bio_(FYM+IR)+NPS₁₅₀ (161.53 cm) fertilizer followed by Bio_(FYM+IR)+NPS₁₀₀ (139.57 cm) which was statically par with Bio_(FYM)+NPS₁₅₀, Bio_(FYM)+NPS₁₀₀, Bio_(FYM)+NPS₅₀,

Bio_(IR)+NPS₁₀₀ and Bio_(IR)+NPS₁₅₀. While, lowest PH were recorded in Bio_(Nil)+NPS₀ (94.13 cm) and Bio_(FYM)+NPS₀ (100.36 cm) (Table 2).

The tallest plant height with application of NPS might be attributed to beneficial effect of phosphorus on root proliferation, nodulation and accelerating the synthesis of protoplasm there by the plants grew tall, higher pace of dry matter production and higher number of branches plant (Singh *et al.*, 2014). The result might also due to the function of nitrogen and sulfur involved in chlorophyll formation, which boost vegetative growth resulting increase in plant height (Deshbhratar *et al.*, 2010). In lined with this result Mam-Rasul (2017) stated that, plant height of faba bean increased with increased in nitrogen and phosphorus fertilizer. Similarly, Rakesh and Verma (2011) stated that, *Rhizobium* inoculation with application of FYM and chemical fertilizers had significantly increased the plant height of common bean over controls. Sharma and Chauhan (2011) reported that 100% NPK+Vermicompost+Bio-fertilizers gave the maximum plant height of pea plant. Similarly, Ifarhad *et al.* (2011) reported that different doses of potassium and sulfur fertilizers had significant effect on the plant height of soybean.

Table 2: Interaction effect of NPS and BOF fertilizers interaction on growth parameter of faba bean

Treatments	NENP	PH (cm)	Treatments	NENP	PH (cm)
T ₁ (Bio _(Nil) +NPS ₀)	119.73 ^{egf}	94.13 ^h	T ₉ (Bio _(FYM) +NPS ₀)	133.55 ^{cdc}	100.36 ^{gh}
T ₂ (Bio _(Nil) +NPS ₅₀)	117.83 ^{egf}	118.96 ^{cdef}	T ₁₀ (Bio _(FYM) +NPS ₅₀)	123.49 ^{egf}	130.70 ^{bcd}
T ₃ (Bio _(Nil) +NPS ₁₀₀)	114.91 ^{gf}	125.18 ^{bcd}	T ₁₁ (Bio _(FYM) +NPS ₁₀₀)	108.33 ^g	138.75 ^b
T ₄ (Bio _(Nil) +NPS ₁₅₀)	89.93 ^h	136.46 ^b	T ₁₂ (Bio _(FYM) +NPS ₁₅₀)	79.11 ^h	141.83 ^b
T ₅ (Bio _(IR) +NPS ₀)	150.0 ^{abc}	103.40 ^{fgh}	T ₁₃ (Bio _(FYM+IR) +NPS ₀)	152.20 ^{ab}	110.26 ^{efgh}
T ₆ (Bio _(IR) +NPS ₅₀)	162.53 ^a	114.35 ^{defg}	T ₁₄ (Bio _(FYM+IR) +NPS ₅₀)	145.23 ^{bdc}	132.29 ^{bc}
T ₇ (Bio _(IR) +NPS ₁₀₀)	130.59 ^{edf}	136.52 ^b	T ₁₅ (Bio _(FYM+IR) +NPS ₁₀₀)	145.25 ^{bdc}	139.57 ^b
T ₈ (Bio _(IR) +NPS ₁₅₀)	83.93 ^h	141.53 ^b	T ₁₆ (Bio _(FYM+IR) +NPS ₁₅₀)	76.00 ^h	161.53 ^a
LCR	17.22	16.72	LCR	17.22	16.72
CV	8.67	7.92	CV	8.67	7.92

NB: Bio= (IR=Inoculation of *Rhizobium*, FYM=Farmyard Manure), LCR=Least critical Range, NENP=Number of effective nodule per plant, PH=plant height. Means sharing the same letter are not significantly different at 5% level of significance.

