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2.7 FERTILIZATION STUDIES UNDER THE RAINFED AGRICULTURE OF SYRIA

by

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SUMMARY

Fertilizer studies carried out in the rainfed regions of Syria, Houran and Djeizireh, with mean annual rainfall 310 and 450 mm respectively, on annual crops showed that the soils responded to N fertilization while the effect of P was not consistent although it had a positive effect during drier years. Wheat was found to require 40-50 kg N/ha but in years of low rainfall N tended to depress yields. From correlating wheat yields with available soil P it was found that the critical level was between 2 and 4 ppm.

A high positive correlation ($r = + 0.97$) between yields of wheat and total rainfall in December and January was established.

Fertilizer field experiments carried out in the subhumid region of Syria showed that the main response of olives was due to N fertilization alone and the average fruit production was almost doubled by the addition of 2.5 kg of ammonium sulphate per tree. Neither phosphorus nor potash had a significant effect on yields.

Foliar sprays of potassium sulphate on tobacco increased the K content from 2.3 to .8 percent, while Fe chelate was very effective in controlling chlorosis of apples. Soil applications of Fe chelate were found to be very effective in controlling chlorosis and gradually increasing the yield of olive fruit.

. INTRODUCTION

Dry farming agriculture is practised on 6 million hectares out of the total agricultural land of Syria. A two-year rotation is almost universally practised in the dry farming area. Wheat is the main crop in rotation with lentils, vetches, chickpeas or mostly with fallow. Traditionally farmers assumed that fallowing the land is an effective means of water conservation, better weed control and maintenance of soil fertility. Although the fallow system had shown its merits in many parts of the world, the improvements made in the fertilizer industry, conservation and soil management, had lessened the traditional values of the fallow system. In 1965 Loizides (1970) initiated two leading experiments in the dry farming area of Syria on crop rotation and fertilization. The first was in the Houran Plain (310 mm mean annual rainfall) and the second in the Djeizireh area (450 mm mean annual rainfall). Both experiments showed the merit of replacing fallow by a legume such as lentils or vetches.

In Syria the dry farming area extends from the coastal plain on the Mediterranean sea to near the Syrian desert inland. Dry farming agriculture is practised on all agricultural non-irrigated land with over 250 mm of annual precipitation.

Soils of the dry farming area differ in depth, texture, topography and productivity depending upon the dominant soil forming factors.

The determination of fertilizer needs of various crops grown in the different soils has been of paramount importance for raising the agricultural production, and consequently an ambitious programme of field plots and tests was initiated in Syria in the early sixties to investigate the fertility of the Syrian soils and their fertilizer needs.

This paper covers the major aspects of the work carried out or in progress in the fields of soil fertility and plant nutrition.

2. FERTILITY POT TESTS

Dry farming agriculture is practised on soils of three main regions of Syria:

In Djeizireh soils occupy the largest part of the dryland area of Syria where cereals are mainly grown with some legume crops, under an annual rainfall of 250 to 500 mm. According to Dubertret (1933) the soil parent materials are of lagoonal Miocene origin covered with a relatively thin gravelly sedimentary layer of the Quaternary. The lagoonal Miocene sediments are formed either from gypsum, or gypsum anhydride, or limestone. The Miocene sediments comprise embedded layers of silt and clay in sandstones. Soils in the Djeireh range from a dark brown clay texture in the wet region to a yellowish brown and silty texture in the drier area with a calcium carbonate content ranging from 13 to 30 percent.

Fertility pot tests were carried out on 23 types of soils, chosen from various sites representing the various great soil groups of the Djeizireh. Wheat was used as an indicator plant. The results of pot tests showed that most soils responded markedly to nitrogen and to a lesser extent to phosphorus. None of the soils responded to potash. Soil chemical tests had shown a low level of N, 0.08 to 0.15 percent, a medium to low level of $NaHCO_3$ - extractable P, 2 and 10 ppm, while exchangeable potassium was very high in most soils, ranging from 390 to 800 ppm.

The soils of Houran are derived basically from a basalt parent material dating from the lower Quaternary. They are clay to clay loams, deep, cracking deeply in summer, calcareous with 8 to 15 percent of calcium carbonate in the top layers with lime concretions in the lower horizons.

