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THE AVAILABILITY OF IRON IN SOIL AND PLANTS TREATED WITH ORGANIC AND INORGANIC FERTILIZERS IN THE JORDAN VALLEY

By

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توفر عنصر الحديد في التربة والنباتات المعاملة بالأسمدة العضوية وغير العضوية في غور الأردن

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تتناول هذه الورقة نتائج الدراسة على وفرة الحديد الجاهز التي أجريت على نباتات الفاصولياء كونه مؤشراً جيداً لنقص الحديد ، وذلك بين شهري تموز ١٩٩٠ وتموز ١٩٩٢ ولموسمين زراعيين في كل عام، باستخدام ستة أنواع من الأسمدة الكيماوية : سوكسترين (حديد) وسوبر فوسفات حبيبي، وسماد فوسفات سائل وأسمدة طبيعية : زبل غنم، زبل بقر، زبل دجاج بياض وذلك على مساحة ٣ دونم في منطقة أريحا (غور الأردن)، باستخدام نفس الوسائل والأساليب والمواد والأسمدة المتوفرة لمزارعي تلك المنطقة كماً ونوعاً. ويتضح من نتائج الدراسة أنها جاءت لتؤكد ما هو معروف في عالم الزراعيين، بأن استخدام الأسمدة الحديدية عن طريق الرش المباشر على الأوراق يعتبر أنجح الوسائل لمعالجة ظاهرة نقص الحديد، يليها استخدام الأسمدة الطبيعية، حيث جاءت نتائج الدراسة حول نسبة ظهور نقص الحديد على النحو التالي :

سوكترين (حديد) < زبل الدجاج < زبل الغنم< زبل الأبقار < سماد فوسفات سائل < سوبر فوسفات حبيبي < شاهد

كما أن هذه الدراسة تؤكد على أن نقص الحديد لا يعود لنقصه في التربة ولكن لقلة جاهزيته، وعلى أن أهم العوامل المؤثرة في ذلك هي : نوع التربة، نوع النبات، درجة الحموضة ودرجة التبادل الأيوني والتضاد الأيوني والتعاون والتداؤب الأيوني والتثبيت وعمليات الغسل والشطف التي تتأثر أساساً بعوامل الجو المختلفة من أمطار ورطوبة وتهوية ودرجة حرارة .

Key Words : Chlorosis, Manure, Soxtrine, Leaching.

ABSTRACT

This paper deals with the reults of a study carried out on "*Phaseolus vulgaris* - Wed" as an indicator of chlorosis. The study took place between July 1990 and July 1992, and for two crop seasons each year. Six kinds of fertilizer were used. Soxtrine (Iron), granular superphosphate, liquid phosphate fertilizers, and natural fertilizers: manure and quarlers waste of sheep, cows and egg-laying hens. An area of about three-quarters of an acre in Jericho (Jordan Valley) was used for the study, using the same means, methods, materials and chemical fertilizers which are available to farmers in that area. The study confirms what is well known to the farmers that direct "Foliar Spraying" is the most efficient method in treating chlorosis, followed by the methods of using natural fertilizers. The study illustrates the rate of chlorosis as follows: Control > Granular Superphosphate > Liquid Phosphate Fertilizer > Cow's manure > Hen's manure > Soxtrine (Iron).

In addition, the study confirms that chlorosis is not attributable to iron deficiency in the soil, but rather to its lack of availability. The main factors which play a role in determining the availability of iron are: nature of soil, kind of plant, pH, rate of ion exchange, antagonism, synergism, and fixation as well as the leaching factor, all of which are related to weather elements like rain, humidity, ventilation and temperature.

INTRODUCTION

This study was carried out in order to explore factors which may contribute in treating or alleviating the problem of chlorosis in *Phaseolus vulgaris*. This is one of the major problems in the Jordan Valley where calcareous soil is abundant. Chlorosis is a yellowness of new plant leaves as a result of lack of chlorophyll, which in turn makes them shrivel or even dry out completely in acute cases. In many cases, slow plant growth or crop failure are ascribed not to nutrient deficiency but rather to their unavailability, in that the plant can not absorb or use the nutrients in biosynthesis. Sometimes, inactivation of these nutrients within the plant can occur. The most explicit example is the iron deficiency phenomenon "Chlorosis". Despite the fact that iron comprises 3–5% of the weight of earth's crust, a major portion of it is unavailable to the plant. Forms of iron available and readily absorbed are usually found in small amounts, mainly as ferrous ion or in coated iron compounds [1].

