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Ramya SH
Senior Research Fellow, Department of Soil Science and Agricultural Chemistry, UAS, GKVK, Bengaluru, Karnataka, India

Hebsur NS
Professor, Department of Soil Science and Agricultural Chemistry, UAS, Dharwad, Karnataka, India

Ravindra VM
Senior Research Fellow, Department of Soil Science and Agricultural Chemistry, UAS, Dharwad, Karnataka, India

Hundekar ST
Subject Matter Specialist Soil Science Saidapur Farm, UAS, Dharwad, Karnataka, India

Correspondence
Ramya SH
Senior Research Fellow, Department of Soil Science and Agricultural Chemistry, UAS, GKVK, Bengaluru, Karnataka, India

Phosphorus fractions and their percentage contribution to total phosphorus in Bt. cotton growing Vertisols of Dharwad district

Ramya SH, Hebsur NS, Ravindra VM and Hundekar ST

Abstract
To know the distribution of different fractions of phosphorus in Vertisols under Bt. cotton in Dharwad district ten villages were selected and from each village five farmers were identified and soil samples were collected from 0-30 cm using GPS. Collected samples were analysed for chemical properties and different phosphorus fractions using standard methodology. From the study it was observed that Ca-P was dominant fraction which ranged from 40.40 to 63.56 ppm and contributed about 9.57 to 24.41 per cent to total - P compared to all other phosphorus fractions. Whereas the saloid-P was the smallest fraction, ranged from 1.30 to 3.95 ppm and it contributes about 0.39 to 1.05 per cent to total-P. The dominance of different inorganic fractions of phosphorus in these soils followed the order: Ca-P > Red-P > Al-P > Occl-P > Fe-P > Saloid-P. The correlation study indicated that the Ca-P correlated significantly and positively with pH (r =0.928**), EC (r =0.371**), $CaCO_3$ (r = 0.969**) and total-P (r = 0.586**) only, but the saloid-P had positive and significant correlation with all the P-forms (Al-P, Fe-P, Red-P and total-P and Occl-P), available P and soil organic carbon**.** Whereas, Al-P was positively correlated with Fe-P (r = 0.551**), Red-P (r = 0.619**), Occl-P (r = 0.761**), total-P (r = 0.345**), available-P (r = 0.577**) and organic carbon (r =0.455**). A Significant and positive correlation of Red-P with saloid-P (r = 0.779**), Al-P (r = 0.619**), Fe-P (r = 0.762**), available-P (r = 0.816**) and Organic carbon (r =0.579**) was observed. Occluded-P had also significant and positive correlation with Saloid-P (r = 0.784**), Al-P (r = 0.761 **), Fe-P (r = 0.749**) and Red-P (r = 0.507**), respectively. The Organic-P was also positively correlated with all the P fractions except Ca-P.

Keywords: Bt. cotton, correlation, phosphorus fractions and vertisols

Introduction
Of the total geographical area, Vertisols occupy about 73 million hectares in India and about 6.9 million hectares in Karnataka. A large area of Vertisols will continue to be occupied under rainfed condition. Rainfed Vertisols contribute to 60 per cent of total cotton production. Phosphorus is considered a major constraint for cotton production in Vertisols. Phosphorus is one of the essential macronutrients, which plays an important role in ensuring the growth and development of cotton. It is essential for the vigorous root and shoot growth, promotes early boll development and hastens maturity. Phosphorus overcomes the effects of compaction besides increasing water use efficiency and energy storage and transfer in plants (Anon., 2003) [1]. Therefore, an adequate supply of phosphorus is indispensible for profitable cotton production. Owing to complex nature of soil phosphorus, the availability of P has become the subject of controversy and continuous research. Generally, plants take up phosphorus in inorganic form that too in anionic form ($H_2PO_4^-$ and HPO_4^{2-}). In case of black soils, the applied phosphorus gets converted into insoluble form and thus its availability to the plants is reduced leading to build up phosphorus status in the soil. To know the distribution of different fractions of phosphorus in Bt. cotton growing Vertisols of Dharwad district present work was undertaken.

Material and Methods
Field survey was conducted and fifty Bt. cotton growing farmers were selected from different villages of Dharwad district *Viz.*, Bandiwad, Byahatti, Dattur, Hebsur, Ingalalli, Kiresur, Kusugal, Rottigwad, Siraguppi and Sulla. From each village five farmers were selected and soil samples were collected from 0-30 cm depth using GPS and analysed for pH EC (dSm^{-1}), $CaCO_3$ (g kg^{-1}) and organic carbon (g kg^{-1}), different phosphorus fractions like saloid bound,

aluminium bound, iron bound, reductant soluble, occluded, calcium bound, total phosphorus and organic phosphorus using standard procedures (Peterson and Corey, 1966) [17].