Chemical analyses had shown that the soils of Houran are very rich in exchangeable K, 450 to 800 ppm, but very poor in total nitrogen (0.04 to 0.13 percent) and available phosphorus (2-5 ppm).

Fertility pot tests demonstrated a strong response to nitrogen and phosphorus for most Houran soils with no response to potash fertilization.

Soils of Sweida are older, derived from an old Neogene basalt, located in a more humid climate (400 to 450 mm annual rainfall) and higher altitude than the Houran Plain. The soils of Sweida are brown to dark brown in colour, heavy to medium textured, strong, lime free in their surface horizon and of a neutral pH. The soils are more leached than the Houran soils, with less exchangeable K, but contain more nitrogen and available P. The fertility pot tests showed medium to strong response to N fertilization, poor to medium response to P and none to potash.

Most soils of the internal plains are derived from calcareous limestones, except in some localized spots with basalts as the parent material. The dominant climate is semi-arid-semi-humid, with 300 to 450 mm of annual rainfall. Soils derived from the hard limestones are red to reddish brown (calcareous Rhodoxeralf), of clay to clay loam texture. Soils derived from the soft limestones are lighter in colour and usually of higher lime content and of lighter texture. The calcium carbonate in the soils is between 0 and 45 percent.

Laboratory analyses of soils, following the dry farming system in the area, showed a low level of total N and of available P with medium to high level of exchangeable K. The fertility pot tests demonstrated a large response to N fertilization, but a medium response to P.

A good part of the internal plains, the Orontes Valley, was put under irrigation, and chemical fertilizers were used extensively by farmers in the last twenty years.

Consequently, soil nutrient contents and pot test responses depended upon the past history of the field, available soil P showing wide fluctuations from 2 to 58 ppm.

2.1 Correlation between $NaHCO_3$ - Extractable P and Fertilizer Response

The $NaHCO_3$ - extractable P in soils used in pot tests was correlated with the relative increase in wheat yield from additions of P fertilizers to soils.

The correlation coefficient was poor when all Syrian soils were included but improved when soils were grouped according to their genesis (Matar and Samman, 1975). The linear correlation coefficients (r) between the available P and the yield response to P were 0.69 and 0.64 for basaltic and limestone soils respectively (Figures 1 and 2).

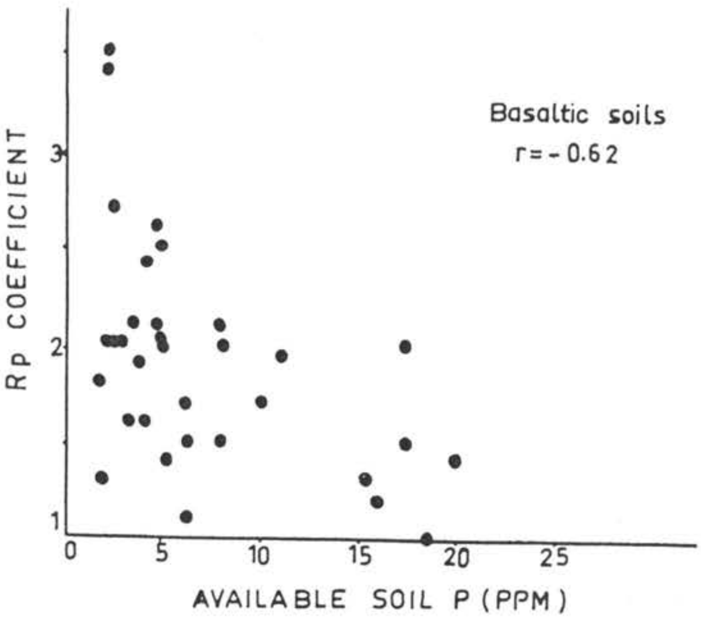

Fig. 1 Response of wheat plants grown in pots to added phosphate in relation to $NaHCO_3$ extractable P in basaltic soils

