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Status of some macronutrients in some soils of fayoum governorate

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Abstract

The main objective of conducting this study is to assess the state, concentrations or levels of some plant macronutrients (N, P, K) in the soils of Ibshway District - Fayoum Governorate - Egypt.

It was found that the general mean of nitrogen concentration was 0.08 mg N/kg soil, and the concentration of total and extractable K was 2720.36 and 281.37 mg K/kg soil, respectively, while the overall mean concentrations of total and extractable P were 995.09 and 15.41 mg P/kg soil, respectively.

Key words: Macronutrients - nitrogen - phosphorous - potassium - soil - Ibshway District – Fayoum.

Introduction:

Like all other living organisms, Plants need food for their growth and development. Plants require 16 essential elements. Carbon (C), hydrogen (H), and oxygen (O) are derived from the atmosphere and soil water. The remaining 13 essential elements (nitrogen (N), phosphorus (P), potassium (K), calcium (Ca), magnesium (Mg), sulfur S), iron (Fe), zinc (Zn), manganese (Mn), copper (Cu), boron (B), molybdenum (Mo), and chlorine (Cl)) are supplied either from soil minerals and soil organic matter or by organic or inorganic fertilizers.

Generally plants obtain their nutrients requirements from the soil, but they are capable to absorb nutrients through the leaves. Foliar plant nutrition is one of the techniques that farmers use for plant nutrition since 1950s, when they were learned that foliar fertilization was effective and economic **Ebrahimian et al., 2010**. Foliar fertilization is extensively used as a practice to accurate the nutritional deficiencies in plants caused by inappropriate deliver of nutrients to roots Silberbush and Ling, 2002. The most important use of foliar sprays has been in the application of micronutrients **Havlin et al., 2004**.

Of the 16 essential elements, three are provided by the atmosphere (C,H,O) and three are supplied through fertilizers (N,P,K). It is taken for granted that soils provide a continuous supply of the remaining ten elements. Jagvir **Singh D. Blaise, 2000.**

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Mocanu et al. 2003, Budoi, 2004 and Iordanescu et al., 2012. mentioned that the macro and micronutrients effect on plants is very complex and dependent on the quantity absorbed and the relationship between them. In the first stages of development vegetable species have higher requirements from mineral components. This involves a good supply of soil, without losing sight that seedlings are sensitive to soil solution concentration. So, fertilization should be done in steps, such as nitrogen fertilizers. Slow leaching products such as phosphorus fertilizers, can be administered with the preparation of the soil **Dima 2012**.

Sources and Beneficial Effects Plant Nutrients:

Samota et al., 2017 stated that Nitrogen as a constituent of all amino acids and proteins (and thus all enzymes), nitrogen serves a central role in cellular metabolism. Additionally, as a component of nucleotides and nucleic acids (deoxyribonucleic acid (DNA) and ribonucleic acid (RNA)), nitrogen is important for the transcription, translation and replication of genetic information. Nitrogen is obtained from the soil environment either as the ammonium (Ne) or nitrate (N4) ions, with nitrate being chemically reduced within the plant to ammonium prior to incorporation into organic molecules. An alternative source of nitrogen for some species is atmospheric nitrogen (N_2), obtained through the process of nitrogen fixation.

Phosphorus has a significant role in energy transfer via the pyrophosphate bond in ATP, and the attachment of phosphate groups to many different sugars provides metabolic energy in photosynthesis and respiration**.** **Conley et al. 2009**. have described the cloning of two genes encoding small purple acid phosphatases (PvPAP3, PvPAP4) from common bean, expression of which in both leaves and roots is increased by P-starvation Phosphorus is absorbed by plants largely as the primary or secondary orthophosphate anions, H_2PO_4 2and HPO_4 . Plant roots acquire P as phosphate. Because phosphate is present at exceedingly low concentrations in the soil solution, plant roots must forage for this element **White and Hammond, 2009**.

