GROUNDNUT

J. S. KANWAR • H. L. NIJHAWAN • S. K. RAHEJA

GROUNDNUT
ITS NUTRITION AND FERTILIZER RESPONSES IN INDIA

J.S. KANWAR
Associate Director
International Crops Research Institute
for the Semi-Arid Tropics
Hyderabad

H.L. NIJHAWAN
Agricultural Chemist
Regional Station
Indian Agricultural Research Institute
Kanpur

S.K. RAHEJA
Head
Division of Sample Survey Methodology
Indian Agricultural Statistics Research Institute
New Delhi

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J.S. KANWAR
H.L. NIJHAWAN
S.K. RAHEJA

1. INTRODUCTION

THE cultivated groundnut *Arachis hypogaea* L. originated in South America and is now grown in 82 countries in the world and India is the largest producer of the crop. India, China, Nigeria, USA and Senegal account for four-fifths of the world's groundnut production. Groundnut was introduced in India in the 16th century. The area under the crop, however, was rather small till the beginning of the present century, being around one lakh hectares. It increased progressively to 6 lakh hectares by the end of the First World War and to 45 lakh hectares by 1950. By the end of the Second Five-Year Plan (1960-61), the area increased to 60 lakh hectares and further to 73 lakh hectares by 1975-76. Correspondingly, the production of groundnut increased from 2 lakh tonnes to about 34 lakh tonnes in 1950 and about 48 lakh tonnes by the end of the Second Five-Year Plan (Table 1.1). The production level during 1975-76 reached 73 lakh tonnes. The importance of the crop can be judged from the fact that India stands first among groundnut-growing countries both with regard to area and production accounting for two-fifths of the world acreage and one-third of the world production. However, with regard to average yield per hectare, India stands eleventh out of the 13 major groundnut-producing countries of the world. Thus, the production of groundnut in India has not kept pace with the growth rate of area under the crop in this country. While between 1951-1972 the average yields of groundnut pods in USA rose from 935 to 2,293 kg/ha and today even yields of over 5,500 kg/ha are not uncommon, in India the yields have virtually remained stagnant. It was 775 kg/ha in 1951 and 948 kg/ha in 1976 (Table 1.1).

The cultivation of groundnut was confined to Tamil Nadu and Maharashtra till the beginning of this century. Today, it is cultivated in almost all states and the area under the crop exceeds one lakh hectares each in 9 states (Table 1.2). However, the major groundnut-producing states in India are Andhra Pradesh, Maharashtra, Karnataka, Tamil Nadu and Gujarat which produce nearly five-sixths of the groundnut crop in the country. It is also observed that out of the 5 major groundnut-producing states, Tamil Nadu has 18.1, Andhra Pradesh 16.0, Karnataka 9.1, Maharashtra 2.2 and Gujarat only 1.3 per cent groundnut area under irrigation. Thus, there is considerable scope for increasing production of this crop by supplemental irrigation particularly during *rabi* reason when yields are high.

The area, production and yield trends in India are shown in Figs. 1.1, 1.2 and 1.3 respectively. It is evident that there are great fluctuations in production from year to year, whereas the area remains almost constant. Groundnut is considered a cash crop by the farmers and any fluctuation in

TABLE 1.1. AREA, PRODUCTION AND AVERAGE YIELD OF GROUNDNUT IN INDIA

Year	Area ('000 ha)	Area irrigated ('000 ha.)	%	Production ('000 tonnes)	Average yield (kg/ha)	Index Numbers* Area	Production	Productivity
1950-51	4494	N.A.	—	3481	775	68.1	71.7	105.3
1955-56	5133	89	(1.73)	3862	752	77.8	79.5	102.2
1960-61	6463	195	(3.02)	4812	745	98.0	101.5	103.6
1961-62	6889	231	(3.37)	4994	725	104.4	102.4	98.1
1962-63	7283	192	(2.64)	5064	695	110.3	106.7	96.8
1963-64	6886	209	(3.04)	5298	769	104.3	111.6	96.8
1964-65	7376	217	(2.94)	6004	814	111.6	129.7	116.2
1965-66	7698	259	(3.36)	4263	554	116.5	92.1	79.1
1966-67	7299	355	(4.86)	4411	604	110.5	95.3	86.2
1967-68	7553	413	(5.35.)	5731	759	114.3	123.8	108.3
1968-69	7088	379	(5.47)	4631	653	107.3	100.0	83.2
1969-70	7125	399	(5.51)	5130	720	107.9	110.8	102.8
1970-71	7326	567	(7.74)	6111	834	110.9	132.0	119.1
1971-72	7510	569	(7.58)	6181	823	113.7	133.5	117.5
1972-73	6990	486	(6.95)	4092	585	105.8	88.4	83.5
1973-74	7024	653	(9.30)	5932	845	106.3	128.2	120.6
1974-75	7063	620	(8.78)	5111	724	106.9	110.5	103.4
1975-76	7376	N.A.	—	6991	948	111.6	151.2	135.5

*Base Year : 1959-60 to 1961-62 = 100

Source : Directorate of Economics and Statistics, Ministry of Food and Agriculture, New Delhi.

its production affects the farmer's economy. It is the most important source of vegetable oil and any fall in production causes great hardship even to the urban population which depends on this source of vegetable fat. The fluctuation in groundnut production has led to spurt in prices of food and caused great misery to people. Groundnut cake is an important source of animal and poultry feed. Thus, any shortage of groundnut affects the animals and poultry as well.

Groundnut has thus a unique importance in our country both for local use and as a foreign exchange earner. Although India is the largest groundnut-producing country, its yields per hectare is one of the lowest and the country is faced with the shortage of groundnut. This makes the situation rather serious. It thus becomes evident that all-out efforts have to be made to improve the yields.

Among measures to increase the crop production, the use of chemical fertilisers is perhaps the quickest and the most important. In fact, fertilizer-use is essential not only for increasing the production of groundnut but even for maintaining the present production levels. This becomes evident when we realise that an average crop of groundnut removes about 112 kg N, 27 kg P_2O_5 and 34 kg K_2O from one hectare. Without fertilizer-

TABLE 1.2. AREA, PRODUCTION AND PRODUCTIVITY OF GROUNDNUT DURING 1950-51 AND 1970-71

State	1950-51			1970-71			
	Area ('000 ha)	Production ('000 tonnes)	Area (kg/ha)	Year ('000 ha.)		Production ('000 tonnes)	Yield (kg/ha)
Andhra Pradesh	1210	1040	860	1480	(16.0)	1143	772
Gujarat	696	383	550	1758	(1.3)	1836	1044
Kerala	11	14	1273	15	—	16	1095
Madhya Pradesh	187	103	551	464	*	334	720
Maharashtra	778	472	607	953	(2.2)	617	647
Karnataka	637	547	859	837	(9.1)	613	732
Orissa	24	15	625	70	(7.1)	87	1243
Punjab	40	26	650	174	(12.1)	169	970
Rajasthan	28	14	500	214	(0.91)	142	664
Tamil Nadu	794	763	961	1009	(18.1)	917	917
Uttar Pradesh	89	103	1157	341	(0.31)	222	651
Haryana	—	—	—	10	(6.9)	9	833
All India	4494	3480	774	7326	(7.8)	6111	834

Figures in brackets indicate percentage irrigated area.
*Less than 500 ha.

use and with regular depletion year after year, the soil would become impoverished and ultimately unproductive leading to gradually declining yields. A redeeming feature of the situation is that groundnut belongs to the family Leguminosae and is, therefore, capable of fixing atmospheric nitrogen by the root nodule bacteria. This is not to say that application of nitrogenous fertilizers is not required but that lower doses of nitrogen would be sufficient for a good crop. Also, the application of phosphorus and potassium becomes more important and these need to be supplied in adequate quantities for obtaining higher yields.

Another aspect of fertilizer-use on groundnut is the high cost of fertilizers and short supply. Unless the responses to fertilizer application are high, the farmers will not have the incentive for its use. Because of short supply of fertilizers, the competition from cereals for use of fertilizers particularly for the irrigated soils is very high.

