Phosphorus Rate Determination for Field pea (*Pisum sativum* L.) Production Under Irrigation

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Abstract

Field Pea (Pisum sativum L.) is among the most cultivated and popular legume crops grown in Ethiopia and many other countries in the world. Howeve, the yield per hectare decreased tremendously for the last two decades due to depletion of soil nutreints specifically phosphorous. Therefore it was peramaount important to return the yield potential of this crop by aplying chemical fertilizers(NP). Hence field experiment was conducted at Adet Agricultural Research center, Koga irrigation scheme to determine the rate of phosphorus fertilizer for field pea production under irrigation conditions for two years. The experiment was arranged in a randomized completed block design and had four replications. Five phosphorus fertilizer rates(0, 23, 46, 69, and 92 P_2O_5) were considered as treatments.The DAP as (18-46-0), 36 kg ha^{-1} N was added as a starter source for all plots. This was done by considering the highest rate of DAP (i.e., 150 kg ha^{-1}) and adjusting the nitrogen for the remaining treatments by urea. The results indicated that the application of 46 kg ha^{-1} P_2O_5 fertilizer gave the higher grain yield (2.37 t ha^{-1}) of field pea and it has 35 % of yield advantages as compared to the control. On the other hand, compared to the control phosphorus application at the rate of 23, 46, 69, and 92 P_2O_5 increased the mean grain yield of field pea by 38%, 53%, 48%, and 43% respectively. However, plant height, pods per plant, and hundred seed weight were not significant among phosphours nutrient rates. The outcomes of the partial budget analysis showed that the maximum net benefit was obtained from the application of 46 kg ha^{-1} P_2O_5 and it was economically feasible. Therefore, the use of this rate of P_2O_5 fertilizer is recommended to maximize field pea in the Koga irrigation scheme and similar agroecology under irrigation.

Keywords: Field pea, Irrigation, Koga, Phosphorus, Yield

Introduction

Field pea is the second most important legume crop in Ethiopia after faba bean in terms of both area coverage and the total amount of production. Field Pea (Pisum sativum L.) is among the most cultivated and popular pulse crops grown in Ethiopia and low in its productivity due to several determinant factors. The field pea has contributed nutrient values for the consumers; for instance, protein, carbohydrates, phosphorus, iron, calcium, and vitamins A and B (Watt and Merrill, 1963). Expanding the production of field peas such as green pods and dry seeds with standard quality is considered as an important issue and could be achieved through using phosphorus and foliar application of humic acid.

Phosphorus is among the most needed elements for crop production in many tropical soils. However, many tropical soils are p deficient (Osodeke and Uba, 2005). Phosphorus is required for plant growth and development and significantly influencing plant growth and metabolic activities. Phosphorus with a combination of nitrogen is the main yield-limiting plant nutrient in most parts of the world. More than 30% of the world's arable land crop production is determined by P availability (Tesfaye et al., 2007). Phosphorus may become a critical factor for the production of pulse crops under the lowest nutrient content areas; this is due to the basic need for P in the nitrogen fixation process (Tsvetkova and Georgiev, 2007). The highest requirement for P inthe pulse crops is related to the presence of P in the highest rates of energy transfer that must carry out in the nodule. Besides, phosphorus has an increasing effect on plant growth, development, and yield throughout its requirement as an energy source and perform important metabolic processes and activities for the plant (Srivastava et al., 1998). However, the availability of P nutrient to plants in acidic soils such as Koga irrigation scheme and similar agroecologies is hampered due to sever soil acidity (Eriksson, 2009). Furthermore, improved production technologies related to field pea production are limited. The yield of recommended varieties in Ethiopia on station ranges from 2 to 5.5 t ha^{-1} with broadcasting sowing and a seed rate of 75 to 150 kg ha^{-1}. The optimum rate of P fertilizer for field pea was lacking in the areas. This is because, phosphorus fertilizer rate depends on soil test levels, yield goals, cropping history, and potential crop yield. For field the main season in variety adaptation trials using 100 kg ha^{-1} DAP and sowing with 20X10 cm inter-row and intra row spacing in the Koga irrigation scheme (unpublished annual report, 2012). However, there is no recommended package of phosphorus fertilizer for the main season and off-season for the production of field pea. Therefore, this activity was conducted to determine the optimum rate of phosphorus fertilizers for field pea production under irrigated condition.

