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PHOSPHATE FERTILIZER AND WEED CONTROL EFFECTS ON GROWTH AND YIELD OF FIELD PEA ON NITISOLS OF CENTRAL HIGHLANDS OF ETHIOPIA

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ABSTRACT: Soil acidity and the associated low phosphorus availability and poor crop management practices are among the major factors constraining field pea productivity in the highlands of Ethiopia. The effect of phosphate fertilizer and weed control on yield and yield components of field pea (*Pisum sativum* L.) were studied on acidic Nitisols of farmers' fields of Welmera Woreda, West Shoa. Factorial combinations of four levels of phosphate fertilizer (0, 10, 20 and 30 kg P ha^{-1}) as triple super-phosphate (TSP) and two levels of weeding (W_0 = no weeding and W_1 = hand weeding once) were laid out in randomized complete block design with three replications. Results indicated that a highly significant positive response of plant height, number of pods per plant, total biomass and grain yields of field pea were noted to phosphate fertilizer and weeding treatments. Application of phosphate fertilizer at the rates of 10, 20 and 30 kg P ha^{-1} increased mean grain yields of field pea by 36, 67 and 57%, respectively compared to the control. Weeding once by hand increased mean grain yield of field pea by 15% compared to the unweeded check. The interaction between applied phosphate fertilizer and weed control (P×W) significantly affected field pea grain yield and total biomass. Grain yield was very significantly and positively correlated with plant height, number of pods per plant and total biomass ($r = 0.59^{**}$, 0.68^{***} and 0.94^{***}, respectively). The results of economic analysis indicated that the treatment with application of 20 kg P ha^{-1} and weeding once during the 4th week after sowing by hand was identified to be the best option with a marginal rate of return of 277%, well above the minimum acceptable rate of return of 100%, which is economically the most feasible alternative.

Key words: Field pea, Nitisol, phosphate fertilizer, soil acidity, weed control

INTRODUCTION

Although field pea is one of the important grain legumes in Ethiopia its productivity is low due to several factors. Among these, the major ones are poor seedbed preparation, untimely sowing, inadequate plant nutrition, sub-optimal weed control, and the lack of improved varieties (Rezene Fessehaie, 1986; Knott and Halila, 1988; Alem Berhe *et al*., 1990).

The growth and grain yield of field pea is affected by the application of fertilizer. Experimental results indicated that grain yield of field pea significantly increased over the control due to application of phosphate fertilizer (Getachew Agegnehu *et al*., 2003; Amare Ghizaw *et al*., 2005). The application of 18/20 kg N/P ha^{-1} on Nitisols increased grain yield of field pea by 103% compared to unfertilized plots. Similarly, Angaw Tsigie and Asnakew Woldeab (1994) reported that the response of both local and improved cultivars of field pea was very high to phosphate fertilizer at many locations. The productivity of food legumes is constrained by low soil pH and associated low P availability. Acid Nitisols are of wide occurrence in the highlands of Ethiopia where the rainfall intensity is high and the land has been under cultivation for many years. These soils have pH values of less than 5.5, thereby resulting in low yields of field pea (Getachew Agegnehu and Rezene Fessehaie, 2006). The low yields in such soils could mainly be either due to the deficiency of nutrients, such as P, Ca and Mg (Taye Bekele and Höfner, 1993; Getachew Agegnehu and Rezene Fessehaie, 2006), or to low pH and toxicity of Al, Fe and Mn (Sharma *et al*., 1990).

Traditionally, field pea is grown under no weeding conditions. The major reason for sub-optimal weeding is the overlapping of farm activities with other crop enterprises (Rezene Fessehaie, 1986; 1994). However, experimental evidence indicated that field pea suffered significant yield reduction when exposed to weed competition for 4, 7 and 10 weeks after sowing; this accounted for respective yield reductions of 0.0, 43.3 and 66.9% (Rezene Fessehaie, 1994). Significant yield reduction was observed during the beginning and post-flowering stages of the crop. For field pea one early hand weeding 3–4 weeks after crop emergence is optimum (Rezene Fessehaie, 1994). Full-season

weed competition in field pea accounted for yield reduction of about 15.3% (Rezene Fessehaie, 1994). Weed competition is high especially in fields in which the land preparation is poor. The efficiency of fertilizer is also low in such fields. The incorporation of research results and judicious application of these factors had a positive effect on growth and yields of field pea. However, the interaction effect of fertilizer and weed control practices on field pea is lacking. Therefore, the objectives of the study were to:
(i) examine the effects of phosphate fertilizer and weed control; and (ii) determine economic optimum combination of phosphorus and weed control for field pea production on Nitisols of central Ethiopian highlands.