Potassium is absorbed as K^+ which is soluble in soil solutions. It is the most abundant cation in the cytoplasm and, because it is not metabolized, K^+ and its accompanying anions contribute significantly to the osmotic potential of cells. **Ilan 1971** reported that cytokinin treatments changed the K^+ and Na^+ selectivity in cells of sunflower leaves and cotyledons Thus, potassium functions in plant water relations processes and affects cell extension and growth through the regulation of turgor, leaf gas exchange through the control of stomatal opening/closing, and long-distance nutrient flow through pressure-driven phloem translocation. It has been proposed that breeding crops that acquire and/or utilize K more effectively can reduce the use of expensive K fertilizers in agriculture **Rengel and Damon, 2008; Fageria, 2009.** The potassium ion also helps establish the electrochemical gradient across membranes, and thus contributes to the membrane transport of numerous chemical species.

Plant Nutrients Forms in soil:

An increase of nitrogen (N), phosphorus (P) and potassium (K) inputs at farm scale been observed in Europe during the last decades due to the intensification of agricultural production **Romstad et al., 1997**. As a consequence, imbalances in nutrient budgets were registered, namely N which is generally not fully used in any production system **Swensson, 2003; Schroder et al., 2004; Nevens et al., 2006**.

Soil plays a major role in determining the sustainable productivity of an agroecosystem. The sustainable productivity of soil mainly depends upon its ability to supply essential nutrients, both macro and micro-nutrients, to the growing plants. The tendency for micronutrient deficiencies to occur in soils where only macronutrient fertilizers are applied as soil amendments strongly indicates the need for balanced fertilization. This will involve the application of both macro- and micro-nutrients in the right amount and proportion. The deficiency of micronutrients has become a major constraint to the productivity, stability and sustainability of soils **Bell and Dell, 2008**.

Primary and secondary nutrients, which are the most deficient in the soil, limit the rice yield and affect the quality **Ghoneim and Ebid 2015**. Therefore, for good agricultural practices, balanced fertilization is primarily important. Nutrient losses caused by denitrification, volatilization and naturally occurring leaching are unavoidable, even under the best agricultural practices **Noor, 2017**. The farmers should be aware of these consequences, because the most persuasive argument for farmers in developing and developed countries is still the return the farmers will receive through the application of fertilizer to his crop during the season of application **Salem, 2006**.

Factors Affecting Plant Nutrients Availability:

It is well known that agricultural activities have a strong impact on the environment, namely due to considerable N and P losses to the environment caused by inefficient nutrient management at farm scale **Wang et al., 1999; Schroder et al., 2004.**

Comerford, 2005 stated that the soil supports plants, is the physical determinant of root growth and extent, and is the main reservoir for plant-available water and nutrients.Therefore, the soil controls the availability of most essential plant nutrients. It regulates availability by means of biophysiochemical processes, which are functions of soil and plant properties. This chapter introduces the concept of soil nutrient bioavailability, and the soil factors that regulate it. It summarizes the processes that control nutrient release and movement in the soil, and points out the importance of selected plant root characteristics in nutrient acquisition.

The soil–plant system's capacity to supply/absorb nutrients is termed soil nutrient bioavailability, and is the ability of the soil–plant system to supply essential plant nutrients to a target plant, or plant association, during a specific period of time as a result of the processes controlling (1) the release of nutrients from their solid phase in the soil to their solution phase; (2) the movement of nutrients through the soil solution to the plant root–mycorrhizae; and (3) the absorption of nutrients by the plant root–mycorrhizal system **Comerford, 1998**.

A winter wheat–14 months fallow (WW–F) rotation is commonly practiced in the PNW to harvest one winter's precipitation for next year's wheat crop because the precipitation in this region is not always sufficient for annual winter wheat cropping. However, fallow conditions have negative impacts on the concentration of SOM and on nutrient availability, and hence reduce the capacity of the soil to supply plant nutrients **Rasmussen et al., 1998**.

