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Effects of Fertilizer, Rhizobium Inoculation and Lime Rate on Growth and Yields Field Pea in Horro and Gedo Highlands

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Abstract

Integrated inputs of production enhance the production and productivity of field pea (*Pisum sativum*). The effect of fertilizer, rhizobium strain and lime rate and their interaction on nodulation and grain yield of field pea was conducted with factorial arrangement in randomized complete block design with three replications. NP fertilizer rate significantly increased mean seed yield of field pea at both locations. Application of rhizobium strains significantly reduced mean seed yield as compared to untreated one indicating the presence of suitable local strain in the soil or high amount of nitrogen in the soil. Application of lime significantly reduced number of nodule plant^{-1}. Mean seed yield of field pea significantly increased with increase in lime rate at both locations. Interaction of NP fertilizer rate with rhizobium inoculation and application of lime significantly increased mean seed yield of field pea at both locations indicting the importance of using integrated inputs production for field pea production. Therefore, application of 23/25 kg NP ha^{-1} fertilizers, 6 kg lime ha^{-1} and without rhizobium inoculation at Horro highlands. Application 23/25 kg NP ha^{-1} fertilizers, without lime and with rhizobium inoculation at Gedo highlands were recommended for field pea production.

Keywords: Rhizobium strain; Field pea; Lime rate; Fertilizer

Introduction

Food security is becoming or is already of paramount concern in Ethiopia. Population pressure and land degradation are major problems which go in tandem and must be threatened crop production [1,2]. Drechsel et al. [3] soil nutrient depletion is considered as the biophysical root cause of declining per capita food production in sub-Saharan Africa. Smallholder agricultural production has remained consistently low and food security is very low [4]. In developing countries, continuous cultivation with inappropriate farming practices has resulted in severe depletion of nutrients and soil organic matter that seriously threatened agricultural productivity [5]. Rao et al. [6] soil acidity and associated infertility and mineral toxicities are major constraints to agricultural production in several parts of the world. Sakala et al. [7] acidic tropical soils, which have generally been considered marginal for food crop production, represent the largest block of potentially arable land in the world. Kang and Juo [8] increased soil acidity may lead to reduced yields, poor nodulation of legumes and stunted root growth. Soil acidity has been shown to constrain productivity in cropping based agriculture, resulting in reduced plant biomass and lower crop yields [9]. Soil acidity constrains symbiotic N_2-fixation [10], limiting rhizobium survival and persistence in soils and reducing nodulation [11], and causes nutrient imbalance [12]. Soil acidity affects the availability of nutrients within the soil and plants have different nutrient needs.

Field pea (Pisum sativum) is the second cool season food legume widely produced in Ethiopia [13]. Since soils in the highlands of Horro and Gedo highlands are ranged from moderate to strongly acidic [14,15]. Field pea produces best on soils, which are neutral or slightly acidic. The desirable pH range for best growth of field pea is in the soils having pH 5.5 to 6.7 [16]. Soil acidity problem has increasingly grown in its scope and intensity and need for urgent solution to minimize its adverse impact in field pea production. Increasing the inputs of nutrients has played a major role in increasing the supply of food to a continually growing world population [17]. The use of NP fertilizer, rhizobium inoculation and lime as ameliorants of soil acidity for the highly weathered soils of the sub-humid tropics offers a viable option. Legume nodules formation with symbiotic partners was stressed by soil pH, water stress, salinity, temperature and heavy metals [18]. Wood et al. [19] indicates that multiplication of rhizobium in the rhizosphere and nodulation were inhibited at pH 4.3 for trifolium. Applications of strains improved early nodulation and increased grain yield [20]. Optimum growth of leguminous plants is usually dependent on symbiotic relationships with N_2-fixing bacteria [21]. Rhizobium inoculation of legumes usually stimulates plant growth through effects on nodulation and N_2 fixation. FAO [22] acid soils place major difficulties for agricultural use but can be very productive if lime and nutrients are constantly applied and appropriate soil management is practiced. Acid soils can be made productive by applying lime in different parts of the world [23]. Lime application to soils most often causes a significant increase in pH and, thus, a change in microbial biomass [24], microbial dynamic and diversity [25]. However, the contribution of lime with different rhizobium strain and fertilizer rate on nodulation and grain yield of field pea in Horro and Gedo highlands had not been determined. Therefore, the objective of this study is to investigate the effect of fertilizer, rhizobium strain and lime rate and their interaction on nodulation and grain yield of field pea in the area.