Review of Literature

In India, the groundnut is generally grown under rainfed conditions and only to small extent under limited availability of irrigation water. Keeping in view the uncertainty of rainfall, no regular manuring and plant protection of the crop is done by the farmers. Cattle manure, village sweepings, etc., are applied to the extent available. Application of ferti-

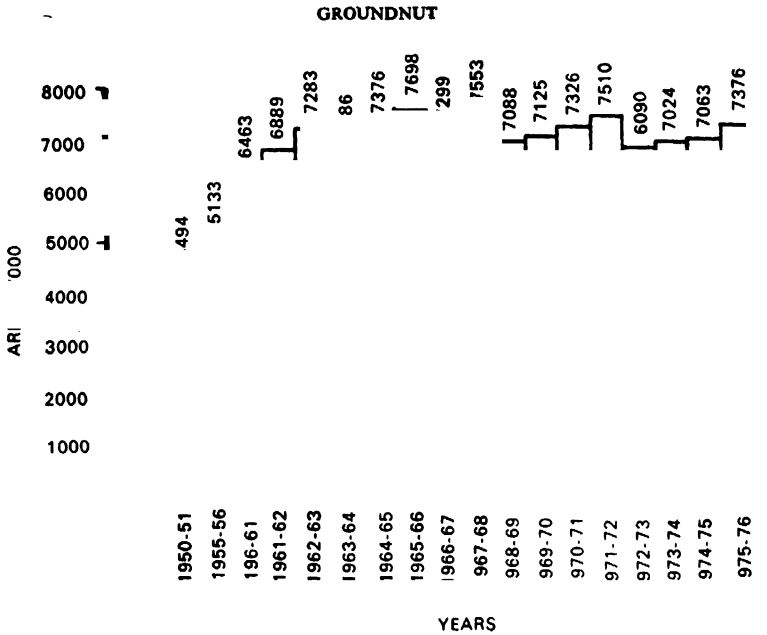

Fig. 1.1. Area trends of groundnut in India

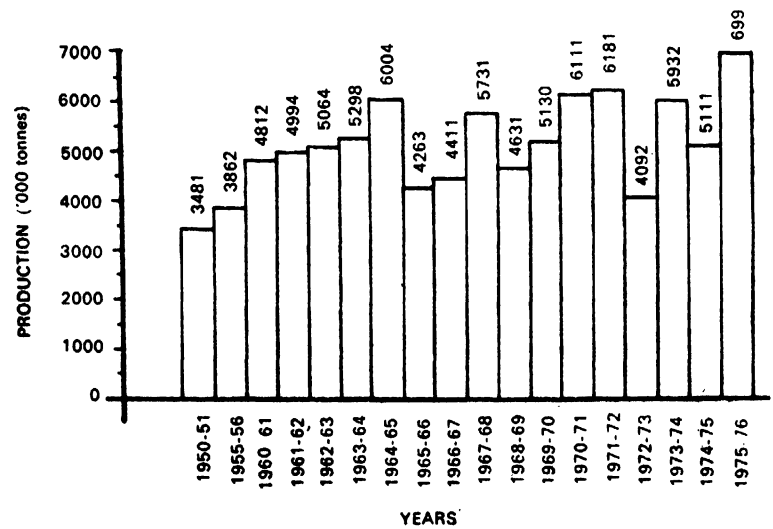

Fig. 1.2. Production trends of groundnut in India

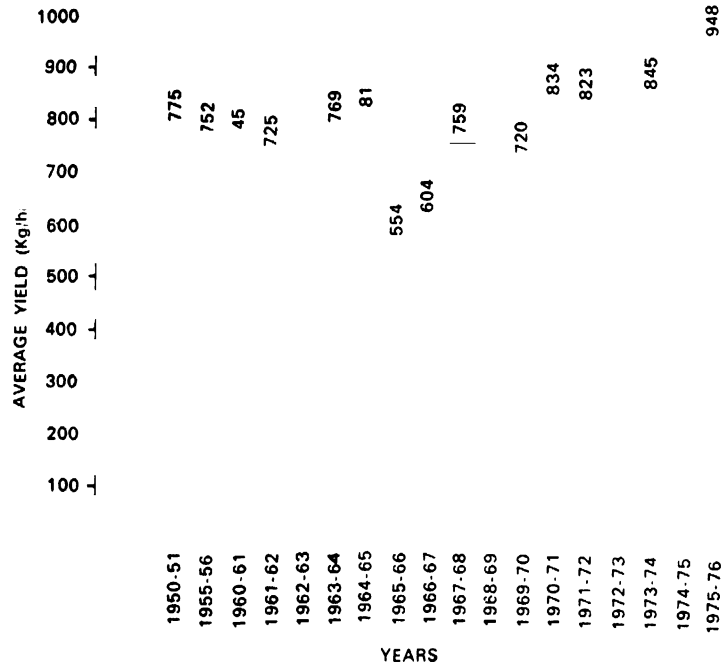

Fig. 1.3. Yield trends of groundnut in India

lizers is practised in very few areas where protective irrigation facilities are available and same is the case with plant protection measures.

The main reason for low yields of groundnut in India is, however, the lack of adequate manuring to the crop which may partly be due to the absence of knowledge of manuring and fertilizer requirements of groundnut in different regions. This information can be obtained from suitably planned experiments for different regions and under varying conditions of cultivation. However, investigations on these aspects do not appear to have received much attention until recently. A review of manuring of oilseed crops was done by Vaidyanathan (1934), Panse *et al.* (1947) and Expert Committee on Manures and Fertilizers (1953). These reviews indicate that the application of nitrogen was found beneficial for the yield of groundnut in parts of Maharashtra, Madhya Pradesh and Tamil Nadu, the additional yield being 7.5 to 12 kg/ha per kg of nitrogen. In Bihar, application of nitrogen and phosphorus showed beneficial effect on the yield of crop. No response was obtained to phosphorus in Kerala while

potash was found to show low response in black soils at Akola (Maharashtra).

The results of manurial experiments conducted in the various states up to 1960 have also been summarised by other research workers. Singh (1958) reported that nitrogen affected yield of groundnut adversely whereas phosphorus was beneficial up to 30 kg P_2O_5/ha. In Tamil Nadu, beneficial effects of P and K application were reported by John and Seshadri (1948). In Punjab, Dalal (1950) reported economic returns with the use of 25 kg/ha of nitrogen as ammonium sulphate as well as with phosphorus as superphosphate. In Uttar Pradesh, Pathak and Verma (1964) reported that no significant beneficial effect was observed with the use of fertilizers. In Gujarat, Patil *et al.* (1958) summarizing the results of 10 year's experiments reported 14 per cent increase in groundnut yield with 5 cartloads of farmyard manure.

In later experiments, phosphorus applied with farmyard manure was also found beneficial. In Karnataka, beneficial effects of P and K application were reported in experiments at Hebbal Farm in red soil.

It is thus clear that while isolated attempts were made to study the responses of groundnut to fertilizers in some of the states, no effort was made on an All-India basis to study the manurial requirements of groundnut. Moreover no experiments were conducted on cultivators' fields. The research done on the manuring of groundnut in the last 15 years is discussed in this publication.

2. CLIMATE AND SOIL

A. CLIMATIC ENVIRONMENTS

THE growth of groundnut is greatly influenced by the climate and soil factors. It can be grown under a wide range of climatic conditions but it thrives best under tropical environments. Temperature and rainfall are two very important environmental factors for the proper development of groundnut crop. Various biometric characters affecting yield, viz., total number of flowers produced and the percentage fertilized, percentage of under-developed and diseased pods and the number of seeds per pod are not merely varietal characters but are also influenced by the amount of rainfall and its distribution. In tropical conditions where temperature is sufficiently high and the rainfall is uncertain, moisture in the soil has to be supplemented through adequate irrigation. A temperature of about 33°C is necessary in the early stage for the young plants to establish. Less warm climate conditions may affect the development of the plant. Groundnut is mostly raised as a *kharif* (rainy season) or a summer crop in India. In Peninsular India where temperatures are favourable during *rabi* or dry season also, groundnut gives excellent yields under irrigation. However, in North India it is only a *kharif* (rainy season) crop. Within a month of sowing, the groundnut crop starts its reproduction phase which is the most important and critical period in the life cycle of the crop. During this phase which lasts for almost 3 months, flowering, formation of gynophores, their development and penetration and final development of pods is completed. The final yield of the crop depends upon the seasonal conditions prevailing during these months. The crop requires intermittent light showers for profuse flowering coupled with sun-shine for further development of flowers. Thus, alternate spells of dry and wet weather are ideal for profuse flowering. Excessive rains are also not desirable for the development of pods since they induce vegetative growth of the plant at the cost of pod formation. Moreover, moist and friable soil is very congenial for the formation and penetration of gynophores and the development of pods. Heavy and continuous rains are not favourable, because they are conducive to high incidence of diseases and pests. Thus, in the life-cycle of groundnut crop, appropriate rainfall pattern is a prerequisite for the success of the crop. Moderate rains during the month of July help the crop in promoting optimum vegetative growth while well-distributed heavy rains during August help to form maximum flowers and pods during the reproductive phase. Moderate rainfall in September and low rainfall in October help in proper development and

maturity of pods and also facilitate easy harvest. Fourrier and Prevot (1958) concluded that rainfall of 25-60 inches is optimum for the growth of groundnut. John*(1937) reported that rainfall of about 3 to 5 inches was required during the period of preparatory cultivation of the land, about 5 to 7 inches of rain during the fortnight of sowing and about 15 to 25 inches of well-distributed rainfall afterwards for the growth period lasting for about 3 to 4 months. Sunny weather at harvest time is essential for getting good yield. The rain at sowing time helps proper germination and good stand while well-distributed rainfall later ensures normal vegetative growth of plants and increases flowering and proper development of pods. Bright sunny weather a little before harvest helps in ripening and later in harvesting and drying operations for good quality crop. Rain or humid weather at harvest time affects proper drying of the produce which gets mouldy and discoloured. The sowing is therefore taken up with the commencement of rains and the harvesting is done after the dry weather sets in. The crop cannot withstand severe drought and water-logging. Heavy and continuous rainfall during the growth period promotes excessive vegetative growth resulting in prolonged growing period and poor yields. Depending on the time of receipt of rains, availability of water supply for irrigation and the variety, the sowing time during the monsoon or summer season has to be fixed taking into consideration various climatic factors. From the experience of growers in most of the states, sowing of the crop whether rainfed or irrigated when done early in the season is most conducive for proper growth and warding off diseases like wilt, thus resulting in high yields. As is well known, long drought periods especially up to pod formation stage have to be avoided as drought conditions during this period reduce the yields considerably.

