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EVALUATION OF SOIL PHOSPHORUS EXTRACTANT FOR GARDEN PEA CULTIVATION IN BISHNUPUR DISTRICT, MANIPUR, INDIA

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ABSTRACT

A pot experiment was carried out at College of Agriculture, Central Agricultural University, Imphal, Manipur during *Rabi* season, 2022-23 to assess the suitable soil phosphorus extractant for garden pea (var. Arkel) cultivation in acidic soil of Bishnupur District, Manipur, India. The study was laid out in a Completely Randomized Design (CRD) with three levels of phosphorus treatments (0, 60 and 80 kg P₂O₅ ha⁻¹) through Single Super phosphate (SSP), replicated thrice. Six chemical extractants were used viz., Bray 1, Bray 2, Mehlich 1, Mehlich 3, Troug and Olsen to assess the available phosphorus status of the collected soils. Simple correlation studies between the extractable phosphorus of the soils by different extractants and Bray's per cent yield of pea showed the highest degree of correlation in descending order of suitability: Bray 1 (r = 0.693**) > Bray 2 (r = 0.660**) > Mehlich 3 (r = 0.531**) > Troug (r = 0.325), Olsen (r = 0.039) and Mehlich 1 (r = 0.024). Results also indicated that among the extractants, Bray 1 reagent showed a significant and positive correlations with dry matter yield, phosphorus content, phosphorus uptake and Bray's per cent uptake. Therefore, extractant Bray 1 serves as a reliable index for available phosphorus in pea for acidic soil condition of Bishnupur District, Manipur. Overall, this research provides useful information about the assessment of suitable extractant for available phosphorus for pea cultivation in acidic soils and highlights the need for appropriate soil management practices to enhance phosphorus availability and improve soil fertility.

Key words: Phosphorus, extractants, Brays percent yield, correlation, acidic soil.

Introduction

Phosphorus (P) is second only to nitrogen in frequency of use as a fertilizer element. The role of phosphorus need not to be over emphasized. Though phosphorus occurs in most plants in concentrations between 0.1 and 0.4 % (Tisdale *et al.*, 1985), a range quite lower than that found for nitrogen and potassium, its importance in seed formation, cell division, strengthening straw, quality improvement and resistance is not less than that of nitrogen and potassium. Besides, its role in energy storage and its transfer is very vital in plant life. Its compound may be considered as energy currency. The most important ones are adenosine di- and

tri- phosphate (ADP and ATP). Likewise, plants rely on P to secure energy production in photosynthesis (Smil, 2000; Ruttenberg, 2009). Phosphorus deficiency is considered to be one of the major limitations for crop production, particularly in the low- input agricultural systems. In many acidic soils, 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 be vital in crop growth and development, with a direct relationship to root proliferation, straw strength, grain output, and crop maturation (Bhat *et al.*, 2013).

Table 1: Location of soil samples collected.

Sample No.	Location Name	Latitude	Longitude
1.	Oinam	24.696305°	93.805631°
2.	Ningthoukhong	24.578446°	93.758530°
3.	Khoijuman	24.59803°	93.769925°
4.	Kwaksiphai	24.612869°	93.770115°
5.	Toubul	24.62673°	93.775632°
6.	Upokpi	24.585241°	93.765528°
7.	YanglemLeikai	24.626711°	93.775612°
8.	Bishnupur	24.630462°	93.759837°
9.	Keinou	24.600036°	93.771533°
10.	Leimaram	24.700530°	93.808241°
12.	Kumbi	24.441317°	93.797896°
13.	Naranshena	24.513122°	93.758588°
14.	Phubala	24.538295°	93.7568849°
15.	Tronglaobi	24.472191°	93.748366°
16.	Kongkham	24.700409°	93.836024°
17.	Kha-Potshangbam	24.597729°	93.769690°
18.	Nachou	24.597467°	93.775329°
19.	Khathong	24.706827°	93.850057°
20.	Nambollaitonjam	24.71943°	93.844688°

Determination of soil phosphorus and its availability to plants are essential for developing principles and deeper understanding of the behavior and nature of soil phosphorus. Different procedures for soil testing are being used to determine the soil phosphorus status and assist in making fertilizer recommendations. The relationship between soil test methods and plant parameters helps in selecting a suitable soil test method for a particular group of soils. A large proportion of soil resource found in acidic soils are deficient in phosphorus. The occurrence of high levels of aluminium (Al) and iron (Fe) in acidic soil usually give rise to low pH and release of phosphorus. Wherever Fe and Al imbalances exist, a corresponding P stress occurs (Fageria *et al.*, 1991). There are several soil characteristics which may affect the phosphate

availability to plants as well as the phosphate extraction by different chemicals. Haney *et al.*, (2006) reported that there is great variation in soil therefore developing a single method of extraction may be an expensive and time consuming, hence identifying an extractant that has more accuracy with respect to plant available nutrient is required.

