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PHOSPHORUS FERTILIZATION AND ITS TRANSFORMATIONS IN DIFFERENT SOILS UNDER DRY DIRECT-SEEDED RICE: AN EXPERIMENTAL ANALYSIS

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ABSTRACT

It was decided to undertake a greenhouse experiment on dry direct-seeded rice (DSR) to investigate the influence of three different amounts of fertilizer P (0, 6.5, and 13 mg kg-1 soil) administration on the changes in P fractions in soils with varied Olsen-P and texture in ten distinct soils. When comparing the administration of P fertilizer to the no-P treatment at the maximum tillering stage, the concentration of Ca-P fraction rose by a substantial amount. The increase in Ca-P fraction at flowering was statistically significant only when 13 mg P kg-1 was applied in comparison to no P administration. The values of the Fe-P and Al-P fractions were not substantially different regardless of the initial Olsen-P concentration or the amount of P applied to the sample. At both the maximal tillering and blooming phases of DSR, the concentration of Olsen-P in soils rose considerably with the use of P fertilizer compared to the no-P control when P fertilizer was applied. Excessive phosphorus (P) treatment may affect soil P availability and restrict plant development by compacting the soil and causing the fixation of P into distinct organic and inorganic forms in different plant tissues. However, it is still unclear whether these changes occur as a result of insufficient fertilization or as a result of an excessive rate of fertilization administered under the winter wheat cropping scheme. The present research aims to determine the transformation of phosphorus (P) into distinct organic (Po) and inorganic (Pi) fractions, as well as their roles in plant P absorption and winter wheat (Triticumaestivum L.) production, to improve crop productivity.

Keywords: Excessive phosphorus, organic, inorganic, fertilization, excessive rate, wheat

INTRODUCTION

The efficiency of phosphorus (P) usage in agricultural systems is very poor, with crops using about 10–20 percent of the fertiliser P applied to them (Johsnton and Syers 2009). As a result of interactions with aluminium (Al) and/or iron (Fe) in acidic soils, as well as reactions with calcium (Ca) in neutral to alkaline soils (Soffe 2003; Mitran et al. 2016), fertiliser P is often transformed to forms that are basically insoluble under aerobic or upland conditions (Sanchez and Uehara 1980). Because of the higher concentration of phosphorus in soil solution under decreased conditions, flooding rice soils are regarded to be less deficient in phosphorus than upland crops (De-Datta 1981). P transformations in lowland rice cropping systems that are subjected to alternating soaking and drying cycles have received significant attention in the literature (Yadvinder-Singh et al. 2000; Huguenin-Elie et al. 2003; Gupta et al. 2007; Mitran et al. 2016). In order to deal with the scarcity of labour during the transplanting process and the depletion of water resources, dry direct-seeded rice (DSR) is currently being advocated as a substitute for puddled transplanted rice. Furthermore, the cultivation of DSR contributes to the improvement of soil physical health, which would otherwise be harmed by the puddling that occurs in the transplanted rice field. When comparing DSR to transplanted rice, the phosphorus changes will be much more pronounced under DSR. P changes in soils under DSR, on the other hand, are less well understood. It is also critical to understand the distribution of P fractions in soil in order to comprehend the processes of repositioning. A few studies have been conducted on the transformation of administered P fertiliser into distinct P fractions during the development of DSR in soils with varied pH, texture, and accessible P. However, further research is needed. The purpose of this research is to determine the changes in soil P fractions after P fertilisation in various soils during the maximum tillering and blooming phases of DSR in different soils.

Phosphorus (P) is one of the most essential nutrients in the agricultural system, and it is one of the nutrients that has the greatest impact on crop productivity. The usage of phosphorus fertiliser in agriculture has expanded dramatically during the last five decades in order to feed a growing world population. A global inorganic P fertiliser use grew from 11.0 Tg (1012 g) P2O5 year1 to 47 Tg P2O5 year1. The use of P fertilisers increases the available amounts of P in the soil and the amount of crop produced. When comparing the output of P applied to soil with the input of P applied to soil for crop consumption, the application of P to soil gives only 10–20 percent output. A further projection for 2050 is a 50% increase in the amount of representative P nutrient used in agriculture compared to 2010 levels, in order to fulfil increased food demand due to population expansion throughout the world. Because of the growth in the usage of phosphorus fertiliser, it is possible that more phosphorus may be lost to the environment. Increased phosphorus losses in surface waters have a negative influence on ecosystems and biodiversity. The majority of soils in North-West China are poor in phosphorus. Because of this widespread practise of P fertilisation to assure adequate P supply, serious soil environmental issues such as P leaching, soil hardness and acidification, and deterioration of soil fertility have resulted in recent years.