Materials and Methods

Description of the study area

The study was conducted at Adet agricultural research centre**,** Koga irrigation scheme starting from the end of November to the beginning of April for -three consecutive years of the irrigation seasons. The research centre is authorized body responsible for accessing the experimental site towards permitting to conduct the research. Thus, this study confirmed that it did not affect the protected species or other practices in the surrounding environment and the site is designed for only research purposes. The site is located at 11^{o} 20'57.9"N latitude,37^{o} 7’29.7"E longitude and at an elevation of 1955 m above mean sea level (m.a.s.s). The scheme is specifically situated adjacent to the town of Merawi in the North Mecha Woreda, West Gojjam zone in Amhara regional state (Eguavoen and Tesfai, 2011). The Koga watershed has the potential to irrigate 7000 ha of arable land. The climatic condition of the study area lies within a cool semi-humid agroecosystem that attributes separate dry and wet season (Gebeyehu and Soromessa, 2018). The research site is characterized as unimodal rainfall pattern which occurs from May to September while the months from October to April were considered as the dry season. However, very small rain occurs irregularly during April and May (Figure 4). The experimental site was situated in the lower catchment and consisted of three major soil classes. Among the main soil classes, Alfsols (Nitosols) are the dominant soil types that contribute to clay textural class (Yitaferu et al., 2013; Gebreselassie, 2002) and (Table 7). Very low available phosphorus content occurred due to the high acidity of the soil (Pam and Murphy, 2007).

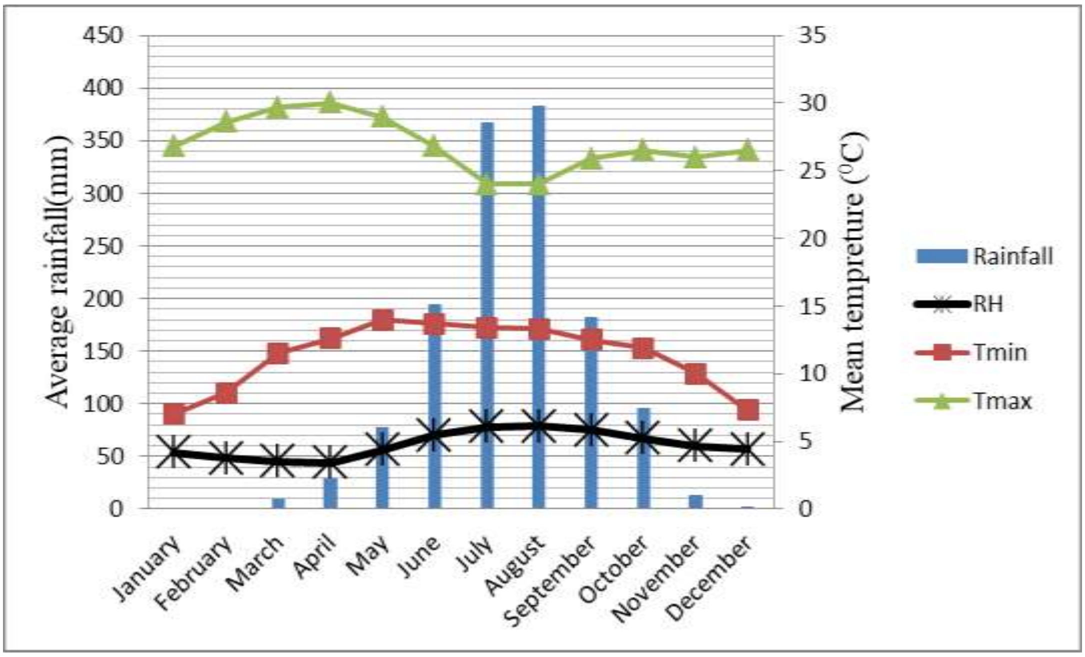

Figure 4. Climatic characteristics of the study area

Table 7. Selected physical and chemical soil properties of the experimental site

Physical parameters	Values	Chemical soil parameters	Values
FC (%)	34.1	PH (%)	4.6
PWP (%)	22.6	EC (ms/cm)	0.18
BD (gcm^{-3})	1.12	CEC (%)	22.2
Sand (%)	24.1	OM (%)	3.18
Clay (%)	67.3	N (%)	0.20
Silt (%)	30.6	Av.P (ppm)	8.72
Texture	Clay	Fe (ppm)	16.5