Results and Discussion

Distribution of different fractions of phosphorus and their percentage contribution to the total phosphorus in the Bt cotton growing Vertisols of Dharwad district are presented in Table.1 and Fig.1. Among the various forms, saliod-P was present in a small quantity compared to all other forms of phosphorus in soils. Saliod P ranged from 1.30 to 3.95 ppm and constituted about 0.39 to 1.05 per cent of total-P. Compared to saloid-P fraction, Fe-P fraction was dominant fraction in these soils (3.50 to 14.50 ppm) and contributed about 1.29 to 3.44 per cent to total P. The per cent contribution of Al-P to total-P ranged from 3.61 to 9.21 per cent. Whereas, reductant soluble-P in soils was higher than saloid-P, Fe-P and occluded-P. Calcium-P was the most dominant inorganic P fraction which ranged from 40.40 to 63.56 ppm and contributed 9.57 to 24.41 per cent to total P. The total mineral phosphorus in soils ranged from 96.44 to 148.28 ppm which constituted about 36.61 to 45.45 per cent to total P. The organic phosphorus content varied from 149.0 to 292.20 ppm and contributed about 57.70 to 72.33 per cent to total-P. The total phosphorus content in soils varied from 154 to 428.70 ppm. The dominance of different inorganic P fractions in these soils followed the order: Ca-P > Red P > Al-P> Occl-P > Fe-P > Saloid-P.

The studies on P fractions indicated that of all the forms of P, saloid-P was present in the lowest amount which varied from 1.30 to 3.95 ppm, contributing 0.39 to 1.05 per cent to total-P in these soils. This might be due to high $CaCO_3$ content of these soils which fixes solution phosphorus into insoluble forms. Similarly, the lowest content of Saloid-P in black soils of Tamil Nadu was reported by Kothandaraman and Krishnamoorthy (1977) [12, 13]. According to Vishwanatha (1988) [28, 29], saloid-P was present in small quantity which contributed about 0.86 per cent to total-P compared to all other inorganic P fractions in Vertisols of North Karnataka. Low amount of saloid-P in the Vertisols of Tungabhadra command area was reported by Patagundi *et al.* (1996) [16]. The soils had Al -P ranging from 9.50 to 30.23 ppm and its contribution varied from 3.60 to 9.21 per cent to total-P. Tekalign Mamo and Haque (1987) [23] also observed high amounts of Al-P in some Ethiopian Vertisols due to their high content of Al oxides, while, the contribution of Al-P to total-P was 5.40 per cent in some calcareous soils of Punjab (Vig *et al.*, 2000) [26]. According to Patgundi *et al.* (1996) [16], the aluminium P contributed 4.60 to 20.90 per cent to inorganic P in black soils of Dharwad region.

On the other hand, Fe-P content was low (3.50 to 14.50 ppm) compared to Al-P and Ca-P and its per cent contribution was 1.29 to 3.44. The low content of Fe-P compared to Al-P and Ca-P might be due to the high activity of Al^{3+} and Ca^{2+} ions than Fe^{3+} ions in these soils. The results are in agreement with the findings of Patgundi *et al.* (1996) [16] who found less amount of Fe-P contributing 2.0 to 11.0 per cent of inorganic P in Vertisols of Tungabhadra command. The reductant soluble-P in soils contributed next to Ca-P in the order of abundance which ranged from 17.50 to 36.70 ppm and 4.51 to 12.68 per cent to total-P. The tendency of Red-P to occur in higher amounts might be attributed to a comparatively dry environment in surface layers in contrast to lower depths (Patgundi *et al.*, 1996 and Dongale, 1993) [16, 5, 6]. Doddamani (1982) [4], Kothandaraman and Krishnamoorthy (1977) [12, 13] also made similar observations in some Vertisols of Karnataka.

There is a slight variation in the occluded-P content and it contributed about 1.99 to 6.72 to total-P in these soils. Similar observation was made by Udo *et al.* (1984) [24] who stated that the low content of occluded -P (4%) compared to Al-P and Ca-P forms might be due to poor drainage and unweathered nature in the soils of Nigeria. The fractionation studies also indicated that Ca-P was the dominant inorganic mineral P fraction (40.40 to 63.56 ppm) compared to all other inorganic forms, contributing about 9.57 to 24.41 per cent to total-P. The high Ca-P might be due to the alkaline soil reaction and calcareous nature of these soils. Similarly, the dominance of Ca-P was also reported by Kothandaraman and Krishnamoorthy (1979) in black soils of Tamil Nadu, Vishwanath and Doddamani (1991) [27] in Vertisols of North Karnataka (18.30%) and Patagundi *et al.* (1996) [16] in the soils of Tungabhadra left bank canal. The high content of Ca-P suggests less weathering of these soils as reported by Puranik *et al.* (1979) and Tekalign Mamo and Haque (1987) [23].

