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Critical Limits of Phosphorus in Soil and Pea Plant Grown in Acid Soils of Senapati District of Manipur, India

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A pot culture study was conducted in 20 acidic soils of Senapati District of Manipur, India during rabi season of 2013-14 to estimate the critical limit of P in soil and pea plant for predicting the response of pea (*Pisum sativum L.*) to P application as well as to study the effect of P application on dry matter yield and uptake of nutrients in pea crop. The experimental soil was acidic in nature, electrical conductivity of the soil was in safe limit for crop growth. The organic carbon status was almost high and soil was clay in textural class. Pot culture studied showed that the application of phosphorus @ 60 kg P_2O_5 ha^{-1} significantly superior (85 %) of the studied soils to any other treatments and 40 kg P_2O_5 ha^{-1} was significantly (15 %) to the total soils in dry matter yield of Pea variety Arkel. The critical limit of the P concentration in the pea was found 0.42 per cent. It was revealed that the critical level of phosphorus in the soils for growing of pea plants varied with the methods of phosphorus extraction. The critical level of soils ranged from 14.30 to 25 kg P_2O_5 ha^{-1} depending upon the methods of phosphorus extraction.

Introduction

Phosphorus is the second most important plant nutrient after nitrogen for agricultural production in most regions of the world. Unlike nitrogen, whose supply from atmosphere is limited by natural cycling, it is recycled in negligible quantities. Phosphorous is one of the major plant nutrients that directly or indirectly affect all plant physiological processes. It is the key component of energy metabolism and synthesis of nucleic acids and membranes as well as atmospheric nitrogen fixation in the leguminous crops.

Phosphorous enhances many aspects of plant physiology, including the fundamental processes of photosynthesis, nitrogen fixation, flowering, fruiting (including seed production), and maturation. Phosphorus has a key role in the energy metabolism of all plant cells and particularly for nitrogen fixation in legume crops. Pea requires a relatively high phosphorus nutrition (Slinkard and Drew, 1988) and phosphorus fertilization and phosphorus fertilization enhances yield and seed quality (Pulung, 1994). In spite of its importance in biology, plant strive hard to obtain this essential nutrient from the crop rhizosphere. Phosphorus deficiency is considered to be one of the major limitations for crop production, particularly in the low-input agricultural systems around the world. P-deficient plants often seem quite normal in appearance. In severe cases, P deficiency can cause yellowing and senescence of leaves. In many acidic soils in developing countries, P deficiency is the main limiting factor for crop production and, therefore, requires the application of P fertilizers for optimum plant growth and production of food and fibre (Attar, 2014). Phosphorus is known to play an important role in growth and development of the crop and have direct relation with root proliferations, straw strength, grain formation, crop maturation (Bhat *et al.,* 2013).

Although P is abundant in soils in both organic and inorganic forms (Khan *et al.*, 2009), the amount of available forms to plants is generally low, because the majority of soil P is found in insoluble forms, while the plants absorb it only in soluble ions (H_2PO_4 - and HPO_4^{2-}) (Bhattacharyya and Jha, 2012).

The North-East Region of India has geographical area of 26.3 million hectares and almost 85% of the soils are moderate to strongly acidic (Das *et al.,* 2016). Phosphorus deficiency is the main limiting factor for crop production in acidic soils and therefore, requires the application of phosphatic fertilizers for optimum plant growth and production of food and fibre (Attar, 2014). Nutrient deficiency of plant can be replenished well in advance before heavy loss. Therefore, the present investigation was planned to study the critical level of phosphorous on the soils and plants and response of phosphorus fertilization for optimum pea production, grown in acidic soils.

Materials and Method

The pot culture experiment was conducted during the rabi season of 2013-14 at Krishi Vigyan Kendra- Senapati, Manipur, India with objective to establish critical limit of P in soil and for pea crop as well as to study the effect of P application on dry matter yield and uptake of nutrients in pea crop. The geographical area of the district is 3271 sq. km with 14.56% of the total geographical area of the state. The average temperature ranges from 4°C to 32°C and average annual rainfall varies from 671 to 1454 mm. It is located between 24° 30′N latitude and 93° 30′E longitude over the globe. The altitude of the district ranges from 800 to 4000 m above MSL. Senapati district has alluvium, lateritic black regur and ferruginous type of soil (Anonymous, 2009). Twenty soil samples in bulk from plough layer (0-20 cm) were collected from different places of Senapati District of Manipur, India and the processed samples (<2mm) were analysed for their physico-chemical characteristics using the standard procedure (Jackson, 1973) and reported in Table 1. 2.5 kilogram of soil was filled in pots and phosphorus was applied at 0, 40 and 60 kg P_2O_5 ha^{-1} through single super phosphate. Similar procedure has also been used by Mahajan *et al.,* 2013 in Wheat. The treatments were replicated thrice in a completely randomized design. A basal application of 30: 40 N: K_2O ha^{-1} was applied in the form of urea and MOP in each pot. Pea (Arkel) seeds were sown and thinning was done ten days after sowing keeping four healthy plants in each pot. The crop was harvested 40 days after germination. The plant samples were washed in water and dried in oven at 65 ºC for 48 hr and the dry matter yield was recorded. The samples were then powdered and requisite quantities of the same were digested in nitricperchlororic acid mixture. Mechanical analysis of various soil samples for its sand, silt and clay fractions was carried out by N.B.S.S and LUP using hydrometer methods described by Buoyoucous (1962). Soil pH was determined by glass electrode systronic pH meter in 1.2.5 soil-water suspension method (Jackson, 1973). Organic carbon was determined by wet oxidation method of Walkley and Black (Jackson, 1973). The cation exchange capacity was determined by leaching the soil with 1 N NH_4^+OAC (ph 7.0) suggested by Borah *et al.,* (1987). Phosphorus was determined by using Vanadomolybdophosphoric acid reagent. To test the suitability, six test methods were used (Table 2). The soil samples were shaken for two minutes with soil to solution ratio of 1:10. Extractable phosphorus was determined Spectrophotometrically.

