Micronutrients Status and Phosphate-fractions in Chitral District Agricultural Soil

F. K. BANGASH, R. AFZAL AND S. ALAM
Department Of Chemistry,
University of Peshawar, Peshawar, Pakistan

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Summary: Micronutrients and phosphorus has been identified as a major factors involved in increasing the agricultural soil fertility. The soil samples from agricultural fields of Chitral District were collected and analyzed for various micronutrients like Cu^{+2}, Zn^{+2}, Mn^{+2}, Fe^{+3}, Na^{+}, Li^{+}, Cd^{+2}, Pb^{+3}, total phosphate and phosphate fractions such as Al-phosphate, Fe-phosphate, Ca-phosphate, Fe-phosphate (occluded), Al-phosphate (occluded) and water-soluble phosphate. The results show adequate amount of micronutrients except lithium, in the samples phosphate-fractions distribution were found in the order of Ca-Phosphate > Fe-Phosphate > Al-Phosphate. Their impacts on soil properties and plant growth have also been discussed.

Introduction

The earth is a cold, globular, solid planet, spins on its axis and revolves around the sun at a constant distance. The solid part of the earth is called lithosphere, including three main layers like crust mantle, outer and inner core. The crust mantle is covered by soil and is an important ecological factor. Soil is the loose, friable, unconsolidated top layer of earth's crust and organic components, which are formed by the decay of dead bodies of plants or animals or through metabolic actions of living organisms and mixture of minerals called mineral particles. Most of these particles originate from the degradation of rocks. Some start off from the residues of plants or animals (decaying leaves, pieces of bone, etc.), called organic matter. These soil particles have spaces called pores. When the soil is dry, the pores are filled with air and after irrigation or rainfall these pores are filled with water [1]. The soil profile can be classified in to three layers. The first layer is called plough layer (20 to 30 cm thick) and is rich in organic matter mainly live roots having dark brown to black in colour.

The second layer is lighter grey in colour and is the deep plough layer, contains much less organic matter and live roots. The third layer is known as subsoil layer, containing organic matter or live roots. This layer is not very significant for plant growth because only some roots will get to it. The fourth one is called parent rock layer, consists of rock called parent material [2].

Soil texture is composed of gravel particles between 2 and 64 mm in diameter. Gravel particles are broken down into sand (< 2mm in diameter), silt (1/16 mm in diameter) clay (1/256 mm in diameter). In coarse textured soils, sand is predominant (sandy soils). In medium textured soils, silt is predominant (loamy soils) while in fine textured soils, clay is predominant (clayey). Soil structure refers to the grouping of soil particles (sand, silt, clay, organic matter and fertilizers) into porous compounds called aggregates, which are separated by pores and cracks. Granular, blocky, prismatic and massive structure blocks the entrance of water making seed germination in to poor aeration. On the other hand in granular structure, the water enters easily and the seed germination is facilitated. In a prismatic structure, movement of the water in the soil is predominantly vertical and therefore the supply of water to the plant roots is usually poor. Unlike texture, soil structure is not permanent. By means of cultivation practices (ploughing, ridging, etc.), the farmer tries to obtain a granular topsoil structure for his fields [1,2].

Nutrients for healthy plant growth are divided into three categories, primary, secondary and micronutrients. Nitrogen (N), phosphorus (P) and potassium (K) are primary nutrients, which are needed, in fairly large quantities compared to the other plant nutrients. Calcium (Ca), magnesium (Mg) and sulfur (S) are secondary nutrients, which are required by the plant in lesser quantities but are no less essential for good plant growth than the primary nutrients. Zinc (Zn) and manganese (Mn) etc. are micronutrients, which are required by the plant in very small amounts. Most secondary and micronutrient deficiencies are easily corrected by keeping the soil at the optimum pH value [3]. Earlier research workers have found primary, secondary and micronutrients in soil [4-21,36-42].