Effect of Drought. Lin and Chen (1967) found that under drought conditions the plants were shorter, had poor root distribution, less branches and leaves and smaller leaves than irrigated plants. The number of flowers and flowering period were reduced by drought and there was a positive correlation between number of flowers and final yield. Prevot and Biliaz (1962) in trials at Senegal observed that drought was more damaging at flowering time. Under deficient rainfall, yield was proportional to the number of leaves produced at 65 days from sowing and resistance to drought could not be ascribed to root development. Shibuya (1935) observed that adequate amount of water was necessary for the initial fructification in groundnut crop which was adversely affected by high concentration of the nutrient solution, the fructification being retarded by the high osmotic pressure of the fruiting medium and delayed by the lack of oxygen. Sindagi (1964) conducted trials and recorded rainfall data for four years from 1957

*Unpublished

to 1961 in Raichur district of Karnataka state to study the effect of rainfall and its distribution on the yield of the crop. He found that well-distributed rainfall ranging from 575 to 625 mm was quite sufficient to get good yield of groundnut crop in Raichur. Heavy rains offered no advantage to the crop. With high rainfall during July and August when vegetative growth is profuse and flower production maximum, the yield of the crop was affected adversely. Irrigation trial on moisture regime basis at various growth stages of groundnut was conducted under the All-India Co-ordinated Project (ICAR) at Junagarh (Gujarat) during 1968-69 (*kharif*). Irrigations to make up a moisture regime of 20–40% in the first stage of plant growth, viz., 1 to 50 days (till maximum peg formation), 20, 40 and 60 per cent in the third stage viz. 101–120 days (pod ripening stage) were applied to find out effect of moisture regime on the yield of crop. It was found that yield was the highest when 60% moisture regime was achieved in second stage. Best results were obtained with a moisture regime of 40, 60 and 20 per cent in the first, second and third stages respectively. Adequate moisture is thus essential during second stage viz., during pod development stage. Kulkarni (1967) collected metereological data for Riachur district for four years from 1961-1965 and conducted field experiments with different varieties to find out the influence of rainfall, temperature and drought on the yield of groundnut. The weekly rainfall data, average maximum and minimum temperature, average soil temperature at 5 cm depth during the months of August-September-October and yield are presented in Tables 2.1, 2.2 and 2.3.

The yield results in Table 2.3 indicate that the highest yields were recorded during 1962-63 and the lowest in 1961-62. Moderate yields were obtained in the remaining two years. The total rainfall in the months of August to October was also lowest in 1961-62 but moderate in 1962-63 though the total rainfall in both the years was almost the same. The results (Table 2.1) show that the distribution of rainfall during crop growth period is more important than the total quantity of rain. Low rainfall was recorded during August and September in 1961-62 (the year of lowest yields) being 116 mm, while in 1962-63 (the year of highest yield) a rainfall of 386 mm was recorded in these months. The low yield in 1961-62 can therefore be attributed to ill distribution of rainfall as well as low rainfall during the months of August and September. In 1963-64, there were inadequate rains during the month of September which affected the yield of the crop and therefore could not compete with 1962-63. Maximum rainfall was received during 1964-65, but due to long periods of drought during August, the crop growth suffered a set back and even heavy rains thereafter could not make up the loss. Rainfall distribution, therefore, plays an important role in determining the yields of groundnut crop. Moderate rainfall in September and low rainfall in October help the development of pods and facilitates easy harvest. It can, therefore, be concluded that the low yields obtained during 1961-62, 1963-64

TABLE 2.1. WEEKLY RAINFALL (MM) DATA OF RAICHUR FROM AUGUST TO OCTOBER FOR 1961-1965

Year	August (week)				September (week)				October (week)				Total rain (August-October)	Total annual rainfall	No. of rainy days
	1st	2nd	3rd	4th	1st	2nd	3rd	4th	1st	2nd	3rd	4th			
1961-62	—	15.2	26.4	39.4	2.0	41.0	2.0	—	39.0	54.5	20.5	38.4	278.4	703	49
1962-63	10.0	146.0	49.4	21.6	77.4	54.8	26.6	—	8.0	2.2	87.2	10.6	495.8	711	57
1963-64	16.4	31.4	170.6	16.6	—	4.0	2.0	67.9	—	131.2	—	75.2	565.3	737	55
1964-65	48.6	—	3.4	73.2	56.0	96.8	20.0	240.4	96.8	23.6	2.0	—	660.8	876	52

TABLE 2.2. AVERAGE MONTHLY AIR TEMPERATURE AND SOIL TEMPERATURE (°C) DATA OF RAICHUR FOR 1961-1965

Year	August				September				October			
	Air Temperature		Soil Temperature		Air Temperature		Soil Temperature		Air Temperature		Soil Temperature	
	Max.	Min.	Mong.	A.N.	Max.	Min.	Mong.	A.N.	Max.	Min.	Mong.	A.N.
1961-62	31.8	22.4	24.5	32.3	32.9	21.8	24.9	32.0	30.9	21.3	24.5	34.6
1962-63	31.1	22.0	24.8	34.3	30.7	21.5	24.5	33.6	34.9	23.1	26.5	37.3
1963-64	30.6	21.6	23.0	31.9	32.8	22.0	25.8	36.2	31.1	21.4	24.5	34.2
1964-65	31.6	21.6	25.2	33.2	20.1	21.3	24.0	32.8	31.8	20.8	24.5	36.6

TABLE 2.3. VARIETAL YIELD (KG/HA) AS INFLUENCED BY THE SEASON IN DIFFERENT YEARS

Year Date of sowing	1961-62 22-6-61	1962-63 22-6-62	1963-64 30-6-63	1964-65 1-7-64
Varieties				
1	184	560	484	423
2	445	681	491	410
3	180	615	495	463
4	460	712	700	502
5	692	757	695	521
6	479	620	378	341
7	186	615	491	422
8	186	560	468	525
9	671	620	680	587
C.D.	162	N.S.	N.S.	91

N.S.—Not significant.

and 1964-65 were due to failure in meeting the water requirements of the crop during the critical months at one stage or the other.

Atmospheric Temperature. From the study of the average maximum and minimum temperature for the months of August, September and October for four years (Table 2.2) it was observed that the crop required intermittent sunshine in August resulting in high temperature besides good rains. These conditions, it was felt, favoured nutrient uptake, flower formation and their fertilization in this month. It was also concluded from these results that the crop required comparatively low level of temperature during September as in 1962-63. This helped the crop gynophores in penetrating into the soil and in promoting initial development of the pods. During October, maximum temperature should be fairly high which would be the result in case of low rainfall as in 1962-63. This would greatly help proper development of kernels to maturity.

Soil Temperature. Soil temperature is reported to affect the groundnut yields markedly. Some of the best yields are reported from Rhodesia, Malawi and they are attributed to favourable soil temperature besides other favourable conditions. Unfortunately, there is little experimental evidence in India about the effect of temperature on this crop. A study conducted on black soils in Raichur (Karnataka) showed that fairly high temperature of soil at 5 cm depth during the months of August, September and October affected the crop yield favourably. The high temperature, perhaps helped the crop in geotropic action of the gynophores and other developmental activities. However, on the other hand it was observed that a long drought

spell in any of the three months had a detrimental effect on the crop. It seems that soil temperature effect on yield needs critical evaluation.