Different plants vary in the degree to which they are affected by the percentage of available iron. Some plants can cope with iron deficiency, like potato, whereas other plants are very sensitive and marks of iron deficiency become visible on the plant, for instance beans [2].

Iron as well as other secondary micronutrients play the role of coenzymes in the enzyme system, "Cytochrome oxidases" (Catalase, Peroxidase). These will allow it to tolerate the reversible oxidation of $Fe^{2+} \rightarrow Fe^{3+} + e^-$ and also its inclination to form coated complexes. The problem of iron deficiency is due to its unavailabiulity which can be attributed either to the increase of the percentage of $CaCO_3$, HCO^-_3, BO^{-3}_4 or NO_3^- because of their effect on the soil pH, or to the existence of heavy metals like managanese, Copper, or Zinc in the soil or in irrigation water due to their ion-exchange effect. Iron deficiency can also occur as a result of excessive irrigation which would be conducive to a rise in humidity and equilibrium in ionic proportion, inadequate ventilation, high or low temperatures, and high light intensity can cause iron deficiency. In addition, deficiency can be caused by the inability of plant roots to absorb iron because of their destruction by microorganisms or for hereditary reasons [1 - 3].

Table 1
Division of Land of Experimentation and Location of Test Samples

Fertilizer	Triplet	Distance from edge of field (in meters)				
		zero	10	20	30	40
control	1	*				
	2		*			
	3			*		
	control				*	
sheep manure	1					*
	2				*	
	3			*		
	control		*			
hen's waste	1	*				
	2		*			
	3			*		
	control				*	
cow's manure	1					*
	2				*	
	3			*		
	control		*			
soxtrine (iron)	1	*				
	2		*			
	3			*		
	control				*	
granular superphosphate	1					*
	2				*	
	3			*		
	control		*			
liquid phosphate fertilizer	1	*				
	2		*			
	3			*		
	control				*	

MATERIALS AND METHODS

Experimentation and study were carried out on an area of about three-quarters of an acre in the Jericho Area (Jordan Valley), between July 1990 and July 1992, and for two crop seasons each year. The same agricultural methods as used by farmers of that area were used in our study including ploughing, preparation and sterilization by methyl bromide. Bean plants *(Phaseolus-vulgaris*-Wed) were used as an indicator crop, and the dripping technique was used for irrigation. The area had been planted to bananas for five consecutive years prior to the study.

The area was ploughed in furrows. In this experiment six kinds of fertilizer were used and every three furrows (triplet) along with a control furrow were planted. The division of the land for experimentation and location of test samples are illustrated in Table 1.

The fertilizers employed

The experiment was carried out by using natural as well as chemical fertilizers (sheep manure, cow's manure, (iron) Soxtrine, liquid phosphate, and granular superphosphate). These fertilizers were employed due to their availability in the market and to their reasonable price. Quantities were used according to the established usage in that area i.e. 1 m^3 of a natural manure was added once to each donum (approximately one-fourth of an acre) of land and 50 kg of chemical fertilizer were added for each season where granular superphosphate was added before the beginning of the season. Soxtrine was directly sprayed onto plant leaves and liquid phosphate was added to irrigation water, both twice in each season.

Composition of Fertilizers

1 – Liquid phosphate: 85% H_3PO_4 which contains 61% of active P_2O_5. It is soluble in water and releases phosphorus in the soil.

2 – Granular superphosphate: contains 25% of active P_2O_5, 11% pure phosphorus, 22% calcium and 11% sulfur. It is slowly soluble and requires a period of about three months to completely decompose.