MATERIALS AND METHODS

Experimental site

The trial sites were located at Welmera Wereda of West Shoa, central highlands of Ethiopia, between 09°03'N latitude and 38°30'E longitude at an altitude of about 2400 m above sea level. The rainfall is bimodal with long-term average annual rainfall of 1100 mm, about 85% of which falls from June to September and the rest from January to May. The average minimum and maximum air temperatures are 6 and 22°C, respectively. The environment is seasonally humid and the major soil type of the trial sites is Eutric Nitisol (FAO classification). Selected soil chemical properties of the experimental field were determined for samples collected during planting from 0–20 cm soil depth in the soil and plant analysis laboratory of the Holetta Research Centre. Soil reactions (pH) were measured in H_2O with a liquid to solid ratio of 1:1 (Black, 1965). Organic carbon was determined according to Walkley and Black (1954) method, and total nitrogen using Kjeldahl method (Bremner and Mulvaney, 1982). Available phosphorus was determined using Bray-II method (Bray and Kurz, 1945). Exchangeable cations and cation exchange capacity were also analyzed using ammonium acetate method (Black, 1965).

Experimental set-up

The experiment was conducted to determine the effects of phosphate fertilizer and weed control practices and their interaction on field pea for two main cropping seasons (2003–2004). Experimental fields were ploughed twice prior to planting by using oxen drawn implement. The design employed was randomized complete block with three replications. The treatments included factorial combination of four levels of phosphate fertilizer (P_0 = 0, P_1 = 10, P_2 = 20 and P_3 = 30 kg P ha^{-1}) and two levels of weeding (W_0 = no weeding and W_1 = hand weeding once four weeks after sowing). Phosphate fertilizer was applied at planting as broadcast in the form of triple super-phosphate (TSP). Experimental plots received a blanket application of 20 kg N ha^{-1} as a starter dressing at planting as urea. Disease or insect control chemicals were not used during the study.

An improved field pea cultivar (*Tegegnech*) was planted on plots of 4 m by 5 m at the rate of 150 kg ha^{-1}. Sowing took place early as per recommendation from 20 to 25 June (Amare Ghizaw and Adamu Molla, 1994). The crop rotation sequence was field pea followed by food barley in the first year and wheat in the second year. Agronomic parameters collected were plant stand count m^{-2} at complete emergence, plant height (average of ten plants), weed oven dry weight at weeding and harvesting of plants, number of pods per plant and seeds per pod (average of ten plants), total aboveground biomass, grain yield and thousand grain weight of field pea. To estimate total aboveground biomass and grain yield of field pea a sample size of 12 m^2 was harvested from each plot. Data on weeding (labour person-days), fertilizer and grain prices were collected. After threshing, seeds were cleaned, weighed and adjusted at the 10% moisture level. Total biomass and grain yields recorded on plot basis were converted to kg ha^{-1} for statistical analysis.

Data analysis

The data were subjected to analysis of variance using the SAS statistical package version 8.1 (SAS, 2001). The total variability for each trait was quantified using pooled analysis of variance over years based on the following model.

$$T_{ijkl} = \mu + Y_i + R_{j(i)} + P_k + W_l + YP_{(ik)} + YW_{(il)} + PW_{(kl)} + YPW_{(ikl)} + e_{ijkl}$$

where, T_{ijkl} is total observation; μ = grand mean; Y_i = effect of the i^{th} year; $R_{j(i)}$ = effect of the j^{th} replication; P_k = effect of the k^{th} phosphorus level; W_l = effect of the l^{th} weed control; YP, YW, PW and YPW are the interactions and e_{ijkl} is the variation due to random error. Results were presented as means, and 5% level of significance was used in order to establish the differences among the means. Coefficients of correlation were also performed using the standard procedures from SAS program at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$.

