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MAPPING OF SOME MAIZE GROWING AREAS OF DISTRICT SWABI ON THE BASIS OF PHOSPHOROUS MINERALIZATION

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Abstract

Laboratory incubation study was conducted to assess the changes in soil Phosphorous concentration of some maize growing areas of district Swabi with time. A total of twenty two rhizosphere soil samples were collected from important soil series of some maize growing areas of district Swabi. 400 g soil from each series was incubated for 6 weeks at field moisture condition and 25±2°C.Phosphorous was determined periodically after each week. All the soils were also analyzed for physico-chemical properties and micronutrient status. Almost all the soil samples were found normal, alkaline in reaction, low in organic matter content and slightly to strongly calcareous in nature, all the soil samples were found silty clay loam in texture except Chota Lahore soil which was found sandy loam in texture. Results showed periodical changes in soil AB-DTPA extractable Phosphorous over incubation period. When averaged across all soil series Phosphorous at beginning time (week 0) gradually increased from 8.15 to 9.14 at week 2 which declined at week 3 to 8.84 and increased again to 12.0 at week 5 but then declined again to 9.89 at week 6. Mean rate of Phosphorous turnover was -0.32, 0.46, 0.20, 0.57, 0.7 and 0.28 mg kg^{-1} wk^{-1} at week 1, 2, 3, 4, 5 and 6 respectively. This mineralized Phosphorous from insoluble sources should be considered while making recommendation for low or medium Phosphorous soils.

Keywords: Incubation, Mineralization, Mapping, Swabi

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1. Introduction

Life in any form on earth planet is impossible without Phosphorous (P). No plant can produce normal growth or give a good yield if it suffers from P deficiency. Phosphorous is a fascinating plant nutrient and it is involved in a wide range of plant process from permitting cell division to the development of a good root system and ensures timely and uniform maturation of plants (Mengel and Kirkby 2000).

It is needed mostly by young, fast growing tissues and performs a number of functions related to plant growth (Tandon, 1987).Pakistani soils are deficient in nitrogen and nearly 80 % of our soils lack adequate amount of P to support prosperous agriculture (Nasir et al., 1989). Some of these soils are inherently deficient in P due to peculiar nature of parent material (lacking of Phosphorous bearing mineral, appetite), others have been made deficient due to mining of this element through intensive cultivation of high yielding crop varieties with no or little P replacement in the form of inorganic or organic fertilizer and crop residue for decades (Ahmad et al., 2013). Thus, a great majority of soils need extraneous supplementation of Phosphorous, for sustainable crop yield. The P transformation, fixation and release characteristics in soil plant system have been reported by numerous researchers (Sarir, 1989; Naseer and Dost 2014, Jamal et al., 2018) but in actual practice, the most pertinent issue is to know how much P can be made available to the growing crop from the native soil pool.

In Pakistan the annual use of phosphatic fertilizer has reached approximately 0.65 million tons, against nitrogen which is 2.35 million tons (Anonymous, 2018). This indicates that the use of P in relation to nitrogen in the country is imbalanced with N and P ratio of 3:1, against the required ratio of 1:1 or 2:1 for most crops. In addition, the phosphatic fertilizer is highly inefficient and the plants can make use of only 18-25 % of the applied phosphatic fertilizer (Mittal et al., 2008). A significant part of the phosphatic fertilizer is lost through different mechanisms, of which both chemical and biological transformation into insoluble form play an important role, so understanding the different aspects of P transformation in the P cycle is must and paramount (Tian et al., 2008).

Phosphorous is both mineralized and immobilized. The process of building up of organic P may be termed immobilization, i.e. inorganic P is converted biologically into organic P compounds, which are unavailable to plants. The microbial conservation of soil organic P into inorganic P is termed as mineralization (Rita et al., 2013). Mineralization of organic P is largely due to the combined activities of soil micro-organisms and the phosphatase enzymes present in soil (Oehlet al., 2004).

Information on P transformation under condition inducing the mineralization of the organic P or the immobilization condition inducing of soil inorganic P is scarce. It is therefore important to study the short term changes in some soil series of district Swabi, which may result in long term changes and will help in understanding the P cycle in these soils.