An attempt was made to find out the critical level of phosphorous on the soils and plants in accordance with the procedure of Cate and Nelson (1965) using a scatter graphical approach, partitioning the two dimensional percentage yields versus soil test levels and phosphorus concentration in the pea plants (control) scattered into two groups.

Bray's percent yield

Bray's percent yield of pea for each soil samples was calculated by using the relationship

$$\text{Bray's percent yield} = \frac{\text{Yield without fertilizer}}{\text{Maximum yield in fertilizer treated pots}} \times 100$$

Bray's percent uptake

Bray's percent uptake of pea was calculated as:

$$\text{Bray's percent uptake} = \frac{\text{Uptake without fertilizers}}{\text{Maximum uptake in fertilizer treated pot}} \times 100$$

Simple correlation analysis was carried out to establish the relationships between the Zn and soil properties.

Results and Discussion

Soils properties

The data of initial physical and chemical properties of soils of Senapati District of Manipur are presented in table 1. From data it was seen that soil texture varied from clay, clay loam and silty clay in the textured class. The percent of studied soils was clay. The soils had pH values ranging from 4.50 to 5.62. All the investigation soil samples were acidic in nature with a mean value of soil reaction 5.15. The organic carbon status of soil samples ranged from 13.40 g kg^{-1} to 24.00 g kg^{-1} with a mean value of 20.35 g kg^{-1}. In general, soils were high in organic carbon content. The CEC of the soils ranged from 11.40 [Cmol(p+)kg^{-1}] to 28.20 with a mean value of 17.81[Cmol(p+)kg^{-1}]. The total nitrogen present in the soils ranged from 0.09 to 0.22 percent with a mean value of 0.14 percent. The available nitrogen content of the soil samples collected from different locations ranged from 208.70 kg ha^{-1} to 423.25 kg ha^{-1} i.e. low to medium available nitrogen content in the study soils. The average of available nitrogen in these soils was 335.14 kg ha^{-1}.

The soils had P values ranging from 18 kg ha^{-1} to 64 kg ha^{-1} with a mean value of 39.40 kg ha^{-1}. The available potassium present in these soils varied from 90.34 kg ha^{-1} to 243.10 kg ha^{-1} with a mean value of 151.90 kg ha^{-1}. Out of the 20 samples collected from various locations, 15 percent & 85 percent were low and medium potash content in the soils, respectively.

Effect of phosphorus on dry matter yield

The data presented in table 3 revealed that the dry matter yield of pea was greatly influenced by different levels of phosphorus concentration. The dry matter yield in the control varied from 1.08 g/pot to 2.89 g/pot as compared with 1.86 g/pot to 3.55 g/pot in 40 Kg P_2O_5 ha $^{-1}$ and 2.32 g/pot to 4.35 g/pot in 60 Kg P_2O_5 ha^{-1}, respectively. An application of phosphorus increased the dry matter yield of pea regardless of its initial phosphorus status of all the soil samples collected from various locations. Similar results of phosphorus on dry matter yield of pea were also reported by Bhalu *et al.*, (1995) and Hussain *et al.*, (2001). Dry matter yield varied with the soils collected from different locations depending upon their physico-chemical properties. Significant difference of dry matter yield of pea was observed among the different soil samples and their interactions with the different levels of phosphorus treatment. The increased dry matter yield due to phosphorus application may probably be increased plant height, number of branches, and number of leaves and the leaf area of the plants and also possibly accelerated the nitrogen fixing power of the plant by increasing activity of nodule bacteria which could lead to more dry matter accumulation.

The dry matter yield of pea due to different treatments of phosphorus was significant at 0.05 level of probability. On the other hand, the dry matter yield of different soils collected from various locations and interaction between different soils and phosphorus treatments was also found significant at 0.01 and 0.05 level of probability.