3 – Soxtrine:Ethylene diamine di [o - hydroxyphenylacetic acid] NaFeEDDHA. It contains 6% of available iron. It is considered one of the fixed iron fertilizers in a pH range of 4 –10. It can be directly absorbed without going through the soil solution. Therefore, it is unlikely to be leached to the underground layers.

4 – Solid organic fertilizers: They comprise waste of broiler chickens, milk cow's manure, milk sheep manure, which contain 50–80% water, 20–50% organic material. All of them were two months old or less, and had not completed their fermentation period. This means that these manures will ferment in the soil. Chemical compositions of these manures are shown by Tisdale[2].

Study Sample

In the experiment 224 samples were analyzed after they were collected at four different times with a rate of two samples at different depths from each locations. Samples were collected according to the Zig-Zag method and locations of samples appear as an asterisk in Table 2. At the same time a study on 112 samples of plant leaves was carried out. Leaves were collected from the same locations as soil samples using the same mehtod of four times at a rate of one sample from each location at a time.

Sampling Methodology

Soil samples were collected using a shovel, holes to the required depth were dug then the sample would be taken from the edge of the hole. Samples were taken at two depths, the first at 0–20 cm, and the second at 20–40 cm. Then, samples were brought to the laboratory in plastic bags [4 - 6]. As for the plant samples, emphasis was on new leaves for marks of iron deficiency which appear only on leaves. Dates of plantation and sample collecting for the two seasons for soil and plants are shown in Table 2.

Sample Analysis

Soil or plant samples were usually left for natural drying. If this was not possible, ovens were used at low

Table 2
Date of Planing and Sampling

Date	Land preparation	Planation	Soil testing	Plant testing
First season				
7/8/1991	*			
15 – 20/8			* Preplantation	
15/9		*		
10 – 20/10			* Midseason	* Midseason
15 – 15/12			* End of season	* End of season
Second season				
5 – 10/1	*			
15 – 20/1				
25 – 30/1		*		
15 – 30/1			* Midseason	* Midseason
15 – 30/1				* End of season

temperature 50–70°C, in order to preserve the contents of the sample from any damage, volatilization, dissolution reactions, or precipitation which would change the *de facto* condition of the field.

Chemical analyses included tests for nitrogen, potassium, phosphate, sodium, iron, calcium carbonate, pH, and electrical conductivity. Morphological tests were also run to detect iron deficiency represented by the ratio of the number of the infected plants to the total number of plants in a certain furrow. Weight measurements were run by weighing the crop in a 20 m length of the furrow while staying about 10 m away from each edge of the furrow, since each furrow was 40 m long.

Iron analyses of soil were carried out by the extraction method using DTPA (Diethylene Triamine pentaacetic acid) and hydrochloric acid, hydroxylamine hydrochloride was used as a regulator, and orthophenanthroline as an indicator to form the colored iron complex, then spectrophotometric method was followed.

The extraction method for phosphate analyses was used using 0.5 N sodium bicarbonate at a nearly constant pH of 8.5, then adding sulfuric acid and ascorbic acid reagent to form the colored complex, their measurements were made spectrophotometrically.

Potassium and sodium analyses of soil were performed by the extraction method using ammonium acetate (1:4 proportion). The reading from the falme photometer gave us the sodium and potassium contents in the samples.

The calcium bicarbonate test involved the quantitative determination of inorganic carbonate by the dissolution of carbonate in acid and the determination of carbon dioxide evolved. The volume of carbon diozide that evolves changes proportionately as the temperature and pressure and with respect to the standard conditions.

Plant samples were subjected to intensive combustion to convert them to ash, dissolving in hydrochloric acid, then proceeding as metntioned in the soil analysis above [5 , 6].