Where; FC = field capacity, PWP = permanent welting point, BD = bulk density, CEC = cathion exchange capacity, and OM = organic matter, Av. P = available phosphorus

Experimental design

The experiment was organized and formulated in a randomized complete block design consisted of four replications. The experiment comprises five different levels of phosphorus fertilizers (0, 23, 46, 69, and 92 P_2O_5 kg ha^{-1}) as treatments. The numbers of plots considered were twenty and the experimental plots had an area of 12.2 m^2 (3.2 X 4.0 m per plot). The intra and inter-row spacing were 40 and 5 cm respectively. There was also a1m and a 2m gap between plots and replications respectively to enable management practices with a uniform amount of water applications in furrow irrigation over the growing period. A recently recommended variety of field pea (Birkitu) by Adet agricultural research centre for the Koga irrigation scheme was used at a seed rate of 75 kg ha^{-1}. All agronomic management practices were conducted uniformly for all plots. And before planting levelling of experimental plots were performed to achieve fair water distribution. DAP was applied side-banded at sowing about 5cm far from the seed. Irrespective of how much would lime improve the phosphorus use efficiency, equal lime rate was applied for all plots (the trial was done on-site treated with lime at a rate of 2 ton ha^{-1}). The rate of starter N used was considered based on the maximum rate of DAP fertilizer used in this trial (Table 8). The reason for the use of starter nitrogen was to support nutrient supply until the crop begins nitrogen fixation and it was applied uniformly for all tested plots.

Table 8. Starter amount of urea fertilizer applied at each treatment during the experiment

Treatments (P_2O_5 levels)	N in DAP (kg ha^{-1})	N in Urea (kg ha^{-1})	Total starter N (kg ha^{-1})	Total starter Urea (kg ha^{-1})
0	0	36	36	78.26
23	9	27	36	58.69
46	18	18	36	39.13
69	27	9	36	19.57
92	36	0	36	0

Data collection

In this research, the data collected includes phenological and agronomic data (growth data). The phenological data comprises days to 50 % flowering, grain yield and days to 90% maturity whereas the growth data collected in this experiment were: plant height, seed per pod and pod per plant at harvest for ten randomly selected plants while the number of branches per plant, stand count at three to four weeks after planting, and 100 seed weight were also collected during the experiment.

Soil sampling and analysis

Composite surface soil samples were collected after harvest at a depth of 0 to 20 cm (topsoil) using auger. The soil parameters analyzed comprise available phosphorus (P), organic matter (OM), soil PH, and organic carbon (OC). The organic carbon of the sampled soil was determined by the Walkley-black wet oxidation method (Walkely and Black, 1945; FAO-UNESCO, 1974) where the carbon was oxidized under standard conditions with potassium dichromate ($K_2Cr_2O_7$) in sulfuric acid solution. During the analysis of soil organic carbon in the laboratory, the reagents used include; potassium dichromate, sulfuric acid, orthophosphoric acid, ferrous ammonium sulfate solution, and diphenylamine indicator. The available P was extracted with sodium bicarbonate solution at PH = 8.5 following the procedure according to (Bray and Kurtz, 1945) and using the apparatus a spectrophotometer. The spectrophotometer was manufactured by UK PRC Milton Roy Company in 1994 having a specification of spectronic 501/601 spectrophotometer and model 6320D. The appropriate chemicals used for the analysis of available phosphorus in the lab incorporates; sodium hydro oxide, sodium bicarbonate solution as extractant, sulfuric acid solution, and p-nitrophenol indicator (Syers et al., 2008). The soil PH was measured potentiometrically in the supernatant suspension of a 1:2.5 with soil and water mixture using a pH meter with a range of 0 to 14 pH and the application of deionized water, pH 4 and pH 7 buffer solutions are used as chemicals for analysis (Syers et al., 2008).

