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Original Research

Response of Groundnut (*Arachis Hypogaea* L.) To Liming and Phosphorus Rates at Haro Sabu, Western Ethiopia

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Abstract

Soil acidity and phosphorus deficiency are the major yield limiting factors to crop production in Haro Sabu area, western Ethiopia. Thus, a field experiment was carried out in 2014 main cropping season to assess the effect of lime and phosphorus rates on yield and yield components of groundnut. The treatments were factorial combination of five rates of phosphorus (0, 11.5, 23, 46, 57.5 kg P_2O_5) and four rates of lime ($CaCO_{3)}$ (0, 2.25, 3 and 3.75 tons ha^{-1}) in randomized complete block design and replicated three times. Groundnut variety 'Jimma' was used as a testing material. The main effect of phosphorus and lime showed a significant effect on the number of mature pods per plant, biomass yield, dry pod yield, shelling percentage and seed yield. Phosphorus rate of 57.5 kg P_2O_5 ha^{-1} gave the highest number of mature pods per plant (13.28), biomass yield (6918.4 kg ha^{-1}) while lime rate of 3 tons and 3.75 tons ha^{-1} gave the highest number of mature pods per plant (14.92) and biomass yield (6997.9 kg ha^{-1}) , respectively. In other cases, phosphorus rate of 23 kg P_2O_5 ha^{-1} gave the highest dry pod yield (2389.49 kg ha^{-1} and seed yield (1701.39 kg ha^{-1}). Number of effective nodule per plant, leaf area index, number of total pods per plant and number of peg per plant were significantly affected by phosphorus and lime interactions. The highest leaf area index (5.44) and number of peg per plant (42.27) were obtained from the combination of 46 kg P_2O_5 and 3.75 tons ha^{-1} lime and 46 kg P_2O_5 and 3 tons ha^{-1} lime, respectively. Maximum seed yield was recorded from the main effects at phosphorus rate of 23 kg P_2O_5 ha^{-1} and lime rate of 3 tons ha^{-1} for the yield of groundnut. From this, it can be concluded that groundnut of Jimma variety can be planted at the phosphorus rate of 23 kg P_2O_5 and lime rate of 3 tons ha^{-1} in Haro Sabu area to attain maximum yield. However, further research is required in similar areas over years to give recommendations for Groundnut production in western Ethiopia.

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INTRODUCTION

Groundnut is one of the world's most popular crops cultivated throughout the tropical and sub-tropical areas where annual precipitation is between 1000-1200 mm for optimum growth of the crop. It is usually grown at altitudes ranging from sea level to 1600 m.a.s.l. and with optimum temperatures 25 to 35°C. A well drained light sandy loam is most suitable for this crop. It has high economic and nutritional value and is an important cash crop for growers in poor tropical countries (ICRISAT, 2012). It is also an important food, feed, fertilizer, oil and fuel crop. The addition of groundnut brings nitrogen to the agricultural production systems through biological nitrogen fixation. Being a leguminous crop, groundnuts can fix atmospheric nitrogen (N) with the aid of root bacteria. For this reason, this crop is not entirely dependent on nitrogen fertilization.

Groundnut is the second important lowland oil of warm climate which is relatively new to Ethiopia and the fifth widely cultivated oilseed crops in Ethiopia (Wijnands et al., 2009). Eastern Hararghe zone of Oromia region hold primary position in producing and supplying groundnut both to domestic and export markets as compared to other parts of the nation (Wijnands et al., 2009). Lack of essential inputs in proper amount and kind is one of the main limiting factors for low yield of groundnut in Ethiopia. Traditionally, farmers maintain or improve the fertility of soils either by practicing fallowing, use of farm yard manure, intercropping and crop rotation. Currently, however, the use of some of these cultural practices as a means of maintaining or improving soil fertility is limited to a great extent due to small land holdings of farmers (Markos, 1997).

The production of groundnut under acidic conditions is low due to the reduction of calcium and magnesium supply and deficiency of beneficial nutrients as well. Groundnut commonly responds to Ca additions under acid soil conditions, due to the fact that Ca is required for adequate pod filling. Phosphorus is essentially required for healthy growth with efficient root system and profuse nodulation, which in turn can affect N2 fixation potential (Ndakidemi *et al*., 2006). In acid soils, availability of certain nutrients like aluminum, iron and manganese increases due to higher dissolution and at times becomes toxic.

To address the calcium demands and to create conducive conditions for better uptake of other essential nutrients particularly phosphorus, liming is an important management practice in acid soils (Ranjit, 2005).

