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Soil fertility in the Great Konya Basin, Turkey

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This is the fourth report in a series of studies on the soils of the Great Konya Basin.

The complete series, to be published by Pudoc (Wageningen), will consist of the following publications.

1. Driessen, P. M. and T. de Meester: Soils of the Çumra Area, Turkey (1969).
2. Meester, T. de (Ed.): Soils of the Great Konya Basin, Turkey (1970).
3. Driessen, P. M.: Soil salinity and alkalinity in the Great Konya Basin, Turkey (1970).
4. Janssen, B. H.: Soil fertility in the Great Konya Basin, Turkey (this report).
5. Meester, T. de: Highly calcareous soils of the Great Konya Basin, Turkey (in preparation, to be published in 1971).

Contents

1 Introduction

Soil fertility was studied in the Great Konya Basin, as part of the study carried out by the Department of Tropical Soil Science of the Agricultural University at Wageningen.

The purpose of the study was to find the agricultural value of prevalent soil types, to learn about the main factors governing fertility, and to work out fertilizer recommendations for dry farming in the Basin.

Fertility research has not often been combined with systematic survey and profile studies, though soil scientists frequently try to correlate productivity with soil type. But in many cases variation in yield has proved to be due to specific properties and not to soil type itself (Butler, 1964). Hence the mapping of soil fertility often amounts to the mapping of one or a combination of more characteristics (de Vries & Dechering, 1960; Cengiz & Başaran, 1966; Hernando, 1962). Since other combinations of properties are used for the mapping of soil units, fertility maps coincide with soil maps more by chance than by rule.

Nevertheless knowledge of genesis allows forecasts of soil fertility in general terms (Schuffelen & Koenigs, 1962). But the influence of climate, topography, kind and level of the prevailing agricultural system, and type of crops is usually overriding.

One of the easiest and cheapest ways to raise yield is to apply fertilizers. The use of fertilizers has often proved the first step to modern agriculture (Williams & Couston, 1962).

Fertilizer consumption is increasing rapidly in Turkey (Kıroğlu, 1968), so that proper recommendations are needed. Such recommendations can be better obtained from integrated studies, like the present one in field, greenhouse and laboratory, than from innumerable replications of the same field trials.

Field studies were carried out in the 1966-7 and the 1967-8 growing seasons. Besides a new technique of greenhouse trials was tried. Such trials, lasting only three weeks, should give semi-quantitative information on the nutrients status of soils and should be particularly useful where field data do not conform with chemical analysis. Most of the physical and chemical analysis and the greenhouse trials was done at Wageningen; a minor part at Ankara.

Chapter 2 describes the Great Konya Basin, in particular the common agricultural system. Chapter 3 reviews literature on the subject. The design and procedure are discussed in Chapter 4. Since the soils have been described fully (Groneman, 1968; Driessen & de Meester, 1969; de Meester, 1970), this report surveys them only briefly in Chapter 5, with special reference to the soils used in fertility trials. The Chapters 6 to 8 give the results and conclusions of the fertility study. I have tried to indicate the influence of the most important yield factors and to correlate them with soil characteristics. Fertilizer recommendations are given in Chapter 9.

2 General data

2.1 Description of the Great Konya Basin

This chapter has been compiled almost exclusively from the description by de Meester (1970), which should be consulted for extensive information.

2.1.1 Geography

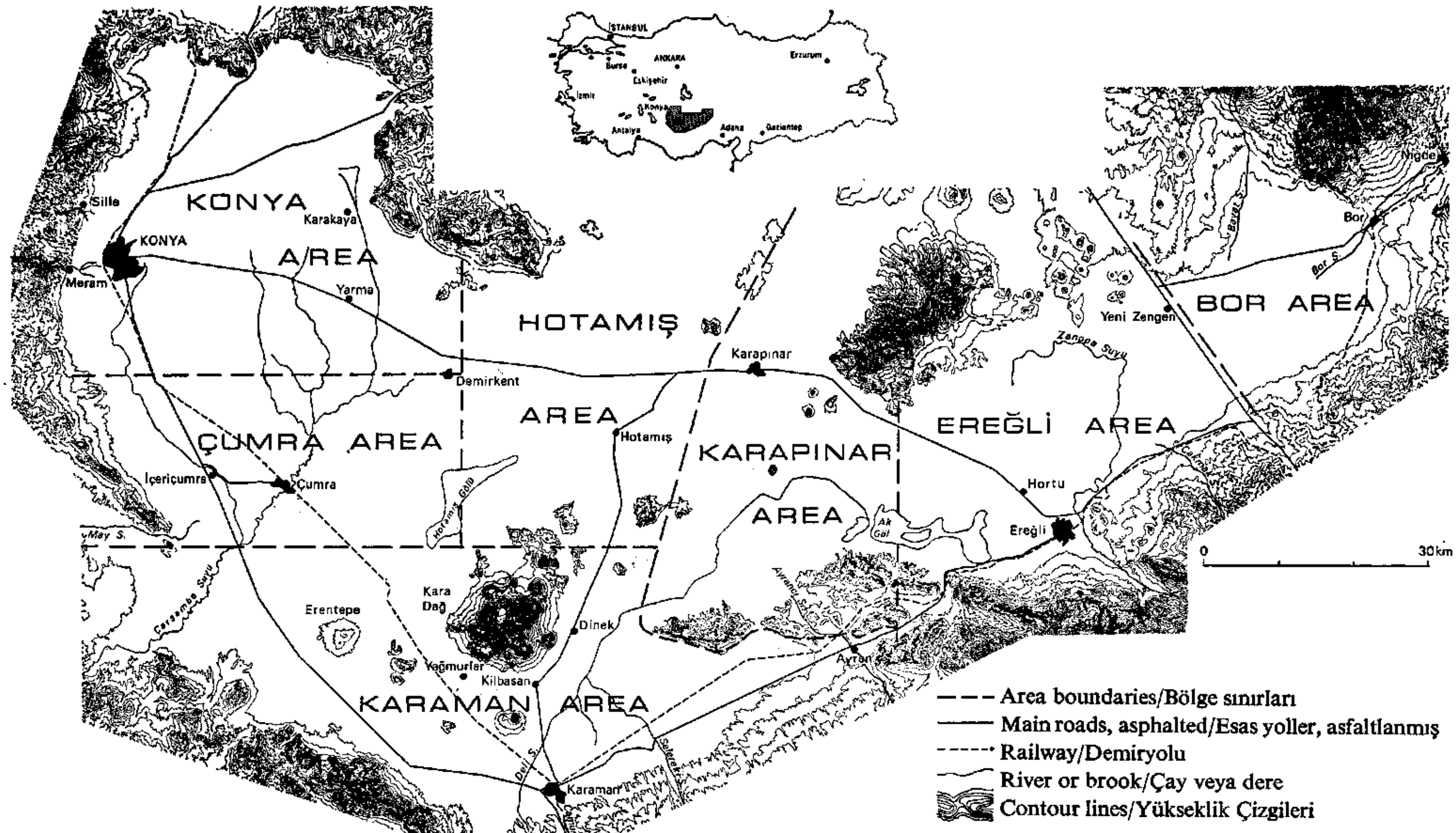
The Great Konya Basin is in the Central Anatolian Plateau (Konya Province, Turkey) at a latitude of 37° and between 33° and 35° East. In it lies the provincial capital of Konya (160000 inhabitants); other towns of importance are Karaman (26000), Karapınar (13000), Ereğli (40000), Bor (14000) and Çumra (11000). For convenience de Meester (1970) divided the Basin into 7 areas, as shown in Figure 1. Outside the towns, the Basin is utterly rural. Villages and yaylas (summer settlements) are scattered evenly over the plains and border areas. The villages are connected with dust roads, which are readily passable in summer, but difficult in winter. Hardly any village has modern conveniences such as piped water and electricity, but schools and medical facilities are adequate and improving. Literacy, about 50%, is near the national average of 48%.

The Great Konya Basin (which will henceforth be referred to just as 'the Basin'), covers about 1000000 ha and is encolsed by uplands and mountains. Several rivers flow into the Basin. The central part is flat and consists of several plains, separated by elevations. The Basin is a structural basin, filled with different Tertiary and Quaternary sediments. Most of the sediments come from the surrounding limestone mountains. Tertiary rocks consisting mainly of andesite, dacite, diorite and tuff are found along the Basin's border, but mainly in the eastern half.

The sediments which fill the Basin are more than 400 m thick locally and consist of clastics, such as clay, marl, sand, gravel and conglomerates, and hard Neogene freshwater limestone. The upper 10-50 m of sediments are Quaternary age. Evidently there was a large, rather shallow lake, Ancient Lake Konya, during the Late Pleistocene, which has dried up during the Würm Period. Its dry floor, shores, and alluvial and colluvial sediments which spread out into the Basin, give the landscape its present form.

The physiographic division of the Basin is discussed in Section 5.1.

Fig. 1. General position of the Great Konya Basin. From de Meester, 1970.



Şekil 1. Alt arazi bölümleri ile Büyük Konya Havzası'nın genel durumu (de Meester 1970'den).

Table 1. Climatological data from several observation stations in the Great Konya Basin (kindly provided by the State Meteorological Sercive in Ankara and Çumra's Experimental Station).

Station	Number of years	Months of the jear												Annual figure
		J	F	M	A	M	J	J	A	S	O	N	D	
Mean temperature in ° C/Ortalama sıcaklık, ° C olarak														
Konya	37	—0.2	1.4	5.0	11.0	15.9	19.8	23.2	23.1	18.0	12.4	6.7	1.9	11.5
Çumra	14	0.6	1.6	5.1	10.8	15.3	19.5	22.6	21.9	16.8	11.8	6.7	3.0	11.4
Karaman	6	1.2	2.4	6.0	10.7	14.0	19.8	22.9	22.4	17.1	12.2	8.0	4.7	11.8
Ereğli	2	2.3	3.4	7.1	12.5	14.8	19.5	21.4	21.2	15.2	9.5	7.3	3.7	11.4
Karapınar	2	—4.6	0.8	6.7	9.9	14.7	19.8	22.7	21.7	16.5	9.4	5.2	3.2	10.5
Mean precipitation in mm/Ortalama yağış, mm olarak														
Konya	37	37.3	33.1	30.6	28.8	43.0	26.4	5.6	3.1	11.6	26.7	29.4	39.6	315.1
Çumra	14	28.7	28.8	25.4	21.8	31.4	17.3	1.3	1.3	9.9	19.4	25.3	43.1	253.1
Karaman	36	44.3	42.4	35.0	38.9	36.5	23.6	3.8	2.5	9.6	25.4	34.0	45.9	342.1
Ereğli	17	31.0	33.2	32.1	34.4	36.3	23.6	2.5	1.7	5.9	20.0	23.9	38.1	282.7
Karapınar	12	36.8	33.8	28.3	24.0	38.4	21.0	2.7	0.7	5.8	14.5	22.3	44.8	273.2
Pan evaporation in mm/Açık havadan buharlasma mm														
Konya	28	20.5	32.9	65.5	103.2	118.4	145.8	204.2	206.2	142.7	86.1	41.0	22.1	1188.8
Çumra	14	3.9	9.0	50.5	127.2	156.4	189.4	238.2	230.1	151.9	90.3	36.7	15.6	1299.2

Tablo 1. Büyük Konya Havzası'nın çeşitli rasat istasyonlarına ait iklim kayıtları (Ankara Devlet Meteoroloji Işleri Genel Müdürlüğünün ve Çumra Sulu Ziraat Deneme Istasyonu'nun lütfuyla temin edilmistir).

2.1.2 Climate

The Basin is one of the driest parts of Turkey. By the Köppen classification the climate is semi-arid (BSak), with cold moist winters and hot dry summers. Evaporation far exceeds total precipitation. Some important climatological data are presented in Table 1.

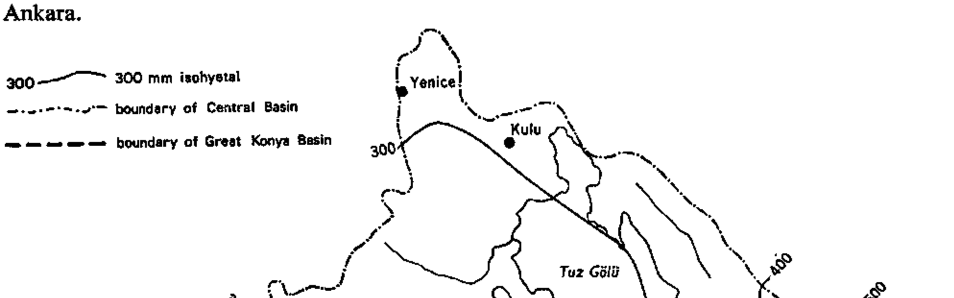
Frost can be severe; night temperatures of —25° C are common in winter. In summer day temperature reaches 35° C. The frost-free period lasts almost 165 days.

The distribution of annual precipitation in and around the Basin is shown in Figure 2. The centre of the Basin is the driest part (see also Çumra and Karapınar in Table 1).

For crops of winter wheat, spring rain is important, but the heavy spring showers are unfortunately irregular in distribution and amount. Crop yields vary greatly over short distances because of this irregularity in spring rain.

The relative humidity is 40-50% in summer and 70-80% in winter.

Fig. 2. Average annual precipitation in and around the Great Konya Basin. From data of DSİ Ankara.



Şekil 2. Ankara D.S.İ. kayıtlarına göre mm olarak Büyük Konya Havzasında ve çevrelerinde senelik ortalama yağış.

2.1.3 Land-use

Four main types of land-use may be distinguished:

1 Irrigated farming; (230000 ha) or 20% of the Basin
2 Dry farming; (420000 ha) or 35% of the Basin
3 Dry range
4 Other use; mostly unsuited for any form of cropping or stocking.

Figure 3 shows the occurrence of different land-use in the Basin. Much of the Basin is unsuitable for agriculture because, for instance, of steepness, stoniness, salinity and marshiness. Another large part is used for steppe pasture, on which sheep and goats commonly range. Cows, donkeys and even horses are also herded there. As generally in Turkey, pastures are overgrazed. More and more land, though not suitable for grazing, is used for it, thus increasing the danger of soil erosion (FAO, 1959).

Most of the dry-farmed land is situated west of the line Karapınar-Akçaşehir. Here only the cereals wheat, barley and rye can be cultivated. In Section 2.2 more attention will be paid on this agricultural system.

Irrigated land forms a rather large proportion of the Basin in comparison with the rest of Central Anatolia (Tümertekin, 1964). This favourable situation is due to the geography of the Basin. In several places water coming down from the mountains can be caught and used for irrigation. The main water-supplying rivers are the Çarşamba the Meram, the Zanopa and the Ayrancı (Fig. 1).

2.2 The dry-farming system in Turkey

The characteristic feature of the dry-farming system in Turkey is a rotation of cereals (mostly wheat) with fallow.

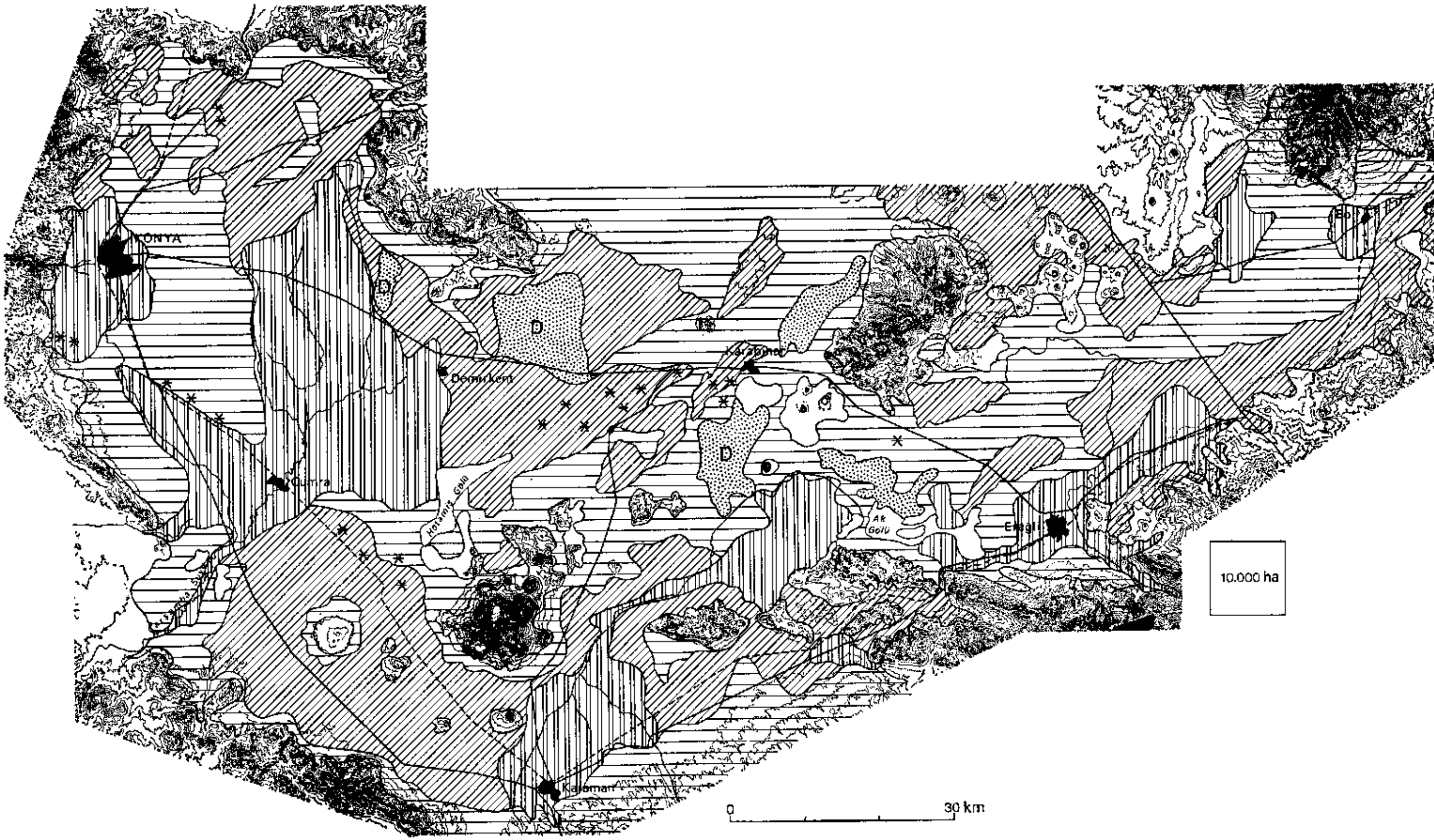
Several studies have been made on the efficiency of this fallow year. The moisture storage and enrichment of soil nitrogen in the fallow year is discussed in Section 3.5. Sections 7.1.1 and 7.1.2 deal especially with moisture storage during the study.

The cultivation practices of dry-farming are directed towards water conservation (Fig. 4).

After harvest the land is kept under stubble till the next spring. The purposes of this procedure are to prevent wind erosion in summer and to hold snow in place in winter. The risk that the stubble and any weeds will consume soil moisture is not serious. After July there is no soil moisture left and from November to spring temperatures are too low for much evapotranspiration.

However, the land must be ploughed in spring as early as possible. Infiltration of rainwater is improved, weed growth is limited and thus loss of moisture in summer is restricted. Early ploughing also promotes nitrification (Christiansen-Weniger, 1934). Trials at Ankara and Eskişehir in 1952-3 showed that the best time for ploughing was March or April (Money-Kyrle, 1957). It seems to be of less importance how deep the ploughing is, at least trials have been inconclusive. Mostly the depth varies between 8 and 15 cm.

Fig. 3. Land-use in the Great Konya Basin. Approximate situation in 1965. From de Meester, 1970.



Şekil 3. Büyük Konya Havzasında 1965 yılı içinde yaklaşık olarak arazi kullanma durumu. (de Meester 1970'den).

Fig. 3. Legend.

- Uplands/Yüksek araziler
- Irrigated arable/Sulu ziraat
- Dry arable/Kuru ziraat
- Dry range/Kuru mera
- Wasteland (dunes or playas)/İşlenmeyen arazi (kumlar ve playalar)
- * Local irrigation from deep wells/Derin kuyulardan mevzii sulama
- D Sand dunes/Kum kümesi

Şekil 3. Lejant.

After the May rains, the dried surface soil depresses evaporation of sub-soil moisture. Of course, after ploughing wind erosion may become detrimental, but it has been proved that when soil is ploughed in big clods, the damage is minor. Nevertheless dust storms are common.

Before sowing, the soil may be loosened, e.g. with disk harrows. Loosening of the soil and sowing is often combined by hanging harrow and seed drill behind each other. With old-fashioned ploughs drills have sometimes been attached right behind the shares, so that the seed falls into the furrow.

The best time to sow is October, as has been demonstrated in many trials, which are summarized in Table 2. Dewey & Nielson (1969) came to about the same conclusions in the American Great Plains. Rohrmoser (1964) found a positive relation between yield and interval between sowing and beginning of winter (date when average day temperature falls below 6° C).

Seeds must be placed at least 3 cm deep. Christiansen-Weniger (1970) recommends a depth of 4-6 cm. Deeply sown plants are in better condition to survive drought after germination and to resist winter killing (Dewey & Nielson, 1969).

Sowing rates of wheat vary in practice between 150 and 180 kg per ha.

Weather conditions in winter do not noticeably influence yields, but rainfall in April and May is probably the most important yield factor (Rohrmoser, 1964).

In the Basin, stem extension of wheat occurs in mid May; flowering in June;

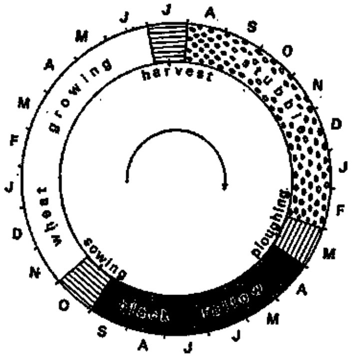


Fig. 4. Scheme of the wheat-allow rotation.

Şekil 4. Buğday nadas rotasyon şeması.

Table 2. Influence of sowing time on yields (expressed as relative yields).

Time of sowing	Christiansen-Weniger (1934)		(1970)	Brandow (1953)
	1931-2	1932-3	1950-60	Twelve-year average
October	100	100	100	100
November	83		93	62
December		95	85	55
January		97	75	40
February		89	58	50
March	78	77	35	47
April	51			25

Tablo 2. Ekin zamanının mahsul üzerine etkisi (nisbi mahsul olarak ifade edilmiştir).

harvesting in July. In the south of the Basin, harvesting is two or three weeks earlier than in the north.

There have been many trials on the fertilizer needs of dry-farmed wheat. They will be discussed in Section 3.1. Although fertilizer consumption is increasing, the average use per ha is still low. Nowadays problems of production and transport of fertilizers limit use more than the unwillingness of the farmers.

3 Literature review

3.1 Fertility research in Turkey

Soil fertility in Turkey is studied by the Soils and Fertilizers Research Institute (Toprak ve Gübre Araştirma Institüsü) at Ankara, by the Agricultural Faculties of the Turkish universities and by the sugar company (Türkiye Şeker Fabrikları). Between 1962 and 1969 also the FAO carried out many trials and demonstrations within the Fertilizer Program of the Freedom From Hunger Campaign. This discussion deals only with dry-farmed wheat, the main crop in my research.

Nearly all studies are of nitrogen, phosphorus and potassium. The success of *nitrogen* dressing depends partly on mineralization during the fallow year but mostly on moisture conditions, especially rainfall in April and May. If there is a positive response, the economic nitrogen rates are between 20 and 60 kg N per ha (Tarım Bakanlıgı, 1957-63, 1959-63). However, responses, if any, are often negative. As yet it is not clear whether nitrogen should be applied in autumn or spring. The conclusion of some trials is that soil moisture in May should be estimated to decide on nitrogen dressing.

For spring dressing ammonium nitrate seems better than ammonium sulphate; for autumn dressing there is little difference between the fertilizers.

Phosphorus nearly always increases yield. According to Yurtsever (1964), 40 kg P_2O_5 is economically optimum, but FAO recommends 60 kg P_2O_5 per ha (Mathieu, 1969).

Soils in Central Anatolia are low in phosphorus (Table 3). Phosphorus fixation is usual and related to carbonate content (Kaçar, 1967).

Superphosphate and triple phosphate are most frequently used. Some FAO trials indicate that superphosphate is more effective than triple phosphate. Trials of the Soils and Fertilizers Research Institute show that 8 cm deep banding of phosphorus fertilizers is better than mixing with soil, either from 0 to 2 cm or from 0 to 8 cm. Broadcasted phosphorus remains on the soil surface, because of the low rainfall.

In Central Anatolia no response has been found to *potassium* fertilizers, since soils are rich in potassium (Özbek, 1953; Fox & Kaçar, 1965; Christiansen-Weniger, 1970). Values usually vary between 70 and 240 kg K_2O per dekar (Tarım Bakanlıgı, 1957-63).

Nowhere does literature mention trials with *minor elements* on wheat in Turkey.

Christiansen-Weniger (1934, 1970) reports succesful trials with *farmyard manure*. Cattle dung, however, is still used as fuel by farmers, so that improvement in soil fertility by that method may not be expected.

Table 3. Phosphorus contents in soils of Central Anatolia.

Reference	Extraction method	Contents	Unit
Tarım Bakanlığı, 1957-63	0.5 *N* $NaHCO_3$	1 - 5	kg P_2O_5/dekar[1]
Yurtsever et al., 1965	0.5 *N* $NaHCO_3$	1 - 5	kg P_2O_5/dekar
Özbek et al., 1967b	0.5 *N* $NaHCO_3$	2 -15	ppm
	0.03 *N* NH_4F + 0.025 *N* HCl	0.1-12	ppm

1. 1 dekar = 0.1 ha

Tablo 3. Orta Anadolu topraklarında fosfor miktarları.

3.2 Interrelations between moisture and plant nutrients

Since the effect of fertilizers depends largely on the moisture conditions, a fertility study is fruitless, certainly in arid regions, unless those conditions are considered.

Relations between moisture and plant nutrients may be divided into effects of soil moisture on nutrient availability and of nutrients on moisture utilization by plants.

Discussion below is focused on nitrogen and phosphorus, as those elements were particularly studied in the Basin.

3.2.1 Soil moisture and nutrient availability

The influence of soil moisture on nutrient availability can be distinguished into effects on the pools of nutrients and on the transport of nutrients through the soil to roots (Viets, 1967; Wiersum, 1969).

Pools are nutrients dissolved in soil solution and nutrients bound in a labile form in or on soil particles. The distribution of nutrients among the pools is to a considerable extent regulated by moisture content of soil.

As moisture increases, concentration of *nitrate* decreases. But when soil is saturated or nearly saturated with water, total amount of nitrate also decreases through denitrification. In dry conditions mineralization and often nitrification are advanced, especially when dry periods are followed by wet (Birch, 1960; Alexander, 1965; van Schreven, 1968).

The total amount of dissolved *phosphorus* is increased under wet conditions, because phosphorus is hardly diluted. Its concentration depends mainly on solubility products, which vary with pH and temperature (Huffman, 1962; Larsen, 1967).

Soil moisture influences transport of nutrients through soil to roots by affecting the transport mechanisms of mass flow and diffusion.

For *nitrate*, mass flow is most important. According to Alberda et al. (1964) and Dilz (1964), the amount of nitrate taken up by plants at least equals the product of nitrate concentration and amount of water absorbed, and it often exceeds that product. When soil moisture decreases, nitrate concentration in the soil solution increases, but transpiration by plants and hence dry-matter production decreases. As a consequence, nitrogen in the plant increases, as has been shown in numerous field trials, particularly in arid and semi-arid zones (Fernandez & Laird, 1959; Collwell, 1963; Johnson et al., 1967; Terman et al., 1969). The opposite, a decrease in plant nitrogen with irrigation is likewise well known (Jensen & Sletten, 1965; Stone & Tucker, 1969).

Phosphate concentration in the soil solution is too low to supply plants by mass flow; diffusion is the main transport mechanism (Barber, 1966). Soil moisture enhances diffusion rate through its effects on tortuosity, sectional area containing water and on concentration gradient of phosphorus (Olsen et al., 1961). As phosphorus diffusion varies from 1 mm to some centimetres according to different authors (Heslep & Black, 1954; Olsen et al., 1962; Lewis & Quirk, 1967), the amount of phosphorus reaching plant roots depends largely on root extension. But root extension itself is also related to soil moisture. In dry soils, root growth is hampered directly because water is needed for root elongation (Peters, 1957) and indirectly by increase in mechanical resistance to root penetration (Maertens, 1964). So, when soil moisture decreases, less phosphorus reaches the root surface and is taken up (van Lieshout, 1960; Olsen et al., 1961; Wesley, 1965). Since dry-matter production decreases also with drought, the change in plant phosphorus depends on what is reduced more: phosphorus uptake or dry-matter production. That is why many contradicting results have been obtained; however, distinct relations between moisture and plant phosphorus could often be indicated (Mederski & Wilson, 1960; Boatwright et al., 1964; Ferguson, 1964).

In conclusion, high soil moisture should stimulate nutrient uptake because of the increase in size of pools, diffusion rates of ions, extension of the root system, and mass flow of water.

3.2.2 Nutrients and efficiency of water-use by plants

In his literature review on fertilizers and efficient use of water, Viets (1962) defines the following concepts. The water requirement or *transpiration ratio* (*TR*) is defined as

$$TR = \frac{\text{weight of water absorbed by the plant during growth}}{\text{weight of dry matter produced by plant during that time}} \qquad (1)$$

The consumptive use or *evapotranspiration (ET)* is the sum of water used by transpiration by plants and evaporation from soil or from intercepted precipitation (in any specified period), usually expressed in mm or inches.

The *water-use efficiency (WUE)*

$$WUE = \frac{\text{dry matter produced (kg/ha)}}{ET \qquad \text{(mm)}} \qquad (2)$$

As *WUE* includes also evaporation, it is not exactly reciprocal to *TR*.

WUE is influenced by plant species, by the climatic conditions and by all cultural practices that change dry-matter production, thus also insect and weed control. *TR* depends upon plant species, moisture supply, soil fertility and weather (especially light intensity and relative humidity). *TR* is usually considered of little value, certainly not as a characteristic of a plant species (Penman, 1956). In arid and sub-arid regions, however, where water is limiting, *TR* proved to be an useful tool, as de Wit (1958) has clearly shown. He arrived at a relation between dry-matter production and relative transpiration:

$$DM = m\, T\, E_0^{-1} \quad (3)$$

where

DM = total dry matter of aerial parts (kg ha^{-1})
m = constant, depending upon plant species (kg ha^{-1} day^{-1})
E_0 = free water evaporation (mm day^{-1})
T = total transpiration (mm)

For Kubanka wheat, de Wit found $m = 115$ kg ha^{-1} day^{-1}. De Wit's formula has been supported by Hanks et al. (1969), who estimated values for m between 113 and 140 kg ha^{-1} day^{-1}. For Equation 3, according to de Wit, the following conditions must hold: a not 'too low' fertility, a not 'too high' availability of water and a not 'too dense' leaf mass. If these conditions are not satisfied, the value of m tends to be lower, i.e. water is less efficiently used.

For a definite region and a definite season, E_0 is fixed. Then *TR* can be calculated by combining equations 1 and 3

$$TR = 10^4\, E_0/m$$

where 1 mm water is equivalent to 10^4 kg water per ha.

In nearly all trials in the literature, fertilizers decreased *TR* and increased *WUE*. An increase in *WUE* was usually caused by a decrease in both *TR* and evaporation. Evaporation decreased because the soil surface was covered earlier by promotion of growth. The beneficial influence of fertilizers on *TR* is probably connected with the rise appearing in net assimilation rate, when nutrient supply is increased from (very) low to adequate (Watson, 1952; Bouma, 1965).

The increment in *WUE* with fertilizers decreases with rate (Viets, 1962). This explains why fertilizers sometimes did not increase *WUE* significantly, namely where soil fertility was already high or where rather concentrated nutrient solutions were compared, as Chaussat (1966) did. That de Wit's (1958) condition was that fertility should be not 'too low' rather than 'optimum', can also be understood in this context.

It is assumed that under arid conditions fertilizers mostly do not change *ET*, as all available water is used, either by a fertilized or an unfertilized crop. Measurements confirm such (Haise et al., 1960; Linscott et al., 1962; Swartz & White, 1966; de Jong & Rennie, 1969). This means that yield increments by fertilizers are caused by more efficient water use. At the beginning of the growing season, however, *ET* may be enhanced by fertilizers as shown by Linscott et al. (1962) (Fig. 5). In that situation, grain yield may be lowered by nitrogen fertilizer because the grain/straw ratio is reduced (Lehane & Staple, 1965; Luebs & Laag, 1969). According to some authors, nitrogen-fertilized crops could withdraw more moisture from great depths (> 1 m), because of deeper root penetration (Linscott et al., 1962; Ramig & Rhoades, 1963; Olson et al., 1964).

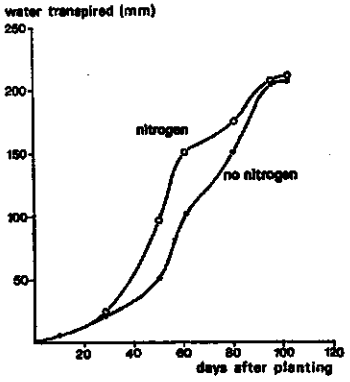


Fig. 5. Cumulative amount of water transpired by nitrogen-fertilized maize and unfertilized maize under arid conditions. From Linscott et al., 1962.

Şekil 5. Arit şartlar altında azotla gübrelenmiş ve grübelenmemiş mısırda kümilatif olarak sarfedilen su miktarı (Linscott ve arkadaşları 1962'den).

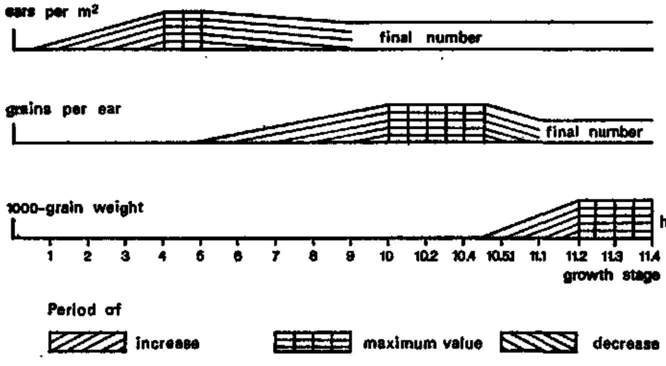
3.3 Yield components as influenced by moisture, nitrogen and phosphorus

Grain yield is the product of the yield components, number of ears, number of grains per ear and grain weight (1000-grain weight).

A change in grain yield with fertilizer or water can thus be analysed into changes in one or more yield components. Which these components are depends on when water or fertilizers are supplied, because each component forms during a certain stage of growth.

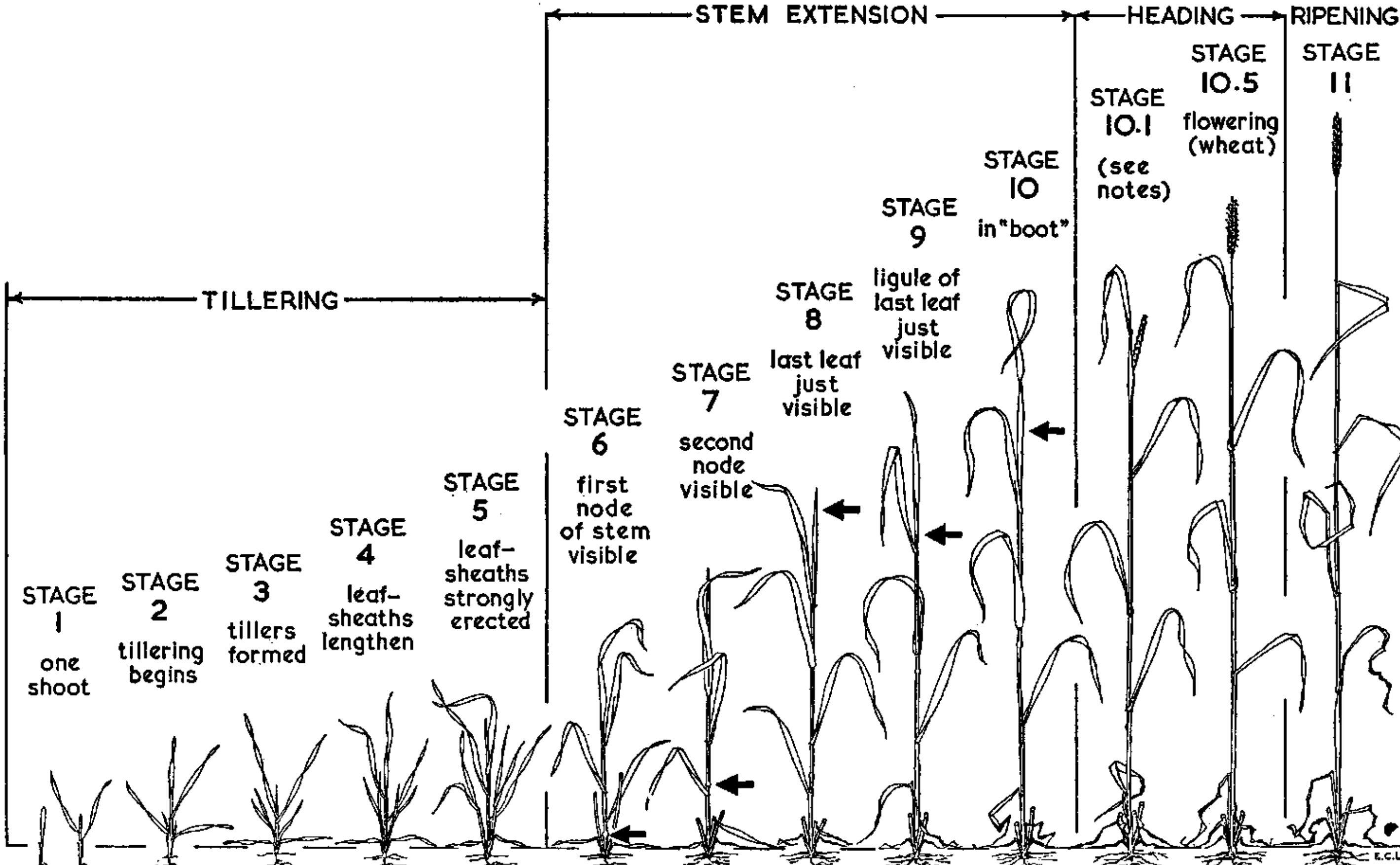
For an useful discussion on this matter, the growth stages must be defined. One of the most used scales for wheat was devised by Feekes (1941). The stages are presented in Figure 6. Henceforth the stages, as numbered there, will be used. The stages at which the different yield components form under normal field conditions are shown schematically in Figure 7. With this figure, intervals can be marked during which the

Fig. 7. Periods of formation of yield components (schematic). After Schrimpf, 1960 and Haensel, 1956, 1965.