Varietal Effects. Groundut varieties require different amounts of water for their growth and development. Rao (1936) conducted varietal trials on three varieties, viz., 'Gudiyatham Bunch' which is a short-duration bunch variety, 'Local Mauritius', and 'Salcum' which are long-duration spreading varieties and found that the total water requirement was the highest for 'Salcum' and least in the 'Guidyatham Bunch.' However, the former variety was better than the other two as far as economy in the utilization of water is concerned. About 1.01 to 1.13 kg of water was required by 'Gudiyatham Bunch', as against 0.84 kg by 'Salcum' per gram of dry matter. Time and distribution of rainfall have different effect on different varieties. In South India, it has been observed that the short-duration bunch varieties suffer most with the failure of early rains. The long-duration spreading varieties can pick up the growth with the north-east monsoon in the later stages. As discussed earlier, growth in fruiting period and other developmental stages is mostly influenced by the pattern of rainfall, a well-distributed rainfall in the early stages being necessary for good vegetative growth and flower production. Bright sunshine helps good pod setting and sufficient soil moisture is required for the growth and subsequent development of pods in the soil. It is, therefore, important that the early growth and the first flush of flowering should be over by heavy monsoon period and alternate spell of dry and wet weather for fruiting phase should follow. To secure this benefit, it is necessary that the crop is sown early in the season or the time of sowing should be adjusted to fit in the environmental conditions depending upon variety. This is substantiated by the observations made for two years by Seshadri (1961) while studying the effect of rainfall and its distribution on the number of flowers produced, percentage fertilized and transformed in the pods for the bunch and spreading varieties. He pointed out that in the first year when rain started late and there were very heavy rains during November, early bunch varieties produced maximum flowers late in the season on account of the failure of early rains while in case of late spreading varieties flowers were produced early in growth period and therefore the percentage of fertilization and number of pods formed expressed as percentage of mature pods and yield were lower in the bunch varieties. Next year, early south-west monsoon was well distributed and late north-east monsoon failed. This resulted in maximum flower production in both the types in early part of flowering season. The failure of north-east monsoon later caused poor fertilization and pod-formation in the spreading varieties. Again, late in the season there were some rains which also produced a few flowers into the bunch and quite a large number in the spreading varieties. These flowers produced on account of late rains did not fully develop, espec-

ially in the spreading varieties and the percentage of multi-kernelled pods was very low.

Crop-Weather-Soil Relations. As discussed, information on crop-weather-soil relationship is very important for planning irrigation and cultural requirements of the crop for maximising yields. To investigate the relationship between yield of groundnut crop with rainfall in the season, broad soil type and its fertility status, correlation studies were undertaken with the help of data collected in trials conducted under the ICAR Co-ordinated Research Project during *kharif* 1969 in a number of C.D. blocks located under different agro-climatic and soil conditions. The soil types covered in the areas were as follows:

(*i*) Black and medium black soils, (*ii*) terai loam, (*iii*) red loam, (*iv*) sandy loam, and (*v*) sandy soils. The fertility of these soils was designated as high (H), medium (M) and low (L) for N, P and K taken from soil fertility map drawn by the All-India Soil and Land-Use Survey, The soil type and soil fertility status of different places with total rainfall received during the months of June to December 1969 and yield of groundnut are given in Table 2.4.

It will be seen from Table 2.4 that the highest yield of 2899 kg/ha was recorded at Khargone with medium black soils under 880 mm of rainfall, and high fertility level of phosphorus and potash. The lowest yield recorded was at Tindivanam, with sandy loam soil, under a rainfall of 1470 mm and low soil fertility. It was also observed that the correlation between total rainfall from June to December and yield was negative. The correlations between the yield of groundnut and the monthly rainfall for seven months from June to December 1969 are given in Table 2.5.

A positive correlation between September rainfall and yield and a negative correlation between November rainfall and yield was obtained in these studies. The negative correlation may not be important in bunch varieties as these are expected to be harvested by November. In a centre like Tindivanam with a total rainfall of 1470 mm, 30 per cent of which was received in November at the time of pod maturity spreading types yielded only 376 kg/ha, on the average, while at the same centre the bunch varieties which were harvested earlier yielded 793 kg/ha, i.e., more than double.

B. SOIL ENVIRONMENTS

It is generally believed that light-textured and well-drained soils are more suited for the normal development of groundnut plants. Wet, poorly drained soils are entirely unsuitable. The crop has a distinct tap-root with secondary and deeply spreading roots. As with other deep-rooted plants, it is essential that it be grown on a well-aerated soil with good drainage. Such light soils are no doubt relatively poor in available nutrients and organic matter but with proper fertilisers and other agronomic practices the crop

TABLE 2.4. SOIL TYPE, SOIL NUTRIENT STATUS, TOTAL RAINFALL AND YIELD OF GROUNDNUT (KG/HA) IN SOME DISTRICTS IN 1969

Sl. No.	Places	Soil type	Soil fertility (NPK)	Total rainfall (mm)	Yield (kg/ha)
1.	Jalgaon (Maharashtra)	Black and medium black	LLM	923.6	1373
2.	Digraj (Maharashtra)	,,	MLM	538.2	1576
3.	Khargone (Madhya Pradesh)	,,	LHH	820.0	2899
4.	Lataur (Gujarat)	,,	——	610.7	955
5.	Amreli (Gujarat)	,,	LLL	261.6	1558
6.	Jamnagar (Gujarat)	,,	——	881.6	2167
7.	Junagadh (Gujarat)	,,	MLL	582.6	881
8.	Pantnagar (Uttar Pradesh)	,,	——	1313.6	2431
9.	Pallachi (Tamil Nadu)	Red loam	LMM	759.0	1293
10.	Dharwar (Karnataka)	,,	MLM	703.2	1302
11.	Raichur (Karnataka)	Loam	MLM	679.2	997
12.	Kadiri (Andhra Pradesh)	,,	LLM	441.9	1230
13.	Yellamanchili (Andhra Pradesh)	Sandy loam	LMH	1188.2	643
14.	Karimnagar (Andhra Pradesh)	,,	MLM	1025.0	2133
15.	Mambalpur (Uttar Pradesh)	,,	MLL	870.0	1342
16.	Mainpuri (Uttar Pradesh)	,,	LMM	833.0	1148
17.	Hissar (Haryana)	,,	LMM	503.4	952
18.	Durgapur (Rajasthan)	,,	——	373.2	2452
19.	Ludhiana (Punjab)	,,	MHM	315.6	2400
20.	Tindivanam (Tamil Nadu)	,,	LLL	1470.0	407
21.	Talod (Maharashtra)	,,	——	323.0	529
22.	Samrala (Punjab)	,,	MHM	430.0	1744

L : Low; M : Medium; H : High.

TABLE 2.5. CORRELATION COEFFICIENT BETWEEN YIELDS (KG/HA) AND MONTHLY RAINFALL EXPRESSED AS A PERCENTAGE OF TOTAL RAINFALL FROM JUNE TO DECEMBER 1969

Month	Correlation coefficient between yield and monthly rainfall	
	Spreading varieties	Bunch varieties
June	—0.0550	+0.1176
July	+0.5375	—0.0305
August	+0.1425	+0.2844
September	+0.6647	+0.5974
October	—0.6164	—0.3232
November	—0.7167	—0.3539
December	—0.5493	—0.4176
Total from June to December	—0.1313	—0.4857

does well on soils which are considered poor for most of the other crops. It would, however, be wrong to conclude that the crop is best adapted to soils of relative low fertility and light texture. The requirements of the crop for proper physical conditions of the soil, probably make sandy loam soils best suited for groundnut production. Further, this fact merely emphasises the need for extremely careful programme of fertiliser or soil management in order to mintain high yields and high quality of groundnut and other crops in rotation with groundnut. Groundnut crop in India is generally grown on a variety of soils with a very wide range of physical and chemical characteristics. These could be divided into four broad productivity classes depending upon the soil characteristics affecting growth and yield.

Excellent Soils

The soils have well-drained sandy loam or sandy clay subsoil. The soils are fairly deep and their topography is favourable for tillage operations. They are least prone to erosion. The nutrient content is also good to sustain high yield for a considerable period.

Good Soils

Soils in this class are generally similar to those in Class I except that surface layer of the soils is a little heavier in texture and a little poorer in internal drainage and more gravelly or stony. These soils are also shallower than excellent soils.

Fair Soils

These soils have certain unfavourable characteristics like very fine texture, very coarse texture or very deep sandy upper layer, eroded conditions, steep topography and poor drainage. They are deficient in one or the other nutrient.

Poor Soils

These soils besides having very bad physical characteristics are low in nutrients. The adverse physical conditions and poor nutrient level prevent proper cultivation of the land, limit yield and affect quality. The soils are very sandy, clayey, wet swampy or rocky.

Root development of the groundnut plant is directly related to the texture and fertility status of the soil. No comparative data are available on the root development of a variety on different soils. Ali Mohammed (1933) studied root system of three varieties of groundnut in the alluvial sandy loam soils at Lyalpur (Pakistan) and Seshadri *et al.* (1958), in the red soils at the Agricultural Research Station, Tindivanam (South Arcot), Tamil Nadu, India. The results are summarised in Table 2.6.