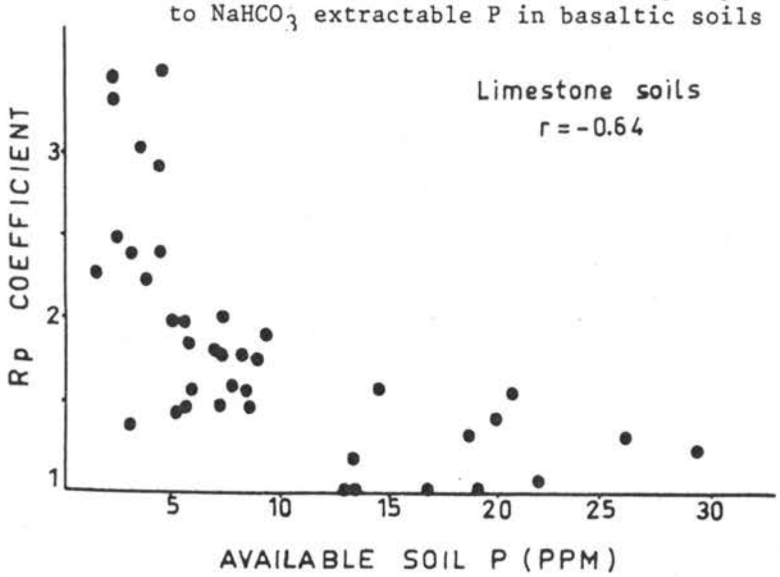

Fig. 2 Response of wheat plants grown in pots to added phosphate in relation to $NaHCO_3$ extractable P in limestone soils

2.2 Calibration of Fertility Pot Tests with Field Experiments

On 20 soils derived from different parent material, field and pot tests were run concurrently to estimate the yield response to P fertilization. Field trials were carried out with various irrigated crops such as cotton, sugarbeet, potato, and wheat as a rainfed crop, which were fertilized with adequate basic dressings of N and K fertilizers. Two P levels, P_0 and P_1 were compared: they ranged from 16 to 50 kg/ha P depending on the type of crop. From comparing the yield responses due to P fertilization in pot tests and in the field, a highly significant linear relationship ($r = + 0.81$) was established:

$$Y = 0.827 + 0.279 X$$

where X is the RP coefficient for pot tests and Y is the RP coefficient for field trials.

It is obvious from the equation that a much greater response to P addition was obtained in the pot test than in the field. These results should be expected since the volume of soil in the pot would be exhausted of P more thoroughly by the numerous seedlings than by the lesser numbers in the field.

It was concluded that the pot test used with wheat as a plant indicator was found satisfactory for determining the potential fertility of major Syrian soils, particularly their available P status. Equally well the P extracted by the $NaHCO_3$ solution gave a good estimation of the available P for a large spectrum of soils, especially when they were grouped according to their genetic origin.

3. FERTILIZER FIELD EXPERIMENTS WITH ANNUAL CROPS

Since the early sixties, fertilizer experiments were carried out in the field, by the staff of the Ministry of Agriculture of Syria. Demonstration field trials showing the benefit of fertilization in raising crop yields, and well designed fertilizer experiments for the determination of types and amounts of each fertilizer needed for the various crops grown in the various ecological conditions of Syria, were carried out.

A fertilizer demonstration trial consisted of a few (4 to 5) different treatments, the control, N, NP, NK and NPK, which were carried out annually on hundreds of field plots throughout the country. The programme was a success. It drew the attention of the farmers to the beneficial effects of fertilizers by organized field days. The demonstration programme lasted until early 1967, when more detailed information on the type, rate and method of fertilizer application was needed for each crop.

Factorial experiments with N, P and sometimes K fertilizers, 3 to 4 levels each and with 3 to 4 replications were carried out in order to estimate the most economic use of fertilizers for optimum yields.

3.1 Wheat and Small Grains

Fertilizer experiments on wheat, lentils, vetches, and other small grains were carried out by Loizides (1970) and Kanbar (1976) on many soils of the rainfed area, including the Houran Plain, the Djeizireh area, and the internal plains of Homs, Aleppo and Hama. The main results of these experiments can be summarized as follows:

i. There was no effect of potash fertilization on yield of wheat or any other small grain crop grown in the rainfed area.

ii. All soils responded to N fertilizers, and rates of 40 to 50 kg N/ha were found very satisfactory for wheat grown in the Houran or the internal plains. Higher rates of N fertilization were found to depress yields in dry years.

iii. Few experiments were carried out to study the effect of source and split applications of N on yield. Single application of N before sowing, mixed with P, was equally as effective as two or more split applications. Ammonium sulphate (21 percent) was used in the early experiments, and then replaced by ammonium nitrate produced by the "Factory of N Fertilizers in Homs".

iv. The effect of P fertilizers was not consistent. It depended on climatic conditions and past fertilization history of the soils.

v. Further combined studies on the effectiveness of P fertilization were needed to evaluate the residual effect of P on crop yields, the effect of climatic conditions on P responses and the correlation of soil tests for available P to P responses.