The other important management practice affecting SOM and nutrient availability is N fertilization. Nitrogen fertilization was shown to increase SOM and total N due to increased root and shoot biomass production **Blevins et al., 1983**. On the other hand, increased N fertilization enhances mineralization and may subsequently contribute to increased N losses through leaching and gaseous emissions **Malhi and Lemke, 2007**.

Li et al., 2013 showed that the availability of micronutrients in the soil can strongly affect the production and quality of crops. As a result of the change of basic soil characteristics, such as pH, organic matter (OM), and nutrients in response to long-term fertilization field experiments, status and behaviors of micronutrients in soil and crop vary with different fertilization practices. For instance, available Zn and Cu levels in cropped treatments were lower than the fallow treatment, probably due to the removal of these micronutrients from the soil through crop uptake and harvest. In contrast, available Mn and Fe levels were higher in cropped treatments compared to the fallow treatment **Wei et al., 2006**. Soil OM exerts a significant and direct impact on the availability of Zn, Fe and Mn but has little influence on the availability of soil Cu **Zhang et al., 2001**. In addition, the interaction of other soil macronutrients and micronutrients also affected micronutrients uptake by crops **Aulakh and Malhi, 2005**.

The distribution of metal micronutrients including iron (Fe), manganese (Mn), zinc (Zn), and copper (Cu) in soils is governed by a variety of reactions that includes complexation with organic and inorganic ligands, ion exchange, adsorption and desorption processes, precipitation and dissolution of solids, and acid-based equilibria **Shuman, 2005**. However, the relative importance of these reactions depends on many factors such as physical, chemical, and mineralogical soil properties and the nature of metal ions. Generally, Fe availability is governed predominantly by the organic fraction in soils, whereas for Zn and Cu, soil pH and adsorption on clay and organic surfaces are important. On the other hand, the major processes in Mn cycling in soils are oxidation-reduction and complexation with natural organic chelates **Havlin et al., 2004**. Many researchers **Sharma et al., 2004; Ammari and Mengel, 2006; Obrador et al., 2007; Wang et al., 2009; C. Wu et al., 2010** studied the relationships between micronutrient availability and some major soil properties and concluded that pH and organic matter are the most important properties which controls micronutrient availability. However, several researchers also obtained significant relationships between micronutrient availability and calcium carbonate equivalent (CCE), cation exchange capacity (CEC), and clay and sand contents **Sharma et al., 1999, 2004**.

It has been found that factors such as climate, physiographic position, and soil development may affect the variability of some soil properties and thereby macro- and micronutrient availability. **Singh et al. 2008** concluded that some soil properties such as CEC and pH may be affected by landform and showed that the highest total Cu content in soil was found on terraces, followed by plateaus and planes.

Sharma *et al.*, (2004) suggested that pedogenic processes may introduce more variation in micronutrient availability than parentmaterial.

Material and methods:

One hundred and seventeen soil samples were collected from thirty-nine sites representing the Ibshway District area following the grid system at distances of 2 kilometers during June 2016. Locations of the studied sites were identified using a "GPS" (Model German).

Three soil samples were taken from each site: the first from the surface soil layer at a depth of (0 –30 cm) the second represented the subsurface soil layer at a depth of (30–60 cm) and the third soil layer at a depth of (60 –90 cm).

The collected soil samples were air-dried, crushed with a wooden hummer, passed through a 2 mm sieve and stored in plastic bottles. The collected soil samples were analyzed for total nitrogen "N", phosphorus "P" and potassium "K", organic matter, total $CaCO_3$, particle size distribution, ECe and pH using the following methods:

- Particle size distribution, by the hydrometer method (ASTM No. 152 H Temp.) using sodium hexameta phosphate - sodium carbonate as dispersing agents **(Jacks *et al.*, 1986)**.
- Calcium carbonate content, volumetrically using Schreiber's calcimeter **(page *et al.*, 1982)**.
- Soil (pH) in soil paste using a pH -meter according to page et al., (1982).
- Electrical conductivity (ECe), in the saturation paste extract using EC- Meter according to **Page *et al.*, (1982).**
- Total content of nitrogen (N) in soil samples using Kjeldahl method **Kjeldahl 1883.**
- Total content of phosphorus (P) in soil in each sample was determined using the Olsen method to extract the available soil phosphorus **Olsen et al., 1982** using Inductively Coupled Plasma (ICP).
- Total and extractable content of potassium (K) in soil samples determined using Flame spectrophotometer.
- Organic matter content according to Walkely and Black method as described by **Page et al., 1982**.