There does not seem to be much difference in the root systems in the

TABLE 2.6. ROOT DEVELOPMENT (PENETRATION AND SPREAD) IN CENTIMETRES

Variety	Age (days)	Penetration (cm)	Spread (cm)	Age (days)	Penetration (cm)	Spread (cm)
	Alluvial soils (source : Ali Mohammed *et al.* (1932)					
'Small Japan'	18	66	31	140	130	105
'Small Spanish'	18	60	41	140	150	80
'Burmese'	18	42	47	140	190	113
	Red soils (source : Seshadri *et al.* (1958)					
'Gudiyatham Bunch'	—	66.2	17			
H.G.I.'	—	60.8	5			
Local Mauritius'	—	69.0	35			

two soils except the spread which was less in red soils. Ali Mohammed (1932) also studied the development of root system of groundnut in different textural components, viz., (*i*) sand, (*ii*) clay, and (*iii*) *kankar** and clay. When the plants were 26 days old, the roots were exposed. It was found that plants raised in *kankar* plus clay had the most vigorous root system and developed the largest number of nodules on its main and lateral roots. The root system of plants grown in clay was very poorly developed and there were no nodules. The plants raised in sand occupied an intermediate position. It is, therefore, evident that neither sand nor clay as such is suited for the normal development of groundnut plants as the root development is also affected by fertility status of the soil and loamy texture favours the root development.

Major Groundnut Soils, their Characteristics and Management Problems

On account of increasing demand for groundnut for home consumption and exports and because of good profits, its cultivation has been extended to all types of soils. It is now grown on all the major soil types of the country. However, most of it is grown on the following four soil groups:

I. Alluvial and coastal alluvial soils
II. Red soils including mixed red and black soils
III. Black or *regur* soils
IV. Lateritic soils

Generally the red, mixed red and black soils (Alfisols) and alluvial and coastal alluvial soils of light texture are preferred for groundnut cultivation.

Effect of type of clay mineral on the yielding potential of soil has been studied to a certain extent. But most of the literature on the manurial and

*Lime concretions

other experiments does not give information about the soil type or the effect of soil characteristics on yield. However, the meagre data available suggests that groundnut yield, kernel quality and calcium content of shell was consistently superior in kaolinitic medium than in montmorillonitic or organic medium. In general, in soils predominantly of the 1 : 1 type (kaolinite) clay minerals and with high Ca availability the yield of groundnut is highter than in soils of 2 : 1 type clay minerals such as hydrous mica and montmorillonite.

I. Alluvial and Coastal Alluvial Soils.

The soils are mainly loam or sandy loams of varying depth. Soluble salts are present in variable amounts. The lower layer of many soils contains *kankar* nodule (lime concretions). The soils are alkaline in reaction due to the presence of sodium in the clay complex. They are adequately supplied with phosphorus and potash but are low in organic matter and nitrogen.

The colloids present in the soils are predominantly of expanding illitic type. They do not have as much of expandable layer as the montmorillonite. These soils have intermediate values between the black and the red soils so far as cation-exchange capacity and water-holding capacity is concerned. They are poor in nitrogen. They can convert large percentage of ammonium and potassium from fertilizers in fixed forms. Phosphorus deficiency is also common. Consequently application of nitrogenous and phosphatic fertilizers gives high responses. This soil type covers Indo-Gangetic plains of north India where groundnut is grown in certain pockets. The coastal and alluvial plains of Kutch, Jamnagar, Bhavnagar and Rajkot in Gujarat and recent alluvium of the river Varade in Dharwar (Karnataka) are important areas of groundnut production. A few typical soils of this group are described in the following paragraphs.

(i) *Alluvial soils from Dharwar district of Karnataka.* Groundnut is cultivated in the recent alluvium of the river Varade, a tributory of Tungabhadra. The soils are deep to very deep, well drained, dark yellowish-brown to very dark yellowish-brown in colour and loam to clay loam in texture. Sand streaks within the profile, at different depths, reveal that the soils are riverborne. Waterworn pebbles are also found on the surface. Structural development is noticed in the subsoil. A typical profile is described as under:

Depth (cm)	Description
0—18	Dark yellowish-brown (10YR 4/ dry; 10YR 3/44 moist), clay loam, moderate medium sub-angular blocky structure breaking into fine granular slightly hard, friable slightly sticky and plastic; pH 6.9; plentiful roots.
18—120	Dark yellowish-brown (10YR 4/4 dry; 10YR 3/4 moist) clay loam; moderate medium sub-angular blocky slightly hard, firm, slightly sticky and plastic; few roots, pH 6.6; gradual and wavy boundary.

120—140 Yellowish-brown (10YR dry; 10YR 5/4 moist), clay loam, moderate medium sub-angular blocky; slightly hard, friable slightly sticky and plastic; pH 6.9; gradual and wavy boundary.

140—153 Yellowish-brown (10YR 4/6 both dry and moist), sandy loam; moderate medium sub-angular blocky breaking into fine granular hard, friable, slightly sticky and plastic; PH 6.1.

Analysis

	0–18 cm	18–120 cm	120–140 cm	140–153 cm
Coarse sand(%)	9.25	5.20	10.70	12.60
Fine sand(%)	50.00	52.25	53.90	60.00
Silt(%)	11.00	12.60	11.00	0.00
Clay(%)	27.00	27.60	23.40	0.00
Moisture equivalent(%)	17.90	20.90	18.80	24.80
Water holding capacity(%)	37.23	41.22	38.65	47.12
pH (1:1)	6.90	6.60	6.80	6.10
Organic carbon(%)	0.45	0.30	0.15	0.40
C.E.C. me(%)	11.6	13.5	13.3	22.3
Total P_2O_5(%)	0.020	0.023	0.018	0.02
Total K_2O(%)	0.288	0.336	0.240	0.58

(*ii*) Groundnut cultivation is also practised in the older alluviums of the rivers Varade and Tungabhadra in Dharwar district. These soils are dark brown in colour, deep to very deep, moderately well drained, heavier textured, silty clay with a few rounded waterworn pebbels and fine lime nodules are present on the surface. The alluvium being old shows profile development and well developed structure. The subsoil often shows clay skims, Sand streaks are present in the lower horizons of the profile.

Horizon	Depth (cm)	Description
Ap	0—23	Dark brown (10YR 4/3 both dry and moist), clay loam with very fine lime concretions, moderate medium blocky structure; slightly hard, friable, sticky and plastic; lime nodules show effervescence with dilute acid; pH 7.7; plentiful roots; clear and smooth boundary.
B1	23—94	Dark grayish-brown (10YR 4/2 dry; 10YR 3/3 moist), silty clay with thin patchy clay skins and fine to very fine lime concretions; moderate medium blocky structure, hard, firm, sticky and plastic; only lime nodules show effervescence with dilute acid; pH 7.5; few roots; clear and smooth boundary.
B2	94—155	Dark brown (10YR 4/3 both dry and moist), clay with fine rounded iron concretions, about 2-3 per cent; clay skins visible; very hard, very fair, very sticky and very plastic; pH 7.4; very few roots; clear and smooth boundary.
B22	155—168	Dark brown (10YR 4/3 both dry and moist), clay with fine rounded iron concretions about 2-4 per cent; clay skins visible; moderate medium angular blocky structure; very hard very firm, very sticky and plastic; pH 7.7; clear and smooth boundary.

Analysis

	0–23 cm	23–94 cm	94–155 cm	155–168 cm
Coarse sand (%)	11.35	5.15	8.35	7.70
Fine sand (%)	36.85	34.90	29.85	26.20
Silt (%)	13.80	16.20	17.20	20.40
Clay (%)	37.70	39.60	41.80	41.70
Moisture equivalent (%)	24.90	25.39	26.70	28.81
Water-holding capacity (%)	43.01	42.96	44.69	45.44
pH (1:1)	7.70	7.50	7.40	7.70
Organic carbon (%)	0.55	0.45	0.40	0.30
C.E.C. me (%)	29.3	27.8	24.9	25.8
Total exchangeable base me (%)	22.5	18.0	18.5	22.0
Total P_2O_5 (%)	0.035	0.031	0.020	0.037
Total K_2O (%)	0.480	0.480	0.468	0.560

A typical alluvial soil from groundnut-producing area Village Balion, Samrala, Ludhiana, Punjab, is described below:

Depth (cm)	Description
0—38	10 YR 6/2 (light brown grey); loamy sand; granular, friable; slight effervescence with HCl; medium and fine roots; clear smooth boundary.
38—80	10YR 6/3 (pale brown); sandy loam; columnar, friable, strong effervescence with HCl; few fine lime nodules; medium to fine roots; clear smooth boundary.
90—150	10YR 6/3 (pale brown); sandy clay loam; weak fine to medium subangular blocky; strong effervescence; few fine lime nodules; few fine roots; clear smooth boundary.
150—180	10YR 6/2 (light brown-grey) silty clay loam; mode medium subangular blocky; few fine Fe, Mn and $CaCO_3$ nodules; strong effervescence, no roots.