Şekil 7. Şematik olarak mahsul, oluşum devrelerinin kısımları (Schrimf, 1960 ve Haensel, 1965, 1965'e göre).

Fig. 6. Growth stages of wheat according to Feekes, 1941. From Large, 1954.



Şekil 6. Feekes 1941'e göre buğdayın büyüme devreleri. Large 1954'den.

amount or weight of a particular yield component may be influenced. Haensel (1956) distinguishes 'Grenz-stadien' at which a yield component has been fixed. Further Haensel (1956, 1965) divides development of each organ into periods of formation (increasing number or weight), of maximum and of reduction, leading to the final value at harvest. In Figure 7 this is rather simplified; the period of reduction may start earlier than indicated, so curtailing the period of maximum.

Cultural measures intended to increase yields may act either by enhancing formation (e.g. tillers, florets) or by limiting reduction (e.g. unheaded tillers, seed set).

Water To understand the influence of a growth factor on yield, it is not only necessary to know when the several yield components are formed, but also when the plant or the component needs the factor most.

Most moisture is needed around flowering (van de Paauw, 1949; Ferguson, 1965; Nix & Fitzpatrick, 1969), and this stage is therefore called the critical period. Around this stage also daily increment of dry-matter is greatest (Watson et al., 1963; Dorohov et al., 1968; de Vos, 1969) which make the high water need comprehensible. Any factor shortening the period after flowering diminishes yield, so it is essential that moisture supply is adequate also from then on. It increases the percentage fertilization of florets (seed set), and 1000 grain weight (Baier & Robertson, 1967; Campbell, 1968).

Fig. 6. Legend.

Stage		
1	One shoot (number of leaves can be added) = 'brairding'	Tillering
2	Beginning of tillering	
3	Tillers formed, leaves often twisted spirally. In some varieties of winter wheats, plants may be 'creeping' or prostrate	
4	Beginning of the erection of the pseudo-stem, leaf sheaths beginning to lengthen	
5	Pseudo-stem (formed by sheaths of leaves) strongly erected	
6	First node of stem visible at base of shoot	Stem Extension
7	Second node of stem formed, next-to-last leaf just visible	
8	Last leaf visible, but still rolled up, ear beginning to swell	
9	Ligule of last leaf just visible	
10	Sheath of last leaf completely grown out, ear swollen but not yet visible	
10.1	First ears just visible (ear escaping through split of sheath)	Heading
10.2	Quarter of heading process completed	
10.3	Half of heading process completed	
10.4	Three-quarters of heading process completed	
10.5	All ears out of sheath	
10.5.1	Beginning of flowering	Flowering
10.5.2	Flowering complete to top of ear	
10.5.3	Flowering over at base of ear	
10.5.4	Flowering over, kernel watery ripe	
11.1	Milky ripe	Ripening
11.2	Mealy ripe, contents of kernel soft but dry	
11.3	Kernel hard (difficult to divide by thumb-nail)	
11.4	Ripe for cutting. Straw dead.	

Beneficial effects on grain yield of rainfall or irrigation at flowering or the oppostie with water shortage are reported by many writers (van de Paauw, 1949; Chinoy, 1960; Lehane & Staple, 1965; Russell, 1968; Nix & Fitzpatrick, 1969; Christiansen-Weniger, 1970).

When moisture stress is low early in the season, many tillers are formed, but not all reach heading (Campbell & Read, 1968).

If water later becomes limiting, grains/ear and 1000-grain weight fall, so that final grain yield falls (Storrier, 1965a; de Vos & Toussaint, 1966; Campbell, 1968). A low number of grains per ear is partly, seldom completely, compensated by an increased 1000-grain weight (Taheri, 1960; Stoy, 1965; Bingham, 1967).

A summary of the preceeding may be seen in the equation of Jensen (1968) who related evepotranspiration (as a measure of water use) to the actual yield of marketable product:

$$\frac{Y}{Y_o} \simeq \prod_{i=1}^{n} \left(\frac{W_{et}}{W_{oc}}\right)_i^{\lambda_i} \qquad (4)$$

where

Y, Y_o = yield when moisture is limiting and not limiting, respectively

W_{et}, W_{oc} = actual use of water and use when moisture is not limiting, respectively

λ_i = relative sensitivity of the crop to water stress during stage i

As the right side of Equation 4 is a product, it implies that yield of marketable product does not have to be linearly related to total water use when plants are stressed.

For wheat, λ proved to be 0.5 between stages 1 and 9, 1.5 between stages 10 and 11.1 and again 0.5 after Stage 11.1. The importance of an adequate moisture supply during flowering is clearly illustrated by the value of 1.5 for λ at that stage.

Nitrogen Wheat absorbes nitrogen most before flowering. Mehrotra et al. (1967) found that about 45% of the absorbed N was taken up between sowing and Stage 5, about 25% between stages 6 and 10.2 and about 30% after Stage 10.2. Fried & Broeshart (1967), gathering data from the literature, mention 15, 27, 42 and 16%, respectively, for the periods before Stage 3, at stages 3-7, at stages 7-10.5 and after Stage 10.5.

On wheat, nitrogen causes an increment to leaves and a slowing down of development, so an increase in the size of the assimilatory apparatus and in the length of its productive period (Volke & Inostroza, 1967; Dorohov et al., 1968; Brouwer, 1969). In trials on very poor soils, however, increasing rates of nitrogen, applied at sowing, promoted initial development of spring wheat, up to an optimum (Limberg, 1964).

Application of nitrogen before Stage 6 or 7 particularly promotes number of tillers; applied at Stage 6 or 7 or later, nitrogen enhances the number of grains per ear and 1000-grain weight. Application at Stage 10.5 is mostly too late to increase yield, because only the 1000-grain weight is increased (Coic & Jolivet, 1953; Taheri, 1960; Limberg, 1964; Wood & Fox, 1965; de Jong & Jonker, 1967).

In moist regions early dressed nitrogen may be leached out before later stages; in arid zones, the consequence is mostly too a rapid exhaustion of soil moisture (Fig. 5), so reducing number of headed tillers, grains per ear and 1000-grain weight (Storrier, 1965b; Volke & Inostroza, 1967). In very dry years, grain yield of nitrogen-fertilized wheat may be even lower, the greater the mass of dry matter produced at about Stage 10.2 (Fischer & Kohn, 1966).

Phosphorus The effect of phosphorus on yield components has received rather little attention. In general phosphorus seems to shorten growth stages, especially ripening (Volke & Inostroza, 1967; Dorohov et al., 1968).

According to Smith (1965), 47% of the total absorbed phosphorus is taken up before Stage 6 or 7 and 79% before Stage 10.2. Fried & Broeshart (1967) gave 7, 23, 49 and 21% for the periods before Stage 3, at stages 3-7, at stages 7-10.5 and after Stage 10.5, respectively.

Taheri (1960) found a positive influence of phosphorus on number of grains per ear, when phosphorus was applied at about Stage 4. Other yield components were not much affected by phosphorus, regardless of the time of application (seeding, Stage 2 and Stage 4 in his trials), but the number of ears was not counted in his study. According to Volke & Inostroza (1967) phosphorus increased the number of tillers and 1000-grain weight, but decreased the number of grains per ear. Gilles (1969) found that tillering was promoted by phosphorus more when applied at sowing than at tillering; Smith (1965) and Fuehring (1969a) mention even an excessive tillering so that phosphorus had a negative effect on grain yield. Pathak (1965) found an increase in number of ears, but no change in 1000-grain weight.

3.4 The relation between chemical composition of wheat and nutritional status

The chemical composition of wheat grains is only rarely used as a tool in the study of soil fertility. The reasons are firstly that any conclusions are of course of no profit for the very crop analysed and secondly that the content of a nutrient in wheat grain may be the same in crops which are very different in yield (Steenberg, 1966). The first difficulty is avoided when plants are analysed at a young stage. The results of such an analysis may support the decision whether top dressing should be applied (Kostic et al., 1967; Fuehring, 1969b; Melsted et al., 1969). The second difficulty holds too for young plants. The nutrient content in the plant depends on many factors: supply from soil, availability of other nutrients, moisture conditions, time of fertilizer application and varietal characteristics. Time of sampling and part of plant also have much influence on the results of the analysis.

Nitrogen fertilizers may change grain yield as well as nitrogen content of grain. Depending on grain nitrogen of unfertilized wheat, wheat may response in three ways (Table 4).

Trials by (among others) Collwell (1963), Russell (1963), Mehrotra et al. (1967), and Beech et al. (1968) show clearly that yield increments, brought about by nitrogen, fall as grain nitrogen increases. If grain nitrogen exceeds 3% or sometimes even 2%,

Table 4. Relations between grain nitrogen of unfertilized wheat and change in grain yield and grain nitrogen with nitrogen fertilizers (simplified from Russell, 1964).

Grain N		Influence of N fertilizer	
		grain yield	grain N
low,	< 1.9%	greatly increased	little affected, may decrease
medium,	1.9-2.5%	increased	increased
high,	> 2.5%	not affected or decreased	(greatly) increased

Tablo 4. Gübrelenmemiş buğday tanelerinde bulunan azot ve azotlu gübrelerle tane mahsul ve tane azotunda meydana gelen değişiklikler arasındaki ilgiler (Russell 1964'ten sadeleştirilmiştir).

yield increments cannot be expected.

Figure 8 shows some results of Steenbjerg (1954), Russell (1964) and Terman et al. (1969). Grain nitrogen sometimes decreases at low fertilizer rates; the same has been observed by other investigators (Fernandez & Laird, 1959; Beech et al., 1968).

Graphs like Figure 8 were not found for phosphorus in the literature, since yield responses to phosphorus are hardly, if at all, related to grain phosphorus. A distinction into types of yield response to phosphorus, such as shown in Table 4 for nitrogen, cannot be made, nor is there a value for grain phosphorus, above which no yield increment can be expected.

Figures for grain phosphorus vary between 0.17 and 0.48%. Goodall & Gregory (1947) give some critical values. Straw phosphorus, less than 0.03%, is too low, whereas 0.07% should be sufficient.

Lower boundaries for potassium in straw are 0.56 and 0.83% according to different sources.

The different features of the relations for nitrogen and phosphorus are caused by the divergent influence of soil moisture on nitrogen and phosphorus (Section 3.2.1). High plant nitrogen, often together with low yields, is found under dry conditions where high plant phosphorus occurs more frequently under moist conditions, mostly independently of yield.

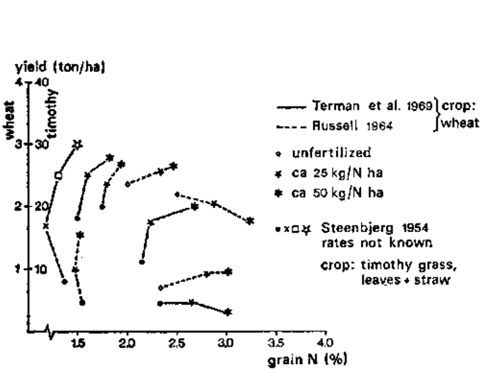


Fig. 8. Effects of nitrogen fertilizer on yield and nitrogen content.

Şekil 8. Azotlu gübrelerin mahsul ve nitrojen miktarı üzerine olan etkileri.

3.5 The significance of the fallow year

In most arid and subarid regions, a fallow period is used, varying in length between 4 and 21 months. Where precipitation occurs mainly during a rather mild winter and the growing season is dry and warm, as in Central Anatolia, the fallow period commonly lasts 14-15 months and the best adapted crop is winter wheat (Taylor, 1960).

The purposes of the fallow period are accumulation of moisture and nitrogen, and control of weeds.

The succes of storing moisture depends on many factors. For a fallow period, the water balance may be written as:

$$\Delta W = P - E - Tw - D \pm O \pm Sd \qquad (5)$$

where

ΔW = change in water stored within the root zone
P = precipitation
E = evaporation
Tw = moisture transpired by weeds
D = deep drainage below the root zone
O = run-off
Sd = snow drifting

A decrease in any term right of P increases fallow efficiency, i.e. the ratio $\Delta W/P$. Usually it amounts to 10-30% (Waring et al., 1958; Mathews & Army, 1960; Staple, 1960; Michalyna & Hedlin, 1961, Ferguson, 1963; Özbek et al., 1967a).

It has often been observed in arid regions that soil properties are of minor importance for ΔW. Factors of some influence are depth of the root zone, water-holding capacity and ease of infiltration. Waring et al. (1958) could not find a correlation between clay content and amount of moisture stored. Lehane & Staple (1953, 1965) and Taylor (1960) ascribe the greater drought resistance of crops on fine-textured soils to the fact that available moisture in those soils is held under greater stress than is moisture in lighter soils. This fact prevents luxury growth initially and rapid exhaustion of soil moisture. Because of the lower capillary conductivity, also the evaporation from clay soils is less than from lighter soils, so that more moisture is available during filling and maturing stages of the crop (Section 3.3).

Plants may extract water from somewhat greater depths than the root zone because of capillary rise of subsoil moisture. In general the soil dries more in the top 100 cm than at greater depths (Dewey & Nielsen, 1969). According to Stanberry & Lowrey (1965), average values for moisture extration by crops were 42, 31, 18 and 9% from the layers 0-30, 30-60, 60-90 and 90-120 cm (irrigated and unirrigated plots). Willits & Erickson (1956) sum up their results with the remark that water is removed from the horizon where it is most abundant.

Waring et al. (1958) found that there was no correlation between total rainfall during fallow and the amount of moisture stored, which was due to differences in rainfall distribution and intensity. Showers less than 13 mm (0.5 inch) did not enter the soil. In Saskatchewan (Canada) single showers had to exceed 10 mm for any moisture to be conserved after 10 days (Hopkins, cited by Staple, 1960). A single heavy shower is more effective in moisture storage than several small showers with the same amount of precipitation. However, heavier rainfall promotes run-off, thus lowering the amount of water stored (Evans & Lemon, 1957).

A clean fallow field is necessary to avoid losses by weed transpiration (*Tw* in Eq. 5). Evans & Lemon (1957) mention trials in which weedy fields stored only 40% as much moisture as weed-free fields. Christiansen-Weniger (1934) reports that yield of wheat after a weed-free fallow was about three times as high as yield after fallow where weeds had not been controlled.

Deep drainage (*D* in Eq. 5) generally does not occur in regions where fallow is needed (Cole & Mathews, 1939); when precipitation exceeds 500 mm, some water drains down, depending on rooting depth and water retention of the soil.

Run-off (*O* in Eq. 5) is enhanced by fallow, especially after ploughing the stubble field.

Snow drifting (*Sd* in Eq. 5) is limited when land is under stubble (Staple, 1960; Bond et al., 1961). Weeds also inhibit snow drifting. The low fallow efficiency in 21 months fallow is often caused by the small gain or even loss of water during the second winter when land is not longer under stubble.

For nitrate accumulation during the fallow year, the source of organic matter must be suitable and moisture content, soil temperature and aeration must be adequate (Staple, 1960). The amount of nitrate that is accumulated during the fallow period is, according to different authors, 30 to 150 kg nitrate nitrogen per ha (Christiansen-Weniger, 1934; Waring & Teakle, 1960; Michalyna & Hedlin, 1961; Wetselaar, 1967). In many trials crops did not respond to nitrogen after a fallow period, thus the level of soil nitrogen was high enough under the (still) limiting moisture conditions. In other cases, nitrogen fertilizers could replace the fallow year, indicating that it was nitrogen, sometimes also other nutrients, and not moisture for which the fallow was necessary (Littlejohn, 1946; Hernando et al., 1955; Evliyar, 1958; Michalyna & Hedlin, 1961; Ferguson, 1963).

A mutual effect has often been found too. By fallow not only the quantity of available moisture is enlarged, but the plants use the water more efficiently as the soil fertility has increased (Section 3.2.2) (Christiansen-Weniger, 1934; Ferguson, 1963). Another aspect is the promotion of the response to fertilizers by the increased moisture supply (Ramig, 1960). However, the extra supply of nitrogen obtained by fallow may cause depletion of moisture earlier (Kohn et al., 1966). For nitrate accumulation, it is also important to have weed-free fallow land, as weeds may to a large extent take up the nitrate formed (Wetselaar & Beech, 1968; Dew, 1968; Christiansen-Weniger, 1970).

The disadvantages of fallow are obvious. The low frequency of land utilization and the low fallow efficiency are thorns in the flesh to many investigators. Further the loss of soil by wind and water erosion are tremendous. Fallow must be justified by yields.

If the net yield after fallow is twice that of annual wheat the fallow has been justified. But as fallow is also an assurance of crops in dry years, as cropping costs over two years in an annual system are higher and as seed rate cannot be ignored with such low yields, the stipulation can be relaxed somewhat.

Russell (1959) says that in the Great Plains of the United States at least 200 mm precipitation is required to produce any grain; in Canada it was found that 125-150 mm water had to be stored, to produce a minimum yield of 70-140 kg grain per ha.

Figures on yield increments per 10 mm stored moisture vary between 70 and 105 kg wheat grain per ha (Russell, 1959; Staple, 1960; Johnson, 1964). Lehane & Staple (1965) found that moisture stored in the upper 30 cm had no influence on yield, but yields were increased markedly by moisture stored deeper.

For Turkey recommendations are conflicting. Evliyar (1948) recommended annual cropping, together with the use of fertilizers. Gerek (1967) showed that continuous growing of wheat is impossible. Çagatay (1954) suggested the use of moisture content in the upper 10 cm of soil at seed time for spring wheat as a criterion whether to sow or fallow the land.

3.6 Fate of soil nitrogen under arid conditions

Soil organic matter is the main source of nitrogen. In arid regions, its content does not commonly exceed 2%. If C/N quotient is 10 and weight of the plough layer 3 million kg per ha, nitrogen in the plough layer may be 3500 kg per ha. According to Bremner (1965), the plough layer of most cultivated soils contains 0.08-0.4% nitrogen (2400-12000 kg nitrogen per ha), commonly more than 90% organic nitrogen. Each year a fraction of this nitrogen is mineralized (5% according to Wetselaar, 1967, 1.5-2% according to Kortleven, 1963).

The fate of mobile nitrogen, which is largely nitrate, is connected with the movements of soil moisture. When evaporation exceeds rainfall, nitrogen does not leach out. In the opposite situation, nitrogen can move downwards. Whether it is lost for plants depends on root depth, water-holding capacity, and infiltration and percolation rates. Downward nitrogen displacement varied from 45 cm per 100 mm rainfall in sandy soils to 20 cm per 100 mm rainfall for heavy clay soils, when soil is around field capacity (Harmsen & Kolenbrander, 1965). Wetselaar (1962a) gives an average value of 11 cm per 100 mm rainfall. Others found that rainfalls between 175 and 250 mm are required to leach nitrate from the surface 15 cm of clay-loam soils (Storrier, 1965b). As long as the surface soil is not saturated, downward movement of water and nitrate is slow and occurs only across short distances. From field trials, Levin (1964) deduced for saturated soils the formula:

$$d = 100\,a/P_v \qquad (6)$$

where

d = soil depth (cm) at which the maximum amount of nitrates will accumulate
a = amount of leaching water (cm)
P_v = field capacity (% V/V).

Fox et al. (1970) say that Equation 6 predicted well the depth of maximum nitrate accumulation in Anatolian soils.

The conclusion for regions with precipitations between 250 and 350 mm per year (as the Basin) is that leaching of nitrate is very restricted. Moreover as plants can absorb nitrogen also from greater depths, a displacement to 80 cm does not mean that nitrate has been lost (Waring & Teakle, 1960; Storrier, 1965b).

In the dry season nitrate moves upward by capillary rise of water and often accumulates just below the surface crust (1-5 cm), where the physical continuity of the soil is broken. This upward movement, however, is usually restricted to the upper 45 cm; nitrate that has been leached deeper cannot be recovered to the surface soil by capillary movement (Wetselaar, 1961a, b; 1962a, b). In Turkey nitrate content has often proved higher between 10-20 cm than in the top 10 cm (Tarım Bakanlıgı, 1957-63).

From the foregoing it may be expected that in arid regions the nitrate content of the soil is rather high. Often about 100 kg nitrate nitrogen has been found per hectare, which is amply sufficient for cereal crops (Waring & Teakle, 1960; Wetselaar, 1961b; Skyring, 1962; Hamid et al., 1963; Tarım Bakanlıgı, 1957-63; Soper & Huang, 1963; Smika et al., 1969; Fox et al., 1970).

4 Design and methods

4.1 Field work

4.1.1 Fertilizer trials

As dry farming will remain the predominant form of land-use, despite the extension of irrigation, only the dry-farmed parts of the Basin have been studied.[1]

The choice of wheat as test crop was obvious, because wheat is the mainstay of Turkish food production.[2] On account of the results of the field trials in the first year I decided to work in the second year also with rye in the trials on Marl soils.

The wheat variety used (111/33, *Triticum vulgare*) is resistant to drought and cold and responds well to fertilizers. The rye variety used is the only tetraploïd variety bred at the Plant Growing and Breeding Department of the Faculty of Agriculture of Ankara University.

Because of the results of Turkish trials (Section 3.1), nitrogen, phosphorus and potassium were included in the trials. Nitrogen and phosphorus were tested in a 3^2 factorial design with rates of 0, 30 and 60 kg N and 0 and 0,40 and 80 kg P_2O_5 per ha. The rates of 60 kg N and 80 kg P_2O_5 were assumed to exceed optimum. Only one treatment with potassium was included, just as a check (60 kg N, 80 kg P_2O_5, 60 kg K_2O). So one replicate consisted of $3^2 + 1 = 10$ treatments, and each trial field had three replicates.

Because of the results in the first season (Janssen, 1969), potassium was omitted in the second year. The rates were extended to 0, 40, 80 and 120 kg P_2O_5 per ha, to 0, 30, 60 and 90 kg N per ha on Bajada soils and on other soils to 0, 20, 40 and 60 kg N per ha. A triplication of this 4^2 scheme would contain 48 treatments. As this number seemed too large to handle in one day, of each replicate four treatments have been dropped out in the way shown in Table 5.

Ammonium sulphate (21% N) was chosen as nitrogen fertilizer. Because ammonium is adsorbed by the clay minerals, leaching is limited in winter (as far as leaching occurs in the Basin). The acid reaction of $(NH_4)_2SO_4$ is probably unimportant in these highly calcareous soils, although some trials showed a distinct influence (Tarım Bakanlıgı, 1957-63).

1. The research stations at Çumra and Karaaslan study the fertilizer requirements of irrigated crops.
2. With its share of 2.8% of total wheat production, Turkey is the ninth wheat-producing country in the world. During the years 1967 to 1969 the year production amounted to 10 millions metric tons (International wheat council, 1969).

Table 5. Fertilizer treatments in the 1967-8 season.

Replicate 1				Replicate 2				Replicate 3			
00	10		30	00		20	30	00	10	20	30
	11	21	31	01	11	21		01			31
02	12	22			12	22	32	02			32
03		23	33	03	13		33	03	13	23	33

The first digit stands for the rate of nitrogen, the second for the rate of phosphorus.

Tablo 5. 1967-8 yıllarında yapılan gübreleme muameleleri.

The high pH of the occurring soils determines the use of superphosphate or triple phosphate as phosphorus fertilizer. Triple phosphate has been used on account of its high nutrient content (43% P_2O_5). The same argument underlay the application of potassium chloride (60% K_2O).

The fertilizers were banded about 10 cm deep. Deep placement suppresses volatilization of ammonia (Jackson & Chang, 1947; Martin & Chapman, 1951; Gasser, 1964) and promotes nitrification of NH_4 (Wetselaar, 1962b). By deep placement the fertilizers are nearer the moist subsoil and will dissolve easier, thus promoting root growth.

The fertilizer was placed with a handdrill (Fig. 9, opposite p. 32). A coulter had been fixed in front of the drill, so that the fertilizer granules fell into the furrow. The seed was drilled 3 cm deep, seed rows running between the fertilizer rows. The distance between the rows was 18 cm.[1]

The seed rates were 160 kg per ha for wheat and 200 kg per ha for rye as advised by officials of the Soils and Fertilizers Research Institute at Ankara. All fertilizers and seeds were supplied by that institute.

The trial fields were laid out on farmers' fields. Commonly the fallowed area was on one side of the village and the cropped area on the other, so facilitating the search for suitable places.

The fields had to meet the following requirements:

1 The soil must be uniform and representative for the soil type studied and must be salt-free.

2 There must be no chance of erosion.

3 The field must be as free as possible from weeds.

4 The field must be a fair distance from the village, in the middle of the cropped area, to prevent damage by children or animals.

5 If possible the fields are not laid out near main tracks, because of the risk of damage by farm wagons, but otherwise they must be accessible.

1. A distance of 18 cm is rather common in Turkish trials, but on farmers' fields the distance is often less (12-16 cm).

6 The farmers may not use fertilizers nor let sheep graze on the stubble; the cultural practice has to be normal.

7 The fields must be rather large (> 1 ha) to limit border effects.

Not always all these conditions could be satisfied and on several occasions animals and farm wagons damaged the crops.

For the situation of the fields, see Figure 15 and Table 7 (Section 5.1).

The trial field was placed at least 6 m from the field track, if possible along the long side of the farmers field. As the farmers did not like such placement, because of the bother with sowing and harvesting, most of the trials in 1966-7 were laid out in the corner of the farmer's field.

The plans of the trials are shown in Figure 10. The dimensions of the plots were changed from 6 × 5 m in the first year to 10 × 3 m in the second year, because border effects proved to be small parallel to the seed and fertilizer rows, but considerable at the ends of the plots (turning points of the fertilizer drill). The sizes of the net plots were 5 × 3.96 m (= 22 rows) and 8.5 × 2.34 m (= 13 rows), or 19.80 m^2 and 19.89 m^2, respectively for the two years.

In 1967-8 the number of plots of fields on Marl soils was 45, since 9 plots, sown with wheat, were added to the normal scheme of 36 plots. The places of the wheat strips are indicated in Figure 10.

Plots were sown in October. The next May the state of the crop was determined by estimating height, growth stage and colour (Section 6.1). The growth stages were estimated according Feekes' scale (Fig. 6). The colours were estimated with a self-made colour-scale in 1967. In 1968 colours were jugded as darker or lighter than the colour of the wheat in Plot 3 (treatment N_1P_0, Fig. 10).

Crops were harvested in July. From every plot ten samples of 1 m were taken and weighed before the rest. The samples were transported to Çumra and threshed by hand.

The grain yields of the plots were calculated as:

$$\frac{\text{weight of grain in sample}}{\text{weight of grain and straw in sample}} \times \text{weight of grain and straw in plots}$$

Henceforth the ratio grain weight/(grain + straw) weight will be called *harvest index* (Russell, 1967).

Subsamples of grain and of straw from each plot were taken to Wageningen, where the 1000-grain weight, the moisture content and for part of them the chemical composition was determined.

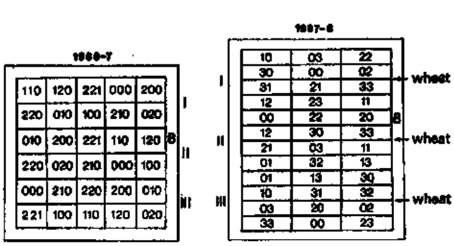


Fig. 10. Plan of the trial fields.

Şekil 10. Deneme tarlaları planı.

The statistical analysis of the results was conducted by the Department of Mathematics of the Agricultural University in Wageningen.

Multiple regression analysis was used to calculate the linear and quadratic effects of nitrogen and phosphorus, the linear interaction of NP, the linear effect of K (in 1967), the replication effect and in 1968 also the strip effect. The strip effect had to be considered because the existence of fertility differences could be proved in two directions across the trial fields, one having the same direction as replication and the other perpendicular to it. The strip effect was annoying, as some treatments were situated by chance only in one strip (treatment 10, 12, 01, 11 and 02 in Fig. 10).

Multiple regression was applied to the characteristics: height, growth stage, colour, grain + straw yields, harvest index, grain yield, straw yield, 1000-grain weight, number of grains per g straw, and number of grains per m^2.

4.1.2 Other field studies

The soil from each field was described according to prescriptions of the Soil Survey Staff (1951). Besides samples taken from each horizon for chemical and physical analysis, core samples were taken for determination of bulk density. On fields, where the soil was irregular the soil was surveyed in detail (Section 7.5).

At least three times during growth, every 10 cm of the profile down to 120 cm and in 1968 to 200 cm was sampled for determination of moisture content (Section 7.1).

Composite samples of surface soil (0-20 cm) were taken in October, just before fertilizers and seeds were drilled into the soil; in 1966 one composite sample from the whole of each field was gathered, in 1967 one sample from each replicate. The samples were used in the greenhouse trials and for physical and chemical analysis.

In 1967 I started a study on root development, according to the 'appraisal method' (Schuurman & Knot, 1957; Schuurman & Goedewagen, 1965). Because of technical difficulties, it was not completed. Some results are reported in Section 7.5.

4.2 Greenhouse trials

For the pot trials, a method was developed, based on Bouma (1965, 1967; Bouma & Dowling, 1962, 1966a, b). Bouma's intention was to assess the nutrient status of plants directly. Instead of adding nutrients to the soil and seeing the plants response (classical pot and field trials), he dug the plants out of the soil and tried to measure the nutritional stress as expressed by growth on complete and on deficient nutrient solutions. Bouma compared the results of this method with results in the field and found satisfactory correlations. (Bouma, 1965; Bouma et al., 1969.)

Bouma did not intend his method as an alternative to leaf or soil analysis, but rather as an economy in field trials. Its application should be especially useful for soils about which little is known. Identification of the elements limiting crop growth should restrict the number of field trials needed.

As little was known of the soils in the Basin, Bouma's method looked attractive.

4.2.1 The technical procedure

Since plants could not be transported from Turkey to the Netherlands to be tested for their nutritional stress, soil samples were transported to the greenhouse. Plants could be raised in pots with soil and transferred to different nutrient solutions after a certain time. This procedure, however, leaves the technical problem of how the plants should be pulled from the soil without damaging them. The difficulty was circumvented by allowing roots to grow in soil and solution at the same time. Small pots are used with a gauze bottom, through which the roots can pass. The pots are placed on containers with the different nutrient solutions. A schematic section is given in Figure 11. Figure 12 (opposite p. 33) shows the development of roots in the nutrient solution. As the containers were filled with the test solutions at the start of the trial, the nutritional stresses were measured while they were developing. Bouma measured the nutritional stresses after the plants had developed these stresses.

4.2.2 Growth measurement and sufficiency quotient

The basic method of measuring plant growth is to estimate dry matter increase. The procedure requires many replicates, as for each estimation of dry weight plants have to be harvested and weighed. Because the variation between the replicates is often considerable, results are frequently unsatisfactory.

A parameter of plant growth, which avoid the need to harvest the plants, is increase in leaf area. Also the length of the leaf (blade or blade and sheath) may be measured. In the present research, the length of the leaves of Orca spring wheat seedlings was measured form the base (soil) to the apex, thus blade and sheath. The lengths of the individual leaves were added; the sum was called *plant size* and the increase in plant size was used as a parameter of plant growth. As there is a good relationship between plant size and dry weight (App. I), plant size can easily be used instead of dry weight.

The results may be presented on several ways. The most obvious method is plotting

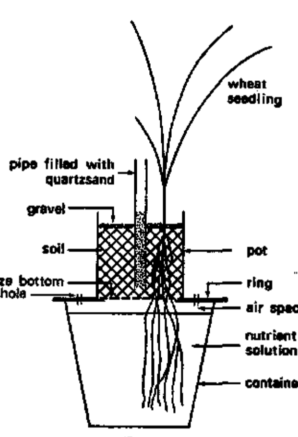


Fig. 11. Schematic section of the equipment in the greenhouse trials.

Şekil 11. Sera denemelerinde kullanılan aletlerin şematik kesiti.

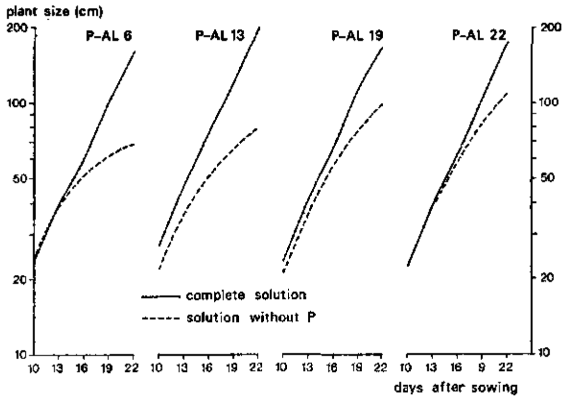


Fig. 13. Growth of plants on soils different in phosphorus content.

Şekil 13. Değişik miktarlarda fosfor ihtiva eden topraklarda bitkilerin gelişimi.

of plant size against time. But as the growth of plants in an early stage is nearly exponential, it is more convenient to plot log plant size against time, as by Bouma. Figure 13 shows the results of a preliminary experiment with soils differing from each other only in the content of phosphorus extractable by ammonium lactate and acetic acid (P-AL). That the shortage of phosphorus decreases from P-AL 6 till P-AL 22 is clearly demonstrated.

When the results of a trial with many soils have to be reproduced, this graphical method is rather impractical. Anyway it is incorrect to simply compare the size of plants; because, as Figure 13 shows, final plant size is determined largely by initial plant size, i.e. the time of sprouting (see also van de Sande Bakhuyzen, 1937). It is therefore better to compare the slopes of the lines than the plant sizes themselves. The slope of the curve is in fact the relative growth rate (*RGR*) which can be seen as follows. *RGR* at any instant is given by:

$$RGR = \frac{1}{L}\frac{\mathrm{d}L}{\mathrm{d}t} \tag{7}$$

where

L = plant size

t = time

Integration of this function over the period t_1 to t_2 gives the mean value of *RGR* during that period:

$$RGR = (\ln L_2 - \ln L_1)/(t_2 - t_1) \tag{8}$$

This formula gives mean *RGR* (Radford, 1967) which is not necessarily the same as actual *RGR* at any instant. They are only equal and constant when the growth is exponential.

In Figure 13 the solid lines are nearly straight, indicating that plant growth was close to exponential. The dashed lines deviate, so that here *RGR* decreases with time. The reduction of *RGR* becomes clear from Day 13 after sowing, when plant size is about 40 cm, i.e. at the beginning of the three-leaf stage. As pointed out in Appendix I, the differences between mean *RGR* of plants growing in soil with different phosphorus levels, may be measured at best in the interval from the beginning of the three-leaf

Table 6. Mean relative growth rates (*RGR*) and sufficiency quotients (SQ_P) of plants on soils with different phosphorus contents (between days 13 and 19 after sowing).

	RGR in % per day		SQ_P
	complete solution	solution without phosphorus	
P-AL 6	15.5	7.5	0.48
P-AL 13	15.4	9.9	0.63
P-AL 19	15.7	12.5	0.80
P-AL 22	15.9	12.6	0.81

Tablo 6. Çesitli fosfor miktarlarına sahip topraklardaki ortalama nisbi gelişme oranları (*RGR*) ve yeterli gelen kısımlar (SQ_P) (hasattan sonra 13 ve 19'uncu günler arasında).

stage till the beginning of tillering (in the present example between days 13 and 19).

Table 6 presents the mean relative growth rates during that period. The mean *RGR* of plants on complete solutions is almost equal, with an average of 15.6% per day. Dividing mean *RGR* of plants in solutions without phosphorus by (the average of) mean *RGR* of plants on complete solutions gives *sufficiency quotient*. Henceforth this quotient will be used to characterize nutrient availability in the soil, as found by greenhouse trials.

