The soil fertility : a problem for some productions under Turkish soil conditions

Kayimoglu S., Yurtsever N., Baker S., Stickley T.

Conservation et utilisation des sols

Paris : CIHEAM
Options Méditerranéennes; n. 25

1974
pages 48-59

S. KAYIMOGLU (1)
N. YURTSEVER (2)
S. BARKER (3)
and T. STICKLEY (4)

The soil fertility : a problem for some productions under Turkish soil conditions

Wheat and sugar beets are grown in large areas in Turkey and play a major role in the economy of the country. Their successful production depends to a great extent on the application of a sound fertility program based on scientific research, which involves the development of refined soil test methods which show accurately the fertilizer needs of specific crops.

The main objective of all studies in the field of soil fertility is primarily to gain the necessary knowledge of soil-plant relationships and consequently to find out the principles which provide for the application of balanced and economical fertilization in practice. Therefore, the calibration of soil tests with crop yields and response to fertilizers has been a subject of major interest in soil fertility work [1, 2, 6, 7, 8, 9, 16]. In Turkey, most of the soils are medium to well-supplied in potassium and response to nitrogen is quite straightforward due to the almost universally low content of organic matter in the soil. Response to phosphorus, however, shows great fluctuations depending on soil type and region. For this reason, in Turkey the major emphasis has been given to soil phosphorus calibrations [3, 4, 5, 12, 17, 18, 19, 20].

The present study was undertaken to calibrate wheat in soil and the rates of phosphorus fertilizer application, with the ultimate aim of determining the most profitable rates of application for these crops under Turkish cultural and economic conditions. For this purpose, two separate research projects were run in two different regions of Turkey during the years 1961-1965. The first project [20] was conducted by the Soil and Fertilizer Research Institute of Turkey in the Thrace Region with wheat as the test crop, and the second project [12] by the Turkish Sugar Research Institute in the Middle Anatolia Region with sugar beets. The data obtained in these studies were used to work out the calibrations and economic analyses presented in this paper.

(1) Biometrics Assistant, Sugar Research Institute, Etimesgut, TURKEY.
(2) Economic and Statistical Researcher, Soil and Fertilizer Research Institute, Ankara, TURKEY.
(3) Research Soil Chemist, Sugar Research Institute, Etimesgut, TURKEY.
(4) Assistant Professor of Agricultural Economics, Faculty of Agricultural Sciences, American University of Beirut, Beirut, LEBANON.

MATERIALS AND METHODS

Field experiments and soil analyses

Characteristics of the soils, the soil test methods used and other pertinent information were given in the previous publications [3, 4, 20]. Since, however, they were not published in any scientific journal in English, a brief mention of them will be made here.

The field experiments with hard winter wheat were conducted on four different great soil groups, namely Noncalcic Brown Soils, Noncalcic Brown Forest Soils, Vertisols (Grumusols) and Calcareous Alluvial Soils [14]. The sugar beet experiments, on the other hand, were conducted only on Calcareous Alluvial Soils.

The experimental design was a Latin square with four rates of phosphorus (0, 3, 6 and 12 kg/decare (5) P_2O_5) in the wheat experiments while a randomized block design with 0, 5, 10 and 15 kg. P_2O_5 per decare application rates were used in the sugar beet experiments. Experiments with both crops were replicated four times. Nitrogen and potassium were added uniformly to all plots at the rates considered to be adequate which were determined according to the previous experimental results in the wheat experiments (8 kg/decare N and 6 kg/decare K_2O), and according to the soil test recommendations in the sugar beet experiments (averaging 9 kg/decare N and 7 kg/decare K_2O). No other elements were known or suspected to be deficient in the soil. The phosphorus fertilizer (16-18 % superphosphate) was broadcast and disked into the soil for wheat and plowed-down for the sugar beets, both in the fall. Wheat seeds were sown by hand-broadcasting while the sugar beets were sown by drills on 40 cm-spaced rows and thinned to 25 cm after establishment. The harvested plot size was 20 m^2 for wheat and 100 m^2 (1961-1962 experiments) and 32 m^2 (1963-1965 experiments) for the sugar beets. The wheat experiments were conducted under dry conditions while the sugar beets were irrigated as many times as required.

The soil test developed by Olsen et al. [15] was used in measuring the available phosphorus in the soil in the wheat experi-

(5) A decare is approximately 1/10 hectare.

ments, as this method was found by Yurtsever et al. [18] to correlate well with the wheat yields in the Thrace Region. On the other hand, a recent investigation by Barker [4] has shown the modified Hellige-Truog soil test to be one of the methods giving the highest correlation with the sugar beet yields. This method which is a modification of the Rothamsted rapid test [13] by the Agricultural Chemistry and Soils Department of the Turkish Sugar Research Institute has been adopted by the said Institute for the routine determination of the available phosphorus in the soil. Therefore this method was used in measuring the available soil phosphorus in the sugar beet experiments.

Interpretation of the Olsen and the modified Hellige-Truog methods is given in Table 1.

TABLE 1

Interpretation of the Olsen and the modified Hellige-Truog soil tests

Olsen (0.5 M Na HCO_3)		Modified Hellige-Truog (0.3 N HCl)	
Available P_2O_5 in soil (kg/decare)	Interpretation [20]	Available P_2O_5 in soil (kg/decare)	Interpretation (*) [3]
1.4	Very low	4.4	Very low
1.5-2.9	Low	4.5-8.8	Low
3.0-4.9	Medium	8.9-17.8	Medium
5.0-7.4	Good	17.9-26.8	High
7.5-10.0.	High	> 26.8	Very high
> 10.0.	Very high		

(*) This interpretation scale corresponds to the original scale used with the method until 1966 when a new modification was made in the method with a necessary change in the scale.

Calibrations and economic analyses

A preliminary screening of the sugar beet experiments was made before working out the calibrations. The soils were classified into several categories according to both the actual yield increases obtained in the field experiments and the soil test interpretation. Only those soils which came under the same category with respect to both classifications [3] were used in the calibrations.