3.2 Direct and Cumulative Effect of P on Yield of Wheat and Lentils

A long-term experiment (1968-72) was carried out in the Houran Plain at Ezraa Experimental Station on soils with 15 percent of $CaCO_3$ to study the effect of rate, method of application, and the residual effect of P on yield of wheat and lentils grown in a two-year rotation (Matar, 1976). The rate of single superphosphate (18 percent P_2O_5) used was 0, 300 and 600 kg/ha for the two-year rotation and applied to wheat alone, lentils alone or split between the two. The main results were:

i. Application of 150 kg of single superphosphate per hectare per year was found adequate for an optimum yield of wheat and lentils under Houran conditions.

ii. Total P accumulated in wheat was higher than in lentils.

iii. The method of P application had no significant effect on yield of lentils.

iv. The application of 300 kg of single superphosphate/ha per year led to a substantial accumulation of available P in the soils as determined by soil tests.

3.4 Correlation between Soil Available P and Yield of Wheat and Lentils

The available P in soils, as determined by the $NaHCO_3$ method, was correlated with the yields of wheat and lentils grown in the Houran Plain. The natural soils are poor in available P, of the order of 1 to 2 ppm. Wheat and lentils were grown in soils fertilized with increasing amounts of phosphate in the year which preceded the experiment. Yields were correlated with the available P in soils, determined just before sowing for three successive years. The results obtained were as follows:

i. The critical level of available P in soils in years of normal rainfall and good yields was found to be 2 and 4 ppm for wheat and lentils respectively. However in dry years with low yields, a linear relationship was found between yields of wheat and available P in soils in the range of 2 - 9 ppm.

ii. The critical level of available P in soil (threshold value) beyond the response was negligible for both crops to application of phosphates, and was found to change from one year to another, depending upon the climatic conditions.

iii. It was concluded that available P in soils in the rainfed area should be represented by a range of adequacy rather than a sharp critical value. Consequently, in order to maintain an adequate level of P in soil, for years of varied climatic conditions, regular fertilization with phosphates is essential for ensuring better yields of wheat and lentils regularly (Matar, 1977). The results of correlation were plotted in Figure 3 for wheat and Figure 4 for lentils.

3.5 Effect of Rainfall Distribution on Response to P Fertilization and Yield of Wheat and Lentils

The response to P fertilization in the Houran Plain has been variable from year to year. The data from the two long-term fertilizer experiments initiated at Ezraa

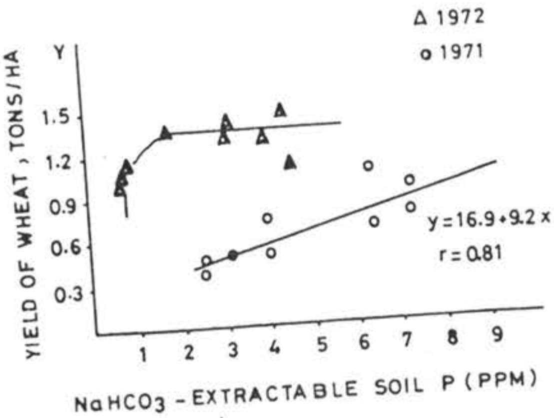

Fig. 3 Relation between available P in soil at seeding time and yield of wheat grain in two consecutive years

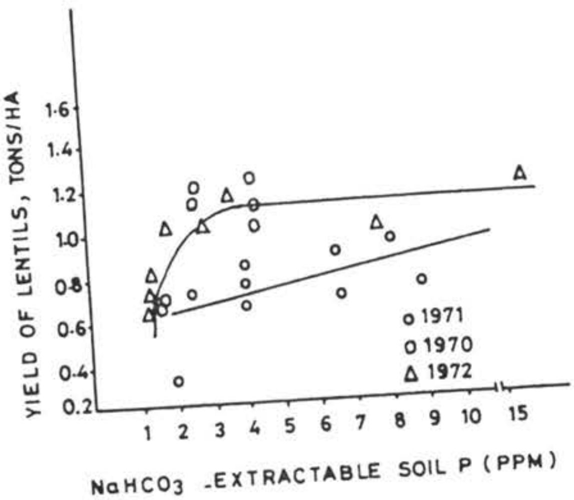

Fig. 4 Relation between available P in soil at seeding time and yield of lentils in three consecutive years

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Experimental Station by Loizides (1970) and Matar (1976a, 1976b) to study some of the P fertilization problems were re-evaluated.