Soil acidity has become a serious threat to crop production in most highlands of Ethiopia in general and in the south, south western and western part of the country in particular. About 41% of potential arable land of Ethiopia is acidic (Workneh, 2013). Currently, it is estimated that about 67% of the total arable land of Wollega is affected by soil acidity (Abdenna *et al.,* 2007). There is dearth of information the effect of liming and phosphors application on yield and yield components of ground nut in western Ethiopia. Therefore, the research was conducted to assess the effect of lime and phosphorus on yield and yield components of groundnut.

MATERIALS AND METHODS

Description of the Study Area

The study was conducted at Haro Sabu Agricultural Research Center (HSARC) during the main cropping season of 2014 from June to November. The center is located in western Ethiopia, Oromiya Regional state at 550 km away to the west from Addis Ababa. It lies at latitude of 8^{o} 52’51” N and longitude of 35^{o}13’18’’ E and altitude of 1515 meters above sea level. According to the weather data recorded by the Asosa meteorological sub-station at Haro Sabu, the average annual rainfall of the study site is 1100 mm with uni-modal distribution pattern and the monthly mean minimum and maximum temperatures are between 11-15.7^{o}C and 23.8 to 33.4^{0}C with warm humid climate conditions. The rainy season ranges from April to October.

Description of the Experimental Materials

Groundnut (*Arachis hypogaea* L.) variety ‘Jimma’ was used as a testing material. This variety is well adapted in the area and locally available planting material with alternate profusely and spreading branching habit and possesses good yield potential. It is adapted to altitude of 1515 meters above sea level and at an average annual rainfall of 1000 mm at Haro Sabu Research Center. This variety has maturity date of 150 days.

The phosphorus fertilizer source used was triple super phosphates (TSP) (46% P_2O_5) and liming material was $CaCO_3$. Uniform application of 43 kg urea (20 kg N) was done at the time of planting. Pure calcium carbonate was used as the liming materials and is assigned a rating of 100 percent (the chemical potential of the material for neutralizing soil acidity).

Treatments and Experimental Design

The treatments consisted of five rates of phosphorus (0, 11.5, 23, 46, 57.5 kg P_2O_5) and four rates of lime (0, 2.25, 3 and 3.75 tons ha^{-1}) in a factorial combination in randomized complete block design and replicated three times. Thus, there were twenty (20) treatment combinations. Treatments were assigned to each plot randomly. The gross plot size of each experimental plot was 10.08 m^2 (3.6 m × 2.8 m) with six rows of plants spaced at 60 cm and 10 cm between rows and plants, respectively, and the net plot size was 1.8 m × 2.6 m (4.68 m^2). Spaces of 1.2 m and 0.8 m between blocks and plots were maintained, respectively. Plants in the outermost rows as well as one plant at the end of each harvestable row were not harvested for data collection to avoid border effects. Thus, from four central rows, three rows were considered for data collection and one row was used as destructive sampling for nodulation record at 50% flowering.

Experimental Procedures

The experimental field was ploughed by tractor two times and harrowed and levelled by hand to get fine seedbed. Narrow furrow was made manually by enforcing the stick down the soil and pulled across the length of the plot and thin line made to place fertilizer and seed. Groundnut was planted at the end of June 2014. Groundnut seed was planted 4-5cm deep with two seeds per hole and thinned to one plant per hole two weeks after sowing. Liming of the experimental plots was done 30 days before sowing when the soil was thoroughly loosened and mixed to the soil very well at depth of 15 cm. Different rates of phosphorus fertilizers were applied at the time of sowing. As starter fertilizer 20 kg ha^{-1} nitrogen was applied in the form of urea as suggested by Ranjit (2005). All the cultural practices such as weeding done timely when it appeared, earthening up of the soil at the time of pegging and pest control such as cut worm by using cultural practices such as hand picking were applied uniformly to all plots. Harvesting was done when the crop reached physiological maturity, *i.e.,* the pods fully veined, kernels have begun to become red in colour and the inside of the shells has begun to colour brown and show darkened veins. The net plots were harvested by digging out the whole plant with a hoe by leaving one plant at the end of each harvestable row. Thereafter, the pods were picked from the main bunch and allowed to air and sundry for six days. The dried pods were then collected on plot basis.

Phenological Data and Growth Parameters

Days to flowering was recorded when 50% of the plants in a plot produced flowers. Likewise, days to 90% physiological maturity of groundnut was taken from date of planting when 90% of the plants in a plot turned their leaves to yellow and the lower most leaves started shading.