The total mineral-P in these soils varied from 96.44 to 148.28 ppm. Among the different inorganic fractions of P, Ca-P, Al-P and Red-P forms contributed maximum to the total mineral P. Viswanath (1988) [28, 29] and Room Singh and Omanwar (1987) [21] also reported the dominance of Ca-P followed by Al-P and Red-P in soils of North Karnataka and Uttar Pradesh, respectively. Organic P content in soils varied from 149.0 to 292.20 ppm. The contribution of organic-P to total-P was found to be 57.70 to 72.33 per cent. The organic-P content in these soils closely related to organic carbon status indicating that the bulk of organic P in soils locked up in organic matter. The high organic P in these soils compared to inorganic suggests less weathering of these soils as referred by Chang and Jackson (1957) [3]. Goel and Agarwal (1959) [9] reported concentration of organic form of phosphorus is high in mature soils compared to immature soils. However, the total P content in soils varied from 154 to 428.70 ppm. High amount of total-P in surface soils might be due to the addition manure and fertilizers to surface soil (Viswanatha and Doddamani, 1991) [27]. Therefore, the findings of the present investigation are in close agreement with the findings of many early workers.

Correlation coefficients between soil properties and different P fractions in Vertisols growing Bt cotton are presented in the Table.2**.** The saloid-P had a significant and positive correlation with Al-P, Fe-P, Red-P, Occl-P, organic-P and total-P. But, it had negative correlation with Ca-P, pH, EC and $CaCO_3$.There was a positive and significant correlation of Al-P and Fe-P with OC, Fe-P, Red-P and Total-P, but they were negatively correlated with pH, EC, $CaCO_3$. On the other hand, Red-P and Occl-P had positive correlation with saloid-P, Al-P, Fe-P, Organic-P, Red-P but, negative relationship with pH, EC, $CaCO_3$, Ca-P correlated significantly with pH, EC, $CaCO_3$, but it had negative correlation with all other P-fractions including available P_2O_5. A significant positive correlation of organic-P with all other P fractions except Ca-P was observed. Similarly, total P correlated significantly with all the P fractions of soil growing Bt cotton.

It is important to study the relationship between various soil properties and P-fractions as it gives an insight into how different soil properties affect the distribution of different forms and availability of P in soil. This, inturn, may also help in taking the suitable P fertilizer management practices so that plants are optimally nourished with respect to the phosphorus.

Saloid phosphorus had significant and positive correlation with Fe-P (r=0.954**), Red-P (r=0.779**). Chandra Bhan and Harishanker (1973) [2] also observed significant and positive correlation of saloid-P with Fe-P (r=0.924**), Al-P (r=0.672*) and considered saloid-P as the important available fraction. Similar relalisationship have been observed by Kumbhar *et al.* (1988) [14] in the Vertisols of Maharashtra. Similarly, a significant and positive correlation of saloid- P with organic carbon (r = 0.751**) and available P (r = 0.979**) P was also observed. A significant and positive correlation of this fraction with organic carbon explains the increased availability of P in soils with increase in organic matter (Tek Chand and Tomar, 1992) [22].

Al-P positively and significantly correlated with available-P (r = 0.577*) and Red-P (r = 0.619**) whereas, it showed significant and negative correlation with EC (r= - 0.481**). Highly significant correlation of Al-P with available-P explains the importance of this fraction in P-availability to plants. Halstead (1967) [10] related Al-P content in soils to plant uptake and established it as an important source of P in soils. Piccolo and Huluka (1986) [18] reported that Al-P, Fe-P and Ca-P, were the fractions the most sensitive to changes in soils and regarded them as indicators of soil weathering. A negative and significant association of Al-P with EC shows that an increase in salt content will bring about reduction in Al-P content.