3.2. Effect of Bio-organic and NPS Fertilizers on Yield Parameters of Faba Bean.

3.2.1. Pod length

The analysis of variance ($p < 0.05$) indicated that, there was presence of significant differences in pod length (PL) due to the main effect of NPS and BOF; but there was interaction effect no significant (Table 3 and Appendix I). Thus, the plots, which received NPS₁₀₀ and NPS₁₅₀ gave, significantly the longest PL (6.92 cm and 6.81 cm), respectively, whereas the plot that received NPS₀ gave the shortest PL (5.39 cm) (Table 3).

Considering BOF, it was observed that plot treated with Bio_(Nil) were significantly gave lower PL (5.91 cm) compared to Bio_(IR), Bio_(FYM), and Bio_(FYM+IR), which in turn were found to be at par with one another.

The beneficial effect of organic manure on growth and yield attributes might be due to additional supply of plant nutrients as well as improvement in physical, chemical and biological properties of soil (Datt *et al.*, 2003). This might also be attributed to the improved vegetative growth, better availability and translocation of nutrients (Singh *et al.*, 2009). These results verified the findings

of Jwan *et al.* (2015) who observed that, pod length of broad bean significantly increased due to the application of organic manure and chemical fertilizer. Corresponding trend were reported in faba bean were found by Neveen and Amany (2008) and Kazemi *et al.* (2007). Muhammad *et al.* (2015) also found that the application of FYM and NPK was significantly increased all growth and yield parameter including pod length, pod weight, 100g grain weight of garden pea.

Table 3: Main effect of NPS and bio-organic fertilizers on pod length (LP) of faba bean.

NPS-fertilizer	PL (cm)	BOF-fertilizer	PL (cm)
NPS ₀	5.39 ^c	Bio _(Nil)	5.91 ^b
NPS ₅₀	6.09 ^b	Bio _(IR)	6.35 ^a
NPS ₁₀₀	6.92 ^a	Bio _(FYM)	6.34 ^a
NPS ₁₅₀	6.81 ^a	Bio _(FYM+IR)	6.60 ^a
LCR		0.27	
CV		5.15	

NB:-IR=Inoculation of *Rhizobium*, FYM=Farmyard Manure, LCR=Least critical Range. Means sharing the same letter are not significantly different at 5% level of significance.

3.2.2. Pod number per plant

The statistical analysis showed that the main and interaction effect of NPS and BOF significantly influences the number of pods per plant (PNP) (Table 4 and Appendix I). Thus, significantly maximum PNP (20.3) was recorded in Bio_(FYM+IR)+NPS₁₀₀ over the other treatments which is in par with Bio_(FYM+IR)+NPS₁₅₀ treatment (19.43) (Table 4). Lower PNP was recorded in plot receiving Bio_(Nil)+NPS₀ (10.57) which was in par with Bio_(FYM)+NPS₀ (11.57).

Increasing number of pods per plant was ascribed to role of FYM in promoting seed germination and root growth of the crop plants by improving the water holding capacity, aeration of the soil and supply of nutrient that is important for increments in number of pod per plant. In addition, sulfur application and inoculation have immense potential of increasing the amount of N₂ fixed by legumes, thus improving fertility status of soil and then favor crop growth (Habtemichael *et al.*, 2007). The result is concurrence with Sohu *et al.* (2015) who reported, application of half dose of NPK (18-36-10 kg ha⁻¹) + poultry manure (PM) or FYM at 20 t ha⁻¹ increased pods per plant and seed yield of chickpea. Abbas *et al.* (2011) also found that application of DAP at 124 kg ha⁻¹ along with 10 t ha⁻¹ of poultry litter gave maximum number of pods per plant of mungbean. In the same way, Patil *et al.* (2011) stated that, application of varied levels of rock phosphate with phosphate solubilizing bacteria and their interaction with organic manures had significant influence on number of pods per plant and grain yield of chickpea.