Sufficiency quotient is the complement of nutrient stress, *S*, as defined by Greenwood et al. (1965):

$$\text{nitrogen stress} = S_N = 100\,(R_M - R)/R_M \quad (9)$$

where

R_M is relative growth rate of plants with adequate nitrogen and

R is that of plants, with insufficient nitrogen.

For the Turkish soils I measured:

$$SQ_N = RGR_{-N}/RGR_C \quad (10)$$

and

$$SQ_P = RGR_{-P}/RGR_C \quad (11)$$

where

RGR_{-N} = mean *RGR* of plants on a solution without N (Greenwood's *R*)

RGR_{-P} = the same without P

RGR_C = the same for complete solution (Greenwood's R_M)

The measurements of plant size and the calculation of sufficiency quotients are time-consuming, but the effort is compensated by the short duration of the trials (about three weeks) and the fact that no laboratory is required.

4.3 Laboratory analysis

4.3.1 Soils

For particle-size distribution, the pipette method was used (Kilmer & Alexander, 1949; Day, 1965). The particle-size distribution of 1966-7 samples of plough layer and some horizons was determined twice: with and without carbonates. The samples of 1967-8 were analysed with carbonates and the carbonate content was determined in each fraction.

Organic matter was determined by wet oxidation with potassium bichromate by Kurmies' method (1949).

The method of Bower et al. (1952) was used in measurement of cation-exchange capacity.

The carbonate content was determined by Scheibler's method (Hofstee, 1963) in the samples of 1966-7, and by van Wesemael's method (1955) in the samples of 1967-8.

The pH of all samples was measured in a 1 : 2.5 suspension of 1 *N* KCl and in the 1966-7 samples also in water and 0.01 *M* $CaCl_2$.

The pF values were determined as described by Bruggenwert et al. (1966).

Electrical conductivity in a saturation extract and analysis of salts (EC_e) were by methods of the Riverside Salinity Laboratory (Richards, 1954) with some modification (Driessen, 1970).

Organic nitrogen was determined by the Kjeldahl Lauro method (Hofstee, 1963).

Nitrate was determined in an 1 : 5 aqueous extract with a NO_3 electrode (Mijers & Paul, 1968).

The Olsen bicarbonate soil test was used for phosphorus (Olsen, 1954) at Ankara and Wageningen.

The analysis for available K_2O was done at Ankara with 0.3 *N* HCl.

The core samples (core volume 100 cm^3) were dried at 105° C, whereupon the bulk density and porosity were calculated, assuming a particle density of 2.65.

4.3.2 Crops

Samples of grain and straw were taken from each plot of the fertilizer fields (Section 4.1.1) and some of them were analysed chemically.

The samples were digested with sulphuric acid and perhydrol by the method of Lindner & Harley (1942). For nitrogen the Kjeldahl micro-method has been used (Silverstein & Perthel, 1950).

Potassium and calcium were determined with flame photometer (Eppendorf)

Phosphorus was determined colorimetrically (Vitatron) with molybdenum and antimony tartrate as reagents and ascorbic acid as reducing agent.

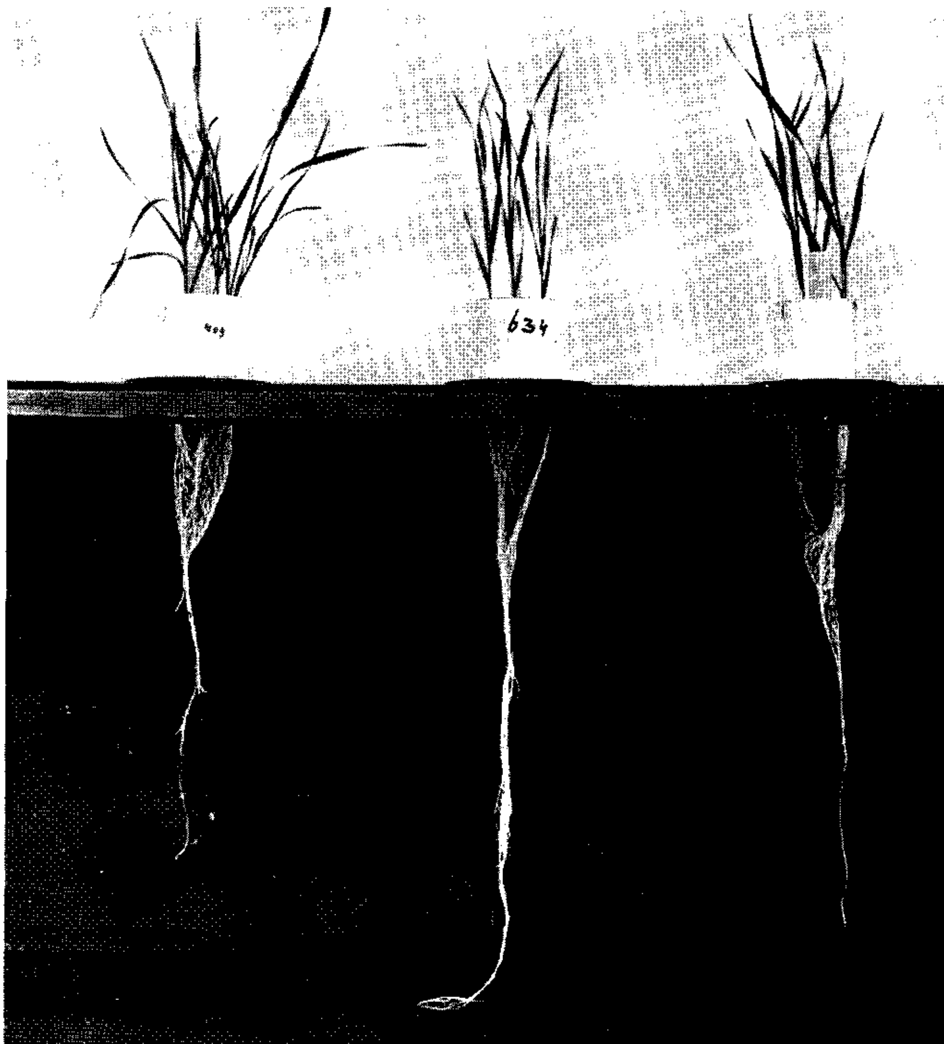
Magnesium was measured by atomic absorption spectrophotometry (Techtron AA 100).

The results were calculated in a dry-matter basis, as dried at 70°.

Fig. 9. Fertilizer drilling.

Şekil 9. Gübreleme sondajı.

Fig. 12. Development of roots in nutrient solutions. From left to right: complete solution, solution without nitrogen (note longer roots and less ramification), solution without phosphorus.



Şekil 12. Besin çözeltileri içinde köklerin gelişimi. Soldan sağa doğru; bütün çözeltı, azotsuz çözelti (fazla köklere ve az dallanmaya dikkat ediniz), ve fosforsuz çözelti.

5 The soils

5.1 General description

The short description below of the soils is derived from de Meester (1970).

The Basin consists of eight physiographic units (Fig. 14):

1 Uplands: limestone and volcanic formations around the Basin

2 Colluvial Slopes: strips and areas of rock debris, or stony and cobbly soil, or volcanic ash at the foot of the Uplands

3 Terraces: horizontally stratified Neogene limestone plateaus

4 Bajadas: belts of ungraded medium-textured or heavy-textured material at the bottom of the footslopes of the Uplands and Terraces

5 Alluvial Plains: fluvial deposits such as alluvial fans and former deltas, characterized by strata of well graded material and including heavy-textured backswamp clays

6 Lacustrine Plains: areas where the original lake bottom of marl is exposed, and including former beaches, sandridges, sandplains of lacustrine origin, and marshes

7 Marshes: areas which are permanently waterlogged

8 Aeolian sandplain: areas covered with shifting and fixed sand dunes.

Each physiographic unit comprises geographically related soils. All together about 75 soil units have been distinguished.

Most of the soils used for dry farming belong to the Terraces, the Bajadas and the Lacustrine Plains. The fertilizer fields were distributed over these units (Table 7, Fig. 15).

Of the *Terrace soils*, I studied the units TeB (sometimes transitional to TeC) and ThA. Typical for the Te soils is a dark-brown surface soil 50 cm thick over a light-pale to nearly white calcareous subsoil. The soils are well drained and have good physical properties, so that they are highly suited for agriculture. The ThA unit is rather complex, because of undulations. The soils are moderately shallow, angular-cobbly, brown or reddish-brown calcareous clays with many lime concretions.

The *Bajada soils* have been divided into Limestone Bajadas (Br) and Volcanic Bajadas (Bv) according to their origin. The Limestone Bajada soils, divided into four units, consist of weathering products of limestone. The BrA soils are deep reddish-brown to yellowish-red clay or loam, with a subangular-blocky surface soil and an angular-blocky subsoil. By the deep profiles they have relatively high waterholding capacities, which make them very suitable for agriculture. Mostly they are well drained and saltfree. One field was laid out on a small fan near Seçmekoy. The profile looks like a shallow BrA (Fig. 15, No. 11) and has been considered with that unit.

Fig. 14. Soil association map of the Basin. From de Meester, 1970.

Şekil 14. Havzanın toprak birlikleri haritası.

Fig. 14. Legend
Lejant

Ur Limestone Upland Soils
Ur Kalkerli yüksek arazi toprakları
Uv Volcanic Upland Soils
Uv Volkanik yüksek arazi toprakları
Cr Limestone Colluvial Soils
Cr Kolloviyal topraklar (Kalker kökenli)
Cv Volcanic Colluvial Soils
Cv Kolloviyal topraklar (Volkanik kökenli)
Te Flat Terrace Soils
Te Düz teras toprakları
Th Undulating Terrace Soils
Th Ondüleli ve bölünmüş teras toprakları
Tc Soft Lime Soils
Tc Yumuşak kireçli topraklar
Br Limestone Bajada Soils
Br Bajada toprakları (Kalker orijinli)
Bv Volcanic Bajada Soils
Bv Bajada toprakları (Volkanik menşeli)
Aa Çamurluk Fan Soils
Aa Çamurluk nehri yelpazesi toprakları
Ab Former Backswamp Soils
Ab Eski bataklık ardı toprakları
Ac Çarşamba Fan Soils
Ac Çarsamba nehri yelpazesi toprakları
Ad Deli Fan Soils
Ad Deli nehri yelpazesi toprakları
Ae Selereki Fan Soils
Ae Selereki nehri yelpazesi toprakları
Af Çakmak Fan Soils
Af Çakmak nehri yelpazesi toprakları

Ag Zanopa Fan Soils
Ag Zanopa nehri yelpazesi topraklari
Ah Bor Fan Soils
Ah Bor nehri yelpazesi toprakları
Ak Meram and Sille Fan Soils
Ak Meram ve sille nehri yelpazesi toprakları
Am May Fan Soils
Am May nehri yelpazesi toprakları
An Bayat Fan Soils
An Bayat nehri yelpazesi toprakları
As Ayran Fan soils
As Ayrancı nehri yelpazesi toprakları
Au Soils of Medium Sized Fans
Au Orta büyüklükte nehri yelpazesi toprakları
Lm Marl Soils
Lm Marn toprakları
LmC with organic surface
LmC sığ koyu gri organik satıh toprağı
LmE with salt crust on surface
LmE Playa'lar. Çok tuzlu, kireçli, toprak, zaman zaman su baskınına maruz
Lr Sandridge Soils
Lr Göl kenarı toprakları
Lp Sandplain and Beach Soils
Lp Kum düzlükleri ve plaj toprakları
Lo Old Sandplain Sils
Lo Eski kum düzlüğü toprakları
Mf Marsh Soils
Mf Bataklık toprakları
Dd Sand Dunes
Dd Hareketli ve sabit kumul'lar

Table 7. Soil units and situation of the field trials.

Soil unit	Area (%)		1966-7		1967-8	
	Total	Dry farmed estimate	Field No	Situation	Field No	Situation
TeB + TeC	5.37	5.3	1	Okçu	101	Okçu
			2	Türkmençamili	102	Türkmençamili
					103	Demiryalı
ThA	8.50	4.3	4	Kızılkuyu	104	Inliköy
LmA Konya	12.52	6.0	6	Tömek	106	Tömek
			7	Ortakonak	107	Zincirli
Hotamış			8	Akçaşehir	108	Hotamış
			10	Kamisağıl		
LmC	3.06	1.0	9	Büyükaşlama	109	Hotamıs[1]
					110	Hotamıs[1]
BrA	5.70	5.0	3	Avdul	111	Çariklar[2]
			11	Seçmeköy (AuA)[3]	112	Eminler
			12	Eminler	113	Mandosun (BvA)[3]
			14	Ilisıra	114	Ilisıra
BrB	2.42	2.0	13	Eğilmez (CrA)[3]	115	Suduraği
			15	Suduraği		
			16	Bulgurluk		
Total	37.57	23.6				

1. Field lost by flooding.
2. Field lost by farmer's mistake
3. Soil transitional to the unit in brackets.

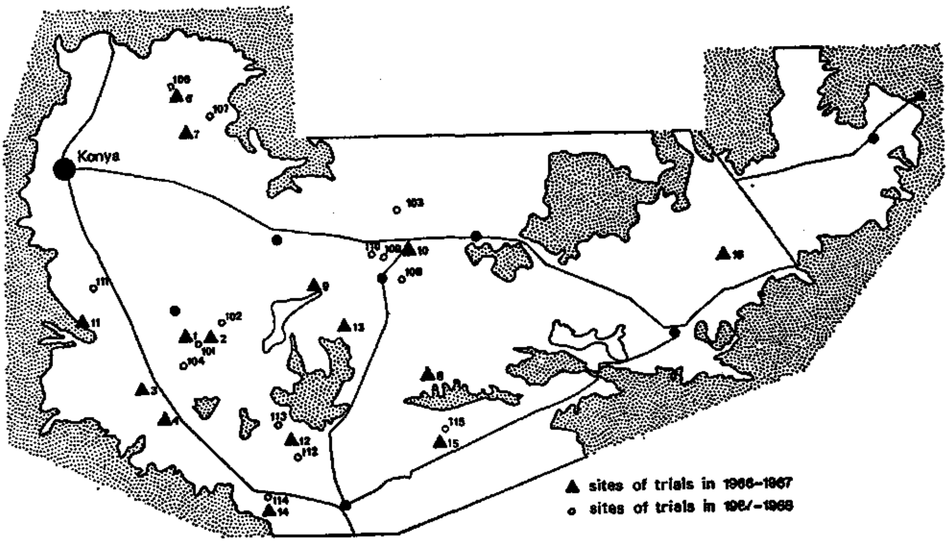
Tablo 7. Toprak üniteleri ve tarla denemelerinin yerleri.

The BrB soils resemble the BrA, but are brown and often coarser textured. A gravelly horizon often occurs. The soils are well drained.

LmA is the most extensive unit of the Lacustrine Plain soils. The soils, coded as Lm, are called *Marl soils*. They consist of deep olive-gray carbonatic clays with subangular-blocky surface soil and fine prismatic subsoil. Agricultural suitability is determined to a large extent by salinity. The soils are partly irrigated, partly ranged and for the main part dry-farmed. For the fertility study the unit LmA was divided into LmA Konya, occuring in the Konya Area, and LmA Hotamış occuring in rhe Hotamıs and Karaman areas. This has been done because of differences in precipitation and hence in moisture storage and productivity. The unit LmC differs from LmA in the dark-gray colour of the surface soil, caused by the higher content of organic matter. Much of it is irrigated.

The dry-farmed parts of the soil units on which the fields were laid out, represent 24% of the Basin's surface and 29% if the transitional soils are included, i.e. 65 and

Fig. 15. Position of fertilizer trials.



Şekil 15. Gübreleme denemelerinin yerleri.

80%, respectively, of the area under dry farming.

Profile descriptions of the most important soil units are given in Appendix II.

5.2 Physical and chemical properties

5.2.1 Plough layers

The textures of the individual samples are shown in Figure 16; the average values of the distinct soil units are presented in Table 8. The reddish-brown Bajada soils have the most clay and the Marl soils the most silt. Both soil units may be classified as silty clay-loams, but the BrA soils tend to clay-loam and clay. All the other soil units are loam, with a clay content between 20 and 30%. The soils of the Undulating Terraces seem to be the most sandy, due to lime concretions, but textures of this unit may vary widely within a short distance.

After removal of carbonate, the soils become more clayey and less sandy. Hence the carbonate is not evenly distributed throughout the soil fractions. The particle-size distribution of carbonates has been estimated (Table 9). Despite the inaccurracy of the figures, it is obvious that only a minute part of the carbonates occurs in the clay fraction. The Marl soils are an exception; the total $CaCO_3$ content of these soils is also higher than of the other soils. The carbonate of the Marl soils is a chemical or biochemical precipitate in the former lake bottom (de Ridder, 1965); in the other soils the carbonate consists of partly weathered pieces of limestone or secondarily formed lime pockets and concretions.

Table 8. Particle-size distribution of samples of the plough layers, averaged per soil unit.

Soil unit	Number of samples	Particle-size distribution (%)			Textural class
		< 2 μm	2-50 μm	> 50 μm	
Te	5	26.5	48.2	25.3	loam
ThA	2	26.6	29.5	43.9	loam
BrA	8	37.4	45.8	16.8	silty clay-loam
BrB	4	23.5	44.0	32.5	loam
LmA	7	33.4	48.5	18.1	silty clay-loam
LmC	3	35.0	55.3	9.7	silty clay-loam

Tablo 8. Her bir toprak ünitesi için pulluk katında ortalama tane büyüklüğü dağılımı.

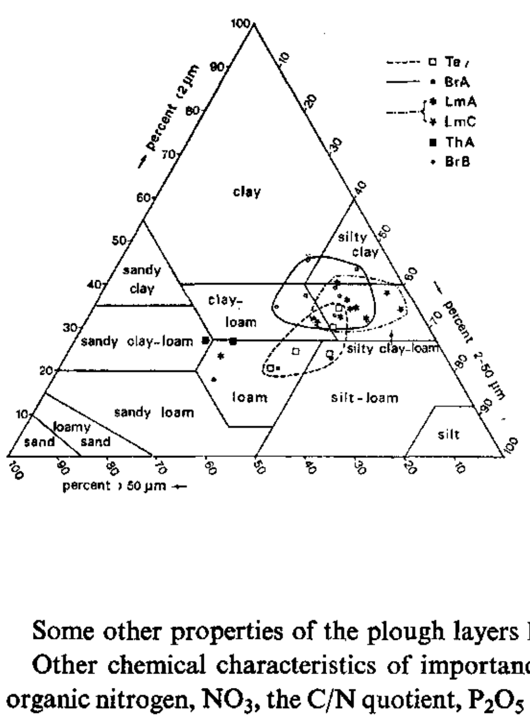


Fig. 16. Particle-size distribution of individual samples from the plough layer.

Şekil 16. Pulluk katından alınan belirli örneklerde parça büyüklüğü dağılımı.

Some other properties of the plough layers have been listed in Table 10.

Other chemical characteristics of importance for the fertility of the soil, such as organic nitrogen, NO_3, the C/N quotient, P_2O_5 and K_2O will be discussed in chapter 7.

The pH-KCl is above 7, the Marl soils having the highest pH. A certain relationship with the pH-H_2O exists, but not with the pH-$CaCl_2$. Neither are the pH-H_2O and pH-$CaCl_2$ correlated. The pH-KCl shows the best relationship with carbonate content (Fig. 17).

The contents of organic matter are low. The brown soils (Te and BrB) have a somewhat higher content than the reddish-brown soils (ThA and BrA). The organic

Table 9. Content of $CaCO_3$ and particle-size distribution of $CaCO_3$ in samples of the plough layers, averaged per soil unit.

Soil unit	Number of samples	$CaCO_3$ (%)	Particle-size distribution (%)		
			$< 2\ \mu m$	2-50 μm	$> 50\ \mu m$
Te	5	21	6	50	44
ThA	2	30	10	60	30
BrA	8	13	8	62	30
BrB	4	29	6	48	46
LmA	7	53	18	61	21
LmC	3	42	13	78	9

Tablo 9. Toprakta $CaCO_3$ miktarı ve her bir toprak ünitesi için pulluk katından alınan örneklerde $CaCO_3$ kısmının ortalama tane büyüklüğü dağılımı.

Table 10. Organic matter content, cation-exchange capacity (CEC) and pH KCl of samples of the plough layers, averaged per soil unit.

Soil unit	Number of samples	Organic matter (%)	CEC (meq/100 g)	pH-KCl
Te	5	1.7	28	7.2
ThA	2	1.2	26	7.3
BrA	8	1.1	37	7.2
BrB	4	1.4	23	7.4
LmA	7	1.6	18	7.6
LmC	3	1.9	19	7.7

Tablo 10. Her bir toprak ünitesi için pulluk katından alınan örneklerin ortalama organik madde, katyon değiştirme kapasitesi (CEC) ve pH-KCl değerleri.

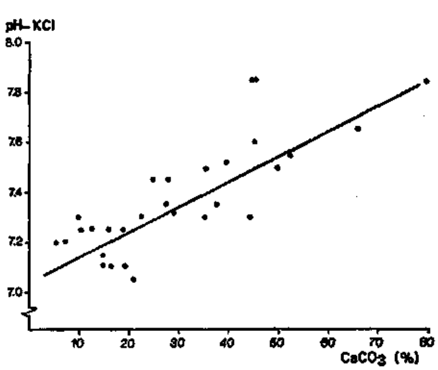


Fig. 17. Relation between carbonate content and pH-KCl.

Şekil 17. Karbonat miktarı ile pH-KCl arasındaki ilgi.

matter content of LmC is higher than of LmA (darker colour of LmC).[1]

The cation-exchange capacities are high, especially of the reddish-brown Bajada soils. Only the Marl soils have a lower CEC than expected from their heavy texture. In Figure 18 CEC has been plotted against clay content. The CEC is 50-60 meq/100 g clay for the Marl soils and 90-100 meq/100 g clay for the other soils. The clay minerals of the Bajada and the Terrace soils must be smectites, as already found by de Meester & van Schuylenborgh (1966). Also Akalan & Unal (1965) suggest that the predominant type of clay mineral in Central Anatolia is montmorillonite. According to van der Plas & Schoorl (1970) the Marl soils contain less smectites and more mica-like clay minerals. The Marl soils of the Hotamış Area contain another mixture of clay

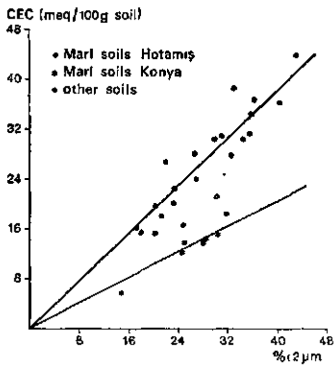
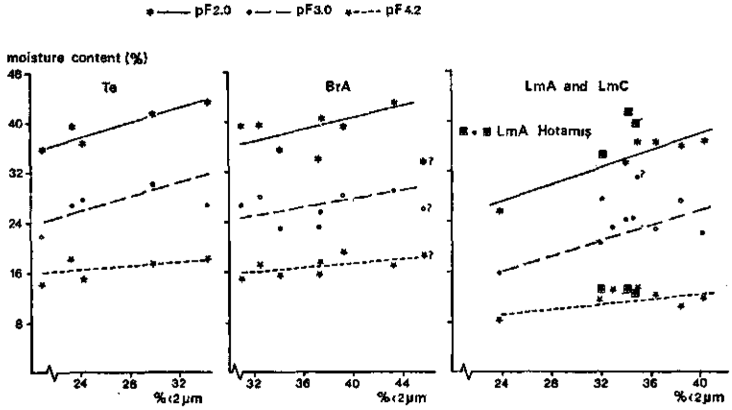


Fig. 18. Relation between clay content corrected for carbonate and cation-exchange capacity corrected for organic matter (2 meq/g organic matter: Akalan & Unal, 1965).

Şekil 18. Karbonatlara göre düzeltilmiş kil miktarlari ile organik maddeye göre düzeltilmiş katyon değiştirme kapasitesi arasındaki ilgi (2 meq/g organik madde: Akalan ve Ünal 1965).

Fig. 19. Relations between clay content and moisture content by weight at pF 2.0, 3.0 and 4.2 for Te, BrA ,LmA and LmC.



Şekil 19. Te, BrA, LmA ve LmC toprak üniteleri için kil miktarları ile pF 2.0, 3.0 ve 4.2'de ağırlığa göre nem miktarı arasındaki ilgi.

1. The present LmC samples are all from the eastern part of the LmC area; their organic matter content is lower than of the LmC near Yarma, where contents of 3.5-4.0% occur.

minerals with a CEC of 70 meq/100 g. Probably particles from the surrounding Bajada and Colluvial soils have been blown into these soils, so that there the smectites take a greater share than in the other Marl soils. An indication for it is the browner colour of the Marl soils near Hotamış (2.5 Y 5/2) against 5 Y 5/2 for the Marls near Konya.

The moisture characteristics depend mainly upon the texture of the soils. Figure 19 shows the relations between clay content and moisture contents by weight at several pF values (the soil units BrB and ThA have been omitted, because they are more or less gravelly and coarse sandy, which makes the results of pF determinations inaccurate).

The Te soils contain relatively more moisture than the BrA soils, probably because of the higher content of organic matter of the Te soils. The deviation of the Marl soils can be ascribed to other clay minerals.

The amount of water between the pF values 2.0 and 4.2 does not differ much between the soils, and is about 22-23%.

5.2.2 Profiles

In all horizon samples the moisture contents at pF 3.0 and 4.2 were determined. These values were taken because undisturbed samples were not available. At pF values of 3.0 and more, there is no water present in the inter-aggregate pores, so that moisture contents determined in disturbed and undisturbed soil samples do not differ much. For the calculation of moisture content on volume basis, the bulk density found with core samples has been used. In fact the bulk density depend partly upon the moisture content of the soil (Free et al., 1947), especially in the upper horizons. This means that the bulk density at pF 3.0 is not equal to that at pF 4.2, but in view of the small difference, this inequality has not been taken into account.

Figure 20 shows the average phase distribution and the moisture contents at pF 3.0 and 4.2 of the Terrace, the reddish-brown Bajada and the Marl soils, the last divided into LmA Konya and LmA Hotamış. The Terrace soils have the greatest pore space. Between the subsoils of BrA, LmA Konya and LmA Hotamış there is not much difference in porosity. The surface soils are more porous than the subsoils. The LmA Hotamış has the most porous surface soil, followed by LmA Konya and BrA.

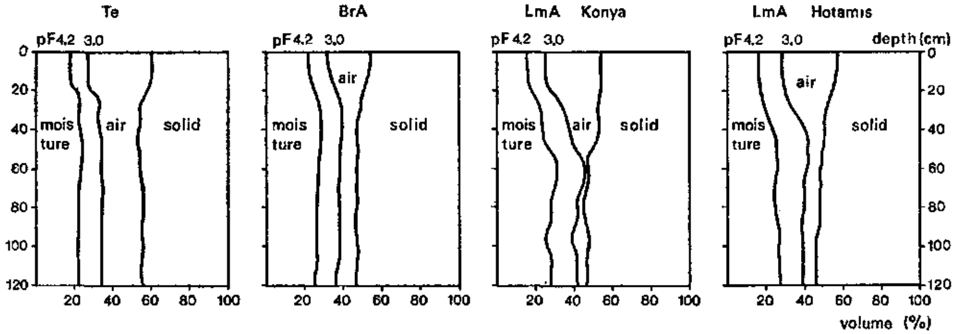
Figure 20 clearly shows that in the LmA and BrA profiles the pores will be filled earlier totally with water than in the Te profiles, at pF values lower than 3.0.

The moisture contents at pF 3.0 and 4.2 of the different soils are shown in Table 11.

The other physical and chemical properties of the profiles, having been determined in only a part of the samples, need a few remarks in passing.

The textures of the subsoils of the BrA profiles are commonly finer than of the surface soils. The BrB profiles contain ofter wavy gravelly and sandy layers, so that the texture is very irregular. The texture of the subsoils of the Marls are about equal to those of the surface soils. The same is true for the Te soils, if texture is determined in samples without decalcifying. After removal of the carbonate, the subsoils of Te

Fig. 20. Average phase distribution and moisture content by volume at pF 3.0 and 4.2 down the profile to 120 cm for Te (5 profiles), BrA (7), LmA Konya (4) and LmA Hotamış (3).



Şekil 20. Te (5 profil), BrA (7), LmA Konya (5) ve LmA Hotamış (3) için ortalama faz dağılımı ve 120 cm ye kadar olan derinlikte; pF 3.0 ve 4.2 deki nem miktarları.

Table 11. Quantity of moisture in profiles till 120 cm at pF 3.0 and pF 4.2 (in mm).

	Te	BrA	LmA Konya	LmA Hotamış
Number of profiles	5	7	4	3
pF 3.0	394	451	453	443
pF 4.2	265	310	298	281
Difference	129	141	155	162

Tablo 11. pF 3.0 ve 4.2'de (mm olarak) 120 cm derinliğe kadar olan profillerde nem miktarları.

are heavier than the surface soils. This is caused by the differences in carbonate content (about 20% in surface soils and 70% in subsoils). Also the subsoils of the other units have a higher carbonate content than the surface soils (occurrence of calcic horizons).

The Marl profiles have been investigated for salts. The EC_e values were always lower than 3 mmho/cm, except in the subsoil (90-120 cm) at Ortakonak (Field 7) were the EC_e value was 9 mmho/cm.

Analysis in some samples of the other soil units showed that EC_e was less than 1 mmho/cm and mostly less than 0.5 mmho/cm. Only the subsoils of the Te units sometimes had EC_e values between 4 and 10 mmho/cm, because of salic horizons. As they commonly occur at depths of more than 100 cm (Driessen & de Meester, 1969; de Meester, 1970), they have probably no influence on the crops. So it may be concluded that none of the trial fields was salt-affected (perhaps with the exception of Field 7 at Ortakonak).

6 Results of field trials

6.1 Growth

As I was in the Netherlands from the end of October till the beginning of May, I could not observe germination and winterkilling.

By May the state of the crop was diverse, through differences in soil types, rates and kind of fertilizers and amounts of precipitation.

To assess the state of the crops, the height, the growth stage and the colour were estimated (Section 4.1.1). As the plants were at about the stage of stem elongation, they grew so much within a week that data from different fields could not be compared. Hence the results of each field were calculated as percentages of the values on control plots.

The relative *heights* of the plants as influenced by nitrogen and phosphorus fertilizers are shown in Figure 21. The responses on ThA were quite similar to those on BrA and BrB soils behaved similarly to the Te soils.

Statistical analysis showed that

1 In both years there was a higly significant linear response to nitrogen on the BrA and ThA soils ($P < 0.01$). In 1967 this was true also for LmA Konya and in two fields on the BrB soils. In 1968 this was so only at Tömek (Field 106, LmA Konya). The positive linear response to nitrogen was sometimes accompanied by a negative quadratic effect, in 1968 more frequently than in 1967. On the Te soils and LmA Hotamış there was no response to nitrogen dressing.

2 In both years there was a very clear response to phosphorus on all soils. The linear effect was always positive and highly significant ($P < 0.01$). In 1968 on 8 of the 12 fields there was a negative quadratic phosphorus effect, but especially in 1967 not always highly significant ($P < 0.1$).

3 In 1967 only on two fields (11 and 16) could a positive interaction between nitrogen and phosphorus be noted; in 1968 there was a positive interaction on the ThA and BrA soils.

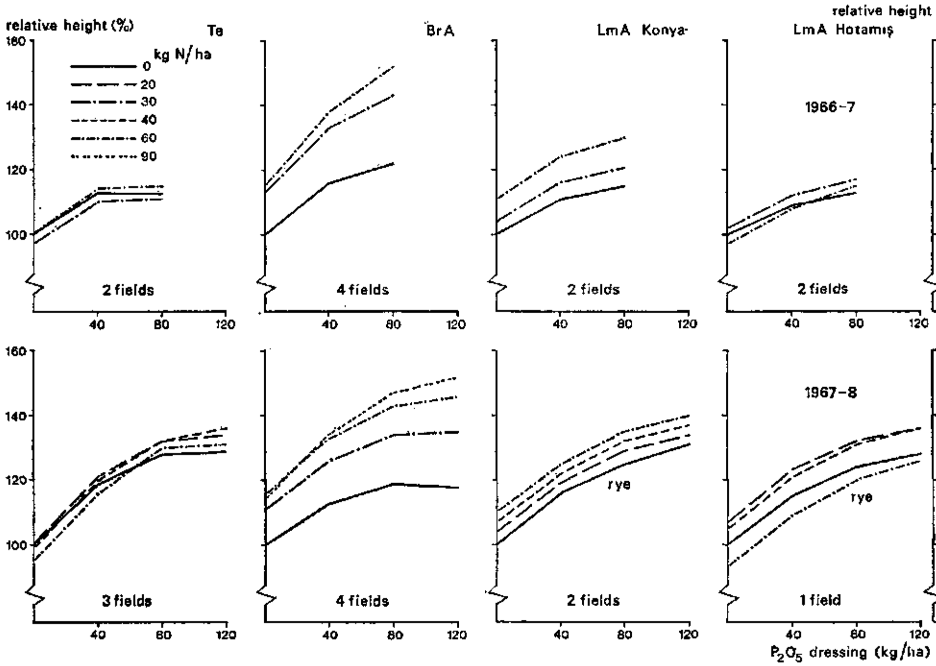
4 There was no response to potassium.

The statistical analysis of the relative *growth stages* showed that:

1 Only on 6 of the 27 fields could a positive linear nitrogen effect be recorded, mostly together with a significant or highly significant negative quadratic response.

2 On each field the linear effect of phosphorus was highly significant positive; they

Fig. 21. Relative height of plants in May (control = 100%) for different soil units in the two years.



Şekil 21. Değişik toprak üniteleri için, iki yıl içinde mayıs aylarındaki, bitkilerin nisbi yükseklikleri (kontrol = %100).

were accompanied by a negative quadratic effect on the Te, ThA and BrA soils in 1968.

3 Positive nitrogen-phosphorus interactions were recorded on two fields and a negative interaction on one field. They seem unimportant.

In comparison with the effect on plant height, the influence on growth stage is far less marked. Nitrogen generally had no effect on development and even acted negatively. Nevertheless for the BrA and ThA soils, nitrogen was beneficial, however less in 1968 than in 1967. As will be seen in Section 7.2, the nitrogen level of these soils is very low. The promotion of development by nitrogen dressing here agreed with the findings of Limberg (1964). The promotion of development by phosphorus is also in accordance with the literature (Section 3.3).

On many fields, fertilizers did not have any influence on plant *colour*. Exceptions were again the BrA and ThA soils, were the linear response to nitrogen was highly significant. On these soils phosphorus sometimes had a positive, sometimes a negative effect and sometimes none. On other soils, nitrogen and phosphorus had no influence.

6.2 Yield

Yields were divergent because of differences in years, soil units and fertilizers. The lowest yield was less than 300 kg/ha (Fig. 22 A); the highest yield approached 3000 kg/ha (Fig. 22B, opposite p. 48).

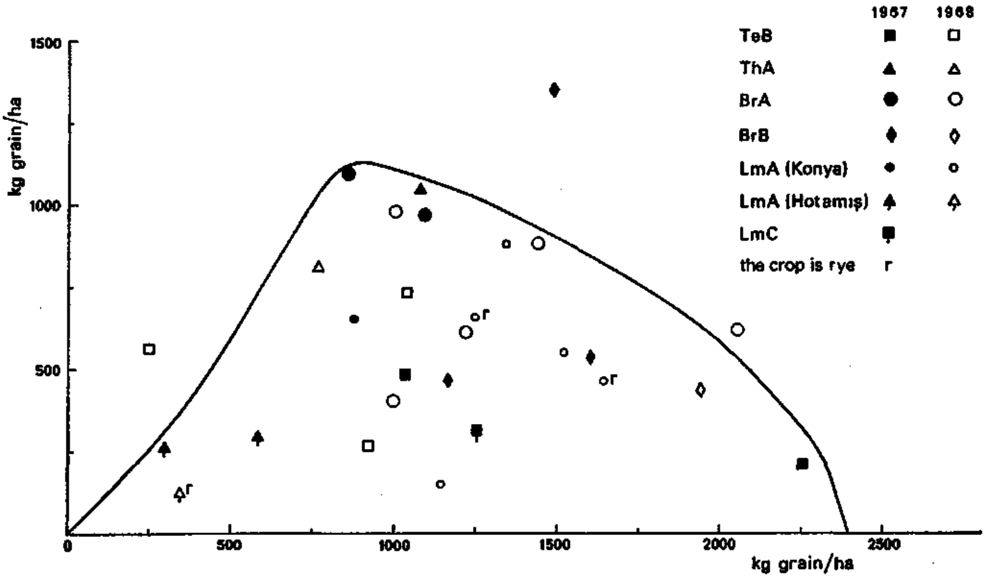
In general the yields tended to be lower in 1968 than in 1967, because of lower spring rainfall in 1968. In 1967 yields were most frequently between 1200 and 1400 kg/ha, and in 1968 between 1000 and 1200 kg/ha.

The distribution of rye yields comes in two parts: yields between 200 and 400 kg/ha (LmA Hotamış) and yields between 1200 and 2200 kg/ha (LmA Konya).