The leaf area was measured by a model CI-202 leaf area meter during the 50% flowering stage of the groundnut. Based on the recorded leaf area, the leaf area index (LAI) was calculated from five randomly taken plants by dividing the leaf area by its respective ground area. When the groundnut attained physiological maturity, plant height was measured from ground level to the tip of main stem of five randomly taken plants and the average of five plants was expressed as plant height in centimeter. Number of primary branches emerged directly from the basal main shoot were counted from five randomly taken plants at physiological maturity and the average was calculated.

The average number of effective nodules per plant was determined by carefully uprooting of five plants per plot at 50% flowering and washing the roots. The effective nodules were separated by their colours where a cross section of an effective nodule made with a pocket knife showed a pink to dark-red colour.

Yield Components and Yield

The stand count was determined by counting from the harvestable rows of each net plot at harvest. Above ground biomass was measured from five plants per net plot area (1.8 m × 2.6 m) at physiological maturity after sun drying to a constant weight for seven days. Number of pegs per plant was determined from five randomly selected plants per net plot at harvest and number of total pods per plant was also recorded as the total number of pods per plant from five randomly taken plants from the net plot area at harvest. For number of mature pods per plant filled and sound pods were recorded from five randomly taken plants from the net plot area at harvest. Number of seeds per pod was determined by calculating the average number of seeds obtained from 10 randomly selected matured pods from the five plants. Hundred seed weight (g) was counted and measured by taking a random sample of 100 seeds from the harvested bulk of seeds obtained from the net plot, weighed using an electronic sensitive balance and the yield was adjusted to 8% moisture level.

Dry pod yield was determined from the net plot and expressed as kilograms ha^{-1}. Shelling percentage was determined by taking sample of about 200 g matured pods per plot and was determined as: SP = $\frac{SY}{PY} \times 100$; where SP is shelling percentage; SY is seed yield; and PY is pod yield. Seed yield (kg ha^{-1}) was determined as shelling percentage multiplied by dry pod yield and was adjusted to 8% moisture level. Harvest index (%) was calculated as the dry pod yield divided by above ground dry biomass per plot and multiplied by 100.

Statistical Data Analysis

All crop data collected were subjected to General Linear model of ANOVA using of SAS version 9.01 software (SAS Institute, 2004). Least Significance Difference (LSD) test at 5% probability level was used to delineate the significant difference between the treatment means when ANOVA showed significant difference.

RESULTS AND DISCUSSION

ANOVA Table for all the parameters recorded is indicated in table one. All the phenological stages showed anon-significant difference due to the main as well as interaction effects (Table 1).

Table 1: Mean squares of ANOVA for Phenological stages, growth, yield and yield components of groundnut grown in response to rates of lime and phosphorus.

** and * Significant at (1 and 5%) probability level respectively, DF= degree freedom.

Crop Growth Parameters Leaf Area Index

	Replication	Phosphorus(P)	Lime(L)	P*L	Error	CV (%)
D F	2	4	3	12	38	
Days to flowering	0.05	0.07	0.04	0.38	0.3	1.1
Days to maturity	3.75	0.98	4.04	2.74	3.8	1.3
Leaf area index	0.13	1.37**	1.85**	0.71**	0.2	10.5
Effective nodule/ plant	76.21	345.23**	452.3**	161.3**	56.1	12.6
Plant height (PH)	31.57*	11.57	9.76	16.28	8.2	9.69
Branch/plant	1.50	0.65	0.43	1.03	0.5	7.48
Pegs/plant	20.50	261.9**	202.43**	63.35**	22.6	15.2
Pods/plant	19.15	17.79	92.87**	28.76**	9.6	18.1
Mature pods/plant	6.44	18.47*	62.03**	10.59	6.5	20.3
Stand count	81.82*	18.04	16.22	17.49	15.97	5.7
No of seed/pods	0.011	0.005	0.011	0.012	0.03	10.1
Biomass yield	499238.1	2416453.1**	3711366.9**	461163.2	400541.2	9.4
100 seed weight	13.81	20.79	20.11	19.74	12.6	4.5
Dry pod yield	385582.5**	162297.6**	180082.2**	70492.7	39636.1	8.8
Shelling percentage	19.22*	34.55**	25.59**	8.62	4.79	3.1
Seed yield	292169.8**	107249.5*	129522.4*	53307.2	30052.7	10.8
Harvest index	42.90*	15.21	4.57	11.07	10.27	9.2

The main effects of phosphorus, lime levels and their interaction showed highly significant ($P<0.01$) effects on leaf area index (LAI) (Table 1).