Data from 1966 to 1972 were used to correlate yields of wheat and lentils or the relative response to P fertilization with monthly and total rainfall during the respective period. The following results were obtained (Matar, 1977):

i. A high positive correlation between yields of lentils in December (r = + 0.90) or March (r = + 0.80) and rainfall while yields of wheat correlated with total rainfall in December and January (r = + 0.97) (Table 1). Somewhat similar results were found in Jordan, using a different statistical method. Early predication of yields could be of great importance to agricultural planning under dryland farming conditions.

ii. The relative response of either wheat or lentils to addition of P fertilizers was largely dependent on rainfall distribution. The correlation coefficient (r) between crop response to P and rainfall distribution was opposite in sign to that observed between yield and rainfall distribution. A negative linear relationship was found between relative response of lentils to P and amount of rainfall in December (r =

-0.89) or March (r = -0.72). The coefficient of correlation between response of wheat to P and amount of rainfall in December and January was -0.95 (Table 2).

In general, the greater response to P fertilization was found in the dry and unproductive years, and a negative linear relationship was found between the relation response to P and the absolute yield of wheat or lentils (r = -0.98) (see Figure 5).

Table 1 LINEAR CORRELATION COEFFICIENTS BETWEEN YIELDS OF LENTIL OR WHEAT AND VARIOUS MONTHLY RAINFALL IN THE PERIOD 1966-1972

Month of rainfall	Type of crop and fertilization			
	Lentil unfertilized	Lentil (+ P)	Wheat (+ NP)	Wheat (+ N)
December	+ 0.90	+ 0.90	+ 0.67	+ 0.64
January	- 0.01	+ 0.24	+ 0.68	+ 0.68
February	- 0.50	- 0.63	- 0.72	- 0.75
March	+ 0.80	+ 0.74	+ 0.33	+ 0.29
April	- 0.46	- 0.68	- 0.82	- 0.73
December/January	+ 0.50	+ 0.72	+ 0.87	+ 0.95
December to February	+ 0.40	+ 0.61	+ 0.88	+ 0.85
December to March	+ 0.86	+ 0.96	+ 0.87	+ 0.82
December/February	+ 0.53	+ 0.44	+ 0.17	+ 0.12
December/March	+ 0.94	+ 0.85	+ 0.53	+ 0.53
December/January/March	+ 0.83	+ 0.96	+ 0.91	+ 0.87
January/February	- 0.31	- 0.06	+ 0.45	+ 0.44
January/March	+ 0.63	+ 0.81	+ 0.87	+ 0.84
December to April	+ 0.91	+ 0.86	+ 0.55	+ 0.56
October to April	+ 0.80	+ 0.70	+ 0.30	+ 0.36

Table 2 LINEAR CORRELATION COEFFICIENTS BETWEEN RESPONSE OF WHEAT AND LENTIL TO P AND RAINFALL DISTRIBUTION

Month of rainfall	Type of crop and fertilization	
	Lentil response to P	Wheat response to P
December	- 0.89	- 0.59
January	+ 0.12	- 0.71
February	+ 0.32	+ 0.71
March	- 0.72	- 0.27
April	+ 0.26	+ 0.88
December/January	- 0.41	- 0.95
December to February	- 0.35	- 0.87
December to March	- 0.77	- 0.81
December/February	- 0.85	- 0.10
December/March	- 0.62	- 0.47
December/January/March	- 0.71	- 0.86
January/February	+ 0.35	- 0.51
January/March	- 0.47	- 0.85
December to April	- 0.98	- 0.39
October to April	- 0.85	- 0.13