Iron phosphorus had highly significant and positive correlation with saloid-P (r=0.954**), Red-P (r = 0.762**), organic carbon (r = 0.796**) and available phosphorus (0.973**). The positive association of iron form with both saloid-P and available-P fractions confirms it as an active P-form in the soil controlling P availability. Similar correlations have been reported by Ram Deo and Ruhal (1970) [20] and Giridhar Krishna and Satyanarayana (1996) [7, 8] in Mewar soils of Rajasthan and Vertisols of Northern Karnataka, respectively. The positive association of Fe-P with Red-P has been also reported by Prasad *et al.* (1986) [19] in soils of Meghalaya. The results of the correlation studies revealed a highly significant and positive correlation of Red-P with saloid-P (r = 0.779**), available P (r = 0.816**) and organic carbon (r = 0.579**). However, its association was negative but significant with pH (r = -0.711**). There is a significant and positive correlation of Red-P with important soil properties such as organic carbon, saloid-P and ultimately with available P, indicates that it is also an important fraction along with other fractions such as Fe-P, Al-P and Ca-P in controlling the available-P status in soils. Conventionally, this form is considered as a semi active form which becomes soluble only under anaerobic conditions. So, it can be inferred that the soils under study are Vertisols with fine texture and poorly drained favourable conditions for its dissolution leading to its closer relationship with available-P. Mehni Lal and Mahapatra (1979) [15] indicated the transformation of P into Fe-P and Occl-P in soils, contribute significantly to the available P in alkaline alluvial soils. Therefore, similar transformation and availability of Red-P fraction seem to be operative in the soils under study. A highly significant and positive correlation of Red-P with available P has been reported by Room Singh and Omanwar (1987) [21] and Giridhar Krishna and Satyanarayana (1996) [7, 8] in Vertisols reported that the available P was positively and significantly correlated with Al-P (r=0.807**), Fe-P (0.864**), Ca-P (0.714**), Red-P (0.505**) and Occl-P (0.829**).

A significant positive correlation of occluded - P was also observed with saliod-P, Al-P and Fe-P forms, while it was negatively correlated with Ca-P. Kothandaraman and Krishnamoorthy (1979) also observed significant positive correlation of occluded-P with Al-P and Fe-P forms in soils of Tamil Nadu. Among the P fractions studied, occluded-P had significant positive correlation with Olsen's-P (r=0.741**).

Ca-P had a significant negative correlation with Al-P and Fe-P while it significantly and positively correlated with pH (r=0.928**) and free $CaCO_3$ (r=0.969**). The highly significant positive correlation of Ca-P with increase pH and $CaCO_3$ was reported by Khanna and Datta (1968) and Kothandaraman and Krishnamoorthy (1979) in Indian soil and Tamil Nadu soils, respectively. Similarly, there was a significant and positive association between pH and Ca-P (r=0.610**) and negative correlation of Fe-P (r= -0.64) and Al-P (r= -0.362) with pH. The positive correlation between $CaCO_3$ and Ca-P (r=0.610**) was observed which indicates less transformation of Ca-P in presence of $CaCO_3$ coupled with high pH (Room Singh and Omanwar, 1987) [21].

Organic- P in soils was found to be significantly and positively correlated with saloid-P (r = 0.389**), Fe-P (r = 0.477**) and total-P (r = 0.963**), organic carbon (r = 0.661**) and Olsen-P (r = 0.407**) while, it was significantly and negatively correlated with soil Ph (r = - 0.441**). The multiple correlation studies carried by Uzu *et al.* (1975) [25] revealed the existence of highly significant correlation of organic-P with soil pH, organic carbon content and total-P content in the soil. The positive correlation between organic-P and total-P was quite evident because of higher correlation of organic P with total P as reported by many workers *viz.*, Chandra Bhan and Harishankar (1973) [2]: Dongale (1993) [5, 6] and Giridhar Krishna and Satyanarayana 1996) [7, 8]. The positive significant correlation between organic-P and available P might be because of mineralization of organic matter as revealed by low organic C/organic P ratio's, particularly in surface soils as reported by Piccolo and Huluka (1986) [18]. Similar observations were also reported by Kothandaraman and Krishnamoorthy (1979) who reported that organic-P correlated significantly and positively with organic carbon (r = 0.654**) and total-P (r = 0.707**). Total-P had significant positive correlation with saloid-P, Al-P, Fe-P, Red- P and organic -P, Olsen's-P (r = 0.623**) and organic carbon (r = 0.753**). These results are in accordance with the reports of Kothandaram and Krishnamoorthy (1977) [12, 13] who stated that there is close relationship of total-P with different fractions of P in soil.