Besides, to investigate the economic feasibility of the treatments partial budget, dominance and marginal analyses were conducted. The average yield was adjusted downwards by 10% to reflect the difference between the experimental yield and the expected yield of farmers from the same treatment. Because experimental yields from on-farm experiments under representative conditions are often higher than the yields that farmers could expect using the same treatments (Amanuel Gorfu *et al*., 1991). The five years (2003–2008) average local market prices (ETB 3.45 kg^{-1}) of field pea and phosphate fertilizer (ETB 4.53 kg^{-1}) were used for economic analysis. The cost of weeding (ETB 8.50 per person-day) was also taken from the study areas. Labour for field pea weeding was 31 person-days per hectare.'

RESULTS AND DISCUSSION

Soil analysis

The results of soil analyses showed that the soil pH (4.73), available P (8.45 ppm) and exchangeable cations were found to be sub-optimal for field pea production (Table 1). This had a direct relationship with the response of yield to applied P which was more at higher rates than at lower ones. In most cases, soils whose pH value is less than 5.5 are deficient in available P, Ca and Mg (Taye Bekele and Höfner, 1993; Marshner, 1995). In such soils the amount of P fertilizer that could immediately be available to a crop becomes inadequate and residues of the fertilizer may be released very slowly (Sikora *et al*., 1991; Somani, 1996).

Legume species differ widely in their ability to grow in soils of low P status. The study of Hocking *et al*. (1997) has explicated that white lupine and, to a lesser extent, pigeon pea can access soil phosphorus from a pool that is relatively inaccessible to other species. Mahler *et al*. (1988) also reported that in terms of nutrient availability pea, lentil, chickpea and faba bean grow best in soils with pH values between 5.7 and 7.2 and require between 13 and 35 kg P ha^{-1} for adequate yields, which agrees with the findings of this study. When pulse crops are grown on soils whose pH values are less than 5.6 they give low yields (Mahler *et al*., 1988; Getachew Agegnehu *et al*., 2005).

Crop growth and yield

The results of the study revealed that plant height, weed biomass at harvest, number of pods per plant, total aboveground biomass and grain yield of field pea were highly significantly ($P \leq 0.001$) different among levels of phosphate fertilization and weed control operations (Table 2). However, thousand seed weight didn't respond both to phosphate fertilizer and weed control. Weed control highly significantly ($P \leq 0.001$) affected weed biomass at weeding and harvesting but application of phosphate fertilizer had a highly significant effect on weed biomass at harvest but not on weed biomass at weeding, *i.e.*, four weeks after sowing. Cropping season had also a highly significant ($P \leq 0.001$) effect on all agronomic parameters recorded (Table 2).

Table 1. Some soil chemical characteristics (0–20 cm depth) of the experimental field at Welmera.

Parameter	Value
pH (1:1 H_2O)	4.73
Total organic carbon (%)	1.50
Total N (%)	0.19
Available P (ppm)	8.45
Available Na (meq100 g^{-1})	0.03
Available K (meq100 g^{-1})	1.71
Available Ca (meq100 g^{-1})	2.73
Available Mg (meq100 g^{-1})	1.92
CEC (meq100 g^{-1})	21.74

Table 2. Significance of variances for plant height (PH), weed dry matter at weeding (WDM1) and harvest (WDM2), pods per plant (PPP), total biomass yield (TBY), grain yield (GY) and thousand seed weight (TSW) in field pea tested at four fertility and two weeding levels at Welmera, 2003–2004.

Source	df	PH	WDM1	WDM2	PPP	TBY	GY	TSW
Year (Y)	1	***	***	***	***	***	***	***
Phosphorus (P)	3	**	NS	***	***	***	***	NS
Y×P	3	NS	NS	NS	NS	**	**	NS
Weeding (W)	1	*	***	***	**	***	***	NS
W×Y	3	NS	***	**	NS	*	NS	NS
W×P	3	NS	NS	***	**	*	*	NS
W×Y×P	3	NS	*	NS	NS	**	NS	NS
R-MSE		14.01	12.3	7.9	1.44	440.5	142.0	14.4

*, **, *** = Significant at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$ probability levels, respectively; NS = Not significant.