The Bray's [6] modification of the Mitscherlich equation was used in both projects to obtain the fertilizer response curve. A quadratic type of equation was also utilized for this purpose for the sugar beet data. The Mitscherlich-Bray equation has the form,

$$\text{Log } (A - y) = \text{Log } A - c_1 b_1 - cx \qquad \text{(I) where:}$$

A = Theoretical maximum yield under a given set of conditions.

Y = The yield obtained from x amount of fertilizer.

b_1 = The soil test value.

x = Any given fertilizer rate.

c_1 = Proportionality constant for b_1.

c = Proportionality constant for x.

This equation which allows for taking into account fully the amount of the fertilizer nutrient already present in the soil (soil test value) in deriving the fertilizer response curve, shows a distinct advantage over other types of equations. As it will be seen later, the economic optimum-fertilizer rate changes significantly with the original nutrient content of the soil.

In applying a quadratic type of equation to the sugar beet data, the soils were grouped into three classes with respect to their available phosphorus values as low, medium and high. In doing this, the modified Hellige-Truog soil test interpretations given in Table 1 was used, but the low and very low categories were combined in a single class as low and the high and very high categories were combined as high. This grouping of soils was necessary in order to take into account the amount of available phosphorus originally present in the soil.

The economic optimum fertilizer rate was found by the following equation which was derived by equating the marginal product to the factor-product price ratio [10, 11, 12] :

$$\frac{dy}{dx} = \frac{Px}{Py - Pv.} \qquad \text{(II) where:}$$

$\frac{dy}{dx}$ = First derivative of the response curve showing the relationship between y (sugar beet or wheat yield) and x (fertilizer rate).

Px = Price of fertilizer.

Py = Price of sugar beets or wheat.

Pv = Variable cost of harvesting, topping (6) and transportation per unit weight of sugar beets.

(6) In the economic analysis of the wheat experiments, the fertilizer cost was considered as the only variable cost, making $P_v = 0$.

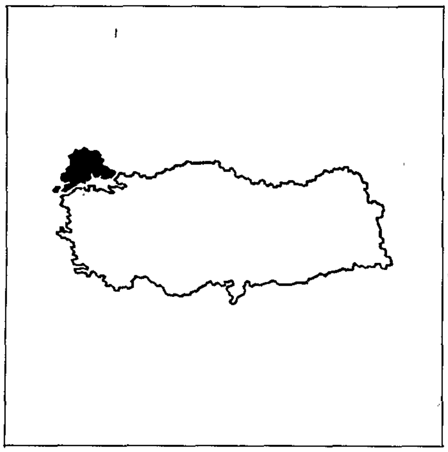


TABLE 2

Results of the field experiments with wheat conducted in the Thrace Region during the years 1962-1965

Experiment No.	Location	Amount of P_2O_5 Added to Soil, kg/Decare				Yield Increase(**) (%)	Soil Test (*) Result kg/Decare P_2O_5	Rank No. of Experiment Considering % Increase
		0	3-4	6-8	12			
		Yield of Wheat, kg/Decare						
1	Edirne-Fidanlik	279.9	292.8	315.3	297.8	6.0	6.26	24
2	Edirne-B. Ismailce.	126.6	203.2	213.2	225.1	43.8	1.84	16
3	Edirne-Bahceköy.	81.4	94.7	100.2	115.4	29.5	3.09	23
4	Tekirdag-Kuyubasi. . . .	99.0	156.4	172.4	164.3	39.7	3.40	19
5	Tekirdag-Karaagac. . . .	52.5	92.1	102.9	113.5	53.7	1.93	9
6	Tekirdag-K. Hidir. . . .	76.8	101.9	109.2	118.9	35.4	3.91	21
7	Kirklareli-D.U.C.	137.5	163.8	206.3	211.9	35.1	4.31	22
8	Edirne-Kosköy	145.0	192.2	228.0	235.0	38.3	3.35	20
9	Edirne-Tayakadin	128.3	248.6	253.6	280.2	54.2	3.50	8
10	Edirne-Musabeyli	126.5	232.3	228.0	258.6	51.1	1.97	10
11	Edirne-B. Ismailce. . . .	118.1	187.8	204.6	237.8	50.3	2.04	12
12	Edirne-Y. Muhacir. . . .	116.7	174.7	217.1	230.7	49.4	2.67	13
13	Tekirdag-Merkez	82.6	126.0	204.0	197.3	58.1	2.04	7
14	Tekirdag-Merkez	118.2	148.0	176.8	207.3	43.0	2.63	17
15	Tekirdag-Esece	75.0	166.6	195.3	206.8	63.7	1.65	3
16	Edirne-Arpac	141.1	213.1	251.3	269.0	47.5	1.88	14
17	Edirne-Sazlidere.	124.2	208.5	247.6	251.7	50.7	2.06	11
18	Edirne-Sinan	91.7	200.9	226.9	242.2	62.1	2.05	5
19	Edirne-Merkez	143.9	207.2	232.0	257.5	44.1	2.52	15
20	Tekirdag-Inanli	87.5	191.6	245.1	239.2	63.4	2.50	4
21	Tekirdag-Esece	124.9	211.2	223.4	219.0	43.0	2.55	18
22	Kirklareli-D. Basi	84.3	204.4	226.0	260.6	67.7	1.58	2
23	Kirklareli-L. Burgaz. . .	70.0	144.0	196.8	225.8	69.0	1.21	1
24	Kirklareli-Babaeski. . . .	100.0	168.4	203.2	252.4	60.2	1.93	6

(*) Olsen et al.