Maize (*Zea mays L.*) is the third most important food crop after wheat and rice, used as a major staple food in many countries of Latin America and Africa. In Asia maize is grown in Pakistan, India and Nepal as a food and fodder crop, however in Indonesia and in Thailand it is not preferred to use as human food. Maize can be used for various aims such as to provide food to men and animals as well. Maize stores approximately 80% starch, 10% proteins, 4.8%, oil, 3.3% fibre and 2% minerals (Reddy, 2006). In Pakistan maize is the second most important kharif cereal, grown mainly in Punjab and Khyber Pakhtunkhwa province. At national level during 2008-2009, the total area under maize cultivation was 1051.7 thousand kg ha^{-1} with a total production of 3604.7 thousand kg ha^{-1} and average grain yield of 3427 kg ha^{-1}. The figures in Khyber Pakhtunkhwa (Figure 1) in the same year were 509 thousand kg ha^{-1} (almost half of the country's acreage) with a total production of 903.9 thousand kg ha-1 and average yield of 1776 kg ha^{-1} (MINFAL, 2006). This highlights the significance of maize in the agriculture production of Khyber Pakhtunkhwa province.

Keeping in view the importance of P in maize crop production, this study was conducted to investigate the P-mineralization of some important soil series of district Swabi use extensively for the production of maize crop and their mapping.

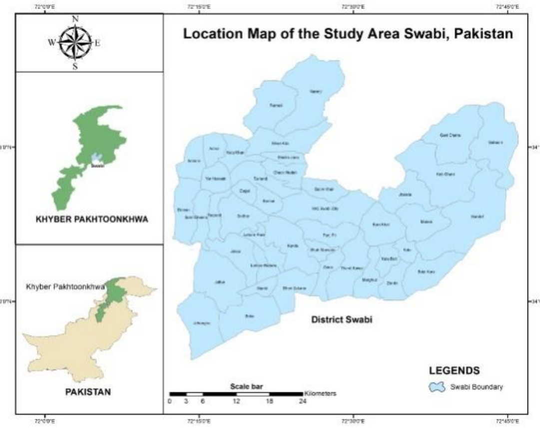

Figure 1. Location map of the study area Swabi, Pakistan.

2. Material and Methods

In order to assess the changes in AB-DTPA extractable soil phosphorous in different maize growing areas of district Swabi, an incubation experiment (6 weeks) was conducted in the laboratory of soil and environmental sciences the university of Agriculture Peshawar, Pakistan during 2015. Location area map and soil sampling area map were prepared by using Arc GIS 10.1 software (Jamal and Sarim, 2018, Arain et al. 2017) (Figure 2).

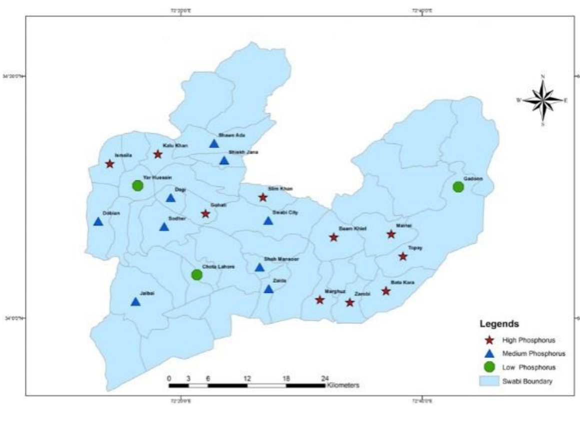

Figure 2. Map showing phosphorous concentrations in different soil series of district Swabi, Pakistan.

2.1. Soil Sampling

A total of twenty two soil samples were collected from different maize growing areas of district Swabi. All the samples were carefully collected adjacent to the roots of matured maize plants with 0-20cm depth with the help of wooden spade to avoid contamination. At least five samples were taken randomly from one location and then were mixed to make a composite sample. All the soil samples were properly labeled and immediately transferred to the laboratory and were kept in freezer at 5°C till incubation and processing.

