Zagazig J.Agric. Res., Vol .31 No.(4B) 2004 **1699 - 1716**

NUTRIENT DEPLETION FROM SOILS BY INTENSIVE CULTIVATION AND CHANGES IN PHOSPHORUS FRACTIONS

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Accepted 5 / 6 / 2004

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ABSTRACT: The present investigation was carried out to study the effect of intensive alfalfa cultivation on the possible depletion of P, K, Fe, and Cu from soils. Further work was carried out to identify changes in the relative abundance of P fractions. A pot experiment was designed in the greenhouse to simulate the nature overstretching scenario of intensive cultivation. Five surface soil samples of different textures were used to support intensively cultivated alfalfa for a total of six cuts. Measurements were taken to determine dry matter production, nutrient uptake, levels of elemental availability in soils, and the P fractions. The data indicate that the dry matter yield of alfalfa declined as a function of progressing cuts but not necessarily in a linear trend. Some soils were able to sustain a flourishing dry matter accumulation before reverting to the falling trend. With the possible exception of Cu, the total uptake of nutrients was closely related to the soil clay content. On the average of all soils, the initial available P and K decreased by 52 % after the final harvest, whereas Fe decreased by only 40 %. Huge amounts of P and K were mined from the soils, reaching 70 and 500 kg per feddan from the two nutrients, respectively. All P fractions were markedly affected by the intensity of cultivation. Reductant soluble P shows a loss of only 50 %, indicating that it was rejuvenated. The Fe-P fraction was reduced to nil, indicating that it was comprised of young small crystallites that are prune to decomposition. It is recommended that calibrated soil management programs should be adopted to make up for nutrients mined by intensive cultivation. The alternative is soil degradation.

Key words: **nutrients, depletion, fractionation, management, ICPS**

INTRODUCTION

The agricultural land base of Egypt is about 7.8 million feddans (each is 0.42 hectares) giving a too little share for individual citizens to obtain required food and services from national sources. In order to produce enough food for the rapidly growing population, a proportional increase in agricultural production must be pursued. One way for attaining this aim is to increase the cropping index of land whereby two or more crops are grown on the same land in a given year, i.e., intensive cropping as advocated by FAO (2003). This approach was widely adopted in Egypt in the past few decades and thus the cultivated area has progressively increased. It is currently estimated that the total cultivated land area reaches about 14 million feddans, giving a cropping intensity of 180% (Abdel-Monem *et al.*, 1998).

It should be realized, however, that crop intensification is not without side effects, where excessive nutrient depletion/nutrient mining may lead to subsequent land degradation. Russell (1973) emphasized that plants take up different amounts and different proportions of nutrients from a soil according to their species. On the average, crops on an acre (about one feddan) retrieve about 30 and 80 kg of P and K, respectively. FAO (2003) reported that these quantities are most likely to keep on the rise due to dramatic increases in productivity attributed to the introduction of high-yielding varieties and adoption of improved cultural practices. Therefore, it is evident that if no manure or fertilizers were added to make up for absorbed nutrients, the soil would rapidly become impoverished to sustain growth requirement of succeeding crops. The case illustrates what environmentalists call nature overstretching, where systems are being utilized at levels far beyond their bearing capacity (Barrow, 1995).

Bharadwaj *et al.* (1994) and Lal (1998) found that the continuous cropping without fertilization decreased the soil content of many nutrients as well as the organic matter contents, total N, and CEC. Generally, soil quality consistently declined with cultivation that was reflected on crop yields. Nofal (1989) concurred that extensive cropping of the Egyptian agriculture induced depletion of micronutrients, because high amounts of used N and P fertilizers resulted in higher crop yields and higher uptake of the micronutrients. The trend of nutrient uptake was lowest in plots receiving no fertilizer or manure.

Chang and Jackson (1957) classified the inorganic phosphate in soils into calcium phosphates (Ca – P), iron phosphates (Fe – P), aluminum phosphates (Al – P), and reductant soluble phosphates (RS – P). These fractions are present in most soils, but differ in their relative abundance according to soil characteristics and from a soil type to the other. Many workers such as Youssef (1976) and Mahmoud (2001) reported that strongly acidic soils are usually highly weathered, and thus Al-P, Fe- P and RS –P fractions are dominant. Neutral and slightly acid soils usually contain all four P fractions in comparable amounts. Alkaline and calcareous soils are often dominated by Ca- P. Little information exists, however, on the effects of intensive cultivation on the distribution and amounts of P within the four inorganic P forms.