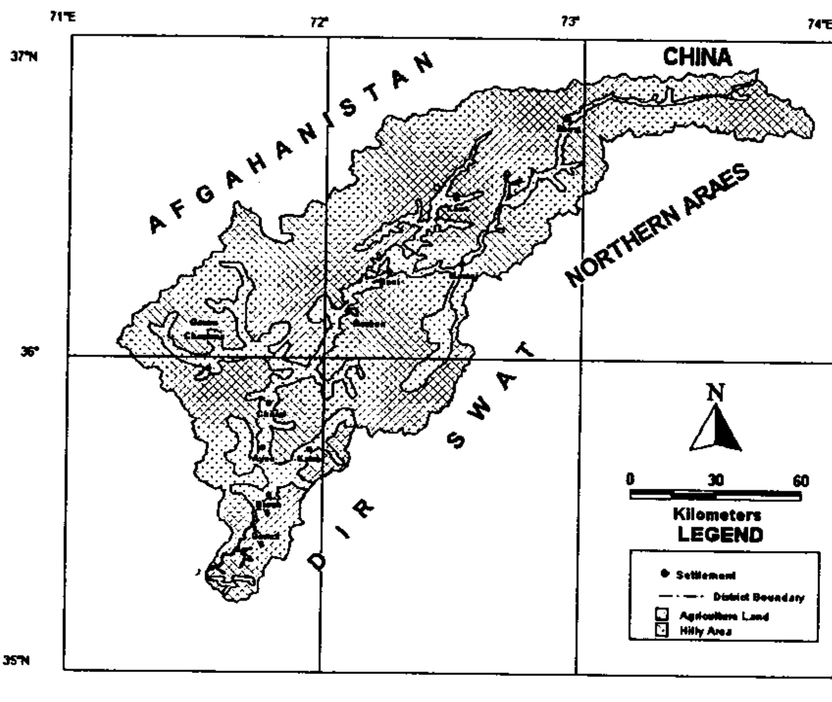
The present study was therefore carried out to assess the micronutrients status and phosphate-fractions in the agricultural soil of Chitral District. The District Chitral of Pakistan is located from 35° and 13` to 36° and 55` North latitudes and 71° and 12` to 73° and 53` East longitudes over the globe. The area is bounded by Dir and Swat Districts in the southeast, Northern Areas in the northeast, Afghanistan in the west, and China in the northeast (Map-1).

Results and Discussion

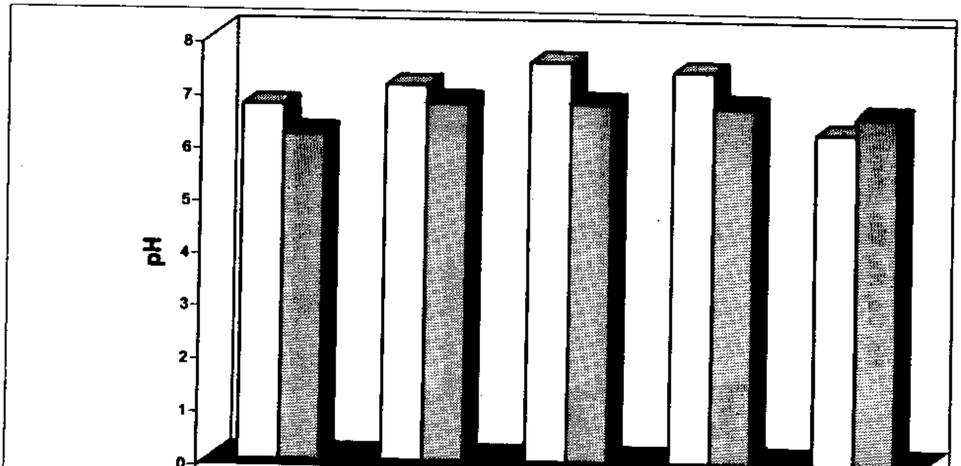
Agricultural Soil from different localities of District Chitral, Pakistan (Map-1), were collected and investigated for parameters like pH, conductivity, micronutrients such as Cu^{+2}, Zn^{+2}, Mn^{+2}, Fe^{+3}, Cd^{+2}, Na^{+1}, Li^{+1} and Pb^{+3}, water soluble, total phosphate and the phosphate fractions like Ca-P, Al-P, Fe-P.

It is evident from the data (Fig.-1) that the soil samples have pH in the range 6.19-7.55, which shows that the soils of the District are from slightly acidic to slight alkaline. The highest pH values was found for Drosh in the southern area of the District and it may be due to the high lime contents while the lowest pH values was found in Yaughaur located in the northern area and it may be due the low level of sodium, lime, phosphorus contents and mineralization of organic matter in the soil [22]. The pH of the soil measured in 0.01M $CaCl_2$ solutions was slightly acidic which ranges from 6.19-6.80. The pH value of a soil is influenced by the kinds of parent materials from which the soil was formed. Soils developed from basic rocks generally have higher pH values than those formed from acid rocks. Rainfall also affects soil pH. Water passing through the soil leaches basic nutrients such as calcium and magnesium from the soil. They are replaced by acidic elements such as aluminum and iron. For this reason, soils formed under high rainfall conditions are more acidic than those formed under arid (dry) conditions. Application of fertilizers containing ammonium or urea speeds up the rate at which acidity develops. The decomposition of organic matter also adds to soil acidity. As the concentration of acidic element in the agricultural soil is low, therefore it shows alkaline nature.