(**) Calculated as: $100 - \frac{\text{Yield of non-fertilized plot}}{\text{Yield of the highest-fertilized plot}} \times 100.$

RESULTS AND DISCUSSION

From the results of the field experiments (Tables 2 and 3), the precentage yields were calculated (Assuming the yield of x_3 plot as 100 %) for each experiment and the constants of the Mitscherlich-Bray equation were determined (Tables 4 and 5), by inserting 100.0 for A and the other appropriate values in equation 1 and solving for c_1 or c. Some of the calculated c values in the wheat experiments were unreliable, therefore those values were not

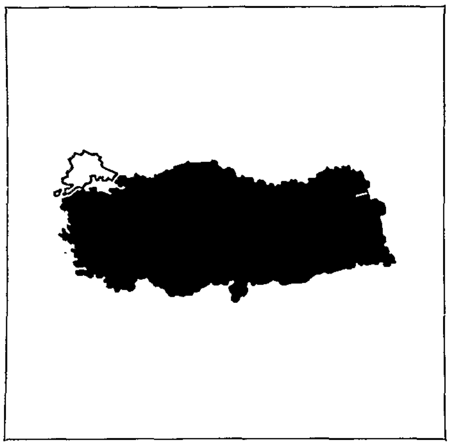


TABLE 3

Results of the field experiments with sugar beets conducted in the Middle Anatolia Region during the years 1961-1965

Experi-ment No.	Location	Amount of P_2O_5 Added to Soil, kg/Decare				Yield Increase (**) (%)	Soil Test (*) Result kg/Decare P_2O_5	Rank No. of Experiment Considering % Increase
		0	5	10	15			
		Yield of Sugar Beets, kg/Decare						
1	Cifteler.	1600	1650	1900	1800	13.5	14.54	17
2	Beylikahir	2200	2850	2300	2500	17.9	12.37	14
3	Yenisehir.	1750	2050	2700	2450	32.2	17.53	6
4	Develi	1250	2550	2500	2600	51.9	15.52	4
5	Bicer.	4250	4150	4500	4350	4.1	16.44	23
6	Fakili.	2200	2300	2450	2950	25.4	11.70	8
7	Cankiri.	2430	2800	3230	2800	19.4	15.77	12
8	Kirikkale.	4500	4950	6330	5200	14.5	14.88	16
9	Bicer.	5230	6000	5900	5780	12.1	11.91	19
10	Fakili.	2100	2300	2500	2350	11.6	20.93	20
11	Bicer.	2750	4900	5050	4750	24.6	15.05	10
12	Fakili.	3050	3550	3350	3830	20.4	15.52	11
13	Yenisehir.	3230	3450	3450	3900	17.2	16.44	15
14	Beylikahir	3880	4030	4200	4000	5.7	15.05	21
15	Beysehir	3350	4400	4550	4000	25.2	16.65	9
16	Eregli.	3650	4100	4250	4150	13.1	11.03	18
17	Karaman	3100	4450	4130	4880	36.5	4.94	5
18	Cumra.	2350	2500	2480	2430	5.6	29.23	22
19	Merkez.	1280	2750	2800	3150	59.4	5.41	2
20	Kadinhani	400	1980	2080	2430	83.5	6.55	1
21	Cumra.	2050	2450	2480	2500	18.0	12.17	13
22	Karaman	2130	2950	2750	2980	28.5	4.28	7
23	Kadinhani.	1430	2880	3530	3330	58.3	6.08	3

(*) The modified Hellige-Truog.

(**) Calculated as: $100 - \frac{\text{Yield of non-fertilized plot}}{\text{Yield of highest-fertilized plot}} \times 100.$

used. Similarly, c values were not calculated for the sugarbeet experiments which showed 98 percent sufficiencies in available soil phosphorus and those values which were smaller than 0.020 were not included in the calculation of the average c value.

These calculations yielded the average c_1 values of 0.131 ± 0.008 and 0.50 ± 0.005 and average c values of 0.110 ± 0.006 and 0.078 ± 0.010 for the wheat and sugar beet experiments, respectively. These average values were used in calculating the theoretical maximum yield (A) in each experiment and for each application rate

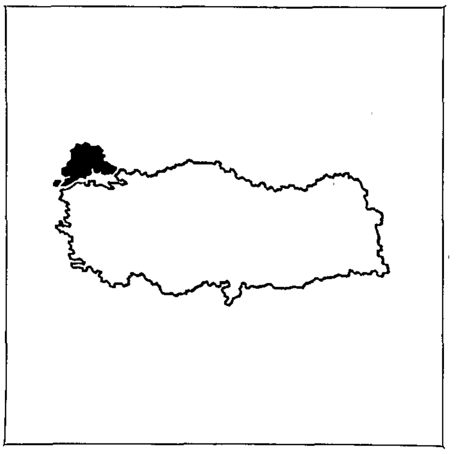


TABLE 4

Olsen soil test results, calculated constants for the Mitscherlich-Bray equation, percentage wheat yields obtained in the field experiments and the actual and theoretical maximum yields for Thrace Region during the years 1962-1965

Experiment No.	Olsen Soil Test Result kg/Decare P_2O_5	Levels of P_2O_5, kg/Decare: 0 (x_0)	3-4 (x_1)	6-8 (x_2)	12 (x_3)	Theoretical Maximum yield (A) kg/Decare	Actual Max. yield kg/Decare (Corresponding to x_3)	Mitscherlich Constants: c_1 for b_1	c for x_1	c for x_2
		Wheat Yield (%)								
		y_0	y_1	y_2	y_3					
1	6.28	94.0	98.3	105.9	100.0	306.5	297.8	0.195	—	—
2	1.84	56.2	90.3	94.7	100.0	234.3	225.1	0.195	0.163	0.115
3	3.09	70.5	81.1	86.8	100.0	107.5	115.4	0.172	0.048	0.043
4	3.40	60.3	95.2	104.9	100.0	180.0	164.3	0.117	—	—
5	1.93	46.3	81.1	90.7	100.0	113.9	113.5	0.140	0.114	0.095
6	3.91	64.6	85.7	91.8	100.0	117.1	118.9	0.115	0.098	0.080
7	4.31	64.9	77.3	97.4	100.0	216.1	211.9	0.105	0.048	—
8	3.35	61.7	81.8	97.0	100.0	241.4	235.0	0.124	0.108	—
9	3.50	45.8	88.7	90.5	100.0	288.2	280.2	0,076	—	0.126
10	1.97	48.9	89.8	88.2	100.0	261.2	258.6	0.148	—	0.107
11	2.04	49.7	79.0	86.0	100.0	240.5	237.8	0.146	0.127	0.093
12	2.67	50.6	75.7	94.1	100.0	235.6	230.7	0.115	0.102	0.154
13	2.04	41.9	63.9	103.4	100.0	220.5	197.3	0.116	0.068	—
14	2.63	57.0	71.4	85.3	100.0	193.0	207.3	0.139	0.059	0.078
15	1.65	36.3	80.6	94.4	100.0	229.7	206.8	0.119	0.171	—
16	1.88	52.5	79.2	93.4	100.0	277.8	269.0	0.172	0.120	0.143
17	2.06	49.3	82.8	98.4	100.0	274.2	251.7	0.143	0.157	—
18	2.05	37.9	82.9	93.7	100.0	270.3	242.2	0.101	—	0.165
19	2.52	55.9	80.5	90.1	100.0	260.8	257.5	0.141	0.118	0.109
20	2.50	36.6	80.1	102.5	100.0	272.9	239.2	0.079	0.168	—
21	2.55	57.0	96.4	102.0	100.0	253.8	219.0	0.144	—	—
22	1.58	32.3	78.4	86.7	100.0	267.5	260.6	0.107	0.166	0.118
23	1.21	31.0	63.8	87.2	100.0	224.9	225.8	0.133	0.093	0.128
24	1.93	39.8	66.7	80.5	100.0	240.0	252.4	0.114	0.082	0.080
Average (Mean)						230.3	221.6	0.131	0.110	
Standard error of the mean						11.0	± 10.2	± 0.008	±0.006	