The objectives of this investigation are both of direct and indirect implications. The direct implication is to assess and evaluate quantitatively changes in soil nutritional levels of some macro and micronutrients in response to a simulated intensive cultivation process, and the associated changes in soil P fractions. The indirect implication is elaborate on issues relevant to soil conservation through the establishment of appropriate nutrient balance. Such balance could enhance nutrient use efficiency and environmental integrity by adding no more than the required dose.

MATERIALS AND METHODS

Five surface soil samples (0-30 cm depth) of different textures were collected from three neighboring villages in the El-Zagazig County, El-Sharkia Governorate. The villages are Gezeret El-Saada, Ghazala, and El-Ghar; all are located within a radius of 5 km from the city of El-Zagazig. Plastic pots having dimensions of 21 cm diameter and 20 cm height were used to hold exactly 5 kg of the almost undisturbed soil samples in triplicates. The experiment was initiated in mid-November 2002.

Alfalfa seeds were sown at a rate of 0.25 g seeds /pot to give about 100 plants per pot; about twofold the normal seeding rate used by farmers in the field. The seeds were covered with a thin layer of soil simulating normal cultivating procedures.

The pots were arranged in a completely randomized block design in the experimental greenhouse of the Soil, Water, and Environment Research Institute, El-Giza. Tap water was used for irrigation as needed to maintain soil moisture content at about 90% of field capacity. Sporadic assessment of water salinity showed an average electrical conductivity of 0.5 dSm^{-1}. No fertilizer was added. Six successive plant cuts each at about 5 cm above the soil surface were taken. The first cut was 70 days after seeding and subsequent cuts were taken every month. The date of the last cut was the first of August 2003.

The plant material was dried at 70 C° in a forced air oven for 48 hours to obtain the dry matter weight and then was ground to pass through 40 mesh sieve prior to storing in plastic bags for subsequent analysis. A mixture of sulfuric and perchloric acids was used for digesting plant material as recommended by Chapman and Pratt (1961). Contents of P, Fe, and Cu were determined using inductively coupled plasma spectrometry (ICPS 400 Perkins Elmer) whereas K was determined by a flame photometer.

The available soil P content was extracted using the sodium bicarbonate method of Olsen and Watanbe (1965), available K, Fe and Cu were extracted using AB-DTPA and determined by the ICPS. The fractionation of soil phosphorus was performed according to the modified method of Chang and Jackson (1957) in soil: solution ratio of 1: 50. RS-P was extracted by 1N NH_4Cl, Al-P was extracted using 0.5 N NH_4F at pH 8.5, Fe-P was extracted using 1 N NaOH + NaCl, and Ca-P was extracted by 0.5 N H_2SO_4. All phosphate determinations were carried out using the ICPS 400 Perkin Elmer.

RESULTS AND DISCUSSION

Basic soil properties:

The clay content of the investigated soils increased progressively across the order listed in Table 1 from 12.4 % in the Gezeret El-Saada 2 soil

Table 1: Some physical and chemical properties of the investigated soils

soil parameters	investigated soils				
	G. Saada 2	**Ghazala 2**	**Ghazala 3**	**Ghazala 4**	**El-Ghar 2**
c. sand, %	75.5	53.1	24.4	7.6	5.9
f. sand, %	10.8	19.5	33.2	52.7	18.7
silt, %%	1.3	5.3	2.7	2.1	22.2
clay, %	12.4	22.1	39.6	47.7	53.2
textural class	sandy l.	s.clay	clay	clay	clay
bulk density, gm/cm^3	1.7	1.4	1.3	1.3	1.3
$CaCO_3$, %	0.4	0.9	2.5	2.8	2.9
O.M., %	0.7	1.5	2.5	1.9	1.9
F.C., %	12.5	22.2	31.4	42.5	46.2
pH *	7.20	7.35	7.56	7.47	7.69
EC*, dSm^{-1}	0.98	0.85	0.41	0.54	0.56
soluble ions concentration (meq l^{-1})*					
Ca^{+2}	5.15	3.12	1.03	2.06	2.06
Mg^{+2}	2.35	1.38	2.03	1.44	1.94
Na^{+}	1.86	4.18	0.79	2.12	1.59
K^{+}	0.66	0.30	0.40	0.10	0.36
HCO^{-}_3	1.56	1.04	1.04	1.04	2.08
Cl^{-1}	5.76	3.84	5.76	3.84	1.92
SO^{-2}_4	2.70	4.10	2.55	0.84	1.95
C.E.C., cmol kg^{-1}100	10.2	19.9	35.6	41.8	49.2
E.S.P.	4.22	5.28	7.30	8.79	11.1