As can be seen from the Fig.-2, the conductivity of all samples varied from 0.14mS to 0.30 mS. This difference is due to the difference in



Map-1: Micronutrients and Phosphate-Fractions Status of Chitral District Agircultural Soils.



	DENIN.	CHUMURKON	DROSH	BROZE	YAUGHAUR
pH in D. Water	6.72	7.11	7.55	7.39	6.25
pH in 0.01M CaCl2	6.19	6.8	6.79	6.75	6.6

pH in D. Water ▨pH in 0.01M CaCl2

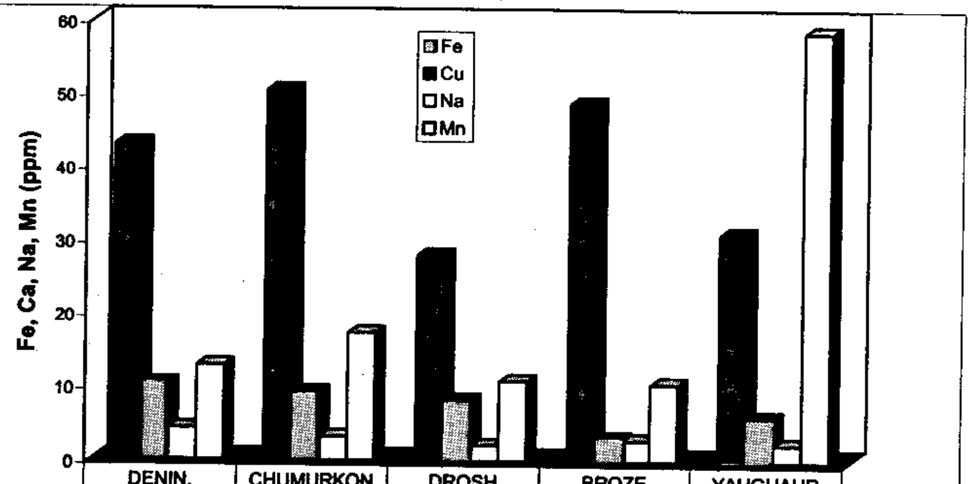
Fig. 1: pH values of Chitral District Agricultural Soil.

	DENIN.	CHUMURKON	DROSH	BROZE	YAUGHAUR
Conductance	0.14	0.18	0.17	0.3	0.29

Fig. 2: Conductance of Chitral District Agricultural Soil.

concentration of free cations and anions i.e. K^{+1}, S^{-2}, Ca^{+2}, Cl^{-1} etc. The highest electrical conductivity was observed in the soil sample of Broze while the minimum value is found in the Danin soil sample.

Copper occurs in soil as copper sulfides and copper hydroxy carbonates. The copper contents varied from 3.022 ppm to 10.30 ppm, as shown in Fig.-3. The suitable values for agricultural soil ranges from 1.00 to 50.00 ppm [30]. The functions of copper in plants include catalysis for respiration, enzyme constitution, chlorophyll synthesis, carbohydrate and protein metabolism [2,23,24]. The deficiency of copper causes wilting with adequate soil moisture, new growth, small chlorosis, leaf distortion and misshapen. While at greater concentrations it may



	DENIN.	CHUMURKON	DROSH	BROZE	YAUGHAUR
Fe	43	50.5	28	48.7	31
Cu	10.3	9.2	8.2	3.022	5.92
Na	4.3	3.2	2.03	2.8	2.3
Mn	12.8	17.3	10.75	10.4	58.55