The combined analysis of variance over two cropping seasons showed that there was a significant (P≤0.01) year by phosphate fertilizer interaction (Y×P) for total biomass and grain yield of field pea. Similarly, year by weed control interaction (Y×W) significantly (P≤0.05 and P≤0.01) affected total biomass and weed biomass at weeding and harvest (Table 2). Weed control by phosphate fertilizer interaction (W×P) had a significant (P≤0.05 and P≤0.01) effect on number pods per plant, total biomass, grain yield and weed biomass at harvest. The interaction of year by phosphate fertilizer and weed control (Y×P×W) significantly (P≤0.01 and P≤0.05) affected field pea total biomass and weed biomass at weeding but not other parameters reported (Table 2). The highest weed biomass at harvest, number of pods per plant, total plant biomass and grain yield of field pea were recorded from the application of 20 kg P ha^{-1} (Tables 3 and 4).This is supported by the results of fertilizer trials at different locations of central highlands of Ethiopia (Angaw Tsigie and Asnakew Woldeab, 1994; Amare Ghizaw *et al*., 1999; Amare Ghizaw *et al*., 2005; Getachew Agegnehu and Rezene Fessehaie, 2006).

The application of phosphate fertilizer at the rates of 10, 20 and 30 kg P ha^{-1} resulted in grain yield advantages of 36, 67 and 57%, respectively compared to the treatment without fertilizer (Table 4). The results of the study indicated that the highest grain yield of field pea was obtained from the application of 20 kg P ha$^{-1.}$ Experimental findings on Nitisols and Alfisols of different locations also revealed that grain yields of field pea increased with increasing rates of phosphate fertilizer application (Angaw Tsigie and Asnakew Woldeab, 1994; Getachew Agegnehu *et al*., 2003; Amare Ghizaw *et al*., 2005). The application of 20 kg P ha^{-1} and one properly timed hand wedding resulted in the highest mean yield (2415 ha^{-1}) of field pea (Table 5). The yield increment was higher by 88% compared to the control treatment that is unfertilized and unweeded checks.

Table 3. Mean plant height (PH), weed dry matter at weeding and harvesting of field pea as influenced by phosphate fertilizer and weed control at Welmera, 2003–2004.

Factor	Plant height (cm)	Weed dry matter at weeding	Weed dry matter at harvest
P (kg ha^{-1})			
0	99b	60	69a
10	116a	57	61b
20	119a	54	48c
30	115a	53	35d
LSD (0.05)	11.6	NS	6.6
Weeding (W)			
Unweeded	107b	49b	77a
Once weeded	118a	63a	30b
LSD (0.05)	8.2	7.2	4.6
C.V. (%)	12.4	21.9	14.9

NS = Not significant.
Means in a column with the same letter are not significantly different at $P < 0.05$.

Table 4. Mean number of pods per plant, total biomass, grain yield and thousand-grain weight of field pea response to phosphate fertilizer and weed control at Welmera, 2003–2004.

Factor	Pods per plant	Total biomass (kg ha^{-1})	Grain yield (kg ha^{-1})	1000 grain weight
P (kg ha^{-1})				
0	5.4cb	4225d	1348d	201
10	7.3a	5748c	1825c	201
20	8.5a	6968a	2256a	203
30	7.5a	6444b	2122b	205
LSD (0.05)	1.20	366.3	118.1	NS
Weeding (W)				
Unweeded	6.6a	5519b	1761b	201
Once weeded	7.8b	6174a	2014a	202
LSD (0.05)	0.85	259.0	83.5	NS
C.V. (%)	20.1	8.5	7.5	4.3

NS = Not significant.
Means in a column with the same letter are not significantly different at P < 0. 05.