Partial budget analysis

To identify economically feasible recommendations, partial budget and sensitivity analysis were conducted. The mean grain yield data were adjusted down by 10% to reflect the farmer's field yield and subjected to partial budget analysis CIMMYT (1998). One kg field pea grain costs 35 birrs) from the local market prices. The current average price of phosphorus fertilizer based on DAP and Urea was 13.40 and 12.60 Ethiopian birr kg^{-1}(ETHB) respectively. The Gross benefit was calculated as grain yield (kg ha^{-1}) multiplied by grain price that farmers receive for the sale of the crop (35 birr kg^{-1}). The fertilizer costs that varied for each treatment were calculated and treatments were ranked in the ascending order of total variable cost. dominance analysis was conducted to identify the dominated traetments by substracting the net benefit of the first traetment from the second, the second treatment from third and so on. The net benefit was estimated by subtracting the total variable cost from the gross benefit. Then the marginal rate of return was calculated using the procedures described as follows: MRR= (change in net benefit/ change in total variable cost)*100.

Data analysis

All the data collected were exposed to the analysis of variance (ANOVA) and computed by SAS (version 9.0) software based on randomized complete block design. The least significant difference (LSD) at 5% confidence interval was used for mean comparison of grain yield, biomass, plant height, pods per plant, seed per pod, and 100 seed weight.

Results and Discussion

Analysis of soil physico-chemical properties

The pH of the soil at the experimental field was found in the range of 5.5 to 5.6 which is acidic in the general classification. The result lay within the range of most agricultural soils of the North-western Amhara region and following the other reports. According to (Landon, (1991), the content of phosphorus in the soil was rated (mg kg^{-1}) in different classes. Therefore, the available P content of the soil less than 3 is very low, 4 to 7 is low, 8 to 11 is medium, and greater than 11 is high. In this experiment, the available P content of the sampled soil is very low, which ranges from 2.06 to 3.2 mg kg^{-1} (Table 9).

Table 9. Soil Chemical properties at depth of (0-20 cm) for the experimental site after harvesting

Treatments	PH(1:2.5H_2O)	Av.P (ppm)	OM (%)	SOC (%)
0	5.508	2.06	3.163	1.834
23	5.635	2.378	3.035	1.760
46	5.545	2.022	3.165	1.836
69	5.476	3.213	3.071	1.781
92	5.607	3.009	3.092	1.793
LSD	0.312	1.41	0.54	0.32
CV	3.6	36.3	11.4	11.4

Av.P = available phosphorus, OM=organic matter, SOC = soil organic carbon

Effect of phosphorus nutrient rates on yield and yield components of field pea

Due to different management problems such as watering and pest management, the yield and yield component data were not satisfactory and below the lower limit of field pea yield in the year 2015. Hence, this year's data were not included in the analysis. However, the combined analysis of variance over the two years (2014 and 2016) revealed that phosphorus nutrient rates had significant effect on the grain and biomass yield of field pea (Table 4). The application of 46 P_2O_5 kg ha^{-1} fertilizer gave a higher but non-significant yield (2371kgha^{-1}) followed by 69 P_2O_5 kg ha^{-1} fertilizer rate (2296 kg ha^{-1}). As compared with the control treatment, 46 P_2O_5 kg ha^{-1} has a 53% yield advantage. Furthermore, phosphorus nutrient application at the rates of 23, 69, and 92 kg ha^{-1} P_2O_5 resulted in an increased grain yield over the non-fertilized treatments by 38%, 48%, and 43% respectively. This result had the same trends as the other investigations reported by Getachew (2009). Getachew (2009) found that the application of phosphate nutrient at the rates of 10, 20, and 30 kg P_2O_5 ha^{-1}enhanced mean grain yields of field pea by 36, 67, and 57%, respectively compared to the control. For seed yield and plant height, the means and the 95 % confidence interval indicated an increment pattern following the fertilizer rates.