A greater rise in local fertiliser application of P fertiliser in an agricultural environment might temporarily enhance the amount of P accessible for crops, however larger application rates affect the bioavailability of P in the soil medium.

Phosphorus is a highly reactive element in its elemental form. Large amounts of fertiliser applied to soils have an impact on deposition as well as on P cycling. The response of plants to various soil conditions and phosphorus fertiliser inputs is a popular research issue. The question of whether P supplied to the soil has an impact on P restrictions on a broad scale has been examined in research. A significant amount of uncertainty exists, however, regarding the P found in different forms adsorbed on the soil surface with different elements (i.e., iron (Fe), aluminium (Al), and calcium (Ca), which differ in their bioavailability, mobility, and behaviour in the soil depending on the pH of the soil, the parent material, and the fertilisation background. Because of this, it is critical to evaluate the impacts of P application on P limitation using a variety of fertiliser rates and varied technique of delivery. Further research into the impact of varied P input rates on P fractions, as well as the link between P fractions and crop productivity and availability, is required.

The availability of phosphorus in soil is strongly reliant on the P fractions present, which in turn influence its primary production. When high rates of P fertilisation are used, the development of non-labile P forms occurs quickly. Because the amount of P fertiliser applied exceeds the amount of P produced by crops, P accumulates in the soil over time. Popular P fractionation techniques allow for the examination of the destiny of P delivered to soils as well as the interaction between soil P nutrition, P forms, and absorption by plants in a given season. In order to strategically optimise the long-term usage of phosphorus, it is necessary to assess the different P forms and their features following a long-term fertilisation background.

Different fractions of soil inorganic P (Pi) exist, including labile (NaHCO3-Pi), moderately labile (NaOH-Pi, HClD-Pi, and non-labile (HClC–Pi) P; Fe– and Al–P (non-occluded Fe– and Al–bound P); and residual Pi (non-occluded Fe– and Al–bound Pi) (P occluded within Fe oxides). A more stable form of Pi, such as those absorbed on the surfaces of metals Ca, Al, and Ca (Ca–P, Al–P, Fe–P, and Residual–P), as well as sequenced Pi fractionation, have been discovered. It is common practise not to further fractionate HCl-Pi fractions since, in non-calcareous soils, these sub-fractions are rather insignificant, but in calcareous soils, they make a significant contribution.

The application of phosphorus to soil may have an impact on soil P forms via a variety of biogeochemical processes. A change in soil microbial activity, for example, may result from a change in P input, which can result in the mineralization of organic P fractions into inorganic Pi. Combining P and N treatment may affect the soil pH via nitrification, resulting in a decrease in soil pH and the generation of organic P, which stimulates primary crop production and the P need of plants. When N is applied to the soil, it mobilises Al and Fe in the soil and causes P sorption on the soil's surface, which results in the transformation of labile Pi and Po into moderately accessible P or resistant P.

Because of the high rate of phosphorus delivery, low plant absorption efficiency is a serious challenge. When the amount of P fertiliser applied rises in relation to the amount of P produced by the crop, the amount of P fixed in the soil increases over time owing to the reduced mobility of the P nutrient. Furthermore, the application of P in conjunction with N may also cause fixation, resulting in the formation of acidic conditions in soil. As a result, in order to solve the issue of long-term P fertilisation, it is necessary to determine the forms and behaviours of P in the soil following continuous fertilisation in a winter wheat cropping system.

