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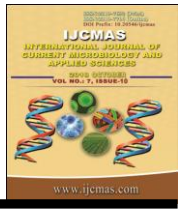

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Critical Limits of Phosphorus in Relation to the Growth and Dry Matter Yield of French Bean (*Phaseolus vulgaris* L.) in Acid Soils of Thoubal District, Manipur (India)

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A B S T R A C T

In a pot culture experiment, the response of French bean (*Phaseolus vulgaris* L.), cv. Contender to phosphorus (P) was studied on 20 acidic paddy soils of Thoubal district, Manipur. All the collected soil samples were acidic in reaction varied from 4.61 to 6.26 with mean value of 5.48, organic carbon content 9.9 to 24.1 g kg^{-1}, CEC 9.21 to 35.71 [cmol $(p^{+})kg^{-1}$] and clay content ranged from 24.78 to 73.38 per cent. Addition of P fertilizer in the soils significantly increased the dry matter production and P uptake by the crop. The critical limit of the soils varied from 10.0 to 23.6 kg P_2O_5 ha^{-1} depending upon the method of P extraction. Bray P_1 method showed the highest degree of correlation than other extractant used with dry matter yield (r=0.702**), P content (r=0.578*), P uptake (r=0.688**), Bray's per cent yield (r=0.679**) and Bray's per cent uptake (r=0.629**). Thus, the critical levels of P in soils and 40 days old French bean plants below which response to P fertilization may be expected are 21.2 kg P_2O_5 ha^{-1} and 0.29 per cent P, respectively.

Introduction

Phosphorus has been called the key to life because it is directly involved in most life process. It is component of every living cell and tends to be concentrated in seeds and in the growing point of plants. Phosphorus is the backbone of fertilization in Indian agriculture.

At present, 5 per cent of Indian soil have adequate available phosphorus, 49.3 per cent are under low category, 48.8 per cent medium and 1.9 per cent high category (Sureshkumar, 1999). Information of phosphorus fertility status of soils is of great importance to determine the level of phosphorus fertilizers to be applied to the crops.

Plants appear to face severe problems in getting phosphorus at early stage in their development. So, phosphorus deficiency symptoms most often occur in seedlings and young plants. Phosphorus is mobile within the plants and its translocation is from the older tissue to the growing points. This causes the deficiency symptoms appeared on the lower

leaves. Deficiency of phosphorus causes stunted growth, dark green colour associated with purplish colour in the seedling stage. Inadequate supply of phosphate generally cause delay in crop maturity and seed formation.

Of all the beans, French bean is most extensively grown as green vegetable. In India, nearly 6000 hectares annually produce 12, 50,000 tonnes of bean. Dry and green beans rank high as a cheap source of nourishing food. They are a valuable source of protein, calcium, iron and vitamins (Choudhury, 2006). In recent years, the cultivation of French bean (*Phaseolus vulgaris* L.), cv. Contender has picked up in Manipur.

Among several agro-techniques, adequate and balanced nutrition plays an important role increasing yield. Correlating nutrients content and their ratio in plant parts during crop growth with yield and yield attributes is prerequisite to find out critical nutrients for optimum yield and quality of crop. Nutrient deficiency of plant can be replenished well in advance before heavy yield losses. However, there is no such work in Manipur and hence, the present investigation was designed to study the response of French bean to phosphorus fertilization in acidic soils and evaluate the critical limits of phosphorus in soils and plant.

Materials and Methods

Twenty surface soil samples (0-15 cm) were collected from different locations of the cultivated fields of Thoubal District, Manipur. The air-dried soil samples were ground in wooden mortar and pestle and passed through 2 mm sieve. The mechanical analysis of the soils is determined by hydrometer method (Bouyoucos, 1951). These samples were analyzed for pH, EC, P_2O_5, and K_2O using standard procedures as described by Jackson (1973), available N (Subbiah and Asija, 1956) and CEC as described by Borah *et al.*, (1987), exchangeable Ca and Mg (Chopra and Kanwar, 1976). Organic carbon was determined by wet oxidation method of Walkley and Black (1934). Available P was determined using Bray P_1 and Bray P_2 (Bray and Kurtz, 1945), Olsen P (Olsen *et al.*, 1954), Truog P (Truog, 1930), Morgan P (Morgan, 1937) and Mehlich P_1 (Mehlich, 1937).