Figure 23 illustrates the variation in control yields and in the highest yield increments with fertilizers. The highest yield increment was sometimes not more than 140 kg/ha (Field 7, Ortakonak), but reached also about 1350 kg/ha (Field 16, Bulgurluk). The very good results at Bulgurluk, however, must be attributed to the flooding of this field in May, so that conditions were not typical of dry farming. Figure 23 indicates that fertilizers have the best chance when control yields vary between 800 and 1500 kg/ha.

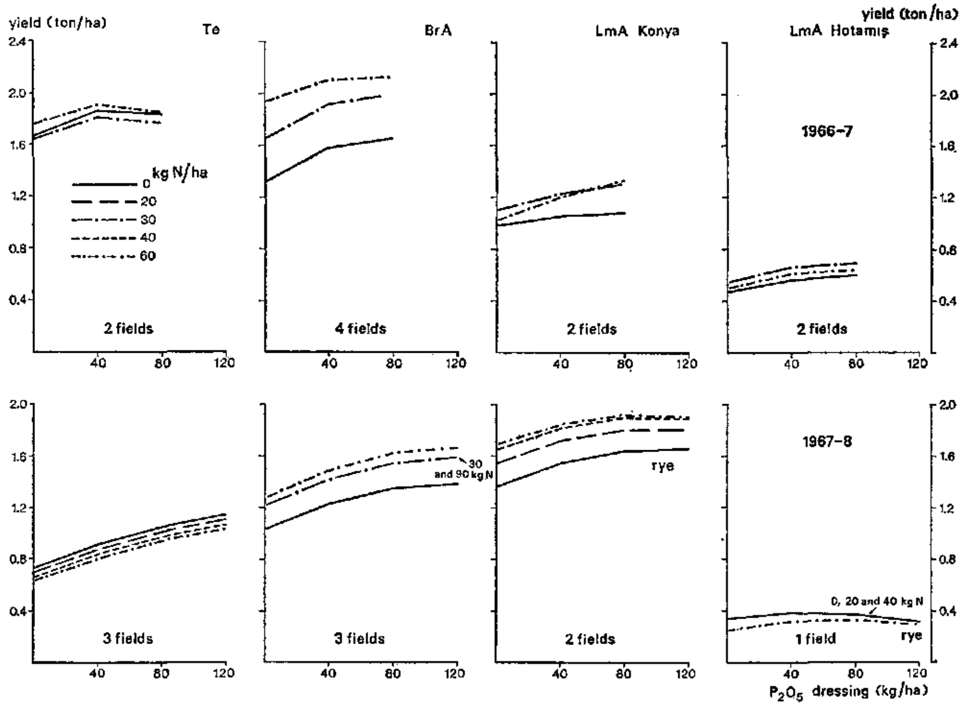
Grain yields have been plotted against rate of fertilizers in Figure 24. Wheat yields of the Marl soils in 1968 have not been indicated, as they are similar to rye yields.

Fig. 23. Highest yield increment (ordinate) of each field plotted against control yields. The crop is wheat.



Şekil 23. Her bir tarlada en fazla mahsul artışının (ordinat) kontrol mahsullere karşı işaretlenmesi. Mahsul buğdaydır.

Fig. 24. Grain yields for different soil units in the two years.



Şekil 24. Degişik toprak ünitelerinde iki sene içindeki tane verimleri.

The statistical analysis of the *grain* yields showed the following. (See also tables 12, 13 and 14).

1 Positive linear responses to nitrogen were found in 1967 on ThA and BrA, on one field on LmA Konya, and on two BrB fields; in 1968 on ThA and LmA Konya, and on BrA only at Mandosun (Field 113). The positive linear response was usually accompanied by a negative quadratic response. Negative linear responses were noted on the LmC field (Field 9) in 1967 and on two Te fields in 1968. Negative quadratic responses, without a linear response, were obtained on one LmA Hotamış field in 1967 and one Te field in 1968. On the single BrB field in 1968 there was a slight negative quadratic effect ($0.1 < P < 0.2$). There was no nitrogen effect on Te and LmA Hotamiş fields, on one LmA Konya and one BrB field in 1967 and on one LmA Hotamış, one Te, one BrB and two BrA fields in 1968.

2 On almost all fields there was a highly singificant positive linear response to phosphorus. Exceptions are the BrA fields 12 in 1967 and 113 in 1968, where phosphorus gave no significant response. Also on Field 108 (LmA Hotamış) there was no response to phosphorus. The response on fields 107 (LmA Konya) and 14 (BrA) was only a trend. In no case did phosphorus have a linear negative effect; only on four fields was a slight negative quadratic (with positive linear) response found.

Table 12. Effects of nitrogen dressing on grain yield, total dry-matter production and yield components (only linear responses).

Field No	Soil unit	Grain yield	Total dry matter	Harvest index	1000-grain weight	Grains per g straw	Grains per m^2
107[1]	LmA-K	++	++	+	-	++	++
104	ThA	++	++	0	0	-	++
12	BrA	++	++	0	--	+	++
106[1]	LmA-K	++	++	0	--	++	++
113	BrA	++	++	0	--	++	++
4	ThA	++	++	0	--	0	++
6	LmA-K	++	++	0	--	0	++
11	BrA	++	++	-	0	0	++
14	BrA	++	++	-	0	-	++
16	BrB	++	++	-	0	--	++
13	BrB	++	++	-	--	+	++
3	BrA	++	++	-	--	0	++
112	BrA	0	++	--	--	-	++
1	Te	0	+	--	0	0	0
7	LmA-K	0	++	--	--	--	0
108[1]	LmA-H	0	0	0	0	0	0
2	Te	0	0	0	-	0	0
8	LmA-H	0	0	-	-	0	0
101	Te	0	0	0	--	0	0
114	BrA	0	0	--	0	0	+
10	LmA-H	0	0	0	-	0	0
15	BrB	0	0	0	--	0	0
115	BrB	0	0	--	--	0	0
9	LmC	-	0	--	--	-	0
103	Te	--	-	-	--	0	-
102	Te	--	-	--	--	-	-

1. Rye.
-- or ++: $P < 0.02$; - or +: $0.02 < P < 0.1$.

Tablo 12. Azotlu gübrelerin tane verimine, toplam kuru madde yapımına ve mahsulü teşkil eden kısımlara olan etkileri (yalnız doğrusal münasebetler).

3 The nitrogen-phosphorus interaction was unimportant. Only at Bulgurluk (Field 16) was there a clear positive interaction.
4 There was no response to potassium.

Straw yields were higher than grain yields. The harvest index (Section 4.1.1) was higher in 1968 than in 1967 (general averages 36.7 and 41.8%). The reaction of the *harvest index* to fertilizers was as follows.
1 Nitrogen had a slightly to very significant negative effect on 14 of the 26 fields (Table 12). In 11 other fields there was no significant effect.

Table 13. Quadratic effects of nitrogen dressing on grain yield, total dry-matter production and yield components, where there was a negative quadratic response of grain yield.

Field No	Soil unit	Grain yield	Total dry matter	Harvest index	1000-grain weight	Grains per g straw	Grains per m²
Positive linear response to nitrogen							
6	LmA-K	-	0	--	+	-	--
107[1]	LmA-K	-	0	--	0	-	-
3	BrA	-	--	0	0	0	-
13	BrB	--	--	0	0	0	--
113	BrA	--	--	0	0	0	--
4	ThA	--	--	0	0	-	--
112[2]	BrA	--	-	-	0	--	--
No linear response to nitrogen							
8	LmA-H	-	0	-	0	-	-
101	Te	-	--	0	0	0	-
115	BrB	-	-	0	0	0	-

1. Rye.
2. In Field 112 there was a positive linear effect at $P = 0.25$.
-- or ++: $P < 0.02$; - or + : $0.02 < P < 0.1$.

Tablo 13. Tane mahsulun negatif kuadratik cevap verdiği yerlerde, kuadratik olarak azotla gübrelemenin tane verimine, toplam kuru madde yapımına ve mahsulü teşkil eden kısımlara olan etkileri.

2 The effect of phosphorus was unclear (Table 14). Positive reactions were obtained in 3 fields, negative in 3 fields and on the 20 other fields there was no effect. In general the harvest index seems unaffected by phosphorus.
3 On 9 fields there was a slight nitrogen-phosphorus interaction; elsewhere there was no interaction.

Since harvest index was affected by fertilizers, the statistical analysis of *straw yield* should differ from that of grain yield.
1 Nitrogen had either a positive linear effect on straw yields or no effect. In fields 15 and 115 (BrB), 9 (LmC) and 101 (Te), there was a faint negative quadratic response. On fields 10 and 108 (LmA Hotamış) and 102 and 103 (Te), nitrogen had no effect on straw yield. On the other 18 fields a positive linear response to nitrogen was recorded, in 7 fields together with a, mostly slight, negative quadratic response.
2 Positive responses to phosphorus were found almost everywhere, sometimes together with a faint negative quadratic response. Exceptions are fields 12 and 14 (BrA), and 6 and 7 (LmA) in 1967, where straw yields did not respond significantly to phosphorus.
3 Nitrogen-phosphorus interactions were not important; if any they were slightly positive; only at Bulgurluk (Field 16) was a highly positive interaction found.

Fig. 22. A. Fertilizer trial on LmA Hotamış (Field 8, Akçaşehir). Yield 300 to 550 kg grain per ha. B. Same stage of growth on BrB (Field 16, Bulgurluk). Yield 1480 to 2840 kg grain per ha.

Şekil 22. A. LmA Hotamış ünitesinde (tarla 8 Akçaşehir) gübreleme denemesi. Mahsul tane olarak hektara 300-500 kg arasındadır. B. BrB ünitesinde gelişme devreleri (tarla 16 Bulgurluk). Mahsul tane olarak hektara 1840 ile 2840 kg arasındadır.

Table 14. Effects of phosphorus on grain yield, total dry-matter production and yield components (only linear responses).

Field No	Soil unit	Grain yield	Total dry matter	Harvest index	1000-grain weight	Grains per g straw	Grains per m²
4	ThA	++	++	++	++	++	++
101	Te	++	++	++	++	++	++
106[1]	LmA-K	++	++	0	+	0	++
16	BrB	++	++	0	++	-	++
3	BrA	++	++	0	0	0	++
6	LmA-K	++	+	0	0	0	++
15	BrB	+	++	0	0	0	+
102	Te	++	++	0	0	0	++
114	BrA	++	++	0	0	0	++
8	LmA-H	+	+	0	0	0	+
13	BrB	+	+	0	0	0	+
103	Te	++	++	0	0	0	++
112	BrA	++	++	0	0	0	++
11	BrA	++	++	0	0	-	++
2	Te	+	++	0	-	0	+
9	LmC	++	++	0	--	0	++
10	LmA-H	+	+	0	-	0	++
104	ThA	++	++	0	--	0	++
115	BrB	++	++	0	-	0	++
1	Te	+	++	-	--	0	++
7	LmA-K	+	0	++	0	++	+
107[1]	LmA-K	0	++	0	0	0	+
14	BrA	0	0	0	0	0	0
12	BrA	0	0	0	0	0	0
108[1]	LmA-H	0	++	-	++	--	0
113	BrA	0	+	--	--	-	+

1. Rye.
-- or ++ : $P < 0.02$; - or + : $0.02 < P < 0.1$.

Tablo 14. Fosforun tane verimine, toplam kuru madde yapımına ve mahsulü teşkil eden kısımlara olan etkileri (yalnız doğrusal münasebetler).

4 Potassium had a negative effect on two fields; on the other 13 fields there was no response.

6.3 Components of yield

Tables 12, 13 and 14 show the effects of nitrogen (linear and quadratic) and of phosphorus (linear) on yield and its components. The fields have been arranged in sequence of diminishing positive response to fertilizer. In Table 12 BrA, LmA Konya and ThA are clearly distinguished from LmA Hotamış, Te and BrB.

Table 15. Averages of grain yield, total dry-matter production and yield components (averaged over all plots per field).

Field No	Soil unit	Grain yield (kg/ha)	Total dry matter (kg/ha)	Harvest index	1000-grain weight (g)	Grains per g straw	Grains per m^2
Wheat 1967							
3	BrA	2454	6446	38.1	32.8	18.9	7525
1	Te	2325	5708	40.8	29.0	23.9	8059
16[1]	BrB	2085	6101	34.3	33.5	15.7	6210
14	BrA	2011	5445	37.1	32.5	18.4	6264
15	BrB	1723	5235	32.9	26.0	19.0	6624
12	BrA	1672	4282	39.1	32.5	19.9	5206
4	ThA	1548	4432	34.6	32.0	16.6	4822
11	BrA	1408	4060	35.0	29.7	18.3	4725
13	BrB	1397	3397	41.2	31.3	22.6	4501
9	LmC	1358	3779	35.9	27.2	20.7	5003
2	Te	1265	3086	40.8	30.3	23.0	4195
7	LmA-K	1181	3596	33.2	31.7	15.8	3728
6	LmA-K	1161	3228	36.1	32.2	17.7	3614
10	LmA-H	778	1876	41.3	29.3	24.0	2635
8	LmA-H	376	1234	30.0	24.9	17.5	1502
Wheat 1968							
115	BrB	2037	5258	38.9	32.8	19.5	6206
107	LmA-K	1864	4263	43.8	38.6	20.1	4820
106	LmA-K	1660	3738	44.4	31.6	25.3	5250
114[2]	BrA	1614	3598	45.0	32.1	25.7	5060
113	BrA	1513	3056	50.0	33.5	29.4	4557
102	Te	1247	2575	45.2	35.1	23.5	3531
112	BrA	1167	2819	42.1	32.4	22.4	3594
104	ThA	1078	2286	47.1	34.3	26.0	3142
103	Te	985	2313	42.5	33.1	22.4	2973
101	Te	488	1496	31.1	28.3	16.1	1688
108	LmA-H	481	1559	30.3	29.2	15.3	1646
Rye 1968							
106	LmA-K	1866	5478	34.1	34.0	15.3	5500
107[2]	LmA-K	1592	5676	28.0	36.1	10.9	4454
108	LmA-H	350	2257	14.3	28.9	5.8	1126

1. Flooded.
2. On these fields grain yield was not exactly the product of total dry matter and harvest index, because harvest index was determined on a greater number of samples than the number of plots that has been harvested for the determination of total dry-matter yield.

Tablo 15. Tane mahsulun, toplam kuru madde yapımının ve mahsulü teşkil eden kısımların ortalamaları (her bir tarla için çeşitli yerlerden toplanan mahsulun ortalaması).

Where nitrogen had a positive effect on grain yield, it was due to rise in total dry matter and in number of grains per m^2. Where the harvest index was negatively influenced by nitrogen, the increase in the grain yield was less than the rise in dry-matter production. The negative effect on harvest index was mostly caused by the lower 1000-grain weight, sometimes together with a lower number of grains per straw.

Where nitrogen had no influence on grain yield, its absence was due to

1 No influence on total dry-matter production

2 The balancing of the rise in total dry matter by the decrease in 1000-grain weight or the number of grains per straw.

Only on two fields had nitrogen a negative effect on all yield components.

Sometimes only the quadratic effect of nitrogen was negative. Table 13 shows that these effects are nearly always caused by a decrease in total dry-matter production (and the number of grains per m^2).

The phosphorus effect on yield components is quite different from the nitrogen effect (cf. tables 12 and 14). In general the harvest index and the number of grains per straw were not changed by application of phosphorus. On some fields the 1000-grain weight was somewhat lowered by phosphorus.

To give an impression of variation in yield components between years and soils, their mean values (averaged over all the plots) have been collected in Table 15 and arranged by year according diminishing yields.

Harvest index was higher in 1968 than in 1967, because of higher 1000-grain weight and greater number of grains per straw.

The number of headed culms was counted on some plots of Field 4 in 1967; it varied between 300 and 600 ears/m^2. The corresponding number of grains/m^2 varied between 3200 and 7100, so that the number of grains per ear was about 10 or 12. This figure is low, but since also the number of grains per straw was low on that field (14-19), it may be assumed that for most fields, the number of grains per ear was more than 12.

The weight per culm, derived from these figures, is about 0.7 g, but as with straw weight the unheaded culms were also included, the weight per culm must be somewhat higher than 0.7 g.

Straw length on Field 4 was quite normal, so that the weight of culms in general would be about 0.7 to 1 g.

6.4 Interrelations between growth and yield

The influence of nitrogen and phosphorus on height of plants in May looked very much like their influence on grain and straw yields. Also the effects of the differences between soils were similar in May and July (cf. figures 21 and 24). The effects of fertilizers seemed to be already fully expressed in May.

The influences of nitrogen were usually somewhat less significant in July than in May, but the general picture was similar.

The linear responses to phosphorus of height in May were the same as of total

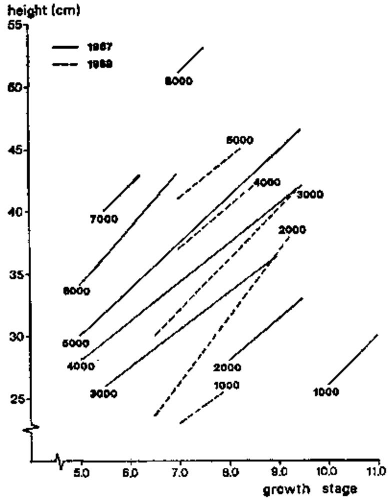


Fig. 25. Dry-matter isoquants in relation to height and growth stage in May. Growth stages are of Feekes' scale, with exception of Stage 11 which is the same as Feekes' stage 10.2.

Şekil 25. Mayıs ayı içinde bitki büyüklükleri ve büyüme devreleri ile ilgili olarak kuru madde izokuantları. Büyüme devreleri Feekes ıskalasına göredir. Burada devre 11 Feekes'in 10.2 devresine tekabül etmektedir.

dry matter on nearly all fields. The resemblance of the fertilizers' effect on plant height in May to that on grain yield is less pronounced. The variation in the harvest index is responsible for that. As harvest index depends also on growth conditions during and after flowering (Section 3.3), there is a relation with plant height in May only in some fields.

Growth stage in May was far less than height influenced by fertilizers, so that comparison with the results in July was less succesful, especially for nitrogen. The similarity between May and July in response to phosphorus is still striking.

These strong correlations make it possible to predict total dry-matter production. In Figure 25, where the axes are growth stage and plant height, dry-matter isoquants have been drawn. The lines for 1968 are steeper and lie above the 1967 lines. From May data, dry-matter production in July can be predicted in units of 1000 kg. When very dry conditions are discounted, harvest index varies between 35 and 45% (Table 15). Using an average value of 40%, the difference between predicted and actual grain yields does not exceed 400 kg + 5% of the dry-matter production. The prediction can be improved if crop density is also taken into account (Section 8.3).

For rye, prediction was less satisfactory. Only differences of more than 2000 kg dry matter could be distinguished.

7 Yield factors

7.1 Moisture

7.1.1 Soil moisture

In Figure 26 the moisture contents are shown of the main four soil units Te, BrA, LmA Konya and LmA Hotamış. For comparison the moisture contents at pF 3.0 and pF 4.2 have also been drawn.

The soil did not differ much in moisture content between years (for the same soil units) in October and July and therefore it was justified to take the average of the two years. Moisture contents in May, however, diverged much between the two years and have not been averaged.

In October soil moisture had a tension between pF 3.0 and 4.2. In the upper 10 or 20 cm of the profile, moisture content was even lower than at pF 4.2; for LmA Hotamış this was true for nearly the whole profile.

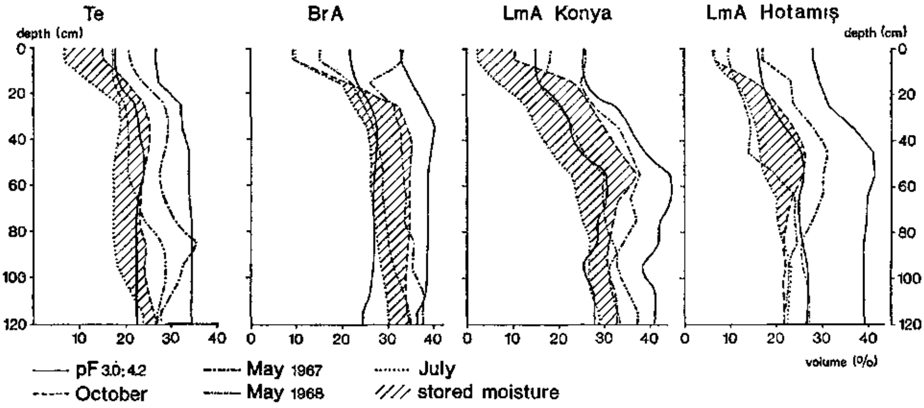
At harvest, moisture had been withdrawn to tensions higher than 15 atm, in agreement with measurements elsewhere (Haise et al., 1955; Yang & de Jong, 1968; Bauer & Young, 1969). On the BrA soils relatively little moisture had been withdrawn beyond pF 4.2. This may have been due to the lower capillary conductivity of these heavy soils (Lehane & Staple, 1965; Section 3.5). At depths of more than 80 cm, crops could not take up moisture to such high tensions. This means that in LmA Hotamış profiles moisture was not withdrawn at all from more than 80 cm depth.

On the three other soils, moisture was presumably taken up too from depths of more than 120 cm. Fox et al. (1970) also found for Turkish soils that water was extracted from depths of at least 140 cm. Hence in 1968 soil samples were taken to a depth of 200 cm, so that the amount of moisture stored between 120 and 200 cm could also be estimated (Table 16). Some values changed somewhat in comparison with earlier data (Janssen, 1970b).

As the soil was sometimes sampled in October just after a shower, the moisture content of the upper 20 cm was not reliable and was therefore discounted. The subsoil of BrA contributes more moisture to the storage than the other subsoils. The value for LmA Konya must be considered with reserve, as in these profiles the watertable can rise to 1.5-2.0 m below surface (Driessen, 1970), so that differences in the amounts of stored moisture may be due partly to fluctuations in the watertable.

The figures of Table 16 are for rainfall from August 1966 to October 1967. They are from Çumra (Te), Karaman (BrA), Konya (LmA Konya) and Karapınar (LmA

Fig. 26. Average soil moisture profiles for Te (5 profiles), BrA (7), LmA Konya (4) and LmA Hotamış (3). October is sowing time, the next July is harvest time.



Şekil 26. Te (5 profil), BrA (7), LmA Konya (4) ve LmA Hotamış (3) ünitelerinde ortalama toprak nemi profilleri. Ekim, ekin ayını, onu takip eden Temmuz ayı hasat ayını işaret etmektedir.

Table 16. Estimates of moisture storage, rainfall and fallow efficiency.

	Te	BrA	LmA-K	LmA-H
Stored moisture between 20-120 cm (in mm)	55	75	85	40
Stored moisture between 120-200 cm (in mm)	25	40	20	0
Total stored moisture	80	115	105	40
Rainfall (see text) (in mm)	315	360	375	290
Fallow efficiency (in %)	25	32	28	14

Tablo 16. Tahmini depo edilen nem, yağış ve nedasın etkisi.

Hotamış) and may be considered as approximations of the average rainfall during the fallow period on these soil units.

The calculated fallow efficiency (Table 16) agrees with what was found by Özbek et al. (1967a). That efficiency decreases with decreasing precipitation corresponds with the absence of penetration by water into the soil when showers are small (see Section 3.5). In years of low precipitation there is more chance of small showers. According to Çuhadaroğlu (1967) the number of days with more than 10 mm precipitation vary from year to year between 0 and 10, and the annual precipitation between 175 and 372 mm. A second reason for low infiltration and hence low efficiency of fallow in LmA Hotamış is probably slaking. Slaking may also have caused the difference in fallow efficiency between LmA Konya and BrA. Soil cracking may improve fallow efficiency (Johnson, 1962) as in BrA.

Table 17. Rainfall and total soil moisture in spring.

Rainfall (mm)	Çumra Te	Karaman BrA	Konya LmA-K	Karapınar LmA-H	Ereğli
1967					
March	55.1	65.6	29.1	35.6	70.8
April	31.5	34.0	24.9	28.0	44.9
May	62.6	52.0	104.1	59.4	82.7
Total	149.2	151.6	158.1	123.0	198.4
Soil moisture[1]	345	403	387	316	
1968					
March	39.0	42.1	27.2	40.9	30.3
April	17.6	6.1	12.7	9.0	5.1
May	20.6	22.9	56.7	40.7	62.4
Total	77.2	71.1	96.6	90.6	97.8
Soil moisture[1]	277	332	328	220	

1. Soil moisture is total soil moisture from 0-120 cm (in mm), as found in May.

Tablo 17. Bahar mevsiminde yağış ve toplam toprak nemi.

Moisture contents in May 1967 exceeded those in October particularly in the Te and LmA Hotamış profiles, but in October these soils had less moisture than other soils. In May 1968 moisture content was much lower than in May 1967, and already at values corresponding with pF 4.2, down to 70 cm (40 cm for BrA). At LmA Hotamış the moisture content in May 1968 seemed less than in July, but the difference can be attributed to error in sampling. Nevertheless the conclusion seems justified that LmA Hotamış was already completely dry down to 50 cm in May 1968.

The differences between May 1967 and May 1968 correspond with differences in rainfall (Table 17). This table indicates that the low rainfall in April 1968 was mainly responsible for the low moisture content in soil. The high rainfall in spring 1967 at Ereğli caused the flooding of Field 16 (Bulgurluk) in May 1967.

7.1.2 Moisture, dry-matter production and yield components

To evaluate the significance of the amount of water stored in the soil, total dry-matter production has been plotted against an estimation of moisture stored between 20 and 200 cm (Fig. 27). Several determinations of moisture during the fallow period showed that the amount of water lost by evaporation almost equals the decrease in moisture in the upper 20 cm during the growing season. For this reason and for reasons already discussed moisture between 0 and 20 cm was not considered in the estimation of stored moisture, that was transpired. Total dry matter and not grain yield has been used, since the latter depends also on distribution of transpired moisture

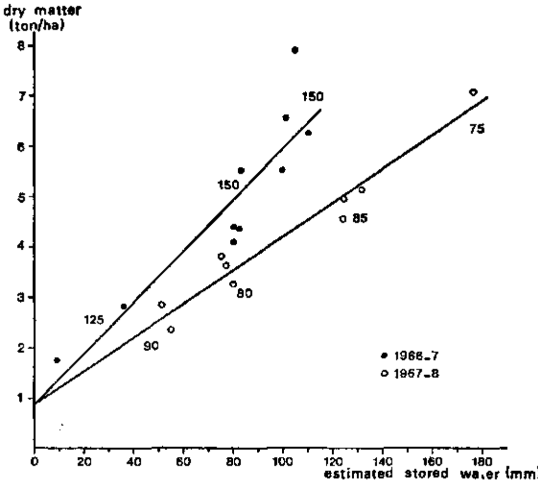


Fig. 27. Relation between estimated stored water and dry-matter production. Numbers next to lines are estimated total rainfall in March, April and May.

Şekil 27. Tahmini biriktirilen nem miktarı ile kuru madde yapımı arasındaki ilgi. Çizgilere yaklaşık rakkamlar Mart Nisan ve Mayıs ayıları içindeki tahmin edilen toplam yağış miktarlarıdır.

over the growing season (Section 3.3), whereas total dry-matter production is determined simply by the amount of moisture transpired, as long as moisture is the only limitation on yield (de Wit, 1958).

To ensure that there was sufficient nitrogen and phosphorus, the average value of the three highest yielding plots was used; from each of the fields 106, 107 and 108 with only 9 wheat plots, only the highest yielding plot of wheat was taken. This procedure assumes that transpiration was equal on all plots from the same field and that changes in dry-matter production were caused by changes in transpiration ratio (Section 3.2.2).

Figure 27 shows that for a same dry-matter production less stored moisture was required in 1966-7 than in 1967-8, because of higher spring precipitation during the first growing season. The difference in spring rainfall between the two years was about 35 mm for the fields with little stored moisture and about 70 mm for the other fields (Table 17; numbers in Fig. 27). This difference explains why the 1966-7 line was steeper than and not parallel to the 1967-8 line. A second cause may be that spring rainfall was used more effectively when more moisture had been stored.

When no moisture was stored, dry-matter production could be about 850 kg/ha. With such a dry-matter production, the harvest index would be 15-25%, so that grain yield would be about 170 kg/ha (the seed rate was 160 kg/ha). With no moisture storage rainfall would be about 200-250 mm. In close correspondence with these results is the statement of Russel (1959), who said that at least 200 mm precipitation was needed to produce any yield.

The increase in dry matter per 10 mm stored moisture was about 500 kg/ha in 1966-7 and about 325 kg/ha in 1967-8 or about 185 and 135 kg grain/ha. These values far exceed those mentioned in Section 3.5 (70-105 kg grain/ha). A reason could be that the cited authors did not subtract evaporated stored moisture.

Storage and (spring)rainfall interacted with each other; the higher the rainfall in spring, the more effective was each millimetre of stored moisture (steeper line in 1966-7), and the more moisture stored, the more effective was rainfall. With high storage, plants cover the soil surface earlier so that evaporation is suppressed. That spring rainfall was used more efficiently may be illustrated by comparing in Figure 27 the situation around 80 and 110 mm storage. For fields with such storage values differences in rainfall between the years were similar, but the differences in dry-matter yield were 1500 and 2000 kg/ha respectively.

The conclusions stated here seem to conflict the general idea that with increasing rainfall the effect of fallow decreases or even disappears. The lack of contradiction can be explained in the following way.

Fallow is necessary when precipitation is less than about 350 or 380 mm. More rainfall may bring the soil to field capacity and when rainfall exceeds 500 mm loss by deep percolation may occur (Cole & Mathews, 1939). The more moisture stored, the sooner water is lost on that way. In the Basin, however, rainfall seldom exceeds 350 mm (Table 1), so that soils are rarely moistened to field capacity. Even in the wet spring of 1967, deep percolation probably did not occur, except perhaps in BrA and, because of the high watertable, LmA Konya. Therefore each extra millimetre moisture stored is advantageous under the conditions of the Basin.

I have tried to calculate the moisture that had actually been transpired by the crops (Janssen, 1970b). The relation was as follows:[1]

$$DM = 28\ T \qquad (12)$$

where

DM = dry-matter production in kg/ha

T = transpiration in mm during the growing season.

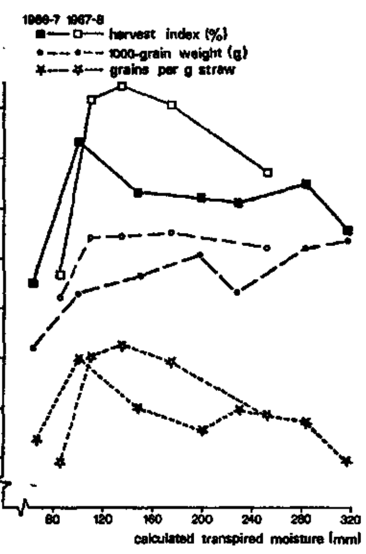


Fig. 28. Relations between calculated transpired moisture and harvest index, 1000-grain weight and number of grains per g straw.

Şekil 28. Hesaplanarak bulunan sarfedilen su miktarı ile hasat indeksi arasındaki ilgi, 100 tanenin ağırlığı ve herbir gr başakta bulunan tane sayısı.

1. The relation was there presented as: $DM = 27.4\ T$.

The equation agrees reasonably with de Wit's equation (Eq. 3, Section 3.2.2). By combining the data on transpiration and storage (Eq. 12; Fig. 27), I calculated the contribution of storage to transpiration as 44% and 64% in 1967 and 1968, respectively, showing the importance of the fallow year in the Basin.

From Equation 12, the amount of moisture transpired for each field has been calculated, where for DM the average of the three highest yielding plots was always taken. The calculated transpired moisture is henceforth used as a parameter for moisture supply.

In Figure 28, harvest index, 1000-grain weight and number of grains/g straw, have been plotted against calculated transpired moisture. In both years, harvest index was optimum around 100 to 130 mm transpired moisture. If less moisture was transpired, crops failed. In the range from 130-320 mm, harvest index decreased, obviously because of a decrease in grains/g straw. See for discussion Section 8.3.

7.1.3 Transpiration and evapotranspiration

In arid regions evapotranspiration may be calculated from the equation

$$ET = P + \Delta W \qquad (13)$$

Table 18. Evapotranspiration (ET), transpiration (T) and evaporation (E).

Field No	Soil unit	*ET* (mm)	*T* (mm)	*E* (mm)	100 *T*/*ET*
1966-7					
3	BrA	388	283	105	73
14	BrA	432	234	198	54
1	Te	410	223	187	54
12	BrA	392	198	194	50
4	ThA	392	197	195	50
9	LmC	364	156	208	43
7	LmA Konya	405	157	248	39
6	LmA Konya	400	146	254	37
10	LmA Hotamış	293	100	193	34
8	LmA Hotamış	260	63	197	24
1967-8					
115	BrB	503	252	251	50
114	BrA	416	166	250	40
113	BrA	375	136	239	36
112	BrA	360	130	230	36
106	LmA Konya	499	176	323	35
107	LmA Konya	518	183	345	35
103	Te	315	101	214	32
108	LmA Hotamış	305	85	220	28

Tablo 18. Toplam buharlaşma (*ET*), transpirasyon (*T*) ve Evaporasyon (*E*).

where

ET = evapotranspiration

P = precipitation

ΔW = change in water stored

(Butler & Prescott, 1955; Ferguson, 1963, Ramig & Rhoades, 1963; Lehane & Staple, 1965; de Jong & Rennie, 1969).

Where data were available, evapotranspiration of the field was calculated. By subtracting transpiration from evapotranspiration, evaporation was found. The relation of T to ET was calculated. The results are presented in Table 18, where the fields have been arranged in sequence of T/ET.

Table 18 shows the following.

1 In general T/ET is higher in 1966-7 than in 1967-8, because of the more favourable distribution of rainfall in 1966-7.

2 The relation T/ET is lowest in the Marl soils. This is probably partly caused by the slaking characteristics of the soils, whereby infiltration is hampered; further ET may have been slightly overestimated, because of fall of watertable.

3 The relation T/ET varies between 25 and 55% (except in Field 3), almost the same range as in the literature 20-50% (Peters, 1960; Power & Evans, 1962).

7.2 Nitrogen

7.2.1 Soil nitrogen

Samples from the plough layer were analysed for organic N and nitrate. The soils were tested for available N (SQ_N) in greenhouse trials (Section 4.2; App. 1).

Values for organic N are related to values for organic matter: variation in C/N quotient is small.

The soils of the fields have been arranged in four groups for content of organic N: < 0.75, 0.75-0.90, 0.90-1.10 and > 1.10‰. The respective groups will be referred to as 0.65, 0.80, 1.00 and 1.25‰ organic N.

The relation between organic N and nitrate N, and between organic N and SQ_N, differed between the years (Fig. 29). The cause must be sought in the fact that 1966-7 samples had been stored a year longer than the 1967-8 samples.[1]

The relation between SQ_N and nitrate N was the same in the two years. Apparently the plants in the greenhouse trials responded mainly to the nitrate N in the soil.

To compare crop response to N in different fields, the increments in grain yield per ha per kg added N per ha were calculated for the lowest N rates of 20 and 30 kg N/ha. This value is indicated as *Yi*/N (kg increment in grain yield per kg added N). Figure 30A shows a fairly good average relationship between organic N and *Yi*/N.

1. As soil samples had not been taken for the express purpose of determining nitrogen, there were no special precautions at sampling and during storage to prevent mineralization.

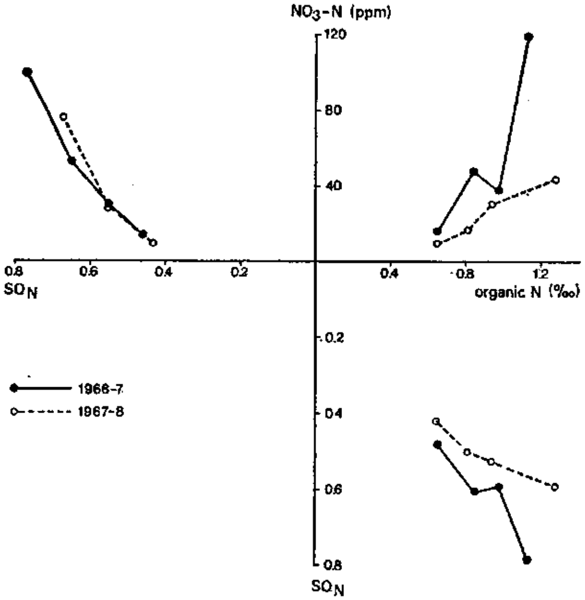
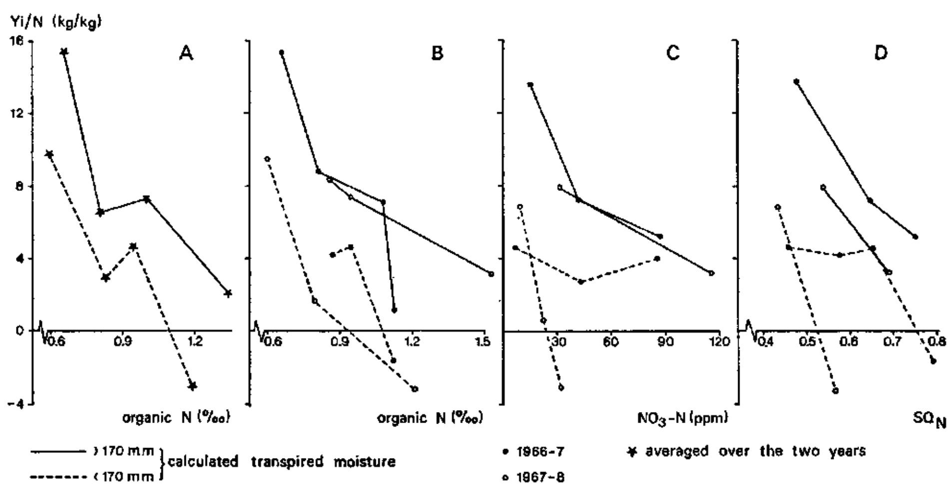


Fig. 29. Relations between organic nitrogen and nitrate nitrogen in soil, SQ_N and nitrate nitrogen, and organic nitrogen and SQ_N.