(viz, x_1, x_2 and x_3) separately as described by Yurtsever [20]. These values were used to calculate the average A value for each experiment and by taking the overall average of these values the theoretical maximum yields of 230.3 kg/decare for wheat and 3 621 kg/decare for sugar beets were obtained. These values gave the following Mitscherlich-Bray equations:

For wheat in the Thrace Region :

$$\text{Log}\ (230.3 - y) = \text{Log}\ 230.3 - 0.131\ b_1 - 0.110\ x \qquad \text{(III)}$$

TABLE 5

The modified Hellige-Truog test results, calculated constants for the Mitscherlich-Bray equation, percentage sugar beet yields obtained in the field experiments and the actual and theoretical maximum yields for the Middle Anatolia Region during the years 1961-1965

oxperiment No.	Modified Hellige-Truog Soil Test result P_2O_5 kg/Decare	Levels of P_2O_5 kg/Decare				Theoretical maximum Yield (A) kg/Decare	Actual Max. Yield kg/Decare (Corresponding to x_3)	Mitscherlich Constants		
		0 (x_0)	5 (x_1)	10 (x_2)	15 (x_3)			c_1 for b_1	c for x_1	c for x_2
		Sugar Beet Yield (%)								
		y_0	y_1	y_2	y_3					
1	14.54	88.9	91.7	105.6	100.0	1820	1800	0.059	0.025	—
2	12.37	88.0	114.0	92.0	100.0	2712	2500	0.060	—	0.018
3	17.53	71.4	83.7	110.2	100.0	2547	2450	0.028	0.049	—
4	15.52	48.1	98.1	96.2	100.0	2961	2600	0.018	—	0.114
5	16.44	97.7	95.4	103.5	100.0	4453	4350	0.008	—	—
6	11.70	74.6	78.0	83.1	100.0	2624	2950	0.051	0.010	0.018
7	15.77	86.8	100.0	115.4	100.0	3090	2800	0.045	—	—
8	14.88	86.5	95.2	121.7	100.0	5733	5200	0.059	0.088	—
9	11.91	90.5	103.8	102.1	100.0	6126	5780	0.077	—	—
10	20.93	89.4	187.9	106.4	100.0	2461	2350	0.045	—	—
11	15.05	78.9	103.2	106.3	100.0	5272	4750	0.040	—	—
12	15.52	79.6	92.7	87.5	100.0	3729	3830	0.044	0.090	0.021
13	16.44	82.8	88.5	88.5	100.0	3680	3900	0.047	0.033	0.017
14	15.05	97.0	100.7	105.0	100.0	4134	4000	0.008	—	—
15	16.65	83.8	110.0	113.8	100.0	4651	4000	0.036	—	—
16	11.03	88.0	98.8	102.4	100.0	4321	4150	0.080	—	—
17	4.94	63.5	91.2	84.6	100.0	4905	4880	0.088	0.124	0.037
18	29.23	96.7	102.9	102.1	100.0	2435	2430	0.043	—	—
19	5.41	40.6	87.3	88.9	100.0	3381	3150	0.042	0.134	0.073
20	6.55	16.5	81.5	85.6	100.0	2751	2430	0.012	0.131	0.076
21	12.17	82.0	98.0	99.2	100.0	2606	2500	0.061	—	—
22	4.28	71.5	99.0	92.3	100.0	3141	2980	0.127	—	0.057
23	6.08	42.9	86.5	106.0	100.0	3762	3330	0.039	0.125	—
Average (Mean)						3621	3439	0.050	0.078	
Standard Error of the Mean						201.6	±217.1	±0.005	±0.010	

For sugar beets in the Middle Anatolia Region:

$$\text{Log}\ (3\,621 - y) = \text{Log}\ 3\,621 - 0.050\ b_1 - 0.078\ x \quad \text{(IV)}$$

where:

y = Yield of sugar beets or wheat.

b_1 = Amount of available P_2O_5 originally present in the surface soil.

x = Amount P_2O_5 — applied to the soil.

(All values are in kilograms per decare.)

A comparison of the actual and theoretical maximum yield values given (Tables 4 and 5) generally shows good agreement,

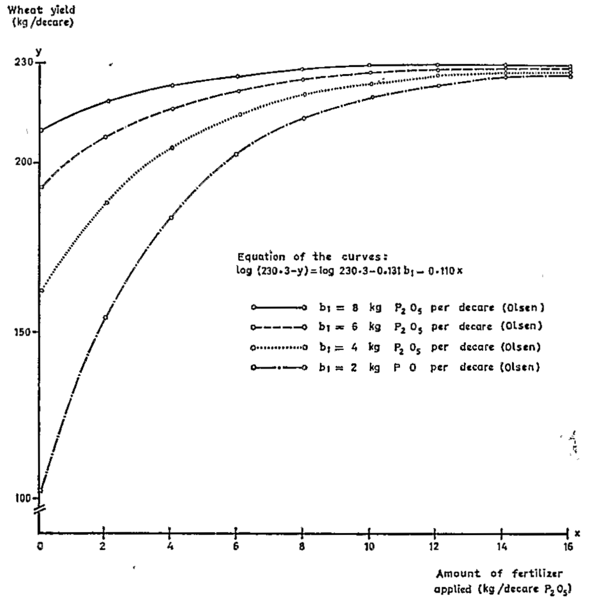


Figure: 1 The relationship between phosphate fertilizer and the wheat yield in Thrace Region of Turkey.