Three kg of soil were filled in pots and phosphorus were applied 0, 60, 80 kg P_2O_5 ha^{-1} through single super phosphate. The treatments were replicated thrice in completely randomized design. A basal dose of N and K_2O @ 50: 60 N: K_2O ha^{-1} in the form of urea and muriate of potash in each pot. French bean cv. Contender were sown and thinned to three plants in each pot after 7 days. The moisture level was maintained at field capacity level in all the pots by irrigating with distilled water as and when required. The crop was harvested 40 days of growing. The plant samples were washed to remove dirt and then oven dried at 65^0C for 48 hours and the dry matter yield was recorded. The samples were ground and powdered samples were analyzed for nitrogen by macrokjeldahl method, phosphorus by tri-acid mixture (HNO_3:$HClO_4$:H_2SO_4) digestion and using vanadomolybdophosphoric acid yellow colour method by spectrophotometry and plant potassium by flame photometry method (Jackson, 1973). The critical limits of soil and plant were determined by technique of Cate and Nelson (1965). Bray's per cent yield and uptake of French bean was calculated as:

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

$$\text{Bray's per cent uptake} = \frac{\text{Uptake without fertilizer}}{\text{Maximum uptake in fertilizer treated pots}} \times 100$$

Results and Discussion

The initial physico-chemical properties of the soils of the Thoubal district of Manipur are presented in Table 1. The soil texture varied from sandy clay loam, clay loam, silty clay and clay in textural class.

All the soil samples are acidic i.e. soil pH varied from 4.61 to 6.26 with mean value of 5.48, EC ranged from 0.12 to 0.33 dSm^{-1} at 25^0C, CEC varied from 9.21 to 35.71 [cmol(p^+) kg^{-1}], Ca content ranged from 1.54 to 5.45 [cmol(p^+) kg^{-1}], and Mg content varied from 1.45 to 5.35 [cmol(p^+) kg^{-1}]. Organic carbon content of the soils are high, it ranged from 9.9 to 24.1 g kg^{-1} and total N content of the soils varied from 0.1 to 0.4 per cent with a mean value of 0.25 per cent.

The available N and K content of soils collected from various locations ranged from 246.21 to 408.38 kg ha^{-1} and 162.61 to 264.99 kg ha^{-1}, respectively.

Dry matter yield

The dry matter yield of French bean cv. Contender was affected with application of phosphatic fertilizer regardless of the initial soil properties. Dry matter yield of the control pot varied from 1.91 to 5.19 g/pot as compared with 3.59 to 5.40 g/pot in 60 kg P_2O_5 ha^{-1} and 3.37 to 5.31 g/pot in 80 kg P_2O_5 ha^{-1} (Table 2).

Application of 60 kg P_2O_5 ha^{-1} results in highest dry matter production significantly. The increased dry matter production due to phosphorus fertilization might be due increase plant height, number of branches, number of leaves and leave area of the plant. Similar observations were also reported by Abbas *et al.,* (1994a and 1994b), Patel and Chandravanshi (1996), Hussain, *et al.,* (2001) and Kakon *et al.,* (2016).

Nitrogen, phosphorus and potassium uptake

The nitrogen, phosphorus and potassium uptake by the plant was highest with the treatment of 60 kg P_2O_5 ha^{-1} (Table 4) which is significantly superior to the other treatments. The uptake of these nutrients by the plant is combined effect of higher nutrient concentration in the plant and higher dry matter production.