However, the decrease in grain yield was observed beyond 20 kg P ha^{-1} including weed control operation (Table 5). Grain yield was most strongly correlated with plant height, number of pods per plant and total plant biomass (r = 0.59**, 0.68*** and 0.94***, respectively), which indicate that large plant height, total plant biomass and number of pods per plant are essential to high grain yield (Table 6). Similarly, Getachew Agegnehu and Rezene Fessehaie (2006) showed that grain yield of faba bean was significantly positively correlated with plant height, total biomass and number of pods per plant.

Table 5. Interaction effects of P fertilization (P) and weed control (W) on field pea grain yield (kg ha^{-1}) at Welmera, 2003–2004.

Source	Weed control		
Phosphorus	W_0	W_1	Mean
P_0	1286	1410	1348
P_1	1615	2035	1825
P_2	2096	2416	2256
P_3	2049	2195	2122
Mean	1762	2014	1888
SE	57.98		

The application of P fertilizer and weed control resulted in a linear response function (Fig. 1). The regression line showed that mean grain yield of field pea was strongly positively correlated with phosphorus rate under weeded and unweeded condition (Fig. 1). This shows that the yield of field pea has increased as the level of P increased. The optimum dose of P for attaining an economic yield of field pea was found to be 20 kg ha^{-1} under weeded condition. A similar finding was also reported on faba bean by Getachew Agegnehu and Rezene Fessehaie (2006).

The critical period of weed competition in cool-season food legumes varies from 3 to 8 weeks after crop emergence. The extent to which the yield is reduced by weeds depends not only on the weed species and density, but also on the period for which the crop is exposed to weeds. Despite not statistically significant, the weight of weed biomass at weeding consistently decreased as the P rate increased (Table 3). Several types of broad-leaf and grass weed species were identified in this experiment, among which *Polygonum nepalense, Plantago lanceolata, Guizotia scabra, Galium spurium, Rumex abyssinicus, Phalaris paradoxa, Avena fatua, Spergula arvensis* and *Corrigiola capensis* were the major species competing with field pea. The density of weeds significantly responded to P fertilizer rate in which the weight of weed biomass decreased consistently as the P rate increased. This showed that the growth of field pea was vigorous and could compete well with weeds. Results revealed that due to high vegetative growth of weeds from unweeded plots and late emerged weeds after weeding the total weed biomass at harvest was relatively high.

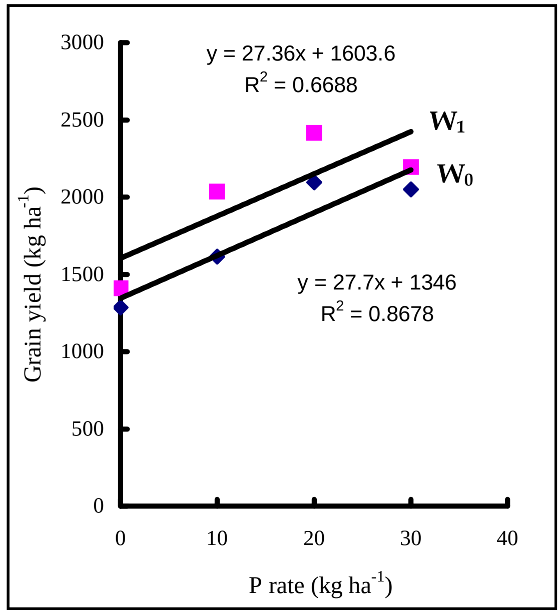

Fig. 1. Field pea grain yield as influenced by the interaction of phosphorus and weed control. (♦ W_0=Unweeded and ▪ W_1=Weeded, 2003–2004.)