Research indicates that pea crop requires relatively high phosphorus nutrition (Slinkard and Drew, 1988). The significance of this research lies in its potential to improve agricultural practices in acid soil, particularly in optimizing phosphorus fertilization for pea crop. By determining the suitable extractant of soil available phosphorus, this study will contribute to sustainable crop management practices that can enhance yield while minimizing environmental impacts. Furthermore, the findings may serve as a basis for future research in nutrient management and soil fertility. Therefore, this study was planned to evaluate the most suitable extractant of soil available phosphorus for pea crop grown in acid soil.

Materials and Methods

Twenty bulk soil samples (15 cm depth) were collected from crop cultivated fields of Bishnupur District, Manipur, India with proper geo referenced using simple random sampling method (Table 1). The samples collected were thoroughly air dried in shade, ground in wooden mortar and pestle and passed through 2 mm sieve and subjected to routine physico-chemical analysis. Four (4) kgs of the soil samples were filled in each pot separately with due labelling and phosphorus was applied at three levels i.e., 0, 60 and 80 kg P₂O₅ ha⁻¹. The experiment was laid out in Completely Randomized Design (CRD) replicated thrice. The recommended dose of nutrients N:K @ 20:40 kg ha⁻¹ were applied as basal through Urea and Muriate of Potash fertilizer to each pot. Garden pea seed (var. Arkel) was sown and thinning was done. The crop

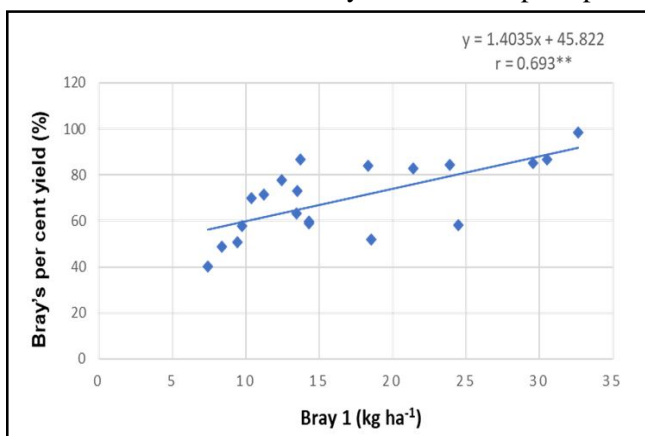
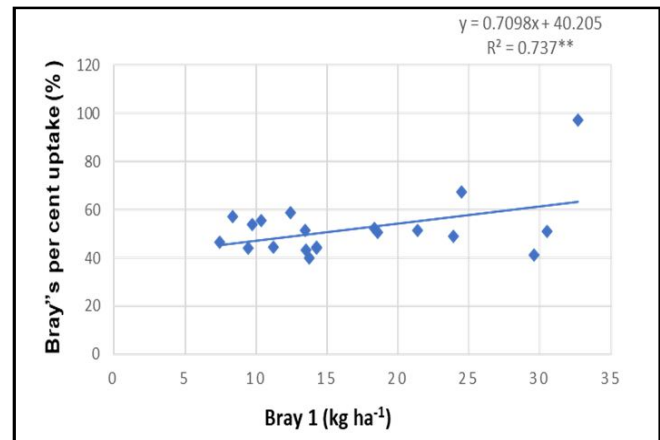
**Fig. 1:** Relationship between Bray 1(kg ha¹) and Bray's percent yield (%).**Fig. 2:** Relationship between Bray 1(kg ha¹) and Bray's percent uptake (%).

Table 2: Various extractants used for determining soil available/ extractable phosphorus.