A luxuriant vegetative growth and higher dry matter accumulation with the phosphatic fertilization might increase the nutrients uptake by the plant. Similar results were also reported by Reddy *et al.,* (1990), Bhalu *et al.,* (1995) and Palb (2015).

Correlation

All the six P extractants used showed the positive and significant correlation with Bray's per cent yield of French bean cv. Contender with varying degree. Among the P extractant used, Bray P_1 showed higher degree of correlation with Bray's per cent yield (r= 0.679**), Bray's per cent uptake (r=0.629**), Dry matter yield (r=0.702**), P content (r=0.578*) and total P uptake (r=0.688**) compared to the other extractants used (Table 3). Therefore, Bray P_1 must be used as P extractant for growing French bean plant cv. Contender in acid soils of Manipur for profitable yield.

Critical limit of P in soil

The critical limit of phosphorus in soils for growing of French bean cv. Contender varied with method of phosphorus extraction. Base on the graphical procedure of Cate and Nelson (1965), the critical limit of soils varied from 10.0 to 23.6 kg P_2O_5 ha^{-1}. However, Bray P_1 showed the higher degree of correlation with the plant parameters than the other extractants (Fig. 2–7).

Table.1 Some physio – chemical properties of the soil

	pH	EC	OC	Total N	Av N	Av K	Ca	Mg	CEC		Texture	
Soil sample		(dS/m-1)	g kg^{-1}	%	($kgha^{-1}$)	($kgha^{-1}$)	[$cmol(p+)kg^{-1}$]	[$cmol(p+)kg^{-1}$]	[$cmol(p+)kg^{-1}$]	Sand%	Silt%	Clay%
1	5.21	0.13	14.3	0.19	246.21	215.88	2.13	1.99	11.10	45.93	19.27	34.80
2	4.77	0.17	11.1	0.35	305.18	221.63	2.63	2.49	12.48	31.67	24.96	43.37
3	5.17	0.24	17.1	0.20	389.08	193.24	2.35	2.22	14.94	39.87	25.30	34.83
4	5.94	0.18	19.6	0.27	342.60	227.63	2.62	2.24	31.34	26.22	29.37	44.42
5	5.47	0.20	20.2	0.38	352.98	206.34	3.56	3.47	30.25	16.06	24.08	59.86
6	5.01	0.15	15.1	0.16	333.16	184.59	2.35	2.24	16.32	43.85	28.56	27.59
7	4.61	0.12	10.0	0.10	250.85	238.65	1.54	1.45	9.21	63.11	12.12	24.78
8	5.47	0.13	09.9	0.28	272.98	203.68	1.88	1.87	18.76	21.72	23.26	55.02
9	5.60	0.17	18.5	0.27	285.41	197.49	3.46	3.44	26.28	19.43	20.18	60.38
10	5.95	0.24	12.4	0.36	305.59	214.50	1.82	1.74	18.44	10.54	18.97	70.49
11	5.41	0.22	20.2	0.12	267.20	227.21	4.30	4.23	20.35	33.93	12.71	53.35
12	5.51	0.21	19.5	0.29	382.23	221.21	4.96	4.76	23.39	16.65	29.18	54.17
13	5.29	0.14	13.4	0.20	372.14	200.26	2.04	1.90	17.48	7.31	19.31	73.38
14	5.84	0.16	17.2	0.35	366.39	209.05	4.71	4.54	22.51	24.67	34.79	41.14
15	6.26	0.33	24.1	0.40	408.38	264.99	5.45	5.35	35.71	4.45	22.49	73.07
16	5.79	0.25	22.1	0.25	365.56	163.85	5.07	4.97	14.45	7.02	21.07	71.90
17	6.09	0.14	11.7	0.25	308.82	236.45	2.24	2.14	13.26	24.15	14.85	61.00
18	5.11	0.16	21.4	0.27	353.58	248.97	4.14	4.08	26.61	7.29	48.14	44.57
19	5.33	0.15	21.7	0.31	309.15	176.15	2.47	2.49	13.82	34.56	30.61	34.84
20	5.82	0.29	09.9	0.15	297.80	162.61	5.06	4.94	9.87	11.93	27.65	60.42
Mean	5.48	0.19	16.5	0.25	325.76	210.75	3.24	3.14	19.33	24.49	24.34	51.17