The fractionation method of Hedley, as refined by Tiessen and Moir, has been extensively used to examine the P forms present in soils for many years. This system distinguishes between distinct P forms, such as organic and inorganic fractions, which are determined by the influence of various soil variables, such as pH, soil moisture, and fertilisation, among others. However, only a few research have been conducted to determine the exact reasons of the impacts of phosphorus fertilisation on crop output and P fixation in loess soils as a result of long-term fertiliser application. Because of this, the purpose of this research is to (I) understand the fluctuations in soil P fractions caused by long-term P application, as well as to (II) understand the effect of P fractions on crop production and nutrient absorption in North-Western China's loess soils. With this research, we want to get better insight into the mechanisms of soil P cycling, which are influenced by changes in different organic and inorganic P fractions as a consequence of long-term fertilisation.

MATERIALS AND METHODS

During 2012, a greenhouse experiment was carried out to investigate the effect of three different levels of P application (Olsen-P: 0, 6.5, and 13 mg kg-1 soil) on the changes in P fractions in ten different soils with varying Olsen-P and texture at the maximum tillering (MT) and flowering (FL) stages of DSR. Bulk soil samples (0-15 cm in diameter) taken from various places in Punjab (India) were air-dried and put through a 2-mm screen before being subjected to conventional analytical procedures to determine essential physical and chemical parameters, such as pH. (Table 1). We filled each pot (which measured 20 cm in height and 20 cm in diameter) with 4 kilogramme of the dry soil. Soil samples were taken from two different development phases in separate pots. As a result, there were 18 pots for each soil. Phosphorus was administered to the pots in the form of monoammonium phosphate in accordance with the instructions. A uniform amount of N (75 mg N kg-1 soil) in the form of urea, K (25 mg K kg-1 soil) in the form of potassium chloride, and Zn (30 mg Zn kg-1 soil) in the form of zinc sulphate were administered to all pots. In order to preserve field capacity, the soil moisture was maintained. The pots were put in a totally random block pattern with no rhyme or reason (CRD). Three times, the therapies were carried out. In each pot, about 10 seeds of rice (cultivar PR 114) were sowed, and five seedlings were kept once they had established themselves. Beginning 20 days after sowing, the crop was sprayed with 1 percent solution of ferrous sulphate three times (5 times for loamy sand soil) at a weekly interval in order to alleviate the iron deficiency problem. In order to keep soil moisture at about field capacity during the growth season, all pots were watered on a daily basis. Soil sample and analysis are required. Initially, soil samples were ground to pass through a 2-mm sieve and then processed and analysed for pH, electrical conductivity (EC; 1:2 soil–water), cation exchange capacity (CEC), organic C (OC) (Walkley and Black 1934), NaHCO3–extractable P (Olsen et al. 1954), NH4OAc–extractable K (Merwin and Peech 1950), and particle size distribution (Merwin and Peech 1950). (Day 1965). For the purpose of identifying the textural class, the USDA textural triangle was employed. At the MT and blooming phases, soil samples were obtained from the pots and used to assess the presence of several inorganic P (Pi) forms, including Olsen-P, Al-P, FeP, and Ca-P, using a stepwise extraction procedure similar to that described by Chang and Jackson (1965). The ascorbic acid technique was used to determine the amount of phosphorus present in the soil extracts (Watanabe and Olsen 1965). Statistics are used in this study. Analysis of variance (ANOVA) was performed on the soil P fraction data using a totally randomised design for the data on soil P fractions. To determine the significance of differences between two treatment means, the least significant difference (LSD) at the 0.05 level of probability was employed to test the hypothesis.