Sl. No.	Extractants	Soil: Extractant	Shaking time	Reference
1.	Mehlich 1 (0.0125 N H ₂ SO ₄ + 0.05 M HCl)	1:4	5 mins.	Nelson <i>et al.</i> , (1953)
2.	Mehlich 3 (0.2 M CH ₃ COOH + 0.25 M NH ₄ NO ₃ + 0.015 M NH ₄ F + 0.013 M HNO ₃ + 0.001 M EDTA)	1:10	15 mins.	Mehlich (1984)
3.	Olsen (0.5 M NaHCO ₃ , pH-8.5)	1:20	30 mins.	Olsen <i>et al.</i> , (1954)
4.	Troug (0.002 N H ₂ SO ₄ , pH-3)	1:200	30 mins.	Troug (1930)
5.	Bray and Kurtz No. 1 (0.03 N NH ₄ F + 0.025 N HCl)	1:7	1 min.	Bray and Kurtz (1945)
6.	Bray No. 2 (0.1 N HCl + 0.03 N NH ₄ F)	1:7	1 min.	Bray and Kurtz (1945)

was harvested 40 days after sowing. Plants were collected and dried in oven at 65°C for 48 hours and the dry matter yield was recorded. The dried plant samples were finely ground and powdered. Nitrogen content was determined using macro-Kjeldahl method, phosphorus content was estimated after digestion with tri-acid mixture (HNO₃:HClO₄:H₂SO₄) using the vanadomolybdophosphoric acid yellow colour method by spectrophotometry and potassium content was measured by flame photometry method (Jackson, 1973). The respective per cent content of different nutrients was multiplied by the corresponding dry matter yield to estimate the nutrient uptake. Bray's per cent yield and uptake of pea crop was calculated using the formulae's:

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

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

Six chemical extractants were used viz., Bray 1, Bray 2, Mehlich 1, Mehlich 3, Troug and Olsen to assessed the available phosphorus status of the collected soils (Table 2). Mean values of data obtained from the experiment were subjected to statistical analysis to test the significance of co-efficient of correlation and the co-efficient of regression for proper interpretation.

Results and Discussion

Soil physico-chemical properties

Table 3: Physico-chemical properties of crop cultivated filed soils of Bishnupur District, Manipur.

Sample No.	pH	E.C. (dSm ⁻¹)	Organic Carbon (g kg ⁻¹)	Av.N (Kg ha ⁻¹)	Av.K (Kg ha ⁻¹)	Bulk Density (g cm ⁻³)	CEC [cmol (p ⁺) Kg ⁻¹]	Sand (%)	Silt (%)	Clay (%)	Textural Class
1	5.37	0.18	14.45	209.06	208.25	1.24	16.25	5.95	42.75	51.30	Silty clay
2	6.10	0.23	17.79	313.60	166.28	1.13	18.25	18.20	20.50	61.30	Clay
3	6.28	0.30	20.36	271.79	134.81	1.21	16.45	10.20	25.95	63.85	Clay
4	5.57	0.28	25.38	229.97	260.10	1.21	11.20	27.95	33.50	38.55	Clay loam
5	6.04	0.28	10.86	334.51	131.79	1.24	19.90	6.30	17.40	76.30	Clay
6	6.04	0.17	18.45	209.07	273.69	1.21	17.90	19.85	29.45	50.70	Clay
7	5.53	0.13	23.76	271.79	244.72	1.20	13.25	10.65	41.50	47.85	Silty clay
8	5.10	0.27	26.26	334.51	299.97	1.25	18.95	15.25	27.85	56.90	Clay
9	4.96	0.26	13.87	229.97	308.52	1.22	16.75	9.35	15.30	75.35	Clay
10	5.59	0.16	19.33	209.07	194.58	1.14	18.40	7.50	8.90	83.60	Clay
11	5.99	0.11	22.98	209.07	316.96	1.24	16.75	11.75	35.80	52.45	Clay
12	4.96	0.30	11.97	104.53	204.59	1.23	18.55	6.15	35.95	57.90	Clay
13	6.12	0.29	15.15	229.97	162.66	1.26	11.50	41.85	22.65	35.50	Clay loam
14	4.89	0.28	16.90	334.51	172.33	1.24	14.70	14.05	10.10	75.85	Clay
15	5.82	0.24	23.56	355.41	195.40	1.14	15.55	18.45	25.85	55.70	Clay
16	5.42	0.18	21.11	209.07	266.60	1.20	19.15	17.60	34.70	47.70	Clay
17	4.99	0.21	20.27	334.51	189.39	1.21	10.35	35.75	26.40	37.85	Clay loam
18	6.75	0.27	14.25	209.07	185.10	1.21	17.85	8.15	30.10	61.75	Clay
19	5.01	0.23	16.29	209.07	165.61	1.19	19.85	21.60	10.50	67.90	Clay
20	5.05	0.16	26.85	355.41	211.05	1.25	19.90	6.90	19.25	73.85	Clay
Mean	5.58	0.23	18.99	258.20	214.62	1.21	16.57	15.67	25.72	58.61	-
SD (±)	0.54	0.06	4.79	68.26	56.49	0.04	2.97	9.99	10.10	13.85	-
CV	0.10	0.26	0.25	0.26	0.26	0.03	0.18	0.64	0.39	0.24	-