Materials and Methods

The experiment was conducted in Horro and Gedo highlands during the 2007 and 2008 cropping seasons. Horro lies between 9°34'N latitude and 37°06'E longitude at an altitude of 2400 meter above sea level. Mean annual rainfall of 1,695 mm [26]. It has a cool humid climate with the mean minimum, mean maximum, and average air temperatures of 8.15, 15.72 and 11.94°C, respectively. Gedo lies between 9°03'N latitude and 37°26'E longitude at an altitude of 2400 meter above sea level receiving mean annual rainfall of 1,026 mm [26]. It has a cool humid climate with the mean minimum, mean maximum, and average air temperatures of 8.51, 18.48 and 13.49°C, respectively. The soil in both sites is Nitisols [27] and the properties are indicated in Table 1.

Soil	Horro	Gedo
pH (H_2O)	5.2	5.7
Total N (%)	0.343	0.36
O C	3.272	4.44
C:N (%)	10	12
Available P (ppm)	5	14.8
K (Meq 100 gm $Soil^{-1}$)	0.74	3.95
Texture	Clay	Clay loam

Table 1: Soil properties of the experimental site.

The experiment was laid in Randomized Complete Block Design in factorial arrangement with three replications. The factorial arrangement were fertilizer rate as factor A, rhizobium inoculation as factor B and lime rate as factor C. Three levels of fertilizer rates were; 13.5/15, 18/20 and 22.5/25 kg NP ha^{-1}. Rhizobium inoculation consisted of: without inoculation and with inoculation (10 g kg of $seed^{-1}$). Lime rates included; 0, 2, 4 and 6 t $CaCO_3$ ha^{-1}, respectively. The field pea varieties used was Tegegnech. The source of fertilizer was Diammonium phosphate. The weighed rate of fertilizer was applied at time of planting. Rhizobium strains (EAL-300) was used at the rate of 10 g per 1 kg seed, and then pelleted with sugar to insure attachment of the inoculants with seed. Lime was weighed and applied to each plot three weeks ahead of seeding field pea and incorporated to soil in 2007 and the residual effect was used in 2008. The recommended seed rate used was 150 kg ha^{-1}. The plot size used was 4 m × 4 m. All cultural practices were done as per the available research recommendation for field pea production.

The soil pH was measured with digital pH meter potentiometrically in the supernatant suspension of 1:2.5 soils to distilled water ratio. Organic carbon was determined following wet digestion methods as described by Walkley and Black [28] whereas kjeldahl procedure was used for the determination of total nitrogen (N) as described by Jackson [29]. The available phosphorus (P) was measured by Olsen method as described by Olsen et al. [30] and available potassium (K) was measured by flame photometry.

Plant data collected included: nodule $plant^{-1}$ at early pod setting; plant height; pods $plant^{-1}$ seeds pod^{-1}; 1000 seed weight and seed yields kg ha^{-1} at right maturity of the crop. Seed yield were harvested from the net plot. The harvested seed yield was adjusted to 10% moisture level according to Biru [31]. The adjusted seed yield at 10% moisture level per plot was converted to seed yield as kilogram per hectare. Thousand seeds were counted from the bulked seed and adjusted to a 10% moisture level from the net plot. The counted seed was weighed to get thousand seed weight. The data analysis was carried out using statistical packages and procedures of SAS computer software [32]. Mean separation was done using least significance difference (LSD) procedure at 5% probability level [33].

Results and Discussion

Location and cropping season

Plant height, seed $pods^{-1}$ and grain yield of field pea were significantly affected by location (Table 2) indicating the difference between two locations with soil fertility and climatic factors. Plant height, seeds pod^{-1} and 1000 seed weight were significantly influenced by cropping seasons indicating variation of climatic factors across different seasons. Similarly, Khan et al. [34] yearly yield difference may have been the results of temperature and rainfall distribution occurred during growing season. The result agrees with Hebblethwaite et al. [35] on faba bean. Seed yields were averaged 2153 kg ha^{-1}. At Horro mean seed yield was 1693 kg ha^{-1} but were higher 2217 kg ha^{-1} in 2007 compared to 2008 that was lower by 89%. At Gedo seed yields were averaged 2612 kg ha^{-1}, but were higher 3099 kg ha^{-1} in 2008 compared to 2007 that was higher by 46%. Thus, considering both locations differently is mostly very important for field pea production.

Effects of NP yield and yield components

All above and below ground parameters of field pea were non-significantly affected by application of NP fertilizer rates except mean seed yields at Horro and Gedo which were significantly affected (Tables 3-5). Number of nodules $plant^{-1}$ at Horro and plant height at both location of field pea was non-significantly with applied rates of NP fertilizer rates at Horro highlands (Table 2). This indicates the fertility status of Horro field was very low and need higher NP fertilizer rates as compared to Gedo Highlands for faba bean production. Brkic et al. [36] reported low doses of applied nitrogen had favorable effects on nodulation and nitrogen fixation.