RESULTS AND DISCUSSION

The Influence of Soil Characteristics at the MT stage, the levels of Ca-P varied from 155-292 mg kg-1 in low P soils, 128-262 mg kg-1 in medium P soils, and 176-281 mg kg-1 in high P soils, respectively (Table 2). In low-phosphorus soils, the Ca-P fraction rose as the pH of the soil increased. For example, S3 had higher Ca-P concentrations than S2 (which had a pH of 7.24), which had a pH of 8.11. S7 soils with the lowest Ca-P fraction showed a similar tendency to S7 soils with medium P. (pH 6.9). In soils containing high quantities of P, a similar trend in Ca-P was found. At the MT stage, it was discovered that the values of the Ca-P percentage had decreased from their start levels in all of the soils (45 days after sowing). It was discovered that the difference in Ca-P concentration between the initial and MT stages reduced as we progressed from low- to high-P category soils. During the 45-day period, it seems that rice absorption of calcium and phosphorus was greater from low P soils than from high P soils (Table 2). During the blooming stage, the average values of Ca-P fraction varied from 95-234 mg kg-1 in low-phosphorus soils to 94-229 mg kg-1 in medium-phosphorus soils and 157-263 mg kg-1 in high-phosphorus soils. According to the data, the highest uptake of Ca-P values occurred between the MT and flowering stages of the plant. Taking soil texture into account, the amount of calcium and phosphorus in the soil dropped as the clay concentration rose. For example, while both soils had the same pH, coarse textured soil (S8) had a larger concentration of calcium and phosphorus than fine textured soil (S1). According to the findings of Mostashari et al. (2008), finer soil particles have a negative connection with the Ca-P percentage of the soil.

Table 1. Physicochemical properties of the soils

Soil No.	S1	S2	S3	S4	S5	S6	S7	S8	S9	S10
pH (1:2)	7.7	7.2	8.1	7.3	7.4	7.8	6.9	7.7	7.3	8
EC (dS m-1)	0.3	0.2	0.4	0.2	0.1	0.6	0.2	0.3	0.3	0.2
NH4OAC-K (kg ha-1)	140	72	240	82	71	492	162	291	257	184
OC (g kg-1)	5.9	2	6.2	5.2	3.2	8	6.7	3.9	5.4	6
Al-P (mg kg-1 soil)	11.4	12.3	10.7	12.1	12	11.4	12.9	11.1	11.8	11
Fe-P (mg kg-1 soil)	22.6	24.8	20.8	24.8	23.7	22.7	25.2	22.2	23.9	20.7
Ca-P (mg kg-1 soil)	232	155	292	162	192	262	128	245	176	281
CEC [cmol(p+)kg -1]	6.9	5.6	7.4	6.2	6.6	7.9	6.9	6.6	7.7	7.7
Olsen-P (mg kg-1)	2.4	35.2	5.2	6.7	6.9	7.4	8.7	10.2	12.5	14.7
Textural class	Clay loam	Loamy	Loam	Sandy	Loamy	Loam	Sandy clay	Sandy loam	Sandy clay loam	Sandy loam
Percentage of silt	44	3.3	33.3	8	3.7	36.4	17.4	13.1	13.8	9.6
Percentage sand	25.7	88.8	46.8	80	86.4	41.7	52.6	72.9	66.2	76.5
Percentage clay	30	8	20	12	10	22	30	14	20	14

Table 2. Changes in P fractions (mg kg-1) in different soils at maximum tillering and flowering stages of DSR

Soil No./ P status	Maximum tillering stage			
	Al	Fe-P	Olsen-P	Ca-P
S1 LOW	9.8	22	5.4	209
S2 LOW	10.3	24.8	7.3	152
S3 LOW	9.1	20	9.3	290
S4 MEDIUM	10.4	24.5	9.7	161
S5 MEDIUM	10.2	23.4	10.2	196
S6 MEDIUM	9.5	21.7	10.5	263
S7 MEDIUM	10.6	25.3	11.1	125
S8 HIGH	9.3	21.9	12.7	251
S9 HIGH	9.9	23.7	14.2	184
S10 HIGH	9.2	20.2	16.4	293
LSD (P=0.5)	NS	NS	3.5	25.8
Flowering stage				
S1 LOW	9.5	21.8	3.9	153
S2 LOW	10	24.3	4.4	95
S3 LOW	8.59	19.5	4.6	234
S4 MEDIUM	9.7	24	4.9	114
S5 MEDIUM	9.7	22.8	5.1	146
S6 MEDIUM	9.1	21.1	5.3	229
S7 MEDIUM	10	24.8	5.6	94
S8 HIGH	8.7	21.5	6.5	222
S9 HIGH	9.4	23.2	6.9	157
S10 HIGH	806	19.6	8.6	263
LSD (P=0.5)	NS	NS	2.4	23.4