Table 4: Simple correlation co-efficient among the extractants of soil phosphorus.

Extractants	Bray 1	Bray 2	Mehlich 1	Mehlich 3	Troug	Olsen
Bray1	1	0.565**	0.176	0.358	0.182	0.289
Bray2	0.565**	1	0.390	0.329	0.064	-0.227
Mehlich1	0.176	0.390	1	0.086	0.013	-0.286
Mehlich3	0.358	0.329	0.086	1	0.544*	-0.012
Troug	0.182	0.064	0.013	0.544*	1	-0.121
Olsen	0.289	-0.227	-0.286	-0.012	-0.121	1

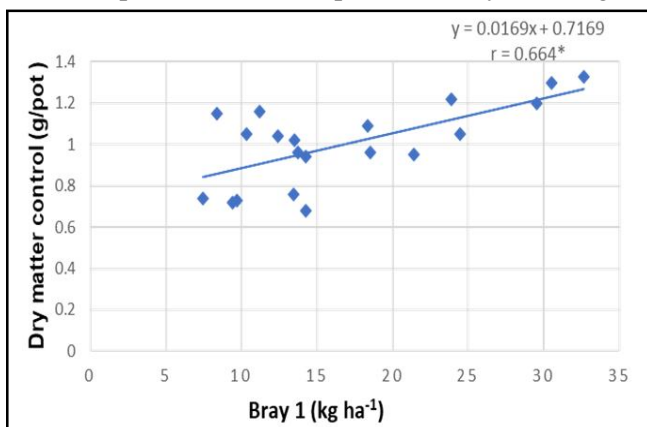
**Correlation is significant at the 0.01 level; *Correlation is significant at the 0.05 level

The data on physico-chemical properties of twenty soil samples of Bishnupur District, Manipur are shown in Table 3. Results indicated that the soils were dominant in clay followed by clay loam and silty clay in textural class. The bulk density of the soils was ranged between 1.13 g cm⁻³ and 1.26 g cm⁻³ with mean value of 1.21 g cm⁻³. The reduction in bulk density might be attributed due to the presence of high organic matter content in the soil (Brar *et al.*, 2015).

The investigated soil samples were acidic in nature with a mean pH value of 5.58. The average electrical conductivity of the soils was 0.23 dSm⁻¹ and CEC of 16.57 [cmol (p⁺) kg⁻¹]. The organic carbon content in the soils ranged from 10.86 g kg⁻¹ to 26.85 g kg⁻¹ with a mean of 18.99 g kg⁻¹. The wide variation of organic carbon content may be due to various locations, altitude of the region, previous soil management practices etc. The available nitrogen content of the soil collected from different locations ranged from 104.53 kg ha⁻¹ to 355.41 kg ha⁻¹ i.e., low to medium. The variation of available nitrogen content in the soil might be due to different amounts of organic carbon present in soils which release variable amount of inorganic nitrogen into the soil on mineralization. The average available potassium content of the soil was 214.62 kg ha⁻¹.