2.2. Soil Incubation

Soil samples were incubated for 6 weeks using the incubation techniques of Jenkinson and Powlson (1976) with some modification. About 400 g fresh soil of each series was taken in plastic pots having 6 cm in diameter and 10 cm deep. The pots were incubated at 25±2°C for 6 week in incubator. The soil moisture was kept at field capacity (about 23 % moisture) by the addition of distilled water during incubation. Fresh air was also allowed to enter pot, which was usually took place at the day of mineral P determination in samples. 10 g fresh soil sample was taken each time from the incubated sample to determine AB-DTPA extractable P in soil and as such to calculate rate of mineralization.

The collected soil samples were also analyzed for various physico-chemical characteristics like EC, pH (Richard, 1954), $CaCO_3$ (Richard, 1954), soil texture (Gee and Bauder, 1986) and soil organic matter content (Nelson and Sommer, 1982). Soil nutrients status was determined by analyzing AB-DTPA extractable P, Mn, Zn, Fe and Cu (Soltanpour, 1985). Soil moisture content was determined by gravimetric method of Atikinson*et al.,* (1958).

2.3. Rate of P-Mineralization

Rate of P-mineralization was calculated as the difference in AB-DTPA extractable P at two incubation periods over time as given below. Rate of P-mineralization (formula 1) was expressed in mg P kg^{-1}soil wk^{-1}. Positive values indicated increase or release of P into soil solution and vice versa.

Formula 1.

P-mineralization (mg kg^{-1} wk^{-1}) =Final P in mg kg^{-1} – Initial P in mg kg^{-1} /Incubation time in weeks

2.4. Statistical Analysis

The collected data were subjected to simple arithmetic means and standard deviation (Jamal and Sarim, 2018)..

3. Results and Discussion

Soil samples collected from selected important maize growing areas of district Swabi were analyzed for different physico- chemical attributes the result with relevant discussion are given below.

3.1. Physico-Chemical Properties of Selected Soil Series

Results regarding physico- chemical attributes of selected soil series revealed that almost all soil samples were found silty clay loam in texture except Chota Lahore soil, which was found sandy loam in texture (Table 1).Jamal et al. (2018) also concluded that Swabi soils belongs to class silt loam, moreover all soil samples were alkaline in reaction with pH ranged from a minimum value of 6.56 at Slim khan to maximum value of 9.0 at Jalbai soil with mean value of 8.12 and found normal with EC values ranged from 0.13 to 1.8 dsm^{-1} with mean value of 0.36 dsm^{-1} (Table 1).

Table 1. Physio-chemical properties of selected soil series of district Swabi.

Soil series	Soil Texture	Organic matter (%)	Lime (%)	pH	EC
Dagi	SCL	1.07	5.24	8.75	0.56
Yarhussain	SCL	1.32	19.88	8.5	0.28
kalu khan	SCL	1.92	22.95	8.75	0.23
Ismaila	SCL	1.93	24.57	7.7	0.36
Shwa	SCL	1.35	6.91	7.98	0.27
Slim khan	SCL	1.86	4.95	6.56	0.22
Sudher	SCL	1.15	8.2	8.5	0.25
Chota Lahore	SCL	1.41	16.55	6.9	0.27
Jalbai	SCL	1.13	4.59	9	0.3
Dobian	SCL	1.25	16.35	8.21	0.13
Sheikh jana	SCL	1.33	9.25	7.5	0.32
Gohati	SCL	2.65	4.18	8.21	0.17
Swabi	SCL	2.19	6.65	7.23	0.35
Shamansoor	SCL	1.24	2.05	8.8	0.38
Baamkheil	SCL	2.99	3.18	7.77	0.24
Zarobai	SCL	2.39	1.89	7.21	0.36
Zaida	SCL	1.72	1.62	8.51	0.16
Maine	SCL	2.98	2.41	8.75	0.18
Bata kara	SCL	1.96	7.55	8.48	1.8
Marghuz	SCL	1.52	9.06	8.51	0.14
Topay	SCL	1.82	3.88	8.49	0.53
Gadoon	SCL	1.24	5.12	8.35	0.6
Minimum values		1.07	1.62	6.56	0.13
Maximum values		2.99	24.57	9.0	1.80
Mean values		1.74	8.50	8.12	0.368
Standard deviation		0.58	6.96	0.67	0.34

SCL= silty clay loam

All the selected soil series were found moderately to strongly calcareous in nature with lime content values range from a minimum of 1.62 % at Zaida soil to a maximum value of 24.57 % at Ismaila soil series with mean value of 8.50 % (Table 1). Our result was in lined with Jamal and Jamal(2018), they also confirmed the calcareous nature of these soil series. Organic matter (OM) content ranged from 1.07 to 2.99 % with mean value of 1.74% (Table 1). The relatively higher OM content in these soils might be due to the fact that soil samples were collected from the root zone area.