Şekil 29. Toprakta organik azot ile nitrat azotu, SQ_N' u ile nitrat azotu ve organik nitrojen ile SQ_N arasındaki ilgiler.

Fig. 30. Relations between Yi/N and organic nitrogen (A and B),nitrate nitrogen (C), and SQ_N (D) for different amounts of calculated transpired moisture.



Şekil 30. Hesaplanarak bulunan sarfedilmiş çeşitli miktarlardaki nem için Yi/N ile organik madde (A ve B), nitrate azotu (C) ve SQ_N (D) arasındaki ilgi.

The curves are somewhat more regular when drawn per year (Fig. 30B). The relation of SQ_N and nitrate N with *Yi*/N are more clear in 1967-8 than in 1966-7. (Fig. 30C and D), most likely because of the shorter period of storage of the 1967-8 samples.

In each of the graphs, the influence of moisture is clear; the more moisture available, the higher the yield increments brought about by N.

7.2.2 Crop nitrogen

Figure 31 gives the relation between N in grain and in straw. The line is curvilinear, probably because the grain's N requirements were easier met, if nitrogen level was high in stems and leaves.

The relation between grain N and grain yield at different N rates is shown for some representative fields in Figure 32. There are all types of responses to N (cf. Section 3.4). Figure 33 shows that when grain N in the N_0 treatments exceeds 2.0 or 2.2%, there was no increase in yield. These figures correspond with Collwell's.

The influence of moisture on *Yi*/N is far less clear in Figure 33 than in Figure 30, since the effect of moisture is already expressed in grain N itself.

Most authors found higher values for *Yi*/N than those presented here. So many factors, such as moisture conditions, climate, level of other nutrients and wheat variety are involved, that full discussion is not possible here.

Phosphorus dressing lowered grain N when yield increments with P were considerable (dilution of N). At high grain N, phosphorus had less influence.

No graphs have been drawn to show the relation between grain N and yield components. In each field seperately, grain N increased as 1000-grain weight decreased; the relation did not hold when the values of the fields were compared all together.

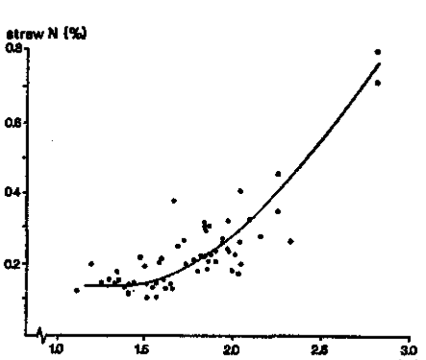


Fig. 31. Relation between nitrogen in grain and in straw. Data are of N_0 and N_1 treatments.

Şekil 31. Tane ve saptaki azotlar arasındaki ilgi. Kayıtlar N_0 ve N_1 işlemlerine göredir.

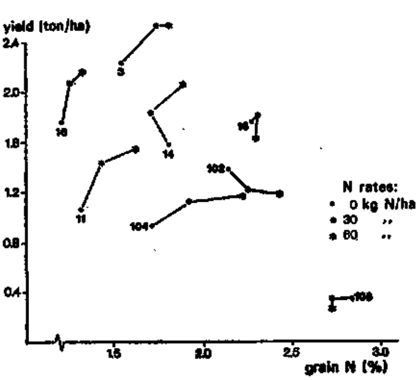


Fig. 32. Effects of nitrogen dressing on yields of wheat and rye and on nitrogen content of grain. Numbers are of the trial fields. For the fields 102, 104 and 108, yield and grain N at 30 kg N/ha are averages of the values at 20 and 40 kg N/ha.

Şekil 32. Azotla muamelenin Buğday, Çavdar tanelerindaki azot miktarına olan etkileri. Rakkamlar deneme tarlalarının numaralarını işaret etmektedir. 102, 104, 108 numaralı tarlalarda 30 kg N/ha'a ait mahsul ve tane azotu değerleri 20 ve 40 kg N/ha'dan elde edilen değelerin ortalamasıdır.

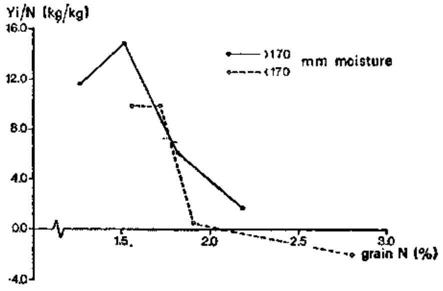


Fig. 33. Relation between Yi/N and nitrogen content of grain in the N_0 treatments for different amounts of calculated transpired moisture.

Şekil 33. Hesapla bulunan sarfedilmiş nem miktarları için N_0 muamelesindeki Yi/N ile tanelerin azot mıktarı arasindaki ilgi.

7.2.3 Interrelations between nitrogen in soil, crop and fertilizer and transpired moisture

Grain N was clearly related to soil organic N (Fig. 34). The effect of moisture was most evident when soil N was low. When soil organic N was 1.25‰, extreme drought caused considerable increase in grain N.

The next graph (Fig. 35) shows the influence of both moisture conditions and soil organic N on nitrogen withdrawal from soil. A very distinct interaction is seen. With low soil N, moisture had little influence on N withdrawal. As N limits yield here, an increase in available moisture often does not raise yield and if yield does rise, grain N falls, so that N withdrawal still does not rise. With high soil organic N, moisture is the limiting factor and the amount of nitrogen withdrawn is proportional to transpiration.

The highest withdrawal was about 60 kg N/ha. On those soils, nitrate N was about 40 ppm (1967-8 samples, Fig. 29) or 120 kg in a hectare of plough layer with 3 million kg soil. That value illustrates that those soils can easily meet crop requirements for N.

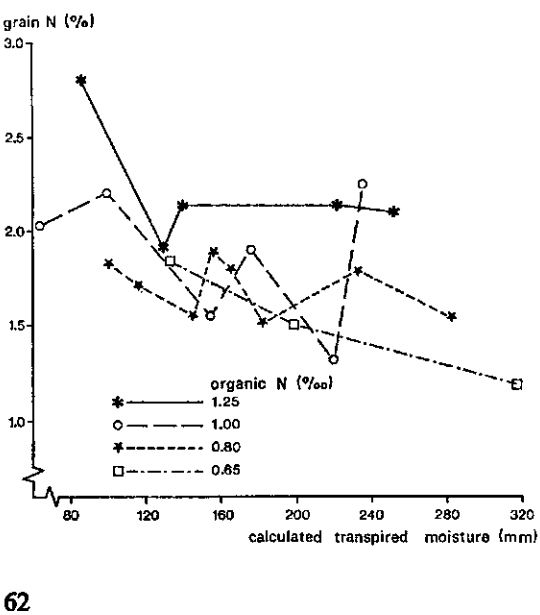


Fig. 34. Relation between nitrogen content of grain in the N_0 treatments and calculated transpired moisture for different levels of organic nitrogen in soil.

Şekil 34. Toprakta değişik azot seviyeleri için N_0 muamelelerinde, tanelerin azot miktarı ile hesapla bulunan safredilmiş su miktarı arasındaki ilgi.

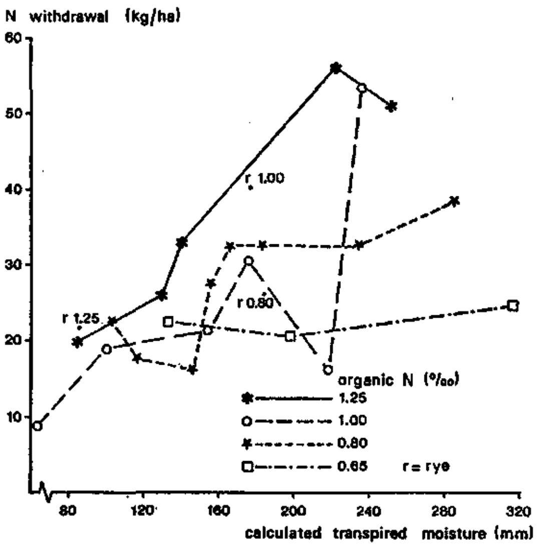


Fig. 35. Relation between nitrogen withdrawal and calculated transpired moisture for different levels of organic nitrogen in soil.

Şekil 35. Toprakta değişik seviyelerde organik nitrojen miktarları için N_0 muamelelerinde tanedeki azot miktarı ile hesapla bulunan sarfedilmiş su miktarı arasındaki ilgi.

Fertilizer rates of 30-60 kg N/ha are small in comparison with N reserves in the soil, even when the 1967-8 samples overestimate the nitrate content.

Recovery of fertilizer N was calculated by subtracting N withdrawal in the N_0 treatments from N yield in the N_1 treatments. The figures are rather rough because only part of the grain samples of the N_1 treatment were analysed and because N in straw was only calculated from Figure 31. Recovery figures were up to 30% (Table 19). This low recovery, even on soils with a clear yield response to dressing, may have been caused by low root density (Section 7.5) and by leaching of nitrogen from surface soil to greater depths where root density was still lower.

A low recovery of fertilizer N has been found in other arid regions, too. In Egypt, Hamid et al. (1963) calculated a recovery between 16 and 40% by wheat. Viets (1960), mentioning trials with recovery figures from 7-50% on United States soils comparable with the Basin soils, could not satisfactorily explain why so much nitrogen was lost.

The relation between N recovery and soil organic N looks very much like the relation between *Yi*/N and soil organic N. Obviously it is rather the yield increment than the increase in grain N that determines N recovery.

7.2.4 Soil units and nitrogen

Some of the N data were averaged by soil unit (Table 19). The different parameters are related to one other.

There was no response to N dressing on Te, LmA Hotamış and LmC soils (Section 6.2) because of the high soil N. High responses to added N were obtained on BrA, ThA and LmA Konya soils. There organic N was lower and available moisture often more than in other soils.

In Tarım Bakanlığı (1959-63) results are reported of fertilizer trials in several villages

Table 19. Nitrogen parameters, averaged per soil unit.

Soil unit	Organic N (‰)	C/N	Grain N (%) (N_0 plots)	Yi/N (kg grain/ kg N)	N withdrawal (kg N/ha)	N recovery (%)
Te	1.10	8.8	2.16	—1.9	31.4	—0.6
ThA	0.74	9.0	1.65	13.0	20.1	30.4
BrA	0.75	8.7	1.65	9.6	26.1	24.1
BrB	1.02	8.0	1.79	5.8	37.3	10.9
LmA-K	0.89	9.9	1.77	7.1	27.1	18.7
LmA-H	1.08	9.4	2.36	—0.3	16.3	10.0
LmC	1.14	9.6	1.92[2]	—0.1[2]	30.6[2]	.[1]

1. No samples analysed of N_1 plots. 2. Only one field.

Tablo 19. Her bir toprak ünitesi için ortalama azot parametreleri.

in the Basin (dry farmed). Only at Kazım Karabekir, situated on BrA and ThA soils, was a N response found, in agreement with my conclusions.

The BrB soils were intermediate. Their figures varied widely: Field 16 (Bulgurluk) was low in organic N (0.66‰) and high in *Yi*/N (10.7), whereas the BrB soils near Sudurağı (fields 15 and 115) were high in organic N (1.26‰) and low in *Yi*/N (about 2).

The Marl soils had a slightly higher C/N quotient than other soils. The average values for Central Anatolia presented by Fox et al. (1970), namely 8.1 for C/N and 0.93‰ soil total N are near the values I found.

7.3 Phosphorus

7.3.1 Soil phosphorus

Phosphorus was determined by Olsen's method. Soils were tested for available phosphorus (SQ_P) in greenhouse trials (Section 4.2; App. 1).

The chemical analysis at Ankara corresponded reasonably with that at Wageningen: 1 mg P_2O_5 per 100 g soil equivalent to about 1.5-2.5 kg P_2O_5 per dekar.[1] Soil P lay between 0.6 and 2.7 mg P_2O_5 per 100 g soil and 1.5 and 4.0 kg P_2O_5 per dekar. According to Yurtsever et al. (1965), such values indicate that yields without P fertilizer are 60-90% of yields with P fertilizer.

There was no correlation between the results of greenhouse trials and chemical data. SQ_P varied between 0.44 and 0.74; values were the same as for Dutch standard soils (App. 1), for which recommended P_2O_5 dressings are from 140 to 90 kg per ha, respectively.

The variation between replicates in greenhouse trials was high (SE 30-40%) and

1. 1 dekar = 0.1 ha.

was similar to the differences between soils. Also the variation in the chemical analyses was high (SE about 20%). As the variation in the Dutch standard soils in the trials was much smaller (SE about 10% at most), the great variation in SQ_P in Turkish soils must have been caused at least partly by the uneven distribution of soil P.

As for nitrogen, the increments in grain yield per kg added P were calculated. No relation of *Yi*/P with SQ_P was found and only at high moisture supply was there a relation between *Yi*/P and P-Olsen.

Further examination of *Yi*/P, P-Olsen and other soil properties suggested that carbonate content, and not P-Olsen was related to *Yi*/P. P-Olsen and carbonate content are moderately correlated with each other (Fig. 36). Marl soils had the highest carbonate content and the texture of carbonate was finer than of the other soils (Section 5.2.1). By chance the Marl soils had also the highest P contents (Fig. 36), so that their effects were confused. It seems, however, more likely that the lower *Yi*/P values on the Marl soils (Fig. 37) were caused by their high content of fine-textured active carbonate, than by their slightly higher, but still very low, P content. Probably

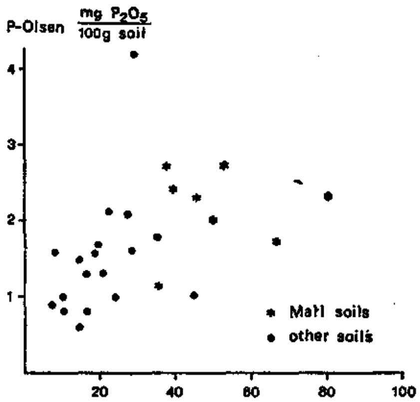


Fig. 36. Relation between P-Olsen and carbonate content.

Şekil 36. P-Olsen ile karbonat miktarı arasındaki ilgi.

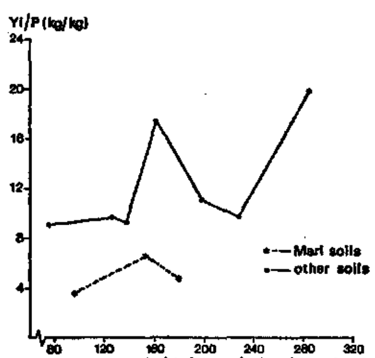


Fig. 37. Relation between Yi/P and calculated transpired moisture for Marl soils and other soils.

Şekil 37. Marn toprakları ve diğer topraklar için Yi/P ile hesapla bulunan sarfedilmiş su miktarı arasındaki ilgi.

the added fertilizer P was rapidly fixed, in accordance with Kaçar's (1967) results (Section 3.1).

The relationship between *Yi*/P and calculated transpired moisture as shown in Figure 37 was unclear. The values of *Yi*/P are low, in comparison with literature data.

7.3.2 Crop phosphorus

P was determined in the same crop samples as those in which nitrogen had been tested. As the P contents of straw were very low (0.003-0.03% P) and the variation between the results was great, the figures for straw P were unreliable and hence were disregarded. They were below the critical value of 0.03% (Section 3.4). Grain P varied between 0.15 and 0.30%, which is below normal (Section 3.4) and, like straw P, indicates that the crops had been phosphorus-stressed, even with P fertilizers.

Figure 38 relates grain P and yield at different P rates in some representative fields. Obviously there was no gradual transition from a predominant increase in grain yield to a predominant increase in P content such as found with nitrogen. This implies that grain P cannot be used as a parameter to predict yield response to fertilizer.

In Figure 39 grain P of fertilized wheat (40 kg P_2O_5/ha) has been plotted against

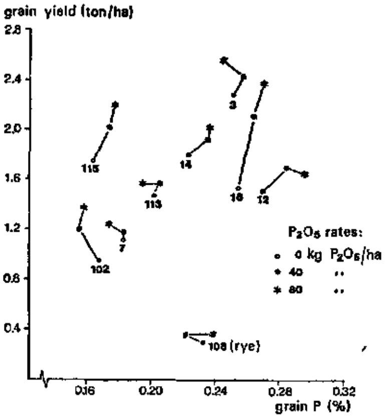


Fig. 38. Effects of phosphorus dressing on yields of wheat and rye and on phosphorus content of grain. Numbers are of the trial fields.

Şekil 38. Fosforla gübrelemenin Buğday ve Çavdar verimleri ve tanedeki fosfor miktarına etkileri. Rakkamlar tarla denemelerine ait numaralardır.

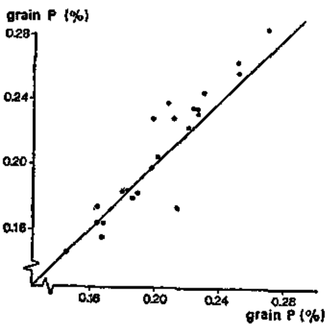


Fig. 39. Relation between phosphorus content of grain in P_1 (ordinate) and P_0 (abcissa) plots.

Şekil 39. P_1 muamelesinde (ordinat) tanelerdeki fosfor miktarı ile P_0 (apsis) muamelesinde tanelerdeki fosfor miktarı arasındaki ilgi.

grain P of wheat without P fertilizer. This graph indicates that the availability of soil and fertilizer P was promoted by the same circumstances. Grain P was not increased by fertilizer P, if grain P on control plots was low, but if the control had a higher grain P, fertilizers raised grain P even more.

Grain P was not influenced by nitrogen fertilizer when nitrogen did not change the yield. When yield was increased by nitrogen, grain P fell.

7.3.3 Interrelations between phosphorus in soil, crop and fertilizer, and transpired moisture.

The main difficulty in studying these complicated relations is that moisture influenced the availability of P of both soil and fertilizer, in the same direction.

For 1966-7 the relation between grain P and calculated transpired moisture was rather clear, but for 1967-8 there seemed to be no relation (Fig. 40). At higher moisture supply grain P was lower in 1968 than in 1967.

The differences between the years may be explained as follows. In 1966-7 spring rainfall supplied a larger share of transpired moisture than in 1967-8 (Janssen, 1970b). Spring rains moisten surface soil chiefly and therefore increase the amount of P, that can be taken up by plants, more than moisture in subsoil does. But both rains and subsoil moisture increase dry-matter production. This may explain why grain P was so low on fields 4, 102 and 115 (Fig. 40); there a fairly great part of the transpired moisture was withdrawn from deeper than 100 cm. On the contrary, on fields where rainfall had contributed more than 100 mm of the transpired moisture, grain P was always above 0.22% (fields 1, 3, 12, 14 and 16).

There are further complications. Moisture promotes control yields directly, as well as indirectly by increasing availability of soil P. Moisture allows also high yield increments with fertilizer P. But if control yield is already high, through the direct and indirect effect of moisture and hence is close to the maximum yield allowed by moisture supply, yield increments from fertilizer can no longer be high. So increase in moisture supply may cause either high or low values of *Yi*/P, as expressed in the irregular shape of Figure 37 (cf. Section 3.2.1).

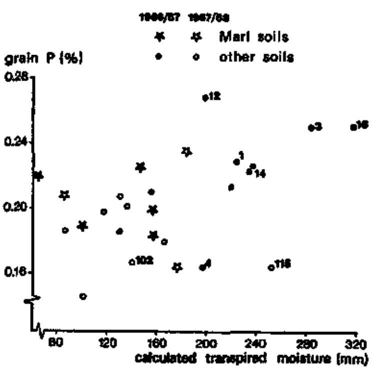


Fig. 40. Relation between phosphorus content of grain in the P_0 plots and calculated transpired moisture. Numbers are of the trial fields.

Şekil 40. P_0 muamelesiyle tanelerdeki fosfor miktarı ile hesaplanarak bulunan sarfedilmiş nem miktarı arasındaki ilgi. Rakkamlar deneme tarlalarına ait numaralardır.

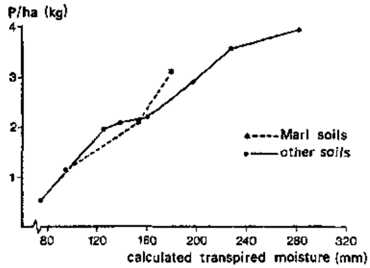


Fig. 41. Relation between phosphorus withdrawal (ordinate) and calculated transpired moisture for Marl soils and other soils.

Şekil 41. Marn topraklar ve diğer topraklar için fosfor alımı (ordinat) ile hesapla bulunan sarfedilmiş su miktarı arasındaki ilgi.

The effect of moisture on grain P was so predominant, that no influence could be shown of other factors, such as soil P or pH (carbonate content). Thus grain P had the same range on Marl soils as on the other soils (Fig. 40).

Withdrawal of P depended chiefly on moisture conditions, since control yield depended on it (Fig. 41). Differences between the Marl soils and other soils were not noted. Withdrawal was extremely low, through both low yield and low P content in the crop, emphasizing the poor P status of the Basin soils.

The recovery of fertilizer P followed the same irregular pattern as *Yi*/P. The very low recovery would be a combined result of high pH, low root density and arid conditions.

7.3.4 Soil units and phosphorus

Table 20 gathers some of the preceeding results, as averaged per soil unit. Unlike the nitrogen data (Table 19), the different parameters were unrelated to each other. The data are not suitable as a basis for fertilizer recommendations. Grain P did not vary much; the higher contents on Bajada soils were related to better moisture conditions, which caused also the higher values for *Yi*/P and P withdrawal on those soils. The high carbonate content of the Marl soils kept *Yi*/P values and hence also P recovery low.

Table 20. Phosphorus parameters, averaged per soil unit.

Soil unit	P-Olsen (mg P_2O_5/ 100 g soil)	Grain P (%) (P_0 plots)	*Yi*/P (kg grain/ kg P)	P withdrawal (kg P/ha)	P recovery (%)
Te	1.7	0.18	9.7	2.0	1.8
ThA	0.9	0.18	11.0	1.8	2.8
BrA	1.1	0.22	12.6	3.1	3.0
BrB	2.3	0.21	15.3	3.2	4.3
LmA-K	2.3	0.20	4.9	2.7	1.7
LmA-H	2.4	0.20	3.8	0.9	1.1
LmC	1.7	0.20	9.6	2.3	1.8

Tablo 20. Her bir toprak ünitesi için ortalama fosfor parametreleri.

7.4 Other nutrients

In addition to nitrogen and phosphorus, potassium received some attention in the field trials of 1966-7. No yield response to potassium was found (Section 6.2).

Contents of available potassium in soils, as analysed at Ankara, varied between 75-300 kg K_2O/dekar, about the same range as elsewhere in Turkey (Section 3.1).

Further information on potassium and all information on magnesium and calcium was derived from chemical analysis of grain and straw. The results are gathered in Table 21. Nutrient contents varied less in grain than in straw, but standard errors were higher in straw samples (uneven mixtures of leaves and stalks). Between soils there was not much difference, but between the years there was. The potassium contents of grain, but especially of straw were higher in 1966-7 than in 1967-8. This may have been caused by the wetter conditions in the former season.

Table 21. Percentages of potassium, calcium and magnesium in grain and straw samples from control plots (%).

Soil unit	K		Ca		Mg	
	1966-7	1967-8	1966-7	1967-8	1966-7	1967-8
Grain						
Te	0.36	0.30	0.03	0.03	0.12	0.11
ThA	0.30	0.30	0.04	0.03	0.10	0.12
BrA	0.35	0.31	0.03	0.03	0.13	0.11
BrB	0.35	0.28	0.04	0.02	0.13	0.10
LmA-K	0.32	0.30	0.02	0.02	0.11	0.11
LmA-H	0.34	0.30	0.04	.	0.11	0.11
LmC	0.35	.	0.04	.	0.12	.
Average	0.32	0.30	0.03	0.03	0.12	0.11
Straw						
Te	1.23	0.69	0.16	0.22	0.08	0.12
ThA	0.80	0.60	0.22	0.27	0.09	0.13
BrA	1.05	0.64	0.14	0.24	0.05	0.08
BrB	1.01	0.65	0.14	0.19	0.06	0.08
LmA-K	1.23	0.88	0.13	0.13	0.08	0.08
LmA-H	1.16	0.50	0.24	0.22	0.11	0.14
LmC	1.44	.	0.15	.	0.07	.
Average	1.11	0.68	0.16	0.21	0.07	0.10

Tablo 21. Kontrollü yerlerden alınmış örneklerin tane ve sapında yüzde olarak potasyum, kalsiyum, magnezyum miktarları.

7.5 Other factors

Besides water and nutrients, many other factors determine yield. Although I tried to keep them as equal as possible on the various fields, many irregularities influenced yields. Sometimes I could correct for them or estimate their extent.

The most important factors were as follows.

The *farmers* were not equally conscientious about tillage so that there were differences in the tilth of seedbeds and in weediness. I often could not discover when the preceeding stubble field had been ploughed; differences, however, certainly existed and must have influenced yields markedly (Section 2.2). The differences in the farmers' tending for the fields could not be quantified. I tried to avoid them by selecting only well tended fields (Section 4.1.1).

The quality of the *seedbed* was further determined by soil characteristics. In general Marl soils gave the finest seedbeds and could be easily worked. Hard big clods were found chiefly on BrA soils and big stones on ThA soils and on soils transitional from Bajada to Colluvial. On some fields, hard plough pans occurred at a depth of about 10 cm. Clods and stones hampered operations with the lightweight hand-drill, so that fertilizing and sowing did not always go as smoothly as desired. Irregularities in these operations proved to have had only small effect on yield.

Slaking occurred chiefly on Marl soils. It caused considerable yield depressions on Field 6 (LmA Konya), up to 25-30% on some plots. On other fields, slaking or some waterlogging was found in plough furrows or against ridges (e.g. fields 102, Te; 107, LmA Konya and 108, LmA Hotamış). The main effect of these unevennesses was an increase in variation between replicates.

Nearly all the fields were laid out on flat land. Some fields, however, were situated on gentle *slopes* (fields 3, 11, 113, BrA; 13, BrB). The differences between replicates and strips on a slope, indicate the slope effect. The plots low on the slope yielded more than higher plots (20, 5, 15 and 20% respectively, for the fields).

On the other fields too differences between replicates and strips were found. Usually they amounted to 2-15% of the average yield. When yields were very poor, the variation was higher (up to 50% on LmA Hotamış).

On some fields there proved to be, often inexplicably, *good* and *bad patches*. On some fields on the irregular soil units ThA and BrB, a detailed survey was made of

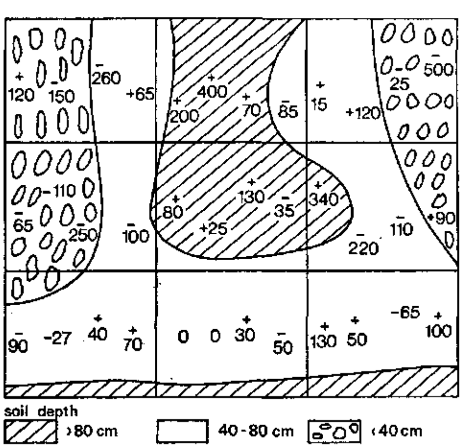


Fig. 42. Influence of soil depth on yield. Numbers are the differences in kg grain per ha from the average yield of the treatment.

Şekil 42. Toprak derinliğinin mahsul üzerine etkisi. Rakkamlar, her bir muamelenin, ortalama mahsul miktarına göre hektar başına kg olarak tanede yaptığı değişiklikleri göstermektedir.

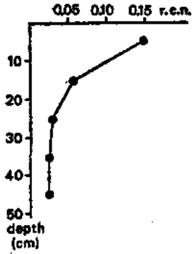


Fig. 43. Average root distribution in a Flat Terrace soil, as indicated by the root covering number (rcn).

Şekil 43. Kök Kaplama Sayısı (rcn) ile işaret edilen bir düz teras toprağında ortalama kök dağılışı.

profile depth, to seek any relation with yield differences between replicates. Where the soil profile was deeper than 80 cm, yields were generally higher that in shallow parts of the field, as is shown for Field 104 (ThA) in Figure 42.

A study on *root density* was started in June 1967 (Section 4.1.2), but it had to be stopped soon as the augers continually broke in the hard dry soils.

Root density was expressed in a 'root-covering number', being the percentage area occupied by roots in cross-sections of cylindrical borings.

The average root distribution in the upper 50 cm of Field 1 (Te) is shown in Figure 43. The impenetrable subsoil of lime started at about 50 cm, so that only the upper part of the profile was examined. Most of the roots were in the upper 20 cm. Between the differently fertilized plots, there was no clear difference but there were too few observations to permit definite conclusions. Schuurman & Knot (1957) give root-covering numbers ranging between 0.01 and 2.0% for oats. The value found here, 0.15% for the surface soil, is far below their maximum.

The most frequently occurring *weeds* were *Glaucium corniculatum* (L.) J. H. Rudolph, *Boreava orientalis* Jaub. et Spach and *Centaurea depressa* Bieb. Nitrogen fertilizer promoted their growth. In 1967 they grew more luxuriantly than in 1968. No estimate could be made of the yield loss but, especially on drier fields, competition for moisture must have been considerable.

Some damage was done by an *insect*, called 'bambul' (Anizoplia sp.). In 1968 they were combated with Hektavin (fields 101, 102, 104 and 115). The damage was estimated not to exceed 1-3% of yield. On some fields, especially on BrA soils (fields 3, 14 and 114), open patches were found. According to the farmers, certain grubs were responsible but this could not be ascertained.

Loose smut (Ustilago tritici) was found on fields 1, 2, 103 (Te); 4 (ThA); 6, 106 (LmA Konya); 11, 12, 14 (BrA); 115 (BrB). Yield depression was assessed at up to 2%.

Rather damage could be done by *groundsquirrels* (Citellus spp.) which have been described by de Meester (1970, p. 280-290). Especially some plots of Field 2 (Te) were damaged, with estimated yield losses of 10-25%.

Also large animals, like sheep and horses, proved to have visited some fields. Usually the damage was only a great bite here and there. As fields were selected more carefully in the second year in the central parts of the cropped area, whither herds did not reach, this type of loss was not found in 1968.

8 Discussion and conclusions

The purpose of this research in the Basin was to gain information about the agricultural value of the soils, to analyse the factors determining soil fertility there and to make fertilizer recommendations. The recommendations are given in the Chapter 9.

8.1 Yield factors and soil units

The agricultural value of soils is difficult to assess, because of the many factors involved, such as management system, that are not pertinent to the soil. De Meester (1970) distinghuished three management systems for the Basin:

1 Dry farming, no fertilizers, little capital or skill
2 Dry farming with fertilizers, more capital and skill
3 Irrigated farming, with fertilizers, sufficient capital and skill, which system was ignored in my research.

The most important yield factors for dry farming in the Basin are water, nitrogen and phosphorus.

Water supply depends directly on precipitation during growth and indirectly on precipitation during fallow, because rainfall supplements moisture reserves in the soil. The soils used for agriculture can store infiltrating rainwater easily. The proportion of water infiltrating is sometimes limited by slaking (Marl soils), which results in higher evaporation.

Precipitation is not related to soil units, but as Figure 2 shows, it coincides to some extent with topography. The centre of the Basin is drier than the borders along the Uplands. This means that in general the Colluvial, the Bajada and the Undulating Terrace soils receive more precipitation than the Hotamış Marl soils and the Flat Terrace Soils. The Konya Marl soils are intermediate.

The second yield factor, *nitrogen*, is related to organic-matter content of the soils. Small differences in organic nitrogen caused considerable changes in soil nitrate. Nitrogen fertilizers are of no benefit if organic matter exceeds 1.6%. Higher values are found in Te, BrB of the Karaman Area, and LmC. BrB soils in the Ereğli Area, BrA and ThA have less organic matter. LmA is intermediate.

I did not investigate why organic-matter contents differ between soil units. Low contents may be caused by erosion of surface soil: BrA and ThA often slope, whereas Te is flat. LmC was marshy until some years ago and hence has much organic matter (de Meester, 1970). Some soils have been cultivated for thousands of years. Differences in the duration of cultivation may also have caused differences in content of organic matter.

The poor nitrate status of BrA and ThA is probably worsened by the higher rainfall there, by which nitrate can be leached out of the plough layers, whereas in the drier conditions of Te and Hotamış Marl soils nitrate may accumulate in the surface soil.

The availability of *phosphorus*, the third factor, is chiefly regulated by moisture conditions. Availability depends on distribution of moisture through the profile and not only on total amount of transpirable moisture: moisture in surface soil (from rainfall) promotes availability more than subsoil moisture (from fallow). Hence soil phosphorus tests do not supply much information. The need for moisture measurements in calibrating soil phosphorus tests has been emphasized by Collwell & Esdaile, 1968.

The only direct relation between soil units and phosphorus was that the response to fertilizer on Marl soils was less than on other units because of the carbonate.

Control yields varied widely. High yield increments with fertilizers were obtained only if the control yields were not too high or too low (Fig. 23). Conditions for high control yields are high supply of moisture and high nitrogen level. Average figures from the three fields with a control yield above 1800 kg/ha were 250 mm calculated transpired moisture, 130 mm stored moisture and 1.17% organic nitrogen. For the four fields with control yields below 700 kg/ha, these figures were 85 mm, 35 mm and 1.10‰, respectively, indicating that it was moisture deficiency that limited control yield.

The highest yield increments with fertilizers were obtained where moisture supply

Table 22. Moisture, nitrogen and yield data, averaged per soil unit.

Soil unit	Number of fields	Calculated transpired moisture (mm)	Organic nitrogen (‰)	Control yields (kg/ha)	Highest yields (kg/ha)	Highest yield increments (kg/ha)
Te	5	135	1.10	1150	1540	390
ThA	2	157	0.74	890	1850	960
BrA	7	195	0.75	1195	1985	790
BrB[1]	2	245	1.26	1710	2250	540
LmA-K	4	165	0.89	1245	1815	570
LmA-H	3	82	1.08	480	735	255
LmC	1	155	0.87	1240	1560	320
Field 16 (fooded)		317	0.66	1540	2840	1300

1. Only the fields 15 and 115 (Karaman Area).

Tablo 22. Her bir toprak ünitesi için ortalama, nem, azot ve mahsule ait kayıtlar.

was high and content of organic nitrogen low. The average figures of the five fields with increments of more than 900 kg/ha were 220 mm calculated transpired moisture, 100 mm stored moisture and 0.76‰ organic nitrogen, showing that it was nitrogen deficiency that limited control yield.

The other fields with intermediate control yields and intermediate responses to fertilizers had either intermediate moisture values or intermediate nitrogen contents (Table 22).

8.2 Soil survey and soil fertility

The soil survey and the fertility research of the Basin complemented each other, in that the soil survey was useful firstly to indicate soils unsuitable for agriculture because they were too shallow, too steep, too salt-affected, too sandy, too wet or too stony, or had horizons impenetrable to roots, or were derived from parent materials inhibiting plant growth (e.g. too much carbonate). De Meester (1970) used these characteristics in his suitability classification. Further survey of the unsuitable soils was not interesting for the fertility research.

As pointed out in the previous section, the most important characteristics of soils suitable for agriculture are moisture supply and content of organic matter. Fortunately the groundpattern of these factors is often related to the distribution of soil units, but further division of the units ThA, LmA and BrB on the factors would have been desirable.

The unit ThA comprises shallow and deep profiles, which differ much in water-holding capacity. However, the differences occur within short distances so that more detailed survey was not practical.

The unit LmA was originaly divided into profiles with a 'thin' and a 'normal' surface soil (Janssen, 1969); later I grounded the distinction on differences in precipitation in the subunits LmA Konya and LmA Hotamış differing much in productivity. Yet some differences in soil properties did exist, for instance colour, CEC, porosity of the surface soil and moisture characteristics.

As the unit BrB is not uniform in organic matter, division would be desirable. For ease of survey, differences in organic matter could perhaps be associated with differences in slope (Section 8.1).

It should be stressed here that the rather good coincidence between soil units and fertility units was favoured by the fact that the soils had not previously received fertilizers. As soon as the farmers start to use fertilizers, the relation fades, and fertility becomes more and more dependent on cultivation history of each field.

The relation between soil unit and fertility is also simple because dry farming consists almost entirely of wheat farming. To make fertilizer recommendations by soil units has little sense for irrigated agriculture. Even so the connections found here between soil units and fertility may still be helpful for the study of fertilizer requirements of irrigated crops.