* soil water extract of 1:2.5

(henceforth named G. Saada for brevity) to 53.3 % in El-Ghar 2 soil. The organic matter content is closely related to the clay content, increasing from 0.67 % in G. Saada 2 to 2.47 % in El-Ghar 2. Furthermore, the CEC values are closely related to the clay content, ranging from 10.2 to 49.19 cmol kg^{-1} soil. All soils are non-saline, with EC values ranging from 0.41 to 0.98 dSm^{-1}. Calcium is the dominant cation in the soil extract and on the exchangeable complex; with a range of ESP extending from 4.22 in the G. Saada 2 to 11.1 % in the soil of El-Ghar 2. The pH of all soils ranges around 7.4$\pm$ 0.2. The complete data concerning these soils are given by Mahmoud (2004).

Dry matter yield:

Table 2 presents the dry matter values of the successive six cuts of alfalfa grown on the investigated soil samples. A quick inspection of the table indicates that the dry matter production by alfalfa in every case of the experiment is specific to the soil used as a growing medium. In general, there is a highly significant difference between soils if arranged according to their clay content. Statistical analysis verifies this relationship, as it shows that the correlation coefficient between the dry matter yield and the clay content is 0.97. It should be added, however, that the soil clay content is associated strongly with its organic matter content, and therefore, the clay content could be considered as key to soil fertility if other physical and chemical constraints are absent. This is well-established soil science paradigm as reported by Russell (1973), and substantiated experimentally by Khaliefa (1995) and Lal (1998).

The dry matter yield of successive cuts of alfalfa of Table 2 presents somewhat complicated relations. In this context, there are three trends. The first is shown by the soils of G. Saada 2 and El-Ghar 2, whose clay contents are lowest and highest, respectively. In both cases, the accumulation of dry matter was sustained at a somewhat stable level from the first until the fourth cut, then significantly declined to less than 50 % of the stable level in the sixth cut. The soil of Ghazala 2 whose clay content is 22.1 % shows the second trend, where there is a marked reduction in the yield beginning with the second cut to an almost constant level until the fourth cut, which then deteriorates to one half of the level reaching

Table 2. Yield of dry matter, P, K, Fe and Cu of successive alfalfa cuts

soil locality \ no. of cuts		1st	2nd	3rd	4th	5th	6th	L. S. D. 0.05	L. S. D. 0.01	total
Dry matter yield (g/pot)										
G. Saada 2		5.77	6.00	5.22	5.33	4.02	2.92	1.12	1.71	29.3
Ghazala 2		8.04	5.19	5.41	6.12	3.20	2.87	0.85	1.30	30.8
Ghazala 3		7.44	8.72	5.84	6.70	3.57	3.71	1.48	2.25	36.0
Ghazala 4		7.71	9.02	9.85	8.98	4.90	5.28	2.04	n. s	45.7
El-Ghar 2		11.4	10.4	10.2	9.32	6.15	5.66	1.82	2.78	53.1
LSD	0.05	0.56	0.85	1.82	1.13	0.47	0.70			
	0.01	0.87	1.34	n.s.	1.76	0.73	1.10			
P uptake (mg/kg soil)										
G. Saada 2		2.6	3.00	2.3	3.00	2.1	1.9	n. s.	n. s.	14.8
Ghazala 2		4.1	3.4	4.00	3.5	2.3	2.0	1.1	n. s.	19.3
Ghazala 3		3.7	4.7	4.2	4.2	2.5	2.5	n. s.	n. s.	22.0
Ghazala 4		3.3	5.8	7.5	5.3	4.3	3.7	1.7	n. s.	29.9
El-Ghar 2		5.8	7.6	8.9	4.3	4.7	3.6	1.9	n. s.	34.9
LSD	0.05	n.s.	1.0	1.1	n.s.	0.6	0.8			
	0.01	n.s.	1.5	1.7	n.s.	0.8	n.s.			
K uptake (mg/kg soil)										
G. Saada 2		24.6	18.4	25.9	47.0	19.2	24.2	n. s.	n. s.	159.3
Ghazala 2		41.7	17.4	23.4	36.7	11.0	13.3	8.7	13.3	143.4
Ghazala 3		43.9	30.3	20.4	46.6	7.3	16.3	9.3	14.2	164.8
Ghazala 4		34.4	34.6	35.1	49.4	13.6	20.3	14.5	n. s.	187.4
El-Ghar 2		72.3	43.1	49.0	48.6	16.1	21.5	13.3	20.3	250.6
LSD	0.05	5.2	4.9	n.s.	n.s.	2.4	n.s.			
	0.01	8.1	7.6	n.s.	n.s.	4.43	n.s			