3.2. Nutrients Concentrations of Different Soil Series

All the collected soil samples were evaluated for AB-DTPA extractable P, Mn, Zn, Fe and Cu. The results revealed that AB-DTPA extractable P in different soil series of district Swabi ranged from a minimum value of 1.16 mg kg^{-1} in Chota Lahore area to a maximum value of 22.25 mg kg^{-1} in Bamkheil soil with mean value of 8.15 mg kg^{-1}. Concentrations of AB-DTPA extractable Mn, Fe, Zn and Cu ranged from 20.50 to 95.60, 2.43 to 39.23, 0.34 to 4.05 and 2.33 to 19.15 mg kg^{-1} respectively with mean values of 49.43, 10.60, 1.57 and 6.52 mg kg^{-1} respectively (Table 2). The variation in P, and micronutrients was found inconsistent among different soil series. On comparing with standard values it was observed that almost all the soil samples had medium to high P, Zn ranged from low to medium while Mn, Cu and Fe were found high in term of soil fertility status. Our results were in lined with the findings of Jamal and Jamal (2018), they concluded that Swabi soils have marginal to sufficient P, adequate in Cu and Fe and found 12% deficient in AB-DTPA extractable Zn. Similarly, Perveen et al. (2010) also concluded the same results for the same soil series.

Table 2. AB-DTPA extractable P, Mn, Fe, Zn, and Cu (mg kg^{-1}) in some selected soil series of district Swabi

Soil series	P	Mn	Fe	Zn	Cu
Dagi	4.08	37.2	2.43	0.37	4.4
Yarhussain	2.42	24.4	5.84	0.72	3.54
kalu khan	10.57	21.6	10.5	1.43	9.9
Ismaila	8.04	32.2	7.75	2.33	10.5
Shwa	4.47	33.79	9.32	1.78	5.7
Slim khan	11.07	20.5	8.11	1.99	4.56
Sudher	3.7	31.9	4.32	3.92	6.56
Chota Lahore	1.16	56.2	10.91	1.04	8.77
Jalbai	3.33	32.1	8.88	3.6	19.15
Dobian	5.52	68.6	9.25	2.76	2.59
Sheikh jana	4.78	62.3	10.5	0.35	2.64
Gohati	14.2	33.1	7.9	2.85	5.63
Swabi	7.92	79.3	11.52	4.05	2.33
Shamansoor	4.21	95.6	6.23	1.77	4.11
Baamkheil	22.25	72	5.55	2.21	7.99
Zarobai	10.64	55.4	3.66	0.45	5.02
Zaida	5.2	58.6	17.12	0.47	6.1
Maine	17.94	93.5	15.9	0.51	6.4
Bata kara	13.33	41.9	39.23	0.34	4.9
Marghuz	11.99	41.2	13.44	0.41	7.01
Topay	9.9	40.7	11.36	0.42	5.4
Gadoon	2.68	55.4	13.54	0.87	10.3
Minimum values	1.16	20.50	2.43	0.34	2.33
Maximum values	22.25	95.60	39.23	4.05	19.15
Mean values	8.15	49.43	10.60	1.57	6.52
Standard deviation	5.45	22.05	7.42	1.24	3.69

3.3. Concentration of P at Different Incubation Period

AB-DTPA extractable P concentrations showed higher variation s among different soil series and maize growing areas of district Swabi (Table 3). Initially P concentration before incubation (Week-0) ranged from 1.16 to 22.25 mg kg^{-1} revealed prominent differences among different soil series. Comparing the areas AB-DTPA extractable P in different soil series of district Swabi ranged from a minimum value of 1.16 mg kg^{-1} in Chota Lahore area to a maximum value of 22.25 mg kg^{-1} in Bamkheil soil with mean value of 8.15 mg kg^{-1} (Table 2 and 3). Comparing the values with low, medium and high P levels, it was found that initially 13.6 % soils were found low, 41% medium and 45.5 % high. Incubating the soil at 25 °C and field moisture conditions exhibited reasonable variations in AB-DTPA extractable P concentrations of the soil at different weeks of incubation. The variation in P concentrations of a soil varied inconsistently among different maize growing areas. However, it was observed that soils with initial higher P concentrations maintained higher P and vice versa.

