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Establishment of critical limit of phosphorus in Vertisolss under safflower-based cropping system

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Abstract

Critical limit of phosphorus in Vertisolss was determined to delineate P responsive from non-responsive sites based on the multilocation field experiments (1995-96 to 2002-2003) data of phosphorus management in safflower (*Carthamus tinctorius* L.) based cropping system. The critical values of phosphorus were determined by graphical, statistical and also few mathematical models [*viz.* quadratic (Q), square root (SR) and linear response plateau (LRP)]. Critical limit of phosphorus was in the range of 9±1 kg ha^{-1} for both rainfed and irrigated Vertisols conditions by graphical and statistical methods. Data fitted well to the mathematical models LRP and SR (R^2 0.87 and 0.79, respectively), and found equally efficient in delineating phosphorus responsive from non- responsive Vertisols sites by giving nearly the same critical range especially under rainfed conditions.

Additional key words : Critical limits, phosphorus, safflower, Vertisolss, mathematical models.

Introduction

Safflower-legume cropping sequence is recommended for the Vertisols regions of India for realizing higher production and profits besides improving soil fertility (Hegde 2002). Appropriate nutrient management is the key to enhance safflower productivity in such a cropping sequence on sustainable basis. Phosphorus is one of the critical and costly inputs to achieve higher oilseed yields. Wide variation was recorded for degree and magnitude of response of safflower for phosphorus nutrition (Abbas *et al.* 1995; Sharma 1997). Hence, it is imperative to identify under field conditions, a critical limit that delineates P responsive from non-responsive sites in Vertisolss.

Materials and methods

The data from multilocation field experiments on safflower-legume cropping sequence (16 rainfed and 16 irrigated) conducted under AICRP (1995-96 to 2002-03) in Vertisols of Maharashtra, Madhya Pradesh, Karnataka and Andhra Pradesh were used to determine the critical initial soil-P status in Vertisols. Safflower crop received recommended dose of phosphorus @ 40 kg ha^{-1} and 30 kg ha^{-1} as basal dose in the form of diammonium phosphate under rainfed and irrigated locations, respectively. Initial available P status, control and maximum safflower seed yield obtained among different P treatments over years and locations is presented in Table 1. The experimental details of the cropping sequence are available elsewhere (AICRP Safflower, Annual Reports 1995-96 to 2002-2003). Bray's per cent safflower seed yield and available initial phosphorus were considered to establish the critical P limit by graphical and statistical procedure (Cate and Nelson 1965, 1971). Three mathematical models, *viz.* quadratic [$Y=a+bX+cX^2$], square root [$Y=a+bX+cX^{1/2}$] and linear response plateau [$Y= MIN (a+bx, y_{max})$] were fit to the data and compared for delineating responsive from non- responsive sites.

Results and discussion

Initial available P status in rainfed and irrigated Vertisols (16 experiments each) ranged from 3.4 to 18.5 and 2 to 15 kg P ha-1 whereas Bray's per cent of safflower seed yield varied from 64.2 to 101.8 and 42.6 to 86.7 per cent, respectively (Table 1). Mean seed yields were lower in control and P treated plots under rainfed (1049 and 1301 kg ha^{-1}) and higher in irrigated (1352 and 1842 kg ha^{-1}) conditions. This may be attributed to better use efficiency of applied phosphorus due to favourable moisture availability, irrespective of the locations, seasonal variations and yield potential of the safflower varieties tried. Ved Singh *et al.* (1995) had reported similar findings. Safflower seed yield per kg of initial available P content was found to be higher at lower phosphorus status and *vice-versa* both under rainfed and irrigated conditions (Table 1).

The graphical and statistical method revealed that the critical limit of initial available P in Vertisols was about 10 kg ha^{-1} under rainfed conditions below which there is a response of safflower-legume cropping sequence to applied phosphorus. Similarly for irrigated conditions the critical phosphorus limit was found to be 8.2 kg ha^{-1} (Fig.1). Slightly lower critical phosphorus value observed for irrigated locations may be an indication of higher P nutrient use efficiency by the cropping sequence.