Table.2 Effect of phosphorus application on dry matter yield, phosphorus concentration and its uptake by French bean

Soil sample	Bray 's extractable P(ppm)	Dry matter yield (g/pot) P_2O_5 level (kg ha^{-1})			Mean	Bray's % P Yield	P concentration in plants of no P Pots (%)	P uptake by uptake (mg/pot) P_2O_5 level(kg ha^{-1})			Mean	Bray's % P Uptake
		0	60	80				0	60	80		
1	7.61	2.33	4.46	4.44	3.75	52.34	0.23	5.26	10.17	10.05	8.49	51.77
2	19.55	3.89	5.12	4.93	4.65	75.93	0.28	10.71	14.25	13.36	12.77	75.14
3	22.60	4.85	5.22	4.87	4.98	92.98	0.32	15.32	17.09	14.93	15.78	89.63
4	20.14	2.01	4.14	4.09	3.41	48.57	0.33	6.63	14.75	12.62	11.34	44.97
5	16.14	3.28	3.59	3.58	3.49	91.38	0.38	12.50	13.71	13.02	13.07	91.18
6	19.83	3.49	3.82	3.62	3.64	91.23	0.23	8.03	8.97	8.34	8.44	89.51
7	4.53	1.91	4.28	5.27	3.82	44.70	0.18	3.48	7.89	10.19	7.19	44.11
8	16.59	4.14	4.75	4.57	4.48	87.23	0.26	10.87	11.71	10.70	11.09	92.77
9	20.38	3.36	4.77	4.52	4.22	70.35	0.26	8.60	11.77	11.95	10.78	73.07
10	21.64	3.70	4.13	4.89	4.24	89.66	0.30	11.24	12.55	13.82	12.54	89.57
11	20.89	3.05	4.38	4.34	3.92	69.53	0.20	6.14	8.87	8.09	7.70	69.21
12	15.94	4.11	5.23	5.17	4.84	78.73	0.40	16.54	21.23	20.73	19.50	77.87
13	16.64	2.46	3.71	3.37	3.18	66.27	0.24	5.80	8.84	8.46	7.70	65.58
14	21.37	3.06	4.41	4.04	3.84	69.39	0.35	10.56	15.79	13.84	13.40	66.89
15	31.12	5.19	5.40	5.31	5.30	96.21	0.45	23.21	26.05	23.39	24.21	89.09
16	27.49	4.09	4.34	4.14	4.19	94.36	0.35	14.34	15.23	13.99	14.52	94.15
17	12.95	1.98	4.32	4.29	3.53	45.78	0.20	3.96	8.82	7.99	6.92	44.91
18	19.70	3.87	5.30	4.26	4.48	72.93	0.29	11.32	15.74	11.09	12.72	71.96
19	20.85	3.37	5.04	5.00	4.47	66.86	0.23	7.78	10.95	10.23	9.65	71.10
20	17.77	3.34	4.80	4.50	4.21	69.49	0.19	6.50	9.01	8.96	8.15	72.18
Mean		3.37	4.56	4.46	4.13	73.70	0.28	9.94	13.17	12.29	11.80	73.23
CD at 5% for P level mean=0.0433 CD at 5% for soil mean = 0.1118 CD at 5% for P × Soil mean = 0.1936												

Table.3 Simple correlation coefficient between different extractants and yield parameters of French bean

Extractant	Dry Matter yield (control)	P content (control)	Total P uptake (control)	Bray's% yield	Bray's % uptake
Bray P1	0.702**	0.578*	0.688**	0.679**	0.629**
Bray P2	0.524*	0.486*	0.553*	0.461*	0.416
Olsen-P	0.450*	0.431	0.510*	0.443*	0.405
Mehlich-P	0.479*	0.499*	0.512*	0.526*	0.480*
Truog-P	0.441	0.406	0.513*	0.410*	0.362
Morgan-P	0.428	0.445	0.452*	0.528*	0.486*