Al-P fraction values in soils classified as low, medium, and high in Olsen-P at the MT stage were between 9.1-10.3, 9.5-10.7, and 9.3-9.9 mg kg-1 in soils characterised as high in Olsen-P. 20.1-

24.8 mg kg-1 for Fe-P fraction, 21.7-25.3 mg kg-1 for Fe-P fraction, and 20.2- 23.7 mg kg-1 for Fe-P fraction, respectively (Table 2). When comparing the initial levels of Al-P in soils to the MT stage, there was only a little change in Al-P content (Tables 1 and 2). The pH of the soils utilised in our investigation ranged from 6.90 to 8.11, at which point there was negligible absorption of P from the Al-P fraction, as expected. Fe-P fraction values ranged from 19.5-24.3 mg kg-1 during blooming stage to 21.1-24.8 mg kg-1, 19.6-23.2 mg kg-1, and 19.6-23.2 mg kg-1 at the end of flowering stage (Table 2). According to the findings above, DSR did not absorb significantly less P from the Fe-P and Al-P fractions as compared to the Ca-P fraction. It has also been shown by Abolfazli et al. (2012) that Ca-P is the most prevalent type of P in calcareous soils, while Fe-P and Al-P fractions prevail in acidic soils. Olsen-P content ranged from 5.40 to 9.31 mg kg-1 in soils classified as low, medium, and high in Olsen-P content, respectively. The values of Olsen-P content ranged from 9.75 to 11.4 mg kg-1 in soils classified as low, medium, and high in Olsen-P content, respectively (Table 2). It was discovered that pH had no effect on Olsen–P concentrations at either the MT or blooming phases of the experiment (Tables 1 and 2). This is understandable since the variation in soil pH in the soils under investigation was too tiny to have an impact on Table 2. Table 2 shows the results of the research. A comparison of changes in P fractions (mg kg-1) in several soil types during the maximal tillering and blooming periods of DSR Soil No./Potential Status Stage of tillering at its most extreme Ca-Al-Fe-Olsen-P Ca-Al-Fe-Olsen-P Ca-Al-Fe-Olsen-P Ca-Al-Fe-Olsen-P LSD (P=0.05): S1-Low 209 9.81 22.1 5.40 S2 -Low 152 10.3 24.8 7.37 S3-Low 290 9.1 20.1 9.31 S4-Middle 161 10.42 24.5 9.75 S5-Middle 196 10.21 23.4 10.26 S6-Middle 263 9.51 21.7 10.53 S7-Medium 125 10.66 25.3 11.14 S8-High 251 9. NS 25.8 NS 3.57 NS Stage of flowering S1-Low 153 9.57 21.8 3.92 S2 -Low 95 10.0 24.3 4.40 S3-Low 234 8.53 19.5 4.64 S4-Medium 114 9.72 24.0 4.97 S5-Medium 146 9.77 22.8 5.19 S6-Medium 229 9.11 21.1 5.31 S7-Medium 94 10.7 24.8 5.60 S8-High 222 8.78 21.5 6.50 S9-High 157 9.45 23.2 Any changes in Olsen-P. 23.4 NS NS 2.41 any changes in Olsen-P. When comparing soils with high available P status to soils with low available P status, a greater reduction in the Olsen-P concentration was seen during the blooming stage. It is possible that the slight drop in Olsen-P concentration in S1 with clay loam texture occurred as a result of increased P fixation in clay loam texture relative to other soils throughout both development stages. It was discovered by Ishizuka (1965) that the proportion of Olsen-P reduced immediately after rice was transplanted, then climbed slowly and reached a high before blooming, before declining until the dough stage.

CONCLUSION

The Ca-P concentration of soils rose as the pH of the soil and the amount of sand in the soil increased. As a result of the administration of P fertilisers during the maximum tillering stage, the concentration of the Ca-P fraction rose. The values of the Fe-P and Al-P fractions did not change considerably throughout the development of the DSR, indicating that the two fractions did not absorb much P during the process. When comparing soils with high available P status to soils with low available P status, a greater reduction in the Olsen-P was seen during the blooming stage. The use of fertiliser P has a considerable impact increased the Olsen-P content in soil compared to noP.

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