Application rates of greater than 40 kg N ha^{-1} reduced nodulation of field pea [37]. At Gedo the number of nodules $plant^{-1}$ was significantly reduced with applied fertilizer indicating higher doses of mineral nitrogen resulted in nodule reduction. El Behidi [38] reported high rates of available soil nitrogen reduced nodulation and biological nitrogen fixation since plants did not require symbiosis with nodule bacteria. Mean seed yield of field was significantly increased with increased applied rates of NP fertilizers at Horro and Gedo highlands and combined over location (Table 5). Nygren et al. [39] found that both yield elements were increased by nitrogen fertilization. Sosulski and Buchan [40] also found that N fertilizer increased seed yield in field pea. Asserting the already recommended fertilizer rate for field pea production and look for economically feasible fertilizer rate for field pea production for the area was required.

Sources of Variation	Mean square						
	DF	Number of Nodule Plant^{-1}	Plant Height	Pods Plant^{-1}	Seeds Pod^{-1}	1000 Seed Weight	Grain Yield
Location	1	222.46	48908.65**	18.2391	10.7882**	2524.425*	60743244**
Year	1	9.582158	7832.038**	8.4013	41.975**	6169.651**	106756.3
NP rate	2	181.132463	237.3499	16.9074	0.464331	324.009	535724.8
Rhizobium inoculation	1	148.818453	61.67276	0.002974	2.743781	8.677918	86067.86
Lime rate	3	481.523951	7.52976	3.35003	0.586982	126.4003	336178.4
NP rate × Rhizobium inoculation	2	234.660285	157.9469	1.461866	0.468475	105.2089	93111.92
NP rate × Lime rate	6	126.838461	176.0411	5.935735	0.715125	270.0392	229449.6
Rhizobium inoculation × Lime rate	3	177.16667	231.71392	9.137191	1.055493	437.2857	455238.7
NP rate × Rhizobium inoculation × Lime rate	6	248.592884	121.16698	17.4216*	1.152425	220.0181	199336.9
Error	260	262.17224	201.377	7.755006	0.841381	414.8745	341983.8
CV (%)		10.52	11.58	32.38	18.66	10.09	27.18

Table 2: Mean square of number of nodules plant^{-1} plant height, number of pods plant^{-1}, number of seeds pod^{-1}, 1000 seed weight and grain yield of field pea due to varieties and management practices across years and location at Horro and Gedo, Ethiopia. *Significant at 5% level of probability, **significant at 1 and 5% probability level.

Effects of rhizobium inoculation

Application of rhizobium inoculation significantly affected mean number of nodule plant^{-1} of field pea at Gedo and combined over location; mean seed yield in 2007 at Gedo but non-significantly affected all other considered parameters of field pea (Tables 3-5). Higher nodule number plant^{-1} was recorded from inoculated seed of field pea as compared to untreated (Table 3) indicting use of rhizobium strains improved nodule formation and N_2-fixation of field pea at Horro and Gedo highlands.

Treatment	Number of Nodule Plant^{-1}			Plant Height (cm)			Pods Plant^{-1}		
	Horro	Gedo	Mean	Horro	Gedo	Mean	Horro	Gedo	Mean
NP kg ha^{-1}									
75	13	15	13	107	135	107	9	9	9
100	17	15	17	109	136	107	9	9	9
125	17	11	17	112	136	112	8	8	8
LSD (5%)	Ns	1.262	NS	Ns	Ns	Ns	Ns	Ns	Ns
Rhizobium Inoculation									
0	15	13	14	110	136	110	8	9	9
10	16	15	16	109	135	109	8	9	9
LSD (5%)	Ns	1.0304	1.3207	Ns	Ns	Ns	Ns	Ns	Ns
Lime rate t ha^{-1}									
0	20	16	18	111	134	123	9	8	8
2	16	13	14	108	137	124	8	9	9

4	13	15	14	109	137	123	8	9	8
6	13	11	12	110	136	123	9	9	9
LSD (5%)	Ns	1.4572	1.8678	Ns	Ns	Ns	Ns	Ns	Ns
CV (%)	24.31	22.64	11.55	12.69	9.1	11.55	22.3	28.26	27.31

Table 3: Effects of NP rate, rhizobium inoculation and lime rate on number of nodule plant^{-1}, and plant height of field pea at Horro and Gedo highlands. Ns=Non-significant at 5% probability level.