Table.4 Effect of Phosphorus application on nitrogen, phosphorus and potassium uptake by French bean

Soil sample	Bray's extractant	N concentration in plants (%) P_2O_5 levels (kg ha^{-1})				P concentration in plants (%) P_2O_5 levels (kg ha^{-1})				K concentration in plants (%) P_2O_5 levels (kg ha^{-1})			
		0	60	80	Mean	0	60	80	Mean	0	60	80	Mean
1	7.61	3.35	3.24	3.26	3.29	0.23	0.23	0.23	0.68	2.14	2.15	2.11	2.13
2	19.55	3.26	3.15	3.11	3.17	0.28	0.28	0.27	0.82	2.17	2.15	2.20	2.17
3	22.60	3.45	3.54	3.54	3.51	0.32	0.33	0.31	0.95	2.00	2.10	2.16	2.09
4	20.14	3.53	3.79	3.81	3.71	0.33	0.36	0.31	1.00	1.80	1.85	2.02	1.89
5	16.14	3.70	3.77	3.75	3.74	0.38	0.38	0.36	1.13	2.01	2.18	2.14	2.11
6	19.83	3.65	3.82	3.80	3.76	0.23	0.23	0.23	0.69	1.76	1.87	1.85	1.83
7	4.53	3.06	3.31	3.33	3.23	0.18	0.18	0.19	0.56	1.74	1.73	1.86	1.78
8	16.59	3.14	3.27	3.17	3.19	0.26	0.25	0.23	0.74	1.94	2.04	2.10	2.03
9	20.38	3.37	3.38	3.38	3.37	0.26	0.25	0.26	0.77	1.60	1.68	1.73	1.67
10	21.64	3.59	3.71	3.69	3.66	0.30	0.30	0.28	0.89	1.82	1.89	1.97	1.89
11	20.89	3.14	3.28	3.29	3.24	0.20	0.20	0.19	0.59	1.76	1.88	1.90	1.85
12	15.94	3.56	3.45	3.43	3.48	0.40	0.41	0.40	1.21	1.87	1.85	1.62	1.78
13	16.64	3.25	3.19	3.24	3.23	0.24	0.24	0.25	0.73	1.84	1.78	1.72	1.78
14	21.37	3.72	3.86	3.69	3.76	0.35	0.36	0.34	1.05	1.79	1.73	1.87	1.80
15	31.12	3.21	3.80	3.75	3.59	0.45	0.48	0.44	1.37	1.74	1.64	1.80	1.73
16	27.49	3.27	3.51	3.39	3.39	0.35	0.35	0.34	1.04	1.90	1.96	2.00	1.95
17	12.95	3.16	3.30	3.25	3.24	0.20	0.20	0.19	0.59	2.03	2.00	2.15	2.06
18	19.70	3.08	3.32	3.30	3.23	0.29	0.30	0.26	0.85	1.76	1.90	2.01	1.89
19	20.85	3.06	3.52	3.17	3.25	0.23	0.22	0.20	0.65	1.93	1.94	1.99	1.95
20	17.77	3.38	3.31	3.37	3.35	0.19	0.19	0.20	0.58	1.89	1.98	1.98	1.95
Mean		3.35	3.48	3.44		0.29	0.29	0.27		1.88	1.92	1.96	
CD at 5 % for N level mean =0.033 CD at 5 % for soil mean =0.087 CD at 5 % for N× Soil =0.151						CD at 5 % for P level mean =0.002 CD at 5 % for soil mean =0.007 CD at 5 % for P× Soil =0.013				CD at 5 % for K level mean =0.018 CD at 5 % for soil mean =0.048 CD at 5 % for K× Soil =0.084			