Table 4: The interaction effect of BOF and NPS fertilizers on pod number per nod (PNN) and pod number per plant (PNP) of faba bean

Treatments	PNP	Treatments	PNP
T ₁ (Bio _(Nil) +NPS ₀)	10.57 ⁱ	T ₉ (Bio _(FYM) +NPS ₀)	11.47 ^{hi}
T ₂ (Bio _(Nil) +NPS ₅₀)	12.43 ^h	T ₁₀ (Bio _(FYM) +NPS ₅₀)	14.17 ^{fg}
T ₃ (Bio _(Nil) +NPS ₁₀₀)	15.97 ^{bcde}	T ₁₁ (Bio _(FYM) +NPS ₁₀₀)	15.50 ^{def}
T ₄ (Bio _(Nil) +NPS ₁₅₀)	17.43 ^b	T ₁₂ (Bio _(FYM) +NPS ₁₅₀)	17.333 ^{bc}
T ₅ (Bio _(IR) +NPS ₀)	12.300 ^h	T ₁₃ (Bio _(FYM+IR) +NPS ₀)	12.433 ^h
T ₆ (Bio _(IR) +NPS ₅₀)	14.3 ^{efg}	T ₁₄ (Bio _(FYM+IR) +NPS ₅₀)	15.70 ^{cdef}
T ₇ (Bio _(IR) +NPS ₁₀₀)	16.50 ^{bcd}	T ₁₅ (Bio _(FYM+IR) +NPS ₁₀₀)	20.30 ^a
T ₈ (Bio _(IR) +NPS ₍₁₅₀₎)	15.67 ^{cdef}	T ₁₆ (Bio _(FYM+IR) +NPS ₁₅₀)	19.43 ^a

LCR	0.08	LCR	0.08
CV	6.54	CV	6.54

NB: Bio= (IR=Inoculation of *Rhizobium*, FYM=Farmyard Manure), LCR=Least critical Range, PNP= Pod number per plant. Means sharing the same letter are not significantly different at 5% level of significance.

3.2.3. Seed number per pod

Seed number per pod (SNP) showed significant variation due to the main effect of NPS and BOF. However, the interaction effects turned non-significant $P < 0.05$ (Table 5 and Appendix I). For the main effect of NPS fertilizer, the significant highest SNP 2.79 and 2.71 was recorded for the plot treated with NPS₁₅₀ and NPS₁₀₀, respectively. Whereas, the NPS₀ treatment produced significantly the lowest SNP over the other plot which receiving 50, 100, and 150 kg ha⁻¹ NPS fertilizer (Table 5). The main effect of BOF gave statistically similar result except Bio_(Nil) which gave significantly the lowest SNP of faba bean.

This might be due to the organic matters realized nutrient slowly thus, supplementary with inorganic fertilizers enhances growth of microorganisms and then hasten decomposition of organic manures thus increasing the availability of nutrients. These results are consistent with the findings of Hanan *et al.* (2016) and Tadele (2016) who mentioned that, FYM and phosphorus fertilizer positively influenced number of pods per plant and seeds per pod of faba bean. Likewise, Sulfur application along with inoculation resulted in significant increase in growth parameter and N-fixation of black gram (Hussain *et al.*, 2011). Susheela *et al.* (2007) also reported that, *Rhizobium* and pseudomonas alone or in combination with FYM, NPK, FYM +NPK and lime increased all yield attributes of pea. As indicated by Getachew *et al.* (2005) the application of the 8 t ha⁻¹ FYM with P fertilizer resulted in the highest number of pods per plant and seeds per pods of faba bean. The work of Datt *et al.* (2003) revealed that NPK fertilizer combined with FYM significantly increased the seed per pod and yield of pea.

Table 5: Main effect of NPS and bio-organic fertilizers on seed number per pod (SNP) of faba bean

NPS-fertilizer	Seed Number per Pod	BOF-fertilizer	Seed Number per Pod
NPS ₀	2.09 ^c	Bio _(Nil)	2.37 ^b
NPS ₅₀	2.30 ^b	Bio _(IR)	2.44 ^{ab}
NPS ₁₀₀	2.71 ^a	Bio _(FYM)	2.53 ^a
NPS ₁₅₀	2.79 ^a	Bio _(FYM+IR)	2.55 ^a
LCR	0.12		
CV	5.79		

NB:-IR=Inoculation of *Rhizobium*, FYM=Farmyard Manure, LCR=Least critical Range. Means sharing the same letter are not significantly different at 5% level of significance.