Effect of phosphorus on nitrogen, phosphorus and potassium uptake

Nitrogen uptake

It was evident from the table that nitrogen uptake by pea plant was highest with phosphorus applied @ 60 kg P_2O_5 ha $^{-1}$ (39.08 mg/pot) which was significantly superior to any other treatments. Irrespective of the initial soil properties, an application of phophatic fertilizer increased the nitrogen uptake by the plants (Table 4). The uptake of nitrogen by the plant is the combined effect of higher nitrogen content in the plants as well as total dry matter yield. On the other hand, various soils collected from different places also influenced the nitrogen uptake by the plants. Similar observation was also reported by Bhalu *et al.*, (1995). A profuse vegetative growth and higher dry matter accumulation due to application of phosphorus might increase nitrogen uptake by pea plants

Phosphorus uptake

It was evident from the table that phosphorus uptake by pea plant was highest with phosphorus applied @ 60 kg P_2O_5 ha $^{-1}$ (18.23

mg/pot) which was significantly superior to the other treatments. The significant increase of phosphorus uptake by the pea plants was effect of higher dry matter accumulation due to phosphorus application as well as increase phosphorus content in the plants. There was consistent increase in phosphorus uptake with increasing levels of phosphorus rate by the pea plants. This increased uptake of phosphorus with phosphorus levels might owe to release of more phosphorus and better utilization with phosphorus application by pea plants. This confirms the finding of Reddy *et al.,* (1990) and Bhalu *et al.,* (1995).

Potassium uptake

It was evident from the table that the amount of potassium uptake was lower than that of nitrogen but higher than phosphorus uptake by the pea plants. However, the pattern of uptake was more or less the same in all the cases (Table 4). It was evident that the potassium uptake by the pea plants increased with the increasing levels of phosphorus application. Similar result was also reported by Reddy *et al.,* (1990) and Bhalu *et al.,* (1995). The highest potassium uptake was found with the application of 60 kg $P_2O_5ha^{-1}$ by the pea plants (36.24 mg/pot) which were significantly superior to other treatments. Significant increase of potassium uptake by the pea plants was the cumulative effect of higher dry matter yield and higher potassium in the plants due to different levels of phosphorus application.

Correlation studies with plant parameters

Bray's per cent yield and uptake

The data (Table 5) revealed that all the extractants showed positive and significant correlation with Bray's per cent and uptake of pea except Olsen and Mehlich 1. Bray's per cent yield and uptake range from 35.88 to 97.93 per cent and 19.42 to 85.36 per cent respectively (Table 3). Among the extractant used for this investigation, Bray 1 showed higher degree of co-efficient of correlation with Bray's per cent uptake with 'r' values of 0.699** than other extractant.

Dry matter yield (control)

Dry matter yield of pea in the control pot showed the highest significant correlation (Table 5) with Bray 1 (r=0.636**) which was followed by Mehlich 3 (r=0.493*). The result suggested that the dry matter accumulation by the plants was more or less influence by phosphorus as indicated by high correlation co-efficient with Bray 1.

Phosphorus uptake (control)

Phosphorus uptake by pea showed significant and positive relationship with available phosphorus as extracted by Bray 1, Bray 2 and Mehlich 3 (Table 5). The result indicated that phosphorus uptake of the control plants had highest and significant positive relationship with Bray 1 extractant (r=0.773**) which was followed by Bray 2 extractant (r=0.535*).

Critical level of phosphorus

Soils

It was revealed that the critical level of phosphorus in the soils for growing of pea plants varied with the methods of phosphorus extraction. According to graphical procedure of Cate and Nelson (1965), the critical level of soils ranged from 16.70 to 25 kg $P_2O_5ha^{-1}$ depending upon the methods of phosphorus extraction. Bray 1 extractant showed highest degree of correlation with Bray's per cent yield and uptake than the other. Among the extractant Bray 1 (16.70 kg P_2O_5 ha^{-1}, Fig. 1) is the most suitable method for assessing critical level as high degree of correlation with Bray's per cent yield and uptake.

Table.1 Initial physical and chemical characteristics of the experimental soils for the pot study

