Agricultural Research & Technology
Open Access Journal
ISSN: 2471-6774

Juniper Publishers
key to the Researchers

Research Article
Volume 28 Issue 5 - September 2024
DOI: 10.19080/ARTOAJ.2024.28.556426

Agri Res & Tech: Open Access J

Effect of Eighteen Years of Continuous Crop Residue Application on Crop Yields, Soil P Fractions, and Crop P Uptake in Conservation Tillage Under Semi-Arid Tropical Rainfed Conditions

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Submission: September 03, 2024; **Published:** September 16, 2024

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Abstract

The continuous use of crop residue in soil can enhance the crop yield and potential availability and mobility of P fractions to crops in conservation tillage. A field experiment was conducted to assess the long-term effects of surface crop residue applications on soil P fractions and their relationship with P uptake and crop yields. Field experiment was conducted at ICAR-Central Research Institute for Dryland Agriculture, Hyderabad, India during 2005 to 2022. The experimental treatments applied were: T_1 - no crop residue application, T_2 - application of crop residue @ 2 t ha^{-1}, T_3 - application of crop residue @ 4 t ha^{-1}, and T_4 - application of crop residue @ 6 t ha^{-1} in conservation tillage. The test crops viz. sorghum (*Sorghum vulgare*) and cowpea (*Vigna unguiculata*) were grown in a yearly rotation every year in the *kharif* season in conservation tillage. The results of the long-term study revealed that the per cent increase in sorghum (*Sorghum vulgare*) grain yield with the application of crop residue at the rate of 2, 4 and 6 t crop residue ha^{-1}was to the tune of 7.9, 16.1 and 26.0%, respectively over no crop residue application. Similarly, the per cent increase in the cowpea (*Vigna unguiculata*) seed yield was to the extent of 25.2, 43.0 and 64.1% in 2, 4 and 6 t ha^{-1}, respectively over no crop residue application. The sorghum and cowpea stover yield also significantly (p=0.05%) increased with the added levels of the crop residue. Significantly higher P uptake by sorghum and cowpea was recorded in 6 t crop residue ha^{-1} as compared to the other crop residue treatments. Results of the current study also showed the significant positive response of long-term crop residue application on the P fractions viz., water-soluble phosphorus (WS-P), aluminum bound P (Al-P), iron bound P (Fe-P), calcium bound P (Ca-P) and reductant soluble P (RS-P), and on available P and total P in soil as compared to no crop residue application. The average percent contribution of P fractions toward the sum-total of extracted P was in the order: Fe-P (30.8%)>RS-P (30.7%)>Al-P (24.2%)>Ca-P (9.4%)>WS-P (4.8%). The WS-P and Al-P were found to be the P fractions indicating their specificity by cowpea crop, and WS-P and Ca-P were found to be P fractions indicating their specificity by sorghum crop. The results of the present study will be highly useful in understanding the effect of crop residue application in conservation tillage on the P fractions and their contribution toward P uptake and crop yields.

Keywords: Sorghum; Cowpea; Correlation; Multiple regression equations; Available P; Total P; P fractions; P-uptake; Alfisols

Introduction

Phosphorus (P) is an essential element for plant growth and development and is one of the important constituents of nucleic acids, phospholipids, and adenosine triphosphate (ATP), and it plays a very crucial role in photosynthesis, the metabolism of sugars, energy storage and transfer, cell division, cell enlargement, and the transfer of genetic information [1-3]. Beside this, P also promotes early shoot growth and healthy root growth and enhances the quality of grains. It is well established that the P dynamics in the soil-plant system is widely influenced by the integrated effects of P availability, P transformation from one form to another, and P utilization caused by soil, rhizosphere, and plant processes. It has been understood that the two vital processes in the transfiguration and translocation of phosphorus elements in the soil are geochemical and biological [4]. von Wandruszka [5] reported that the short-term availability of P to crops is strongly influenced by biochemical processes that affect organic matter, while its long-term status is generally determined by geochemical transformations. Based on several research studies, it has been brought out that although the total amount of P in the soil may be high, it is often present in an unavailable form and may not be adequately available to plants. According to Sharpley et al. [6]. in agricultural ecosystems, the quantity of P available for plant uptake is generally low due to the low solubility of P compounds present in soils. Soil P exists dynamically in dissolvable, labile, and non-labile forms. It has been reported that the P chemical equilibrium between labile P and non-labile P is generally weaker as compared to the balance between dissolvable P and labile P [7]. Phosphorus, mainly organic phosphorus, is only available for plant uptake after hydrolysis by the enzyme phosphatase [8]. Solution P, sorbed P, and mineral P are the broad conceptually defined pools of inorganic P (Pi) [9]. Soil Pi can be 'labile' or 'nonlabile' in terms of plant availability. Bünemann et al. [10] have reported that the relative proportion of P fractions present in any soil is very much dependent on factors like pH, degree of weathering, organic matter, cropping system, stubble management, tillage practices, fertilizer practices, etc. Both inorganic P (Pi) and organic P (Po) fractions interact extensively with soil components and are subject to various chemical transformations that affect the retention of the element. Kothandaraman & Krishnamoorthy [11] reported a close relationship between total P and other forms of P, indicating the existence of equilibrium between total P and the different forms of P in the soil.

A significant amount of P can be present in crop residues and the microbial biomass associated with their decomposition, and the potential contribution of this pool to the P nutrition of cropping systems is significant [12,13]. Wang et al. [14] have observed that composition-wise, in a carbon-rich biomass, crop residues contain C (40%-45%), N (0.6%-1%), P (0.45%-2%), K (14%-23%), and micronutrients, which are essential for crop growth. Decaying crop residues are considered basic components in the nutrient cycle. Recycling of crop residues to soil can enhance the content of OC, N, P, K, and micronutrients in soils [15,16]. Zhang et al. [17] has observed that crop residue application into soil can help in preventing the loss of nutrients and improve essential nutrient availability.

The P content and its form present in the crop residue have a significant influence on the immediate bioavailability and on the subsequent reactions of P with soil constituents. It has been observed that the application of crop residues in crop rotation has a significant effect on the dynamics and partitioning of soil P [10]. It has been reported that the P characteristics of crop residues are highly dependent on the environmental conditions, soil conditions, and physiological age of the crop from which they are derived [18]. Some of the studies reported increased soil P availability with the incorporation of crop residues [19-21], while others observed immobilization of soil P [18, 22]. The results emanated from several studies have indicated that the surface application of crop residue may help in improving the P availability, and consequently enhance the current productivity and long-term sustainability [23-26]. These researchers have concluded that the increase in yields due to recycling of crop residues depends on agricultural management practices, the duration of the experiment, climatic conditions prevailing in the region, soil properties, etc. The increase in crop yield by the use of crop residue can be attributed to (i) increased contents of organic matter, available nutrients, fulvic acid, and humic acid in the soil; (ii) enhanced carbon sources for microorganisms in the soil; (iii) increased porosity leading to soil aeration, enhanced water infiltration rate, and soil water availability ; (iv) reduced soil compaction, surface crusting, and bulk density; (iv) reduced amount of chemical fertilizers required; and (v) improved plant growth. In other words, surface recycling of crop residues favorably impacts the soil's physical, chemical, and biological conditions for ensuring better crop growth and higher crop yields [24-28].