8.3 Yield factors and yield components

Knowledge of which yield components are involved in yield changes helps to clarify the action of yield factors. I analysed grain yield into the following components.

$$\text{Grain yield} = \text{straw yield} \times (\text{grains/g straw}) \times \text{1000-grain weight} \quad (14)$$

$$\text{Straw yield} = \text{number of tillers} \times \text{tiller weight} \quad (15)$$

$$\text{Grains/g straw} = (\text{ears/tiller}) \times (\text{grains/ear}) \times (1/\text{tiller weight}) \quad (16)$$

Table 23 notes the times when the components have reached their final value.

Extra *moisture* increased total dry-matter production, but decreased harvest index (Fig. 28). The increase in total dry-matter production was caused by an increase in number of tillers and in tiller weight. The decrease in the number of grains per g straw, which brought about the lower harvest index, must have been caused by either a decrease in ears per tiller or in grains per ear or by an increase in tiller weight (Eq. 16). The increase in tiller weight is probably the main factor. It is improbable that ears per tiller was lowered, as the ears were formed before the extra moisture had been utilized (Table 23). Seed set (grains per ear) was perhaps lowered because of drought in the second half of June, through the greater moisture demands of the larger and more numerous plants. With the reduction in number, the remaining grains could be filled normally.

It was noted that in 1968 the harvest index exceeded that in 1967, through a rise both in number of grains per g straw and in 1000-grain weight. One cause of the higher number of grains per g straw in 1968 was the lower tiller weight in 1968 (shorter stalks). Whether ears per tiller and kernels per ear differed between the years was not checked. In 1968 the number of tillers and hence the number of grains per m^2, was less than in 1967. That was why the dry-matter isoquants lay higher for 1968 than for 1967 (Fig. 25) and why 1000-grain weight in 1968 was higher (more moisture per grain available after flowering).

These phenomena agree with results of Campbell (1968) and Storrier (1965a). The

Table 23. Times when yield components of dry-farmed wheat have reached their final value in the Basin (schemetic).

			Component	Time
	Straw yield		Number of tillers	Before mid May
			Tiller weight	End of June
Grain yield		Grains/g straw	Ears/tiller	Before mid May
	Harvest index		Grains/ear	End of June
			1000-grain weight	Mid July

Tablo 23. Havzada kuru ziraat buğdayının mahsulü teşkil eden kışımlarının son değerine ulaştığı zamanlar (taslak).

conclusion seems justified that higher yields could be obtained if the wheat flowered earlier, as more moisture would be available during the critical stage around flowering. The same was observed by Fischer & Kohn (1966) and Nix & Fitzpatrick (1969).

Thus the grain yield increment caused by extra spring rain and extra stored moisture is brought about chiefly by an increased number of ears (tillers); it is to some extent counteracted by a decrease in harvest index, caused by higher tiller weight. The 1000-grain weight may be promoted to some degree, perhaps by a decrease in number of grains per ear.

The effect of *nitrogen* on yield components may be distinguished as follows (Table 12).

1 Increase in grain yield, no change in harvest index. The increase in dry-matter production was caused by an increase in number of tillers and in tiller weight. This caused drought during seed filling so that 1000-grain weight decreased. Although tiller weight was increased, grains per g straw increased or did not change, so that either ears per tiller or grains per ear must have increased (Eq. 16). Increase in ears per tiller was improbable, since number of tillers had already increased and since there was not much moisture avaibable during ear formation for fields 106, 107 and 113 (Table 17; April 1968). So grains per ear must have increased (longer culms, longer ears).

2 Increase in grain yield, slight decrease in harvest index. The decrease of harvest index was caused by a decrease in 1000-grain weight or in grains per g straw. Increased tiller weight is responsible for the decrease in grains per g straw but as the decrease was less than the increase in tiller weight, ears per tiller or grains per ear must still have increased.

3 No change in grain yield, increase in dry-matter production, decrease in harvest index. On these fields initial positive nitrogen effects were nullified by lowering of 1000-grain weight and grains per g straw. There grains per g straw decreased more than tiller weight increased, so that grains per ear or, less probably, ears per tiller must have decreased too.

4 No change in dry-matter production. These fields are high in soil nitrogen and commonly also in May there was no influence of nitrogen. Any decrease in 1000-grain weight was probably caused by more severe drought through increased foliation.

5 Decrease in dry-matter production. These fields were high in nitrogen and low in moisture. Probably number of tillers or of plants was decreased by damage during germination (salt injury).

From Point 1 to Point 5, the stage at which negative effects appear becomes earlier and, less clearly, the nitrogen content of soil increases. Only in few fields was initial positive response to nitrogen completely nullified by water deficiency later in the season. Lack of response in grain yield was already apparent in most fields from lack of response in plant height in May. Hence the reason could not be exhaustion of moisture supply but must be high soil nitrate.

Early flowering would also improve response to nitrogen.

Postponement of the dressing may be advantageous in that it enables a judgment of moisture conditions in spring. However the dressing should not be too late, as the main effect of nitrogen is stimulation of tillering. March is perhaps the best month. In practice there are difficulties because of inaccessibility of fields then.

Thus nitrogen promoted grain yields by increasing the number of tillers and sometimes grains per ear; the effect was always counteracted by a lower 1000-grain weight.

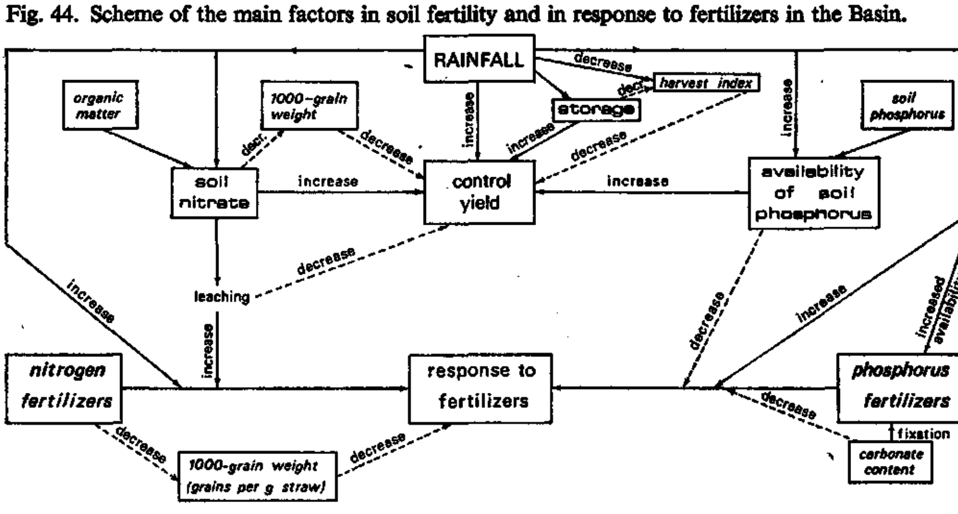
Phosphorus had in general little influence on number of grains per g straw and on 1000-grain weight. The effect on grain yield was achieved by an increased number of tillers. As tiller weight also increased (longer and thicker culms), the number of ears per tiller or the number of grains per ear or both must have increased (Eq. 16). An increase of ears/tiller is not probable as the number of tillers increased already. Thus grains/ear must have increased (longer culms, longer ears).

In a few fields, phosphorus had a negative effect on 1000-grain weight. In 1967 1000-grain weight on those fields was below average, indicating that moisture deficiency after flowering was severe on all plots of those fields. In 1968 the negative effect occurred on the very fields where 1000-grain weights was high on control plots, so that even at the highest phosphorus rates, the 1000-grain weight was not below Basin's average.

Theoretically it may be advantageous also to postpone phosphorus dressing till March, because the availability of phosphorus is improved in moist soils. A practical difficulty is that the rainfall is too low to let phosphorus penetrate the soil. Deep placement would also be impossible because of damage to roots.

Thus phosphorus promoted grain yield by increasing number of tillers and probably number of grains per ear.

Fig. 44. Scheme of the main factors in soil fertility and in response to fertilizers in the Basin.



Şekil 44. Havzada toprak verimliliğine ve gübrelemeye karşı verilecek cevaba etki eden başlıca faktörlerin şeması.

Several reasons can be put forward to explain why phosphorus gave positive results in the Basin more often than nitrogen did.

1 All soils are very low in phosphorus.
2 Phosphorus does not cause high salt concentrations (no germination damage).
3 Phosphorus may promote root growth more than nitrogen does.

The main factors influencing control yield and yield response to fertilizers are presented schematically in Figure 44. Central in the scheme is the influence of rainfall, because in the Basin it increases control yield and response to nitrogen. Rainfall increases the availability of soil phosphorus and so sometimes counteracts its positive direct influence on response to phosphorus fertilizer.

8.4 Final remarks

Fallow system The system of fallow is often condemned because of low efficiency of fallow, 20 to 30%. However, the percentage of rainfall during the cropping season available for the crop is also about 30%, as the plant can only take up infiltrated water for transpiration. Hence, if precipitation in two subsequent years is about equal, the contributions to transpiration by stored moisture from fallow and by rainfall from the cropping season must be about the same, as was found (Janssen, 1970b). Similar results are mentioned by Nix & Fitzpatrick (1969), who found as averages over a 16-year period that storage and rainfall contributed 52 and 48% to crop evapotranspiration, respectively. If fallow were abolished in the Basin, on many fields less than 100 mm transpirable moisture would be available and crops would fail. Even if the yield of crops each year were slightly higher than the yield of a crop every alternate year in the fallow system, the latter would be more profitable, because seed and labour are expended only once.

Greenhouse trials The results of this study give an indication of the value of the introduced system of greenhouse trials.

For nitrogen there was good agreement with results in the field. Since, however, SQ_N was related quantitatively with nitrate content of the soils, it is easier to determine soil nitrate. If no laboratory is available, greenhouse trials are an alternative.

For phosphorus results did not correspond with field results. The reasons were that phosphorus economy was regulated primarily by moisture conditions and that all soils were low in phosphorus.

Chemical analysis of wheat For a preliminary assessment of nitrogen requirements it is easiest to determine grain nitrogen. For research on fertility in the dry-farming system in Turkey, determination of grain nitrogen should be encouraged, as it allows a quick survey of nitrogen status of the soils and of the response to nitrogen dressing that can be expected. It can indicate whether and where trials with nitrogen fertilizers are justified. For the wheat variety used, 111/33, no (further) response to nitrogen fertilizers would be expected, if grain N exceeds 2.0-2.2%.

8.5 Conclusions

The main conclusions of this study on the soil fertility of the Basin are:

1 *General*

1.1 Differences in productivity of the soils suitable for crops depend largely on moisture conditions and on content of organic matter.

1.2 Wheat yield can be predicted in May by combining records on height, growth stage and crop density.

1.3 Higher yields can be obtained when the flowering period of wheat is advanced.

2 *Moisture*

2.1 The fallow year is essential.

2.2 The effect on yield of increased moisture supply is brought about by increased tillering.

2.3 The relation between transpiration and maximum production of dry-matter, where moisture is the limiting factor, is: $DM = 28 \cdot T$, where DM = production of dry-matter in kg/ha, and T = total transpiration of the crop in mm.

3 *Nitrogen*

3.1 Response to nitrogen fertilizers depends on moisture conditions and on content of organic matter. Where there is more than 1.6% organic matter, the response is absent or low.

3.2 Extra nitrogen decreases 1000-grain weight. If there is a yield increase, it is due to increased tillering and sometimes increased grains per ear.

3.3 Grain nitrogen is a good indication of nitrogen supply for wheat; with more than about 2.0-2.2% nitrogen in grain, no response to nitrogen can be expected.

3.4 Nitrate and organic nitrogen in soil are both suitable indicators of response to nitrogen, if the moisture conditions are also known.

3.5 The technique of greenhouse trials gives a good estimate of available nitrogen (nitrate) in soil.

4 *Phosphorus*

4.1 Response to phosphorus fertilizers depends on moisture conditions and on content and texture of carbonate.

4.2 Phosphorus fertilizer raises yield by increasing the number of tillers and probably the number of grains per ear.

4.3 Grain phosphorus is not suitable as an indicator of responses to phosphorus.

4.4 The significance of laboratory soil tests for phosphorus is doubtful.

4.5 The technique of greenhouse trials does not provide information on response to phosphorus.

9 Fertilizer recommendations

9.1 Methods of determining the optimum combination of fertilizers

The most economic rates of fertilizers can be determined algebraically or graphically. Both methods are based on the same principles. For extensive discussion, see Heady (1956), Munson & Doll (1959), Willemsen & Ferrari (1959) and Dillon (1968).

9.1.1 Algebraic method

The algebraic method requires the fitting of experimental data into a response function. Over the years many functions have been proposed, whether based on biological models or not. They all assume returns diminish. When the net return on the last unit of fertilizer added becomes zero, i.e. when the price of the product formed with the last unit of added fertilizer equals the price of the fertilizer unit, profit is maximized. At that point the distance between yield and costs (both in money) is maximum:

$$P_Y \, dY - P_f \, dF = 0, \text{ or } dY/dF = P_f/P_Y \qquad (17)$$

where P_Y and P_f are the prices of unit of product and of fertilizer.

When the response function (Y) is known, the optimum fertilizer rate can be calculated by making the first derivative equal to the price ratio of a unit of fertilizer and a unit of product.

My yield data have been fitted into quadratic equations of the form:

$$Y = Ax_1 + Bx_1^2 + Cx_2 + Dx_2^2 + Ex_1x_2 + Fx_3 + Gx_4 + \text{constant} \qquad (18)$$

where

x_1 = nitrogen rate in units of 30 or 20 kg N/ha, according to the rates used (Section 4.1.1)

x_2 = phosphorus rate in units of 40 kg P_2O_5/ha

x_3 = block effect

x_4 = strip effect

To find the profit-maximizing combination of nitrogen and phosphorus the partial derivatives were first set for x_1 and x_2 of Equation 18 and made equal to the price ratios of the two fertilizers and the product. (Equation 17). Let R_1 and R_2 be the price ratios of a unit N and a unit P_2O_5 per kg product. Then

$$dY/dx_1 = A + 2Bx_1 + Ex_2 = R_1$$
or

$$x_1 = \frac{R_1 - A - Ex_2}{2B} \tag{19}$$

and

$$dY/dx_2 = C + 2Dx_2 + Ex_1 = R_2$$
or

$$x_2 = \frac{R_2 - C - Ex_1}{2D} \tag{20}$$

Equation (19) gives the economically optimum rate of x_1 at known rates of x_2 and Equation (20) gives the optimum rates of x_2 at known rates of x_1. The optimum combination of x_1 and x_2 is given by simultaneously solving Equations 19 and 20:

$$x_1 = \frac{2D(R_1 - A) - E(R_2 - C)}{4BD - E^2} \tag{21}$$

$$x_2 = \frac{2B(R_2 - C) - E(R_1 - A)}{4BD - E^2} \tag{22}$$

The prices used for the calculations and the corresponding values of R_1 and R_2 are presented in Table 24.

Equations 21 and 22 were difficult to solve from the results of some fields for the following reasons.

1 The yield responses to fertilizers did not always follow the law of diminishing returns. This means that B or D (Eq. 18) is positive or about zero (increasing outputs or linear response, respectively). Under such conditions an economic optimum does not exist. Solution of Equations 21 and 22 leads to strange figures for x_1 and x_2.

2 Sometimes the values of A or C were small (no significant linear response). If so, Equation 21 or 22 gives a negative value for x_1 or x_2, respectively. This difficulty can be avoided by substituting $x_2 = 0$ in Equation 19, or $x_1 = 0$ in Equation 20, and

Table 24. Prices in Turkish Lira (TL) per kg and price ratios of grains and fertilizers.

	Prices	R_1		R_2
		$x_1 = 20$ kg N	$x_1 = 30$ kg N	$x_2 = 40$ kg P_2O_5
Wheat	0.78	70.8	106.2	101.2
Rye	0.57	96.9	145.3	138.7
Ammonium sulphate	0.58			
Triple phosphate	0.85			

Tablo 24. Harbir kg gübrenin ve tanelerin fiat oranlarının Türk Lirasi (TL) değerleri.

solving the remaining equations:

$$x_1 = \frac{R_1 - A}{2B} \qquad (x_2 = 0) \tag{23}$$

$$x_2 = \frac{R_2 - C}{2D} \qquad (x_1 = 0) \tag{24}$$

To avoid the difficulty of Point 1, B and D should also now be negative (diminishing returns).

Whether to use equations 21 and 22 or equations 23 and 24 can most easily be decided from the calculated values of Yi/N and Yi/P. To get any net return for wheat from nitrogen, Yi/N should be at least

$$(\frac{100}{21} \times 0.58) / 0.78 = 3.54$$

and similarly for phosphorus, Yi/P should be at least

$$(\frac{100}{43} \times \frac{142}{62} \times 0.85) / 0.78 = 5.80.$$

For rye the values must be at least 4.85 and 7.95, respectively.

Equations (21) and (22) were used on fields 3, 11, 12 (BrA) 13, 16 (BrB), 104 (ThA); 6 (LmA Konya) and 8 (LmA Hotamış). Equation (23) was used for fields 112 and 113 (BrA) and 107 (LmA Konya, rye) and Equation (24) for fields 1, 2, 101, 102 (Te), 9 (LmC), 106 (LmA Konya, rye), 10 (LmA Hotamış); 114 (BrA) and 115 (BrB). Yi/N and Yi/P were both too low for fields 7 (LmA Konya); 108 (LmA Hotamış, rye) and 103 (Te). Economic optima could not be calculated by the algebraic method (no diminishing return) for fields 4 (ThA), 14 (BrA) and 15 (BrB).

9.1.2 Graphical method

The response function for two variables cannot be represented by a single curve. It depicts a surface in three-dimensional space with axes x_1, x_2 and Y. Because of the difficulty of three-dimensional graphs, the function is often represented by a series of two-dimensional curves. These curves are either vertical (Fig. 45B) or horizontal (Fig. 45C) sections of the response surface (Fig. 45A). The vertical sections form together a family of response curves to one fertilizer at constant rates of the other fertilizer; the horizontal sections form a family of isoquants.

The position of the isoquants must be calculated by rewriting Equation 18 and solving the new equation for fixed yields; for instance

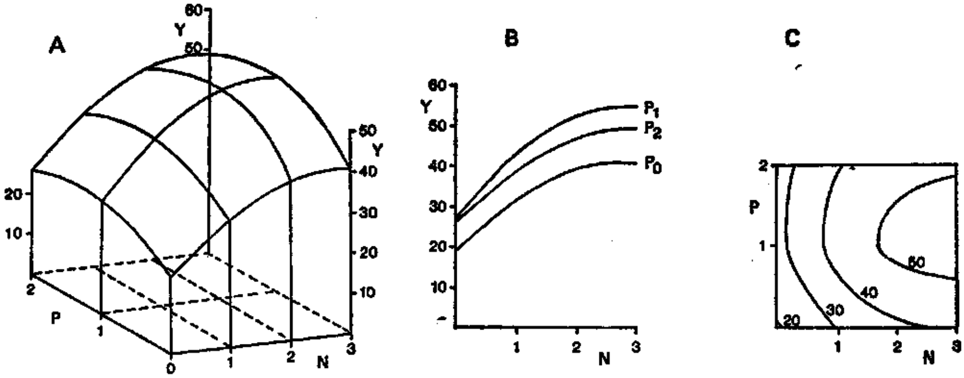
$$x_2 = \frac{-C-Ex_1 \pm \{x_1^2(E^2-4BD)+2x_1(CE-2AD)+C^2-4DK+4DY^*\}^{0.5}}{2D} \tag{25}$$

Where Y^* = fixed yield

$K = Fx_3 + Gx_4$ + constant from Equation 18.

Another way of obtaining the isoquants is to determine where single fertilizer

Fig. 45. Three-dimensional response surface (A), family of response curves to nitrogen at constant phosphorus rates (B), and family of isoquants (C).



Şekil 45. A. Üç boyutlu Sorumlu Saha (response surface). B. Sabit fosfor miktarında azota sorumlu eğriler familyası ve. C. Izoquantlar familyası.

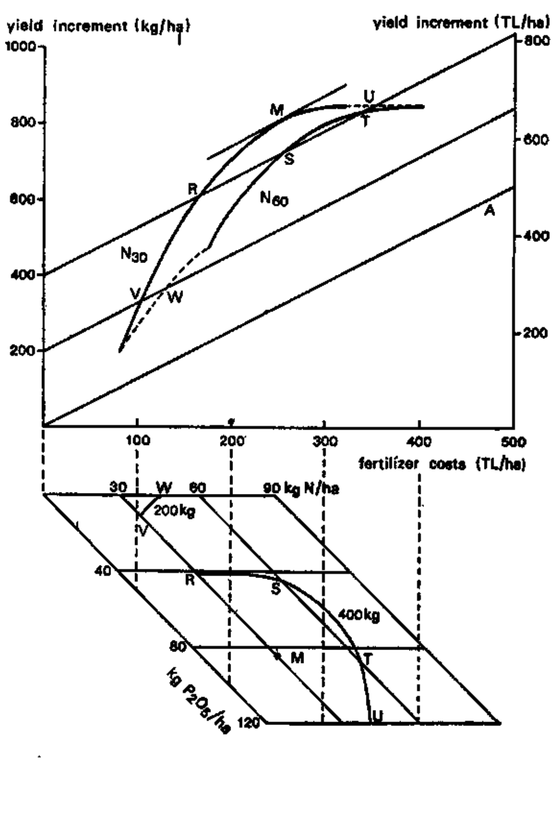


Fig. 46. Plan for the graphical construction of iso-profit maps. For explanation see text.

Şekil 46. Grafiksel olarak eş-kâr (iso profit) haritalarının yapılması için plân. Izah için yazı kısmına bakınız.

response curves (Fig. 45B) intersect the yield levels to be mapped in the isoquant diagram and to plot these points as in Figure 45C. Connexion of these points results in isoquants.

Figure 46 shows a graphical method of determining iso-profit lines that looks like a combination of figures 45B and 45C. The variables x_1, x_2 and Y are expressed in money units. In the upper graph, x_1 and x_2 are added together and plotted on the abcissa. The lower diagram shows how fertilizer rates (x_1 and x_2) are converted into Turkish Lira and added together. The scale of the axis P_2O_5 in kg per ha has been chosen in such a way that its projection on the abscissa of the upper graph gives money units.

In the upper part the yields found with several combinations of fertilizers are plotted; the examples given are the response curves to phosphorus at the nitrogen rates of 30 kg and 60 kg per ha.

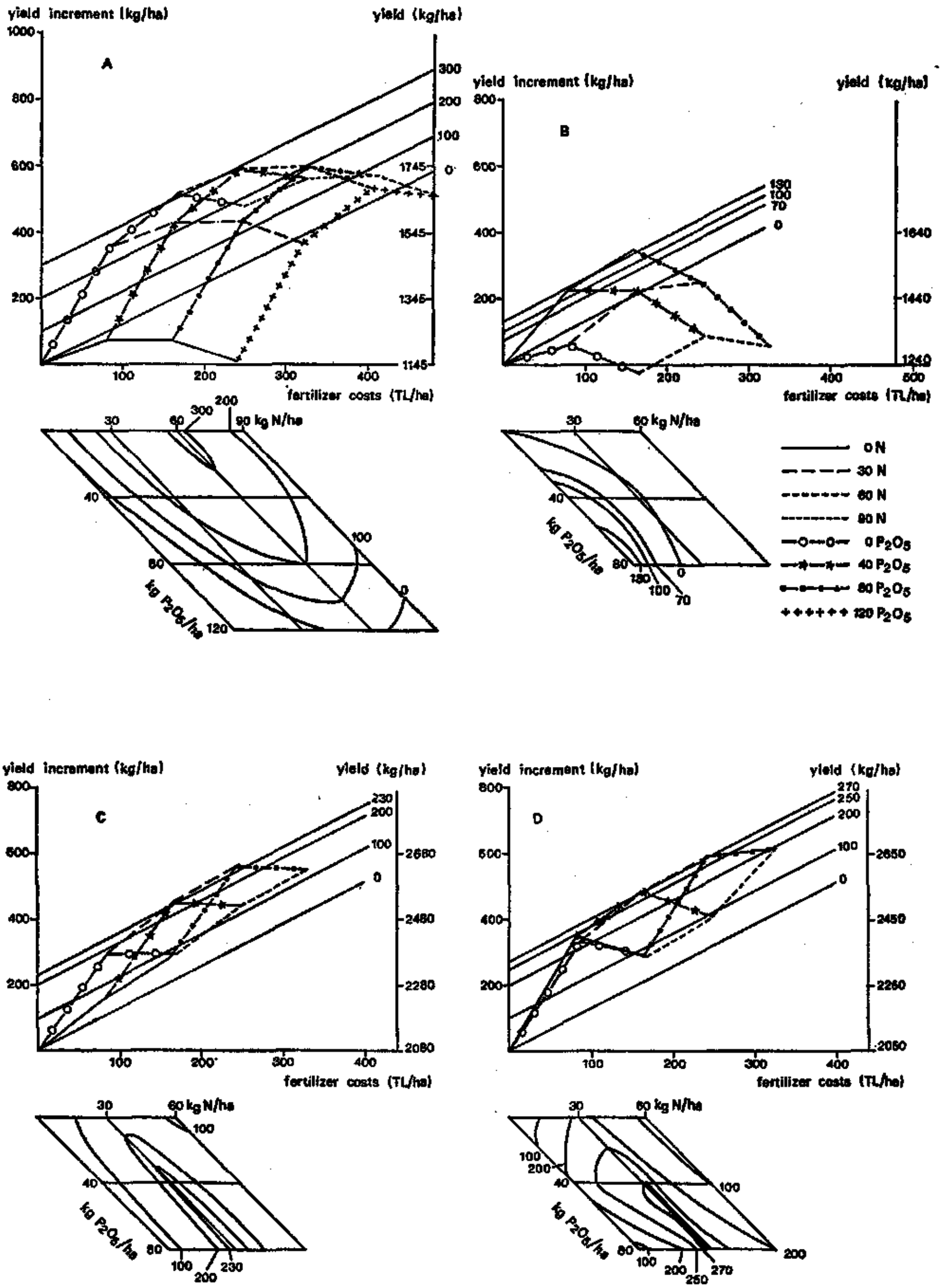
On the line $0A$, costs and gross returns are equal. Lines parallel to $0A$ represent iso-profit lines on each of which the net returns are constant. For convenience, iso-profit lines are drawn at profit rates expressed in kg wheat per ha.

The highest net return of a certain yield response curve is obtained where an iso-profit line is tangential to the response curve (Point M in the N_{30} curve). The optimum combination with phosphorus can be read off in the lower part (point M on the N_{30} line).

If the intersections of iso-profit lines with yield response curves are projected onto the lower part, connection of these projected points results in a map of iso-profit lines (not isoquants!), henceforth called iso-profit map. In Figure 46 the iso-profit lines of 200 and 400 kg wheat have been drawn, as far as they intersect the response curves at N_{30} and N_{60}. (Point V and points R, S, T). The points U and W are intersections with the response curves to nitrogen at P_2O_5 rates of 0 and 120 kg per ha.

If only a few points of the response curve are known, it is hazardous to draw smooth response curves but a reasonably accurate iso-profit map can be constructed if the points in the upper part are connected by straight lines. The usefulness of such an iso-profit map is that the financial consequences of any deviation from optimum fertilizer application can easily be analysed, e.g. Figure 47. This figure represents three fields: one with net returns only to nitrogen (Fig. 47A); one with net returns only to phosphorus (Fig. 47B); and one with net returns to both (Fig. 47C, D); Figure 47C shows yields according to the regression equation; Figure 47D shows yields as measured in the field and has less regular iso-profit lines. The optimum combination, however, is similar in figures 47C and D (30 kg N, 40-50 kg P_2O_5). The optimum rates in figures 47A and B (fields 113 and 9) are easily recognized and correspond with calculated rates (Table 25); according to Figure 47D, the fertilizer recommendation for Field 3 lies at about 30 kg N and 40-50 kg P_2O_5, the latter lower than in Table 25 (71 kg/ha). Of course the algebraic method gives exact solutions, but the diagram shows clearly that a rise from 40 to 70 kg P_2O_5 increases net returns so little that it is safer to recommend 40 kg P_2O_5 per ha.

Fig. 47. Iso-profit maps of Field 113 (A), Field 9 (B), Field 3 (C) with yields according to regression equations, and of Field 3 with yields as measured in the fields (D).



Şekil 47. Tarla 113'e (A), tarla 9'a (B), regresyon denklemlerine göre mahsullerle beraber Tarla 3'e ve tarlada ölçülen mahsul olarak tarla 3'e ait eş kâr haritaları.

9.2 Fertilizer recommendation map

9.2.1 General remarks

The costs of cultivation per ha can be calculated as follows:

160 kg seed at TL 0.95 per kg	152
Ploughing, harvesting	150
Total	TL 302

Since farmers receive TL 0.78 per kg wheat, yield must exceed 302/0.78 $\approx$ 400 kg per ha to cover costs. As control yields on fields 101 (Te), 8 and 108 (LmA Hotamış) were below 400 kg per ha, cultivation was not profitable there.

The map with recommended rates of fertilizers is based on Table 25. The net return on fertilizer has been calculated twice, firstly for the optimum combination of fertilizers for each field and secondly for the combination recommended for the whole of each soil unit. The recommended rates are a bit lower than the averages of the calculated optimum combinations, especially for phosphorus. Use is made of the information in the iso-profit maps. As Figure 47 shows, a change in phosphorus rate commonly has less effect on net returns than a change in nitrogen rate. Hence the recommendations have been stepped down more for phosphorus than for nitrogen. At these lower rates, value/costs is higher. This is mathematically shown for one element as follows:

V = gross return $= Ax + Bx^2$

C = costs $= Px$

Thus

$V/C = A/P + Bx/P$

As B is negative for diminishing returns, V/C decreases as x increases.

FAO recommends the use of fertilizers when V/C exceeds 2. This value could not always be reached (Table 25). Besides the fixed costs of drilling fertilizers were discounted; they are valued at TL 40 per ha. Hence fertilizer-drilling costs were not covered on fields 1, 8 and 10, although there was a net return on fertilizer costs.

9.2.2 Recommendations

The following combinations of nitrogen and phosphorus are recommended.

1 *40 kg N; 40 kg P_2O_5 per ha*

This is the highest recommended nitrogen rate, calculated to be optimum for BrA soils. Response to nitrogen is favoured by the better moisture situation and the lower content of organic matter than in other soils. Hence the same recommendation holds for BvA and the least steep AuA soils. The recommended phosphorus rate agrees with results from the Soils and Fertilizers Research Institute at Ankara.

2 *30 kg N; 50 kg P_2O_5 per ha*

This recommendation was derived from fields on ThA soils. The recommendation for phosphorus is lower than the calculated optimum rate of 65 kg P_2O_5 per ha for

Table 25. Optimum fertilizer rates in kg per ha derived algebraically unless otherwise stated for each field, rates recommended for each soil unit, net returns in TL per ha at optimum and recommended fertilizer rates, and value/costs (*V/C*) as calculated for recommended fertilizer rates.

Soil unit	Field No	Rates				Net returns		*V/C*
		Optimum		Recommended		Optimum	Recommended	
		N	P_2O_5	N	P_2O_5			
Te	1	0	34	0	40	17	16	1.2
	2	0	38			133	133	2.7
	101	0	77[1]			71	.	.
	102	0	101			176	110	2.4
	103	0	0			0	—7	0.9
ThA	4[2]	30	70	30	50	353	274	2.6
	104	33	60			117	114	1.7
BrA	3	33	71	40	40	201	179	1.9
	11	50	73			503	419	3.2
	12	57	34			480	448	3.4
	14[2]	60	40			523	397	3.1
	112	30	0			74	54	1.3
	113	53	0			240	192	2.0
	114	0	66			194	52	1.3
BrB	15[2]	0	60	0	50	146	100	2.0
	115	0	60			95	93	1.9
CrA	13	28	31	25	25	127	124	2.1
LmA-K	6	37	57	20	50	217	179	2.2
	7	0	0			0	—126	0.2
	106[2]	40	65			240	140	1.9
	107[2]	20	80			200	80	1.5
LmA-H	8	15	15	0	0	4	.	.
	10	8	44			26	.	.
	108	0	0			0	.	.
LmC	9	0	54	0	50	101	99	2.0
BrB	16[3]	150	185	.	.	1524	.	3.0

1. Not taken into account for the recommendation because control yield was less than 400 kg/ha.
2. Optimum rates assessed graphically.
3. Field flooded. *V/C* for this field was calculated for optimum fertilizer rates.

Tablo 25. Başka türlü beyan edilemediği takirde, cebirsel olarak türetilen, kg olarak hektara düşen normal ve tavsiye edilen gübre oranları, hektara Türk Lirasi olarak normal ve tavsiye edilen gübre oranları ile düşen saf kâr ve tavsiye edilen gübre oranlarından hesap edilen kıymet/masraflar (*V/C*).

prudence (higher V/C ratio). The unit ThA is very irregular and the effect of fertilizers depends largely on soil depth (Fig. 42). When the soil is shallow, the rates should be lowered. The rates of 30 kg N and 50 kg P_2O_5 are advised for ThA soils (unless shallow) and for BrB soils near Yeniköy and Azizie (Ereğli Area).

3 *25 kg N; 25 kg P_2O_5 per ha*

These rates were optimum for Field 13 (CrA transitional to BrB and BrC). The soils are low in organic matter. The rates are kept low, because the soils are drought-sensitive. The recommendation seems appropriate for light-textured soils, if cultivated: CrA, CvA, BrC, BrD, BvB and BvC.

4 *20 kg N; 50 kg P_2O_5 per ha*

These are the proper rates for Marl soils receiving sufficient rainfall and with up to 1.6% organic matter content, as in LmA Konya.

5 *0 kg N; 50 kg P_2O_5 per ha*

These are the optimum rates for Field 9 (LmC). These soils have so much organic matter that there is no need for nitrogen fertilizer. The phosphorus rate is the same as for LmA Konya. The same rates hold for LmB (organic matter 1.5-2.0%) and for BrB east of Suduraği (Karaman Area). The BrB soils in the Ereğli Area contain less organic matter and hence are covered by Recommendation 2.

Table 26. Fertilizer recommendations for dry-farmed wheat for soil units of the Basin.

	Soil unit	N (kg/ha)	P_2O_5 (kg/ha)
Limestone colluvial	CrA	25	25
Volcanic colluvial	CvA	25	25
Flat Terraces	Te	0	40
Undulating Terraces	ThA	30	50
Limestone Bajadas	BrA	40	40
	BrB 1	0	50
	BrB 2	30	50
	BrC	25	25
	BrD	25	25
Volcanic Bajadas	BvA	40	40
	BvB	25	25
	BvC	25	25
Medium-Sized Fans	AuA	40	40
Marls	LmA Konya	20	50
	LmA Hotamış	0	0
	LmB	0	50
	LmC	0	50
Sandplain and Beach	Lp	0	0

BrB 1: Karaman Area, east of Suduraği — LmA Konya : Konya Area
2: Ereğli Area, near Yeniköy — Hotamış: Hotamış, Karaman and Karapinar Area

Tablo 26. Havzada kuru ziraat buğdayı için toprak ünitelerine tavsiye edilen gübrelemeler.

6 0 kg N; 40 kg P_2O_5 per ha

These are optimum rates for Terrace soils. No response to nitrogen was obtained because they had more than 1.6% organic matter; the response to phosphorus was limited by drought (Field 103). The rate of 40 kg P_2O_5 is advised for TeA (where unirrigated), TeB, TeC (unless shallow) and TeD (where cultivated). The net returns are often low on these soils.

7 0 kg N; 0 kg P_2O_5 per ha

This recommendation is given for LmA Hotamış and for Sandplain and Beach soils (where cultivated). Fertilizer costs are not recovered because of drought.

In addition to the map, Table 26 presents the recommendations for dry-farmed wheat for the soil units, arranged in the same sequence as in the legend of the soil map (de Meester, 1970). For soils not mentioned in Table 26, no recommendation is given, because they are either unsuitable for crops or are irrigated. For rye, no recommendations are given. The price of rye was too low to cover the cost of fertilizers.

Appendix 1. Technical and theoretical details of the greenhouse trials

The procedure is the result of several preliminary trials. In these trials the influence of different conditions was tested, e.g. type of pot, number of plants, duration of trial and of interval between measurements. Some of these factors can be approached theoretically.

Procedure

Air-dried and sieved (2 mm) soil, 200 g, is mixed with some water but not enough to bring it to field capacity. The soil is then put in a pot with a gauze bottom (Fig. 11). A plastic pipe is inserted in the centre of the pot and filled with pure quartz sand. Six equal-sized (3.8-4.0 mm) wheat grains are sown 0.5 cm deep in the soil which is then brought up to field capacity. The pot is placed on a ring, and pot with ring is weighed. Ring and pot are put on a container of nutrient solution (Fig. 11).

About 8 days after sowing, at the beginning of the two leaf stage, seedlings are thinned; three equal-sized plants remain in each pot. On the soil surface, 40 g gravel is spread to reduce evaporation.

Pot with ring is weighed daily, before adding water through the plastic pipe to keep soil at field capacity.