Maximum N_2-fixation in a legume requires that the legume be adequately nodulated [41]. Applied rhizobium inoculum did not give higher mean seed yield of field pea as compared to without rhizobium at Horro and Gedo highlands. Almost all mean seed yields of field pea were lower with rhizobium applied as compared to untreated seeds (Table 5).

Treatment	Seeds Pod^{-1}			Thousand Seed Weight		
	Horro	Gedo	Mean	Horro	Gedo	Mean
NP kg ha^{-1}						
75	5	5	5	199	206	202
100	5	5	5	201	206	203
125	5	5	5	197	202	200
LSD (5%)	Ns	Ns	Ns	Ns	Ns	Ns
Rhizobium Inoculation						
0	5	5	5	199	205	202
10	5	5	5	199	205	202
LSD (5%)	Ns	Ns	Ns	Ns	Ns	Ns
Lime rate t ha^{-1}						
0	5	5	5	196	206	201
2	5	5	5	195	206	201
4	5	5	5	197	207	202
6	5	5	5	207	206	204
LSD (5%)	Ns	Ns	Ns	7.0638	NS	Ns
CV (%)	15.85	19.65	18.63	7.61	7.77	10.08

Table 4: Effects of NP rate, rhizobium inoculation and lime rate on pods plant^{-1}, seeds pod^{-1} and thousand seed weight of field pea at Horro and Gedo highlands. Ns=Non-significant at 5% probability level.

This might be attributed to availability local adapted strains in the soil since field pea is produced in area for five decades or low adaptability and competitiveness of inoculated strains in the soil. Besides accessibility soil N in the soil helps performance of bacteria for luxury life rather than biological N_2-fixation.

McKenzie et al. [42] found that rhizobium inoculation of field pea increased yield on land with no history of legumes, and yield was increased on an average of 19%. Non-responsive to added inoculant were due to the presence of indigenous rhizobia [43]. It is also possible that the existing population of rhizobium in the soils of Horro and Gedo highlands was maintained to a sufficient level through yearly or continuous cultivation of field peas.

Treatment	Horro			Gedo			Mean
	2007	2008	Mean	2007	2008	mean	
NP kg ha^{-1}							
75	2089	1023	1556	2018	3172	2595	2076
100	2277	1153	1715	2039	3074	2606	2161
125	2285	1333	1809	2218	3050	2634	2221
LSD (5%)	74.683	57.892	71.852	82.32	97.777	NS	Ns
Rhizobium Inoculation							
0	2220	1172	1696	2178	3114	2646	2171
10	2214	1167	1691	2072	3083	2578	2134
LSD (5%)	Ns	Ns	Ns	67.21	Ns	NS	Ns
Lime Rate t ha^{-1}							
0	2013	1017	1515	2093	3138	2616	2065
2	2153	1119	1636	2100	3227	2664	2150
4	2319	1222	1771	2115	2998	2557	2164
6	2383	1321	1852	2192	3031	2611	2234
LSD (5%)	86.236	66.847	82.968	95.055	112.9	Ns	Ns
CV (%)	5.8	8.53	10.5	6.67	5.43	8.91	27.15

Table 5: Effects of NP rate, rhizobium inoculation and lime rate on seed yield of field pea at Horro and Gedo highlands. Ns=Non-significant at 5% probability level.

Effects of lime rate

Number of nodule plant^{-1} at Gedo and combined over location and mean seed yield of field pea were significantly affected by application of lime rate (Tables 3 and 5). Higher mean number of nodule plant^{-1} of field pea was harvested from untreated field with lime as compared to limed fields (Table 3). This might be due to tolerance the rhizobium strains to the acidity levels in the soil. In addition, the acidity of the soil is in medium to weak acidity range which might favor symbiosis of rhizobium strains with field pea in the area. Application of lime gave significantly better mean seed yield of field pea at Horro, Gedo and

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combined over locations (Table 5). Significantly higher mean seed yield of field pea was produced with increased lime application. Liming increased the grain yield of field pea by 22% in conventional tillage and by18% in non-tillage system [44]. Buerkert et al. [45] reported lime application resulted in a yield increase of 76 to 313% above unlimed controls across locations. At both locations better, mean seed yield of field pea was recorded at higher rate of lime treated fields. Liming of acidic soils can improve yield substantially [46,47]. This indicates use of lime gradually improves the yield of field pea at Horro and Gedo highlands. Therefore, increasing rate of lime application with rhizobium inoculation and NP fertilizer rate significantly improved field pea production at Horro and Gedo highlands.