The obtained concentrations of total nitrogen "N", phosphorus "P" and potassium "K" and other soil characteristics were classified into different categories (ranges), their geographical distribution throughout the whole area of Ibshway District were identified and mapped using the Geographic Information System (GIS) and Integrated Land and " ILWIS software"to produce colored soil maps for each tested component.

RESULTS AND DISCUSSION

The results of this study were interpreted under 117 soil samples collected from thirty-nine sites (three samples were taken from three depths (0-30, 30-60 and 60 – 90 cm from each site) to represent all Ibshaway District soils in order to assessment the levels and status of some macro (N, P and K) and micronutrients (Fe, Mn and Zn) and their relationships with some soil properties (e.g. Organic matter% $CaCo_3$% soil pH, ECe and particle size distribution).

Total soil Nitrogen:

Data in table (1) which is illustrated by maps (1 a, b and c) represented concentrations and distribution of total nitrogen in the studied soil samples throughout Ibshaway District. Also the results indicated that the highest value of total nitrogen in the surface layer (0 – 30 cm) was 0.149%, while the lowest value was 0.029%, Also, in the subsurface layer (30 – 60 cm) the highest value was 0.140% but the lowest value was 0.020%. On the other hand, the highest and lowest values of total nitrogen in the third layer (60 – 90 cm) were 0.133 and 0.013% respectively.

Generally, the values of total nitrogen in tested soil samples of Ibshaway District ranged between 0.013 and 0.149. So, the values of total nitrogen in three studied layers of Ibshaway District soils could be arranged in the following order: (0 -30 cm) > (30 – 60 cm)> (60- 90 cm).

It was clear that a pronounced increase in total nitrogen content in the surface layer, which is due to its high organic matter content.

The results took the same trend with **Harold et al., 2020** who found that the inorganic nitrogen is liberated from the sources of organic matter nitrogen. Also, they showed that the organic compounds account for roughly 30% of total nitrogen found in soil, but this number can vary greatly based on soil management practices such as applications of animal manures.

Table (1) Levels of soil nitrogen throughout Ibshway District area.

Depth	Range (mg/kg)	Area (Feddan)	% of area
0 - 30	< 0.1	30760.93	80.88
	0.1 – 0.12	6181.85	16.25
	0.12 – 0.14	1066.18	2.80
	> 0.14	26.25	0.07
30 - 60	< 0.1	37389.16	68.30
	0.1 – 0.12	536.04	1.41
	0.12 – 0.14	109.77	0.29
	> 0.14	0.00	0.00
60 - 90	< 0.1	38035.47	100.00
	0.1 – 0.12	0.00	0.00
	0.12 – 0.14	0.00	0.00
	> 0.14	0.00	0.00