Table 2: The interaction effect of rates of phosphorus and lime on leaf area index of groundnut

Phosphorus levels (kg ha^{-1} P_2O_5)	Lime levels (ton ha^{-1})			
	0	2.25	3.0	3.75
0	3.80^{f}	3.88^{f}	4.02^{ef}	4.18^{def}
11.5	3.85^{f}	3.90^{f}	4.22^{def}	5.38^{ab}
23.0	3.86^{f}	3.97^{ef}	5.19^{abc}	3.83^{f}
46.0	4.15^{ef}	4.53^{cdef}	3.99^{ef}	5.44^{a}
57.5	4.4cdef	4.91^{abcd}	4.65^{bcde}	5.43^{a}
LSD (0.05) (P×L)	0.76			
CV (%)	10.5			

LSD (0.05) = Least significant difference at 5% probably level, CV = Coefficient of variation, means in the columns and rows followed by the same letter(s) are not significantly different.

The highest leaf area index (5.44) was obtained from the combination of 46 kg P_2O_5 and 3.75 ton ha^{-1} lime which were statistically in parity with 57.5 kg P_2O_5 and 3.75 ton ha^{-1} whereas the lowest LAI (3.80) was obtained from the treatment without phosphorus and lime (Table 2). Increasing both phosphorus and lime rates together increased the leaf area index from the control treatment to third rate (23 kg P_2O_5 and 3 ton lime ha^{-1}) in both cases. This increase might be due to the improvement of soil environment for nutrient availability and hence promote root growth for absorption of water and nutrients in good manner for the growth of the plants. Since at desirable pH range rhizobia is active for nitrogen fixation and availability and solubility of nutrients like phosphorus enhanced due to the application of lime which might in turn results better plant growth that leads to more dry matter accumulation of the plant contributing to better yield of the crop.

The result was in agreement with Bhadoria *et al*. (2011) who reported that the groundnut plants in lime treated plots recorded significantly higher LAI (4.42) as compared to no lime application (2.24). Similarly, Barasa *et al.* (2013) reported that most calcium in fertilizers is associated with phosphorus compounds and is applied for the benefit to be derived from the phosphorus as observed from the plots receiving the phosphorus and lime treatment combinations. Moreover, Kabir *et al*. (2013) reported that plant growth and total dry weight were increased due to P application that might have been attributable to the fact that P is known to help in the development of more extensive root system. Tairo and Ndakidemi (2013) also reported that phosphorus have significantly increased the number of leaves, leaf area (LA) and leaf area index (LAI) on soybean.

Number of Effective Nodules per Plant

The main and interactions effect of phosphorus and lime levels showed highly significant (P<0.01) effect on number of effective nodules per plant (Table 1). The highest number of effective nodules per plant (78.13) was obtained from the combination of 46 kg P2O5 and 2.25 ton ha-1 lime, whereas the lowest (45.40) was obtained from the phosphorus rate of 57.5 kg P2O5 ha-1 without lime (Table 3). This result revealed that when phosphorus level increased without lime, minimum nodule number was recorded but increased with the application of lime in combination with phosphorus. The probable reason of high number of nodules with increasing lime application might be that under pH near to alkaline the existence of rhizobia and its performance for fixation of nitrogen enhanced. Rhizibia might be perform better when pH of the soil improved due to the fact that its population and infection potential of the root increased which resulted in better nodule formation for nitrogen fixation under optimum pH range obtained by the addition of lime in acidic conditions. The result was in line with Crozier and Hardy (2003) who reported that with proper liming; nodulation of legumes is enhanced, which improves nitrogen fixation.

Ranjit (2005) also stated that the number of nodules per plant differed significantly by lime and phosphorus interactions at all the growth stages except at harvest. Similarly, Hart et al. (2013) reported that nodulation depends on calcium supply and nodules on greenhouse-grown alfalfa roots increased from 35 to 70 per plant when soil pH increased from 5.3 to 5.8 and soil Ca increased. Halt also added that phosphorus is needed in relatively large amounts by legumes to promote legumes growth and yield, nodule number and nodule mass in different legumes.