Table 4. Effect of phosphorus ratess on grain and biomass yields of field pea at Koga irrigation site in 2014 and 2016.

	2014		2016		Combined	
P_2O_5 kg ha^{-1}	G. Yield (kg ha^{-1})	Biomass (kg ha^{-1})	G. Yield (kg ha^{-1})	Biomass (kg ha^{-1})	G. Yield (kg ha^{-1})	Biomass (kg ha^{-1})
0	1662.2c	4322.9	1430b	6300b	1549^{b}	4653^{b}
23	2177.7b	5156.3	2053.4a	9039.3a	2134^{a}	6096^{ab}
46	2645.8a	6301.1	116.3a	328.6a	2371^{a}	929^{a}
69	2548.4a	6510.1	058.9a	218.8a	2296^{a}	704^{a}
92	2305.5ab	5937.5	098.6a	109.8a	2215^{a}	373^{a}
P (0.05)	**	Ns	**	**	*	*
CV	8.5	13.8	10.63	10.67	12.9	16.9

Means followed by the same letter within a column are not significantly different from each other at P< 0.05 according to Fishers LSD; LSD = Least significant difference; CV=Coefficient of variation; ns = -non-significance, PH=plant height

The combined analysis of variance over the years (2014 and 2016) revealed that the main effect of phosphorus nutrient rates on plant height, pods $plant^{-1}$, seeds pod^{-1}, and hundred seed weight were not affected by the various levels of phosphorus fertilizers (Table 5). The result of the analysis of variance in 2014 showed that plant height, pod per plant, seed per pod and biomass yield were not significantly affected by the effect of phosphorus nutrients (Table 4&5). Whereas hundred seed weight and grain yield was significantly differed in the same year (Table 4&5). Similarly, the result of analysis of variance for the year 2016 showed that plant height, pod per plant, and seed per pod were not significantly affected by the effect of phosphorus nutrient rates (Table 5). However, hundred seed weight, biomass and grain yield was significantly differed between P_2O_5 fertilizer rates in this year (Table 4&5).

Table 5. Effect of phosphorus nutrient rates on yield components of field pea in the years 2014 and 2016 irrigation season at Koga irrigation site

	2014				2016				Combined			
P_2O_5 kg ha^{-1}	PH (cm)	Pods $plant^{-1}$	Seed pod^{-1}	100 seed wt (gm)	PH (cm)	Pods $plant^{-1}$	Seed pod^{-1}	100 seed Wt (gm)	PH (cm)	Pods $plant^{-1}$	Seed pod^{-1}	100 seed Wt (gm)
0	99.27	7.3	5.67	24.67a	83.2	4.3	5.7	18a	90.10	5.5	5.7	19.57
23	110	7.67	5.67	20b	93.1	4.85	5.45	18a	100.3	6.0	5.5	18.86
46	115.73	8	5.33	20.33ab	90.25	4.15	5.45	16.5b	101.2	5.9	5.5	18.14
69	126.07	10.33	6.33	18.33c	93.4	5.0	5.45	16.5b	108.6	7.3	5.9	17.29
92	116.27	8	6	18.33c	95.45	4.85	5.65	16.5b	103.2	6.3	5.7	17.29
P(0.05)	Ns	Ns	Ns	**	Ns	Ns	Ns	*	Ns	Ns	Ns	Ns
CV	7.2	21.58	9.2	4.3	9.29	1.08	9.17	5.54	14.4	36	8.6	9.6

Means followed by the same letter within a column are not significantly different from each other at P< 0.05 according to Fishers LSD; LSD = Least significant difference; CV=Coefficient of variation; ns = non-significance, PH=plant height