Table 2, continued

Fe uptake (mg/kg soil)										
G. Saada 2		1.0	0.8	1.2	1.9	1.4	2.0	n. s.	n. s.	8.31
Ghazala 2		1.5	1.1	2.0	2.6	1.2	0.6	0.91	n. s.	9.08
Ghazala 3		1.8	1.5	1.1	2.3	0.9	1.3	n.s.	n. s.	8.90
Ghazala 4		1.2	2.6	2.8	3.00	1.6	2.4	n. s	n. s.	13.5
El-Ghar 2		1.8	2.4	2.9	2.4	2.5	2.6	n. s.	n. s.	14.6
LSD	0.05	n.s.	n.s.	n.s.	n.s.	0.5	0.02			
	0.01	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.			
Cu uptake (mg/kg soil)										
G. Saada 2		0.01	0.01	0.01	0.01	0.01	0.01	n. s.	n. s.	0.07
Ghazala 2		0.01	0.01	0.01	0.01	0.01	0.01	0.04	n. s.	0.07
Ghazala 3		0.02	0.02	0.01	0.02	0.01	0.01	0.01	n. s.	0.08
Ghazla 4		0.02	0.02	0.21	0.02	0.01	0.01	0.01	n. s.	0.09
El-Ghar 2		0.24	0.02	0.03	0.02	0.01	0.01	0.01	n. s.	0.11
LS	0.05	0.005	0.003	0.007	n.s.	n.s.	n.s.			
D	0.01	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.			

the fifth and sixth cuts. Ghazala 4 shows a rather unique trend as cuts 2 through 4 show flourishing dry matter production (significant at the 0.05 level) compared to the first cut, then there is a marked significant reduction to one half as much in the fifth and sixth cuts.

It is interesting to mention that many workers such as Oliveria *et al.* (1971), Pal and Mukhopadhyay (1992) and Khaliefa (1995) reported that the dry matter production in successive cuttings of plants decreases by age of plants. The data of this work substantiate this statement but add a qualifier in terms of soil variables to quantify the extent of reduction.

Nutrient uptake:

The data of P taken up by alfalfa are given in Table 2 which shows considerable variation as a function of soil and cutting variables. It should be emphasized, however, that an unknown extent of this variation is ambiguous and thus could not be rationally explained as the past P management history of the utilized soil samples is not known. The same observation was previously emphasized by Tahoun *et al.* (1975) in work investigating soil capacity to immobilize added P fertilizers.

Having concurred with this observation, it is feasible to state some apparent trends. First, P uptake from the G. Saada 2 soil was almost constant across the six plant cuts, probably due to a modest P requirement for a modest dry matter production. Second, the uptake from Ghazala 2 and Ghazala 3 shows a somewhat steady level till the fifth and six cuts. Third, the trend for Gazala 4 and El-Ghar 2 shows a flourishing uptake in the second and third cuts followed by a collapse in the succeeding cuts leading to significant differences at the 0.05 level.