It has been well established that tillage practices alter the soil profile in terms of nutrient distribution, thus impacting the availability, adsorption, leaching, decomposition, and mineralization of nutrients. Xu et al. [26] have reported that tillage practices can regulate the accumulation and depletion of soil organic matter (SOM), carbon sequestration, and soil aggregation through microbial processes and significantly contribute to higher crop yields. Contrary to normal tillage practices, conservation tillage practices result in the accumulation of crop residues on the soil surface, which can increase nutrient availability and improve nutrient use efficiencies, leading to potential yield responses [29]. Crop residue accumulation and less soil disturbance under conservation tillage help to sustain P on a long-term basis. It is understood that conservation tillage-based practices help to enhance P availability by changing the soil microbial diversity and enzyme activity, which in turn influences the availability of soil P [30,31]. However, the effects of conservation tillage on P availability depend on various factors including crop management practices, soil characteristics, and prevailing climatic conditions. Researchers reported that crop residue return could increase crop yield under conservation tillage, mainly due to the enhancement of soil fertility. Therefore, conservation tillage can enhance crop yield, soil nutrients status and soil resistance to external environmental changes [32].

This field experiment was conducted on the Alfisol soil order, and this soil order represents approximately one-third of the land in the semi-arid tropics [33]. About 62% of the world's Alfisols are present in West Africa and India [34]. In India, in dryland regions, nearly 30% of soils are covered by Alfisols and associated soils [35]. However, in SAT regions, the productivity of these soils is low due to interactions between the climate and soil. These Alfisol soils are inherently poor in plant nutrition and suffer from many physical constraints [35,36]. Alfisol soils occurring in Indian arid, semi-arid, and sub-humid eco-regions are extensively deficient in phosphorus (P), and it is one of the most important factors limiting crop productivity. The increasing cropping intensity, particularly in dry land agriculture, will further increase crop demands for P

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due to its unavailability. The sorghum-cowpea system is one of the important cropping systems found suitable for the rain-fed regions of the semiarid tropics (SATs) of India. The information on the long-term use of crop residues in conservation tillage on inorganic P fractions in soil and their relationship to P uptake by sorghum and cowpea crops grown in rotation and the contribution of different inorganic P fractions toward total and available P pools of soil is very scanty. Knowledge about various forms of any nutrient in soil is essential since not all the forms contribute equally to a specific process. Therefore, it becomes important to determine to what extent the addition of crop residue will affect the availability of different P fraction. We hypothesized that the incorporation of crop residue increases the potential availability and mobility of fractions of P to crop plants in conservation tillage. Therefore, the objectives of this study were (i) to assess the long-term effect of the crop residue application on the performance of the cowpea and sorghum crop in conservation tillage, (ii) to assess the fractions of P in soils and their contribution towards the availability of P to plants, and (iii) to assess the dynamic interrelationship of P chemical fractions between themselves under semi-arid tropical (SAT) rainfed conditions in long-term experimentation.

Materials and methods

Details of the experimental site

A long-term field experiment was conducted during 2005-2022 with *sorghum* {*Sorghum vulgare* (L.) Walp.} and cowpea {*Vigna unguiculata* (L.) Walp.} as the test crops grown in rotation at Hayathnagar Research Farm of ICAR-Central Research Institute for Dryland Agriculture, Hyderabad, India. The experimental location is situated at 17°18' N latitude and 78° 36' E longitude at an elevation of 515 m MSL. The experimental field represents a semi-arid tropical (SAT) region with hot to very hot summers and mild winter. The mean annual temperature of the experimental region is 25.7°C. The average rainfall of study region is 750 mm and about 70% of the total precipitation is received during the south-west monsoon season (June to September). Soils of the experimental field belong to Hayathnagar series (Typic Haplustalf). The soils are mildly acidic to neutral in reaction (pH 6.5) and having sandy loam soil texture. These soils are mostly low to medium in fertility (organic carbon <5.6 g kg^{-1}, available N <120 kg ha^{-1}, available P 15 kg $ha^{-1}$and K 209.0 kg ha^{-1}. The test crops viz. *Sorghum* (*Sorghum vulgare*) and cowpea (*Vigna unguiculata*) were grown in a yearly rotation every year in the *kharif* season in conservation tillage using tractor drawn seed planter or using a non-inversion type plough depending upon the situation. The experimental treatments applied were: T_1 - No crop residue application, T_2 - application of crop residue @ 2 t ha^{-1}, T_3 - application of crop residue @ 4 t ha^{-1}, and T4 - application of crop residue @ 6 t ha^{-1}which were replicated thrice using in a randomized block design (RBD) under conservation tillage. The crop residue treatments were applied to the soil surface by using the dry sorghum stover after 25-30 days after sowing (DAS) as per the treatments. To allow the anchored residue in the field, at the time of the harvest of the crop, the stubbles were retained at 30 cm height in case of sorghum and full biomass was retained after the harvest of the pods in case of cowpea. The remaining upper part (above 30 cm height) of the sorghum stover was removed out of the field and stored for field application during the next *kharif* season. Sorghum and cowpea crops received N every year as per the recommended doses of 60 and 30 kg N ha^{-1}, respectively, in the form of urea. Phosphorus was applied every year uniformly to all the plots and to both the test crops @ 30 kg P2O5 ha^{-1} using single super phosphate. In sorghum crop, 50% of N was applied as basal dose and balance 50% as top dressing, and for cowpea 100% N was applied as basal dose. The weeds were controlled using pre-emergence herbicides and mechanical methods as and when required. The summer sprays of broad-spectrum herbicide were also made, whenever needed.

Soil sampling and analytical methods

After the 18th year of study, soil samples were collected from 0 to 20 cm depth from each plot in triplicate. The samples were air-dried under shade and ground to pass through a 2 mm sieve. The samples were air-dried under shade and ground to pass through a 2 mm sieve. These samples were then passed through 0.5 mm sieve to study the effect of crop residue application levels under conservation tillage on chemical phosphorus fractions viz. water-soluble P (WS-P), aluminium bound P (Al-P), iron-bound P (Fe-P), calcium bound P (Ca-P), reductant soluble P (RS-P), available P (Avail P) and total P (Total P). For inorganic phosphorus fractionation, procedure given by Chang & Jackson [37] and modified by Peterson & Corey [38] was followed. Available P was determined by Olsen's method [39]. The collected plant samples (grain and stover) were digested with di-acid mixture (HNO_3: $HClO_4$ in 3: 1 ratio) and P content in the acid digest was estimated by vanado-molybdo yellow colour method (Jackson 1973) [40]. The uptake of phosphorus by grain/seed and stover was determined by obtaining the product of P concentration in plant and yield. The data on P fractions, crop yield, and P uptake was statistically analysed by using analysis of variance (ANOVA) technique. Correlation and regression equations were also developed to assess the relationship between crop yield, P uptake and P fractions, total P and available P. The statistical analysis of the data was performed using IBM, SPSS Statistics 19.

Results and discussion

Effect on crop yields

From the results of the study, it was found that sorghum grain yield significantly increased with the different level of crop residue application (Table 1). The sorghum grain yield varied from 2037 to 2566 kg ha^{-1} across the crop residue application treatments in conservation tillage. Significantly higher sorghum grain yield was observed with the surface application of crop residue at the rate of

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2 t ha^{-1} (2198 kg ha^{-1}), 4 t ha^{-1} (2365 kg ha^{-1}) and 6 t ha^{-1} (2566 kg ha^{-1}) compared to no residue application (2037 kg ha^{-1}) (Table 1). The per cent increase in sorghum grain yield with the application of crop residue at the rate of 2, 4 and 6 t ha^{-1} was to the extent of 7.9, 16.1 and 26.0%, respectively over no residue application. The per cent increase in the sorghum stover yield was 10.0, 19.0 and 30.1% in 2, 4 and 6 t crop residue ha^{-1}, respectively as compared to the no crop residue application.

Table 1: Effect of crop residue application on sorghum yield (during 2021) and cowpea yield (during 2022) in conservation tillage.