Table 1: Distribution of different fractions of phosphorus and their percentage contribution to the total phosphorus in the Bt cotton growing Vertisols of Dharwad district

Sl. No.	Village	Name of the farmer	Phosphorus fractions (ppm)								
			Saloid-P	Al-P	Fe-P	Red-P	Occl -P	Ca-P	Total min-P	Org-P	Total P
1	Bandiwad	Ayyappa.V. M	2.58 (0.88)*	17.50 (5.95)	7.41 (2.52)	29.7 (10.10)	11.50 (3.91)	53.26 (18.12)	121.94 (41.49)	171.95 (58.51)	293.89
2		Bharmappa V. D	2.72 (0.86)	20.00 (6.33)	9.25 (2.93)	33.5 (10.60)	13.50 (4.27)	47.94 (15.18)	126.91 (40.17)	189.00 (59.83)	315.91
3		Chandrasekhar. M	1.70 (0.64)	12.94 (4.90)	3.50 (1.33)	20.5 (7.77)	8.50 (3.22)	58.76 (22.27)	105.90 (40.13)	158.00 (59.87)	263.90
4		Goudappa Patil	2.61 (0.86)	18.80 (6.20)	7.80 (2.57)	30.2 (9.96)	12.75 (4.20)	48.11 (15.86)	120.27 (39.66)	183.00 (60.34)	303.27
5		Siddaramayya G.H	1.50 (0.47)	10.63 (3.35)	3.90 (1.23)	18.4 (5.81)	6.00 (1.89)	61.52 (19.41)	101.95 (32.17)	215.00 (67.83)	316.95
6	Byahatti	Basavanagouda D. K	2.67 (0.86)	19.40 (6.22)	7.95 (2.55)	31.5 (10.10)	14.20 (4.55)	50.21 (16.10)	125.93 (40.37)	186.00 (59.63)	311.93