3.2.4. Biomass Yield

The analysis of variance (Appendix II) revealed that biomass yield (BMY) was significantly ($P < 0.01$) affected main and interaction effect of NPS and BOF. Statically, maximum BMY was recorded in the plot received Bio_(FYM+IR)+NPS₁₅₀ (11.11 t ha⁻¹) which was statistically in par with Bio_(FYM+IR)+NPS₁₀₀. While, the minimum BMY were obtained with Bio_(Nil)+NPS₀ (3.14 t ha⁻¹), Bio_(Nil)+NPS₅₀ (5.52 t ha⁻¹), Bio_(IR)+NPS₀ (4.62 t ha⁻¹), and Bio_(FYM)+NPS₀ (4.75 t ha⁻¹) (Table 6). The increment of BMY is related to the increment of plant growth and yield attribute with BOF and NPS fertilize by its cumulative effects, such as enhanced supply and availability of N, P and S to the crop in addition to other essential substances provided by FYM. This may enhance the

synthesis of assimilates which can result in increase in dry matter yield (Gobarah *et al.*, 2006). This result is in concurrence with the findings of Tadele *et al.* (2016) who mentioned that, application of P fertilizer in conjunctions with FYM improves the biomass yield of faba bean. Correspondingly, El-Shouny and Behiry (2011) suggested that, application of compost and sulfur alone or in combination enhanced the seed yield of faba bean. Shahid *et al.* (2009) demonstrated that, phosphorus and inoculation of rhizobium strains have quite prominent effects on nodulation, growth and yield parameters of soybean.

3.2.5. Hundred Seeds weight

Table 6 and Appendix II depicted that the presence of significant difference for HSW among the treatments due to simple and interaction effect of the NPS and BOF ($p < 0.05$). Statistically maximum 100 seeds weight (HSW) was observed in the treatment received $\text{Bio}_{(\text{FYM}+\text{IR})} + \text{NPS}_{100}$ (76.11 g) which was in par with $\text{Bio}_{(\text{FYM}+\text{IR})} + \text{NpPS}_{150}$ (72.64 g). The minimum HSW was obtained in $\text{Bio}_{(\text{Nil})} + \text{NPS}_0$ (43.14 g) treatment, which was in par with $\text{Bio}_{(\text{FYM})} + \text{NPS}_0$ (49.29 g).

This could be due to significant contribution of extra N from N_2 -fixation and FYM to chemical fertilizer for the crop, as it is a major constituent of amino acids and many biological compounds that play major roles in photosynthesis, which eventually increased seeds weight. The P might be increased the amount of phytin stored in the seeds, which serves as the main source of stored P in most grains contribution to seed size and increased 100-grain weight (Nikfarjam and Aminpanah, 2015). The current result is in agreement with the findings of Nazar *et al.* (2016) who reported that, application of FYM to both inoculated and uninoculated guar plants increased the 100 seed weight. Similarly, Muhammad *et al.* (2015) found that increasing the application of FYM and NPK was significantly increase all growth and yield parameter of garden pea. Jakusko and Dakato (2015) reported that, application of NPK rates significantly affect 100 seed weight and seed yield of groundnut. Combined fertilization with N, P and K had a significant positive effect on 100-seed weight and seed yield per fed of faba bean (Nawar *et al.*, 2010).

3.2.6. Grain yield

Grain yield (GY) which is the result of morphological and physiological processes occurring during growth and development of a crop was significantly increased with an increased in mineral and organic fertilizer over control (Table 6 and Appendix II). At a given level of BOF variation in NPS fertilizer significantly caused a corresponding variation in grain yield. Thus, plots that received $\text{Bio}_{(\text{FYM}+\text{IR})} + \text{NPS}_{150}$ and $\text{Bio}_{(\text{FYM}+\text{IR})} + \text{NPS}_{100}$ recorded significantly the higher yield (5.85 and 5.62 t ha⁻¹, respectively). Whereas, plot treated with $\text{Bio}_{(\text{Nil})} + \text{NPS}_0$ produce the lowest grain yield (1.58 t ha⁻¹) which was in par $\text{Bio}_{(\text{IR})} + \text{NPS}_0$ and $\text{Bio}_{(\text{FYM})} + \text{NPS}_0$ which gave GY value of 1.87 and 1.78 t ha⁻¹, respectively (Table 6).