Extractable phosphorus

The soil samples collected from different locations of Bishnupur District, Manipur was analyzed using six

**Fig. 3:** Relationship between Bray 1 (kg ha⁻¹) and Dry matter yield control (g/pot).

extractants. The extractable phosphorus in the studied soils was found to be in the following decreasing order: Bray 2 > Troug > Mehlich 3 > Bray 1 > Mehlich 1 > Olsen (pH-8.5). The different behaviour of different extractants could be due to their selectivity in solubilizing specific fractions of phosphorus. The higher solubility in Bray 2 may be due to its relatively higher strength of acidity and complexing of Al³⁺ and Fe³⁺ ions with F⁻ ions and consequent release of P adsorbed by these trivalent ions (Ballard and Fiskell, 1974). Similar results were also reported by Patiram and Prasad (1990); Ravindra and Ananthanarayana (1999). Olsen extractant removed lesser P than Bray 2, Troug, Bray 1, Mehlich 1 and Mehlich 3 due to mild alkaline nature which displaces P from the surface of Ca, Al and Fe phosphate by decreasing Ca activity and repression of Al and Fe activities, respectively (Jackson, 1973). Similar results were also reported by Patiram *et al.* (1993). Watham *et al.*, (2014), Meitei *et al.*, (2015), Athokpam *et al.*, (2016) and Athokpam *et al.*, (2018) in similar situation of soil condition.

Correlation among the extractants

To ascertain whether the extractants used in this study could provide a comparable and consistent assessment of the extractable phosphorus, the values of soil extractable P using different soil testing methods and reagents were analyzed through correlation analysis. The

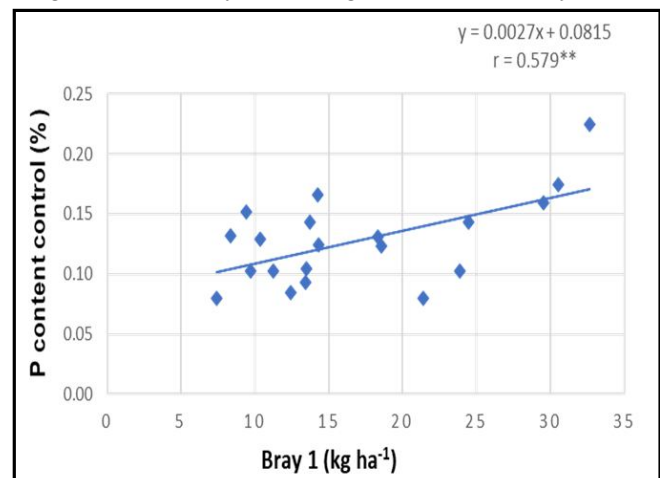
**Fig. 4:** Relationship between Bray 1 (kg ha⁻¹) and phosphorus content control (%).

Table 5: Simple correlation co-efficient of soil phosphorus with yield and uptake of Pea.

Sl. No.	Extractants	DM yield (control)	P content (control)	P uptake (control)	Bray's percent yield	Bray's percent uptake
1	Bray1	0.664**	0.579*	0.690**	0.693**	0.737**
2	Bray2	0.448*	0.447*	0.514*	0.660**	0.700**
3	Mehlich1	0.145	-0.136	0.414	0.024	0.339
4	Mehlich3	0.545*	0.471*	0.576**	0.531*	0.461*
5	Troug	0.509*	0.281	0.160	0.325	0.116
6	Olsen	0.270	0.308	0.030	0.039	-0.254

**Correlation is significant at the 0.01 level; *Correlation is significant at the 0.05 level

correlation analysis among the extractants (Table 4) observed a positive significant correlation between Bray 1 and Bray 2 ($r=0.565^{**}$, $p<0.01$), highlighting that these two extractants provide broadly comparable estimates of available phosphorus. Similarly strong and significant correlation was also recorded between extractants Mehlich-3 and Troug ($r = 0.544^*$, $p < 0.05$), suggesting that these methods extract overlapping pools of soil phosphorus. Moderate positive correlations were found among Bray 2 with Mehlich 1 extractant ($r = 0.390$) and Bray 1 with Mehlich 3 reagent ($r = 0.358$). A weak correlation was observed between extractant Mehlich 1 and Mehlich 3 ($r = 0.086$) supporting that extractants with similar chemical bases may vary substantially in extraction efficiency across soil types. In contrast, the Olsen extractant exhibited negative correlations with most other reagents including Bray 2 ($r = -0.227$), Mehlich 1 ($r = -0.286$), Mehlich 3 ($r = -0.012$) and Troug ($r = -0.121$) suggesting that Olsen reagent extracts a distinct phosphorus pool compared with the predominantly acidic extractants. Sims (2000) noted that the Olsen extractant has less ability to remove P from the soil than the acidic extractants. The Olsen extractant has alkalizing character being poor replacer of phosphorus in acidic soils, the HCO_3^- extractant extract only the free phosphorus, as a result they generally gave poor correlation with Mehlich

3, Bray 1 and Bray 2 which has ability to extract adsorbed, labile and free phosphorus as well be complexing of Al^{3+} and Fe^{3+} with phosphorus ions. This observation was corroborated by Ravindra and Ananthanarayana (1999).