Most points in the graphic diagram of irrigated Vertisols (Fig. 1) of present study are in the lower left or upper right quadrants and hence the soil test almost accurately predicted the crop performance. Conceptually, low soil tests will have low Bray's per cent yield and high soil test will have high Bray's per cent yield. Few points observed in the upper left and lower right quadrants of the scatter diagram are associated with low soil test value and high Bray's per cent yield and *vice-versa*. Some such abberrations under field conditions are likely to happen in a complex soil-plant system. Normally a fully developed scatter diagram over various years and locations will provide more points in the immediate area of the critical level making the determination more precise.

Table 1. Soil available phosphorus (kg ha^{-1}), safflower seed yield and Bray's per -cent yield in safflower-legume cropping sequence under rainfed and irrigated Vertisols

Field experi-ments	Av.P (kg ha^{-1})	Seed yield (kg ha^{-1}) Control	P treatment	Response: Av.P*	Bray's per cent yield
Rainfed					
1	8.6	917	943	3.0	97.2
2	4.5	1019	1178	35.3	86.5
3	3.4	1542	2231	200.3	69.1
4	8.6	1439	1686	28.7	85.3
5	4.5	828	1071	54.0	77.3
6	18.5	1271	1498	12.3	84.8
7	14.0	458	450	-0.6	101.8
8	18.5	1197	1557	19.5	76.9
9	14.0	1325	1716	27.9	77.2
10	12.0	842	1136	24.5	74.1
11	16.0	1204	1608	25.3	74.9
12	12.5	1010	1372	29.0	73.6
13	14.2	1033	1482	31.6	69.7
14	17.0	742	1156	24.4	64.2
15	12.5	722	1063	27.3	67.9
16	14.2	1237	1490	17.8	83.0
Mean	12.1	1049	1352		
Irrigated					
1	11.1	877	1171	26.5	74.9
2	2.0	976	1323	171.8	73.8
3	2.0	1417	2078	330.5	68.2
4	6.0	1202	1427	37.5	84.2
5	15.0	1850	2454	40.3	75.4
6	13.0	1481	2213	56.3	66.9
7	15.0	1071	1566	33.0	68.4
8	15.0	1125	1465	22.7	76.8
9	13.0	2403	2981	44.5	80.6
10	8.0	781	1312	66.4	59.5
11	15.0	1085	1395	20.7	77.8
12	8.0	986	1965	122.4	50.2
13	15.0	1492	2010	34.5	74.2
14	8.0	982	2307	165.6	42.6
15	15.0	1175	1600	28.3	73.4
16	2.3	1910	2203	127.4	86.7
Mean	10.2	1301	1842		

Rainfed locations : Annigeri, Solapur, Tandur and Indore; Irrigated locations: Indore, Parbhani, Phaltan and Jalgaon

* Yield per kg of initial available phosphorus

In the present study, both graphical and statistical procedure of Cate and Nelson (1971) gave the same critical P values. Similar observation was reported with P critical limit in Vertic Ustochrepts by Subba Rao and Ganeshamurthy (1994).

The same data was fitted to the mathematical models *i.e.* linear response plateau, quadratic and square root and compared. The critical values derived by the models were 8.6, 15.1(LRP); 9.3, 8.9 (SR) and 11.7, 13.1 (Q) and coefficients of determination (R^2 values) were 0.87, 0.91 (LRP); 0.79, 0.50 (SR) and 0.52, 0.19 (Q) for rainfed and irrigated Vertisols, respectively. Based on R^2, LRP was found better than the other models. SR model predicted nearly the same critical phosphorus values as determined by Cate and Nelson (1971) procedures while quadratic model showed slightly higher values for rainfed and irrigated Vertisols. Present study indicates that LRP and SR mathematical models could be useful in delineating responsive from non-responsive Vertisols sites efficiently.

Graphical, statistical and other mathematical models stated above clearly indicate that for the field experiments, an initial P status of 9±1 kg ha^{-1} is observed to be the critical level for P management both under rainfed and irrigated conditions, to delineate responsive from non-responsive Vertisols irrespective of the locations, years, legumes (soybean, chickpea, mungbean, *etc.*) and safflower varieties (Bhima, Sharda, A–1 *etc.*) tried in the cropping sequence. In Vertisols where oilseed crops are grown, the critical nutrient limit of phosphorus varied from 5.6 (Patel and Savani 1987) to 16.1 kg P ha^{-1} (Gupta and Vyas 1993). Critical limits of phosphorus observed in the present study were in consonance with the reported range of values.