Comparing P concentrations at week 1, inconsistent fluctuation was observed among different soil series. When averaged across all the samples, it was found that P ranged from 2.37 to 22.83 mg kg-1 with a mean value of 7.85 ± 5.50 mg kg-1 soil (Table 3). Comparable mean P concentrations at week 1 and week 0 but higher minimum value of at week 1, (2.37 mg kg-1) as compared to minimum value at week 0 (1.16 mg kg-1) showed releases of P into soil solutions with incubation of soils which were initially low P in concentration comparing ecological zone. Comparing the fluctuation of P in all soil series the higher decrease of 14.87 mg kg-1 was found in Baamkheil soil, while the higher increase was observed in Zarobai soil series, which is 12.23 mg kg-1 (Table 3).

P concentrations at week 2 ranged from 2.56 to 18.22 mg kg-1 with a mean value of 9.14 ± 4.87 mg kg-1 (Table 3). The higher mean as compared to week 1 and week 0 revealed releasing of P into soil solution at week 2. The higher minimum value of 2.56 as compared to 1.16 mg kg^{-1} at week 0 and lower maximum value of 18.22 mg kg^{-1} at week 2 as compared to 22.25 mg kg^{-1} at week 0 showed releases of P from initially low P soils and decrease of P from initially high P soils.

P concentrations at week 3 ranged from 1.87 to 19.94 mg kg^{-1} with mean value of 8.84 ± 5.59 revealed decreases of P in soil solution as compared to week2. While P concentrations at week 4 ranged from 3.37 to 23.27 mg kg^{-1} with mean value of 10.52 ± 6.30 showed again increases of P at week 4 as compared to week 3. P concentrations at week 5 further increases with ranged from 3.32 to 28.85 mg kg-1 with mean value of 12.01 ± 7.82 mg kg-1. However, mean value of P concentrations at week 6 showed reduction in P levels as compared to week 5. P concentrations varied from 2.97 to 21.39 mg kg-1 with mean value of 9.89 ± 5.50 mg kg-1 at week 6 (Table 3).

Comparing low, medium and higher P soils showed that soil with initially low P showed higher fluctuations as compared to high P soils (Figure 3). It was observed that mean P concentration was increased from 2.08 at week 0 to 3.28, 4.31 and 6.11 at week 1, 2 and 3in low P soils, showing increased of 193.75 % at week 3 as compared to week 0. However all these soils showed mean higher concentration at same incubation week i.e. week 5. Periodical changes in P concentration over the incubation period were observed. P concentrations increased from week 0 to week 2 and then declined at week 3 in first spell and P concentration again increased from week 3 to 5 taking 14 days and then declined at week 6. This periodical increase in first spell from week 0 to week 2 (14 days) and week 3 and week 5 (14 days) in second spell and similarly the declines of P after each 14 days in both spells showed microbial association with P content of the soil. It could be concluded that at time of high microbial growth P was immobilized in microbial bodies.

Table 3. AB-DTPA extractable phosphorous (mg kg^{-1}) at different incubation period in selected soil series of district Swabi