In the case of K uptake by alfalfa given in Table 2, there are several interesting results. First, uptake in the first and second cuts is proportional to the clay content of soils; being significant at the 0.01 level. This is an easily explicable result as it is well-established fact that most of the easily accessible soil K is carried by its K-bearing minerals, particularly illite which exists in the clay fraction (Tahoun and Hamdi, 1973; Tahoun, 1974; and Tahoun and Assal, 1986). Uptake in the second cut is much lower in all soils, indicating a considerable available K depletion. However, for some unknown reason, it seems that there was a renewal of K supply that replenished its available pool, as the uptake of K is elevated beginning the third cut to reach a fairly high hump in the fourth cut. Whether or not this unusual K hump is related to an enhancement by favorable weather conditions (April) or the establishment of a robust root system needs further elaboration.

The replenishment was, however, short-lived as the uptake collapsed to a minimum in the fifth and sixth cuts. Interestingly, the uptake in the last cut bears no relation to the soil variable beginning with the G. Saada 2 soil with its 12.4 % clay or the El-Ghar 2 soil with its 53.2 % clay. The average K uptake for all soils is 19.1 mg/kg soil extending over a range of $\pm$ 5.1 mg/kg. Therefore, it seems that the amount of K-bearing minerals in the clay fraction is not at issue in this case. It is most likely that the rate at which structural K is being transformed into a readily available form is the relevant issue. Such subject is widely considered by soil chemists in the domain of chemical kinetics as given by Sparks (1989).

The successive uptake of Fe and Cu by alfalfa grown on the investigated soil samples is given in Table 2. The data indicate that both nutrients were taken up in small quantities, especially Cu in few micrograms to emphasize the obsolete connotation trace element for the nutrient (Russell, 1973). In most cases, no well-defined effect is evident for either the soil variables or for the cutting sequence to warrant significant differences. This result contradicts the finding of Mohamed (1990) who reported a reduction in Cu-uptake during intensive cropping by alfalfa in different soils. The result of the present work is interpreted in terms of three possible reasons. First, the slight requirement of alfalfa from both nutrients was conveniently provided by all soils across the six cuttings. Another possibility is that the tap water used for irrigation might have contained adequate Fe and Cu to alleviate a hypothetical soil deficiency in the two nutrients. Third, the major growth constraint in this experiment pertained to the availability of macro rather than micronutrients.

Table 3 presents the total uptake of nutrients by alfalfa grown on the investigated soils along with their available contents prior and after cultivation. It is interesting to note that the initial K, Fe, and Cu contents of all soils are closely related to their clay content. Phosphorus stands odd as its initial available content bears no relation to the clay content. It was previously outlined that the P management history of the investigated soils is not known. In the circumstances, different quantities of P fertilizers might have been applied to soils. Given that the efficiency of P fertilizers does not exceed 25 % in the first year of application, appreciable amounts of the nutrient are left in soils to the benefit of succeeding crops in years to come (Russell, 1973; Lindsay et al., 1989; and Zhang et al., 2004).

It is most interesting to note that the total P uptake by alfalfa is proportional to the clay content of the soils. As a matter of illustration, the uptake from the clayey soil of El-Ghar 2 is greater than that of the loamy sand of G. Saada 2 by a factor of 2.4 (34.9 vs 14.8 mg/kg soil). Knowledgeable readers would not be confused by the apparently contradicting results outlined in the preceding paragraph. They are well-aware of the fact that estimates of availability concentration in soils express intensive properties, whereas estimates of nutrient uptake deal with extensive properties. Reviews of the subject could be found in many textbooks such as that of Sparks (1995).

Table 3 shows that with the possible exception of Cu, the total uptake of nutrients is closely related to the soil clay content. On the average of all soils, the initial available P and K decreased by 52 % after the final harvest, whereas Fe decreased by only 40 %. It is interesting to note that the difference between the two available K levels could be equated with the total K uptake by alfalfa, whereas such equation does not hold for P.