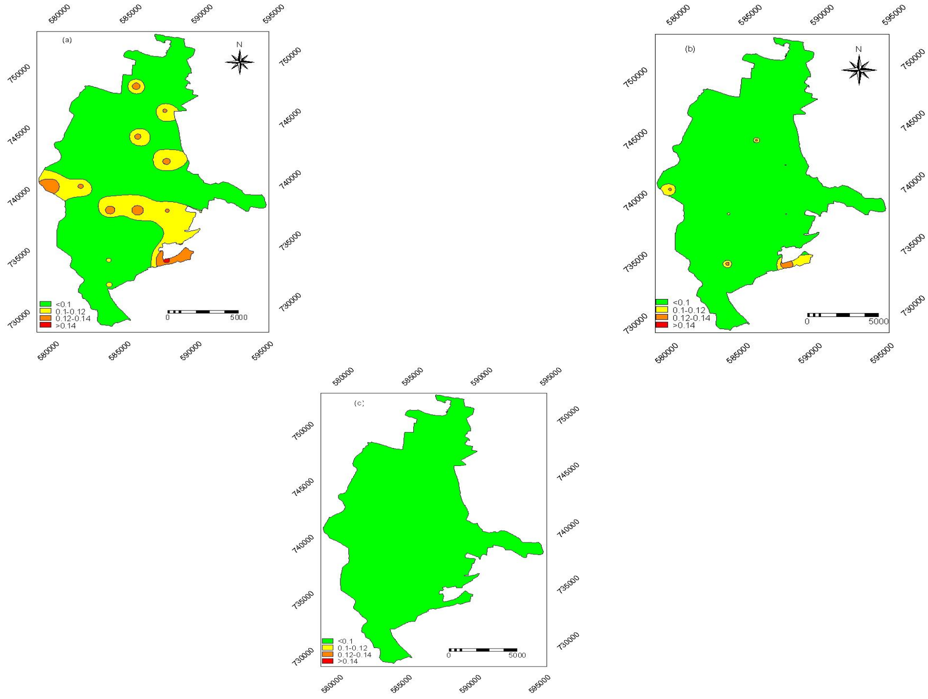

Fig. (1) Spatial distribution of total nitrogen levels throughout Ibshway District area (soil depth 0-30, 30 -60 and 60-90 cm).

Soil phosphorus:

Data in table (2) which is illustrated by maps (2 and 3 a, b and c) showed levels and distribution of the total and extractable phosphorus in the studied soil samples throughout Ibshaway District. Generally, the total and extractable phosphorus in the studied soil samples ranged from 274 to 1913 and from 1.62 to 44.20 mg P / kg soil respectively.

In addition, the results showed that the greatest values of total and extractable phosphorus in the surface layer (0 – 30 cm) in the studied samples were 1913 and 44.20 mg P / kg soil respectively. On the other hand, these values were 1440 and 34.50 mg P / kg soil for the subsurface layer (30 – 60 cm), while in the third layer (60 90 cm) they were 1313 and 31.20 mg P / kg soil respectively.

Also, data showed that the lowest values of the total and extractable phosphorus in the studied soil samples were 583 and 1.96 mg P / kg soil in the surface layer (0 – 10 cm), 536 and 1.62 mg P / kg soil in the subsurface layer (10 – 30 cm) and 274 and 1.62 in the third layer (30 – 60 cm) respectively. It was clear that the total and extractable phosphorus contents is soils of Ibshaway District could be arranged in the following order: (0 – 30 cm) > (30 – 60 cm) > (60 – 90 cm).

Table (2) Levels of total soil phosphorus throughout Ibshway District area.

Depth	Range (mg/kg)	Area (Feddan)	% of area
0 - 30	< 500	20.28	0.05
	500 - 1000	15888.13	41.77
	1000 - 1500	21258.19	55.89
	> 1500	867.88	2.28
30 - 60	< 500	0.00	0.00
	500 - 1000	18573.99	48.83
	1000 - 1500	19460.60	51.16
	> 1500	0.00	0.00
60 - 90	< 500	0.00	0.00
	500 - 1000	34791.56	91.47
	1000 - 1500	3243.13	8.53
	> 1500	0.00	0.00