The nutrient solutions are renewed once or twice a week. The composition of the nutrient solutions is given in Table 27. The total salt concentration and the ratios between the ions have been kept as constant as possible.

The leaves have to be measured at least twice. When the availability of nitrogen is being tested, they must first be measured in the two-leaf stage; for phosphorus, in the three-leaf stage. They can be measured again about 5 days later for nitrogen and 5-8 days later for phosphorus. However, it is safer to measure more than twice.

Relation between plant size and dry weight

In several trials the relation between sizes and dry weights of aerial parts of the plant tops was assessed. The results are collected in Figure 48. The lines of the several trials are similar, so justifying the use of plant size instead of dry weight. Only in Trial 12 was plant size less relative to dry weight; these plants were grown in a phytotron with artifical light; in the other trials plants were grown in normal greenhouses (sometimes with supplementary artificial light). This difference in illumination may have caused a slightly different leaf-shape and hence another size-weight relation.

In general only a small influence could be ascertained of nutrition on the relation. Phosphorus-deficient plants tended to have higher dry weights relative to plant size; the dry-matter content was a little higher and the plants had a slightly woody appearance.

Course of the relative growth rate (RGR)

The relative growth rate is only constant for exponential growth (Section 4.2.2). For a short period, the wheat plant grows exponentially, at least if environmental conditions are constant. After germination, relative growth rate of individual plant components as well of whole plants decreases rapidly (Fig. 49). From about Day 10 till at least Day 21, leaves and stems grow nearly

Table 27. Composition of the nutrient solutions.

Macronutrient	Complete	—N	—P
$Ca(NO_3)_2.4H_2O$	6 meq/l		6 meq/l
KNO_3	2		2
NH_4NO_3			1
$NH_4H_2PO_4$	2		
KH_2PO_4		2	
KCl	2		2
K_2SO_4		2	
$MgSO_4.7H_2O$	1.5	1.5	1.5
$CaCl_2.6H_2O$		6	
Total	13.5	11.5	12.5

Trace nutrient (Composition is the same for all solutions)

FeEDTA	35 ppm	Fe	5 ppm
H_3BO_3	2.86	B	0.5
$MnCl_2.4H_2O$	1.81	Mn	0.5
$ZnSO_4.7H_2O$	0.22	Zn	0.05
$CuSO_4.5H_2O$	0.16	Cu	0.04
$(NH_4)_6Mo_7O_{24}.4H_2O$	0.04	Mo	0.02

Tablo 27. Besin çözeltilerinin bileşimi.

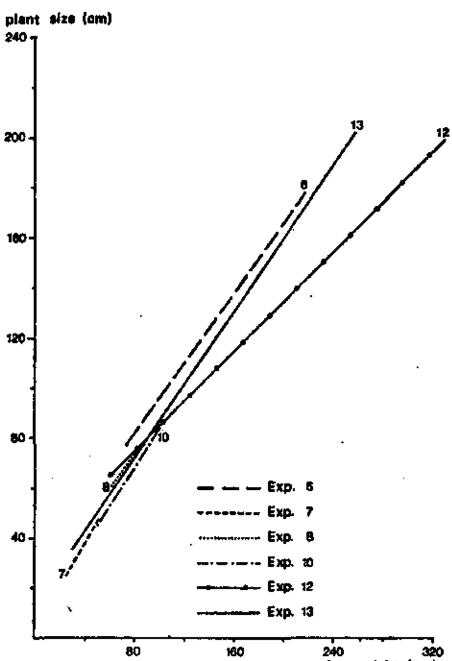


Fig. 48. Relation between plant size and dry weight, as found in different experiments.

Şekil 48. Çeşitli denemelerde bulunan bitki genişliği ile kuru ağırlık arasındaki ilgi.

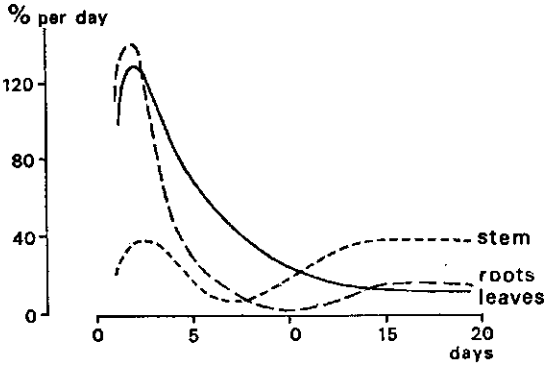


Fig. 49. Relative growth rates for leaves, stem and roots as a function of time. From Williams, 1960.

Şekil 49. Zamana bağlı olarak yapraklar, gövde ve kökler için nisbi gelişme oranları (Williams 1960'dan).

exponentially. In this period the influence of the seed has ceased and the supply of nutrients, light and other growth factors determine the *RGR*.

If the supply of a nutrient is insufficient, the shortage increases with time, as the demand by the growing plant increases. This implies that *RGR* cannot be kept at the initial level and will decrease. When *RGR* is very small, growth becomes linear, as can be shown mathematically as follows. The expression for exponential growth is:

$$L_T = L_0 \, e^{RT} \tag{26}$$

where

L_T, L_0 = plant size at time T and time 0, respectively
R = relative growth rate (*RGR*)
T = time

Instead of e^{RT}, it may be written:

$$e^{RT} = 1 + \frac{RT}{1} + \frac{(RT)^2}{1.2} + \frac{(RT)^3}{1.2.3} + \ldots$$

When RT is small:

$$e^{RT} = 1 + RT.$$

Substituting in Equation 26

$$L_T = L_0 (1 + RT)$$

or

$$L_T = RL_0 \, T + L_0$$

a linear relation between plant size and time.

Figure 50 shows the relation of mean RGR with plant size or time as found in some experiments. *RGR* becomes almost constant at a plant size of about 50 cm, i.e. at the three-leaf stage (Exp. 9 and 12, Fig. 50), provided the external conditions are kept constant. If not, *RGR* is predominantly governed by these external conditions, as in Experiment 10. Nevertheless there also *RGR* is related to plant size (if less than 50 cm). This is shown in Figure 51, where *RGR*, measured from Day 15 to Day 21 has been plotted against plant size on Day 15. The consistencies of these relations are that values for *RGR* may be compared only if they are measured over the same interval and if plant size is more than 50 cm, so that *RGR* is independent of plant size.

To measure SQ_P, the interval in terms of plant size from 50 to about 125 cm seems most appropriate, or in terms of development, from the three-leaf stage until tillering from the second axil of the main shoot. This period, however, is not suited for measurement of SQ_N because plants growing on a nitrogen-deficient solution already show deficiency at the two-leaf stage. The supply of nitrogen from the seed is exhausted earlier than the supply of phosphorus, as may be illustrated by some simple calculations.

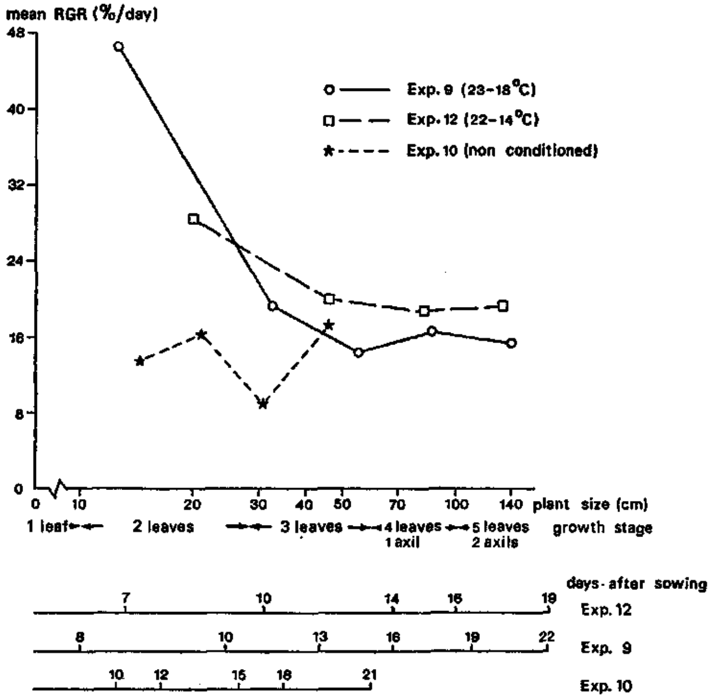
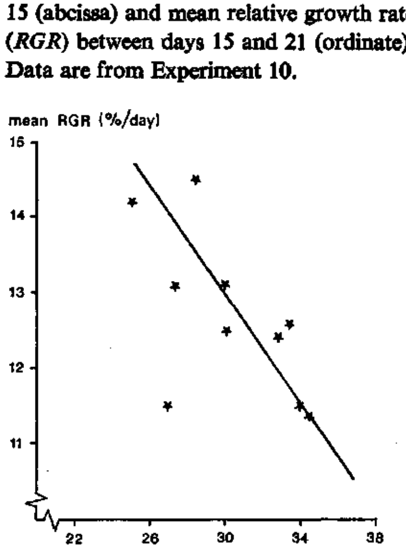


Fig. 50. Mean relative growth rate (*RGR*) plotted against log plant size, growth stages and time for different experiments.

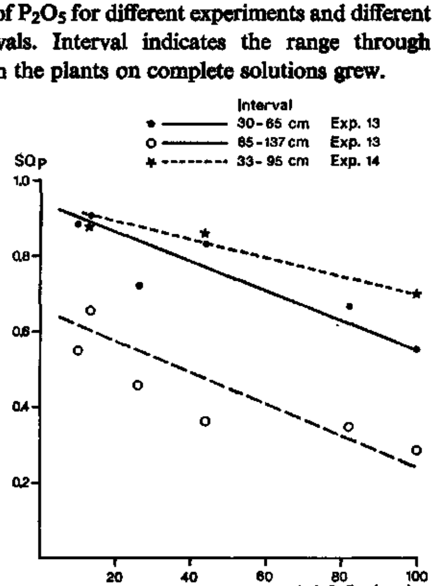
Şekil 50. Bitki gövdesi kalınlığına, gelişme devrelerine, çeşitli denemelere ait zamana karşılık olarak işaretlenmiş ortalama nisbi gelişme oranı (*RGR*).

Fig. 51. Relation between plant size at Day 15 (abcissa) and mean relative growth rate (*RGR*) between days 15 and 21 (ordinate). Data are from Experiment 10.



Şekil 51. 15'inci günde bitki büyüklüğü ile (apsis) 15'inci ve 21'inci günler arasındaki ortalama nisbi gelişme orani (*RGR*) (ordinat) arasındaki ilgi. Kayıtlar 10 nolu deneyden alınmıştır.

Fig. 52. Relation between SQ_P and recommended rate of P_2O_5 for different experiments and different intervals. Interval indicates the range through which the plants on complete solutions grew.



Şekil 52. Değişik deneyler ve aralıklar için SQ_P ile tavsiye edilen P_2O_5 miktarı arasındaki ilgi. Degişik aralıklar tam çözeltide gelişmiş bitkilerdeki değişme miktarlarını işret etmektedir.

Table 28. Calculation of SQ_N without and with correction for differences in initial plant size.

	Soil 1		Soil 2	
	Complete	—N	Complete	—N
Plant size at T_1 (cm)	36	26	34	32
Plant size after 6 days (cm)	70	46	68	59
Calculated *RGR* (%/day)	10.9	9.2	11.5	9.9
UncorrectedSQ_N	0.84		0.86	
Corrected RGR_C (Fig. 51) (%/day)	14.5		12.3	
SQ_N, according to corrected RGR_C	0.63		0.80	

Tablo 28. SQ_N 'in, başlangıçtaki bitki büyüklüğündeki değişikliklere göre düzeltilmiş ve düzeltilmiş olarak hesaplanması.

A hundred grains of wheat, weighing 4000 mg, and with a normal N and P_2O_5 content of 2.25 and 1.0%, respectively, can supply at most 90 mg N and 40 mg P_2O_5. The weight of wheat seedlings at the two-leaf stage (without grain and roots) is about 30 mg. The tops of 100 seedlings with normal contents of 5% N and 1.5% P_2O_5 thus require 150 mg and 45 mg P_2O_5. If about 15 mg N go to the roots and 5 mg N remain in the seed (van Dobben, 1963), the seeds can supply only 70 mg N to the tops, whereas the phosphorus requirement is almost covered.

Hence a reduction in plant growth appears earlier when the soil is short of nitrogen than of phosphorus. An annoying implication is that SQ_N has to be measured partly while *RGR* is still related to plant size. Therefore if sizes of plants growing on a complete and nitrogen-deficient solutions are not equal at the beginning of the period when SQ_N is being measured, *RGR* must be corrected for this difference in initial plant size, as in Table 28. This example assumes that *RGR* of plants on complete solutions is related to plant size, as shown in Figure 51. If SQ_N is calculated by dividing RGR_{-N} by RGR_C, the SQ_N of Soil 1 does not differ much from the SQ_N of Soil 2. Yet Soil 1 obviously contains more nitrogen (as appears not only from plant size, but also from colour), but since RGR_C decreases with increasing plant size, differences in SQ_N between soils 1 and 2 are blurred. With Figure 51, RGR_C can be corrected. Plant sizes of 26 and 32 cm correspond to RGR_C values of 14.5 and 12.3% per day, respectively. Values for SQ_N calculated with these RGR_C give a much better indication of nitrogen levels in the soils. Thus in experiments to find SQ_N, RGR_C must be calculated to find the relation between RGR_C and plant size.

Standard soils

As said above, values for *RGR* from different treatments may be compared only if measured over the same interval. This makes comparisons between different experiments hazardous. Therefore standard soils are needed as references in all experiments. If the fertilizer requirements of the standard soils are known, a semiquantitative recommendation for the unknown soils can be deduced from the relation between *SQ* and the recommended dressing. Figure 52 shows that the relation depends on experimental conditions (Contrast Exp. 13 and Exp. 14) and that *SQ* decreases with increasing plant size (the two lines of Exp. 13). These facts emphasize the need for reference soils.

Appendix 2. Description of some representative profiles

Profile of Field 1, Okçu

TeB Loamy or clayey Flat Terrace Soils over limestone

Great Konya Basin, Çumra Area, 49.6N, 84.8E, alt. about 1020 m; 29-7-1967 (Janssen)

Geomorphology: structural terrace
Parent material: calcareous clay loam
Relief and slope: flat, level
Stoniness: Class 0
Hydrology: well drained, watertable below 10 m
Moisture: dry
Salinity: saltfree
Biology: 0-15 cm common roots; 15-80 cm few roots; below 80 cm very few roots; krotovinas
Land-use: dry farming, wheat
Classification: 1967 Mollic Calciorthid

Soil description

Ap	0-15 cm	brown to dark-brown (10YR 4/3) clay-loam, yellowish-brown (10YR 5/4) when dry; massive and moderate fine granular structure; sticky and plastic when wet, soft when dry; many macropores and common mesopores; gradual smooth boundary.
B2ca	15-42 cm	brown to strong-brown (7.5YR 5/5) clay-loam, yellowish-brown (10YR 5/4) when dry; compound weak to moderate medium angular and subangular blocky and moderate medium granular structure; sticky and plastic when wet, slightly hard when dry; common macropores and common mesopores; few to common fine distinct lime concretions; gradual wavy boundary.
BCca	42-55 cm	yellowish-brown (10YR 5/6) clay-loam, light-yellowish-brown (10YR 6/4) when dry; moderate fine and medium angular and subangular blocky and moderate medium granular structure; sticky and plastic when wet, slightly hard to hard when dry; common macropores and common mesopores; few to common fine distinct lime concretions; gradual wavy boundary.
Cca	55-130 cm	very pale brown (10YR 7.5/3) soft lime, white (10YR 8/1) when dry; massive; sticky and slightly plastic when wet, hard when dry; common macropores and many mesopores; krotovinas filled with a mixture of B and C material.

This profile has an ochric epipedon, a cambic and a calcic horizon.

Profile of Field 104, Inliköy

ThA Angular-cobbly, locally very shallow clayey Undulating Terrace Soils over limestone

Great Konya Basin, Karaman Area, 44.0N, 86.0E, alt. about 1040 m, 22-5-1968 (Titulaer & Janssen)

Geomorphology: undulating structural terrace
Parent material: calcareous angular cobbly loam
Relief and slope: subnormal, undulating
Stoniness: Class 1
Hydrology: well drained, watertable below 10 m
Moistness: 0-100 cm dry, below 100 cm moist to dry
Salinity: saltfree
Biology: 0-20 cm common roots; 20-55 cm few roots; 55-150 cm very few roots
Land-use: dry farming, wheat
Classification: 1967 Typic Xerorthent

Soil description

Ap	0-20 cm	brown (7.5YR 5/4) angular-cobbly loam when dry; weak very fine and fine subangular and angular blocky; slightly sticky and slightly plastic when wet, slightly hard when dry; few to common macropores and few mesopores; faint lime mycelium; gradual irregular boundary.
AC	20-55 cm	brown (7.5YR 5/4) and white (2.5Y 8/2) cherty sandy loam when dry; massive; non to slightly sticky and non-plastic when wet, loose when dry; few macropores and many mesopores; gradual wavy boundary.
C	55-160 cm	white (2.5Y 8/2) coarse cherty limestone fragments and brown (7.5YR 5/4) loam when dry; massive; non to slightly sticky and non to slightly plastic when wet, soft when dry; few macropores and common mesopores; many fine distinct black mottles.

This profile has an ochric epipedon.

Profile of Field 14, Ilisıra

BrA Predominantly reddish-brown clayey limestone Bajada Soils

Great Konya Basin, Karaman Area, 17.5N, 100.5E, alt. about 1030 m; 20-7-1967 (Ruessink & Janssen)

Geomorphology: bajada
Parent material: clay with fine limestone gravel
Relief and slope: subnormal, nearly level
Stoniness: Class 0
Hydrology: moderately well drained, watertable about 4 m
Moistness: 0-30 cm dry, below 30 cm moist
Salinity: saltfree
Biology: 0-50 cm common roots; 50-140 cm few roots; some insects
Land-use: dry farming, wheat
Classification: 1967 Xerertic Camborthid

Soil description

Ap	0-20 cm	dark-reddish-brown (5YR 3/5) clay, reddish-brown (5YR 4.5/4) when dry; moderate fine to medium subangular to angular-blocky structure; sticky and plastic when whet, very hard when dry; common macropores and common mesopores; fine gravel; wide cracks; clear smooth boundary.
B21ca	20-51 cm	dark-reddish-brown (5YR 3/5) clay, reddish-brown (5YR 4.5/4) when dry; weak to moderate fine and medium subangular to angular-blocky structure; sticky and plastic when wet, slightly hard when dry; common macropores and common mesopores; few medium distinct powdery lime pockets; fine gravel; clear smooth boundary.

B22ca	51-110 cm	reddish-brown (5YR 4/4) clay; compound moderate coarse prismatic and moderate medium and coarse angular-blocky structure; sticky and plastic when wet, friable when moist; few macropores and few mesopores; common medium and coarse distinct lime pockets; clay coatings; diffuse smooth boundary.
B23ca	110-140 cm	do, but with slickensides.

This profile has an ochric epipedon and a cambic horizon.

Profile of Field 115, Suduraği

BrB Predominantly brown loamy or clayey Limestone Bajada Soils

Great Konya Basin, Karaman Area, 30.0N, 140.4E, alt. about 1020 m, 21-5-1968 (Titulaer & Janssen)

Geomorphology: bajada
Parent material: calcareous loam and silt loam
Relief and slope: subnormal, level
Stoniness: Class 0
Hydrology: well drained, watertable below 10 m
Moistness: dry to 125 m, moist 125-155 cm
Salinity: saltfree
Biology: 0-20 cm common roots; 20-50 cm few roots; below 50 cm very few roots
Land-use: dry farming, wheat
Classification: 1967 Mollic Calciorthid

Soil description

Ap	0-20 cm	pale-brown (10YR 6/3) silt-loam when dry; massive and single grain; sticky and slightly plastic when wet, soft to slightly hard when dry; common macropores and many mesopores; some faecal pellets; abrupt smooth boundary.
B2	20-40 cm	pale-brown to very-pale-brown (10YR 6.5/3) loam when dry; weak very fine to fine subangular and angular-blocky; sticky and slightly plastic when wet, slightly hard when dry; very few macropores and few mesopores; clear wavy boundary.
C1ca	40-105 cm	light-brown (7.5YR 6/5) sandy-loam when dry; massive; non-sticky and slightly plastic when wet, soft to slightly hard when dry; few macropores and common mesopores; few medium distinct soft lime concretions; some root remnants; some rounded faecal pellets and minerals; irregularly distributed gravel; gradual smooth boundary.
C2ca	105-155 cm	light-brown to pink (7.5YR 6.5/4) loamy-sand to sandy-loam when dry; massive; non-sticky and non to slightly plastic when wet, soft when dry; common macropores and common mesopores; few medium faint to distinct soft lime concretions; some pores filled with lime; gravelly layers 1-2 cm thick consisting of dark minerals, 5-15 cm vertically distant; some old root pores.

This profile has an ochric epipedon, a cambic and a calcic horizon.

Profile of Field 7, Ortakonak

LmA Clayey Marl Soils with shell fragments

Great Konya Basin, Konya Area, 103.2N, 76.1E, alt. about 1000 m, 23-5-1967 (Christen & Janssen)

Geomorphology: lacustrine marl plain
Parent material: highly calcareous silty clay

Relief and slope: flat, level
Stoniness: Class 0
Hydrology: moderately well drained, watertable 2 m
Moistness: moist
Salinity: surface soil saltfree; subsoil moderately salt effected
Biology: 0-19 cm common roots, 19-120 few to very few roots
Land-use: dry farming, wheat
Classification: 1967 Aquollic Calciorthid

Soil description

Ap	0-19 cm	olive-gray (5Y 4.5/2) silty-clay; weak fine subangular-blocky structure; slightly sticky and plastic when wet, friable when moist; many macropores and very few mesopores; clear smooth boundary.
A1	19-53 cm	light-olive-gray to olive-gray (5Y 5.5/2) silty-clay; moderate fine subangular to angular structure; sticky and plastic when wet, friable to firm when moist; many macropores, very few mesopores; gradual and smooth boundary.
B2	53-88 cm	light-gray (2.5Y 7/2) clay; moderate to strong very fine angular-blocky structure; sticky and plastic when wet, friable to firm when moist; many macropores and few mesopores; some vertical cracks filled with light-olive-gray to olive-gray (5Y 5.5/2) silty clay; diffuse and smooth boundary.
Ccs	88-120 cm	light-olive-gray (5Y 6/2) carbonatic clay; compound weak fine prismatic and strong very fine blocky structure; sticky and plastic when wet, firm when moist; common macropores and few mesopores; many medium and coarse distinct strong-brown (7.5YR 5/8) rust mottles; gypsum crystals; shell fragments.

This profile has an ochric epipedon, a cambic and a gypsic horizon.

Summary

Soil fertility was studied in the Great Konya Basin, as part of the study carried out by the Department of Tropical Soil Science of the Agricultural University at Wageningen.

The purpose was to find the agricultural value of the soils, to learn about the main factors governing soil fertility, and to work out regional fertilizer recommendations for winter wheat, the main crop in dry farming.

The study was in the field, greenhouse and laboratory. Because of results already available from Turkish scientists, only nitrogen and phosphorus were examined.

In 1966-7 and 1967-8 a total of about thirty trial fields were laid out on the most important soils suitable for crops, mainly Terrace, Bajada, and Marl soils. The trials were carried out on farmers' fields in the common wheat-fallow rotation. As rainfall is low (about 300 mm per year), the land is fallowed each alternate year to conserve moisture for the next crop. To study the significance of this fallow year, the course of soil moisture content was observed during the trial years.

In the greenhouse, short-term trials (3 weeks) were used. A technique was developed, by which young wheat plants could take up nutrients simultaneously from the studied soil and from a nutrient solution (Fig. 11). If a nutrient is omitted in the solution, plants can take up that nutrient from the soil only. The availability of that nutrient in the soil is indicated by the 'sufficiency quotient', the ratio between the relative growth rates of plants on deficient and complete solutions (SQ_N and SQ_P for nitrogen and phosphorus, respectively).

In the laboratory, several physical and chemical soil characteristics were determined; also grain and straw samples from the field trials were chemically analysed.

Wheat yields of the field trials ranged from 300 to 3000 kg grain per ha. The response to fertilizers varied with precipitation and soil unit. There was a reasonable relation between crop data in May (height and growth stage) and final dry-matter production in July.

The yield factors moisture, nitrogen and phosphorus were studied in more detail.

The amount of water stored in soil at sowing proved to depend mainly on precipitation in the preceeding fallow period and slightly on soil unit. There was a clear connexion between the amount of stored water and maximum dry-matter production. Because of differences in spring rainfall, the relation was not the same for 1967 as for 1968. Between transpiration and maximum dry-matter production, a linear relation was found; it was used to calculate transpiration from each field, so quantifying moisture supply.

The different characteristics for nitrogen status in soil, namely organic nitrogen, nitrate nitrogen and SQ_N, corresponded well with each other. Yield increase with nitrogen fertilizer, nitrogen content of grain and nitrogen withdrawal from soil depended on soil nitrogen and on moisture supply. If grain nitrogen exceeded 2.0-2.2%, there was no yield increase with nitrogen fertilizer. Nitrogen recovery, the percentage of applied nitrogen absorbed by the crop, varied from 0 to 30%.

The results of soil phosphorus determinations by P-Olsen did not correspond with SQ_P. Both parameters, as well as phosphorus content in the crop, indicated a very poor phosphorus status of all soils. The interrelations between soil, crop, and fertilizer phosphorus were complex and were governed by moisture conditions. Phosphorus withdrawal from soil was low, did not depend on soil properties and was determined almost entirely by moisture supply. Phosphorus recovery, low for all soils, was lowest on Marl soils, probably because of the fine texture and the high content of carbonate.

On some fields, soil slaking, profile depth and slope were factors influencing yield.

Yield increments from the factors moisture, nitrogen and phosphorus were effected mainly by increased tillering. The greater number of tillers could cause moisture shortage later in the season to become more severe, and could sometimes cause decrease of seed set and of 1000-grain weight. Phosphorus did not much change the grain/straw relation; longer culms were associated with more grains per ear.

Differences in productivity and in response to fertilizers between the soil units could be ascribed to differences in content of organic matter and in moisture supply. Since those factors have been included partly directly, partly indirectly in many units of de Meester's soil map, a fertilizer recommendation map could be drawn. For recommendations, the profit-maximizing combinations of nitrogen and phosphorus were determined by an algebraic and a graphical method. For the algebraic method, regression equations were used that had been calculated for the statistical analysis of field results. The graphical method was based on the construction of 'maps' with iso-profit lines. On these 'maps' the optimum combination of fertilizers as well as financial consequences of non-optimum rates, can easily be found.

Appendix 1 gives details of the developed technique of greenhouse trials, discusses the course of relative growth rate and its consequences for the determination of SQ_N and SQ_P, and shows that reference soils are needed.

Özet

Wageningen Ziraat Üniversitesi Tropikal Toprak ilmi Bölümü tarafından yapılan çalışmanın bir parçası olarak, Büyük Konya Havzası'nda toprak verimliliği araştırılmıştır.

Bu çalışma, toprakların tarısmal kıymetlerini bulmak toprak verimliliğine etki yapan faktörler hakkında bilgiler elde etmek ve kuru ziraatın başlıca ürünü olan kış buğdayı için bölgesel gübreleme tavsiyelerinde bulunmak gayesiyle yapılmıştır.

Çalışmalar tarla, sera ve laboratuvarda yürütülmüştür. Türk toprakçılar tarafından bilinen mevcut bilgilerden dolayı yalnız azot ve fosfor üzerinde denemeler yapılmıştır.

1966-67 ve 1967-68 yıllarında, genellikle Teras, Bajada, ve Marn topraklarında olmak üzere, mahsullere elverişli en önemli topraklar üzerinde otuz deneme tarlası seçilmiştir. Denemeler buğday-nadas devridaiminin yapıldığı çiftçi tarlalarına inhisar edilmiştir. Yağışın düşük olması sebebiyle (takriben yıllık 300 mm). topraklar birdahaki bitkiye su toplamak gayesiyle bir yıl aralıkla nadasa bırakılmıştır. Nadas yılının önemini anlamak maksadıyla deneme süresi içinde toprak neminin seyri takip edilmiştir. Serada kısa süreli (3 hafta) denemeler yapılmıştır. Genç buğday bitkilerinin, kendiliğinden, üzerinde çalışılan topraklardan ve besin maddeleri ihtiva eden çözeltiden besin maddelerini alabilecek bir metod geliştirilmiştir (şekil 11). Herhangi bir besin maddesinin çözeltiye konulmamış olduğu durumda o besin maddesi sadece topraktan temin edilmektedir.

Toprakta besin maddelerinin yarayışlılığı, 'yeterli gelen kısım (sufficiency quotient)' ve eksik ve tam çözeltiler (SQ_N ve SQ_P sırasiyle azot ve fosforu işaret etmektedir) arasındaki bitkilerin nisbi gelişme derecelerine bakılarak bulunmuştur.

Laboratuvarda çeşitli fiziksel ve kimyasal toprak özellikleri tayin edilmiş ve aynı zamanda, deneme tarlalarından alınan tane ve sap örneklerinde kimyasal analizler yapılmıştır.

Deneme tarlalarindaki buğday miktarı hektar başına 300 ile 3000 kg arasında değişmektedir. Gübrelemeye karşı verilen cevap yağış ve toprak ünitesi ile birlikte değişmektedir. Mayıs ayı içindeki mahsul miktarı ile (büyüklük ve gelişme devresi) temmuz ayı içindeki nihai kuru madde arasında göz önüne alınacak derecede bir ilgi bulunmuştur.

Mahsul faktörlerin, nem, azot ve fosfor miktarları daha detaylı incelenmiştir.

Ekim zamanında toprakta biriktirilen su miktarının, genellikle nadas süresindeki yağışa ve az miktarda toprak ünitesine bağlı olduğu görülmüştür. Biriktirilen su miktarı ile kuru madde yapımı arasında açık bir ilgi bulunmuştur. Bahar aylarındaki yağışlardan dolayı 1968' de bulunan ilginin 1967' de bulunan ilgiden ayrı olduğu

ortaya çıkmaktadır. Transpirasyon ve en fazla kuru madde yapımı arasında doğrusal bir ilgi bulunmuş ve her bir tarla için su ihtiyacını bulmak için transpirasyonu hesaplamada kullanılmıştır.

Toprakta değişik azot durumlarına ait özellikler, yani organik azot, nitrat azotu ve SQ_N miktarları birbirleriyle yakından ilgi halindedirler. Su miktarı ve toprak azotuna bağlı olarak, mahsul artışı, azotlu gübrelerle, tanedeki azot miktarı ve topraktan alınan azotla artmaktadır. Tane azotu % 2.0-2.2'ye ulaştığında azotlu gübrelerle mahsulün artmadığı görülmüştür. Azot ihtiyacının temini maksadıyla tatbik edilen azot'un mahsul tarafından absorbe edilen kısmı 0 ile % 30 arasında değişmektedir.

P-Olsen ile toprak fosforunun tayininden elde edilen sonuçlarla SQ_P fosforunun biribirine uyamdığı bulunmuştur. Her iki parametre ve aynı zamanda mahsuldeki fosfor miktarı toprakların fosfor bakımından fakir olduğunu işaret etmektedir. Toprak, mahsul ve fosforlu gübreler arasındaki münasebetler su durumları tarafından idare edilmektedir. Topraktan fosfor alımı düşük çıkmaktadır ve bu husus toprak özellikleri tarafından değil hemen hemen tamamen su miktarı tarafından tayin edilmektedir. Ihtimalki ince yapıdan ve yüksek karbonat miktarından dolayı fosfor'un bitkiler tarafından temini, en düşük marnlı topraklarda olmak üzere, bütün topraklarda düşüktür.

Bazı topraklarda toprak gevşekliği, profil derinliği ve eğimin mahsule etki eden faktörler olduğu tesbit edilmiştir.

Su, azot ve fosfor faktörlerinden dolayı mahsul artışı genellikle köklerin gelişmesini sağlamaktadır. Fazla sayıdaki kök saçakları su biriktirerek, hatta mevsim sonuna doğru su miktarı çok artarak tohum ve dolayısiyle 1000 buğday tanesinin ağırlığının azalmasına sebep olmaktadırlar. Fosfor'un tane/sap oranına etki etmediği bulunmuştur. Uzun sapla başağa düşen taneler arasında bir münasebet mevcuttur.

Toprak üniteleri arasındaki verimlilik ve gübrelemeye karşı verilen cevaptaki değişiklikler, değişik organik madde miktarlarına ve su teminine istinat ettirilebilir. Bu faktörlerin çoğunun doğrudan veya dolaylı olarak de Meester' in toprak haritası ünitelerine ilave edilmiş olmasından dolayı bir gübreleme tavsiye haritasının çizimi imkân dahiline girmiştir. Azot ve fosforun en yüksek geleri temin edecek karışımının temini, cebirsel ve grafik metoduyla tayin edilmiştir. Cebirsel metod için tarlaların istatistik analizleri sonuçlarından hesap edilmiş olan regresyon denklemleri kullanılmıştır. Grafiksel metod eş-kâr (iso-profit) çizgilerine sahip haritaların yapılmasına dayandırılmıştır. Bu haritada optimum gübre bileşimi ve optimum olmayan oranların mali sonuçları kolaylıkla bulunabilir.

Ek I, sera denemeleri için geliştirilen alet hakkında bilgi vermekte, nisbi gelişme oranı cereyanını ve SQ_N ve SQ_P tayini sonuçlarını münakaşa etmekte ve ilgili toprakların ihtiyacını göstermektedir.

References

Akalan, İ. & H. Ünal	1965	The organic matter contents of some typical great soil groups of Turkey and their effects to cation exchange capacity. Yb. Fac. agric. Univ. Ankara: 12-19.
Alberda, T., W. Louwerse & R. Brouwer	1964	The relation between salt and water uptake with intact and decapitated tomato plants. Jaarb. Inst. biol. scheik. Onderz. Landb Gewass.: 61-76.
Alexander, M.	1965	Nitrification. In: Bartholomev, W.V. et al. (Ed.): Soil nitrogen. Agron. Ser. Am. Soc. Agron. 11: 309-346.
Baier, W. & G. W. Robertson	1967	Estimating yield components from calculated soil moisture. Can. J. Pl. Sci. 47: 617-631.
Barber, S. A.	1966	The role of root interception, mass flow and diffusion in regulating the uptake of ions by plants from soil. In: Limiting steps in ion uptake by plants from soil. Techn. Rep. Ser. Int. atom. Energy Ag. 65: 39-45.
Bauer, A. & R. A. Young	1969	Influence of management and environmental factors on extent of soil water depletion by spring wheat. N. Dak. Res. Rep. 23.
Beech, D. F., M. J. T. Norman & G. A. Mc Intyre	1968	The effect of wet season land treatment and nitrogen fertilizer on safflower, linseed and wheat in the Ord River valley. 3 Wheat. Austr. J. exp. Agric. Anim. Husb. 8: 72-80.
Bingham, J.	1967	Investigations on the physiology of yield in winter wheat by comparisons of varieties and by artificial variation in grain number per ear. J. agric. Sci., Camb. 68: 411-422.
Birch, H. F.	1960	Soil drying and soil fertility. Trop. Agric., Trin. 37: 3-10.
Boatwright, G. O., H. Ferguson & P. L. Brown	1964	Availability of P from superphosphate to spring wheat as affected by growth stage and surface soil moisture. Proc. Soil Sci. Soc. Am. 28: 403-405.
Bond, J. J., C. E. van Doren & T. J. Army	1961	Fallowing for wheat production. J. Soil Wat. conserv. 16 163-165.
Bouma, D.	1965	Growth changes of plants following the removal of nutritional stresses. Thesis, Wageningen.
Bouma, D.	1967	Growth changes of subterranean clover during recovery from phosphorus and sulphur stresses. Austr. J. biol. Sci. 20: 51-66.
Bouma, D. & E. J. Dowling	1962	The physiological assessment of the nutrient status of plants. I. Preliminary experiments with phosphorus. Austr. J. agric. Res. 13: 791-800.
Bouma, D. & E. J. Dowling	1966a	Ibid. II. The effect of the nutrient status of the plant with respect to phosphorus, sulphur, potassium, calcium, or boron on the pattern of leaf area response following the transfer to different nutrient solutions. Ibid. 17: 633-646.
Bouma, D. & E. J. Dowling	1966b	Ibid. III. Experiments with plants raised at different nitrogen levels. Ibid. 17: 647-655.