SL. No.	Locations/ Village	Soil characteristic											Tectural Class
		pH	Organic carbon (g kg^{-1})	Total N (%)	Available N (kg ha^{-1})	Available P_2O_5 (kg ha^{-1})	Available K_2O (kg ha^{-1})	Ca [Cmol(p+) kg^{-1}]	Mg [Cmol(p+) kg^{-1}]	Clay (%)	Silt (%)	Sand (%)	
1.	Hengbung	5.00	19.00	0.14	356.12	38.40	119.00	2.20	1.30	48.80	40.10	11.10	Silty clay
2.	Mayangkhang	5.40	21.22	0.13	338.51	42.44	90.34	3.00	1.50	56.90	33.00	9.10	Clay
3.	T. Khullen	4.50	23.00	0.22	278.41	18.00	243.10	2.60	1.40	63.50	20.70	15.80	Clay
4.	Ningthoupham	5.22	19.00	0.12	345.25	44.00	186.17	2.75	3.20	53.97	34.93	11.10	Clay
5.	Changoubung	5.00	22.00	0.09	208.70	31.30	128.20	1.70	1.90	67.30	14.60	18.10	Clay
6.	Kangpokpi	5.11	19.00	0.16	267.25	29.50	230.00	2.85	1.60	58.99	28.80	12.21	Clay
7.	Daily village	4.60	24.00	0.17	279.34	33.05	172.30	3.20	2.50	55.30	30.00	14.70	Clay
8.	Yaikongpao	5.14	23.00	0.11	412.42	55.95	209.50	1.80	0.70	56.30	33.50	10.20	Clay
9.	Keithelmanbi	5.05	18.50	0.15	339.07	54.00	191.70	2.50	0.80	40.10	28.60	31.30	Clay loam
10.	Gopibung	5.60	13.40	0.12	341.80	30.00	102.00	2.70	0.70	53.90	31.00	15.10	Clay
11.	Sapormeina	4.89	21.50	0.18	420.05	51.90	103.20	1.25	0.70	56.80	32.00	11.20	Clay
12.	Koubruleikha	5.16	16.70	0.12	352.52	35.45	171.50	2.20	1.40	37.90	33.50	28.60	Clay loam
13.	Motbung	4.99	24.00	0.12	346.60	40.10	185.40	2.65	0.35	59.82	22.20	17.98	Clay
14.	Taphou Kuki	5.62	16.10	0.11	228.50	22.80	92.10	3.80	2.40	47.07	32.93	20.00	Clay
15.	Parengba	5.22	22.10	0.14	359.00	28.25	150.00	3.90	1.30	56.90	34.00	9.10	Clay
16.	Karong	5.09	22.00	0.18	423.25	64.00	155.00	3.80	2.70	55.40	29.80	14.80	Clay
17.	Katomei	5.14	23.00	0.13	370.34	49.50	172.00	2.60	1.40	50.00	38.00	12.00	Clay
18.	Senapati Bazar	5.18	19.40	0.14	332.14	39.50	125.00	2.70	0.80	47.47	35.93	16.60	Clay
19.	Makhan	5.55	23.00	0.09	375.50	53.65	92.20	4.00	1.15	54.90	37.00	8.10	Clay
20.	Purul	5.60	17.00	0.18	328.06	19.90	119.20	2.50	0.80	42.80	25.90	31.30	Clay loam
Range value		**4.50-5.62**	**13.40 - 24.0 0**	**0.09-0.22**	**208. 70 - 4 23.25**	**18 - 64**	**90. 34 - 243. 10**	**1. 25 - 4**	**0. 35 - 3.2 0**	**37.9 0 - 67. 30**	**14. 60 - 40.10**	**8.10 - 31. 30**	
Mean		**5.15**	20.35	**0.14**	**335.14**	39.40	**151.90**	**2.74**	**1.43**	**53.21**	**30.82**	**15.92**	

Table.2 Amount of available soil P content extracted by various methods (ppm)

Extractant	Range	Mean	References
Bray and Kurtz No.1 0.003 N NH_4F +0.025 N HCl	7.54 - 28.90	15.93	Bray and Kurtz (1945)
Bray No. 2 0.1N HCl+0.03N NH_4F	15.44 - 50.06	29.26	Bray and Kurtz (1945)
Mehlich1(0.0125 M H_2SO_4+0.05M HCl)	7.50 - 25.00	13.49	Nelson *et al.*, (1953)
Mehlich3 0.2M CH_3COOH, 0.25M NH_4	8.22 - 25.00	16.29	Mehlich (1984)
Olsen P (0.5 M $NaHCO_3$), pH-8.5	6.00 - 22.00	14.34	Olsen *et al.*, (1954)
Troug (0.002 NH_2SO_4, pH-3)	11.11 - 41.00	23.67	Troug

Table.3 Effect of phosphorus application on dry matter yield, phosphorus concentration and its uptake by pea crop