$Y = 27.7P + 1346, \quad r^2 = 0.87$ (W_0 trend line)

$Y = 27.4P + 1604, \quad r^2 = 0.67$ (W_1 trend line)

(Y = grain yield; P=phosphorus rate)

Hand weeding once during the 4th week after sowing increased mean grain yield of field pea by 15% compared to the unweeded control treatment (Table 4). Similarly, a review by Rezene Fessehaie (1994) indicated that weed control operation at the proper growth stages of plants significantly increased mean grain yield and major yield components of field pea. Results of similar studies indicated that full-season weed competition caused yield reduction up to 15.3% in field pea (Rezene Fessehaie, 1994), which agrees with the findings of this study. The presence of weeds during the first 4, 7 and 10 weeks after sowing accounted for respective yield reduction of 0.0, 43.3 and 66.9% in field pea (Rezene Fessehaie, 1986). Despite non-significance, the relationship between grain yield and weed biomass at harvest was negative ($r = -0.18^{ns}$) (Table 6). This shows that as the weed biomass increased the seed yield of field pea decreased and negatively correlated with weed biomass and *vice versa*.

Table 6. Coefficients of correlation among, plant height (PH), number of pods per plant (PPP) and seeds per pod (SPP), total biomass yield (TBY), grain yield (GY), thousand seed weight (TSW), weed dry matter at weeding (WDM1) and at harvesting (WDM2).

Character	WDM2	WDM1	TSW	GY	TBY	SPP	PPP
PH	-0.10^{ns}	0.41^{**}	0.16^{ns}	0.59^{**}	0.67^{**}	0.53^{**}	0.74^{***}
PPP	-0.26^{ns}	0.44^{**}	0.24^{ns}	0.68^{***}	0.71^{***}	0.32^{*}	
SPP	-0.09^{ns}	0.04^{*}	-0.02^{ns}	0.31^{*}	0.32^{*}		
TBY	-0.09^{ns}	0.26^{*}	0.31^{*}	0.94^{***}			
GY	-0.18^{ns}	0.19^{ns}	0.33*				
TSW	-0.09^{*}	0.33^{*}					
WDM1	-0.30^{*}						

*, **, *** Significant at $P \leq 0.05$, $P \leq 0.01$ and $P \leq 0.001$ probability levels, respectively; ns = Not significant

Economic analysis

As farmers attempt to evaluate the economic benefits of shift in practice, partial budget analysis was done to identify the rewarding treatments. Yield from on-farm experimental plots was adjusted downward by 10% to reflect the difference between the experimental yield and the yield farmers could expect from the same treatment. According to the results of partial budget analysis, the highest net benefit was obtained from the application of 20 kg P ha^{-1} and weeding once (Table 7). The net benefit increased proportionally for the increment in the total costs that vary up to the treatment with application of 20 kg P ha^{-1} and weeding once (P_2/W_1). The cost-benefit curve also depicts this fact (Fig. 2). According to dominance analysis, out of the total eight treatments considered for economic analysis, four of them were dominated by the other treatments. This is because the value of the increase in yields of the dominated treatments is not enough to compensate the increase for costs. Hence, no farmer would choose treatments that incur additional fertilizer and weeding costs. The dominated treatments were, therefore, eliminated from further economic analysis (Table 7).

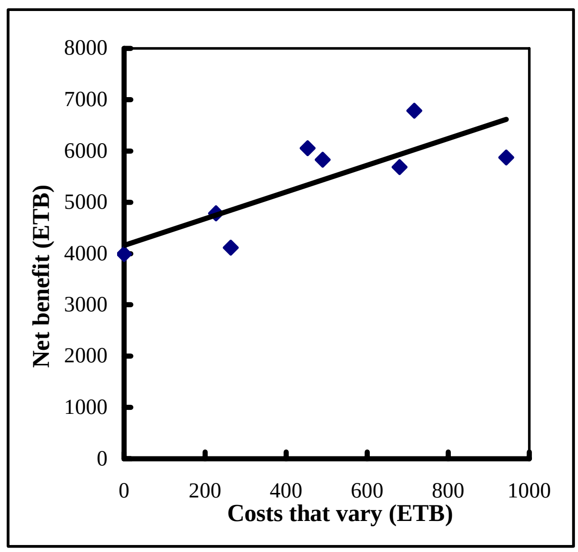

Fig. 2. Cost benefit curve for treatments weeding vs. phosphorus rate net benefit (ETB ha^{-1}).

$$Y = 2.60C + 4162.2, \quad r^2 = 0.65$$

Table 7. Partial budget analysis for phosphorus and weed control treatments.