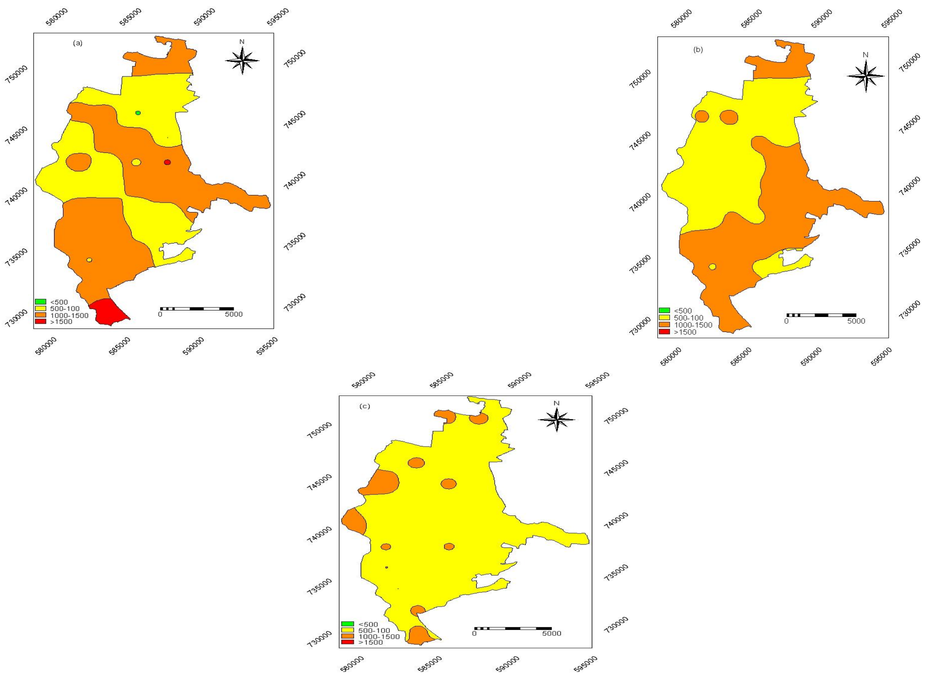

Fig. (2) Spatial distribution total P content throughout Ibshway District area (soil depth 0-30, 30 -60 and 60-90 cm).

Many researchers were studied the importance of soil phosphorus for plants such as **Esther 2019** who reported that phosphorus is the second most important plant macronutrient after nitrogen. Phosphorus is an essential macronutrient that plays an important role in all plant biochemical processes such as photosynthesis, respiration, energy storage and transfer, cell division and cell enlargement. It is also important in seed germination, seedling emergence and root, shoot flower and seed development.

Table (3) Levels of extractable soil phosphorus throughout Ibshway District area.

Depth	Range (mg/kg)	Area (Feddan)	% of area
0 - 30	< 10	5245.13	13.79
	10 -20	23518.21	61.83
	20 – 30	9248.81	24.32
	> 40	23.20	0.06
30 - 60	< 10	3890.79	10.23
	10 -20	32897.79	86.49
	20 – 30	1245.88	3.28
	> 40	0.86	0.00
60 - 90	< 10	2168.14	5.70
	10 -20	25800.43	67.83
	20 – 30	9704.87	25.52
	> 40	360.91	0.95