Treatments	Sorghum yield (kg ha^{-1})		Cowpea yield ((kg ha^{-1})	
	Grain yield	Stover yield	Seed yield	Stover yield
No crop residue (T_1)	2037	7433	798	2061
2 t crop residue ha^{-1} (T_2)	2198	8178	1027	2581
4 t crop residue ha^{-1} (T_3)	2365	8846	1166	2947
6 t crop residue ha^{-1} (T_4)	2566	9671	1327	3383
CD (p=0.05%)	150.2	658.1	121.3	351.3

Similarly, the cowpea seed yield ranged from 798 to 1327 kg ha^{-1} across the crop residue application treatments (Table 1). Significantly higher cowpea seed yield was recorded with the application of crop residue at the rate of 6 t crop residue ha^{-1} (1327 kg ha^{-1}), followed by crop residue applied at the rate of 4 t ha^{-1} (1166 kg ha^{-1}), crop residue applied at 2 t ha^{-1} (1027 kg ha^{-1}), and no crop residue application (798 kg ha^{-1}). Application of crop residue 2, 4 and 6 t ha^{-1} recorded higher cowpea seed yield to the extent of 28.7, 46.1 and 66.3%, respectively over no crop residue application (Table 1). Similarly, the per cent increase in the cowpea stover yield was 25.2, 43.0 and 64.1% in 2, 4 and 6 t ha^{-1}, respectively as compared to the no crop residue application in conservation tillage.

Effect on P uptake

The amount of P taken up by sorghum grain ranged from 7.20 to 12.51 kg ha^{-1} among the crop residue treatments (Table 2). Significantly higher phosphorus uptake by sorghum grain (12.51 kg ha^{-1}) was recorded with crop residue application at the rate of 6 t ha^{-1} followed by 4 t ha^{-1} (10.06 kg ha^{-1}) and 2 t ha^{-1} (8.52 kg ha^{-1}) compared to control (no crop residue application) (7.20 kg ha^{-1}) (Table 2). The per cent increase in phosphorus uptake by sorghum grain with the application of crop residue at the rate of 2, 4 and 6 t crop residue ha^{-1} was to the extent of 18.3, 39.8 and 73.8%, respectively over no crop residue application. Similarly, the sorghum stover P uptake was also influenced by the added levels of the crop residues. The significantly highest sorghum stover P uptake (15.7 kg ha^{-1}) was recorded in 6 t ha^{-1} crop residue application as compared to the rest of the treatments. The per cent increase in sorghum stover P uptake with the application of crop residue at the rate of 2, 4 and 6 t ha^{-1} was to the extent of 20.2, 41.2 and 71.7%, respectively over no crop residue application. The total P uptake by sorghum (grain and stover) followed the trend: 6 t ha^{-1} (28.22 kg ha^{-1}) > @ 4 t ha^{-1} (22.98 kg ha^{-1}) > 2 t ha^{-1} (19.52 kg ha^{-1}) > no crop residue application (16.35kg ha^{-1}).

Table 2: Effect of crop residue application on P uptake by sorghum (during 2021) and cowpea crop (2022) in conservation tillage.

Treatments	P uptake by sorghum (kg ha^{-1})			P uptake by cowpea (kg ha^{-1})		
	Grain uptake	Stover uptake	Total P uptake	Seed uptake	Stover uptake	Total uptake
No crop residue (T_1)	7.2	9.15	16.35	2.75	1.6	4.36
2 t crop residue ha^{-1} (T_2)	8.52	11	19.52	4	2.29	6.28
4 t crop residue ha^{-1} (T_3)	10.06	12.92	22.98	4.92	2.84	7.76
6 t crop residue ha^{-1} (T_4)	12.51	15.71	28.22	6.15	3.56	9.71
CD (p=0.05%)	1.29	1.82	1.51	0.46	0.75	1.09

Further, data presented in Table 2 revealed that P uptake by cowpea seed varied from 2.75 to 6.15 kg ha^{-1} across the residue treatments. Significantly higher phosphorus uptake by cowpea seed was observed with the crop residue application at the rate of 6 t ha^{-1} (6.15 kg ha^{-1}), 4 t ha^{-1} (4.92 kg ha^{-1}) and 2 t ha^{-1} (4.00 kg ha^{-1}) compared to the no crop residue application (2.75 kg ha^{-1}) (Table 2). The per cent increase in P uptake by cowpea seed with the application of crop residue at the rate of 2, 4 and 6 t ha^{-1} was 45.2, 78.5 and 123.4%, respectively over no crop residue application. Similarly, significantly higher phosphorus uptake by cowpea stover was recorded with the crop residue application at the rate of 6 t ha^{-1} (3.56 kg ha^{-1}), 4 t ha^{-1} (2.84 kg ha^{-1}) and 2 t ha^{-1} (2.29 kg ha^{-1}) compared to the no crop residue application (1.60 kg ha^{-1}). The total P uptake by cowpea crop followed the trend:

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crop residue application @ 6 t ha^{-1} (9.71 kg ha^{-1}) > 4 t ha^{-1} (7.76 kg ha^{-1}) > 2 t ha^{-1} (6.28 kg ha^{-1}) > no crop residue application (4.36 kg ha^{-1}).

The use of crop residue coupled with conservation tillage play a key role to sustain soil fertility, improving water use efficiency, soil microbial status, physical conditions of soils and enhance crop productivity. The enhancement in the crop yield might be due to cumulative effect on these soil properties. The crop residue application on soil surface also reduce the soil crusting by reducing the beating action of rains and bulk density which create the congenial condition for root proliferation [27]. This in turn provide more soil volume to plants to extract the nutrients including the P, resulting in more uptake of P as was observed in this study. Moreover, crop residues also contain the nutrients including P, which contributed to available P pool in soil after decomposition of the crop residue. Thus, residue application enhanced the soil P content and later uptake by the crops. Kouyaté et al. [41] reported that the addition of crop residues to the soil growing cereals increased their grain production by 37% as compared to when these were not added. In another study, it was reported that amongst tillage treatments, zero tillage with residue application during both *kharif* and *rabi* season and only during *rabi* season for four years significantly increased the seed yield of cowpea by 49 and 18%, respectively over control [42]. Kumawat at et [43] reported that crop residue retention significantly enhanced grain and straw yield of maize as compared to no residue retention. They also recorded the higher total P uptake with the application of crop residue retention as compared to the no crop residue retention. Sharma et al. [44] mentioned that the addition of crop residue increased the sorghum and castor yield over the no residue application and maintained the higher P uptake by crops in the crop residue treatments as compared to no crop residue application under conservation tillage practices. The increase in P uptake by crop could be attributed to higher yields as well as higher P content in grain and stover.

Effect on soil P fractions and their per cent contribution toward the total soil P

Results pertaining to the P fractions indicated that the water-soluble phosphorus (WS-P) in these soils varied from 12.42 to 19.56 kg ha^{-1} across the treatments as seen in Table 3. Significantly higher water-soluble phosphorus (19.56 kg ha^{-1}) was observed with the surface application of crop residue @ 6 t ha^{-1} followed by @ 4 t ha^{-1} (16.14 kg ha^{-1}) and 2 t ha^{-1} (13.94 kg ha^{-1}) compared to no crop residue application (12.42 kg ha^{-1}). Thus, the per cent increase in water-soluble P due to application of crop residue @ 2, 4 and 6 t ha^{-1} was to the extent of 12.2, 29.9 and 57.4%, respectively over no crop residue application. In the present study, the Al bound phosphorus (Al-P) was significantly influenced by the crop residue application and it varied from 64.89 to 91.20 kg ha^{-1}across the treatments (Table 3). The Al bound P (Al-P) was observed to be significantly higher with the surface application of sorghum residue @ 6 t ha^{-1} ((91.20 kg ha^{-1}) followed by @ 4 t ha^{-1} (82.94 kg ha^{-1}) and @ 2 t ha^{-1} (73.30 kg ha^{-1}) compared to no crop residue application (64.89 kg ha^{-1}). The increase in Al bound phosphorus (Al-P) with surface application of sorghum residue @ 2, 4 and 6 t ha^{-1} was to the extent of 12.9, 27.8 and 40.6%, respectively over the control.