Table 3: The interaction effects of rates of phosphorus and lime on the number of effective nodules per plant of groundnut

Phosphorus levels (kg ha^{-1} P_2O_5)	Lime levels (ton ha^{-1})			
	0	2.25	3	3.75
0	54.07^{defg}	64.47^{bcde}	65.40^{bcdef}	46.07^{g}
11.5	56.67^{cdefg}	61.73^{bcdef}	62.60^{bcdef}	64.67^{bcde}
23	52.33^{efg}	46.73^{g}	62.20^{bcdef}	68.00^{abc}
46	52.20^{efg}	78.13^{a}	74.27^{ab}	66.53^{abcd}
57.5	45.40^{g}	56.60^{cdefg}	61.33^{cdef}	51.33^{fg}
LSD (0.05) (P×L)	12.38			
CV (%)	12.58			

LSD (0.05) = Least significant difference at 5% probably level, CV = Coefficient of variation,
Means in the columns and rows followed by the same letter(s) are not significantly different

Yield Components Number of pegs

The analysis of variance on the number of pegs per plant showed highly significant (P<0.01) influence due to the main effects of rates of lime and phosphorus and their interactions (Table 1). On the average, the different treatments gave 31.24 pegs per plant. The highest number of pegs per plant (42.27) was obtained from the combination of 46 kg P_2O_5 and 3 ton ha^{-1} lime, whereas the lowest (19.20) was obtained from the treatment without application of phosphorus and lime (Table 4). The increase in number of pegs with higher rates of phosphorus and lime could be due to the application of lime might have enabled the fixed phosphorus to be available to the crop for their growth than the control in addition to the supply of calcium. This result was in line with the report of Meena *et al*. (2007) who stated that among the secondary nutrients, calcium deficiency causes groundnut pegs and pods to abort and reduce yield. Likewise, Kamara (2010) also reported the application of phosphorus significantly increased the number of pegs by 52.4%.

Table 4: The interaction effects of rates of phosphorus and lime on the number of pegs per plant of groundnut

Phosphorus levels (kg ha^{-1} P_2O_5)	Lime levels (ton ha^{-1}) 0	2.25	3.0	3.75
0	19.20^{f}	20.87^{ef}	26.47^{def}	27.40^{de}
11.5	26.93^{def}	27.73^{de}	36.07^{abc}	41.93^{a}
23.0	29.13^{cd}	30.47^{bcd}	37.40^{ab}	26.33^{def}
46.0	30.53^{bcd}	41.33^{a}	42.27^{a}	28.80^{cd}
57.5	29.20^{cd}	33.40^{bcd}	37.60^{ab}	31.80^{bcd}
LSD (0.05) (P×L)	7.85			
CV (%)	15.2			

LSD (0.05) = Least significant difference at 5% probably level, CV =Coefficient of variation, Means in the columns and rows followed by the same letter(s) are not significantly different.

Number of total pods

The number of total pods per plant was highly significantly ($P<0.01$) influenced by the interaction of rates of phosphorus and lime as well as by the main effect of lime rate (Table1). The highest number of total pods per plant (24.13) was obtained from the combination of 46 kg P_2O_5 and 3 ton ha^{-1} lime while the lowest number (12.33) was obtained from the treatment without phosphorus and limes (Table 5). The number of total pods per plant was increased with increasing phosphorus and lime rate increased up to 46 kg P_2O_5 and 3 ton ha^{-1} lime. This could be due to groundnut responded to calcium and lime application raised the pH of the soil to the range where the phosphorus is available for plant uptake and cause to set more number of total pods.

At the highest rates of both lime and phosphorus the number of total pods was decreased probability due to high P concentration in the soil "lock" and reduce the absorption and utilization of micronutrients especially Zn and Fe through P to micronutrients interactions which attribute micronutrients deficiency and consequently reduces enzymatic activities on physiological and metabolic processes which in turn negatively affect dry matter accumulation (Mousavi, 2011; Murphy et al., 1981). This result was in line with the study by Angaw and Desta (1988) who reported that under acidic conditions, lime and phosphorus application were significantly correlated with many agronomic parameters and had positive interaction effects. Ranjit (2005) also reported significant increases in total number of pods per plant from 16.89 to 22.78 due to increased lime from 0 to 3.7 ton ha^{-1} and phosphorus from 37.5 to 75 kg P_2O_5 ha^{-1} levels at harvest of groundnut. Similarly, Kisinyo *et al.* (2005); and Negi *et al*. (2006) reported that liming acid soil make the soil environment better for leguminous plants and associated microorganisms as well as increased concentration of essential nutrients by raising its pH and precipitating exchangeable aluminum.