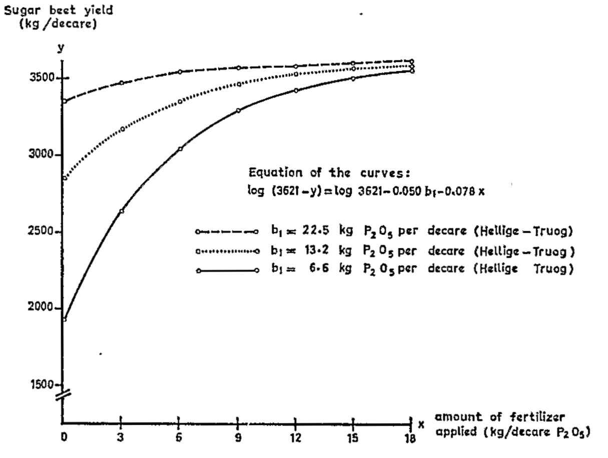


Figure: 2 The relationship between phosphate fertilizer and the sugar beet yield in the Middle Anatolia Region of Turkey

indicating that the error involved in using the yield of the x_3 plot as A in the calculation of c_1 and c values was small.

The fertilizer response curves corresponding to these equations were given in Figures 1 and 2 for soils having different available phosphorus values (b_1). Four different curves representing low, medium, good and high phosphorus soils for the Thrace Region, and three different curves representing low, medium and high phosphorus soils for the Middle Anatolia Region were drawn. These curves or their equations may be used in estimating the response to phosphorus fertilizer if the soil test value is known. The curves show clearly how the response to phosphorus fertilizer changes with the available soil phosphorus value.

Another set of curves showing the relationship between the soil test value and the phosphorus requirement of wheat in Thrace and sugar beets in the Middle Anatolia for the various percentage sufficiency levels were obtained from Equations III and IV and are given in Figures 3 and 4. If the soil test value of a field is known, the amount of phosphorus fertilizer to raise the yield to a chosen percentage sufficiency (in terms of the maximum yield) level may be read directly from the curves. These values may serve as a guide in making recommendations for wheat production in the Thrace and sugar beet production in the Middle Anatolia Regions.

The ultimate objective in any soil testing program is to recommend the most profitable rates of fertilizers to the farmers. The individual farmer will be interested in knowing not the rate for maximum production but the rate which will give him the maximum net return. Therefore, the calibrations obtained so far would not mean much in practice unless they are expressed in terms of the economic return to phosphorus fertilization.

The most profitable, or more technically, Figure : 3 The relationship between the soil test results and the phosphate requirement for wheat.

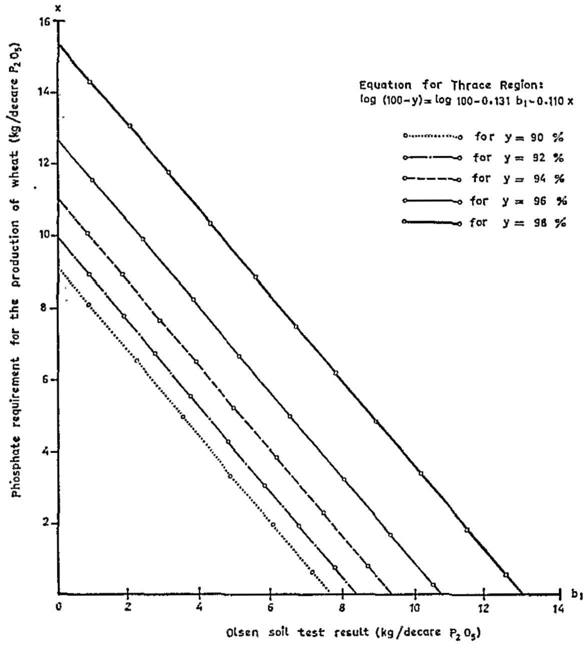
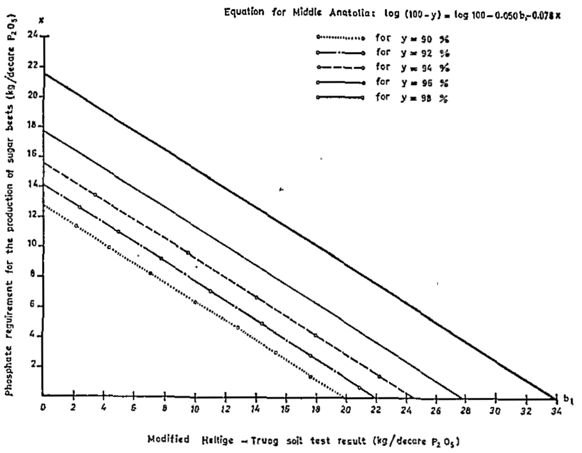


Figure : 4 The relationship between the soil test results and the phosphate requirement for sugar beets.



the economic optimum rate depends on three factors: *a*) the fertilizer response function, *b*) the price of the fertilizer and *c*) the price of the crop [10]. Due to the " law of diminishing returns ", the marginal return to fertilization decreases as the rate of fertilizer is increased, while the cost of fertilization remains essentially constant. The point corresponding to the economic optimum rate on the fertilizer response curve (economic optimum yield) is reached when the marginal return equals the marginal cost (assuming the farmer has unlimited capital). In other words, it is the point where the last infinitesimally small investment in fertilizer just pays for itself, making the marginal profit equal to zero. After this point, although the yield continues to increase until the physical optimum yield is reached, the profit for the farmer starts to decrease.