Treatments	Average yield (kg ha^{-1})	Adj. yield (ha^{-1})	Gross benefit (ETB ha^{-1})	Costs that vary (ETB ha^{-1})			Net benefit (ETB ha^{-1})	Dominance
				Fertilizer cost	Labor cost	Total cost		
P_0W_0	1286	1157.4	3993.03	-	-	-	3993.03	-
P_1W_0	1615	1453.5	5014.57	226.5	-	226.5	4788.07	-
P_0W_1	1410	1269.0	4378.05	-	263.5	263.5	4114.55	D
P_2W_0	2096	1886.4	6508.08	453.0	-	453.0	6055.08	-
P_1W_1	2035	1831.5	6318.67	226.5	263.5	490.0	5828.67	D
P_3W_0	2049	1844.1	6362.15	679.5	-	679.5	5682.65	D
P_2W_1	2416	2174.4	7501.68	453.0	263.5	716.5	6785.18	-
P_3W_1	2195	1975.5	6815.48	679.5	263.5	943.0	5872.48	D

P_0 = No P, P_1 = 10 kg P ha^{-1}, P_2 = 20 kg P ha^{-1}, P_3 = 30 kg P ha^{-1}; W_0 = No weeding, W_1 = Once weeded
ETB = Ethiopian Birr; $1USD = 9.68 ETB; D = Dominated.

Table 8. Marginal analysis of phosphorus and weed control treatments.

Treatments	TCTV	Marginal cost	Net benefit	Marginal benefit	MRR
P_0W_0	-	-	3993.03	-	-
P_1W_0	226.5	226.5	4788.07	795.04	351.0
P_2W_0	453.0	226.5	6055.08	1267.01	559.4
P_2W_1	716.5	263.5	6785.18	730.1	277.1

P_0 = No P, P_1 = 10 kg P ha^{-1}, P_2 = 20 kg P ha^{-1}; W_0 = No weeding, W_1 = Once weeded
TCTV = Total costs that vary; MRR= Marginal rate of return.

For a treatment to be considered as a worthwhile option to farmers, the minimum acceptable rate of return need to be at least between 50 and 100% (CIMMYT, 1988). However, for this study to make farmer recommendations from marginal analysis, 100% return to the investment was considered as reasonable minimum acceptable rate of return since farmers in the study area usually neither weed nor apply fertilizer for field pea. Accordingly, treatments with applications of 10 and 20 kg P ha^{-1} and no weeding (P_1/W_0) and P_2/W_0) and application of 20 kg P ha^{-1} and weeding once (P_2/W_1) are well above the minimum acceptable rate of return, 351%, 559.4% and 277.1% MRR, respectively (Table 8). This implies that for ETB 1.00 investment in field pea production, the producer can get ETB 1.00 and additional ETB 2.77 for the treatment with 20 kg P ha^{-1} and weeding once (P_2/W_1). Thus, since no farmer will prefer less return than the best alternative return, application of 20 kg P ha^{-1} and weeding once by hand (P_2/W_1) is recommended as best economically rewarding treatment.

CONCLUSION

Poor soil fertility, soil acidity and the associated low phosphorus availability are among the major constraints affecting productivity of highland food legumes. Phosphorus fertilizer application and weed control significantly increased grain yield of field pea. The pH value and P content of the soil were sub-optimal to field pea production. If the pH of the soil were between 5.5 and 7.0 the effect of phosphorus on field pea yield could be more than what has already been achieved. In order to produce optimum yield the soil acidity needs to be ameliorated using organic and inorganic sources of materials. Hence, to optimize the availability and efficiency of P fertilizer, it is suggested that application of lime will be very important in soils whose pH is below 5.5 based on the exchange acidity of soils. Weed control had a significant effect on yields of field pea. Timely weeding could also enhance efficient utilization of applied fertilizer by plants. Therefore, application of 20 kg P ha^{-1} and weeding once by hand four weeks after sowing was identified to be the best option with a marginal rate of return of 277%, well above the minimum acceptable rate of return of 100%, which is economically the most feasible alternative.

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