Bouma,D., K. Spencer & E. J. Dowling	1969	Assessment of the phosphorus and sulphur status of subterranean clover pastures. 3. Plant tests. Austr. J. exp. Agric. Anim. Husb. 9: 329-340.
Bower, C. A., R. F. Reitemeier & M. Fireman	1952	Exchangeable cation analysis of saline and alkali soils. Soil Sci. 73: 251-261.
Brandow, G. E.	1953	Agricultural Development in Turkey. Agricultural Technical Assistence Group. Ankara.
Bremner, J. M.	1965	Organic nitrogen in soils. In: Bartholomew, W.V. et al. (Ed.): Soil Nitrogen. Agron. Ser. Am. Soc. Agron. 11: 93-149.
Brouwer, R.	1969	De groeifactor stikstof en de productie. In: Min. v. Landb.: Landbouwplantenteelt 1968, voordrachten B-leergang. 's-Gravenhage: 44-67.
Bruggenwert, M. G. M., A. R. P. Janse & F. F. R. Koenigs	1966	Algemene Bodemkunde. Handleiding Kandidaats Practicum. Landbouwhogeschool, Wageningen.
Butler, B. E.	1964	Assessing the soil factor in agricultural production. J. Austr. Inst. agric. Sci. 30: 232-240.
Butler, P. F. & J. A. Prescott	1955	Evapotranspiration from wheat and pasture in relation to available moisture. Austr. J. agric. Res. 6: 52-61.
Çağatay, M.	1954	Deneme tarlalarında Nadasın su toplama yetkisi ve toprakda su hareketlerı üzerinde araştırmalar. Ankara Üniv. Zir. Fak. Yıll., Fasikül 3: 330-349.
Campbell, C. A.	1968	Influences of soil moisture stress applied at various stages of growth on the yield components of Chinook wheat. Can. J. Pl. Sci. 48: 313-320.
Campbell, C. A. & D. W. L. Read	1968	Influence of air temperature, light intensity and soil moisture on the growth, yield and some growth analysis characteristics of Chinook wheat grown in the growth chamber. Can. J. Pl. Sci. 48: 299-313.
Cengiz, Y. & R. Başaran	1966	Karadeniz Bölgesi topraklarinin verimlilik envanterı. Topraksu Yayınları 186.
Chaussat, R.	1966	Variation du coefficient de transpiration en conditions climatiques contrôlées. Annls Physiol. Vég. Paris 8: 147-160.
Chinoy, J. J.	1960	Physiology of drought resistance in wheat. I. Effect of wilting at different stages of growth on survival values of eight varieties of wheat belonging to seven species. Phyton, B. Aires 14: 147-157.
Christiansen-Weniger, F.	1934	Die Grundlagen des türkischen Ackerbaus. Werkgemeinschaft. Leipzig.
Christiansen-Weniger, F.	1970	Ackerbauformen im Mittelmeerraum und Nahen Osten dargestellt am Beispiel der Türkei. DLG-Verlag, Frankfurt/M.
Coïc, Y. & E. Jolivet	1953	La fertilisation azotée semi-tardive et tardive du blé d'hiver. I. Action sur le rendement. C.r. hebd. Séance Ac. Agric. Fr. 39: 741-744.
Cole, J. S. & O. R. Mathews	1939	Subsoil moisture under semi arid conditions. Techn. Bull. U.S. Dep. Agric. 637: 1-70.
Collwell, J. D.	1963	The effect of fertilizers and season on the yield and composition of wheat in Southern New South Wales. Austr. J. exp. Agric. Anim. Husb. 3: 51-62.

Collwell, J. D. & R. J. Esdaile 1968 The calibration, interpretation and evaluation of tests for the phosphorus requirements of wheat in Northern New South Wales. Austr. J. Soil Res. 6: 105-120.

Çuhadaroğlu, D. 1967 Çumra'da Meteorolijik olaylar (1955-1966). Bölge Sulu Ziraat Deneme İstasyonu Müdürlüğü. Neşriyat Sayısı 14.

Day, P. R. 1965 Particle fractionation and particle-size analysis. In: Black, C.A. et al. (Ed.): Methods of soil analysis. Part I. Agron. Ser. Am. Soc. Agron. 9: 545-567.

Devlet Su İşleri (DSİ) 1966 1964 Rasat yıllığı. Ankara.

Dew, D. A. 1968 Effect of summer fallow tillage on soil physical properties and yield of wheat. Can. J. Soil Sci. 48: 21-26.

Dewey, W. G. & R. F. Nielson 1969 Effect of early-summer seeding of winter-wheat on yield, soil moisture and soil nitrate. Agron. J. 61: 51-55.

Dillon, J. L. 1968 The analysis of response in crop and livestock production. Pergamon Press, London.

Dilz, K. 1964 Over de optimale stikstofvoeding van granen. Thesis, Wageningen.

Dobben, W. H. van 1963 De betekenis van het stikstofgehalte van zaaizaad voor het gewas. Stikstof 38: 46-54.

Dorohov, L. M., I. I. Barbarina & S. N. Maharinec 1968 Vlijanie mineral'nogo pitanija na fotosintez, nakoplenie suhogo veščestva i urožaj ozimoj pšenicy i jarogo jačmenja. In: Sbornik: Izučenie fotosinteza važnejših sel' skohozjasjtvennyh kul'tur Moldavii. Kišinev, 'Kartja Moldavenjaské': 5-30. Abstr. in: Referat. Zh. 55. Rastenievodstvo, 1968, no. 9.55.206.

Driessen, P. M. 1970 Soil salinity and alkalinity in the Great Konya Basin, Turkey. Agric. Res. Rep. 743, Wageningen.

Driessen, P. M. & T. de Meester 1969 Soils of the Çumra Area, Turkey. Agric. Res. Rep. 720, Wageningen.

Evans, C. E. & E. R. Lemon 1957 Conserving soil moisture. In: Soil. Yb. U.S. Dep. Agric.: 340-359.

Evliyar, H. 1948 Water and the fallow-manure problem in Central Anatolia. Zir. Derg. 9: 3-13. Abstr. in: Soil Fertil. 12 (1949), abstract 90.

FAO 1959 Mediterranean development project. Turkey. Country report.

Feekes, W. 1941 De tarwe en haar milieu. Versl. techn. Tarwe Comm. 17: 560-561.

Ferguson, W. S. 1963 Effect of intensity of cropping on the efficiency of water use. Can. J. Soil Sci. 43: 156-165.

Ferguson, W. S. 1964 Effect of rainfall on plant response to phosphorus. Can. J. Soil Sci. 44: 180-187.

Ferguson, W. S. 1965 Relationship between evapotranspiration by wheat and the stage of crop development, Bellani-plate evaporation, and soil moisture content. Can. J. Soil Sci. 45: 33-38.

Fernandez, G. R. & R. J. Laird 1959 Yield and protein content of wheat in central Mexico as affected by available soil moisture and nitrogen fertilization. Agron. J. 51: 33-36.

Fisher, R. A. & G. D. Kohn 1966 The relationship of grain yield to vegetative growth and post flowering leaf area in the wheat crop under conditions of limited soil moisture. Austr. J. agric. Res. 17: 281-295.

Fox, R. L. & B. Kaçar 1965 Mobilization of non-exchangeable potassium and sodium in a calcareous soil during plant growth. Pl. Soil 22: 33-45.

Fox, R. L., B. Kaçar, A. Aydeniz & S. Zabunoğlu	1970	Nitrate accumulation, distribution and utilization during fallow-wheat culture in Turkish soils. Soil Sci. 109: 60-65.
Free, G. R., J. Lamb & E. A. Carleton	1947	Compactibility of certain soils as related to organic matter and erosion. J. Am. Soc. Agron. 39: 1068-1076.
Fried, M. & H. Broeshart	1967	The soil plant system. Academic Press, New York.
Fuehring, H. D.	1969a	Irrigated wheat on a calcareous soil as affected by application of nitrogen, phosphorus, potassium and zinc. I. Yield, composition and number of heads. Agron. J. 61: 591-594.
Fuehring, H. D.	1969b	Ibid. II. Analysis of the young plant in relation to yield. Ibid.: 594-596.
Gasser, J. K. R.	1964	Some factors affecting losses of ammonia from urea and ammonium sulphate applied to soils. J. Soil Sci. 15: 258-272.
Gerek, R.	1967	Is it possible to grow wheat continuously in Central Anatolia by applying fertilizers? Eskişehir Toh. İsl. Den. İst. Neşr. 2. Abstr. in: Turkish Scientific and Technical Documentation Centre, Agric. (1968) vol. 1 no. 2: 13.
Gilles, Ph.	1969	The role of phosphate fertilizer in the winter nutrition of wheat. Phosphorus in Agric. 52: 17-23.
Goodall, D. W. & F. G. Gregory	1947	Chemical composition of plants as an index of their nutritional status. Techn. Commun. Imp. Bur. Hort. Plantn Crops. 17.
Greenwood, E. A. N., D. W. Goodall & Z. V. Titmanis	1965	The measurement of nitrogen deficiency in grass swards. Pl. Soil 23: 97-116.
Groneman, A. F.	1968	The soils of the wind erosion control camp area Karapınar, Turkey. Dep. of Tropical Soil Science, Agric. Univ., Wageningen.
Haensel, H.	1956	Entwicklungs-Relationen ertragbildender Organe von Winterweizen (und Winterroggen) und ihre Bedeutung fur Termine zusätzlicher Nährstoff und Wassergaben. Z. Acker- u PflBau 100: 77-98.
Haensel, H.	1965	Physiologie der Ertragsbildung und Züchtung auf Ertrag bei Getreide. Z. PflZücht. 54: 97-110.
Haise, H. R., H. J. Haas & L. R. Jensen	1955	Soil moisture studies of some Great Plain Soils. I. Field capacity as related to 1/3 atmosphere percentages and 'minimum point' as related to 15 and 26 atmosphere percentages. Proc. Soil Sci. Soc. Am. 19: 20-25.
Haise, H. R., F. G. Viets & J. S. Robins	1960	Efficiency of water use related to nutrient supply. Trans. 7th Int. Congr. Soil Sci., Madison 1: 663-671.
Hamid, H., A. H. Agiza & A. El Shabassy	1963	The utilization of soil and fertilizer nitrogen by wheat plant. J. Soil Sci. U.A.R. 3: 217-255.
Hanks, R. J., H. R. Gardner & R. L. Floran	1969	Plant growth – evapotranspiration relations for several crops in the Central Great Plains. Agron. J. 61: 30-34.
Harmsen, G. W. & G. J. Kolenbrander	1965	Soil inorganic nitrogen. In: Bartholomew, W.V. et al. (Ed.): Soil nitrogen. Agron. Ser. Am. Soc. Agron. 10: 43-92.
Heady, E. O.	1956	Methodological problems in fertilizer use. In: Baum, E.L. et al: Economic analysis of fertilizer use data. Iowa St. Coll. Press, Iowa: 3-21.

Hernando, V., L. Jimeno & A. Guerra | 1955 | Experimental study of the use of fertilizers in dispensing with the fallow period. An. Edafol. Fisiol. veg. 14: 161-176. Abstr. in Soils Fertil. 18 (1955), abstract 2617.

Hernando, V. | 1962 | Soil fertility mapping in Spain. Trans. Comm. IV and V. Int. Soil Conf. New Zealand.

Heslep, J. M. & C. A. Black | 1954 | Diffusion of fertilizer phosphorus in soil. Soil Sci. 78: 389-401.

Hofstee, J. | 1963 | Analysemethoden voor grond, gewas, water en bodemvocht. Rijksdienst voor IJsselmeerpolders, Kampen.

Hopkins, J. W. | 1940 | Agricultural meteorologoy: a statistical study of conservation of precipitation by summer fallowed tanks at Swift Current, Saskatchewan. Can. J. Res. (C) 18: 388-400.

Huffman, E. O. | 1962 | Reactions of phosphate in soils: recent research by T.V.A. Proc. Fert. Soc. 71.

International wheat council | 1969 | Review of the world grains situation 1968/69.

Jackson, M. L. & S. C. Chang | 1947 | Anhydrous ammonia retention by soils as influenced by depth of application, soil texture, moisture content, pH value and tilth. J. Am. Soc. Agron. 39: 623-633.

Janssen, B. H. | 1969 | Konya ovasi verimlilik denemeleri üzerine ön çalisma raporu. In: Tarım Bakanlığı, 1962-1967. Yılları deneme raporları, Bölge Sulu Ziraat Deneme İstasyonu Müdürlüğü, Konya: RR1-RR6.

Janssen, B. H. | 1970a | Soil fertility. In: Meester, T. de (Ed.): Soils of the Great Konya Basin, Turkey. Agric. Res. Rep. 740, Wageningen: 161-168.

Janssen, B. H. | 1970b | Investigations on soil moisture and dry-matter production in the Great Konya Basin. Ibid: 228-238.

Jensen, M. E. | 1968 | Water consumption by agricultural plants. In: Kozlowski, T.T. (Ed.): Water deficits and plant growth, 2. Academic Press, New York: 1-22.

Jensen, M. E. & W. H. Sletten | 1965 | Evapotranspiration and soil-moisture-fertilizer interrelations with irrigated winter wheat in the southern High Plains. Conserv. Res. Rep. U.A. agric. Res. Serv. 4.

Johnson, W. C. | 1962 | Controlled soil cracking as a possible means of moisture conservation on wheat lands of the southwestern Great Plains. Agron. J. 54: 323-325.

Johnson, W. C. | 1964 | Some observations on the contribution of an inch of seeding-time soil moisture to wheat yield in the Great Plains. Agron. J. 56: 29-35.

Johnson, V. A., P. J. Mattern & J. W. Schmidt | 1967 | Nitrogen relations during spring growth in varieties of *Triticum aestivum* L. Differing in grain protein content. Crop Sci. 7: 664-667.

Jong, E. de & D. A. Rennie | 1969 | Effect of soil profile type and fertilizer on moisture use by wheat grown on fallow or stubble land. Can. J. Soil Sci. 49: 189-197.

Jong, G. J. de & J. J. Jonker | 1967 | Invloed van gedeelde stikstofgiften en van CCC op enkele opbrengstbepalende eigenschappen van granen in Oostelijk Flevoland. Stikstof 56: 360-364.

Kaçar, B.	1967	A study on fixation of phosphorus on some soils of Turkey and factors affecting the fixation. Ankara Üniv. Zir. Fak. Yıll. 17 (2): 215-234. Abstr. in: Turkish Scientific and Technical Documentation Centre, Agric. (1968) vol. 1 no 1: 26.
Kilmer, V. J. & L. T. Alexander	1949	Methods of making mechanical analyses of soils. Soil Sci. 68: 15-24.
Kıroğlu, M.	1968	Turkey's fertilizer supply and demand position for 1969-82 by product types, import projections, and dollar value. Report of the CENTO ad hoc working party on fertilizers, Islamabad, Pakistan. Central Treaty Organisation, Ankara: 169-181.
Kohn, G. D., R. R. Storrier & E. G. Cuthbertson	1966	Fallowing and wheat production in Southern New South Wales. Austr. J. exp. Agric. Anim. Husb. 6, 233-241.
Kortleven, J.	1963	Kwantitatieve aspecten van humusopbouw en humusafbraak. Thesis, Wageningen.
Kostic, M., W. Dijkshoorn & C. T. de Wit	1967	Evaluation of the nutritional status of wheat. Neth. J. agric. Sci. 15: 267-280.
Kurmies, B.	1949	Humusbestimmung nach dem Bichromatverfahren ohne Kaliumjodid. Z. PflErnähr. Düng. Bodenk. 44: 121-125.
Large, E. C.	1954	Growth stages in cereals. Pl. Path. 3: 128-129.
Larsen, S.	1967	Soil phosphorus. Adv. Agron. 19: 151-210.
Lehane, J. J. & W. J. Staple	1953	Water retention and availability in soils related to drought resistance. Can. J. agric. Sci. 33: 265-273.
Lehane, J. J. & W. J. Staple	1965	Influence of soil texture, depth of soil moisture and rainfall distribution on wheat yields in S. W. Saskatchevan. Can. J. Soil Sci. 45: 207-219.
Levin, L.	1964	Movement of added nitrates through soil columns and undisturbed soil profiles. Trans. 8th Int. Congr. Soil Sci., Bucharest IV: 1011-1022.
Lewis, D. G. & J. P. Quirk	1967	Phosphate diffusion in soil and uptake by plants as indicated by P^{32} autoradiography. Pl. Soil 26: 445-453.
Lieshout, J. W. van	1960	Invloed van het bodemmilieu op de ontwikkeling en activiteit van het wortelstelsel. Thesis, Wageningen.
Limberg, P.	1964	Der Einfluss von Stickstoff auf Entwicklung und Ertragsbildung. Z. Acker- u PflBau 119: 119-137.
Lindner, R. C. & C. P. Harley	1942	A rapid method for the determination of nitrogen in plant tissues. Science, N.Y. 96: 565-566.
Linscott, D. L., R. L. Fox & R. C. Lipps	1962	Corn root distribution and moisture extraction in relation to nitrogen fertilization and soil properties. Agron. J. 54: 185-189.
Littlejohn, L.	1946	Some aspects of soil fertility in Cyprus. Emp. J. exp. Agric. 14: 123-124.
Luebs, R. E. & A. E. Laag	1969	Evaporation and water stress of barley with increased nitrogen. Agron. J. 61: 921-924.
Maertens, C.	1964	La resistance mécanique des sols à la penetration, ses facteurs et son influence sur l'enracinement. Annls Agron. 15: 539-554.
Martin, J. P. & H. D. Chapman	1951	Volatilization of ammonia from surface fertilized soils. Soil Sci. 71: 25-34.

Mathews, O. R. & T. J. Army — 1960 — Moisture storage on fallowed wheat-land in the Great Plains. Proc. Soil Sci. Soc. Am. 24: 414-418.

Mathieu, M. — 1969 — The working in the field of the F.A.O. fertilizer program. Phosphorus in Agric. 52: 25-29.

Mederski, H. J. & J. H. Wilson — 1960 — Relation of soil moisture to ion absorption by corn plants. Proc. Soil Sci. Soc. Am. 24: 149-152.

Meester, T. de (Ed.) — 1970 — Soils of the Great Konya Basin, Turkey. Agric. Res. Rep. 740, Wageningen.

Meester, T. de — 1971 — Morphological studies on highly calcareous soils in the Great Konya Basin, Turkey. Agric. Res. Rep. Wageningen (in preparation).

Meester, T. de & J. van Schuylenborgh — 1966 — Genesis and morphology of reddish brown coloured soils of the Konya Basin, Anatolia. Trans. Conf. on mediterranean soils, Sociedad Española de Ciencia del Suelo, Madrid: 365-374.

Mehrotra, O. N., N. S. Sinha & R. D. L. Srivastava — 1967 — Studies on nutrition of Indian cereals. I. The uptake of nitrogen by wheat plants at various stages of growth as influenced by phosphorus. Pl. Soil 26: 361-369.

Melsted, S. W., H. L. Motto & T. R. Peck — 1969 — Critical plant nutrient composition values useful in interpreting plant analysis data. Agron. J. 61: 17-21.

Michalyna, W. & R. A. Hedlin — 1961 — A study of moisture storage and nitrate accumulation in soil, as related to wheat yields on four cropping sequences. Can. J. Soil Sci. 41: 5-16.

Ministry of Agriculture (Turkey) — See Tarım Bakanlığı.

Money-Kyrle, A. F. — 1957 — Agricultural development and research in Turkey. Faculty of agricultural Sciences, American University of Beirut. Beirut, Lebanon.

Munson, R. D. & J. P. Doll — 1959 — The economics of fertilizer use in crop production. Adv. Agron. 11: 133-169.

Myers, R. J. K. & E. A. Paul — 1968 — Nitrate ion electrode method for soil nitrate nitrogen determination. Can. J. Soil Sci. 48: 369-371.

Nix, H. A. & E. A. Fitzpatrick — 1969 — An index of crop water stress related to wheat and grain sorghum yields. Agric. Meteor. 6: 321-337.

Olsen, R., C. V. Cole, F. S. Watanaba & L. A. Dean — 1954 — Estimation of available phosphorus in soils by extraction with $NaHCO_3$. Circ. U.S. Dep. Agric. 939.

Olsen, S. R., W. D. Kemper & R. D. Jackson — 1962 — Phosphate diffusion to plant roots. Proc. Soil Sci. Soc. Am. 26: 222-227.

Olsen, S. R., F. S. Watanabe & R. E. Danielson — 1961 — Phosphorus absorption by corn roots as affected by moisture and phosphorus concentration. Proc. Soil Sci. Soc. Am. 25: 289-294.

Olson, R. A., C. A. Thompson, P. H. Grabouski, D. D. Stukenholtz, K. D. Frank & A. F. Dreier — 1964 — Water requirement of grain crops as modified by fertilizer use. Agron. J. 56: 427-432.

Özbek, N.	1953	Potassium conditions of the soils of Ankara and researches on the value of laboratory methods used in determination of fertilizer requirement of the soils. Ankara Univ. Zir. Fak. Yayinl. 45.
Özbek, N., T. Aksoy & G. Çelebi	1967a	The neutron-moisture meter in studies on the effect of fallow on water conservation in arid regions. Proc. Symp. Istanbul, Int. Atomic Energy Agency, Vienna: 39-45.
Özbek, N. & M. Sadiq	1967b	A modified anion exchange resin equilibration method for the determination of available phosphorus in soils. Yb. Fac. agric. Univ. Ankara: 95-106.
Paauw, F. van de	1949	Water relations of oats with special attention to the influence of periods of droughts. Pl. Soil 1: 303-341.
Pathak, S. S.	1965	Response of unirrigated wheat to N and P. Indian J. Agron. 10, 393-398.
Penman, H. L.	1956	Evaporation: an introductory survey. Neth. J. agric. Sci. 4: 9-29.
Peters, D. B.	1957	Water uptake of corn roots as influenced by soil moisture content and soil moisture tension. Proc. Soil Sci. Soc. Am. 21: 481-484.
Peters, D. B.	1960	Relative magnitude of evaporation and transpiration. Agron. J. 52: 536-538.
Peterson, R. F.	1965	Wheat. Leonard Hill Books, London. Intersc. Publ. Inc., New York.
Plas, L. v. d. & R. Schoorl	1970	Mineralogy of heavy clay from former Backswamp soils of the Great Konya Basin. In: Meester, T. de (Ed.): Soils of the Great Konya Basin, Turkey. Agric. Res. Rep. 740, Wageningen: 213-220.
Power, J. F. & D. D. Evans	1962	Influence of soil factors on the water requirements of crops. In: Cannell, G. H. (Ed.): Water requirements of crops. Am. Soc. agric. engng, spec. publ. sp-sw-0162: 40-46.
Radford, P. J.	1967	Growth analysis formulae – their use and abuse. Crop Sci. 7: 171-175.
Ramig, R. E.	1960	Relationships of soil moisture at seeding time and nitrogen fertilization to winter wheat production. Diss. Abstr. 21: 1320-1321.
Ramig, R. E. & H. F. Rhoades	1963	Interrelationships of soil moisture level at planting time and nitrogen fertilization on winter wheat production. Agron. J. 55: 123-127.
Rennie, D. A. & J. S. Clayton	1966	An evaluation of techniques used to characterize the comparative productivity of soil profile types in Saskatchevan. In: Soil Chemistry and Fertility. Meeting of Commissions II and IV of the International Society of Soil Science, Aberdeen: 365-376.
Richards, L. A. (Ed.)	1954	Diagnosis and improvement of saline and alkali soils. U.S. Dep. of Agric. Handbook 60.
Ridder, N. A. de	1965	Sediments of the Konya Basin, Central Anatolia, Turkey. Palaeogeography, Palaeoclimatology, Palaeoecology 1: 225-254.
Rohrmoser, K.	1964	Untersuchungen über Beziehungen zwischen Witterung und Ertrag bei Weizen, Gerste (und Baumwolle) in einigen Gebieten der Türkei. Diss., Hohenheim.

Russel, J. S. 1963 Nitrogen content of wheat grain as an indication of potential yield response to nitrogen fertilizer. Austr. J. exp. Agric. Anim. Husb. 3: 319-325.

Russel, J. S. 1964 Some observations on the influence of nitrogen fertilizer applied at seeding on the nitrogen content of the wheat grain. Austr. J. exp. Agric. Anim. Husb. 4: 345-351.

Russel, J. S. 1967 Nitrogen fertilizer and wheat in semi-arid environment. I. Effect on yield. Austr. J. exp. Agric. Anim. Husb. 7: 453-462.

Russel, J. S. 1968 Ibid. II. Climatic factors affecting response. Ibid. 8: 223-232.

Russel, M. B. 1959 Moisture conservation in subhumid areas. Adv. Agron. 11: 110-115.

Sande Bakhuysen, H. L. v. d. 1937 Studies on wheat grown under constant conditions. A monograph on growth. Stanford University, California. Food Res. Inst. Misc. Publ. no. 8.

Schreven, D. A. van 1968 Mineralization of the carbon and nitrogen of plant material added to soil and of the soil humus during incubation following periodic drying and rewetting of the soil. Pl. Soil 28: 226-245.

Schrimpf, K. 1960 Die Bedeutung bestimmter entwicklungsphysiologischer Beobactungen fur Züchtung und Ertrag. Z. PflZücht. 43: 390-403.

Schuffelen, A. C. & F. F. R. Koenigs 1962 Plant nutrients in soils of different genesis. Trans. Comm. IV and V. Int. Soil Conf. New Zealand.

Schuurman, J. J. & M. A. J. Goedewagen 1965 Methods for the examination of root systems and roots. Pudoc, Wageningen.

Schuurman, J. J. & L. Knot 1957 Het schatten van hoeveelheden wortels in voor wortelonderzoek genomen monsters. Versl. Landbk. Onderz. 63.14.

Silverstein, R. M. & R. Perthel 1950 Kjeldahl micro-determination. Analyt. Chem. 22: 949.

Skyring, G. W. 1962 Inorganic nitrogen transformation in a black earth. Trans. Comm. IV and V. Int. Soil Conf. New Zealand.

Smika, D. E., A. L. Black & B. W. Greb 1969 Soil nitrate, soil water, and grain yields in a wheat-fallow rotation in the Great Plains as influenced by straw mulch. Agron. J. 61: 785-788.

Smith, A. N. 1965 The influence of superphosphate fertilizers on the yield and uptake of phosphorus by wheat. Austr. J. exp. Agric. Anim. Husb. 5: 152-157.

Soil Survey Staff 1951 Soil survey manual. U.S. Dep. Agric. Handbook 18.

Soper, R. J. & P. M. Huang 1963 The effect of nitrate nitrogen in the soil profile on the response of barley to fertilizer nitrogen. Can. J. Soil Sci. 43: 350-358.

Stanberry, C. O. & M. Lowrey 1965 Barley production under various nitrogen and moisture levels. Agron. J. 57: 31-34.

Staple, W. J. 1960 Significance of fallow as a management technique in continental and winter-rainfall climates. Arid Zone Res. 15: 205-214.

Steenbjerg, F. 1954 Manuring, plant production and the chemical composition of the plant. Pl. Soil 5: 226-242.

Steenbjerg, F. 1966 Fertilization, yield quality and quantity. TagBer. dt. Akad. LandbWiss. Berl. 85: 49-59.

Stone, J. F. and B. B. Tucker 1969 Nitrogen content of grain as influenced by water supplied to the plant. Agron. J. 61: 76-78.

Storrier, R. R.	1965a	The influence of water on wheat yield, plant nitrogen uptake and soil mineral nitrogen concentration. Austr. J. exp. Agric. Anim. Husb. 5: 310-317.
Storrier, R. R.	1965b	The leaching of nitrogen and its uptake by wheat in a soil from Southern New South Wales. Austr. J. exp. Agric. Anim. Husb. 5: 323-328.
Stoy, V.	1965	Photosynthesis, respiration and carbohydrate accumulation in spring wheat in relation to yield. Physiologia Pl. Suppl. 4.
Swartz, G. L. & B. J. White	1966	Interaction of moisture storage at planting and nitrogen fertilization on wheat yield on a black earth. Qd. J. agric. Anim. Sci. 23: 397-406.
Taheri, T.	1960	Untersuchungen über die Entwicklung der Ähre und der Bekörnung bei Winterweizen. Diss., Hohenheim.
Tarım Bakanlığı	1957-'63	Yılları Araştırma Raporu (5 reports). Toprak ve Gübre Araştırma Enstitüsü, Ankara.
Tarım Bakanlığı	1959-'63	Yili Calişmalari (3 reports). Çumra Bölge Sulu Ziraat Deneme İstasyonu. Konya.
Tarım Bakanlığı	1969a	1962-1967. Yılları Deneme Raporları. Çumra Bölge Sulu Ziraat Deneme Istasyonu. Konya.
Tarım Bakanlığı	1969b	1967-1968. Ibid.
Taylor, S. A.	1960	Principles of dry land crop management in arid and semi arid zones. Arid Zone Res. XV: 192-203.
Terman, G. L., R. E. Ramig, A. F. Dreier & R. A. Olson	1969	Yield-protein relationships in wheat grain as affected by nitrogen and water. Agron. J. 61: 755-759.
Tümertekin, E.	1964	Land use in Turkey. Arid Zone Res. 26: 91-93.
Viets, F. G.	1960	Recovery of fertilizer nitrogen on irrigated and dry land soils of the Western United States. 7th Int. Congr. Soil Sci., Madison II: 486-493.
Viets, F. G.	1962	Fertilizers and the efficient use of water. Adv. Agron. 14: 223-264.
Viets, F. G.	1967	Nutrient availability in relation to soil water. In: Hagan, R. M. et al. (Ed.): Irrigation of agricultural lands. Agron. Ser. Am. Soc. Agron. 11: 458-471.
Volke, V. & O. Inostroza	1967	Effect of nitrogen and phosphorus on yield components and other characteristics of winter wheat var. Capelle Deprez. Agricultura téc. 27: 99-105.
Vos, N. M. de	1969	Het produktiepatroon van de granen. In: Min. v. Landb.: Landbouwplantenteelt 1968, voordrachten B-leergang. 's-Gravenhage: 68-87.
Vos, N. M. de & Toussaint, C. G.	1966	De vochtvoorziening van zomergranen op een droogtegevoelige zandgrond. Versl. landbk. Onderz. 67.9.
Vries, O. de & F. J. A. Dechering	1960	Grondonderzoek. 4e druk, Ceres, Meppel.
Waring, S. A. W. E. Fox & L. J. H. Teakle	1958	Fertility investigations on the black earth wheatlands of the Darling Downs, Queensland. I. Moisture accumulation under short fallow. Austr. J. Agric. Res. 9: 205-216.
Waring, S. A. & L. J. H. Teakle	1960	Ibid. III. Mineral nitrogen in the soil and its relation to the wheat crop. Ibid. 11: 27-41.
Watson, D. J.	1952	The physiological basis of variation in yield. Adv. Agron. 4: 101-144.

Watson, D. J., G. N. Thorn & S. A. W. French 1963 Analysis of growth and yield of winter and spring wheats. Ann. Bot. 27: 1-22.

Wesemael, J. C. van 1955 De bepaling van het calcium-carbonaatgehalte van gronden. Chem. Weekbl. 51: 35-36.

Wesley, D. E. 1965 Phosphorus uptake by oat seedlings from phosphorus fertilizer applied to a subsoil as affected by soil moisture. Diss. Abstr. 26: 606.

Wetselaar, R. 1961a Nitrate distribution in tropical soils. I. Possible causes. Pl. Soil 15: 110-120.

Wetselaar, R. 1961b Ibid. II. Extent of capillary accumulation. Ibid: 121-133.

Wetselaar, R. 1962a Ibid. III. Downward movement and accumulation in the subsoil. Ibid. 16: 19-31.

Wetselaar, R. 1962b The fate of nitrogeneous fertilizers in a monsoonal climate. Trans. Comm. IV and V. Int. Soil Conf. New Zealand.

Wetselaar, R. 1967 Determination of the mineralization coefficient of soil organic nitrogen on two soils at Katherine, N. T. Austr. J. exp. Agric. Anim. Husb. 7, 266-274.

Wetselaar, R. & D. F. Beech 1968 The effect of wet season land treatment and nitrogen fertilizer on safflower, linseed, and wheat in the Ord River valley. 1. Soil and crop nitrogen. Austr. J. exp. Agric. Anim. Husb. 8: 59-65.

Wiersum, L. K. 1969 Soil water content in relation to nutrient uptake by the plant. In: Soil water plant, Versl. Meded. Comm. hydrol. Onderz. TNO 15: 74-89.

Willemsen, A. & Th. J. Ferrari 1959 Bedrijfseconomische aspecten van de bemesting. Rapport landbecon. Inst. (LEI) 340, Den Haag.

Williams, M. S. & J. W. Couston 1962 Crop production levels and fertilizer use. FAO Fert. Prog. 1.

Williams, R. F. 1960 The physiology of growth in the wheat plant. I. Seedling growth and the pattern of growth at the shoot apex. Austr. J. Biol. Sci. 13: 401-428.

Willits, N. A. & A. E. Erickson 1956 Moisture utilization by several forage crops. Proc. Soil Sci. Soc. Am. 20: 126-128.

C. T. de Wit 1958 Transpiration and crop yields. Versl. landbk. Onderz. 64.6.

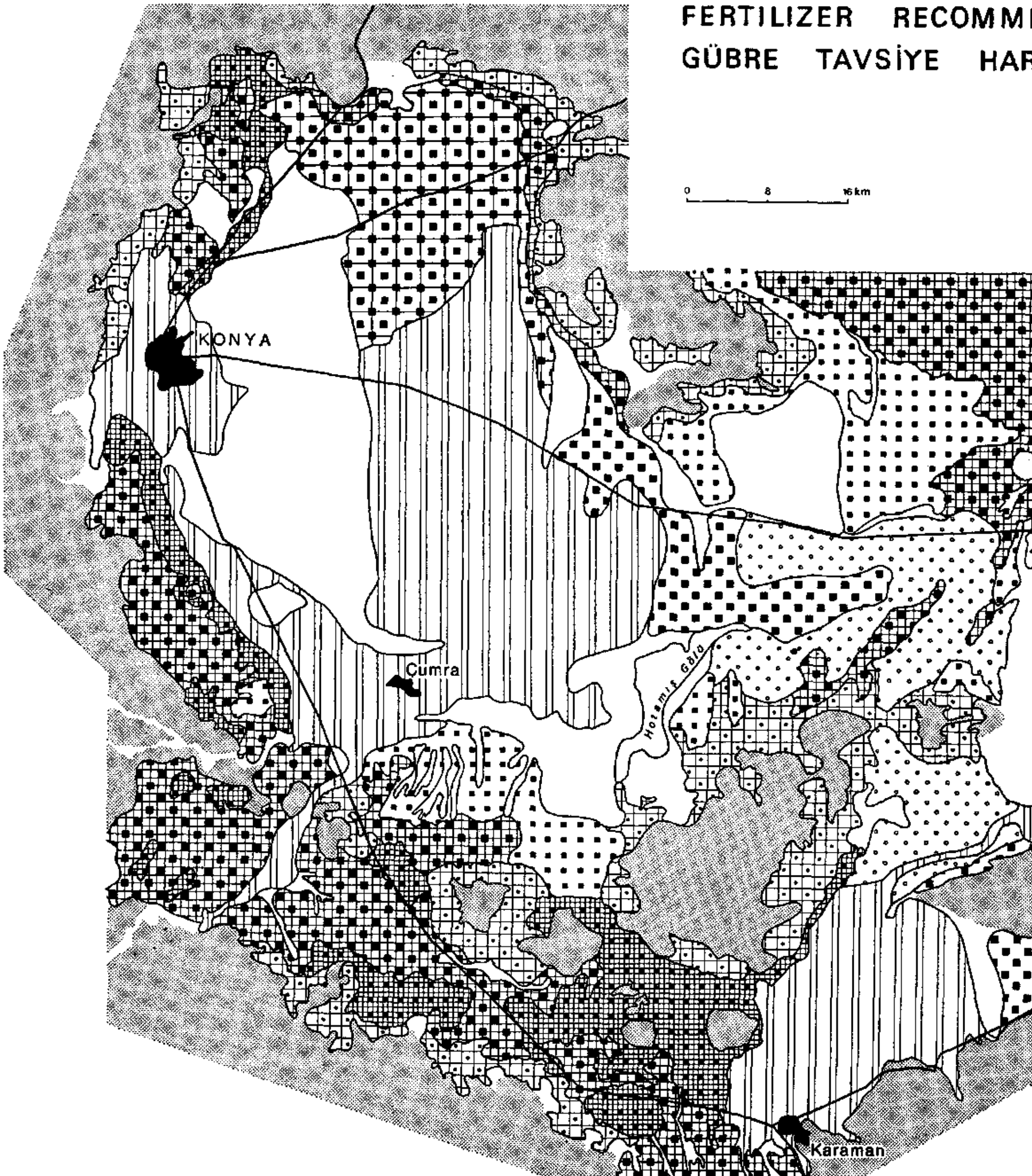
Wood, H. L. & W. E. Fox 1965 The interaction of nitrogen and water on yield, protein and mottling in wheat grown on black earth in Queensland. Expl. Agric. 1: 107-112.

Yang, S. J. & E. de Jong 1968 Measurement of internal water stress in wheat plants. Can. J. Pl. Sci. 48: 89-95.

Yurtsever, N. 1964 The effects of fertilizers on wheat production under irrigated and dry farming conditions in Turkey. 5th Nesa regional irrigation practices seminar, New Delhi. Soil Conservation and Farm Irrigation, Ankara.

Yurtsever, N., M. Atesalp & S. W. Melsted 1965 A tentative correlation for the Olsen bicarbonate phosphorus soil test with wheat responses under Turkish soil conditions. Soil Sci. 100: 163-167.

FERTILIZER RECOMME
GÜBRE TAVSİYE HARİ



DATION MAP
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