The response of haricot bean (*Phaseolus vulgaris* L.) to integrated use of phosphorus and manure, Eastern Ethiopia

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Haricot bean (*Phaseolus vulgaris* L.) production in Ethiopia is limited mainly due to soil nutrient depletion. Some attempts in using limited amounts of mineral fertilisers only brought small improvements in soil fertility and yield of the crop. Hence, to evaluate the response of haricot bean to integrated use of phosphorus and manure, an experiment was conducted with three replications of a randomised block design comprising the nine treatment combinations of three levels of P (0, 50 and 100 kg triple super phosphate (TSP) ha^{-1}) and three levels of manure (0, 5 and 7.5 t ha^{-1}). All the collected agronomic data were subjected to ANOVA using Genstat 18th Edition software. Results showed that the highest number of pods per plant (38.13) was recorded from the main effect of 100 kg TSP compared to the lowest (30.40) for the control. The highest effective number of nodules (221.1) was recorded from the main effect of 100 kg TSP. The highest harvest index (0.56) was recorded when 0 t manure ha^{-1} was applied. Simple correlation analysis confirmed that grain yield was correlated with total number of nodules, effective number of nodules and number of pods per plant. The results showed that use of 100 kg TSP with 5.0 t manure ha^{-1} gave the highest grain yield (3.40 t ha^{-1} vs 1.95 t ha^{-1} control). Increasing manure to 7.5 t ha^{-1} gave the highest dry matter yield (7.2 t ha^{-1} vs 3.5 t ha^{-1} control). The integrated use of 50 kg TSP with 7.5 t manure ha^{-1} was found beneficial for haricot bean producers in the study area. Combined applications of TSP and manure doubled haricot bean yield at Mechara area in Darolebu district of the eastern Ethiopian highlands.

Keywords: Mineral fertiliser, manure, haricot bean yield, integrated use

Agriculture is a vital sector for feeding the world population. However, developing countries face the problem of improving food availability by enhancing the sustainability of soil productivity and nutrient level base on which agriculture depends. In Ethiopia, the agriculture sector accounted for 42% of the country's GDP, 90% of export value and 70% of raw materials required by industries (ATA 2015). However, the sector is not producing the required yields; decreasing farm size, decline in soil nutrients and land degradation are root causes for food production shortages and high livelihood vulnerability, especially in the densely populated areas in the eastern highlands of Ethiopia (Wondimagegn and Lemma 2016; Mulualem and Yebo 2015).

Pulse crops are important components of crop production among most legume crops in Ethiopia's smallholders' agriculture, providing an economic advantage, and food security. Haricot or common bean (*Phaseolus vulgaris* L.) is among the main export crops and is evolving as an important source of foreign currency (Girma 2009). The average yields are low, usually less than 1.3t ha^{-1} (CSA 2016) due to lack of inputs, moisture stress, low soil nutrients (FAOSTAT 2008; Wondosen and Tamado 2017). Soil nutrient depletion is the leading cause for limiting the production of haricot bean in Ethiopia in general (Habtamu et al. 2017) and in Hararghe in particular.

In Ethiopia, haricot bean is mainly cultivated under limited fertiliser application (CSA 2016) and there is limited information on the effects of combined application of organic and mineral fertilisers. Haricot bean is also vulnerable to diseases and moisture. Hence, haricot bean production in Ethiopia remains low and declining. So far, no work has been conducted on the determination of the integrated use of triple super phosphate (TSP) and manure rates for production of haricot bean in eastern Hararghe, Ethiopia. Thus, there was a need to acquire information on the impact of the integrated use of phosphorus and manure on yield and yield components of haricot bean and to estimate the optimum rate of combined use of TSP and manure in the study area. Therefore, the experiment was conducted to evaluate the response of Haricot bean to the

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integrated use of phosphorus and manure on Nitisol at Mechara, Eastern Ethiopia.

Materials and methods

Description of the study area

The experiment was conducted at Mechara in Darolebu district during the main cropping season of 2017. Mechara is situated in West Harerghe zone of Oromia Regional State in the eastern part of Ethiopia, 434 km east of Addis Ababa. The study area has an elevation range between 1680 – 1705 m and located at 8° 33' – 8° 36' N and 40° 19' – 40° 20' E.

The district has a bimodal rainfall distribution and its distribution is mostly uneven. It receives an annual rainfall ranging from 900 – 1300 mm with an average of 1103 mm; the temperature of the district ranges from 14 to 29°C with an average of 20°C (Mechara Meteorological Station). The type of soil on which the experiment was conducted was Nitisol; which has a deep well-weathered profile with shiny deep red color and clay dominated soil, consisting of 12% sand, 24% silt and 64% clay. Hence, the soil is dominated by clay texture.