7		Hanumanthagouda S	2.55 (0.87)	16.00 (5.49)	7.50 (2.57)	29.5 (10.12)	11.75 (4.03)	53.00 (18.18)	120.30 (41.26)	171.30 (58.74)	291.60
8		Ismail sab	3.20 (0.75)	23.30 (5.47)	11.5 (2.70)	35.50 (8.34)	17.50 (4.12)	43.60 (10.24)	135.60 (31.86)	290.00 (68.14)	425.60
9		Neelappa H.	1.30 (0.40)	23.83 (7.25)	3.70 (1.13)	17.5 (5.33)	18.80 (5.72)	63.37 (19.29)	128.50 (39.12)	200.00 (60.88)	328.50
10		Siddanagouda M.G	2.28 (0.81)	14.50 (5.18)	7.55 (2.70)	18.5 (6.61)	10.50 (3.75)	53.11 (18.97)	106.44 (38.02)	173.50 (61.98)	279.94
11	Dattur	Kallappagudi	3.52 (0.82)	26.00 (6.06)	13.5 (3.14)	36.50 (8.51)	22.00 (5.13)	43.20 (10.08)	145.72 (33.99)	284.00 (66.24)	428.72
12		Anand Pujar	3.30 (0.78)	23.85 (5.64)	11.0 (2.60)	33.50 (7.90)	18.00 (4.26)	40.40 (9.57)	132.05 (31.27)	292.20 (69.20)	422.25
13		Yallappagoudar	3.20 (0.96)	22.90 (6.90)	10.2 (3.07)	36.2 (10.90)	17.50 (5.27)	45.00 (13.55)	135.00 (40.66)	197.00 (59.34)	332.00
14		Shekappa Mulimani	2.57 (0.86)	18.35 (6.12)	7.75 (2.58)	29.5 (9.84)	14.20 (4.74)	53.08 (17.70)	125.45 (41.84)	174.40 (58.16)	299.85
15		Basavangoudar	3.20 (0.76)	23.72 (5.65)	10.5 (2.50)	36.7 (8.74)	17.30 (4.12)	43.50 (10.36)	134.92 (32.13)	285.00 (67.87)	419.92
16	Hebsur	Channagouda S.P	3.08 (0.96)	20.41 (6.38)	9.88 (3.09)	35.5 (11.10)	16.32 (5.10)	46.50 (14.55)	131.69 (41.19)	188.00 (58.81)	319.69
17		Narayanappa V.M	2.86 (0.94)	18.10 (5.96)	9.25 (3.05)	33.5 (11.03)	12.0 (3.95)	48.05 (15.82)	123.76 (40.74)	180.00 (59.26)	303.76
18		Ramappa B.A	2.97 (0.99)	18.50 (6.18)	9.75 (3.26)	34.4 (11.50)	14.50 (4.84)	47.20 (15.77)	127.34 (42.54)	172.00 (57.46)	299.34
19		Subhash R.C	3.40 (1.06)	23.00 (7.20)	10.39 (3.25)	36.0 (11.27)	16.00 (5.01)	45.70 (14.30)	134.49 (42.10)	185.00 (57.90)	319.49
20		Thimmaraddi G. K	2.37 (0.80)	15.00 (5.03)	7.45 (2.50)	32.1 (10.77)	11.50 (3.86)	53.65 (18.00)	122.07 (40.95)	176.00 (59.05)	298.07
21	Ingalalli	Basavaraj Dundur	3.40 (1.03)	24.23 (7.32)	10.39 (3.14)	35.3 (10.66)	17.00 (5.13)	45.80 (13.83)	136.12 (41.11)	195.00 (58.89)	331.12
22		K.G. Vasthra	3.30 (0.98)	23.34 (6.91)	10.25 (3.04)	35.2 (10.42)	16.33 (4.84)	44.30 (13.12)	132.72 (39.30)	205.00 (60.70)	337.72
23		Murgappa H.N	3.65 (1.12)	26.50 (8.17)	11.5 (3.54)	32.5 (10.03)	22.35 (6.90)	40.50 (12.50)	142.20 (43.89)	187.00 (57.72)	324.00
24		Muthappa Talwar	3.60 (1.10)	30.23 (9.26)	11.5 5 (3.53)	33.0 (10.11)	24.50 (7.51)	40.40 (12.38)	148.28 (45.45)	183.00 (56.09)	326.28
25		S.P. Dundur	1.60 (0.50)	11.53 (3.57	4.50 (1.40)	18.5 (5.74)	7.23 (2.24)	61.16 (18.96)	104.52 (32.41)	218.00 (67.59)	322.52
26	Kiresur	Basappa Y. K	3.95 (1.10)*	18.70 (5.23)	14.25 (3.99)	30.50 (8.54)	24.0 (6.72)	40.70 (11.40)	137.80 (38.59)	225.00 (63.01)	357.1
27		Govindaraddi T.B	1.94 (0.66)	17.50 (5.93)	5.35 (1.81)	20.90 (7.08)	10.5 (3.56)	53.88 (18.26)	110.07 (37.30)	185.00 (62.70)	295.07
28		M.S. Thirlapur	1.80 (0.70)	11.99 (4.67)	4.99 (1.94)	20.50 (7.98)	7.88 (3.07)	54.78 (21.32)	101.94 (39.67)	155.00 (60.33)	256.94
29		Somanna Hurali	3.01 (1.00)	18.00 (5.96)	9.35 (3.10)	33.50 (11.10)	12.5 (4.14)	50.50 (16.73)	126.86 (42.03)	175.00 (57.97)	301.86