Fig.1 Relationship between the soil phosphorus and relatively yield of French bean

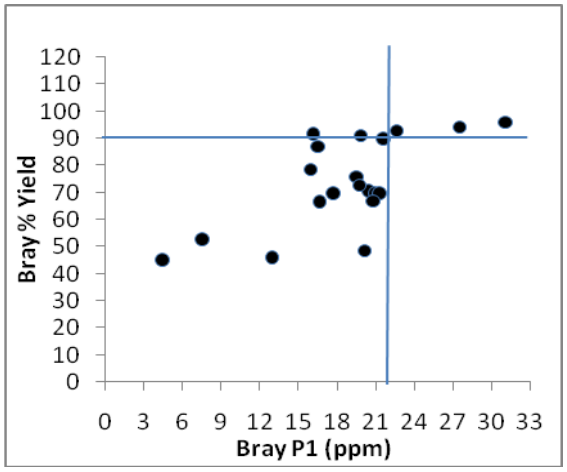


Fig.2 Relationship between the soil phosphorus and relatively yield of French bean

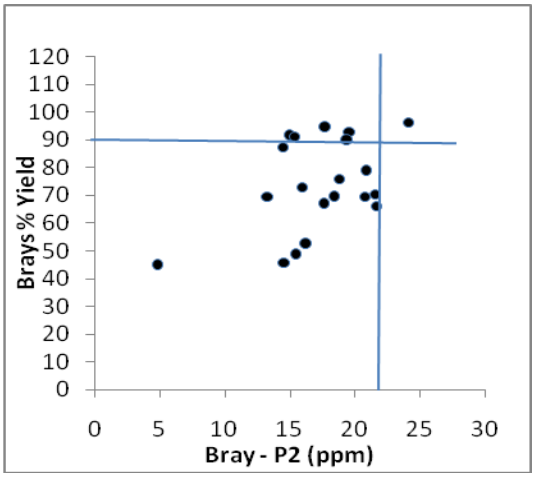


Fig.3 Relationship between the soil phosphorus and relatively yield of French bean

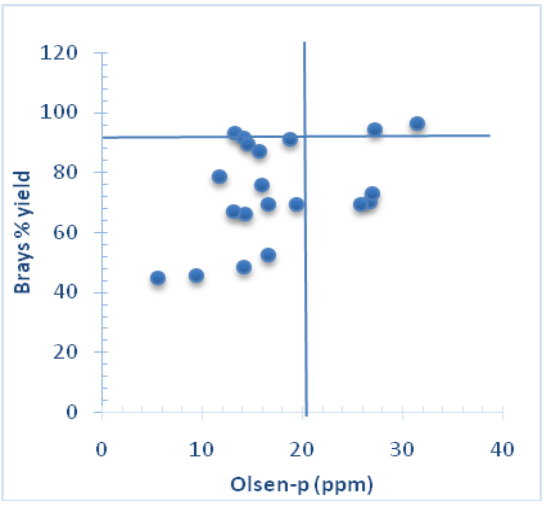


Fig.4 Relationship between the soil phosphorus and relatively yield of French bean

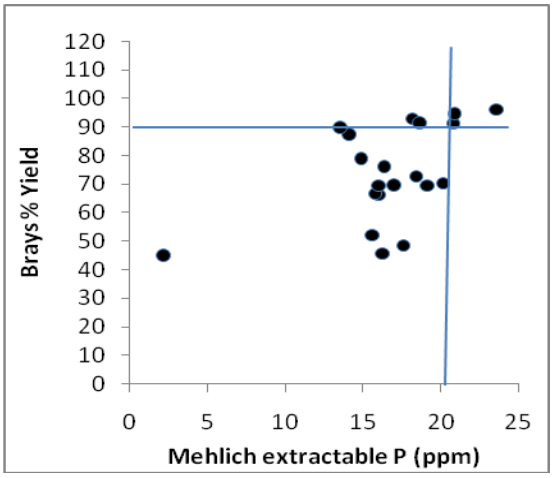


Fig.5 Relationship between the soil phosphorus and relatively yield of French bean