The iron bound P (Fe-P) was significantly influenced by the added levels of the crop residues. The higher Fe-P was observed with the surface application of sorghum residue viz., 6 t ha^{-1} (118.88 kg ha^{-1}), 4 t ha^{-1} (103.16 kg ha^{-1}) and 2 t ha^{-1} (95.27 kg ha^{-1}) compared to no crop residue (80.28 kg ha^{-1}). Thus, the use of crop residue @ 2, 4 and 6 t ha^{-1} significantly influenced the Fe-P content which was 18.7, 28.5 and 48.1% higher compared to no residue application, respectively. The iron bound P (Fe-P) varied from 80.28 to 118.88 kg ha^{-1} across the different levels of crop residue application (Table 3). Similarly, the residue application significantly increased the calcium bound phosphorus (Ca-P) in soil which ranged from 24.80 to 36.07 kg ha^{-1}. Significantly higher calcium bound phosphorus (CA-P) was observed with the application of crop residue @ 6 t ha^{-1} (36.07 kg ha^{-1}), followed by @ 4 t ha^{-1} (32.52 kg ha^{-1}) and 2 t ha^{-1} (28.46 kg ha^{-1}) compared to no crop residue application (24.80 kg ha^{-1}). Results on Ca-P revealed that the crop residue treatments significantly influenced the Ca-P content which was 14.7, 31.1 and 45.5% higher as compared to no crop residue application in 2, 4, 6 t ha^{-1} crop residue application, respectively (Table 3).

Table 3: Effect of crop residue application on P fractions, total P and available P (kg ha^{-1}) in conservation tillage after eighteen years of experimentation.

Treatments	WS-P	Al-P	Fe-P	Ca-P	RS-P	Total-P	Avail-P
No crop residue (T_1)	12.42	64.89	80.28	24.8	87.76	270.15	16.47
2 t crop residue ha^{-1} (T_2)	13.94	73.3	95.27	28.46	93.93	304.89	18.72
4 t crop residue ha^{-1} (T_3)	16.14	82.94	103.16	32.52	99.9	334.66	21.79
6 t crop residue ha^{-1} (T_4)	19.56	91.2	118.88	36.07	114.43	380.13	25.48
CD (p=0.05%)	1.42	4.55	11.14	2.09	15.37	12.17	1.2

Abbreviations: WS-P: Water Soluble Phosphorus; Al-P: Aluminum-bound P; Fe-P: Iron-bound P; Ca-P: Calcium-bound P; RS-P: Reductant soluble P; Avail P: Available P.

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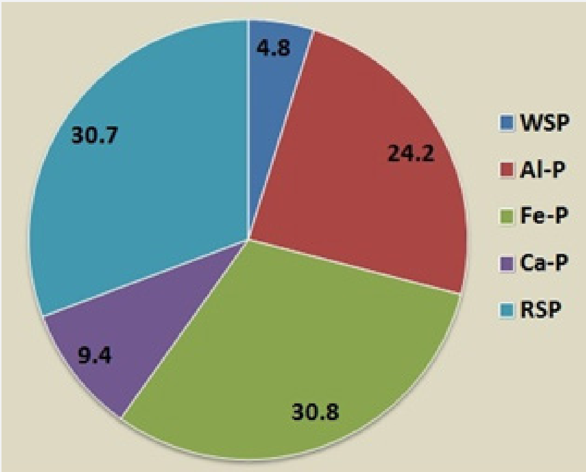

Figure 1: Per cent contribution of different P fractions (averaged over residue levels) toward the total soil P in conservation tillage.

In the current study, the reductant soluble phosphorus (RS-P) ranged from 87.76 to 114.43 kg ha^{-1}across the crop residue treatments (Table 3). Results of the current study highlighted that the significantly higher reductant soluble phosphorus was observed with the surface application of crop residue @ 6 t ha^{-1} (114.43 kg ha^{-1}) followed by @ 4 t ha^{-1} (99.90 kg ha^{-1}) and 2 t ha^{-1} (93.93 kg ha^{-1}) compared to no crop residue application (87.76 kg ha^{-1}). Thus, the increase in reductant soluble phosphorus due to application of sorghum residue @ 2, 4 and 6 t ha^{-1} was to the extent of 7.03, 13.83 and 30.39%, respectively, over no crop residue treatment (Table 3).

Effect on available P and total P

A significantly higher available phosphorus was recorded with the application of crop residue @ 6 t ha^{-1} (25.48 kg ha^{-1}) followed by @ 4t ha^{-1} (21.79 kg ha^{-1}) and 2 t ha^{-1} (18.72 kg ha^{-1}) compared to no crop residue (16.47 kg ha^{-1}) (Table 3). The application of crop residue @ 2, 4 and 6 t ha^{-1} increased the available phosphorus in soil to the extent of 13.7, 32.4 and 54.8%, respectively compared to no crop residue application. From the perusal of the data, it was observed that, the available phosphorus (Avail-P) in soil varied from 16.47 to 25.48 kg ha^{-1} across the surface residue treatments. Similarly, the total phosphorus (total-P) ranged from 270.15 to 380.13 kg ha^{-1} across the crop residue treatments. The application of sorghum residue @ 2, 4 and 6 t ha^{-1} increased the soil total phosphorus by 12.9, 23.9 and 40.7%, respectively over no crop residue application (Table 3).

Several researchers have reported that in the acid soils (pH 4.21- 5.67), having moderate to high organic carbon content, the Al-P was the chief form of inorganic fraction (Pi), followed by Fe-P [45]. Sahrawat [46] reported that the distribution of P in Indian Alfisols falling under the pH range of 5.5 to 6.8 was in order: Fe-P>Ca-P>Al-P. Gupta et al. [47] reported that the Fe-P was the dominant fraction of P in Alfisols. In our study, we also recorded the higher Fe-P fraction as compared to the other P fractions. About 55% share of the fractions was contributed by Fe-P and Al-P in our study. It was understood that in the present study, the P fractions were significantly affected by crop residue application in conservation tillage. It can be further explained that the addition of crop residue might have enhanced the rhizosphere activities due to more root growth proliferation which might have led to the dissolution of native P, and its dynamic transformation from one fraction to another fraction. The crop residue also serves as a C source for microbes which enhance the decomposition process of crop residues and could further contribute to the dissolution and transformation of P fractions in soil. Some other studies also reported that crop residue favored the build-up of labile inorganic and organic P at the expense of recalcitrant P [48,49]. It has been reported that due to acidification of soil the Fe and Al oxides get dissolved and they may release Al-P and Fe-P which too contribute to soil available P pool and become available to plants [50]. Several other studies have revealed that conservation tillage system led to significantly higher soil organic matter (SOM) content, total P, and available P concentrations compared with conventional tillage. Therefore, crop residue plays an important role in conservation tillage to control the mineralization and immobilization process of soil P, and can modify the P dynamics [43,48,51].

Inter- correlations and multiple regressions equation of different P fractions with total P and available P

The correlation coefficient values (r) among different soil P fractions, available P and total P ranged from 0.566 to 0.981 (Table 4). The result exhibited that P fractions, available P and total P have shown highly significant positive correlation among themselves, except Al-P and RS-P, which was found non-significant positive correlation. Simple linear regression equations were developed to predict the relationship of all the P fractions with total P content to understand the contribution of different fractions towards the total P content in the soil and to plan their best management for crop production.