Soil series	W-0	W-1	W-2	W-3	W-4	W-5	W-6
Dagi	4.08	4.58	4.98	6.91	5.14	4.97	5.12
Yarhussain	2.42	3.95	6.29	1.87	3.37	5.3	2.97
Kalu khan	10.57	8.49	14.84	4.9	10.69	11.69	10.9
Ismaila	8.04	6	7.3	3.63	6.25	7.72	6.54
Shwa	4.47	8.81	6.15	2.39	6.46	17.49	12.46
Slim khan	11.07	4.09	6.9	8.62	11.7	9.21	7.2
Sudher	3.7	4.16	13.89	6.64	15.4	3.76	13
Chota Lahore	1.16	2.37	2.56	4.21	5.09	14.38	9.13
Jalbai	3.33	2.75	3.8	10.45	12.5	17.05	10.79
Dobian	5.52	4.28	6.62	9.55	7.5	13.92	11.58
Sheikh jana	4.78	4.29	3.66	2.33	3.86	5.38	4.09
Gohati	14.2	19.56	16.42	12.99	17.7	18	14
Swabi	7.92	6.2	12.28	13.84	14.91	10.05	9.85
Shamansoor	4.21	4.88	4.31	2.2	3.86	3.65	3.82
Baamkheil	22.25	7.38	9.9	13.25	18.18	24.13	19.27
Zarobai	10.64	22.83	11.5	12.89	17.21	28.85	19.54
Zaida	5.2	4.2	5.22	3.93	4.73	5.11	4.73
Maine	17.94	12.32	18.22	18.11	22.17	28.28	21.39
Bata kara	13.33	13.02	15.57	17.44	23.27	15.18	12.92
Marghuz	11.99	12.47	13.67	19.94	11.03	11.92	11.6
Topay	9.9	12.59	13.1	6.22	4.45	3.32	3.21
Gadoon	2.68	3.54	4.1	12.25	6.14	4.96	3.5
Minimum values	1.16	2.37	2.56	1.87	3.37	3.32	2.97
Maximum values	22.25	22.83	18.22	19.94	23.27	28.85	21.39
Mean values	8.15	7.85	9.14	8.84	10.52	12.01	9.89
Standard deviation	5.45	5.50	4.87	5.59	6.30	7.82	5.50

W= week

3.4. Rate of P- Mineralization

Changes in AB-DTPA extractable P concentration over the incubation period as referred to rate of P- mineralization in soil is shown in Table 4.Results on P- mineralization showed inconsistent variation among different soil series. P mineralization varied from -15.07 in Baamkheil to 12.19 mg kg^{-1} wk^{-1} in Zarobai soil series, respectively at week 1 with mean value of -0.32± 5.01 mg kg^{-1} wk^{-1}. The mineralization rate increased with further incubation at week 2 with mean value of 0.46 mg kg^{-1} wk^{-1} but at week 3, the P-mineralization rate decreased to 0.20 mg kg^{-1} wk^{-1}, which showed decrease in P- mineralization as compared with week 2. However, P-mineralization rate increased with further incubation at week 4, which ranged from -1.38 to 2.93 mg kg^{-1} wk^{-1} with mean value of 0.57± 1.11 mg kg^{-1} wk^{-1}. The increasing trend in P-mineralization continued and it ranged from -1.33 to 3.64 mg kg^{-1} wk^{-1} with mean value of 0.76 ± 1.24 mg kg^{-1} wk^{-1} at week 5 (Table 4).

Table 4. Rate of phosphorous mineralization (mg kg^{-1} wk^{-1}) at different incubation period in selected soil series of district Swabi.

Soil series	W-1	W-2	W-3	W-4	W-5	W-6
Dagi	0.49	0.45	0.94	0.26	0.18	0.17
Yarhussain	1.53	1.94	-0.18	0.24	0.58	0.09
Kalu khan	-2.08	1.14	-2.56	-0.47	-0.17	-0.28
Ismaila	-2.04	-0.37	-1.47	-0.45	-0.07	-0.25
Shwa	4.34	0.84	-0.7	0.5	2.6	1.33
Slim khan	-6.98	-2.09	-0.82	0.16	-0.37	-0.65
Sudher	0.46	5.1	0.98	2.93	0.02	1.57
Chota Lahore	1.22	0.71	1.02	0.98	2.65	1.33
Jalbai	-0.71	0.18	2.33	2.29	2.72	1.24
Dobian	-1.26	0.54	1.33	0.49	1.68	1.01
Sheikh jana	-0.49	-0.56	-0.82	-0.26	0.12	-0.12
Gohati	5.33	1.1	-0.41	0.89	0.77	-0.03
Swabi	-1.72	2.18	1.97	1.72	0.43	0.32
Shamansoor	0.49	0.05	-0.67	-0.09	-0.11	-0.07
Baamkheil	-15.07	-5.78	-2.82	-0.82	0.54	-0.35
Zarobai	12.19	0.48	0.72	1.64	3.64	1.48
Zaida	-0.94	-0.06	-0.47	-0.15	-0.03	-0.09
Maine	-5.62	0.18	0.06	1.06	2.07	0.58
Bata kara	-0.31	1.13	1.41	2.51	0.39	-0.06
Marghuz	0.48	0.84	2.65	-0.24	-0.02	-0.07
Topay	2.64	1.53	-1.25	-1.38	-1.33	-1.12
Gadoon	0.86	0.71	3.19	0.87	0.46	0.14
Minimum values	15.07	-5.78	-2.82	-1.38	-1.33	-1.12
Maximum values	12.19	5.10	3.19	2.93	3.64	1.57
Mean values	-0.32	0.46	0.20	0.57	0.76	0.28
Standard deviation	5.01	1.91	1.59	1.11	1.24	0.73