The increment of GY might be related to the increment of hundred grain yield, pod number per plant and seed number per plant due to the effect of NPS, as well as enhancement of phosphorus and nitrogen availability to plants by Rhizobium and FYM. This positive response could be due to increased absorption of nutrient from NPS and BOF resulting in increased formation of reproductive structure or sink strength and increased production of assimilates to fill the seeds. This result confirm the findings of Akbari *et al.* (2011) who suggest that, different combinations of FYM and N fertilizer treatments had significant effect on grain yield and biological yield groundnut. Similarly, Interaction effect of organic manures (5 t ha⁻¹ of compost and FYM) along with rock phosphate 200 kg ha⁻¹ cause significantly higher grain yield of chickpea (Patil *et al.*, 2011). Applications of sulfur with 20 kg S ha⁻¹ and 50 kg P₂O₅ ha⁻¹ significantly increased in grain and straw yield of pigeon pea (Deshbhratar *et al.*, 2010). Application of fertilizers NPK

(40:80:25 kg ha⁻¹) with 5 t ha⁻¹ FYM also gave significantly increases higher yield and yield components of soybean (Maheshbabu *et al.*, 2008).

3.2.7. Straw yield

Analysis of ANOVA expressed that, straw yield (SY) was significantly influenced by individual and interaction effects of BOF and NPS (Table 6 and Appendix II). The interaction effect of BOF and NPS fertilizer gave statistically better SY than their simple application effect. Accordingly, maximum SY was recorded in the plot received Bio_(FYM+IR)+NPS₅₀ (6.51 t ha⁻¹) while, the minimum SY were observed for Bio_(Nil)+NPS₀ (1.56 t ha⁻¹) which was also statistically in par with Bio_(FYM)+NPS₀ respectively (Table 6).

The effect of fertilizers on straw yield could be attributed to rapid expansion of dark green foliage, which could intercept and utilize more incidence light energy in the production of food through the process of photosynthesis due to N fertilizer. Thus, increased production of photosynthate might have helped increase in plant height, number of primary, secondary and tertiary branches per plant (number of tillers), which might be responsible for higher seed and straw yield (Shroff, 2003). This result supported by the findings of Hanan *et al.* (2016) who found that, the effect of NPK fertilization without and with bio-inoculation was increased yield and yield components of faba bean. Phosphorus and sulfur application resulted in increase in dry matter yield of chickpea up to 10-27 % (Muhammad *et al.*, 2013). Organic manure in combination with the chemical fertilizer achieved better yield of soybean as well as to improve soil fertility status (Khaim *et al.*, 2013).

3.2.8. Harvest index

Harvest index is very useful in measuring nutrient partitioning in crop plants, which provides an indication of how efficiently the plant utilized acquired nutrients for grain production. It is obvious from the results described in Table 6 and Appendix II ($p < 0.05$) harvest index (HI) was influenced by the sole and interaction effect of NPS and BOF but not by individual effect of BOF. The combined application of NPS with BOF resulted statistically maximum HI (59.91%) in the plot received Bio_(FYM+IR)+NPS₁₀₀ compared to other treatments, while, the plot treated with Bio_(FYM+IR)+NPS₀ and Bio_(IR)+NPS₀ gave the lowest HI (39.37% and 39.41%), respectively. The possible reason could be the increased rate of FYM and inorganic NPS that might have increased the efficiency of the faba bean to partition the dry matter to the seed. Parallel results were reported by Malik *et al.* (2006) found that seed inoculation with Rhizobium significantly increases plant height, seed yield and harvest index in soybean. However, Tanner and Vlek (2000) who disclosed that, HI decreased by P application due to enhanced straw production of faba bean. Amany (2007) reported that urea application had a significant impact decrease the harvest index of chickpea due to its role in more vegetative growth.