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Multiple quantitative predictive relationships of total P with phosphorus fractions (WS-P, Al-P, Fe-P, Ca-P and RS-P) and available P in soils were worked out and the data are presented in Table 5. The coefficient of multiple determinations (R2) for total P and available P with phosphorus fractions were found to be 0.997 and 0.986, respectively which explained about 99.7 % to 98.6 % variation in the total P and available P, respectively due to simultaneous influence of phosphorus fractions. This study also showed that the WS-P, Al-P, Fe-P, Ca-P and RS-P played a positive role in contribution towards the total-P, while available-P was positively influenced by the WS-P, Al-P, Fe-P and Ca-P. Some of the phosphorus fractions viz., WS-P, Al-P, Fe-P and Ca-P were found to be common phosphorus fractions in positively influencing both total-P as well as available-P (Table 6 & 7).

Table 4: Correlation coefficients (r) among phosphorus fractions, available P and total P in soil.

P fractions	WS-P	Al-P	Fe-P	Ca-P	RS-P	Total-P	Avail- P
WS-P	1						
Al-P	0.930**	1					
Fe-P	0.907**	0.950**	1				
Ca-P	0.949**	0.920**	0.917**	1			
RS-P	0.788**	0.566	0.602*	0.766**	1		
Total-P	0.977**	0.933**	0.948**	0.974**	0.808**	1	
Avail- P	0.973**	0.960**	0.964**	0.962**	0.713**	0.981**	1

Abbreviations: WS-P: Water Soluble Phosphorus; Al-P: Aluminum-bound P; Fe-P: Iron-bound P; Ca-P: Calcium-bound P; RS-P: Reductant soluble P; Avail P: Available P. ** and * indicates significant at p = 0.01 and p = 0.05, respectively.

Table 5: Linear regression equations between total P, available P and P fractions.

Dependent variable	Linear regression equation	R^2
$Y_{total\ P}$	90.523+14.95 (WS-P)	0.986**
$Y_{total\ P}$	6.2587+4.0497 (Al-P)	0.987**
$Y_{total\ P}$	35.362+2.8884 (Fe-P)	0.993**
$Y_{total\ P}$	33.902+9.4726 (Ca-P)	0.988**
$Y_{total\ P}$	77.16+4.0363 (RS-P)	0.976**
$Y_{total\ P}$	77.455+11.884 (Avail P)	0.994**
$Y_{total\ P}$	-0.745 + 0.989 (WS-P) +1.000 (Al-P) + 0.966(Fe-P) + 1.105(Ca-P) + 1.012 (RS-P)	0.998**
$Y_{avail\ P}$	-1.698 + 0.544 (WS-P) + 0.024 (Al-P) + 0.083 (Fe-P) + 0.132 (Ca-P) – 003 (RS-P)	0.986**

Abbreviations: WS-P: Water Soluble Phosphorus; Al-P: Aluminum-bound P; Fe-P: Iron-bound P; Ca-P: Calcium-bound P; RS-P: Reductant soluble P; Avail P: Available P. ** indicates significant at p = 0.01.

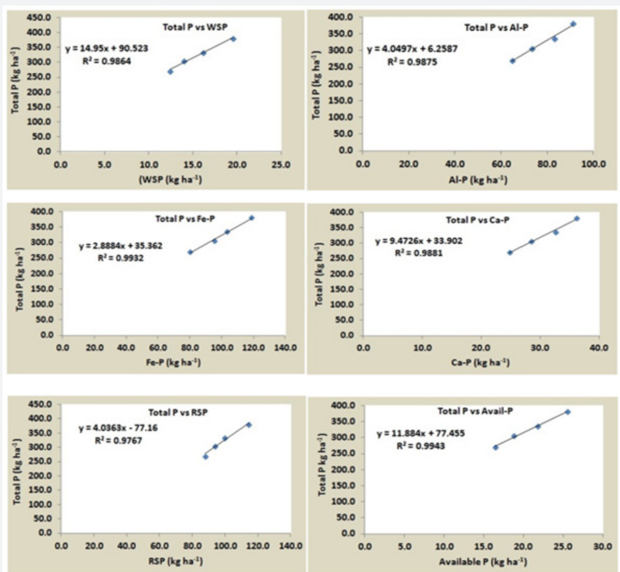

Figure 2: Linear relationships of different soil P fractions and avail P with total soil P.

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Inter-correlations and multiple regressions of different P fractions with sorghum yield and P uptake

The correlation coefficient values in case of sorghum grain yield, stover yield, grain P uptake, stover P uptake and total P uptake of sorghum and different soil phosphorus fractions (r) varied from 0.515 to 0.982 (Table 6). Similarly, all the fractions have shown highly significant positive correlation among themselves. Although, RS-P found to exhibit non-significant positive correlation with sorghum grain yield and stover yield.

Table 6: Simple correlation coefficients (r) among sorghum yield, P uptake, P fractions, available P and total P.

	Sorghum grain yield	Sorghum stover yield	Sorghum grain P uptake	Sorghum stover P uptake	Total crop P uptake	WS-P	Al-P	Fe-P	Ca-P	RS-P	Total P	Avail-P
Sorghum grain yield	1											
Sorghum stover	948**	1										
Sorghum grain P uptake	0.869**	0.821**	1									
Sorghum stover P uptake	0.885**	0.906**	0.855**	1								
Total P uptake	0.911**	0.901**	0.954**	0.971**	1							
WS-P	0.845**	0.873**	0.938**	0.938**	0.973**	1						
Al-P	0.854**	0.923**	0.890**	0.903**	0.931**	0.930**	1					
Fe-P	0.816**	0.848**	0.944**	0.831**	0.915**	0.907**	0.950**	1				
Ca-P	0.897**	0.887**	0.944**	0.947**	0.982**	0.949**	0.920**	0.917**	1			
RS-P	0.566	0.515	0.737**	0.764**	0.780**	0.788**	0.566	0.602*	0.766**	1		
Total P	0.840**	0.854**	0.960**	0.931**	0.980**	0.977**	0.934**	0.949**	0.974**	0.806**	1	
Avail-P	0.865**	0.883**	0.966**	0.908**	0.969**	0.973**	0.960**	0.964**	0.962**	0.713**	0.982**	1

Abbreviations: WS-P: Water Soluble Phosphorus; Al-P: Aluminum-bound P; Fe-P: Iron-bound P; Ca-P: Calcium-bound P; RS-P: Reductant soluble P; Avail P: Available P. ** and * indicates significant at p = 0.01 and p = 0.05, respectively.

Multiple quantitative predictive relationships of sorghum grain and stover yield, phosphorus uptake of grain and stover and total P uptake of sorghum crop with phosphorus fractions (WS-P, Al-P, Fe-P, Ca-P, RS-P), total P and Avail-Pin soils were worked out and the data are presented in Table 7. The coefficient of multiple determinations (R2) for grain yield, stover yield, grain P uptake, stover P uptake and total P uptake of sorghum with P fractions were found to be 0.866, 0.908, 0.967, 0.964 and 0.982, respectively which explained about 86.6, 90.8, 96.7, 96.4 and 98.2 % variation in the grain yield, stover yield, grain P uptake, stover P uptake and total P uptake by sorghum, respectively. This study also revealed that the WS-P, Ca-P and total-P played a positive role in grain yield, WS-P, Al-P, Ca-P and total-P played a positive role in stover yield; WS-P, Fe-P, Ca-P, total-P and avail-P played a positive role in grain P uptake; WS-P, Al-P, Ca-P, RS-P and total-P played a positive role in stover P uptake; and WS-P, Al-P, Ca-P, RS-P and total-P played a positive role in total P uptake of sorghum. Some of the P fractions viz., WS-P, Ca-P and total-P were found to be the common P fractions in positively influencing the sorghum grain yield, stover yield, grain P uptake, stover P uptake and total P uptake, in-turn, these fractions indicate their specificity or preference by sorghum crop.