Thus, P management in safflower-legume cropping sequence was found beneficial where the initial available phosphorus content in Vertisols was less than 9±1 kg ha^{-1} under rainfed and irrigated conditions. LRP and SR mathematical models are also found useful in delineating responsive from non-responsive Vertisols sites.

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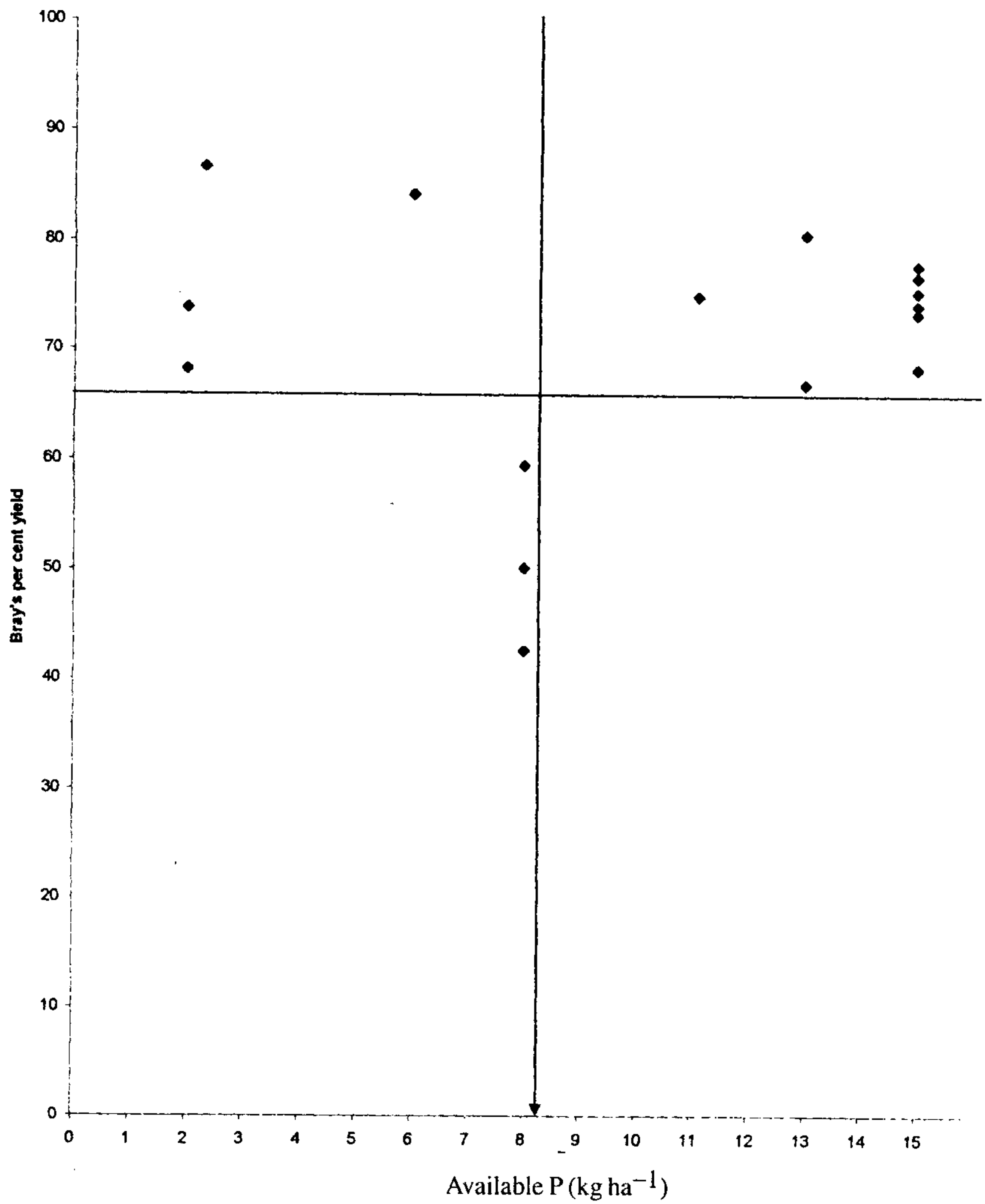

Figure 1. Critical available P (kg ha^{-1}) in irrigated Vertisols

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