Description of experiment materials and design

One variety of white haricot beans (Awash1) was used for the experiment. Triple super phosphate (TSP) was used as a source of phosphorus and nitrogen fertiliser was used as a starter for all treatments at 20kgha^{-1}. Cow manure was used as the source of organic fertiliser. The trial was laid out in a randomised complete block design factorial arrangement with three replications. There were nine treatments:

0 kg TSP ha^{-1} + 0 t manure ha^{-1}
0 kg TSP ha^{-1} + 5 t manure ha^{-1}
0 kg TSP ha^{-1} + 7.5 t manure ha^{-1}
50 kg TSP ha^{-1} + 0 t manure ha^{-1}
50 kg TSP ha^{-1} + 5 t manure ha^{-1}
50 kg TSP ha^{-1} + 7.5 t manure ha^{-1}
100 kg TSP ha^{-1} + 0 t manure ha^{-1}
100 kg TSP ha^{-1} + 5 t manure ha^{-1}
100 kg TSP ha^{-1} + 7.5 t manure ha^{-1}

Agronomic and yield data collection

Agronomic data were collected on days to 50% emergence, days to 50% flowering, days to physiological maturity, number of nodules per plant, number of pods per plant, seeds per pod, dry matter, grain yield, harvest index and a thousand seed weight.

Statistical data analysis

All agronomic and soil data were analysed by analysis of variance using Genstat 18th Edition software (Genstat 2015). Mean separations were carried out using least significant difference (LSD) at 5% probability level. Simple correlation coefficients were calculated to assess the relationship and dependence among yield components, grain yield and above ground biomass yield.

Results and discussion

Main effects of TSP and manure on phenological parameters

Table 1 shows the analysis of the main effects of the phenological parameters to the application of TSP and manure.

Days to 50% emergence

The main effect of TSP on days to 50% emergence of haricot bean was significant; however, there was no significant ($P > 0.05$) difference for the main effect of manure on days to 50% emergence. The earliest days to 50% emergence (7.55) was recorded for the TSP application rate of 50kg ha^{-1} whereas the maximum (8.00) was recorded for the application of 100 kg per hectare.

Days to 50% flowering

The analysis of variance showed that the effect of the TSP on days to 50% flowering was not significant (P > 0.05), but the difference between the main effect of manure on days to 50% flowering was highly significant (P < 0.01). Applying manure at 5t ha^{-1} extended the days to flowering, applying more manure led to a further increase in the days to flowering. Contrary to this result P fertilisation initiated early flowering in haricot bean grown in the Ultisols of Areka, Southern Ethiopia (Gidago et al. 2011). This variation might be due to improved moisture content of soil, the N content in the manure and to starter N that was applied at planting time (Bhanwaria et al. 2022; Dion et al. 2020). According to Marschner (2012) fertilisation of P is related with enhanced cytokinins synthesis as well as supply of photosynthesis for formation of flowers.

Days to 95% physiological maturity

For days to attain 95% physiological maturity, the main effect of the treatments was significant (P < 0.05) and highly significant (P < 0.01) for TSP and manure respectively. For application of TSP the shortest days (89.56) to attain 95% physiological maturity was for the rate of 100 kg ha^{-1}, whereas 91.78 days were needed for the plots with no TSP. This finding agrees with the previous finding on the same crop in eastern Ethiopia by Wondwosen and Tamado (2017), who reported that increasing rates from 0 kg to 92 kg P_2O_5 ha^{-1} shortened physiological maturity up to 5 days. Similarly, (Veeresh 2003) reported that the number of days required to 90% physiological maturity of common was reduced by 3 days due to increasing P_2O_5 from 25 kg to 75 kg P_2O_5 ha^{-1}. Gidago et al. (2011) found a significant decrease in days to physiological maturity with increasing rate of P from 40 to 60 kg P_2O_5 ha^{-1}.

It is well known that phosphorus plays a vital role in hastening maturity of crops through activating enzyme reaction that helps to facilitate ripening (Marschner 2012). For manure application, the shortest days to maturity (88.22) were for the plots that received no manure, while the longest was 92.11 days for plots that received 7.5t ha^{-1}. This implies that length of days to 95% physiological maturity was extended in response to manure rate increment. The lengthy days to maturity, due to increase in manure, could be most probably due to the nitrogen obtained by the crop from the manure. According to the report by Veeresh (2003), days required to attain physiological maturity extended by 3 days when N rate increased from 40 to 80kg ha^{-1}.