30		Veeranna Kamdolli	3.46 (1.06)	25.00 (7.66)	11.5 (3.52)	35.70 (10.94)	22.0 (6.74)	45.60 (13.98)	141.26 (43.30)	183.00 (56.09)	326.26
31	Kusugal	Basavaraj P.A	3.02 (0.97)	20.45 (6.56)	9.77 (3.13)	34.20 (10.97)	13.43 (4.31)	47.80 (15.34)	128.67 (41.28)	183.00 (58.72)	311.67
32		Basavaraj E.A	2.00 (0.61)	12.10 (3.67)	5.40 (1.64)	21.00 (6.38)	8.10 (2.46)	54.80 (16.64)	103.40 (31.39)	226.00 (68.61)	329.40
33		Huchappa M	3.06 (1.04)	20.53 (7.00)	9.97 (3.40)	34.90 (11.91)	13.5 (4.61)	48.10 (16.41)	130.06 (44.38)	163.00 (55.63)	293.03
34		Neelappa Mattigatti	2.00 (0.77)	10.20 (3.92)	5.10 (1.96)	21.10 (8.12)	6.99 (2.69)	54.50 (20.97)	99.89 (38.44)	160.00 (61.56)	259.89
35		M V Kodli	3.10 (1.07)	19.10 (6.62)	9.81 (3.40)	34.42 (11.93)	12.99 (4.50)	44.15 (15.30)	123.57 (42.82)	165.00 (57.18)	288.57
36	Rottigwad	Ashwini M.K	1.40 (0.53)	9.50 (3.61)	4.96 (1.88)	20.10 (7.63)	5.25 (1.99)	55.23 (20.96)	96.44 (36.61)	167.00 (63.39)	263.44
37		Basappa. D. B	3.65 (1.11)	26.00 (7.92)	11.55 (3.52)	35.50 (10.83)	21.5 (6.56)	41.42 (12.63)	141.82 (43.25)	188.30 (57.42)	327.92
38		Basavannappa F.K	2.67 (0.80)	12.50 (3.76)	7.95 (2.39)	34.00 (10.22)	8.36 (2.51)	52.30 (15.72)	117.78 (35.39)	215.00 (64.61)	332.78
39		Ningappa F. K	2.79 (0.87)	26.45 (8.24)	8.50 (2.65)	35.50 (11.06)	9.21 (2.87)	48.50 (15.11)	130.95 (40.80)	190.00 (59.20)	320.95
40		Subhash Bengeri	3.46 (1.21)	19.25 (6.77)	11.5 (4.04)	36.01 (12.68)	14.8 (5.21)	45.94 (16.18)	128.96 (45.41)	153.00 (53.88)	283.96
41	Siraguppi	Ajrasab Gulsab M	3.59 (1.13)	22.64 (7.12)	12.3 (3.87)	34.20 (10.75)	17.25 (5.42)	43.20 (13.58)	133.18 (41.86)	185.00 (58.14)	318.18
42		Eranna Shekappa B	1.35 (0.52)	16.42 (6.31)	3.85 (1.48)	18.50 (7.11)	5.68 (2.18)	63.56 (24.41)	109.36 (42.00)	151.00 (58.00)	260.36
43		Gadiyappa B.G	2.10 (0.72)	18.13 (6.21)	5.25 (1.80)	21.20 (7.26)	11.82 (4.05)	53.33 (18.27)	111.83 (38.32)	180.00 (61.68)	291.83
44		Rachappa M. A	3.26 (0.99)	24.2 (7.32)	9.97 (3.02)	35.80 (10.83)	20.00 (6.05)	44.30 (13.40)	137.53 (41.61)	193.00 (58.39)	330.53
45		Rudragoudar K	3.20 (0.77)	14.62 (3.52)	14.5 (3.49)	35.61 (8.59)	11.00 (2.65)	43.26 (10.44)	117.19 (28.28)	292.20 (70.51)	414.39
46	Sulla	Eranna Rudrappa A	3.38 (0.85)	13.10 (3.28)	10.3 (2.58)	36.50 (9.15)	10.85 (2.72)	44.55 (11.17)	118.68 (29.75)	280.30 (70.25)	398.98
47		B.S. Asundi	1.40 (0.54)	15.50 (6.00)	5.00 (1.93)	19.00 (7.36)	7.50 (2.90)	60.80 (23.55)	109.20 (42.29)	149.00 (57.70)	258.21
48		G.C Ingalagi	3.10 (1.07)	19.50 (6.72)	9.81 (3.38)	29.97 (10.32)	11.27 (3.88)	44.70 (15.40)	118.35 (40.76)	172.00 (59.24)	290.35
49		Mahadevappa. C	1.55 (0.54)	23.65 (8.26)	5.21 (1.82)	31.80 (11.11)	7.35 (2.57)	58.76 (20.52)	128.32 (44.82)	158.00 (55.18)	286.32
50		Veerabhadrappa. A	3.65 (0.90)	15.62 (3.86)	12.00 (2.97)	18.20 (4.51)	20.5 (5.07)	41.81 (10.35)	111.78 (27.67)	292.20 (72.33)	403.99
		Mean	2.74	19.06	8.66	29.84	13.72	49.36	123.70	196.91	320.36
		S.D	0.74	4.97	2.91	6.77	5.11	6.49	13.05	41.23	45.48