Analysis

	0–38 cm	38–80 cm	80–150 cm	150–180
Sand (%)	80.0	72.0	60.0	12.0
Silt (%)	8.0	10.0	13.0	60.0
Clay (%)	12.0	18.0	27.0	28.0
Max. water-retention capacity (% by wt.)	22.6	26.3	28.7	34.3
pH (1:2) Soil : Water	8.2	8.3	8.4	8.4
Electrical conductivity (mmhos/cm)	0.51	0.58	0.64	0.75
Organic carbon (%)	0.44	—	—	—
$CaCO_3$ (%)	1.7	3.1	3.5	3.8
Exchange capacity (me/100 g)	6.3	8.4	12.3	16.4
K_2O (kg/ha)	155.0	—	—	—
P_2O_5 (kg/ha)	9.5	—	—	—

II. Red Soils including Mixed Red and Black soils

The red soils grade from the poor, thin, gravelly and light coloured types of the uplands to the much more fertile, deep, dark types in the plains and valleys. They are generally poor in nitrogen, phosphorus and humus. In comparison with the regular soils these soils are poorer in lime, potash iron oxide and are also uniformly low in their phosphorus content. The red soils can be divided into two broad sub-groups, viz. (*i*) red loams, characterised by argillaceous soil with a cloddy sructure and the presence of only a few concretionary material, and (*ii*) red earths where the top-soil is loose and friable but rich in secondary concretions as a consequence of sesquioxide type of clay.

The red soils in Tamil Nadu occupy nearly two-thirds of the cultivated area. The parent rocks are micacious or red granitic, the latter being acidic. The soils are shallow, and open textured with pH ranging from 6.6 to 8.0. They have a low base status and low cation exchange capacity. They are also deficient in organic matter and poor in plant nutrients. An analysis of their clay fractions gives a SiO_2/R_2O_3 ratio of 2.5 to 3.0.

The acid soils in South Bihar, Ranchi, Hazaribag, Santhal Paragnas, Manbhum and Singbhum are red soils. Their pH ranges from 5.0 to 6.8. Another distinguishing feature is the high percentage of acid soluble Fe_2O_3 compared with high silica.

In the Telangana division of Hyderabad, where the predominant geological formation is granite and gneissic complex, both red and black soils predominate. The red soils or *chalkas* are sandy loam located at higher levels. Such soils are used for growing groundnut.

The colloids in red soils have higher percentage of kaolintic clay minerals which show high ionic activities of alkali metal cations. The calcium availability is therefore high and that of NH_4 ion low. NH_4 ion is also less absorbed in these soils than in the black soils. The availability of phosphorus is also lower. The fixation of K is also low. Therefore, these soils give high responses to low doses of nitrogenous and potassic and high doses of phosphatic fertilisers. Since fixation of phosphate is high, placement of phosphatic fertilisers is of special advantage in these soils.

The red soils have content of kaolinitic clay minerals which have low cation exchange capacity and low moisture-retention capacity. They are also very porous soils and can be easily cultivated. They have good drainage and better permeability to water and air. On account of low moisture-retention capacity they require small amount of irrigation at short intervals. They are distributed in all the important groundnut-growing states such as Andhra Pradesh, Tamil Nadu, Karnataka, Bihar, Orissa, Assam and Manipur.

Profile Description of Red Soils : Description of typical red soils of

groundnut tracts of Andhra Pradesh, Karnataka and Tamil Nadu is given in the following pages:

Rayalaseema Region of Andhra Pradesh. Soils are generally formed from the weathering of granite and granite gneiss rocks with a thin layer of colluvial material on the surface. The colour of the top-soil ranges from reddish-brown to yellowish-red and and texture from sandy loam to sandy clay loam depending on erosion. The soils contain coarse fractions of quartz, gravel and weathered rock fragments. It is friable and porous. The texture of the subsoil varies from gravelly clay loam to clay loam, very hard and firm when dry and firm when moist which acts as a hard pan and restricts root penetration and infiltration of water.

A typical red soil profile

Horizon	Depth (cm)	Description
Ap	0—10	Yellowish red (5 YR 5/6 dry and 5 YR 4/6 moist), sandy loam; medium moderate ganular structure; loose when dry, friable when moist; many fine and few coarse roots; clear smooth boundary, pH 6.1.
B2	10—32	Red (2.5 YR 4/6) and dark red (2.5 YR 3/6 moist) gravelly sandy clay loam with quartz gravel 35 to 40 per cent by volume and 5 to 10 mm size; medium, weak subangular blocky structure; very hard when dry, firm when moist, sticky when wet; few fine roots; clear smooth boundary; pH 6.2.
B3	32—86	Very similar to horizon above but gravelly clay loam with quartz gravel 45-55 per cent by volume and 5 mm size gradual smooth boundary; pH 6.4.
C	86—120	Weathered hornblende biotite granite.

Analysis

	—10 cm	10—32 cm	32—86 cm
Coarse sand (%)	48.60	42.10	49.10
Fine sand (%)	37.60	25.35	19.10
Silt (%)	3.52	5.20	7.28
Clay (%)	9.68	26.60	22.96
Moisture equivalent (%)	7.50	15.32	17.62
Water holding capacity (%)	21.10	29.22	30.43
pH (1:2.5)	6.1	6.2	6.4
Organic carbon (%)	0.24	0.24	0.13
C.E.C. me (%)	8.0	11.8	14.4
Total exch. base me. (%)	3.25	7.0	7.85
Total K_2O (%)	0.132	0.180	0.168
Total P_2O_5 (%)	0.038	0.018	0.023
Available P (ppm)	4.8	3.0	1.0
Available K (ppm)	158.0	108.0	90.0

Red Soils from Salem District of Tamil Nadu. These soils are derived from the weathering of gneissic rocks. They are moderately deep to deep, moderately well-drained gravelly sandy loam. The colour of the top-soil ranges from light yellowish-brown to reddish-brown. These soils generally occur on 1 to 3 per cent slopes and occasionally up to 5 per cent slope.

Horizon	Depth (cm)	Description
A	0—15	Light yellowish-brown (10 YR 6/4 dry) coarse gravelly sandy loam with few quartz gravel; single grain structure; loose when dry and non-sticky when wet; pH 7.6; clear smooth boundary; abundant roots.
B	15—48	Dark red (10 YR 3/6 dry) gravelly clay loam with abundant quartz; subangular blocky structure; slightly hard when dry and sticky when wet; pH 7.0; gradual wavy boundary; abundant roots; 25-30 cm thick.
C	48 +	Weathered hornblende gneiss.

Analysis

	0—15 cm	15—48 cm
Coarse sand (%)	49.6	41.3
Fine sand (%)	39.4	22.4
Silt (%)	4.9	8.1
Clay (%)	4.4	26.8
Moisture equivalent (%)	7.0	16.5
pH (1:2.5)	7.6	7.0
Organic carbon (%)	0.18	0.36
C.E.C. me (%)	4.8	10.4
Total Exch. Base me (%)	3.7	9.9
Total K_2O (%)	0.22	0.67
Total P_2O_5 (%)	0.02	0.06

Red Soils of Bellary District of Karnataka. The groundnut-growing areas are mainly confined to yellowish-red to reddish-brown or dark red colluvial soils derived from the residium of banded haematite quartzite. They are moderately deep to deep, moderately well-drained, heavy-textured soils having clay loam to sandy clay loam texture in the surface grading to clay loam to clay or silty clay loam in the subsoil underlain by chlorite schist. Both ferruginous and quartz gravel are present.

Horizon	Depth (cm)	Description
Ap	0—10	Yellowish-red (5 YR 4/8 both dry and moist) clay loam; weak medium blocky structure breaking to weak fine granular structure; slightly hard when dry, slightly firm when moist and sticky and slightly plastic when wet; pH 8.0; plentiful roots; clear and smooth boundary.

B1	10—36	Reddish-brown (5 YR 4/4 both dry and moist) silty clay loam; weak medium blocky structure breaking to weak fine granular; hard when dry, slightly firm when moist and sticky and plastic when wet; pH 8; plentiful roots; clear and smooth boundary.
B2	36—84	Dark reddish-brown (5 YR 3/4 both dry and moist), silty clay loam with ferruginous gravels; moderate medium blocky structure; hard when dry firm when moist and sticky and plastic when wet; pH 8.3; few roots, gradual and wavy boundary.
D	84 +	Weathered chlorite schist with abundant iron pellets about 40 to 50 per cent by volume.