Partial budget analysis

The result of partial budget analysis indicated that the cost for the different fertilizers was varied due to their different levels of phosphorus nutrients. However, the fertilizer application, weeding, and harvesting costs were similar for all treatment. Based on this assumption, estimating the minimum rate of return acceptable to producers in the recommendation domain is important. The marginal rate of return of the non-dominated treatment (Table 6) showed that 23 and 46 kg P_2O_5 ha^{-1} records a positive marginal rate of return 3202.29 birrs and1241.23 birrs, respectively. According to CIMMYT (1998), on-farm economic analysis of major cereals reported that MRR >100 % is acceptable. Therefore, from this experimental study, two treatments provided MRR greater than 100%. Hence, treatments those receive 23 kg P_2O_5 ha^{-1} records the highest MRR and is within the acceptable range. However, the net benefit obtained by using 46 kg $P_2O_5ha^{-1}$ is greater than using 23 kg P_2O_5 ha^{-1} and hence, it is recommended that farmers should use 46 kg P_2O_5 ha^{-1} which is cost-effective and economically feasible.

Table 6. Partial budget analysis of field pea production under various levels of P_2O_5

P_2O_5 $kgha^{-1}$ levels	GY(kg)	AGY(kg)	GB(birr)	TVC	NB	Dom	MRR(%)
0	1529.5	1376.55	48179.25	1040.76	47138.49	-	
23	2106.8	1896.12	66364.2	1591.27	64772.93	-	3203.291
46	2341.2	2107.08	73747.8	2141.78	71606.02	-	1241.229
69	2268.7	2041.83	71464.05	2692.29	68771.76	Dominated	-
92	2187.2	1968.48	68896.8	3242.8	65654	Dominated	-

GY = grain yield, AGY=average grain yield, GB = gross benefit, TVC = total variable cost, NB =net benefit, DOM. =dominance and MRR =marginal rate of return

Conclusion and recommendation

The recommendation of the best level of phosphorous nutrients for crops is necessary to attain the optimum yield of field pea. The two-year results indicated that the application of 46 kg ha^{-1} P_2O_5 fertilizer gave the highest grain yield (2371 kg ha^{-1}) with the maximum net benefit. The experiment illustrated that the grain yields and biomass of field pea increased as the phosphorus application rate increased from 0 to 92 kg ha^{-1}. On the other hand, the treatment effect do not clearly indicate the changes in seed per pod, pod per plant, and 100 seed weight. Therefore, based on the partial budget analysis it can be recommend that 46 P_2O_5 kg ha^{-1}fertilizer rate is appropriate and economically feasible to produce field pea around Koga and similar agroecology for the irrigation season.

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Reference

Bray RH, Kurtz L (1945). Determination of total, organic, and available forms of phosphorus in soils. Soil science. 1945;59(1):39-46.

Eguavoen I, Tesfai W.2011.Rebuilding livelihoods after dam-induced relocation in Koga, Blue Nile basin, Ethiopia. ZEF Working Paper Series, 2011.

Eriksson S. 2012. Water quality in the Koga Irrigation Project, Ethiopia: A snapshot of general quality parameters.

FAO-UNESCO I. Soil map of the world. Revised legend Reprinted with corrections World Soil Resources. 1974;30.

Gebeyehu G, Soromessa T. 2018.Status of soil organic carbon and nitrogen stocks in Koga Watershed Area, Northwest Ethiopia. Agriculture & Food Security. 2018;7(1):9.

Gebreselassie Y. Selected chemical and physical characteristics of soils of Adet research center and its testing sites in North-western Ethiopia. Ethiopian Journal of Natural Resources. 2002.

Getachew G. 2009. Phosphate fertilizer and weed control effects on growth and yield of field pea on Nitisols of central highlands of Ethiopia. SINET: Ethiopian Journal of Science. 2009;32(2):109-16.

Landon J. R. (ed.), 1991. Booker Tropical Soil Manual: A Handbook for Soil Survey and Agricultural Land Evaluation in the Tropics and Subtropics. Longman Scientific and Technical, Essex, New York. 474p.

Olsen SR. Estimation of available phosphorus in soils by extraction with sodium bicarbonate: US Department of Agriculture; 1954.

Osodeke V and Uba A .2005. Determination of phosphorus fraction in selected soils of southeasternNigeria. International Journal of Natural and Applied Sciences. 2005;1(1):10-

Pam H, Murphy B. Interpreting Soil Test Results. What Do All the Numbers Mean. Available on http://www publish csiro au (Accessed on 14/12/12). 2007.