Soil No.	Bray 1	Dry matter yield (g/pot)			Mean	Bray's % yield	P concentration in plants of no P pots (%)	P Uptake by plants (mg/pot)			Bray's % P Uptake
		P_2O_5 level (kg ha^{-1})						P_2O_5 level (kg ha^{-1})			
		0	40	60				0	40	60	
1	18.18	2.53	2.67	3.86	3.02	65.54	0.35	10.40	11.48	18.91	54.99
2	14.90	1.7	2.65	2.62	2.32	64.15	0.48	7.50	18.55	19.39	38.68
3	22.56	2.72	2.98	2.99	2.90	90.97	0.43	10.61	13.41	15.25	69.58
4	10.05	1.33	2.06	2.59	1.99	51.35	0.4	5.32	8.86	13.47	39.50
5	16.31	2.54	2.79	3.86	3.06	65.8	0.42	10.70	12.83	19.30	55.44
6	24.67	2.89	2.84	2.9	2.88	97.93	0.53	14.20	15.62	21.17	67.08
7	21.00	1.72	2.81	2.83	2.45	92.58	0.63	14.11	17.98	20.38	69.25
8	18.22	2.56	2.68	4.19	3.14	60.78	0.41	10.50	11.79	20.95	50.12
9	11.40	1.43	2.91	3	2.45	47.67	0.47	7.80	15.13	16.20	48.15
10	13.43	1.37	2.75	2.84	2.32	48.24	0.29	3.42	8.25	17.61	19.42
11	12.00	2.51	2.57	4.32	3.13	58.1	0.38	7.00	12.59	20.74	33.76
12	19.17	1.31	2.8	2.82	2.31	46.45	0.42	7.50	13.44	16.64	45.08
13	16.22	2.12	2.7	2.8	2.54	75.71	0.42	14.00	15.39	21.00	66.67
14	12.65	1.8	2.56	4.35	2.90	41.38	0.39	9.50	12.29	20.01	47.48
15	18.00	1.08	3.01	2.95	2.35	35.88	0.36	4.00	15.05	15.34	26.08
16	11.00	1.51	3.55	3.05	2.70	42.53	0.4	6.02	14.56	19.83	30.37
17	28.90	2.81	2.85	2.32	2.66	81.4	0.51	16.30	19.10	16.70	85.36
18	9.08	1.35	2.09	2.59	2.01	52.12	0.37	4.40	9.20	15.80	27.85
19	13.32	2	2.77	2.85	2.54	70.17	0.41	8.10	15.24	22.80	35.53
20	7.54	1.29	1.86	2.78	1.98	46.4	0.4	4.42	8.18	13.07	33.83
Mean	**15.93**	**1.93**	**2.70**	**3.13**	**2.58**	61.1	**0.42**	**8.79**	**13.45**	**18.23**	**47.21**

Table.4 Effect of phosphorus application on nitrogen, phosphorus and potassium uptake in pea crop

Soil No.	Bray 1	N uptake in plants (mg/pot)				P uptake in plants (mg/pot)				K uptake in plants (mg/pot)			
		P_2O_5 level (kg ha^{-1})				P_2O_5 level (kg ha^{-1})				P_2O_5 level (kg ha^{-1})			
		0	40	60	Mean	0	40	60	Mean	0	40	60	Mean
1	18.18	26.57	30.97	48.25	35.26	10.40	11.48	18.91	13.60	27.83	30.17	49.41	35.80
2	14.90	15.30	26.50	32.23	24.68	7.50	18.55	19.39	15.15	16.15	26.77	30.13	24.35
3	22.56	25.30	35.76	37.38	32.81	10.61	13.41	15.25	13.09	24.21	29.50	36.18	29.96
4	10.05	11.70	21.63	32.63	21.99	5.32	8.86	13.47	9.22	10.11	17.10	23.57	16.93
5	16.31	26.67	32.09	49.02	35.93	10.70	12.83	19.30	14.28	21.84	30.41	50.95	34.40
6	24.67	26.88	31.24	35.67	31.26	14.20	15.62	21.17	17.00	25.43	27.26	31.61	28.10
7	21.00	16.51	28.38	35.09	26.66	14.11	17.98	20.38	17.49	14.62	25.29	30.85	23.59
8	18.22	27.39	32.16	55.73	38.43	10.50	11.79	20.95	14.41	26.88	29.75	51.96	36.19
9	11.40	12.87	29.10	37.50	26.49	7.80	15.13	16.20	13.04	11.73	36.08	41.10	29.64
10	13.43	13.15	29.43	33.51	25.36	3.42	8.25	17.61	9.76	10.55	22.83	25.84	19.74
11	12.00	26.10	32.13	56.16	38.13	7.00	12.59	20.74	13.44	25.10	32.38	50.98	36.15
12	19.17	11.27	28.84	34.12	24.74	7.50	13.44	16.64	12.53	13.36	32.76	35.25	27.12
13	16.22	20.35	27.81	34.44	27.53	14.00	15.39	21.00	16.80	19.08	26.73	35.00	26.94
14	12.65	18.36	29.95	58.29	35.53	9.50	12.29	20.01	13.93	19.08	29.44	50.46	32.99
15	18.00	11.45	37.93	30.09	26.49	4.00	15.05	15.34	11.46	8.75	36.12	31.57	25.48
16	11.00	15.86	45.09	40.87	33.94	6.02	14.56	19.83	13.47	13.14	33.73	32.94	26.60
17	28.90	28.10	30.78	31.32	30.07	16.30	19.10	16.70	17.37	25.01	27.08	26.91	26.33
18	9.08	12.02	22.78	33.41	22.74	4.40	9.20	15.80	9.80	16.34	26.75	32.89	25.33
19	13.32	19.40	30.47	33.92	27.93	8.10	15.24	22.80	15.38	16.60	33.24	30.78	26.87
20	7.54	12.26	20.46	31.97	21.56	4.42	8.18	13.07	8.56	7.48	16.00	26.41	16.63
Mean	**15.93**	**18.87**	**30.17**	**39.08**		**8.79**	**13.45**	**18.23**		**17.66**	**28.47**	**36.24**	