Table 5: The interaction effects of rates of phosphorus and lime on number of total pods per plant of groundnut

Phosphorus levels (kg ha^{-1} P_2O_5)	Lime levels (ton ha^{-1})			
	0	2.25	3.0	3.75
0	12.33^{g}	14.07^{fg}	14.93^{efg}	19.33^{abcde}
11.5	13.93^{fg}	15.93^{defg}	17.93^{bcdef}	20.53^{abcd}
23.0	14.27^{efg}	16.53^{cdefg}	21.53^{abc}	20.60^{abcd}
46.0	14.66^{efg}	16.67^{cdefg}	24.13^{a}	14.60^{efg}
57.5	13.93^{fg}	23.13^{ab}	20.40^{abcd}	14.47^{efg}
LSD (0.05) (P×L)	5.13			
CV (%)	18.04			

LSD (0.05) = Least significant difference at 5% probably level, CV= Coefficient of variation, Means in the columns and rows followed by the same letter(s) are not significantly different.

Number of mature pods per plant

The number of mature pods per plant was highly significantly ($P<0.01$) affected by the main effect of lime and significantly ($P<0.05$) due phosphorus, but non-significantly influenced due to the interactions (Table 1). The highest number of mature pods per plant (13.28) was obtained from phosphorus rate of 57.5 kg P_2O_5 ha^{-1} whereas the lowest number of mature pods per plant (10.35) was obtained from the treatment without phosphorus. Likewise, the highest number of mature pods per plant (14.92) was obtained from lime rate of 3 ton ha^{-1} whereas the lowest number of mature pods per plant (10.03) was obtained from the treatment with no lime added (Table 6).

The positive response of the number of mature pods due to liming and phosphorus might be because of groundnut responded to calcium for pod filling and application of lime to the soil could make phosphorus available for the plant uptake not only from inorganic fertilizers but also from decomposed organic matters due to creation of favorable soil pH to decomposers besides to calcium supply. This result was in agreement with Ranjit (2005) who reported that liming and different levels of phosphorus application influenced the number of filled pods per plant significantly by increasing with the increased rates of lime and P. Calcium deficiency leads to a high percentage of aborted seeds (empty pods or "pops"), improperly filled pods and shriveled fruit, including darkened plumules and production of pods without seed (Ntare *et al.*, 2008; Singh & Oswalt, 1995).

Number of seeds per pods

The number of seed per pod showed non-significant response due to the main effects of phosphorus and lime and their interactions (Table 1). This possibly due the lack of genetic difference that probably responded similarly to calcium since the soil had moderate calcium content.

Yields and Harvest Index

Biomass yield

The main effects of phosphorus and lime showed highly significant ($P<0.01$) influence on biomass yield but non-significant due to their interactions (Table1). The highest biomass yield (6918.4 kg ha^{-1}) was obtained from phosphorus rate of 57.5 kg P_2O_5 ha^{-1} whereas the lowest (5778.3 kg ha^{-1}) was obtained from the treatment without phosphorus. Likewise, the highest biomass yield (6997.9 kg ha^{-1}) was obtained from lime rate of 3.75 ton ha^{-1} whereas the lowest biomass yield (5884.7 kg ha^{-1}) was obtained from the treatment with no lime added (Table 6). The increase in biomass yield with the application of lime and phosphorus to the soil probably makes phosphorus available for the plant uptake not only from inorganic fertilizers applied but also from decomposed organic matters due to creation of favorable soil pH to decomposers besides to calcium supply.

This result was in agreement with Kisinyo *et al*. (2005) who reported that the shoot biomass; shoot nitrogen and phosphorus of legume crops were increased with increasing rates of both lime and phosphorus. Gobarah *et al*. (2006) also reported higher biomass yield from phosphorus application was due to the fact that phosphorus is known to help in the development of more extensive root system and thus enabled the plants to absorb more water and nutrients from the soil which lead to enhanced production of more assimilates. Further there is also reduction of Al toxicity which restricting roots growth that creates difficulty in accessing nutrient and water from longer distance in the soil and finally application of lime along with phosphorus could improve root nutrient uptake of the plant through promoting its growth.

Table 6: The main effects of rates of phosphorus and lime on the number of mature pods per plant stand count per plot, number of seeds per pod and biomass yield of groundnut

Treatments	No of mature pods per plant	Stand count per plot	No of seeds per pod	Biomass yield (kg ha^{-1})
Phosphorus levels (kg ha^{-1} P_2O_5)				
0	10.35^{b}	68.83	1.56	5778.3^{c}
11.5	12.68^{a}	71.50	1.58	6387.2^{b}
23.0	13.27^{a}	70.08	1.56	6698.0^{ab}
46.0	13.05^{a}	69.58	1.55	6740.5^{ab}
57.5	13.28^{a}	68.33	1.52	6918.4^{a}
LSD (0.05)	2.10	NS	NS	523.05
Lime levels (ton ha^{-1})				
0	10.03^{c}	68.93	1.53	5884.7^{c}
2.25	12.12^{b}	69.13	1.54	6336.7^{bc}
3.0	14.92^{a}	69.40	1.55	6798.6^{ab}
3.75	13.04^{b}	71.20	1.59	6997.9^{a}
LSD (0.05)	1.88	NS	NS	467.83
CV (%)	20.27	5.74	10.07	9.73