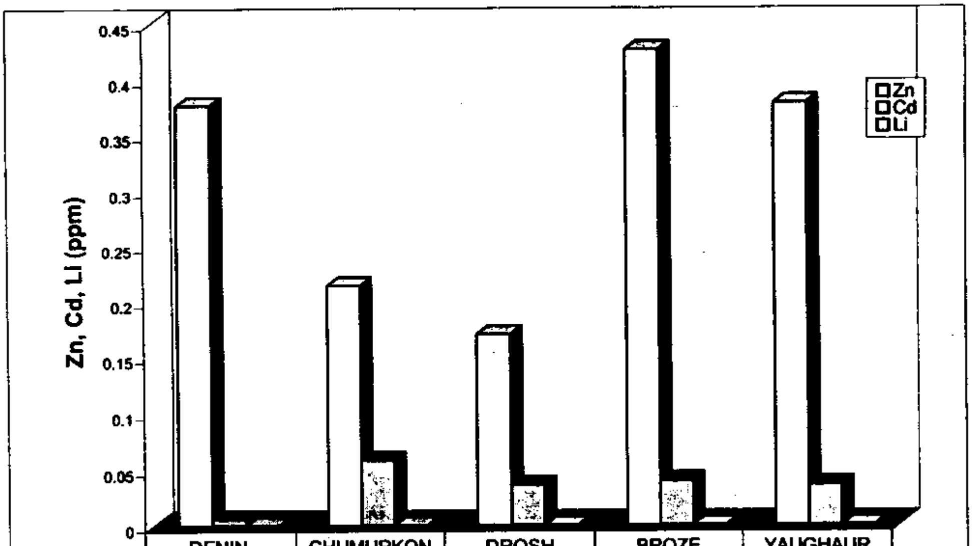
Fig. 3: Micronutrients Status of Chitral District Agricultural Soil.

cause stunting and reduce branching [25]. The concentration of copper in the soil sample is within the permissible limit and thus causes no harm to plant body.

The major sources of zinc through which it enter to soil are zinc sulphides, zinc oxide and zinc silicates. Soil Zn availability is diminished by high soil phosphorous levels and soil pH greater than 6.5. Deep sandy soils have inherently low Zn supplies. The required level of Zn in soil is 10-300 ppm [31]. The functions of zinc in plants are the formation of growth hormones, promotion of protein synthesis, seed and grain maturation and production [2]. The total zinc contents in all the samples studied were in the range of 0.17 ppm to 0.426 ppm. (Fig.-4) The soil of Broze contains the maximum amount of zinc while that of Drosh shows minimum amount of zinc. When the concentration of zinc in the soil is low then the probable affects on the plant growth are, reduction in size of leaves, short internodes, distorted or puckered leaf margins, interveinal chlorosis, firing of lower leaves due to limited water uptake etc. While at greater concentration it reduces the amount of iron and interference with magnesium [2]. As the soils of the District have low concentration of zinc than the recommended value thus it may cause the above-mentioned effect on the plant body.

Cadmium is the heavy metal of greatest concern in agricultural soils. Fig.-4, shows the concentration of cadmium in the range of 0.006-0.058 ppm, which is lower than the desirable level for a fertile soil therefore it may cause diseases like necrosis, wilting, red orange coloration of leaves & general reduction in growth (0.1-1.0 ppm). Cadmium is loosely held by soil constituents and is readily available to plants. Thus, increased concentrations in soil result in increased concentrations in crops. Cadmium accumulation in plant materials varies with crop type and plant part. In general, broadleaf plants accumulate more cadmium than grasses and plant leaves and stems accumulate more than seeds. Broad-leaved vegetables, such as lettuce and Swiss chard accumulate more cadmium than most other plants.

As can be seen from Fig.-3, iron contents were noted in the range of 28-50.5 ppm. Iron is the fourth most abundant element on the earth, mostly in the form of ferromagnesian silicate. Soil typically contains 1-5% total iron. Most of the iron in soil is found in silicates minerals, iron oxides and hydroxide. The reddish and yellowish colors of soil indicate the presence of iron oxides and iron hydroxides. Iron occurs in soil both in ferrous (Fe^{++}) and ferric (F^{+++}). Soil pH and the aeration status determine which form predominates.. Ferric iron



	DENIN.	CHUMURKON	DROSH	BROZE	YAUGHAUR
Zn	0.376	0.214	0.17	0.426	0.378
Cd	0.006	0.058	0.036	0.04	0.036
Li	0	0	0	0	0

Fig. 4: Micronutrients Status of Chitral District Agricultural Soil.

compounds have low solubility in soil solution, thus decreasing the ferric iron contents in the soil. The concentration of iron in the soil decreases with the increase in pH of the soil, with a minimum around pH 7.4- 8.5. Such situations mostly occur in calcareous soils. Iron deficiencies occur most frequently in cool, wet soil early in the growing season, when microbial activity and root growth are limited. As the soil warms, microbial activity and root proliferation increase, allowing plants to absorb more iron. If microbial activity is sufficient to decrease the oxygen supply in acid soil, some ferric iron oxide and hydroxide will be transferred to more soluble ferrous forms. On the other hand, in alkaline soil high microbial respiration may produce sufficient carbon dioxide to react with water to form carbonates ions. Plants absorbed carbonates ions immobilize iron within plants, resulting in deficiency. The deficiency symptoms of iron appear in the form of chlorosis in the plant.