Analysis

	0—10 cm	10—36 cm	36—84 cm
Coarse sand (%)	15.50	12.50	14.20
Fine sand (%)	33.50	31.10	31.45
Silt (%)	24.48	35.72	33.12
Clay (%)	26.16	20.68	20.44
Moisture equivalent (%)	27.28	27.29	21.96
Water-holding capacity (%)	49.95	45.43	49.80
pH (1:2.5)	8.0	8.0	8.3
Organic carbon (%)	0.78	0.84	0.30
C.E.C. me (%)	28.0	30.4	30.4
Total P_2O_5 (%)	0.015	0.021	0.009
Total K_2O (%)	0.438	0.092	0.581

III. Black or Regur Soils

Black soils of India are comparable with the Chernozems of Russia and the prairie soils of the cotton-growing states of the United States. They are derived from the Deccan and the Rajmahal trap and ferruginous gneisses and schists occurring under semi-arid condition. The former attain sometimes considerable depths while the latter are generally shallow. Many black areas are very fertile while uplands are quite poor, sandy on the slopes with a good monsoon. Between the hills they are darker, deeper and richer and are constantly enriched by the material washed down from the hills.

A number of groundnut-growing black soil profiles have been examined in Tamil Nadu. Four types of profiles are distinguished, viz. (*i*) shallow with gypsum, (*ii*) shallow without gypsum, (*iii*) deep with gypsum, and (*iv*) deep without gypsum. The shallow profiles mostly range in depth from three to four feet and in some cases go to a depth of one-and-half to two feet. The deep ones extend up to nine feet and more. The black soils are very heavy and contain up to 65 to 80 per cent finer fractions. They have high pH (8.5 to 9.0) and rich in lime (5—7%). They have low permeability and high hygroscopic coefficient, high water-holding capacity. Due to montmorillonite type of clay minerals they swell on wetting and crack on drying. Sometimes the cracks are very deep. They are low in nitrogen and sufficient in potash

and phosphorus. Black soils have generally a high base status and high base exchange capacity (40 to 60 me). Analysis of clay fractions shows that iron content is about 10 to 13 per cent. The calcium and magnesium contents are high. SiO_2/R_2O_3 varies from 3 to 3.5. The colloids present in black soils are predominantly montmorillonite and have high exchange capacity. The fixation of potassium is more in dry than in wet phase of the soil The basic amino groups of organic cations are also strongly sorbed by these clays so that organic nitrogen decomposition products are not readily decomposed by enzymes. The fixation of ammonium is more in the dry than in the wet phase. In these soils with high amount of $CaCO_3$ and high degree of saturation with Ca the availability of P is low.

As the predominant clay mineral is of expanding type, the soils absorb large quantities of water and therefore show high degree of hydration and swelling. These clay minerals have large specific surface and this results in high water film tension and high plasticity, low air capacity, low hydraulic conductivity, and high power of swelling. These soils become very hard when dry and plastic when wet. As the force required to cultivate them is very high these cannot be cultivated deep very frequently. Shallow cultivation at the low plastic limit is more beneficial and gives good aggregation with large and porous aggregates. On account of these characteristics the irrigation and drainage also presents special problems. Irrigation has to be applied very frequently as the wetting front is restricted. The provision of mole or tile drains at shorter intervals is necessary to drain these soils. These soils are found in west of Maharashtra, part of Karnataka, Tamil Nadu, Madhya Pradesh, southern districts of Rajasthan, Uttar Pradesh, south-east Bihar and north-west of Orissa. These soils are not suited for groundnut cultivation. Description of a few typical black soils is given in the following pages.

Black Soils of Dharwar District of Karnataka. The black soils derived from chlorite schist are generally deep to very deep, moderately well drained, silty clay loam to silty clay. Calcium carbonate is in the concretionary form and the soil matrix does not give any effervescence with dilute acid. The slicken sides on the pod surfaces are well pronounced and the structure is strong, coarse blocky.

Horizon	Depth (cm)	Description
Ap	0—15	Very dark greyish-brown (2.5 YR 3/2 both dry and moist) silty clay loam with lime concretions of 2.4 mm size, 2-3 per cent; moderate coarse subangular blocky; slightly hard when dry, friable when moist, sticky and plastic when wet; pH 8.0; only lime concretions effervescence with dilute acid; plentiful roots; clear and smooth boundary.
B1	15—59	Very dark greyish-brown (2.5 YR 3/2 both dry and moist) silty clay loam with lime concretions of 2.6 mm size, about

		3.5 per cent by volume moderate coarse blocky structure with slickensides; hard when dry, firm when moist, sticky and plastic when wet; pH 8.5; only lime concretions give slight effervescence with dilute acid; few roots; gradual and smooth boundary.
B2	59—112	Very dark greyish-brown (2.5 YR 3/2 both dry and moist); silty clay with strong coarse blocky structure with lime concretions of irregular shape, 5-10 mm size, about 25-30% by volume and prominent, slickensides; very hard when dry, very firm when wet; pH 8.2; lime concretions give effervescence with dilute acid; gradual and smooth boundary.
C	112—155	Weathered chlorite schist of pale olive brown colour.

Analysis

	0—15 cm	15—59 cm	59—112 cm
Coarse sand (%)	9.10	10.00	7.30
Fine sand (%)	22.35	22.50	17.30
Silt (%)	29.20	27.32	28.04
Clay (%)	35.36	37.60	44.04
Moisture equivalent (%)	37.83	34.11	42.10
Water-holding capacity (%)	47.05	51.69	52.81
pH (1:1)	8.0	8.5	8.2
Organic carbon (%)	0.45	0.40	0.45
C.E.C. me (%)	49.5	36.7	43.2
Total Exch. Base me (%)	36.2	32.5	33.8
Total P_2O_5 (%)	0.026	0.024	0.020
Total K_2O (%)	0.384	0.456	0.444

Black Soils of Bellary District of Karnataka. Groundnut is also cultivated on black soils in Bellary district. The soils derived from calcareous gneissic rock and chlorite schists are deep to very deep, moderately well-drained, fine-textured soils having an A_p horizon of 15–22 cm thick, grading to a structurally well-developed B-horizon of finer textured silty, clay or clay of subangular blocky to blocky structure with slickensides. The soil besides containing lime concretions gives violent effervescence with dilute acid.

Horizon	Depth (cm)	Description
Ap	0—20	Dark greyish brown (10 YR 3/2 dry and moist), silty clay loam with lime concretions, 2-6 mm in size and about 15% by volume; moderate and medium subangular blocky structure breaking into weak fine granular structure; slightly hard when dry friable, when moist sticky and plastic when wet; pH 8.0; strong effervescence with dilute HCl, plentiful roots; gradual and wavy boundary.
B1	20—37	Dark brown (10 YR 3/3 both dry and moist), silty clay loam with lime concretions, 2-10 mm in size about 10% by volume;

		moderate medium subangular blocky structure; hard when dry, firm when moist, sticky and plastic when wet; pH 8.1; violent effervescence with dilute HCl, few rectangular, gradual and smooth boundary.
B2—1	37—65	Dark brown (10 YR 3/3 both dry and moist), slity clay loam with lime concretions of 2-10 mm in size about 15% by volume; moderate medium subangular blocky structure; hard when dry, firm when moist, very sticky and plastic when wet; pH 8.5; violent effervescence with dilute HCl; very few roots; gradual and smooth boundary.
B2—2	65—125	Very dark greyish-brown (10 YR 3/2 both dry and moist) clay with lime concretions, of 2-10 mm size and about 10% by volume; strong medium blocky structure with slickensides of the pod surface; hard when dry; firm when moist, very sticky and plastic when wet; pH 8.8; violent effervescence with dilute HCl.
Cca	125+	Calcium carbonate concretions violently effervescencing with dilute HCl.

Analysis

	0—20 cm	20—37 cm	37—65 cm	65—125 cm
Coarse sand (%)	7.55	8.05	7.90	8.25
Fine sand (%)	26.60	23.30	23.30	21.25
Silt (%)	31.28	30.00	33.04	24.40
Clay (%)	32.80	35.32	33.12	43.60
Moisture equivalent (%)	25.68	36.19	32.92	29.93
Water-holding capacity (%)	40.18	43.80	47.08	48.65
pH (1:2.4)	8.0	8.1	8.5	8.8
Organic carbon (%)	0.4	0.45	0.55	0.55
C.E.C. me (%)	34.0	37.8	37.7	35.9
Total Exch. base me (%)	24.60	25.56	22.20	24.30
Total P_2O_5 (%)	0.040	0.031	0.029	0.024
Total K_2O(%)	0.360	0.279	0.741	0.054

IV. Lateritic Soils

Groundnut cultivation in lateritic soil areas is very much limited. The soils are generally deep to very deep, well drained and yellowish-brown to strong brown in colour. The surface soil with sandy loam texture grades to sandy clay loam and gravelly clay. The gravel consists of mostly ferruginous concretions of 1 to 5 mm size and 50 to 60 per cent volume. Description of a typical lateritic soil profile from Kolar district, Karnataka state is as follows:

Horizon	Depth (cm)	Description
Ap	0—20	Light yellowish-brown (10 YR 6/4 dry) to strong brown (7.5 YR 5/6 moist) sandy loam; moderate medium granular; plentiful roots; clear smooth boundary.