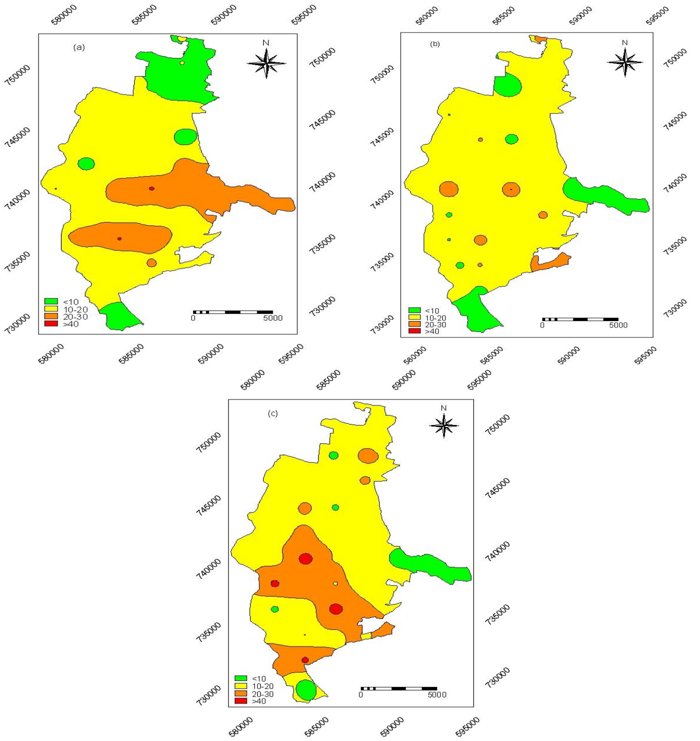

Fig. (3) Spatial distribution of extractable P content throughout Ibshway District area (soil depth 0-30, 30 -60 and 60-90 cm).

Soil potassium:

Data in the table (4) which is illustrated by maps 4 and 5 a, b and c) showed values and distribution of the total and extractable potassium in the studied soil samples throughout Ibshaway District. Generally, the total and extractable potassium ranged between 1299 and 5773 mg K/ kg soil and between 221 and 320 mg K/ kg soil respectively.

Table (4) Levels of total soil potassium throughout Ibshway District area.

Depth	Range (mg/kg)	Area (Feddan)	% of area
0 -30	< 2000	84.32	0.22
	2000 – 3000	28054.53	73.76
	3000 – 4000	8947.15	23.52
	> 40000	984.88	2.49
30 - 60	< 2000	148.50	0.39
	2000 – 3000	32919.46	86.55
	3000 – 4000	4944.51	13.00
	> 40000	22.18	0.06
60 - 90	< 2000	609.94	1.60
	2000 – 3000	34742.60	91.34
	3000 – 4000	2682.51	7.05
	> 40000	0.00	0.00

Also, the results indicated that the values of total and extractable potassium in surface layer (0 – 30 cm) of Ibshaway District soils ranged from 1698 to 5773 mg K/ kg soil, while these values ranged between 1574 to 4611 mg K/ kg soil in subsurface layer (30 – 60 cm). On the other hand, these values of total and extractable potassium in the third layer (60 – 90 cm) ranged from 1299 to 3747 mg K/ kg soil.

In addition, data showed that the values of extractable potassium in the surface layer 90 – 30 cm) ranged from 236 to 320 mg K/ kg soil, from 236 to 320 mg K/ kg soil in subsurface layer (30 – 60 cm) and from 236 to 320 mg K/ kg soil in the third layer (60 – 90 cm) respectivel.

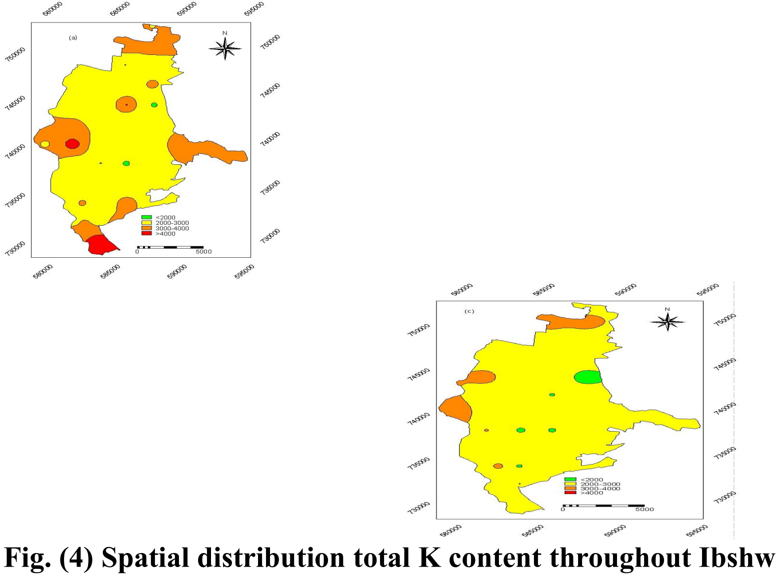

Fig. (4) Spatial distribution total K content throughout Ibshway District area (soil depth 0-30, 30 -60 and 60-90 cm).