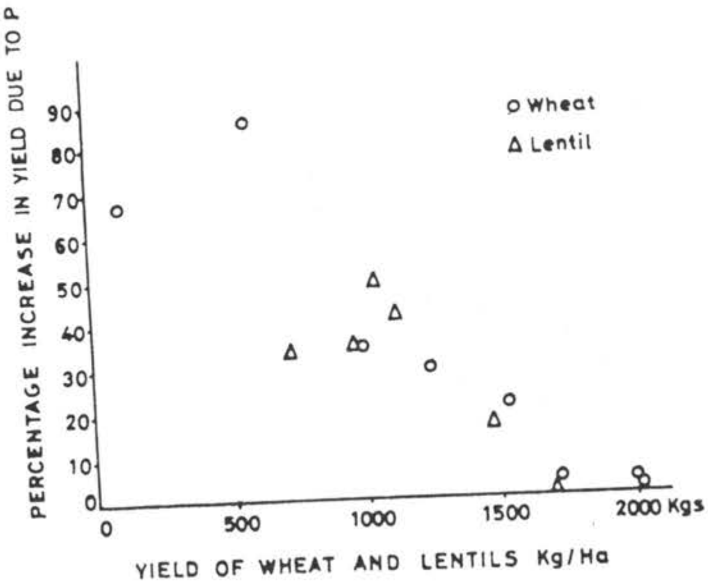

Fig. 5 Increase in average yield of wheat and lentils in relation to added phosphate

The positive effects of phosphorus in improving crop tolerance to drought conditions can be attributed to more extensive root proliferation, utilizing available moisture more effectively from deeper soil horizons.

In addition, the application of P reduced the rate of plant transpiration, thus lowering the water requirements of a crop (Williams, 1935).

Olsen et al. (1961) observed that absorption of P by roots is greatly reduced under conditions of low soil water availability. The application of P in dry years raises the concentration of P in the water film around the soil particles and thus compensates for the low number of contact sites for uptake of P resulting in improving yield. Marais and Wiersma (1975) found recently that the response of soybean to P fertilizers is greater under soil water stress conditions.

It seems, therefore, highly desirable that the soils in the Houran Plain used for rainfed crops receive annual applications of phosphate fertilizers to maintain levels of 9-12 ppm $NaHCO_3$ - extractable P.

3.6 Fertilizer Field Experiments on Rainfed Olives

Olives, almonds and pistachios are the most important rainfed tree crops in Syria.

Subhumid Region

Fertilization studies on olives started some fifteen years ago. A long experiment was initiated in the rainfed area of the subhumid region (850 mm of average annual rainfall) to study the response of olives to N, P and K. The olive grove with 25-year old trees growing in calcareous soils was located at the foothills of the coastal plain of Syria. Samples of recently matured leaves were taken for analysis at the beginning of each month, during the whole period of the experiment. The experiment lasted for five years.

The main response was due to nitrogen fertilization only. The average fruit production was almost doubled by the addition of 2.5 kg of ammonium sulphate per tree (Table 3). Phosphorus or potash fertilization had no significant effect on P or K leaf concentration but either fruit production or leaves from trees fertilized with nitrogen had significantly lower P or K, possibly due to a dilution effect from more profusive vegetative growth.

Table 3 EFFECT OF N, P, K FERTILIZATION ON AVERAGE PRODUCTION OF FRESH OLIVE FRUIT (kg/tree/year)

Fertilizer treatment 1/	Season 2/				Total
	1968	1969	1971	1972	
O	20.2	26.3	44.0	39.1	129.6
P	13.2	33.5	57.5	14.0	118.2
K	3.9	35.7	44.0	25.5	109.1
PK	0.1	59.4	53.3	25.5	138.3
N	1.5	80.3	57.0	105.0	243.8
NK	0.5	78.3	88.3	56.0	223.1
NP	2.8	67.0	66.0	63.3	199.1
NPK	18.0	58.3	85.0	41.7	203.0

1/ N = 2.5 kg of ammonium sulphate per tree
P = 3.0 kg of single superphosphate per tree (18% P_2O_5)
K = 2.0 kg of potassium sulphate per tree (50% K_2)

2/ The 1970 season was not harvested.

These results suggest that the traditional method of application of phosphates or potash at depths of 20-25 cm in a ring around the trees is not the most suitable method for rainfed olives but rather the injection of liquid fertilizers including phosphates should be considered in future research of the dryland areas.