LSD (0.05) = Least significance difference at 5% probably level, CV = Coefficient of variation, Means in column followed by the same letter(s) are not significantly different, NS = non-significant at 5% probability level

Dry pod yield

The main effects of phosphorus and lime showed highly significant ($P<0.01$) influence on dry pod yield but non-significant due to their interactions (Table 1). The highest dry pod yield (2389.49 kg ha^{-1}) was obtained from phosphorus rate of 23 kg P_2O_5 ha^{-1} whereas, the lowest dry pod yield (2089.11 kg ha^{-1}) was obtained from the treatment without phosphorus (Table 7). With regards to liming, the highest dry pod yield (2362.38 kg ha^{-1}) was obtained from lime rate of 3.75 ton ha^{-1}, while the lowest dry pod yield (2125.46 kg ha^{-1}) was obtained from the treatment without lime (Table 7). Increasing phosphorus up to 23 kg P_2O_5 ha^{-1} increased the dry pod yield and then declined probably due to the peak stage of the plant for phosphorus demand could be addressed at this stage. On the other hand, increasing the level of lime to higher rate (3.75 ton ha^{-1}) increased the dry pod yield and this might be the indication of lime requirement to supply calcium for pod filling (Table 7).

The highest result obtained from the main effects of dry pod and seed yield at higher phosphorus rate could be due to the fact that liming of acidic soils made the fixed phosphorus in the soil by Aluminum and Iron available to the plant and the increase of inorganic phosphorus application might match the requirement of the plant at higher levels that provided higher yields than at control treatments. Similarly, there could be the probability of obtaining the available phosphorus from decomposed organic matter by microorganisms when the optimum pH range attained due to liming. In line with this result, Bhatol *et al*. (1994) reported that application of 25 kg P_2O_5 ha^{-1} markedly increased the pod yield of groundnut over the control, but a higher rate decreased the yield significantly. Debnath *et al.* (2000) also reported that the increase in saloid bound P in limed soils was due to release of P by hydrolysis of iron and aluminum phosphates and mineralization of organic P at an enhanced rate.

Mupangwa and Agwira (2005) also described no significant phosphorus and calcitic lime interaction effect on groundnut yield. Similarly, Ranjit (2005) reported application of lime lowered the concentration of Al^{3+} and Fe^{3+} ions by causing increase in the pH and thereby reduced the possibility of fixation of added P by these ions as Al-P and Fe-P. The result regarding lime levels which recorded the highest dry pod yield also confirmed with Ranjit *et al.* (2007) who reported significantly higher pod yield with lime level of 3.7 tons ha^{-1} than other lime levels.

Shelling percentage

The main effects of phosphorus and lime showed highly significant (P<0.01) influence on shelling percentage but non-significant interactions (Table 1). The highest shelling percentage (73.57) was recorded from 46 kg P_2O_5 ha^{-1}, whereas, the lowest shelling percentage (69.24) was obtained from the treatment without phosphorus (Table 10). With regards to lime, the highest shelling percentage (72.20) was obtained from lime rate of 3 ton ha^{-1}, while the lowest shelling percentage (69.44) was obtained from the treatment without lime (Table 7). The result was in agreement with Ranjit (2005) who stated significant increase in the shelling percentage from 67.82 to 70.99 with increasing lime rate from 0 to 3.7 ton ha-1 and phosphorus rate from 37.5 to 75 kg P2O5 ha-1. Ranjit et al. (2007) also described that liming and the application of different levels of phosphorus affected the shelling percentage significantly but their interactions were not significant. Similarly, Kabir et al. (2013) reported the application of Ca along with P, and B fertilizers increased nutrients availability to the crop during the growing season which leads to greater utilization of assimilates into the pods and ultimately increased number of filled pods and shelling percentage.