Program CE, Maize I, Center WI. From agronomic data to farmer recommendations: An economics training manual: CIMMYT; 1988.

Srivastava T, Ahlawat I, Panwar J. 1998. Effect of phosphorus, molybdenum and biofertilizers on productivity of pea (Pisum sativum l). Indian journal of plant physiology. 1998;3(3):237-9.

Syers J, Johnston A, Curtin D. Efficiency of soil and fertilizer phosphorus use. FAO Fertilizer and plant nutrition bulletin. 2008;18(108).

Tesfaye M, Liu J, Allan DL, Vance CP. 2007. Genomic and genetic control of phosphate stress in legumes. Plant Physiology. 2007;144(2):594-603.

Tsvetkova GE, Georgiev GI. Changes in phosphate fractions extracted from different organs of phosphorus starved nitrogen fixing pea plants. Journal of plant nutrition. 2007;30(12):2129-2140.

Uniyal S, Mishra AC. Effect of different levels of nitrogen and phosphorus on performance of vegetable pea in rainfed hills. Pantnagar Journal of Research. 2009;7(2):184-6.

Walkely A. A critical of a rapid method for determining organic carbon in soils-effects of variations in digestion conditions and of organic soil constituents. Journ of Soil Sci. 1947;63(1):251-64.

Watt BK, Merrill AL. 1963. Composition of foods, raw, processed: Consumer and Food Economics Research Division, Agricultural Research Service …; 1963.

Yitaferu B, Abewa A, Amare T. 2013. Expansion of Eucalyptus woodlots in the fertile soils of the highlands of Ethiopia: could it be a treat on future cropland use? Journal of Agricultural Science. 2013;5(8):97.

Appendeces

Appendix Table 1. Mean squares of analysis of variance for yield and yield components of Field pea in 2014 Irrigation season

Sources	DF	PH	PP	SP	100 seed wt	BY	GY
Treatment	4	289.05*	4.23ns	0.43ns	6.07**	2439778.65*	448440.06**
Replication	3	28.84ns	1.27ns	0.2ns	2.47ns	60221.35ns	120211.17ns
RMSE		8.13	1.78	0.53	0.85	779.4	194.47
CV		7.16	21.58	9.18	4.3	13.8	8.57
R-square		0.7	0.43	0.4	0.84	0.67	0.87

DF=degree of freedom, PH=plant height, PP = pod per plant, seed per pod, BY=biomass yield, GY=grain yield

Appendix Table 2. Mean squares of analysis of variance for yield and yield components of Field pea in 2016 Irrigation season

Sources	DF	PH	PP	SP	100seedwt	BY	GY
Treatment	4	91.34ns	0.57ns	2.7ns	2.7ns	6656555.17**	342769.627**
Replication	2	19.22ns	0.19ns	1.4ns	1.4ns	803954.08ns	39194.351ns
RMSE		8.47	0.7	0.51	0.95	918.3	207.61
CV		9.3	15.21	9.17	5.55	10.68	10.64
R-square		0.33	0.33	0.3	0.58	0.74	0.74

DF=degree of freedom,PH=plant height,PP = pod er plant, seed/pod, BY=biomass yield, GY=grain yield

Appendix Table 3. Mean squares of combined analysis of variance for yield and yield components of Field pea in Irrigation season

Sources	DF	PH	PP	SP	100 seed wt	BY	GY
Treatment	4	317.13^{ns}	3.01^{ns}	0.29^{ns}	6.97**	8215380.8***	734864.7***
Replication	3	118.99^{ns}	0.5^{ns}	0.3^{ns}	3.36ns	5750832.7**	16508.1
Year	1	3962.9***	96.48	0.97	50.7***	59275959.3***	905345.3**
RMSE		8.16	1.24	0.49	1.1	961	224.16
CV		8.11	20.09	8.71	6.04	11.7	10.74
R-square		0.76	0.76	0.32	0.74	0.85	0.75

DF=degree of freedom, PH= plant height, PP = pod per plant, seed per pod, BY=biomass yield, GY=grain yield