At the economically optimum point the slope of the profit curve, which is given by the first derivative of the curve of this point, will be equal to zero. From this relationship, the previously given Equation II is derived which was used in the calculation of the economically optimum phosphorus rates for wheat and sugar beets.

Under the cultural conditions in the Thrace Region, and on the basis of current prices (7), the most economical rates of phosphorus fertilizer for wheat were found to be 11, 10, 7 and 5 kg P_2O_5 per decare, while the soil test value by the Olsen et al. method was 1, 2, 4 and 6 kg P_2O_5 per decare, respectively.

For sugar beets (8) in the Middle Anatolia Region, the most economical phospho-

(7) 1970 prices were used which were 0.45 TL (Turkish Lira) per kg for 16-18 percent superphosphate and 0.95 TL per kg for hard wheat.

(8) For sugar beets, 1971 prices were used which were 0.45 TL per kg for 16-18 percent superphosphate and 17.00 Turkish piasters (krs) per kg for sugar beets (after deducting the variable cost).

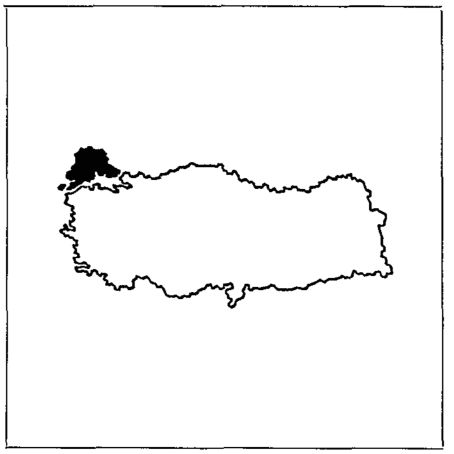


TABLE 6

The marginal P_5O_2 applications and marginal cost and revenue values for wheat production in Thrace Region (*)

P_2O_5 Application kg/decare	Marginal Fertilizer Application kg/decare		Marginal cost for P_2O_5 (T.L.) (**)	$b_1 \pm$ 1 kg P_2O_5 per decare (available in the soil)			$b_1 \pm$ kg P_2O_5 per decare (available in the soil)			$b_1 \pm$ 4 kg P_2O_5 per decare (available in the soil)			$b_1 \pm$ 6 kg P_2O_5 per decare (available in the soil)		
	P_2O_5	Superphosphate (16-18 %)		% of maximum yield	Marginal yield kg/decare	Marginal revenue (T.L.) (***)	% of maximum yield	Marginal yield kg/decare	Marginal revenue (T.L.)	% of maximum yield	Marginal yield kg/decare	Marginal revenue (T.L.)	% of maximum yield	Marginal yield kg/decare	Marginal revenue (T.L.)
1	1	5.88	2.65	43	38.2	36.3	57	31.2	29.6	77	15.4	14.6	87	8.4	8.0
2	1	5.88	2.65	55	29.6	28.1	67	22.0	20.9	82	12.0	11.4	90	6.6	6.3
3	1	5.88	2.65	65	23.1	21.9	74	17.0	16.2	86	9.3	8.8	92	5.1	4.9
4	1	5.88	2.65	73	17.8	16.9	80	13.2	12.5	89	6.2	5.9	94	3.9	3.7
5	1	5.88	2.65	79	13.9	13.2	85	10.5	10.0	92	5.1	4.9	95	3.1	3.0
6	1	5.88	2.65	84	10.7	10.2	88	7.8	7.4	93	4.8	4.6	96	2.4	2.3 ←
7	1	5.88	2.65	87	8.3	7.9	91	6.1	5.8	95	3.4	3.2	97	1.8	1.7
8	1	5.88	2.65	90	6.5	6.2	93	4.8	4.6	96	2.6	2.5 ←	98	1.4	1.3
9	1	5.88	2.65	92	5.0	4.7	94	3.7	3.5	97	2.0	1.9	98	1.1	1.1
10	1	5.88	2.65	94	3.9	3.7	96	2.9	2.8	98	1.6	1.5	99	0.9	0.9
11	1	5.88	2.65	95	3.0	2.8	97	2.3	2.2 ←	98	1.3	1.2	99	0.7	0.7
12	1	5.88	2.65	96	2.4	2.3 ←	97	1.7	1.6	99	0.9	0.9		0.5	0.6
13	1	5.88	2.65	97	1.8	1.7	98	1.3	1.2	99	0.7	0.7		0.4	0.4
14	1	5.88	2.65	98	1.4	1.3	98	1.1	1.1		0.6	0.6		0.3	0.3
15	1	5.88	2.65	98	1.1	1.1	99	0.8	0.8		0.5	0.5		—	—
16	1	5.88	2.65	99	0.9	0.8		0.6	0.6		0.3	0.3		—	—

(*) Prices and costs were based on the actual 1970 prices.
(**) Price of one kg of superphosphate was 0.45 Turkish Lira (T.L.).
(***) One kilogram of wheat was 0.95 T.L.

rus fertilizer rates were found to be 17, 13 and 7 kg P_2O_5 per decare while the soil test values by the modified Hellige-Truog method were 6.6, 13.2 and 22.5 kg, P_2O_5 per decare, respectively.

As an alternative method for determining the economic optimum fertilizer rate, the marginal cost and revenue (return) values were also calculated and are given in Tables 6 and 7. The points corresponding to the economically optimum rates (where marginal revenue just equals marginal cost) were marked with an arrow on the tables. A comparison of the economic optimum—phosphorus rates found by two methods indicate that the two methods yield practically the same values. The percentage sufficiencies in terms of the maximum yield were also shown in the Tables 6 and 7. An examination of the percentage sufficiency values reveals that, under the current prices fertilization of the wheat crop to 94 percent sufficiency will be economical in the Thrace Region. In the case of sugar beets for the Middle Anatolia Region, however, fertilization to 98 percent sufficiency or practically to the maximum yield seems to be economical. This result may be explained by the more favorable factor-product price ratio for sugar beets than for wheat, relative to their decare yields.