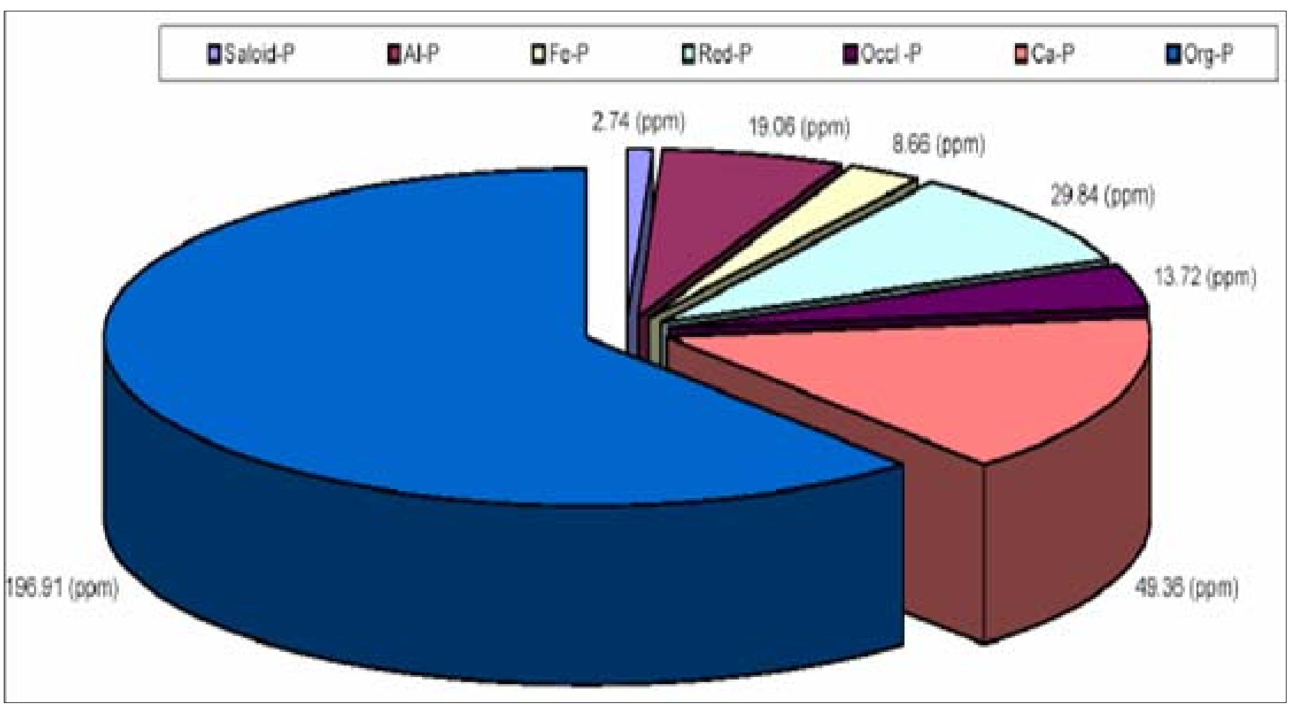

Fig 1: Average distribution of different fractions of phosphorus in Bt. cotton growing Vertisols of Dharwad district

Table 2: Correlation coefficients between soil properties and different P fractions in Vertisols growing Bt cotton

Soil properties	Phosphorus fractions												
	pH	**EC**	**$CaCO_3$**	**OC**	**Available P_2O_5**	**Saloid-P**	**Al-P**	**Fe-P**	**Red-P**	**Occl -P**	**Ca-P**	**Org-P**	**Total-P**
pH	1												
EC	0.368**	1											
$CaCO_3$	0.963**	0.357**	1										
OC	-0.725**	-0.262	-0.780**	1									
Available P_2O_5	-0.931**	-0.346**	-0.979**	0.795**	1								
Saloid- P	-0.924**	-0.312*	-0.967**	0.751**	0.979**	1							
Al-P	-0.580**	-0.481**	-0.574**	0.455**	0.577**	0.587**	1						
Fe-P	-0.927**	-0.316*	-0.967**	0.796**	0.973**	0.954**	0.551**	1					
Red-P	-0.711**	-0.464**	-0.765**	0.579**	0.816**	0.779**	0.619**	0.762**	1				
Occl –P	-0.758**	-0.199	-0.750**	0.613**	0.742**	0.784**	0.761**	0.749**	0.507**	1			
Ca-P	0.928**	0.371**	0.969**	-0.775**	-0.950**	-0.957**	-0.576**	-0.932**	-0.742**	-0.747**	1		
Organic-P	-0.441**	-0.017	-0.405**	0.661**	0.407**	0.389**	0.104	0.477**	0.209	0.336*	-0.437**	1	
Total-P	-0.597**	-0.085	-0.568**	0.757**	0.580**	0.562**	0.345*	0.638**	0.419**	0.530**	0.586**	0.963**	1

Conclusion

Among the different forms of P, Ca-P was dominant fraction which ranged from 40.40 to 63.56 ppm and contributed about 9.57 to 24.41 per cent to total - P whereas, saloid-P was the smallest fraction which ranged from 1.30 to 3.95 ppm contributing about 0.39 to 1.05 per cent to total-P. The dominance of different inorganic fractions of phosphorus in these soils followed the order: Ca-P > Red-P > Al-P > Occl-P > Fe-P > Saloid-P. The correlation study indicated the saloid-P had positive and significant correlation with all the P-forms (Al-P, Fe-P, Red-P, and Total-P and Occl-P), available P and soil organic carbon**.** Whereas, Al-P was positively correlated with Fe-P (r =0.551**), Red-P (r=0.619**), Occl-P (r =0.761**), Total-P (r =0.345**), available-P (r =0.577**) and organic carbon (r =0.455**). A significant and positive correlation of Red-P with saloid-P (r=0.779**), Al-P (r = 0.619**), Fe-P (r = 0.762**), available-P (r =0.816**) and organic carbon (r =0.579**) was observed. Occluded-P had also significant and positive correlation with Saloid-P (r = 0.784**), Al-P (r = 0.761 **), Fe-P (r = 0.749**) and Red-P (r = 0.507**), respectively. The Ca-P correlated significantly and positively with pH (r=0.928**), EC (r=0.371**), $CaCO_3$ (r = 0.969**) and total-P (r = 0.586**). The organic-P was also positively correlated with all the P fractions except Ca-P.

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