Table.5 Simple correlation co-efficient between the different forms of phosphorus and yield parameters of pea

No.	Extractant	Dry matter yield (Control)	P uptake (Control)	Bray's % Yield	Bray's %Uptake
1	Bray 1	0.636**	0.773**	0.699**	0.783**
2	Bray 2	0.463*	0.535*	0.480*	0.517*
3	Mehlich 1	-0.319	-0.326	-0.091	-0.301
4	Mehlich 3	0.493*	0.509*	0.469*	0.578**
5	Troug	0.475*	0.310	0.518*	0.308
6	Olsen	-0.322	-0.141	-0.136	-0.004
7	Saloid-P	-0.217	0.099	0.009	0.04
8	Iron-P	0.205	0.101	0.315	0.113
9	Aluminium-P	0.410	0.575**	0.471*	0.616**
10	Reductant-soluble-P	0.361	0.33	0.406	0.465*
11	Occluded-P	-0.179	0.061	0.06	0.214
12	Calcium-P	-0.005	0.046	0.002	0.060
13	Organic-P	-0.366	-0.011	0.079	-0.052
14	Total-P	-0.096	0.169	0.274	0.191

Fig.1 Relationship between Bray 1 and Bray's percent yield

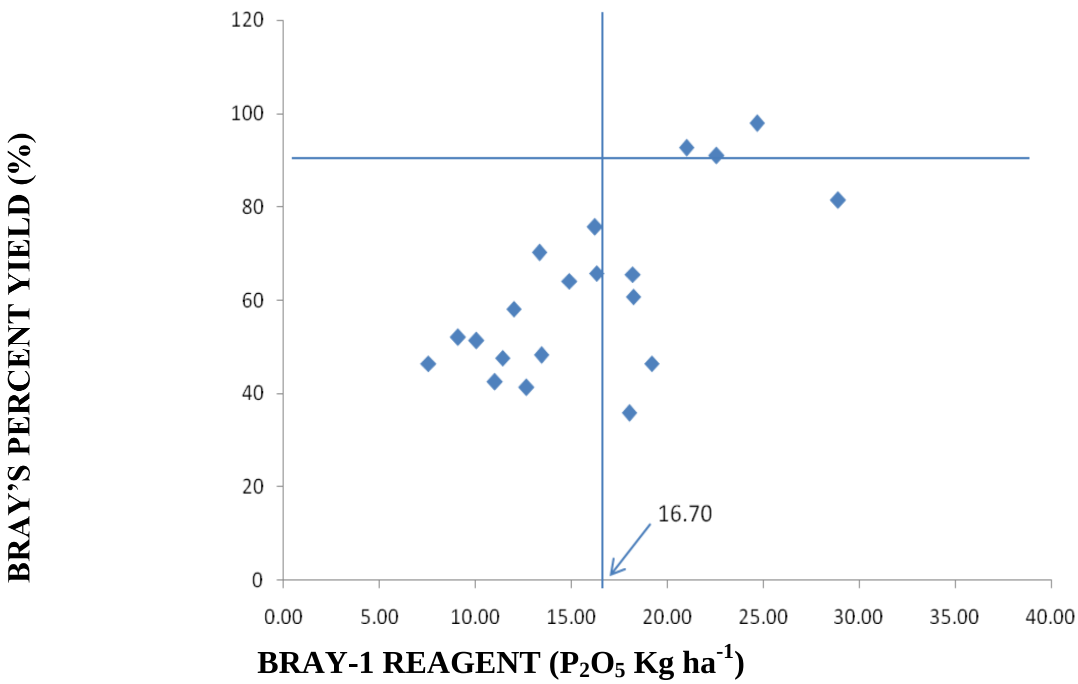


Fig.2 Relationship between Bray 2 and Bray's percent yield

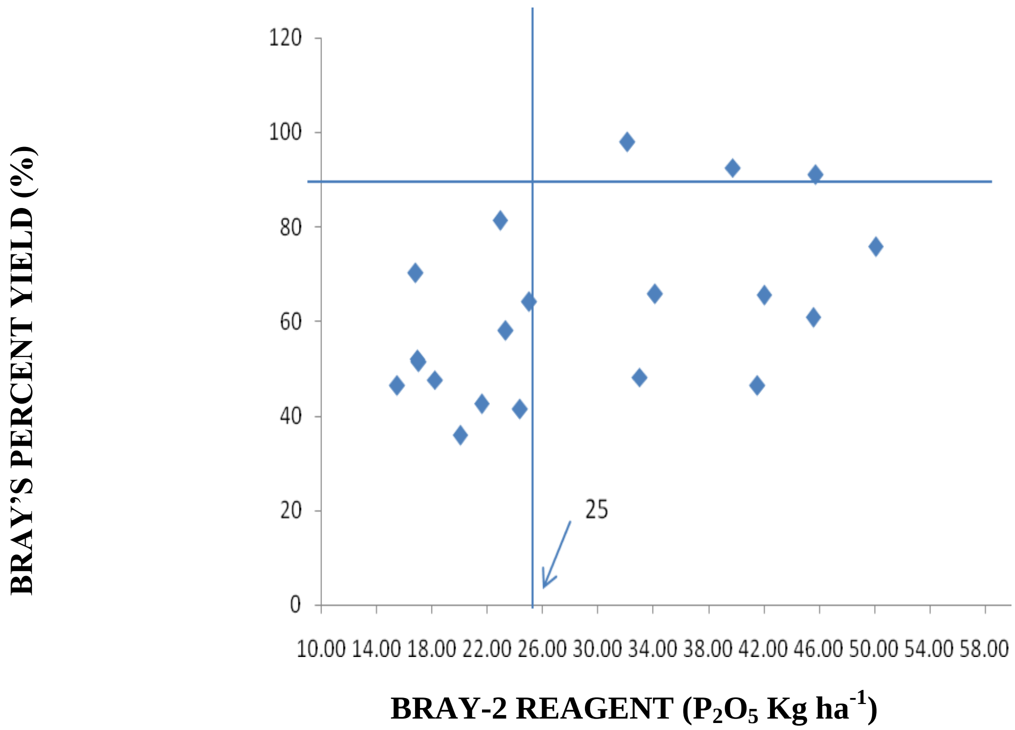


Fig.3 Relationship between Mehlich 3 and Bray's percent yield