The manganese concentration in the samples was from 10.47 ppm to 58.55 ppm (Fig.-3). The amount of manganese varies from soil to soil. Soil may have has 300-ppm manganese but still unavailable for the plant use [32]. Most available manganese occurs as exchangeable manganese. Manganese is associated with organic matter or is present as various manganese oxides and as a component of ferromagnesian silicate minerals in soils. The functions of manganese in plants are nitrogen and inorganic acids metabolism, carbon dioxide assimilation during photosynthesis, carbohydrates breakdown and formation of carotene, riboflavin and ascorbic acid. The amount of available manganese in soil is highly influenced by soil pH, organic matter contents, moisture, microorganism and soil aeration. The manganese availability increase with the decrease of soil pH and when the organic matter content increases the available manganese in the soil decreases due to the formation of organic matter - manganese complexes. Poor soil aeration or reduce oxygen level is usually caused by excess moisture along with the high microbial activity, converting the manganese oxide to soluble manganese (Mn^{++}) and thus leached out from the soil. Crops with high requirement of manganese include bean, lettuce, oat, onion, radish, soyabean, spinach and wheat. Those with medium relative manganese needs are beet, barley, cabbage, carrot, cauliflower, corn, cucumber etc. Deficient manganese soil causes Interveinal chlorosis of leaves followed by brown spots producing a checkered effect. Whereas in excess may cause Reduction in growth, brown spotting on leaves and in sever cases leaf tissues begins to die at the leaf margins and continues back from the margins as toxic conditions increase. The manganese concentration in our samples is less than

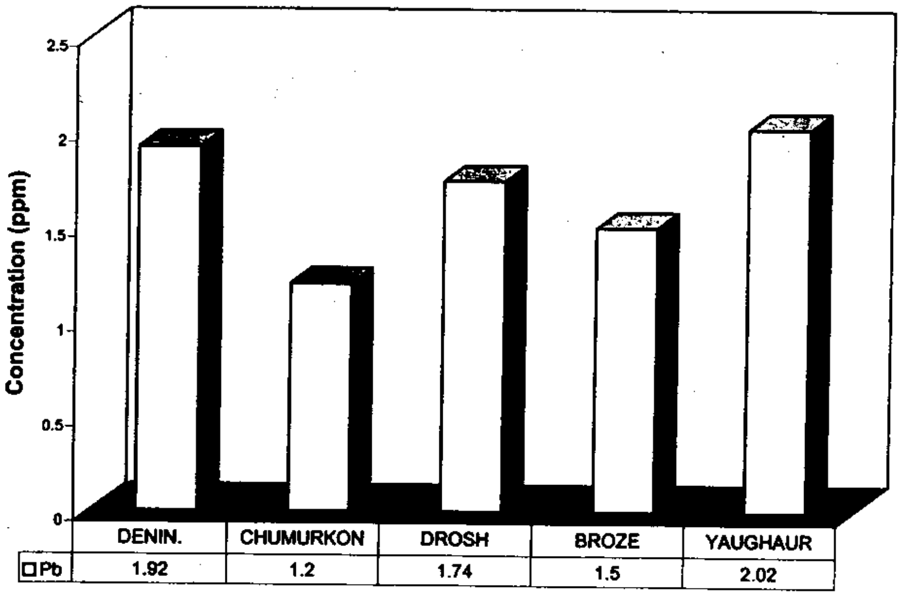


Fig. 5: Micronutrient (Pb) Status of District Chitral Agricultural Soil.

the reported value of 450 ppm for soil [32], the deficiency of manganese in the soils studied therefore may cause the toxic effects as mentioned above.