Table 3

Averaged Data of Weight And Morphological Measurements

Fertilizer	% of Crop with Iron Deficiency		Crop Weight kg/20m
	Mid-Season	End of Season	
Hen's manure	8 %	1 %	19.3
Sheep manure	11 %	3 %	22.7
Cow's manure	13 %	5 %	20.5
Soxtrine (Iron)	5 %	0 %	21.0
Liquid phosphate	23 %	8 %	15.9
Control	20 %	8 %	14.5
Granular superphosphate	22 %	9 %	12.2

Table 4

Averaged Data of Iron Analyzed in Plant Samples (ppm Fe in dry weight)

Fertilizer	First Season		Second Season	
	Mid-Season	End of Season	Mid-Season	End of Season
Soxtrine (Iron)	221	420	189	319
Hen's manure	196	388	190	301
Sheep manure	189	370	179	318
Cow's manure	190	347	168	289
Liquid phosphate fertilizer	157	327	140	258
Control	151	293	134	219
Granular superphosphate	142	282	132	204

Table 5

Averaged Data of Iron Analysis in Soild samples (ppm)

Fertilizer	Depth	First Season			Second Season
		Pre-Palntation	Mid-Season	End of Season	Mid-Season
Hen's manure	0 – 40	0.40	2.68	3.35	4.83
	20 – 40	0.37	2.48	3.22	3.92
Sheep manure	0 – 40	0.37	1.38	2.92	3.60
	20 – 40	0.41	1.34	3.10	3.42
Cow's manure	0 – 40	0.60	1.42	2.57	3.01
	20 – 40	0.68	2.19	2.89	3.82
Soxtrine (Iron)	0 – 40	0.48	2.04	2.47	2.14
	20 – 40	0.42	1.95	2.03	2.24
Liquid phosphate fertilizer	0 – 40	0.41	1.70	2.13	2.09
	20 – 40	0.04	1.91	2.27	2.13
Control	0 – 40	0.41	1.50	2.05	2.15
	20 – 40	0.35	1.40	1.90	2.01
Granular superphosphate	0 – 40	0.46	0.96	1.23	1.89
	20 – 40	0.31	0.87	1.05	1.95

Table 6

Averaged Data for different elements in soil samples

Fertilizer	pH	EC mS/cm	N ppm	P ppm	K ppm	Na ppm
Sheep manure	6.4	4.4	85.5	5.4	692	4.1
Granular superphosphate	7.9	2.7	72.2	4.9	121	2.9
Hen's manure	6.9	3.6	81.3	5.8	205	3.7
Soxtrine (Iron)	7.2	3.4	43.6	3.2	89	3.2
Cow's manure	6.9	3.4	75.5	5.1	208	3.9
Control	7.6	3.2	52.7	3.5	167	2.1
Liquid phosphate fertilizer	7.3	3.3	4.0	6.2	146	3.4

RESULTS AND DISCUSSION

Results of laboratory studies and morphological measurements are shown in Tables 3–6.

There are three main things to consider : kind of samples (soil or plant), rate of iron deficiency, and crop weigth. Sample analyses show the following :

1 – Soil Analyses: There is an increase in soil iron percentage as the season proceeds, secondary: the order of percentage iron in the soil varies depending on the fertilizer used, as follows: Table 5
Hen's manure > Sheep manure > Cow's manure > Liquid phosphate > granular superphosphate > control.

As the season proceeds, the percentage of Fe in the plants increases. This can be ascribed to the fact that as the roots grow, a larger effective area for ion exchange is provided. The plants need different micronutrients so the absorption of different ions compete with the iron complexes of calcium, copper and manganese. This absorption of iron also causes the fixation of the insoluble compounds of iron and its phosphates. As a result of this iron exchange the plants secrete more of the H^+ ion as a substitute for the other positive ions which will lead to a decrease in the pH and reflect positively on the solubility and the availability of iron in the soil [7, 8].

The order of the effect of various fertilizers on the availability of iron in soil is attributed to their various compositions, as well as to their ability either to liberate iron or to fix it. Animal manure gives the highest increase in the availability of iron in soil, this is due to the fact that these manures may add large amounts of acidic elements like sulfur and nitrogen in the form NH^+4 which decreases in the soil pH. This decrease has a positive effect on providing iron in the soil avilable for absorption since ferric ion (Fe^{3+}) reduction will be facilitated.

The organic substance (humus) which is considered as the main product of the manure's decomposition enhances the ion-exchange since it has an ion-exchange capability two to three times as much as the soil particles. This is because of the fast decomposition they undergo and the amount of acidic compounds that they add to the soil in addition to the other interfering substances which help fix the iron.