Table 7: Multiple regressions between P fractions, total P and available P with sorghum yield and P uptake.

Dependent variable	Multiple regression equations	R^2
$Y_{\text{sorghum grain yield}}$	1461.430 + 44.29 (WS-P) - 8.481 (Al-P) - 6.170 (Fe-P) + 71.376 (Ca-P) - 10.703 (RS-P) +108.010 (Total-P) + 14.731 (Avail-P)	0.866**
$Y_{\text{sorghum stover yield}}$	3862.176 + 249.970 (WS-P) + 38.429 (Al-P) - 19.880 (Fe-P) + 181.924 (Ca-P) - 34.264 (RS-P) +17.281 (Total-P) -115.534 (Avail-P)	0.908**
$Y_{\text{sorghum grain P uptake}}$	-0.472 + 0.241 (WS-P) - 0.155 (Al-P) + 0.070 (Fe-P) + 0.143 (Ca-P) - 0.19 (RS-P) +108.739 (Total-P) + 0.438 (Avail-P)	0.967**
$Y_{\text{sorghum stover P uptake}}$	- 8.769 + 0.276 (WS-P) + 0.224 (Al-P) - 0.082 (Fe-P) + 0.413 (Ca-P) + 0.042 (RS-P) +64.321 (Total-P) -0.457 (Avail-P)	0.964**
$Y_{\text{sorghum total P uptake}}$	- 9.286 + 0.517 (WS-P) + 0.069 (Al-P) - 0.011 (Fe-P) + 0.556 (Ca-P) + 0.023 (RS-P) + 87.255 (Total-P) -0.022 (Avail-P)	0.982**

Abbreviations: WS-P=Water soluble phosphorus, Al-P=Aluminum-bound P, Fe-P=Iron-bound P, Ca-P=Calcium-bound P, RS-P=Reductant soluble P, Avail P=Available P. ** indicate significant at p = 0.01.

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Inter-correlations and multiple regressions of different P fractions with cowpea yield and P uptake

The values of correlation coefficients in case of cowpea seed yield, stover yield, seed P uptake, stover P uptake and total P uptake of cowpea and different soil phosphorus fractions (r) varied from 0.309 to 0.982 (Table 8). Similarly, all the fractions have shown highly significant correlation among themselves. While RS-P showed non-significant positive correlation with cowpea seed yield, stover yield, seed P uptake, stover P uptake, total P uptake and Al-P.

Multiple quantitative predictive relationships of yield and P uptake by cowpea crop with phosphorus fractions (WS-P, Al-P, Fe-P, Ca-P, RS-P), total P and Avail-P in soils were worked out (Table 9). Results showed that the coefficient of multiple determinations (R^2) for seed yield, stover yield, seed P uptake, stover P uptake and total P uptake of cowpea with P fractions were found to be 0.899, 0.912, 0.946, 0.971 and 0.964, respectively which explained about 89.9, 91.2, 94.6, 97.1 and 96.4 % variation in the seed yield, stover yield, seed P uptake, stover P uptake and total P uptake by cowpea, respectively. This study also revealed that the WS-P, Al-P and avail-P played a positive role in seed yield; WS-P, Al-P, Fe-P and avail-P played a positive role in stover yield; WS-P, Al-P, Fe-P and avail-P played a positive role in seed P uptake; WS-P, Al-P, Fe-P and total-P played a positive role in stover P uptake; and WS-P, Al-P, Fe-P and avail-P played a positive role in total P uptake of cowpea. Some of the P fractions viz., WS-P and Al-P were found to be common P fractions in positively influencing the cowpea seed yield, stover yield, seed P uptake, stover P uptake and total P uptake, in-turn, these fractions indicate their specificity or preference by cowpea crop.

Table 8: Correlation coefficients (r) among cowpea yield, P uptake, P fractions, available P and total P.

	Cowpea seed yield	Cowpea stover yield	Cowpea seed P uptake	Cowpea stover P uptake	Total crop P uptake	WS-P	Al-P	Fe-P	Ca-P	RS-P	Total P	Avail-P
Cowpea seed yield	1											
Cowpea stover yield	992**	1										
Cowpea seed P uptake	0.959**	0.979**	1									
Cowpea stover P uptake	0.943**	0.963**	0.962**	1								
Total P uptake	0.962**	0.982**	0.995**	0.985**	1							
WS-P	0.778**	0.828**	0.875**	0.829**	0.866**	1						
Al-P	0.879**	0.906**	0.943**	0.942**	0.951**	0.930**	1					
Fe-P	0.833**	0.873**	0.906**	0.923**	0.921**	0.907**	0.950**	1				
Ca-P	0.707*	0.761**	0.806**	0.795**	0.809**	0.949**	0.920**	0.917**	1			
RS-P	0.309	0.389	0.469	0.36	0.433	0.788**	0.566	0.602*	0.766**	1		
Total P	0.748**	0.804**	0.858**	0.826**	0.854**	0.977**	0.934**	0.949**	0.974**	0.806**	1	
Avail-P	0.7827**	0.871**	0.906**	0.887**	0.907**	0.973**	0.960**	0.964**	0.962**	0.713**	0.982**	1

Abbreviations: WS-P: Water Soluble Phosphorus; Al-P: Aluminum-bound P; Fe-P: Iron-bound P; Ca-P: Calcium-bound P; RS-P: Reductant soluble P; Avail P: Available P. ** indicates significant at p = 0.01.

Table 9: Multiple regressions between cowpea yield and P uptake with P fractions, available P and total P.

Dependent variable	Linear regression equation	R^2
$Y_{cowpea\ seed\ yield}$	345.411 + 42.008 (WS-P) + 9.777 (Al-P) - 1.403 (Fe-P) - 44.281 (Ca-P) - 8.729 (RS-P) - 134.439 (Total-P) + 81.132 (Avail-P)	0.899**
$Y_{cowpea\ stover\ yield}$	737.239 + 119.453 (WS-P) + 15.468 (Al-P) + 2.403 (Fe-P) - 91.957 (Ca-P) - 17.861 (RS-P) - 102.073 (Total-P) + 159.017 (Avail-P)	0.912**
$Y_{cowpea\ seed\ P\ uptake}$	-3.066 + 0.224 (WS-P) + 0.93 (Al-P) + 0.014 (Fe-P) -0.251 (Ca-P) - 0.14 (RS-P) - 37.295 (Total-P) + 0.218 (Avail-P)	0.946**
$Y_{cowpea\ stover\ P\ uptake}$	- 1.176 + 0.160 (WS-P) + 0.030 (Al-P) + 0.029 (Fe-P) - 0.062 (Ca-P) - 0.028 (RS-P) + 30.086 (Total-P) -0.036 (Avail-P)	0.971**
$Y_{cowpea\ Total\ P\ uptake}$	- 4.300 + 0.379 (WS-P) + 0.124 (Al-P) + 0.043 (Fe-P) - 0.315 (Ca-P) - 0.042 (RS-P) - 12.177 (Total-P) + 0.254 (Avail-P)	0.964**

Abbreviations: WS-P=Water soluble phosphorus, Al-P=Aluminum-bound P, Fe-P=Iron-bound P, Ca-P=Calcium-bound P, RS-P=Reductant soluble P, Avail P=Available P. ** indicates significant at p = 0.01.