For comparison purposes, a quadratic equation was also used to calibrate the

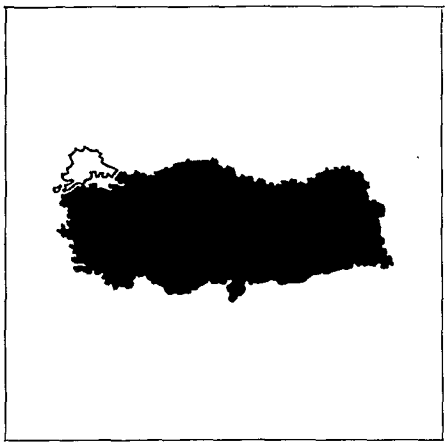


TABLE 7

The marginal P_5O_2 applications and marginal cost and revenue values for sugar beet production in the Middle Anatolia Region (*)

P_2O_5 Application kg/decare	Marginal Fertilizer Application kg/decare		Marginal cost for P_2O_5 (T.L.) (**)	b_1 = 6.6 kg P_2O_5 per decare (available in the soil)			b_1 = 13.2 kg P_2O_5 per decare (available in the soil)			b_1 = 22.5 kg P_2O_5 per decare (available in the soil)		
	P_2O_5	Super-phosphate (16-18 %)		% of maximum yield	Marginal yield kg/decare	Marginal revenue (T.L.) (***)	% of maximum yield	Marginal yield kg/decare	Marginal revenue (T.L.)	% of maximum yield	Marginal yield kg/decare	Marginal revenue (T.L.)
1	1	5.88	2.65	61	279	47.43	82	130	22.10	94	45	7.65
2	1	5.88	2.65	67	234	39.78	85	109	18.53	95	37	6.29
3	1	5.88	2.65	73	193	32.81	87	91	15.47	96	32	5.44
4	1	5.88	2.65	77	162	27.54	89	76	12.92	96	26	4.42
5	1	5.88	2.65	81	136	23.12	91	63	10.71	97	21	3.57
6	1	5.88	2.65	84	114	19.38	93	53	9.01	97	19	3.23
7	1	5.88	2.65	87	94	15.98	94	45	7.65	98	15	2.55 ←
8	1	5.88	2.65	89	79	13.43	95	37	6.29			
9	1	5.88	2.65	91	67	11.39	96	31	5.27			
10	1	5.88	2.65	92	55	9.35	96	26	4.42			
11	1	5.88	2.65	93	46	7.82	97	21	3.57			
12	1	5.88	2.65	95	39	6.63	97	18	3.06			
13	1	5.88	2.65	96	36	6.12	98	15	2.55 ←			
14	1	5.88	2.65	96	23	3.91						
15	1	5.88	2.65	97	22	3.74						
16	1	5.88	2.65	98	19	3.23						
17	1	5.88	2.65	98	16	2.72						
18	1	5.88	2.65	98	13	2.21 ←						

(*) Prices and costs were based on the actual 1971 prices.
(**) Price of one kilogram superphosphate was 0.45 Turkish Lira (T.L.)
(***) The price of sugar beet was 20.70 Turkish piasters per kilogram and the calculated variable cost was 3.70 Turkish piasters per kilogram which was deducted from the sugar beet price to obtain a net beet price of 17.00 Turkish piasters per kilogram.

sugar beet yields with the modified Hellige-Truog soil test results after grouping the soils in three classes as low, medium and high with respect to available phosphorus. The following equations were obtained:

$Y = 2\,271.9 + 237.7 \times 9.2\ X^2$ (V) for the low phosphorus fertility class.

$Y = 3\,407.8 + 123.1 \times 5.0\ X^2$ (VI) for the medium phosphorus fertility class.

Where:

Y = sugar beet yield (kg/decare).

X = amount of P_2O_5 (kg/decare).

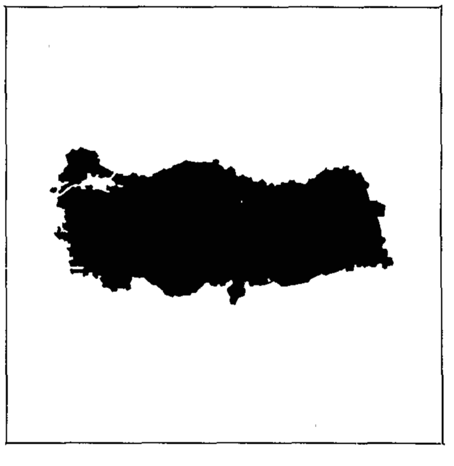
TABLE 8

A comparison of the economically optimal phosphorus fertilizer levels determined by two different methods for sugar beets in the Middle Anatolia on the basis of 1971 prices

Quadratic Equation		Mitscherlich-Bray Equation	
Available P_2O_5 in soil (kg decare)	Economic Optimum P_2O_5 application (kg/decare)	Available P_2O_5 in soil (kg/decare)	Economic Optimum P_2O_5 application (kg/decare)
< 8.8 (Low) . . .	12.0	6.6 (Low)	17
8.9-17.8 (Medium)	10.7	13.2 (Medium)	13
> 17.8 (High). . .	7.1 (*)	22.5 (High)	7

(*) Economic optimum rate could not be calculated for this class due to the unreliable response curve. This value was estimated arbitrarily.

The economically optimum rates of P_2O_5 were found to be 12.0, 10.7 and 7.1 for the low, medium and high phosphorus fertility classes, respectively. A comparison of the values found by the two methods is given in Table 8 which shows good agreement between the two sets of values.



SUMMARY

Wheat and sugar beets are two of the principle crops in Turkey. Their successful production depends, to a great extent, on the application of a balanced and economical fertilization program in practice. Phosphorus fertilizers recommendations play an important part in this program.

To recommend the farmers the most economical phosphorus fertilizer application rates, two research projects were conducted during 1961-1965 one with wheat in the Thrace and the other with sugar beets in the Middle Anatolia Regions of Turkey. The fertilizer response curves showing the relationship between the available soil and fertilizer phosphorus and the wheat and sugar beets were derived and phosphorus fertilizer recommendations based on these curves were presented in graphs and tables. For wheat production in the Thrace Region the most economical phosphorus application rates were calculated as 11, 10, 7 and 5 kg P_2O_5 per decare for low, medium, good and high phosphorus classes, respectively, corresponding to 94 percent sufficiency in terms of the maximum yield. For sugar beets in the Middle Anatolia Region these values were 17, 13 and 7 kg P_2O_5 per decare for low, medium and high phosphorus classes, respectively, corresponding to 98 percent sufficiency.