This conflicting response could be reasonably explained by elaborating the soil pools of the two nutrients. With respect to K, the readily available fraction comprises soluble and exchangeable forms, which are in a dynamic equilibrium with the native structural K (Tahoun and Hamdi, 1973; Tahoun, 1974; and Tahoun and Assal, 1986). The high mobility of K in soils would

Table 3. Total uptake of P, K, Fe and Cu from available and immobile forms in different soil

characters / soil locality	available element			uptake by alfalfa
	initial	final	difference	
		P, mg/kg soil		
G. Saada 2	31.4	14.8	16.6	14.8
Ghazala 2	14.6	7.6	7.0	19.3
Ghazala 3	18.6	10.9	7.7	22.0
Ghazala 4	22.0	6.1	15.9	29.9
El-Ghar 2	11.6	7.8	3.8	34.9
		K, mg/kg soil		
G. Saada 2	229.3	79.0	150.3	159.3
Ghazala 2	278.5	140.4	138.1	143.4
Ghazala 3	493.7	351.0	142.7	164.8
Ghazala 4	234.8	57.5	177.3	187.4
El-Ghar 2	329.2	127.1	202.0	250.6
		Fe, mg/kg soil		
G. Saada 2	9.1	6.5	2.6	8.3
Ghazala 2	15.4	7.3	8.2	9.1
Ghazala 3	10.4	9.1	1.4	8.9
Ghazala 4	30.3	19.3	11.0	13.5
El-Ghar 2	27.9	13.6	14.3	14.6
		Cu, mg/kg soil		
G. Saada 2	1.9	1.8	0.1	0.1
Ghazala 2	3.6	3.5	0.1	0.1
Ghazala 3	8.4	8.4	0.1	0.1
Ghazala 4	7.5	7.5	0.1	0.1
El-Ghar 2	8.2	8.2	0.1	0.1

swiftly compensate depleted available K to provide for the plant requirement. As given by Griffin et al. (2003), the P pool comprises three components: (1) soluble P, (2) labile P in the solid phase that is easily exchangeable from mineral surfaces and (3) nonlabile P that that is slowly exchangeable or nonexchangeable from the mineral surface. It seems that restoration of distorted equilibrium in the P pool initiated by plant uptake is slow and sluggish (Tahoun and El-Sayed, 1976; and Zhang el al., 2004).

It should be emphasized, however, that huge amounts of P and K were extracted from the soils, reaching 70 and 500 kg per feddan from the two nutrients, respectively. Considering that these amounts were taken by only one crop in a single season, appropriate measures should be considered to adopt site-specific programs to replenish the soil fertility level. Otherwise, soil degradation is an eminent hazard.

Phosphorus fractionations:

Table 4 presents the inorganic P fractions of the investigated soils prior and after the final harvest of cultivated alfalfa in the classical chemical domain proposed by Chang and Jackson (1957). It is evident from the table that Ca-P is the dominant fraction in all soils, as would be expected for soils of slightly alkaline reaction whose chemical environment is saturated with Ca and Mg ions in the soil solution and the exchange complex (see Table 1 and more details can be found in Eissa (2004). This result supports earlier findings on similar soils as reported by Youssef (1976) and Mahmoud (2001).

Ghazala 3 soil is unusually rich in its Ca-P fraction reaching 1248 mg per kg, which far exceeds other soils by a multiplicity factor of 2 or 3. This elevated content may be attributed to past applications of large amounts of P fertilizers and/or the fairly high organic matter content of the soil at 2.47 %. Normally, soil organic matter are constantly subjected to microbial attack, where inorganic P is released in the process and subsequently may be precipitated as one of many possible P-Ca phases (Tahoun *et al*., 1975; and Tahoun and El-Sayed, 1976).

The different levels of the Ca-P fraction in Table 4 seem to be inversely proportional to the clay content of the soils. In a chemical context, this is an

Table 4: Soil P fractions prior and after intensive alfalfa cultivation

soil sample	initial, mg/kg soil				final, mg/kg soil			
	Ca – P	Al – P	Fe – P	RS – P	Ca – P	Al – P	Fe – P	RS – P
G. Saada 2	246.3	57.6	16.8	47.1	184.2	42.7	5.3	27.1
Ghazala 2	409.2	65.2	82.5	47.2	935.3	55.0	3.5	27.0
Ghazala 3	1248.3	32.6	48.4	10.1	679.8	22.7	0.0	09.3
Ghazala 4	513.7	20.2	20.9	3.3	289.3	2.2	0.0	0.0
El Ghar 2	470.2	11.9	25.0	2.5	305.2	6.7	0.0	0.0
Average	577.5	37.5	38.7	23.8	478.8	26.8	1.8	12.7

expected result given the inept activity of sand and strong activity of many clay-sized particles in soils. This point was well-illustrated for P reaction in soils by Tahoun *et al*. (1975). They showed that soluble P fertilizers persisted for much longer time in sandy soils compared to clayey and calcareous soils.