Interaction effects

Interaction of NP fertilizer with rhizobium inoculation significantly affected combined mean seed yield of field pea (Table 6).

NP (kg)+RI (g 1 kg Seed) +Lime Rate (t) ha^{-1}	Seed Yield kg ha^{-1}						
	Horro			Gedo			Combined Mean
	2007	2008	Mean	2007	2008	Mean	
75-0-0	1572	973	1273	1951	2900	2426	1849
75-0-2	1970	847	1408	1998	3329	2663	2036
75-0-4	2089	1269	1679	1950	3233	2592	2135
75-0-6	2244	1097	1671	2389	3451	2920	2295
75-10-0	1786	869	1327	1831	3101	2466	1897
75-10-2	2323	888	1605	2023	3090	2556	2081
75-10-4	2575	1020	1797	1858	3173	2515	2156
75-10-6	2156	1221	1687	2144	3097	2620	2154
100-0-0	2362	941	1651	1813	3215	2514	2083
100-0-2	2114	1331	1722	2259	3310	2785	2253
100-0-4	2719	1283	2001	2351	2584	2468	2234
100-0-6	2710	1343	2026	2073	3012	2542	2284
100-10-0	2083	884	1484	2603	3076	2839	2161
100-10-2	1698	1024	1361	1722	3357	2539	1950
100-10-4	2284	1344	1814	1980	3257	2618	2215
100-10-6	2249	1073	1661	2311	2783	2547	2104
125-0-0	1925	973	1449	2090	3094	2592	2021
125-0-2	2204	1269	1736	2299	3073	2686	2211
125-0-4	2047	1105	1576	2610	3011	2810	2193
125-0-6	2681	1632	2156	2349	3158	2753	2455
125-10-0	2349	1460	1904	2271	3444	2857	2381
125-10-2	2609	1353	1981	2302	3203	2753	2409
125-10-4	2203	1310	1756	1940	2731	2336	2046
125-10-6	2262	1559	1910	1885	2685	2285	2097
LSD (5 %)	211.2	163.7	203.2	232.8	276.6	266.8	Ns
CV (%)	5.8	8.53	10.5	6.67	5.43	8.93	27.15

Table 6: Effects of NP rate, rhizobium inoculation and lime rate on seed yield field pea at Horro and Gedo combined over location and year. Ns=non-significant at 5% probability level, NP=diammonium phosphate, RI=rhizobium strain inoculation (EAL-110).

At Horro higher mean seed yield of field pea was produced by interaction of applied 125 kg NP ha^{-1} and 6 t lime ha^{-1} followed by 100 kg NP ha^{-1} and 6 t lime ha^{-1} applied field (Table 6). At Gedo significantly, higher mean seed yield of field was recorded from interaction of 125 kg NP ha^{-1} and rhizobium inoculation followed by 100 kg NP ha^{-1} and rhizobium inoculation (Table 6).

Higher seed yield of field pea was obtained from combined application of rhizobium inoculation with NP fertilizer. Similarly, Mishra et al. [48] reported combined use rhizobium inoculation with recommended fertilizer rate significantly increased mean seed yield of field pea. Rhizobium inoculation to field pea was more important at Gedo highlands as compared to Horro highlands. This might be attributed to long-term production field pea at Horro highlands and presence indigenous strains of rhizobium in the area. Application of lime for field production was more important in Horro highlands as compared to Gedo highlands. Horro highlands are more acidic than Gedo highlands. Mesfine [15] soil acidity increases from central highlands to western Ethiopia. Therefore, considering integrated use of 23/25 kg NP ha^{-1} with lime for field pea production in Horro highlands and with rhizobium in Gedo highlands was recommended since lime mobilize fixed P in Horro highlands.

Conclusion

Application of NP fertilizer significantly affected mean seed yield of field pea at both locations separately indicating both locations are different. Rhizobium inoculation non-significantly affected mean seed yield of field pea showing the existence of effective local rhizobium strains in the area. Mean seed yield of field pea was significantly increased by applied lime rate. Higher combined mean seed yield of field pea was obtained from 6 t lime ha^{-1}. Therefore, application of 23/25 kg NP ha^{-1}, with rhizobium inoculation and without application of lime at Gedo; and application of 23/25 kg NP ha^{-1}, without rhizobium inoculation and application of lime 6 t lime ha^{-1} for Horro highland were recommended for field pea to get economically profitable and agronomically higher yield. Considering of the existing population of rhizobium in the soils of Horro and Gedo highlands was very important before designing inoculation faba bean seed for production.

Conflicts of Interest

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

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