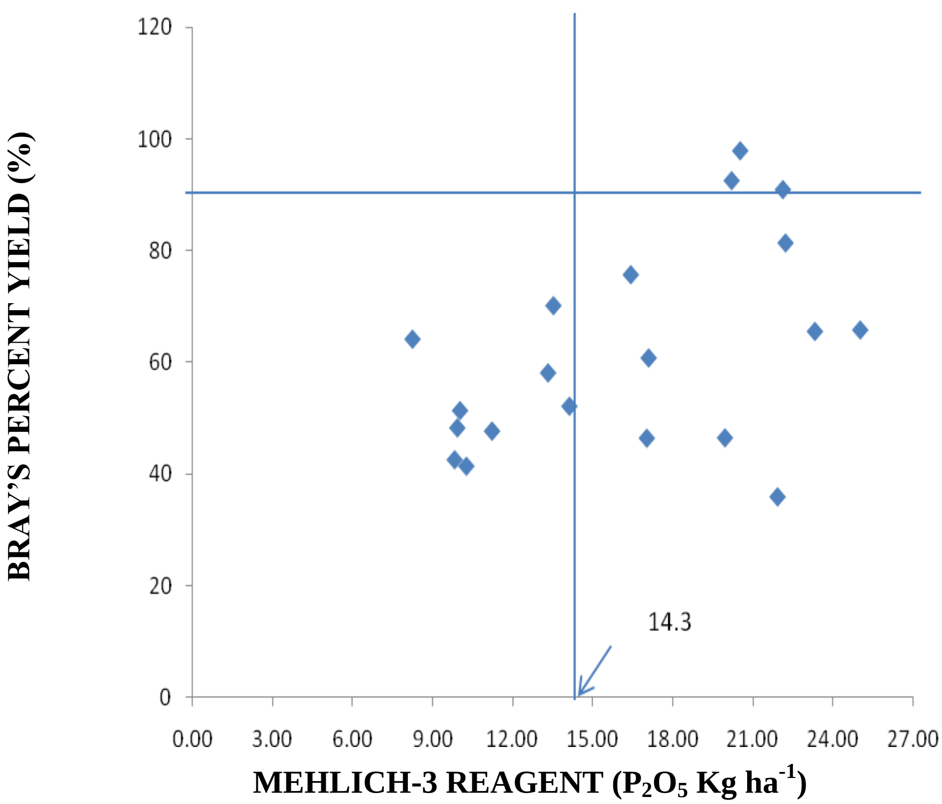


Fig.4 Relationship between Troug and Bray's percent yield

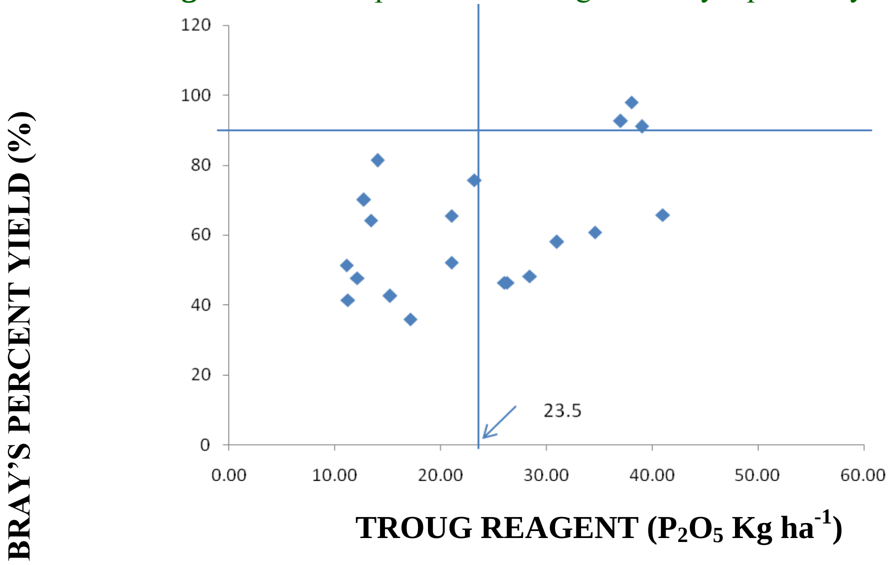
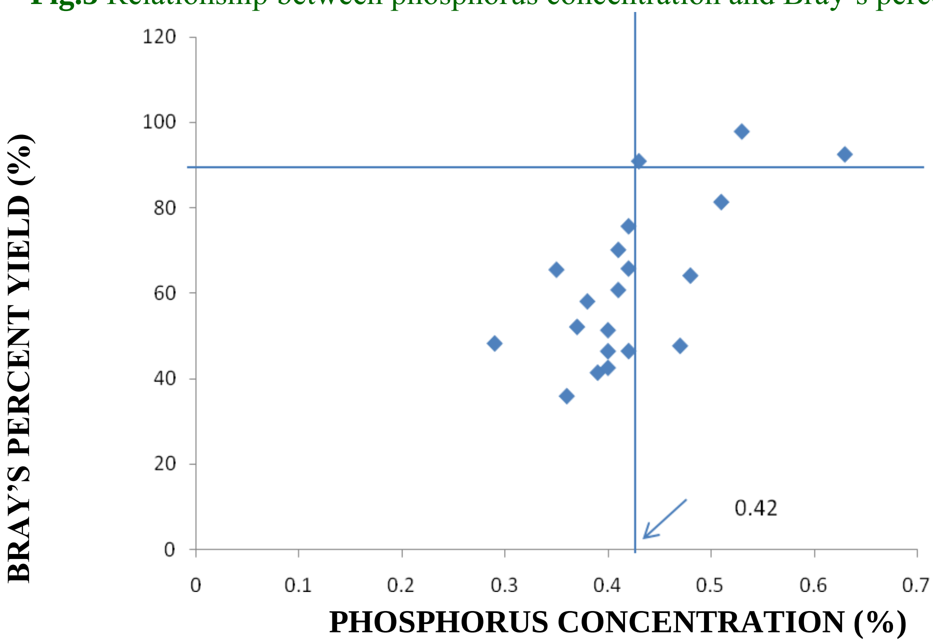


Fig.5 Relationship between phosphorus concentration and Bray's percent yield



Plant

The result revealed that the critical level of the phosphorus concentration in the pea was found 0.42 per cent (Fig. 5) according to graphical procedure of Cate and Nelson (1965) using a scatter diagram (Fig. 2), partitioning the two dimensional percentage yield versus phosphorus content in the 40 days old pea plants (control) scattered into two groups (Fig. 3 and 4).

From the above findings, it can be concluded that the method employed for extraction of soil Phosphorous was negatively and significantly correlated with pH, except

Olsen. Troug was positively and significantly correlated with silt and clay. Among the various extractants used for phosphorus extraction, Bray 2 extracted highest amount of phosphorus from soils. However, Bray 1 extractant found highest and significantly correlated with Bray's per cent yield and uptake. Accordingly, Bray 1 reagent can be used as estimating phosphorus contents of the soils for pea growing. All the studied soils below 16.70 kg P_2O_5 ha^{-1} may respond to phosphorus application. The critical level of the soils varies from different extractants used for estimation of phosphorus.

From the pot culture studies, it was observed that for estimating the critical plant tissue concentration of phosphorus in pea, a value of 0.42 per cent was the critical level. A value of 0.42 per cent plant tissue phosphorus concentration could distinguish the phosphorus deficient plants. Thus, the present study lays emphasis on phosphorus fertilization of pea plant on the basis of critical values in soil and plant. Therefore, the farmers growing pea crops should fertilized based on the critical limit of both soil and plant.

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