Soil is contaminated by lead from various sources. Lead particles are deposited in the soil from flaking lead paint, from incinerators (and similar sources) and from motor vehicles that use leaded gasoline and also from waste disposal. Lead in soil is found as lead sulfide, lead carbonate, lead sulfate and lead oxide [26]. Wide variations in soil lead levels have been reported, ranging from less than 100 ppm to well over 11,000 ppm [27]. Natural levels of lead in surface soils are usually below 50 ppm [28]. Soils adjacent to houses with exterior lead-based paints may have lead levels of greater than 10,000 ppm [29]. The lead content in the samples studies is in the range, 1.2 –2.02ppm and is given in Fig. 5.

The Fig. -3 shows the sodium concentration in the range of 2.03-4.30 ppm. High concentration of sodium act as destroying agent for soil texture, which then have poor capillary rise because of the low porosity in the soil, which thus affect the crops growth and productivity. [35]

The soil samples studied are lacking in lithium. Lithium is distributed throughout the world up to 50-65 mg/kg. It is present in soil as a component of silicates and for this reason sand stone soil is rich in lithium while soil having high amount of organic matter tend to be low in lithium i.e. 3-4 mg/kg. The lithium amount is different in different species for example in cereal and cereal based product contain little amount (1 mg/kg) but most vegetable contain less than 1 mg/kg. Fruits like apple and lemon have lithium concentration of 1.4 mg/kg. The basic functions of lithium in the plant body are the facilitation of enzymes activity associated with both glycolysis and nitrogen metabolism [34].

Table 1: Micronutrients Average Concentration.

S. NO.	Micronutrients	Concentration (ppm)
1	Copper [46]	30
2	Zinc [48]	40
3	Manganese [48]	450
4	Cadmium [46]	0.35
5	Lead [47]	< 1

Chemical fractionation of soil inorganic phosphate provides method for identifying the predominant individual forms of inorganic phosphate in soils, most commonly Al-phosphate, Fe-phosphate, Ca-phosphate, Fe-phosphate (occluded), Al-phosphate (occluded), water-soluble phosphate and total phosphate. Fractionation of inorganic phosphate is commonly carried out to know the effect of soil type and phosphate source on the fate and potential availability and mobility of phosphate in soil [19]. Table-2 show the phosphate-fractions in soil samples, which indicate that most of the

Table-2: Phosphate Fractions (ppm) of Chitral District Agricultural Soil.

Sample Sites	Al- Phosphate	Al-Phosphate (Occluded)	Ca-Phosphate	Fe-Phosphate	Fe-Phosphate (Occluded)	Water Soluble Phosphate	Total Phosphate
Danin	3.1	3.4	16.2	7.25	1.8	10.0	084
Chumurkun	2.0	3.2	15.8	4.20	2.4	6.00	064
Drosh	2.1	3.2	22.0	3.40	3.4	0.30	105
Broze	3.6	3.0	22.2	3.79	2.8	4.40	076
Yaughaur	4.8	2.0	5.00	11.2	2.4	8.20	112

phosphates occur in Ca-phosphate fraction having concentration range 5.0-22.2 ppm. The phosphate distribution was found in the order of Ca-Phosphate > Fe-Phosphate > Al-Phosphate. This agrees with the work of several other authors [44]. This high concentration of Ca-phosphate is due to the reaction of phosphate ions with calcium carbonate as in the alkaline soils the activity of calcium is greater which lead to the precipitation of hydroxyapetite and carbonate appetite. And another reason is retention by clay particles like Clay-Ca-H_2PO_4 [43]. Many research workers have shown that the amount of Al-phosphate and Fe-phosphate is greater in acidic soil while that of Ca-phosphate is greater in alkaline soil and have also shown the correlation of pH with phosphate [45].

Experimental

Agricultural soil from different localities of Chitral district of N.W.F.P Pakistan were collected and investigated for parameters like pH, conductivity, micronutrients such as Cu^{+2}, Zn^{+2}, Mn^{+2}, Fe^{+3}, Cd^{+2} and Pb^{+3} and phosphate fractions like Ca-P, Al-P, Fe-P, Fe-P (occluded), Al-P (occluded), water soluble and total phosphate. Soil samples were collected from 0-15 cm depth of the agriculture fields, dried at 105 °C, ground and passed through a 100 mesh and stored in airtight plastic bottles. pH was determined by using pH meter and conductance by conductometer. The amounts of micronutrients in the soil extract were determined by using atomic absorption spectrophotometer and phosphate fractions by the Jackson's method [33]. Water-soluble phosphate was determined in the soil extract from the soil solution ratio of 1:20, by the method of Murphy and Riley [49].

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