W= week

P-mineralization again started decline at week 6 ranging from -1.12 to 1.57 with mean value of 0.28± 0.73 mg kg^{-1} wk^{-1}. Comparing the P-mineralization rate at different incubation period, the higher mean mineralization of 0.76 mg kg^{-1} wk^{-1} was observed at week 5 followed by week 4 with mean value of 0.57 mg kg^{-1} wk^{-1}.

Readings at week 6 showed the net turnover of P over the entire incubation period. It was observed that net P-mineralization greatly varied among different soil series. On average P turnover ranged from -1.12 to 1.57 with mean value of 0.28± 0.73 mg kg^{-1} wk^{-1} over 6 weeks of incubations. Higher net P mineralization of 1.57 mg kg^{-1} $wk^{-1}$was observed in Sudher area and the lowest was recorded at Topay soil series with value of -1.12 mg kg^{-1} wk^{-1} (Table 4).

Mineralization of P has been studied very rarely in detail because of lack of suitable analytical techniques. (Enwezor, 1976) used temperature ranging from 26-30 °C, and air dry sample for incubation study. While others (Somani, 1987; Hedley et al., 1982; Bowman and Cole, 1978) either used different organic substrates or added inorganic P and used different incubation periods and extractant. Due to these reasons, various research workers have reported different rate of P-mineralization. (Enwezor, 1976) studied P-mineralization in some air-dried soil samples at 30 ˚C. He reported that 6.6mg P kg^{-1} soil was mineralized after 12 weeks of incubation (0.55 mg P $kg^{-1}wk^{-1}$). Sarir (1989) studied P-mineralization at 20 ˚C in 30 fresh soil samples which were acidic in nature and low in bicarbonate extractable P. The rate of change in extractable P was found in ranged from -0.6 to + 0.6 mg P $kg^{-1}wk^{-1}$. He concluded that soil having small amount of labile P, the P cycle did not remain very active. In another study (Palomo et al., 2006) hypothesized the release of organic acid anions from plant roots into soil to be a mechanism for enhancing P availability in the rhizosphere. Organic P comprises around 50% of the total soil P and is plant-available only after mineralization (Lopez-Gutierrez et al., 2004).

Table 5. Rate of P-mineralization (mg kg^{-1} wk^{-1}) as influenced by initial P levels

P levels	W-1	W-2	W-3	W-4	W-5	W-6	Mean
Low (3)							
Mini	0.86	0.71	-0.18	0.02	0.46	.09	0.32
Max	1.53	1.94	3.19	0.87	2.65	1.33	1.91
Mean	1.20	1.12	1.34	0.37	1.23	0.52	0.96
SD	0.33	0.7	1.7	0.44	1.23	0.7	0.85
Medium (9)							
Mini	-1.72	-0.56	-0.82	-0.26	-0.11	-0.12	-0.6
Max	4.34	5.10	2.33	2.93	2.72	1.57	3.1
Mean	.07	0.96	0.54	0.85	0.84	0.59	0.64
SD	1.7	1.72	1.22	1.16	1.16	0.7	1.08
High (10)							
Mini	-15.07	-5.78	-2.82	-1.38	-1.33	-1.12	-4.58
Max	12.19	1.53	2.65	2.51	3.64	1.48	4.0
Mean	-1.14	-0.18	-0.44	0.29	0.54	-.07	-0.16
SD	7.3	2.2	1.7	1.2	1.4	.07	2.3

W= week

The reduction in P content over time in soils initially high in P might be associated with formation of insoluble calcium compounds, which decrease the rate of mineralization. Most of the soils under investigation are calcareous, and their calcium carbonate might be instrumental in forming insoluble carbonate-phosphate of calcium, which decreases the rate of mineralization. However, the biological immobilization can also not be ignored as mineralized may be recombined into organic forms by microorganisms, and the P release may be fixed into insoluble inorganic PO_4.