The amounts of both Al-P and Fe-P fractions as reported in Table 4 are small and their variations are not tenable to rational explanation. The RS-P fraction is somewhat unique. It represents the reductant soluble P which exists as adsorbed and/or mineral coating (occluded) oxides and hydroxides of Fe and Al. This inorganic P fraction is sometimes called soloid representing P bound as an H_2PO_4-Ca-micelle linkage. It is considered as highly available to plants (Hesse, 1971).

Differences among soils in the RS-P fraction bring two important points for considerations. First, the values are greater in the light-textured soils validating the previous finding of Tahoun *et al*. (1975) regarding the persistence of soluble P phases in sandy soils. Second, RS-P values do not conform to the values of available P as given in Table 3 in contrast to the finding of Hesse (1971). This contrasting point is a good pretext to emphasize that RS-P and available P should not be compared to each other, as the analytical procedures to determine each are fundamentally different.

All P fractions were markedly reduced after cultivating six cuts of alfalfa as made clear in Table 4. The single exception in the table is the Ca-P value of Ghazala 2, which seems to be an inexplicable experimental error. Summing individual P fractions across all soils to obtain an overall average, it is obvious that Ca-P and Al-P suffered relatively less by cultivating alfalfa compares to other fractions. Therefore, it could be concluded that a considerable portion of the Ca-P fraction is present in the apatite phase which is known for its high stability, and consequently, sparse availability (Tahoun *et al*., 1975; and Tahoun and El-Sayed, 1976).

The case of RS-P shows a loss of about 50 % after cultivation. Presumably, this is most labile P fraction, and one would expect that it suffers greater loss upon growing plants. It should be concluded then that this fraction was reformed in the soil through some transformation processes undergone by other fractions once its level was diminished below certain limit.

The case of Fe-P is rather interesting, as the data make it abundantly clear that intensive cultivation inflicted a devastating effect on this phase. The established analytical constants testify that normal aged Fe-P phases are extremely stable. The fact that the Fe-P fraction was unstable in this work implies that the fraction is composed of young small crystallites. Such crystallites posses a great surface energy, and thus are doomed to decompose, i. e., deliver their P to plant roots in the vicinity.

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استنزاف العناصر الغذائية من الأراضي بالزراعة الكثيفة والتغيرات المصاحبة في المركبات الفوسفورية

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يستهدف هذا البحث دراسة تأثير الزراعة الكثيفة على استنزاف الفوسفور والبوتاسيم والحديد والنحاس ، وكذلك تغير مركبات الفوسفور في خمسة أراض زرعت بالبرسيم الحجازي زراعة مكثفة دون تسميد لستة حشات في تجربة أصص بالصوبة الخشبية ، لتماثل سيناريو الضغوط المتناهية لإستغلال الموارد الأرضية في الزراعة الكثيفة . وتدل النتائج على تدهور انتاج المادة الجافة للمحصول مع توالي الحشات ، وان تأثر معدل التدهور بمستوى الخصوبة الكامنة للأرض . وقد تسببت الزراعة الكثيفة في خفض محتوى الأراضي من العناصر الغذائية الميسرة الى أقل من نصف محتوياتها الإبتدائية لكل من الفوسفور والبوتاسيوم ، أما الحديد فانه فقد نحو ٤٠% من محتواه الإبتدائي . وتدل هذه الأرقام على أن فدانا من الأرض يمكن أن يفقد بالزراعة الكثيفة كميات تصل الى ٧٠ كيلوجرام من الفسفور و ٥٠٠ كيلوجرام من البوتاسيوم. وتدل النتائج أيضا على ان مركبات الفوسفور الكالسيومية تفقد نحو ٥٠ % من محتواها الإبتدائي بالزراعة الكثيفة ، على حين تعرضت مركبات الفوسفور الحديدية للإنقراض ربما لتكونها من بللورات حديثة متناهية في الصغر . وتلخص الدراسة الى أن الواجب يقتضي أن يصاحب الزراعة الكثيفة برنامج موثق لخدمة الأرض يتضمن حسابات الداخل والخارج من العناصر الغذائية. والبديل المتوقع لغياب هذا البرنامج هو تدهور الأرض.