Table 1: Main effects of triple super phosphate (TSP) kg/ha and manure (t/ha) on days to 50% emergence (DE), days to 50% flowering (DF), days to 95% physiological maturity (DPM), total number of nodules (TNN), number of effective nodules (ENN), number of pods/plant (NPP) and harvest index (HI) of haricot bean

TSP	DE	DF	DPM	TNN	ENN	NPP	HI
0	7.77^{ab}	41.67	91.78^{b}	142.9^{a}	130.2^{a}	30.40^{a}	0.47^{a}
50	7.55^{a}	41.11	90.67^{ab}	167.6^{a}	165.0^{b}	34.23^{b}	0.50^{b}
100	8.00^{b}	40.56	89.56^{a}	241.1^{b}	222.1^{c}	38.13^{c}	0.52^{c}
$LSD_{0.05}$	0 .45	ns	1.54	37.0	34.2	3.69	0.02
P value	0.019	0.197	0.025	0.001	0.001	0.017	0.007
Manure							
0	7.89	39.22^{a}	88.22^{a}	123.9^{a}	110.4^{a}	30.18^{a}	0.56^{c}
5	7.78	41.56^{b}	91.67^{b}	183.0^{b}	193.1^{b}	34.02^{b}	0.49^{b}
7.5	7.44	43.56^{c}	92.11^{b}	221.6^{c}	204.2^{b}	37.86^{c}	0.45^{a}
$LSD_{0.05}$	ns	1.24	1.54	37.0	34.2	3.69	0.02
P value	0.126	0.001	0.001	0.001	0.001	0.027	0.001
CV (%)	5.9	3.0	1.7	20.1	20.2	10.2	5.2

LSD: least significant difference, CV: coefficient of variation, ns: not significant. The same letter shows no significant difference, and different letters show significant differences between the means.

Nodulation

Significant ($P < 0.01$) differences were observed on the total and effective number of nodules in response to the main effects of TSP and manure. On low pH soil of Areka (southern Ethiopia) greater nodule numbers per plant were observed as levels of P increased (Tesfaye et al. 2016). Likewise, nodulation was meaningfully enhanced in faba bean grown in Lay Gayint district of northern Ethiopia due to application of manure (Fekadu et al. 2018). The improvement in available nutrients like P and Ca created conducive media for nitrogen fixer bacteria, and availability of various essential nutrients including P for the crop (Dereje et al. 2017).

Number of pods per plant

Applied manure and TSP fertiliser levels significantly ($P < 0.05$) increased the number of pods per plant over the control. The highest numbers of pods per plant of 38.13 and 37.86 were recorded due to main effects of 100 kg TSP ha^{-1} and 7.5t manure ha^{-1} respectively. The current observation agrees with the findings of Meseret and Mohammed (2014) and Dereje et al. (2017), who reported significantly increased pods per plant due to application of P at different rates in comparison with unfertilised plots. Similarly, sole application of farmyard manure resulted in an increase in number of pods per plant on faba bean grown in northern Ethiopia (fekadu et al. 2018).

Harvest index

The analysis of variance showed the existence of highly significant ($P < 0.01$) differences on harvest index for the main effects of TSP and manure. The application of TSP at rate 100 kg ha^{-1} resulted in the highest (0.52) harvest index. However, the reverse was true for the main effect of the manure where harvest index decreased due to application of manure. This finding revealed the vital role of P for grain development while manure contributed to vegetative growth. The outcome of this finding was in concord with the previous report by Dereje et al. (2017), who reported that harvest index increased due to sole application of P as it attributed to better partitioning of dry matter into grain yield. Similarly, Veeresh (2003) reported that total biomass production of haricot bean improved significantly with the levels of nitrogen and phosphorus fertilisers.

Interaction effects of TSP and manure on phenological parameters

Analysis of variance showed there was no significant ($p>0.05$) difference among the interaction effect of TSP and manure on phenological parameters and yield component of the crop (Table 2).