Table 6: The interaction effect of NPS and BOF on yield parameters of faba bean

Treatments	BMV (t ha ⁻¹)	HSW(g)	GY (t ha ⁻¹)	HI (%)	SY (t ha ⁻¹)
T ₁ (Bio _(Nil) +NPS ₀)	3.14 ⁱ	43.14 ⁱ	1.58 ^h	50.34 ^{bcd}	1.56 ^h
T ₂ (Bio _(Nil) +NPS ₅₀)	5.52 ^{hi}	59.21 ^{fg}	2.21 ^{gf}	41.19 ^{ef}	3.31 ^{fg}
T ₃ (Bio _(Nil) +NPS ₁₀₀)	8.27 ^e	63.23 ^{defg}	4.04 ^{cd}	48.96 ^{cde}	4.22 ^{de}
T ₄ (Bio _(Nil) +NPS ₁₅₀)	8.89 ^{de}	71.99 ^{abc}	4.26 ^c	47.92 ^{cde}	4.63 ^{cd}
T ₅ (Bio _(IR) +NPS ₀)	4.61 ⁱ	50.98 ^h	1.87 ^{gh}	39.41 ^f	2.74 ^g
T ₆ (Bio _(IR) +NPS ₅₀)	6.63 ^{gf}	58.66 ^g	3.20 ^c	53.03 ^{abc}	3.43 ^{fg}
T ₇ (Bio _(IR) +NPS ₁₀₀)	8.66 ^e	64.20 ^{defg}	4.39 ^c	58.86 ^a	4.28 ^{de}
T ₈ (Bio _(IR) +NPS ₁₅₀)	9.92 ^c	65.57 ^{cdef}	4.46 ^c	47.07 ^{cdef}	5.46 ^b

T₉(Bio_(FYM)+NPS₀)	4.75 ⁱ	49.29 ^{hi}	1.78 ^{gh}	40.54 ^{ef}	2.97 ^{fg}
T₁₀(Bio_(FYM)+NPS₅₀)	6.77 ^f	60.77 ^{efg}	3.17 ^e	45.91 ^{cdef}	3.60 ^{ef}
T₁₁(Bio_(FYM)+NPS₁₀₀)	9.87 ^c	68.86 ^{bcd}	4.97 ^b	53.82 ^{abc}	4.90 ^{bcd}
T₁₂(Bio_(FYM)+NPS₁₅₀)	9.66 ^{cd}	66.33 ^{bcde}	5.04 ^b	52.28 ^{abc}	4.62 ^{cd}
T₁₃(Bio_(FYM+IR)+NPS₀)	5.72 ^{gh}	50.88 ^h	2.45 ^f	39.37 ^f	3.26 ^{fg}
T₁₄(Bio_(FYM+IR)+NPS₅₀)	10.10 ^{bc}	60.53 ^{efg}	3.59 ^{cd}	42.90 ^{def}	6.51 ^a
T₁₅(Bio_(FYM+IR)+NPS₁₀₀)	10.94 ^{ab}	76.11 ^a	5.62 ^a	59.91 ^a	5.32 ^{bc}
T₁₆(Bio_(FYM+IR)+NPS₁₅₀)	11.12 ^a	72.64 ^{ab}	5.85 ^a	58.70 ^{ab}	5.26 ^{bc}
LCR	0.96	6.64	0.47	8.48	0.77
CV	7.39	6.49	7.75	10.43	11.11

NB: Bio= (IR=Inoculation of *Rhizobium*, FYM=Farmyard Manure), LCR=Least critical Range, HSW=Hundred Seeds Weight, GY=Grain yield, BMY=Biomass yield, HI=Harvest, SY=Straw yield.

Means sharing the same letter are not significantly different at 5% level of significance.

4. Conclusion

The current results clearly indicated that, yield and yield attribute of faba bean increased through combined application of NPS and bio-organic fertilizers. The interaction effect of NPS₁₀₀ with Bio_(FYM+IR) application significantly increased yield and yield components a faba bean except for pod length and seed number per pod. Generally, it was possible to recommend that, use of 100 kg ha⁻¹ of NPS fertilizer with the combination of 10 t ha⁻¹ of FYM and rhizobium inoculation was prominent to enhance yield and yield components of faba bean in study area. This combination might give similar result in an area having similar agro-ecological condition with study site. To confirm and recommend this combination, further research is needed to be conducted in multiple locations and seasons.

Abbreviations

BOF: Bio-Organic Fertilizer; CSA: Central Statistically Agency; DAP: Di-ammonium phosphate; EGZAD: East Gojjam Zone Agricultural Department; EIAR: Ethiopian Institute for Agricultural Research; FYM: Farm Yard Manure; IFPRI: International Food Policy Research Institute; NPK: Nitrogen, Phosphorus and Potassium;

Data availability Data and Material: The data used to support the finding in this research are quantitative and organized in excel format and will be readily available from the corresponding author upon request. Addisu Ebbisa, Tel: +251917648657, Email: saebbisa@gmail.com (PhD. in Agronomy).

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