Semi-arid Region

Several NPK fertilizer experiments in the semi-arid region were carried out on olive, pistachio and almonds, under the supervision of the Arab Centre for the Studies of Arid Zones and Dry Lands (ACSAD). Olive experiments were carried out in the region of Aleppo-Idlib (300-350 mm of annual rainfall), on reddish brown calcareous soils on trees 20-25 years old. In addition, experimenting with minor elements, Fe, Zn and Mn, and pruning methods for olives on the nutrient status of fruit production, oil content and other fruit properties, were carried out. The results from four consecutive seasons showed little or no response to the nutrients studied. Summer ploughing for water conservation was found more effective in raising fruit production than fertilization.

It is believed now that soil fertilizer experiments on trees of the semi-arid area should be carried out for a much longer time than experiments in the more humid area. The main limiting factors for growth is water and responses to fertilization are only possible under conditions of efficient water conservation. Moreover, the extensive root system of fruit trees grown in the semi-arid areas requires a more efficient distribution of fertilizers in the zone of the feeding roots, which is not accomplished by surface applications of fertilizers.

3.7 Foliar Application of Nutrients on Rainfed Crops in the Rainfed Area

1. Potassium Application on Tobacco

Several fertilizer experiments carried out in various zones cultivated with the oriental and semi-oriental non-irrigated tobacco had shown that the application of potassic fertilizers to soils did not have any significant effect on K composition of leaves. The percentage potassium in leaves remained below the optimum level required by the tobacco industry. A good supply of available moisture in soil is required apparently for the absorption of potassium, and the response of potash fertilization is uncertain under high soil water stress and in soils with high lime content where calcium excess could compete with K absorption by plants.

Several experiments were carried out in the tobacco region of Syria, to compare the effect of potassic fertilizers added to the soil at four different levels, 0, 250, 500 and 1000 kg K_2SO_4/ha with foliar application of K_2SO_4 solution in four different concentrations, 0, 0.5, 1.0 and 1.5 percent. The latter method of application was found superior to soil application, especially for lower leaves of the plants which normally receive a larger number of sprays than the top recent leaves (see Figure 6). By spraying it was possible to raise the K content of lower leaves of tobacco from 2.3 to 3.8 percent.

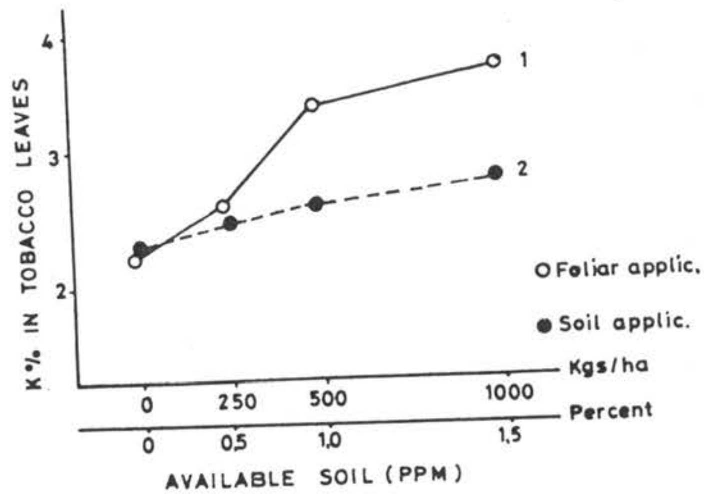

Fig. 6 Effect of foliar and soil application of K_2SO_4 on tobacco leaf content (Experimental Station in Lattaquia)

However, the applicability of foliar application of K fertilizers is subject to the availability of water at the farm and the possibility of mixing fertilizers with other insecticides or fungicides to reduce costs. Another consideration is the effect of foliar application on the industrial qualities of tobacco leaves. No doubt foliar application of fertilizers on important cash crops grown in the rainfed area is a worthwhile investigation.

ii. Foliar Application of Nitrogen Solution to Olive Trees

Foliar application of N fertilizers in the form of urea or ammonium nitrate was tried on olives grown in the semi-arid region of Idlib, Aleppo. The experiment was factorial, with two kinds of N fertilizers and three levels of concentration (0, 0.5, 1.0 percent under urea or its equivalent in N concentration of NH_4NO_3). Trees were sprayed twice at 15 day intervals, the first application being after fruit set. The results were positive and the foliar application of N increased the yield of oil significantly, by about 50 percent.