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All the fractions of P increased with the addition of crop residue in this study. This finding is in close conformity with Lee et al. [52], who also observed a significant increase in all P fractions upon application of organic amendments. Ghosh et al. [53] reported that the addition of organic manure and residue incorporation reduces the fixation of P by blocking the P adsorption sites and thereby increasing the available pool of P. It has been reported that P fractions with yield and total P uptake by maize are positively and significantly correlated with each other. In this study, we also found a positive and significant correlation with the p fractions, total P, and available P [44,53]. In this study, we found that WS-P and Al-P were common factors that positively influenced both yield and P uptake by cowpea crops, while WS-P and Ca-P were common factors that positively influenced both yield and P uptake by sorghum. It has been reported that yield of crops and P uptake by crops was positively influenced by P fractions, and it depends upon the type of crop, type of crop residue, crop growth period, the uptake capacity of the roots, and the distribution of the requirement of P [44, 54]. Sharma et al. [44] reported that Fe-P and RS-P were the common P fractions that positively influenced both yield and total P uptake by castor, while WS-P, Fe-P, Ca-P, and RS-P were found to be common fractions influencing the sorghum yield and P uptake in rainfed Alfisols. From the correlation study, it was found that except for RS-P, other fractions positively correlated with the yield and uptake of P in both crops. It shows that these fractions positively contribute to the yield and P uptake of both crops.

Conclusion

The continuous use of different levels of crop residues for 18 years significantly increased the sorghum and cowpea crop yield and P uptake. In the current study, it has also been clearly established that the continuous use of crop residues for as long as 18 years played an important role in influencing the different P fractions (WS-P, Al-P, Ca-P, Fe-P, RS-P), available P, and total P in the sorghum-cowpea crop rotation. The WS-P and Ca-P fractions indicated their specificity by sorghum crop and positively influenced the sorghum grain yield, stover yield, grain P uptake and stover P uptake. While, the WS-P and Al-P positively influenced the cowpea seed yield, stover yield, seed P uptake and stover P uptake, indicating their preference for the cowpea crop. Different P fractions have significantly contributed toward the soil available P and total P. Further, most of these P fractions have shown highly positive and significant correlation among themselves, only except RS-P, indicating their dynamism in influencing the P transformation from one form to another and their influence on P availability in soil. Multiple regression relationships developed between crop yield, P uptake with P fractions (WS-P, Al-P, Fe-P, Ca-P, RS-P), total P, and avail-P in these soils could be useful in predicting or estimating the changes in the total P and available P from the unit changes in the P fractions. Therefore, the results of the current study will be highly useful in understanding the influence of crop residue application on the soil P fractions, P uptake, and their significant contribution toward the P uptake by the crops and consequently in crop yield enhancement. Therefore, in SAT rainfed conditions, it could be a soil-crop management technology for enhancing crop yield and P uptake. The addition of crop residues not only serves as a source of plant nutrients but also improves the soil's physical condition and microbial status, which leads to better uptake and higher crop yield. Therefore, the effect of crop residue application on soil physical properties and microbial properties needs to be investigated.

Acknowledgement

Author acknowledged the technical manpower support provided by the National Innovations in Climate Resilient Agriculture (NICRA) project during the study period.

References

1. Vance CP, Uhde Stone C, Allan DL (2003) Phosphorus acquisition and use: critical adaptations by plants for securing a nonrenewable resource. New Phytol 157: 423-447.

2. Elser JJ, Fagan WF, Kerkhoff AJ, Swenson NG, Enquist BJ (2010) Biological stoichiometry of plant production: metabolism, scaling and ecological response to global change. New Phytol 186: 593-608.

3. Assuero SG, Mollier A, Pellerin S (2004) The decrease in growth of phosphorus-deficient maize leaves is related to a lower cell production. Plant Cell Environ 27: 887-895.

4. Cross AF, Schlesinger WH (1995) A literature review and evaluation of the Hedley fractionation: Applications to the biogeochemical cycle of soil phosphorus in natural ecosystems. Geoderma 64: 197-214.

5. Von Wandruszka R (2006) Phosphorus retention in calcareous soils and the effect of organic matter on its mobility. Geochem Trans 7(6).

6. Sharpley AN, Weld JL, Beegle DB, Kleinman PJA, Gburek WL, et al. (2003) Development of phosphorus indices for nutrient management planning strategies in the United States. J Soil Water Conserv 58: 137-151.

7. Larsen S (1967) Soil Phosphorus. In: AG Norman [Ed], Advances in Agronomy 19: 151-210.

8. Zhu Y, Wu F, Feng W, Liu S, Giesy JP (2016) Interaction of alkaline phosphatase with minerals and sediments: activities, kinetics, and hydrolysis of organic phosphorus. Colloids Surf A: Physicochem Eng Asp 495: 46-53.

9. Das A, Roy A, Pal D, Chowdhury A (2022) Pools and Fractions of Inorganic Phosphorus in Indian Soil and Evolution of its Fractionation Schemes: A Mini Review. Biol Forum An Int J 14(3): 888-895.

10. Bünemann E, Heenan D, Marschner P, McNeill A (2006) Long-term effects of crop rotation, stubble management and tillage on soil phosphorus dynamics. Aust J Soil Res 44: 611-618.

11. Kothandaraman GV, Krishnamoorthy KK (1979) Forms of Inorganic Phosphorus in Tamil Nadu Soil. J Indian Soc Soil Sci 12: 243-248.

12. Kwabiah AB, Palm CA, Stoskopf NC, Voroney RP (2003) Response of soil microbial biomass dynamics to quality of plant materials with emphasis on P availability. Agric Ecosyst Environ 100(1): 53-61.

13. Nachimuthu G, Guppy C, Kristiansen P, Lockwood P (2009) Isotopic tracing of phosphorus uptake in corn from 33P labelled legume residues and 32P labelled fertilisers applied to a sandy loam soil. Plant Soil 314(1-2): 303-310.

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14. Wang XL, Yang ZL, Liu X, Huang G, Xiao W (2020) The composition characteristics of different crop straw types and their multivariate analysis and comparison. Waste Manag 110: 87-97.

15. Zhao X, Yuan G, Wang H, Lu D, Chen X (2019) Effects of Full Straw Incorporation on Soil Fertility and Crop Yield in Rice-Wheat Rotation for Silty Clay Loamy Cropland. Agronomy 9(3): 133.

16. Tan C, Cao X, Yuan S, Wang W, Feng Y, et al. (2015) Effects of long-term conservation tillage on soil nutrients in sloping fields in regions characterized by water and wind erosion. Sci Rep 5(1): 17592.

17. Zhang SJ, Zhang G, Wang DJ, Liu Q (2021) Abiotic and biotic effects of long-term straw retention on reactive nitrogen runoff losses in a rice-wheat cropping system in the Yangtze Delta region. Agric Ecosyst Environ 305: 107162.

18. Damon PM, Bowden B, Rose T, Rengel Z (2014) Crop residue contributions to phosphorus pools in agricultural soils: a review. Soil Biol Biochem 74: 127-137.

19. Nest TV, Ruysschaert G, Vandecasteele B, Houot S, Baken S, et al. (2016) The long-term use of farmyard manure and compost: effects on P availability, orthophosphate sorption strength and P leaching. Agric Ecosyst Environ 216: 23-33.

20. Ding L, Wu J, Xiao H, Zhaou P, Syers JK (2011) Mobilization of inorganic phosphorus induced by rice straw in aggregates of a highly weathered upland soil. J Sci Food Agric 92(5): 1073-1079.

21. Mitran T, Mani PK, Basak N, Majumder D, Roy M (2015) Long-term manuring and fertilization influences soil inorganic phosphorus transformation vis-avis rice yield under rice-wheat cropping system. Arch Agron Soil Sci 62(1):1-18.

22. Espinosa D, Sale P, Tang C (2017) Effect of soil phosphorus availability and residue quality on phosphorus transfer from crop residues to the following wheat. Plant Soil 416: 361-375.

23. Yu YY, Turner NC, Gong YH, Li FM, Fang C, et al. (2018) Benefits and limitations to straw- and plastic-film mulch on maize yield and water use efficiency: A meta-analysis across hydro-thermal gradients. Eur J Agron 99: 138-147.