Table (5) Levels of extractable soil potassium throughout Ibshway District area.

Depth	Range (mg/kg)	Area (Feddan)	% of area
0 - 30	< 250	80.49	0.21
	250 - 300	32360.06	85.08
	> 300	5594.65	14.71
30 - 60	< 250	189.00	0.50
	250 - 300	36611.12	96.26
	> 300	1234.58	3.25
60 - 90	< 250	517.15	1.36
	250 - 300	37340.25	98.17
	> 300	178.26	0.47

It is well known that the mineral K which is the major proportion of total K in soil can become available very slowly only through long- term soil weathering. In addition, wetting – drying and freezing – thawing cycles influence the transformations of K between nonextractable, exchangeable and solution phases. Also, soils initially high in exchangeable K tend to fix K upon drying, while those initially low in exchangeable levels release K upon drying **Pedro, et al., 2006**.

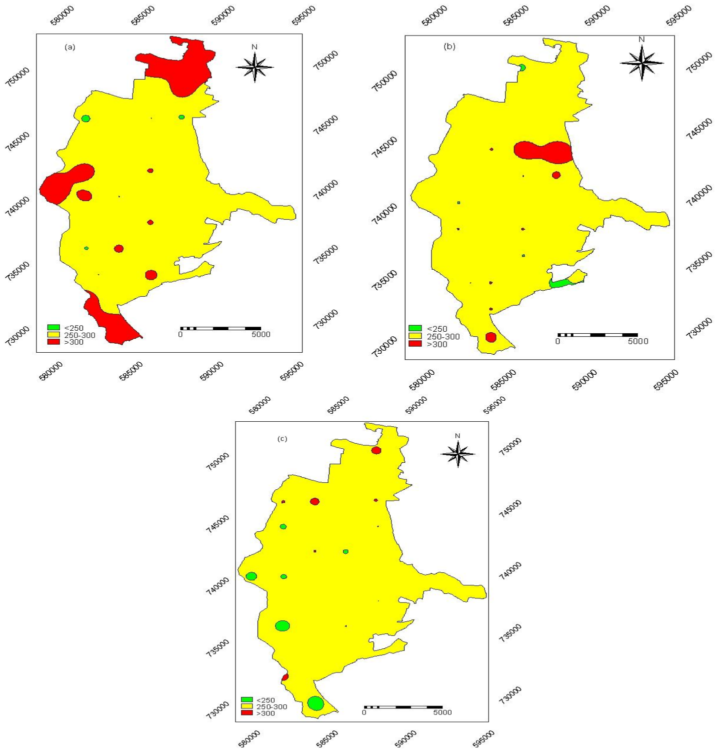

Fig. (5) Spatial distribution of extractable K content throughout Ibshway District area (soil depth 0-30, 30 -60 and 60-90 cm).

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حالة بعض عناصر المغذيات النباتية الكبرى في بعض أراضي محافظة الفيوم

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إن الهدف الرئيسي من هذه الدراسة هو تقييم حالة وتركيزات أو مستويات بعض عناصر المغذيات النباتية الكبرى (نيتروجين، فوسفور، بوتاسيوم) في أراضي مركز إبشواي بمحافظة الفيوم بجمهورية مصر العربية.

وقد بينت النتائج أن المتوسط العام للنيتروجين هو 0.08 ملليجرام نيتروجين/ كجم تربة، أما التركيز الكلي والمستخلص للبوتاسيوم هما 2720.36 و281.37 ملليجرام بوتاسيوم/ كجم تربة أما المتوسط العام لكل من الفوسفور الكلي والمستخلص فكانت 995.09 و15.41 ملليجرام فوسفور/ كجم تربة على الترتيب.