4. MICRONUTRIENT PROBLEMS IN THE RAINFED AREA

Micronutrient deficiencies of iron and zinc appeared on several species of trees grown in the rainfed areas. Apples, cherries and especially olives, grown on the calcareous Rendzina hills of the subhumid region of the rainfed area, were most affected by these deficiencies.

Several experiments have been carried out since 1972 to study effective control of iron and zinc deficiencies on rainfed apples and olives. Foliar application of 1 percent of Fe EDTA (VERSENOL) or 1 percent of the chelate Fe EDDHA (SEQUESTREN Fe 138), twice in early spring, at a one month interval, was found effective in controlling chlorosis on apples.

Three successive experiments were carried out on olives badly affected by chlorosis to investigate the effect of Fe, Zn and Mn application to soils on the control of chlorosis, yield of fruit, and the residual effect of these micronutrients (Matar, 1976). A single soil application of 125 g of Fe chelate of the type Fe EDDHA was found very effective in controlling chlorosis and gradually increasing yield significantly (Table 4).

Table 4 EFFECT OF IRON CHELATE (Fe EDDHA) ON FRUIT PRODUCTION OF OLIVES

Treatment	Average yield of fruit * (kg/tree)			Total Yield
	1973	1974	1975	
+ Fe once	0.0	2.9	35.0	37.9
+ Fe twice	0.0	6.0	37.0	43.0
Control	0.0	0.0	3.9	3.9

* Values in table are averages of six replicates.

Leaf analysis of affected area by chlorosis showed a low level of iron, zinc, manganese and copper, as compared with averages from other Mediterranean countries found by Bouat (1964).

REFERENCES

Bouat A. 1964 L'analyse foliaire et l'olivier. Dans ler Colloque Européen sur le Contrôle de la Nutrition Minérale et de la Fertilization en Viticulture, Arboriculture et Autres Cultures Mediterranéennes. Laboratoire Cooper de Diagnostic Foliaire, Montpellier, France. pp. 251-264.

Dubertret L. 1933 La carte géologique 1/1 000 000 de la Syrie et du Liban. Rev. Géogr. Physique. 6:269.

Kanbar R. 1976 Progress Report on Permanent Experiment on Fertilization and Crop Rotation at Ezraa Experimental Station. Year 1970 to 1974. Directorate of Soils, Ministry of Agriculture, Syria.

Loizides P.A. 1970 Experiments with Dryland Rotation in the Syrian Arab Republic. UNDP/SF Damascus Agricultural Station Project.

Marais J.N. and Wiersma. 1975 Phosphorus uptake by soyabeans as influenced by moisture stress in the fertilized zone. Agron. J. 67:677-781

Matar A.E. Direct and cumulative effects of phosphates in calcareous soil under dry
1976a farming agriculture of southern Syria. Soil Science P-1. pp. 1. The Arab Centre for the Studies of Arid Zones and Dry Lands, Damascus.

Matar A.E. Correlation between $NaHCO_3$ extractable P in soils and yields of wheat and
1976b lentil grown under dryfarming conditions. Soil Science P-2. pp.1. The Arab Centre for the Studies of Arid Zones and Dry Lands, Damascus.

Matar A.E. Yields and response of cereal crops to P fertilization under changing rainfall
1977 conditions. Agron. J. 69:879-881.

Matar A.E. Diagnosis and control of lime induced chlorosis by Fe chelate on olive grown
1976 under the Mediterranean conditions. 4th International Colloquium on the Control of Plant Nutrition Proc. Vol. II. pp. 391-397. Ghent, Belgium.

Matar A.E. and Samman M. Potential fertility of major Syrian soils as determined by pot
1969 tests and soil analyses. 10th Week of Science Book 5. pp. 131-182. High Council of Sciences, Damascus.

Matar A.E. and Samman M. Correlation between $NaHCO_3$ extractable P and response to P
1975 fertilization in pot tests. Agron. J. 67:616-618.

Olsen S.R. <u>et al</u>. Phosphorus absorption by corn roots as affected by moisture and phos-
1961 phorus concentration. Soil Sci. Soc. Amer. Proc. 25:282-294.

Williams E.F. An analysis of the effect of P supply on the transpriation ratio of plants.
1935 Austr. J. Exp. Biol. Med. Sci. 13:49-66.