These recommendations apply to average general farming conditions in the two regions and under current prices. Adjustments in the phosphorus recommendations should be made according to the deviations from the average and with the significant changes in the factor product price ratio.

In the application of these results to fertilizer recommendations in practice, the following points should be taken into consideration:

1. The fertilizer response curves given in this study represent the average relationship between the available soil and fertilizer phosphorus and the sugar beet and wheat yields for the soil test methods employed and under the growing conditions of the study. A change in the methods or growing conditions will change the response curve with a resulting change in the phosphorus recommendations. Although the growing conditions were selected to represent the general practices in both regions, deviations from the

average conditions should be expected due to the variations in soil, climate, season and the individual farmer. This is evident from the fact that the theoretical maximum yields ranged between 107.5 and 306.5 kg/decare for wheat and 1 820 and 6 126 kg/decare for the sugar beets (Tables 4 and 5). The economically optimal phosphorus recommendations based on the average maximum yield will serve well the majority of the farmers in the area but adjustments should be made in the recommendations for yield levels deviating significantly from the average.

2. In calculating the economically optimal phosphorus recommendations the current prices prevailing at the time of the study were used. A change in the price of phosphorus fertilizer, wheat or sugar beets causing a significant change in the factor-product price ratio will also change the economic optimum phosphorus levels. Small changes in this ratio, however, will not cause a significant change in the recommendations for practical purposes.

RÉFÉRENCES

[1] ARNOLD (C. Y.). — The phosphorus requirements of transplanted tomatoes on heavy soils. *Soil Sci.*, 1953, **76**, 405-419.

[2] BALBA (M. A.) and BRAY (R. H.). — New fields for the application of the Mitscherlich equation: I. A. quantitative measure for the relative effectiveness of the nutrients. *Soil Sci.*, 1956, **82**, 497-502.

[3] BARKER (S.). — The Results of the Phosphorus Correlation Experiments (1961-1969). 51 numbered pages in Turkish. Turkish Sugar Factories Corporation, Sugar Research Institute, Ankara. 1970.

[4] BARKER (S.). — Correlation between the sugar beet yields and the available phosphorus values found by six chemical methods (Turkish with English Summary). *Seker*, 1972, **82**, 19-26, Official publication of the Turkish Sugar Factories Corporation, Ankara, Turkey.

[5] BARKER (S.). — Calibration of the available soil phosphorus values found with the modified Hellige-Truog method with the phosphorus requirement of sugar beets: I. Determination of the fertilizer application rates to obtain selected yield levels (Turkish with English Summary). *Seker*, 1973, **86**, 7-17.

[6] BRAY (R. H.). — Soil—plant relationships: I. The quantitative relation of exchangeable potassium crop yields and to crop response to potash additions. *Soil Sci.*, 1944, **58**, 305-324.

[7] BRAY (R. H.). — Soil-plant relations: II. Balanced fertilizer use through soil tests for potassium and phosphorus. *Soil Sci.*, 1945, **60**, 463-473.

[8] BRAY (R. H.) and KURTZ (L. T.). — Determination of total, organic and available forms of phosphate of soils, *Soil Sci.*, 1945, **59**, 39-45.

[9] BRAY (R. H.). — Correlation of soil tests with crop response to added fertilizer and with fertilizer requirement, 1948. (*In* Diagnostic Techniques for Soil and Crops, pp. 53-86. The American Potash Institute, Washington, D.C.)

[10] CARTER (H. O.), DEAN (G. W.) and McCORKLE (C. O. Jr.). — Economics of fertilization for selected California crops. 73 numbered pages Division of Agricultural Sciences, University of California, Mimeographed Report No. 230, California, 1960.

[11] HEADY (E. O.) and DILLON (J. L.). — Agricultural Production Functions. Iowa State University Press, Ames, Iowa, 1961.

[12] KAYIMOGLU (S.). — The Economic use of fertilizer in sugar beet production in Turkey. M.S. thesis, presented at the American University of Beirut, Lebanon, 1972.

[13] MATTINGLY (E. G.) and PINKERTON (A.). — Some relationships between isotopically exchangeable phosphates, soil analysis and growth in the greenhouse. *J. Sci. Food Agr.*, 1961, **12**, 772-777.

[14] OAKES (H.). — The soils of Turkey. Dogus Ltd. Sirketi, Ankara, Turkey, 1957.

[15] OLSEN (S. R.) et al. — Estimation of available phosphorus in soils by extraction with sodium bicarbonate. U.S. Department of Agr. Sci. 939, Washington, D.C., 1954.

[16] VAJRAGUPTA (Y.), HALLEY (L. H.) and MELSTED (S. W.). — Correlation of phosphorus soil test values with rice yield in Thailand. *Soil Sci. Soc. Amer. Proc.*, 1963, **27**, 395-397.

[17] YURTSEVER (N.). — The effect of fertilizers on wheat production under irrigated and dry farming conditions in Turkey. 5th irrigation practices Seminar, NESA Region, New Delhi, India, 1964, pp. 474-485.

[18] YURTSEVER (N.), ATESALP (M.) and MELSTED (S. W.). — A tentative correlation for the Olsen bicarbonate phosphorus soil test with wheat responses under Turkish soil conditions, 1965.

[19] YURTSEVER (N.). — Soil test calibrations and economic analyses. (In Turkish). Soil and Fertilizer Research Institute Technical Publication No. 18, Ankaar, Turkey, 1969.

[20] YURTSEVER (N.). — A study on the calibration of the Olsen soil test for available phosphorus with the wheat yield responses to added fertilizers under Thrace Region conditions. (In Turkish with English summary), Ph. D. Thesis. Presented to the Faculty of Agriculture of Ankara University, Turkey, 1971.