The iron Soxtrine fertilizer is considered as a direct source of iron when sprayed onto leaves, thus intensifying the green color of the leaves and increasing the activity and the potency of the plant in absorbing cations from soil. These cations can be substituted by H^+ ion secretion, which in turn lowers the pH. In addition, absorption causes an increase in the ion-exchange which may reduce interference with iron, hence increasing its availability

Phosphate fertilizers are a rich source of nutrients like phosphrous, calcium and sulfur which are needed by the plant, but phosphorus may cause the deposition of iron and aluminum as insoluble triphosphate. When comparing phosphate fertilizers together, one can see that liquid phosphate fertilizer is highly soluble in water and lowers the pH of the soil since it contains phosphoric acid. This lowering of pH increases the availability of iron. The granular superphosphate is slightly soluble in water and decomposes slowly. It contains calcium, sulfur, and phosphorus which are considered as essential elements to the plant. Phosphrous in particular provides the plant with H_2PO_4 which lowers the pH and hence increases the availability of iron. On the other hand, calcium interferes with iron in which case the availability of iron would be decreased. Therefore one can conclude that liquid superphosphate is more efficient in maintaining the availability of iron than the granular superphosphate.

2 – Plant Analyses :
Available iron in plants is related to the kind of fertilizer employed (Table 4).
Soxtrine > Hen's manure > Sheep manure > Cow's manure > Liquid phosphate > granular super phosphate > granular super phosphate > Control

The highest percentage of iron is found in Soxtrine-fertilized plants. This is due to the fact that soxtrine is available iron (NaFeEDDHA) and is sprayed directly onto plant leaves. In that case, leaves will directly be provided with iron rather than absorb it via the roots of the plant, or via the ionic interference process.

As for the other kinds of fertilizer, variation of the amount of iron in the soil will lead to a variation in its proportion in plant leaves, since that amount is directly proportional to the degree of absorbency and the availability of iron in the plant. The latter, as was mentioned before, is basically dependent on soil conditions.

The rate of appearance of iron deficiency was in the following order : as follows (Table 3).

Control > Grandular superphosphate > Liquid phosphate > Cow's manure > Sheep manure > Hen's manure > Soxtrine.

These observations confirm the result from the analyses of the plant leaf samples, which indicate that symptoms of iron deficiency are directly proportional to the amount of available iron in the leaves.

Results of the crop weight study show the following order (Table3).

Sheep manure > Soxtrine > Cow's manure > Hen's manure > Liquid phosphate > Granular superphosphate > Control.

This is similar to the findings from the iron level determinations, in that a decrease in iron deficiency means more intensely green leaves, and more activity and productivity. This will give a better chance for the plant to grow and to give a better crop. In addition organic fertilizer (i.e. animal manure) is considered as a good source of other nutrients which are necessary for the plant's growth, whereas chemical fertilizers, especially phosphate, are considered as a poor source of nutrients.

Recommendations

In order to alleviate the problem of iron deficiency in calcareous soil and to increase the rate of availability of iron in the plant, adequate conditions for the reduction of Fe3+ must be provided. In addition, solubility of deposited iron complexes must be enhanced, pH be lowered, and the soil potential for ion exchange be enhanced. Therefore, the following are recommended:

1 – Sowing plants which can cope with iron deficiency in the soil.

2 – Upgrading the soil's potential by efficient ploughing which will allow a good ventilation, and by adding humus to promote ion-exchange.

3 – Adding nutrient fertilizer upon the recommendations, standards and quantities set by specialist agronomists.

4 – Being aware of excessive humidity in order to reduce hydrolysis of calcium-containing substances.

5 – Increasing amounts of CO_2 in the air surrounding the soil, in order to curb the activity of OH- resulting from carbonate hydrolysis.

6 – Acidifying calcareous soil by adding acidic fertilizers, for instance those containing sulfur.

7 – Promoting cooperation among farmers and among guiding agricultural institutions.

8 – Educating farmers in the use of fertilizers.

9 – Conducting regular soil and plant analysis.

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