Table 2: Interaction effects of triple super phosphate (TSP) and manure on days to 50% emergence (DE), days to 50% flowering (DF), days to 95% physiological maturity (DPM), total number of nodules (TNN), number of effective nodules (ENN), number of pods/plant (NPP) and harvest index (HI) of haricot bean

TSPkg/ha	Manure (t/ha)	DE	DF	DPM	TNN	ENN	NPP	HI
0	0	8.00	40.33	90.00	104.30	94.30	27.13	0.55
	5	8.00	40.67	92.00	163.30	151.00	31.93	0.46
	7.5	7.30	44.00	93.33	161.00	145.30	38.40	0.42
50	0	8.00	39.33	89.00	120.70	109.30	35.90	0.56
	5	8.30	42.00	91.67	174.70	163.00	39.87	0.50
	7.5	7.60	42.00	91.33	207.30	194.00	38.63	0.47
100	0	8.00	38.00	85.67	144.00	127.70	35.00	0.59
	5	7.00	42.00	91.33	283.00	265.30	36.27	0.51
	7.5	7.33	41.67	91.67	296.30	273.30	36.53	0.46
$LSD_{0.05}$		ns	ns	ns	ns	ns	ns	ns
P value		0.237	0.079	0.195	0.175	0.128	0.184	0.051
CV (%)		5.9	3.0	1.7	20.1	20.2	10.4	5.2

LSD: least significant difference, CV: coefficient of variation, ns: not significant.

Main effects of TSP and manure on dry mass yield and grain yield of haricot bean and plant P and N concentrations

Analysis of variance showed a highly significant ($P < 0.01$) difference between the main effects of TSP and manure rates with dry matter and grain yield of haricot bean. The applications of TSP and manure at all rates resulted in significantly higher dry matter yield than the controls (Table 3). For TSP application the highest dry matter yield (6.52t ha^{-1}) was recorded from the application of 100 kg TSP ha^{-1} and the lowest (4.97t ha^{-1}) from the control (Table 3). For manure, the highest (6.62t ha^{-1}) dry matter yield was recorded with the application of 7.5t manure ha^{-1}, whereas the lowest (4.61t ha^{-1}) was recorded with the control. A grain yield of 3.37t ha^{-1} was recorded with the application of TSP at the rate of 100 kg ha^{-1} and a grain yield of 1.95t ha^{-1} was recorded with the control. For manure a grain yield of 2.84t ha^{-1} was recorded from the application of 5t ha^{-1}, and a grain yield of 2.13t ha^{-1} was recorded from the control.

Table 3: Main effects of triple super phosphate (TSP) and manure on dry matter yield (DMY) and grain yield (GY) and plant tissue contents of haricot bean

			Plant tissue	
TSP (kg ha^{-1})	DMY (t ha^{-1})	GY (t ha^{-1})	P (%)	N (%)
0	4.97[a]	1.95[a]	0.228[a]	3.15
50	5.61[b]	2.86[b]	0.537[b]	3.27
100	6.52[c]	3.37[c]	0.602[c]	3.22
$LSD_{0.05}$	0.266	0.165	0.0229	Ns
P-value	<0.001	<0.001	0.001	0.106
manure (t $ha^{-1)}$				
0	4.61[a]	2.13[a]	0.423[a]	2.99[a]
5	5.76[b]	2.84[c]	0.463[b]	3.30[b]
7.5	6.62[c]	2.63[b]	0.481[b]	3.36[b]
$LSD_{0.05}$	0.266	0.165	0.0229	0.110
P-value	0.001	0.001	<0.001	0.001
CV (%)	4.7	5.8	5.2	3.4

LSD: least significant difference, CV: coefficient of variation

The results showed that TSP and manure application significantly improved the dry matter and grain yield of haricot bean under the ecology of the study area. Girma (2009) found a significant increment in dry matter yield of common bean with increased rates of NP fertiliser from 0 N, 0 P_2O_5 to 27 N, 69 kg P_2O_5 ha^{-1}. Similarly, Wondwosen and Tamado (2017) reported that higher dry matter yield was obtained due to vigour stand, good canopy development and dry matter production in response to NP fertilisation. Likewise, the dry matter yield of common bean was increased significantly by the application of different rates of N and P fertilisers (Veeresh 2003).

The reason for minimum grain yield for the controls might be attributed to poor soil nutrient status, poor nodulation, growth and development of the crop. Wondwosen and Tamado (2017) reported that the application rate of combined NP fertilisers improved the grain yield of common bean. Similarly, the application rate of P fertiliser had a positive effect on the grain yield of common bean (Meseret and Mohammed 2014) .

Similarly, Gidago et al. (2011) reported that the grain yield of haricot bean is directly related to the amount of dry matter yield. Wondwosen et al. (2018) reported that higher

seed yield of haricot bean was attributed to the improved yield components. Generally, the main effects of TSP and manure showed positive effect on grain yield of haricot bean, due to the improvement of plant available phosphorus as a result of applied phosphorus.