Comparatively lower P turn over in soil series of district Swabi resulted either from chemical changes (in the presence of high amount of $CaCO_3$) brought about during moist aerobic incubation, which altered the extractability of soil P or from the conversion of soil P to microbial P which was not extractable. In short, under present condition, both the initial labile pool of P and lime content play important role in directing the path of P cycle. However further study is needed on P transformation taking into consideration all aspects of P cycle e.g. respiration rate, enzymatic study along with field experiment.

3.5. Relationship of Phosphorous Releases with Initial P Content

Soil P was grouped into low (< 3 mg kg^{-1}), medium (3-8 mg kg^{-1}) and high (>8 mg kg^{-1}) concentration to see the effect of initial P levels on AB-DTPA extractable P at different incubation period and rate of releases with time. Result showed higher influences of initial P on concentration and releases of P with time (Figure 3). Soils, which were initially low in P content, showed mineralization all over the incubation period (Table 5). It ranged from 0.52 at week 6 to 1.34 at week 3 with mean value of 0.96 mg kg-1 wk-1 over 6 weeks of incubation. But those soils which were initially high in P contents showed either immobilization or mineralization with incubation period but these values were very low as compared to low and medium P soils ranging from -0.44 at week 3 to 0.54 mg $kg^{-1}wk^{-1}$ at week 5 with net immobilization of -0.16 mg kg^{-1} wk^{-1} over 6 weeks of incubation. This rate of immobilization is very low indicating the capacity of soil to maintain higher P levels at all incubation periods.

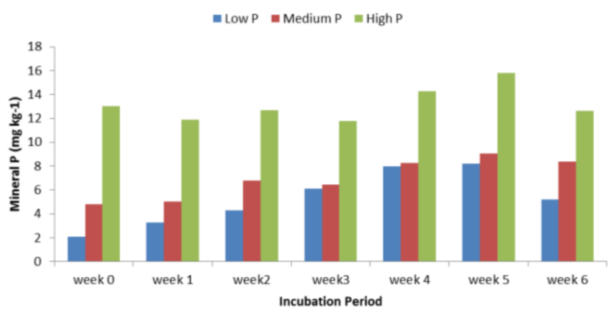

Figure 3.AB-DTPA extractable P at different incubation period as influenced by initial P levels.

Soils having initially medium P resulted in the release of P with range from .07 at week 1 to 0.96 at week 2 with mean value of 0.64 mg kg^{-1} wk^{-1} over 6 weeks of incubation. It was observed that the release of P from medium P soils were lower than the releases of P from low P soils. Low, medium and high P soils also showed different peaks of mineralization at different incubation periods. Low P soils showed higher P mineralization at week 3 (1.34 mg kg^{-1} wk^{-1}) while high P soils showed peak at week 5 (0.54 mg kg^{-1} wk^{-1}) and medium soils at week 2 (0.96 mg kg^{-1} wk^{-1}) (Table 5).

4. Conclusions

Swabi soils were found silty clay loam in texture, all soils were normal but were found alkaline in reaction with slightly to strongly calcareous in nature and low in organic matter content. Mean values showed P turnover of -0.32, 0.46, 0.20, 0.57, 0.7 and 0.28 mg kg^{-1} wk^{-1} at week 1, 2, 3, 4, 5 and 6 respectively showing periodical changes. Initial soil P before incubation had significant effect on soil P and rate of turnover at all incubation periods. Soils with initially low in P contents showed mineralization all over the incubation period, while high P soils showed both immobilization and mineralization. Crop experiments are strongly suggested to correlate P-mineralization rate of an area with growth and yield of various crops.

Conflict of Interest

The authors declare that there is no conflict of interest.

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