24. Yang HK, Wu G, Mo P, Chen SH, Wang SY, et al. (2020) The combined effects of maize straw mulch and no-tillage on grain yield and water and nitrogen use efficiency of dry-land winter wheat *(Triticum aestivum L.)*. Soil Till Res 197: 104485.

25. Cai T, Zhang C, Huang Y, Huang H, Yang B, et al. (2015) Effects of different straw mulch modes on soil water storage and water use efficiency of spring maize *(Zea mays L.)* in the Loess Plateau of China. Plant Soil Environ 61: 253-259.

26. Xu J, Han HF, Ning TY, Li ZJ, Lal R (2019) Long-term effects of tillage and straw management on soil organic carbon, crop yield, and yield stability in a wheat-maize system. Field Crop Res 233: 33-40.

27. Indoria AK, Rao CR, Sharma KL, Reddy KS (2017a) Conservation agriculture- a panacea to improve soil physical health. Curr Sci 112(1): 52-61.

28. Indoria AK, Sharma KL, Reddy KS, Rao CS, Srinivas K, et al. (2018) Alternative sources of soil organic amendments for sustaining soil health and crop productivity in India - impacts, potential availability, constraints and future strategies. Curr Sci 115 (11): 2025-2062.

29. Jakab G, Madarász B, Szabó JA, Tóth A, Zacháry D, et al. (2017) Infiltration and soil loss changes during the growing season under ploughing and conservation tillage. Sustainability 9(10): 1726.

30. Wang JB, Chen ZH, Chen LJ, Zhu AN, Wu ZJ (2011) Surface soil phosphorus and phosphatase activities affected by tillage and crop residue input amounts. Plant Soil Environ 57: 251-257.

31. Bezerra RPM, Loss A, Pereira MG, Perin A (2015) Phosphorus fractions and correlation with soil attributes under no-tillage and crop-livestock integration systems in Cerrado of Goias. Semin Cienc Agrar 36: 287-306.

32. Ligang Lv, Gao Z, Liao K, Zhu Q, Zhu J (2023) Impact of conservation tillage on the distribution of soil nutrients with depth. Soil Till Res 225: 105527.

33. Kampen J, Burford JR (1980) Production systems soil-related con straints and potentials in the semi-arid tropics with special reference to India. In 'Priorities for Alleviating Soil Related Constraints to Food Production in the Tropics'. Symposium Proceedings, IRRI, Los Banos, Laguna, Philippines pp: 141-145.

34. ICRISAT (2022) Alfisols of the Semi-Arid Tropics: Problems and Potentials.

35. Indoria AK, Sharma KL, Reddy KS, Rao CS (2017b) Role of soil physical properties in soil health management and crop productivity in rainfed systems-I: Soil physical constraints and scope. Curr Sci 112(12): 2405-2414.

36. Indoria AK, Sharma KL, Reddy KS, Rao CS (2016) Role of soil physical properties in soil health management and crop productivity in rainfed systems-II. Management technologies and crop productivity. Curr Sci 110(3): 320-328.

37. Chang SC, Jackson ML (1957) Fractionation of soil phosphorus and the environment. ASA, CSSA, and SSSA, Madison, WI. Soil Science 84: 133-44.

38. Peterson GW, Corey RB (1966) A modified change and Jackson's procedure for routine fractionation of inorganic soil phosphate. Proceedings of Soil Science Society of America 30: 563.

39. Olsen S, Cole C, Watanabe F, Dean L (1954) Estimation of available phosphorus in soils by extraction with sodium bicarbonate. United States Department of Agriculture Circular pp: 939.

40. Jackson ML (1973) Soil Chemical Analysis. Prentice Hall (India) Pvt Ltd, New Delhi.

41. Kouyaté Z, Franzluebbers K, Anthony SR, Lloyd J, Hossner R (2000) Tillage, crop residue, legume rotation, and green manure effects on sorghum and millet yields in the semiarid tropics of Mali. Plant Soil 225: 141-151.

42. Sasode DS, Joshi E, Jinger D, Sasode RS, Gupta V (2020) Conservation tillage and weed management practices effect on weeds, yield and profitability of cowpea (Vigna unguiculata). Indian J Agric Sci 90(1): 86-90.

43. Kumawat C, Sharma VK, Meena MC, Dwivedi BS, Barman M, et al. (2018) Effect of crop residue retention and phosphorus fertilization on P use efficiency of maize and biological properties of soil under maize-wheat cropping system in an Inceptisol. Indian J Agric Sci 88: 1184-1189.

44. Sharma KL, Indoria AK, Srinivas K, Reddy KS, Charry GR, et al. (2020) Effect of Long-Term Use of Tillage, Crop Residue and N Application on Phosphorus Fractions in Soil under Sorghum (Sorghumvulgare) (L.)-castor System (Ricinus Communis) in Rainfed Alfisol Soils. Commun Soil Sci Plant Anal 51(1): 1-13.

45. Dutta S, Mukhopadhyay D (2007) Fractionation of inorganic phosphorus in some acid soils of West Bengal, (India). Asian J Soil Sci 2(1): 18-23.

46. Sahrawat KL (1977) EDTA extractable phosphorus in soils as related to available and inorganic phosphorus forms. Commun Soil Sci Plant Anal 8(4): 281-287.

47. Gupta AK, Tripathi LK, Patra PK (2022) Distribution of phosphorus fractions in different soil orders of Indo-Gangetic plains of India. Ann Plant Soil Res 24(2): 221-225.

How to cite this article: A K Indoria, Munna Lal1, K Srinivas, K L Sharma, K Sammi R, S Kundu, et al. Effect of Eighteen Years of Continuous Crop Residue Application on Crop Yields, Soil P Fractions, and Crop P Uptake in Conservation Tillage Under Semi-Arid Tropical Rainfed Conditions. Agri Res& Tech: Open Access J. 2024; 28(5): 556426. DOI: 10.19080/ARTOAJ.2024.28.556426

48. Reddy D, Kushwah S, Srivastava S, Khamparia RS (2014) Long-term wheat residue management and supplementary nutrient input effects on phosphorus fractions and adsorption behavior in a Vertisol. Commun Soil Sci Plant Anal 45: 541-554.

49. Appelhans SC, Novelli LE, Melchiori RJM, Boem FHG, Caviglia OP (2021) Crop sequence and P fertilization effects on soil P fractions under no-tillage. Nutr Cycl Agroecosyst 120: 275-288.

50. Zhang S, Yang X, Hsu L, Liu Y, Wang S, et al. (2021) Soil acidification enhances the mobilization of phosphorus under anoxic conditions in an agricultural soil: Investigating the potential for loss of phosphorus to water and the associated environmental risk. Sci. Total Environ 793: 148531.

51. Kumar A, Behera UK, Dhar S, Shukla L, Bhatiya A, et al. (2018) Effect of tillage, crop residue and phosphorus management practices on the productivity and profitability of maize cultivation in Inceptisols. J Agric Sci 88: 1558-1167.

52. Lee CH, Park CY, Park KD, Jeon WT, Kim PJ (2004) Long-term effects of fertilization on the forms and availability of soil phosphorus in rice paddy. Chemosphere 56: 299-304.

53. Ghosh D, Mandal M, Pattanayak SK (2021) Long Term Effect of Integrated Nutrient Management on Dynamics of Phosphorous in an Acid Inceptisols of Tropical India. Commun Soil Sci Plant Anal 52(19): 2289-2303.

54. Shen J, Li R, Zhang F, Fan J, Tang C, et al. (2004) Crop yields, soil fertility and phosphorus fractions in response to long-term fertilization under the rice monoculture system on a calcareous soil. Field Crops Res 86(2-3): 225-238.

DOI: 10.19080/ARTOAJ.2024.28.556426

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