Main effects of TSP and manure application on plant N and P concentration

All treatments of TSP and manure significantly increased the P concentration in the crop leaves as compared to the control. For TSP application the highest value of P (0.602%) in the shoot tissue was recorded for the application of 100 kg TSP ha^{-1} and the lowest P (0.228%) was recorded from the control (Table 3). For the application of manure, the highest phosphorus concentration (0.481%) was recorded for the rate of 7.5t ha^{-1} and the lowest (0.423%) was recorded from the control (Table 3). The low phosphorus status of the experimental soil was expected to encourage a positive response to the applied rates of TSP fertiliser and manure.

Sole application of manure significantly ($P < 0.01$) affected the N concentration in the leaf tissues, but the sole application of TSP did not have a significant effect on N concentration. For manure application, the highest value of N in the leaf (3.36 %) was recorded at the rate of 7.5t ha^{-1}, whereas the lowest value (2.99%) was recorded for the control. Increasing rates of manure improved the N concentration in the shoot tissue of haricot bean leaves. This might be attributed to the application of organic manure to improve the soil properties which in turn led to increasing the available N at the early stage of crop growth and development by improving nutrient uptake by the plants. Feleafel and Mirdad (2014) reported that application of chicken manure and bio-fertiliser improved N content in pods and leaves of the snap bean plant. Application of organic source of nitrogen increased nitrogen concentration in the leaf tissue of snap bean plant, thereby improving the soil physical and chemical properties and soil nitrogen availability. Samah (2007) reported that the application of manure improves leaf N concentration content of beans than application of P fertiliser.

The result of this study agrees with the experiment conducted at Mechara Agricultural Research Center by Wondwosen et al. (2018), who observed that minimum values of nitrogen (2.72%) contents in the shoot tissue were recorded for haricot bean varieties due to the soil nutrient status of the experimental site. Sole application of P fertiliser or manure significantly ($P< 0.01$) affected the phosphorus concentration in the leaf tissue. Phosphorus content in haricot bean shoot tissues showed an increasing trend with increased rates of P and manure application from 0 to 100 kg TSP ha^{-1}. Increasing rates of TSP and manure steadily enhanced the P concentration in haricot bean leaf tissues. This might be due to the fact that higher rates of applied manure and TSP increased the concentration of P elements in the soil solution, which in turn may have improved plant growth and development, with subsequent increase in the P concentration in the leaf tissue. Wondwosen and Tamado (2017) reported that combined application of N and P fertilisers for haricot bean varieties resulted in high P concentration in shoot tissue.

Interaction effects of TSP and manure on dry mass and grain yield of haricot bean

Dry matter yields were highly significantly ($P < 0.05$) improved by combined application of TSP and manure. The highest dry matter yield of 7.24t ha^{-1} resulted due to the integrated application of 100kg ha^{-1} TSP with 7.5t ha^{-1} of manure, while the lowest value was observed from the unfertilised plot (Table 4).

Table 4: Interaction effects of triple super phosphate (TSP) kg/ha and manure t/ha on dry matter yield (DMY), grain yield (GY) and plant tissue contents of haricot bean

TSP (kg ha^{-1})	Manure (t ha^{-1})	DMY (t ha^{-1})	GY (t ha^{-1})	Plant tissue	
				P%	N%
0	0	3.54^{a}	1.95^{a}	0.164^{a}	2.927
	5	5.07^{bc}	2.32^{b}	0.255^{b}	3.180
	7.5	6.28^{e}	2.66^{c}	0.263^{b}	3.043
50	0	4.67^{b}	2.62^{c}	0.517^{c}	3.197
	5	5.50^{cd}	2.80^{c}	0.533^{c}	3.373
	7.5	6.66^{e}	3.15^{d}	0.560^{d}	3.560
100	0	5.62^{d}	3.33^{d}	0.587^{e}	3.130
	5	6.70^{e}	3.40^{d}	0.600^{e}	3.440
	7.5	7.24^{f}	3.38^{d}	0.620^{f}	3.440
$LSD_{0.05}$		0.461	0.28	0.018	ns
P value		0.018	0.032	0.001	0.051
CV (%)		4.7	5.8	5.2	3.4

LSD: least significant difference, ns: interaction not significant

This result is supported by the study conducted in South Jordan by Althrout et al. (2016) who reported that combined use of NP fertiliser with manure improved the productivity of haricot bean over control. Chinthapalli et al. (2015) revealed that combined use of inorganic NP fertiliser with organic nutrient sources improved dry matter yield of faba bean and field pea. The increased dry weight of the crop could be partly credited to the nutrients released through decomposition of the manure.