Correlation of soil phosphorus with Bray's percent yield and uptake

Among the six extractants tested, Bray 1 extractable phosphorus reagent showed the highest degree of correlation with Bray's per cent yield of pea crop. The suitability of the extractants could be arranged in descending order as follows: Bray 1 ($r = 0.693^{**}$) > Bray 2 ($r = 0.660^{**}$) > Mehlich 3 ($r = 0.531^{**}$) whereas Troug, Olsen and Mehlich 1 extractable phosphorus were not significantly correlated. Bray's per cent uptake was also significantly correlated with Bray 1 ($r = 0.737^{**}$), Bray 2 ($r = 0.700^*$) and Mehlich 3 ($r = 0.461^*$). Simple correlation co-efficient study between different extractable phosphorus and dry matter yield (control) showed significant positive relationship with Bray 1 ($r=0.664^{**}$), Bray 2 ($r = 0.448^*$), Mehlich 3 ($r = 0.545^{**}$), Troug ($r = 0.509^*$) as shown in Table 5. The relation between the extractable phosphorus and phosphorus uptake in no phosphorus applied pot also indicated positive and significant relationship with Bray 1 ($r = 0.690^{**}$), Bray 2 ($r = 0.541^{**}$) and Mehlich 3 ($r=0.576^{**}$). The regression equations presented in Figures 1-5 showed that there were highly significant linear relationships ($p<0.01$) of extractable phosphorus (kg ha^{-1}) determined by Bray 1 reagent with Bray's percent yield, Bray's percent uptake, dry matter yield, phosphorus content and phosphorus uptake. From the investigation, it was revealed that Bray 1 extractable phosphorus was the most suitable extractant for estimating available soil phosphorus in the studied soils, as the degree of co-efficient of correlation between the quantities of phosphorus extracted by this extractant and crop parameters were found to be significant.

Conclusion

From the investigation, it was concluded that the soils collected from crop cultivated fields of Bishnupur District,

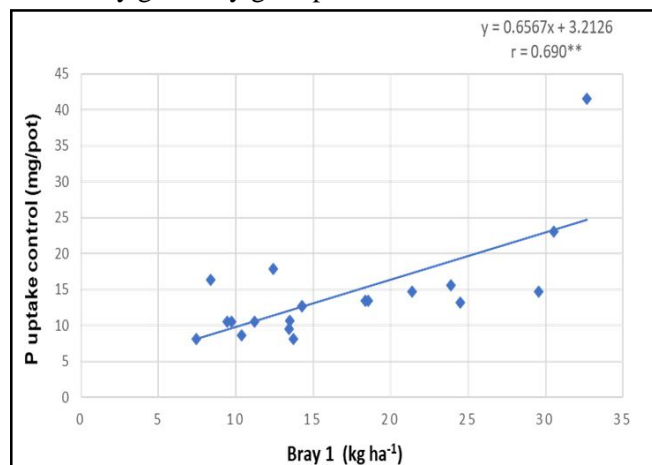


Fig. 5: Relationship between Bray 1 (kg ha^{-1}) and phosphorus uptake control (mg/pot).

Manipur were predominantly clayey, with moderate to low proportions of silt and sand. Bulk density values were relatively low, suggesting good soil structure and porosity and the soils were acidic in nature and non-saline. Organic carbon content showed considerable variation across locations but was generally moderate. Available nitrogen levels ranged from low to medium, while available potassium was mostly in the medium range. Among the six extractants evaluated, Bray 1 extractable phosphorus reagent showed the highest degree of correlation with Bray's per cent yield, Bray's percent uptake, dry matter yield, phosphorus content and phosphorus uptake. Therefore, Bray 1 extractant was found to be the most effective extractant, providing a reliable index for estimating available phosphorus in garden pea crop grown in acidic soils of Bishnupur District, Manipur. This study establishes a standardized diagnostic framework ensuring precise application of phosphorus in acidic soils to prevent both nutrient deficiency and environmental waste for sustainable crop production.

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