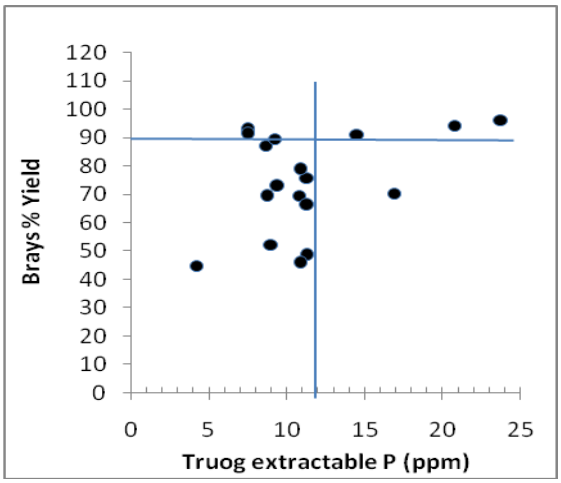


Fig.6 Relationship between the soil phosphorus and relatively yield of French bean

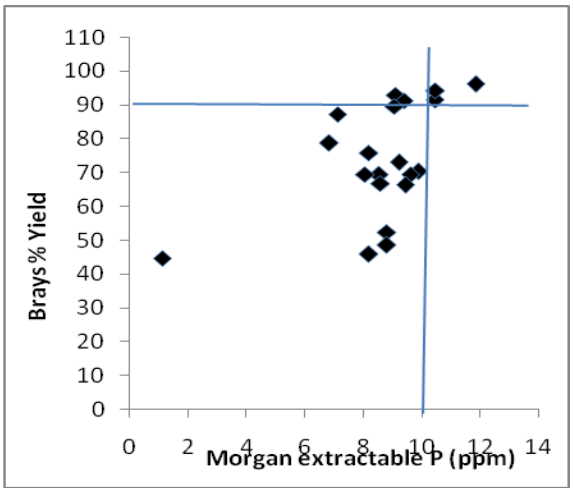
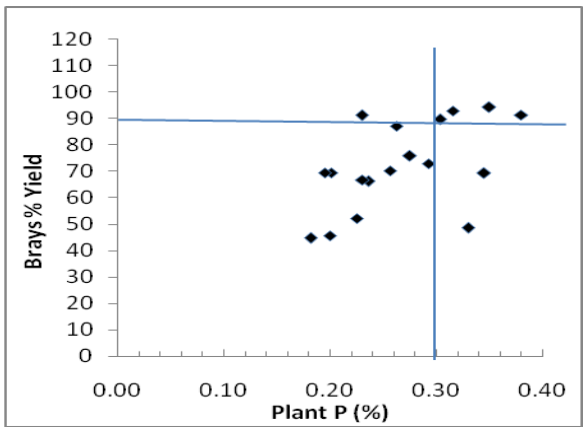


Fig.7 Relationship between the plant P concentration and relatively yield of French bean



Thus, 21.2 kg P_2O_5 ha^{-1} (Fig. 1) is the critical limit of available phosphorus in these soils for demarcating the phosphorus responsive soil from the unresponsive soil ones. A soil was to be considered as nonresponsive to phosphorus application where Bray's per cent dry matter was more than 90. All the soil testing below 21.2 kg P_2O_5 ha^{-1} by this method may be responded to phosphorus application for French bean growing.

Critical limit of P in plant

The critical limit of phosphorus concentration in French bean plant was also estimated using Cate and Nelson (1965) technique. A value of 0.29 per cent could distinguish the phosphorus deficient plants from those of sufficient ones (Fig. 7), partitioning the two dimensional percentage yield versus phosphorus content in 40 days old French bean cv. Contender plant scattered into two group. Thus, the present study lays emphasis on phosphorus fertilization on French bean on the basis of critical values in the soils and plant.

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