Grain yield of the crop was highly significantly ($P < 0.01$) affected by the interaction of the treatments. The application of 100 kg ha^{-1} TSP in combination with 5t ha^{-1} manure resulted in the highest grain yield of 3.40t ha^{-1}. Previous findings by Al-Chammaa et al. (2014) showed that combined application of sheep manure and P fertiliser resulted in a significant increase in soybean grain yield over the control. Fekadu et al. (2018) discovered that the combined use of organic fertilisers and P fertiliser improved the yield and quality of faba bean. The mineralisation of manure and the subsequent release of macronutrients as well as micronutrients, in addition to P nutrition contributed to the overall performance of the crop and subsequent increase in grain yield (Hellal et al. 2014).

Interaction effects of TSP and manure application on plant N and P concentration

The interaction effects of TSP and manure rates were significant on the P concentration of the leaf tissues, but not significant for N concentration. The P contents in haricot bean shoot tissues showed an increasing trend with increased rates of TSP and manure application. The highest value of P of 0.62%, in the shoot tissue, was recorded for the combined application of 100 kg ha^{-1} TSP along with 7.5t manure ha^{-1}; followed by 0.6% which was recorded for the combined application of 100 kg ha^{-1} TSP along with 5 t manure ha^{-1}. The lowest value (0.164%) of P was recorded for the control (Table 4). Similarly, Wondwosen and Tamado (2017) reported that combined application of N and P fertilisers at a site with similar agro-ecology for haricot bean resulted in high P concentration in shoot tissue.

Although it was statistically insignificant, increasing rates of the treatment combinations improved the N concentration in the shoot tissue of the haricot bean leaf. This might be attributed to the improvement of the soil properties and biological N fixation. Different research reports (Samah 2007; Feleafel and Mirdad 2014) revealed that the application of manure improved N content in different leguminous plant species.

Correlations of phenology, yield components and dry matter with grain yield of haricot bean

Correlation coefficient analysis helps to determine the nature and degree of relationship between measurable parameters. It resolves the complex relations between events into simple forms of association. To know the nature and extent of the relationship present between grain yield and its component parameters as well as the association among the phenologic, growth, and yield components. Correlations, among the 12 parameters were conducted and results are presented in Table 5. Grain yield showed positive and highly significant correlations with total number of nodules (r=0.60**), effective number of nodules (r=0.60**), dry matter yield (r= 0.81**) and number of pods per plant (r=0.59**). Therefore, any improvement of these characteristics would result in a substantial increment of grain yield.

Table 5: Correlation analysis among phenology and yield components with dry matter and grain yield of haricot bean

	DE	DF	TNN	ENN	DPM	NPP	DMY	HI	GY
DE	1								
DF	-0.17^{ns}	1							
TNN	-0.27^{ns}	0.38*	1						
ENN	-0.28^{ns}	0.39*	0.99**	1					
DPM	-0.07^{ns}	0.77**	0.19^{ns}	0.19^{ns}	1				
NPP	-0.18^{ns}	0.22^{ns}	0.42*	0.43*	0.20^{ns}	1			
DMY	-0.36^{ns}	0.42*	0.72 **	0.72**	0.31^{ns}	0.75**	1		
HI	0.15^{ns}	-0.75**	-0.35^{ns}	-0.35^{ns}	-0.68**	-0.39*	-0.51**	1	
GY	-0.29^{ns}	-0.03^{ns}	0.60**	0.60**	-0.09^{ns}	0.59**	0.81**	0.11^{ns}	1

DE = days to emergence, DF = days to flowering, TNN = total number of nodules, ENN = effective number of nodules, DPM = days to physiological maturity, NPP = number of pods per plant, DMY = dry matter yield, HI = harvest index, GY = grain yield.

A similar finding has been reported by Gidago et al. (2011), who reported that the grain yield was highly correlated with number of pods per plant and dry matter yield. The results of this study also agreed with the findings of Girma and Gebreyes (2017), who reported that grain yield was positively and highly significantly correlated with biomass yield.

Recommendation

For smallholder farmers in the Darolebu district, the combined use of TSP and manure is necessary for improving haricot bean yield and can increase their farm income.

Data Availability

The data used to support the findings of this study are available from the corresponding author on request.

Conflicts of interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

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