Seed yield

The seed yield was significantly (P<0.05) influenced by the main effects of phosphorus and lime, but non-significantly due to their interactions (Table 1). The highest seed yield (1701.39 kg ha^{-1}) was recorded from phosphorus rate of 23 kg P_2O_5 ha^{-1}, whereas the lowest seed yield (1462.06 kg ha^{-1}) was obtained from control treatment of phosphorus. Similarly, the highest seed yield (1683.77 kg ha^{-1}) was obtained from lime rate of 3 ton ha^{-1}, whereas the lowest seed yield (1480.43 kg ha^{-1}) was obtained from control treatment of lime (Table 7). Though the highest seed yield was recorded at 23 P_2O_5 and 3 ton lime ha^{-1}, the yield was statistically similar with the highest rate of phosphorus and lime applied. Regarding the seed yield, additions of both rates (phosphorus and lime) in increasing order increased the seed yield up to 23 kg P_2O_5 ha^{-1} and 3 ton lime ha^{-1} and beyond this it gradually decreased even if statistically not different. This might have emphasized the sufficiency level of the nutrients addressed when 3 ton lime ha^{-1} applied to the soil which could create conducive condition for nutrient absorption by plants at this level and surplus addition of phosphorus more than 23 kg P_2O_5 ha^{-1} might lead to decline in yield above the peak (Table 7). The low seed yield at higher phosphorus rates might also be a reflection of the suppressive effect of the phosphorus rate on pod filling. Mandimba and Kilo (1997) stated that liming increased shoot mass, shoot N accumulation, pod yield and seed yield.

The result was also in line with Ndakidemi *et al*. (2006) who reported supplementing legumes with nutrients P has great potential for increasing yields, as it not only promotes plant growth but also enhances symbiotic establishment for increased N_2 fixation. Shiyam (2010) also reported low seed yield in plots with high phosphorus might also be a reflection of the suppressive effect of the phosphorus rate on pod filling, a critical phenomenon in seed yield in grain legumes. Murphy *et al*. (1981) and Mousavi (2011) stated that micronutrients such as zinc (Zn), iron (Fe) and copper (Cu) play important roles in plant physiology and metabolic processes but high P concentration in the soil is known to "lock" and reduce the absorption and utilization of these micronutrients especially Zn and Fe through P to micronutrients interactions that resulted in P-induced micronutrients deficiency hence reduces enzymatic activities on physiological and metabolic processes which in turn negatively affect dry matter accumulation and leads to low yields. This could be one of the reasons of negative effect of higher P rate above 20 kg. Similarly, Kamara *et al*. (2011) reported that P fertilizer application significantly improved the pod and grain yields due to the important role played by P in the physiological process of plants.

Table 7: The main effects of rates of phosphorus and lime on hundred seed weight, dry pod yield, shelling percentage, seed yield and harvest index of groundnut

Treatments	Hundred seed weight (g)	Dry pod yield (kg ha^{-1})	Shelling percentage	Seed yield (kg ha^{-1})	Harvest index (%)
Phosphorus levels (kg ha^{-1} P_2O_5)					
0	77.54	2089.11^{b}	69.24^{c}	1462.06^{b}	35.74
11.5	79.10	2240.20^{ab}	70.72^{bc}	1586.42^{ab}	35.15
23.0	77.50	2389.49^{a}	72.07^{ab}	1701.39^{a}	35.89
46.0	80.41	2326.88^{a}	73.57^{a}	1680.17^{a}	33.55
57.5	79.78	2325.38^{a}	70.16^{c}	1615.82^{a}	33.66
LSD (0.05)	NS	164.54	1.80	143.27	NS
Lime levels (ton ha^{-1})					
0	77.42	2125.46^{b}	69.44^{b}	1480.43^{b}	34.99
2.25	78.54	2258.25^{ab}	70.83^{ab}	1602.33^{ab}	35.40
3.0	79.39	2350.76^{a}	72.20^{a}	1683.77^{a}	34.71
3.75	80.11	2362.38^{a}	72.13^{a}	1670.16^{a}	34.09
LSD (0.05)	NS	147.17	1.62	128.15	NS
CV (%)	4.51	8.75	3.08	10.77	9.21

LSD (0.05) = Least significant difference at 5% probably level, CV= Coefficient of variation, Means in columns followed by the same letter are not significantly different, NS = non-significant at 5% probability level

CONCLUSIONS

Soil acidity and phosphorus deficiency are the major yield limiting factors to crop production in the study area. Hence, devising management practice that tackles the constraints of soil acidity is important. Liming is an important management practice in acid soils to meet the calcium demands as well as to create favorable conditions for better uptake of the other essential nutrients particularly phosphorus. Increasing both phosphorus and lime rates increased phonological growth and yield parameters.

Thus from the study, it can be concluded that the combination 3 ton ha^{-1} lime and 23 P_2O_5 kg ha^{-1} produced the highest groundnut yield. To recommend this result to producers further studies in similar areas and years should be conducted in the future for western Ethiopia and similar agro-ecologies.

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