B1	20—56	Yellowish red (5 YR 4/6 moist) sandy clay loam; moderate medium subangular blocky; firm when moist, sticky and slightly plastic when wet; plentiful roots, clear wavy boundary.
B2	56—92	Yellowish red (5 YR 4/6 moist) gravely clay with ferruginous concretions, 1-5 mm size and 50—60 per cent by volume; structureless; very firm when moist and sticky when wet.
B3	92—121	Yellowish red (5 YR 5/6 moist) gravely clay with abundant ferruginous and quartz gravel; very hard, firm and sticky.

Description of a typical laterite soil of a groundnut-growing area of Sambalpur, Orissa, is given in the following pages.

The Bandpalli series consists of well-drained, deep to very deep soils occurring on gently sloping uplands (Guda lands) in Sambalpur district, Orissa. The soil pedons have red to yellowish-red loamy sand to sandy loam. A horizon grading to red or dark red clay loam B underlain by massive unconsolidated C horizons. The mean annual precipitation varies from 1400 to 1700 mm and mean annual temperature is about 28°C. Bandpalli series is a member of fine loamy, kaolinitic hyperthermic family of udic Rhodustalfs.

Horizon	Depth (cm)	Description
Ap	0—19	Red (2.5 YR 4/6) loamy sand; weak fine subangular blocky; soft, friable, few fine long roots; few coarse common medium pores; rapid permeability; clear wavy boundary, pH 6.0.
B31 t	19—47	Red (2.5 YR 4/6) sandy loam; weak medium to corase subangular blocky; slightly sticky; few fine and hard ferromanganese concretions; few fine roots; thin patchy clay skins on the root channels; few coarse and many medium pores; moderately rapid permeability; gradual smooth boundary; pH 6.2.
B22 t	47—96	Red (2.5 YR 4/6) clay loam; weak medium subangular blocky; hard, firm and sticky; common dark reddish-brown ferruginous concretions; few fine medium roots; thin discontinuous clay skins; moderate permeability; gradual wavy boundary; pH 6.4.
C1	96—150	Ferruginous gravel and quartz felspathic material.

Analytical Data

Horizon	Depth (cm)	Gravel (%)	Sand (%)	Silt (%)	Clay (%)	Organic carbon (%)	pH (1:2.5)	CEC me/100g soil
Ap	0—19	1.03	87.56	5.92	5.76	0.34	6.0	3.92
B21 t	19—47	4.30	71.68	7.92	19.84	0.24	6.2	8.04
B22 t	47—96	6.23	58.36	11.60	29.36	0.16	6.4	10.00

These soils are very poor in nutrients and have high phosphate-fixation capacity. Their calcium status is very low and liming is considered essential for attaining good yield of groundnut from these soils. They also have deficiency of many micronutrients like molybdenum, zinc, boron and copper which need to be applied to attain good yields.

When groundnut is introduced in such soils for the first time inoculation with a suitable rhizobial culture and application of phosphate. is essential after liming

Classification of Soil Climate Zones for Groundnut Production

Suitable agronomic practices for groundnut-growing areas in the country are very much dependent upon the climatic and soil conditions. Temperature and rainfall are the two most important climatic factors which determine the fertilizer and other cultural practices that affect the yield of the crop. Besides nutrient level, physical soil factors, such as texture, structure, depth, topography and the moisture storage capacity of the soil, also affect the yield of the crops. Consequently, the suitability of these practices for different areas is, to a large measure, controlled by climate interacting with soil. It it thus important to describe soil climatic zones of the country in which groundnut is mostly grown.

Krishnan and Mukhtiar Singh (1972) and Kanwar (1972) have described soil-climatic zones of India on the basis of soil superimposed with moisture indices and thermal indices. Taking the most efficient areas of production under a crop, they have divided the country into eight zones on the basis of moisture regime as indicated by the index:

$$\frac{P - PET}{PET} \times 100$$

where P = Precipitation

PET = Potential evapotranspiration

Based on temperature index each moisture zone is subdivided into three thermal sub-zones.

The accompanying map illustrates these eight zones:

Zone 1 — 80-100 per cent moisture deficient

Zone 2 — 60-80 per cent moisture deficient

Zone 3 — 40-60 per cent moisture deficient

Zone 4 — 20-40 per cent moisture deficient

Zone 5 — 0-20 per cent moisture deficient

Zone 6 — 0-50 per cent moisture excess

Zone 7 — 50-110 per cent moisture excess

Zone 8 — 100 per cent moisture excess

Mean temperature classes for sub-zones

A — Above 28°C

B — 25°-28°C
C — 20°-25°C

Out of 8 zones groundnut is extensively grown in zones 2, 3, 4 and to a small extent in zone 5.

Zone 2. It is the zone of 60–80 per cent moisture deficit. It extends from southern parts of the Punjab and Haryana to Saurashtra. The temperature condition in this dry zone ranges from mild in the north to hot in the south. The zone also includes hot and very hot areas of Rayalaseema and Bellary-Bijapur. Groundnut is grown in the *kharif* season in the north and *rabi* season in the south.

Zone 3. It is a zone of 40–60 per cent moisture deficit. It extends from the Punjab in the north to Anantapur and Cuddapah districts of Andhra Pradesh in the south covering parts of eastern U.P., eastern Rajasthan and Punjab, Haryana and most of the Deccan plateau. It also includes sizable area of southern peninsula as separate pocket. The temperature condition in the zone varies from mild in the Punjab, Haryana and parts of U.P. to very hot in Andhra Pradesh and Tamil Nadu.

Zone 4. It is a zone of 20–40 per cent moisture deficit. It runs as a narrow belt in northern Punjab, Haryana, and western U.P. and covers whole of eastern U.P. and extends up to Bhagalpur in Bihar. It occurs as narrow belt through western parts of Madhya Pradesh, north Maharashtra, north Andhra Pradesh and southern parts of Orissa. The temperature is mild except in Bihar, east U.P. and Maharashtra where it is hot and in a small area in Andhra Pradesh where it is very hot. Another pocket of the zone lies between parts of Zone 3 and includes south Karnataka and adjoining parts of Tamil Nadu. The temperature condition of this pocket varies from mild in the west to very hot in the east.

Zone 5. This is a zone of 0–20 per cent moisture deficit. It covers a very large area in the central part of the country covering most of Madhya Pradesh, south Bihar, Orissa and West Bengal The temperature in northern part of this zone is mild and of the southern part hot. There is a small strip of this zone covering parts of Tanjavur and north Arcot in Tamil Nadu which is very hot.

Groundnut crop is mostly grown in Zone 2 in parts of Gujarat. There are also sizable areas under this crop in Zones 3 and 4 in red and mixed red and black soils. The area under this crop in black soils is mostly in Zones 2 and 3. The crop is practically absent in Zone 1, the driest and the wet Zones 6 to 8. It is advantageous to grow this crop in the *rabi* season in the southern and eastern parts of the country with irrigation.

The areas of high production for groundnut crop are parts of Tamil Nadu, Andhra Pradesh, Maharashtra, Karnataka and Gujarat. Groundnut and sorghum are being grown efficiently in the same climatic belts (4) and (5), but groundnut is more dominant in the red soil and sorghum in the black soil.

TABLE 2.7. DISTRIBUTION OF IMPORTANT CROPS IN IMPORTANT GROUNDNUT GROWING SOIL-CLIMATIC SUB-ZONES IN INDIA

Zone No.	Moisture deficit percentage	Thermal index	Soil group	Districts included in the soil-climatic sub-zones	Important crops
1	2	3	4	5	6
2	80—60	A	Mixed red and black soil	Kurnool, Raichur, Mehbubnagar	*Jowar* (29), Groundnut (14), Rice (6), *Bajra* (4)
		B	Coastal and deltaic alluvium	Kutch, Jamnagar, Junagadh, Bhavanagar, Rajkot, Amreli	*Ragi* (2), Groundnut (30), *Bajra* (23), *Jowar* (18), Cotton (9), Wheat (3), *Til* (2)
		B	Medium and deep black soil	Bijapur, Gulbarga	*Jowar* (45), *Bajra* (10), Cotton (10), Groundnut (10), Wheat (4), *Tur* (4), Linseed (2), Gram (2)
3	60—40	A	Red soil	Nalgonda, Salem, Tiruchirapalli	*Jowar* (20), Rice (18), *Bajra* (13), Groundnut (11), *Ragi* (6), Castor (5), Cotton (2)
		A	Mixed red and black soil	Khammam, West Godavari, Krishna, Cuddapah, Nellore, Madurai, Ramanathapuram, Tirunelveli, Warrangal.	Rice (32), *Jowar* (19), Groundnut (8), Cotton (5), *Bajra* (5), *Til* (4)
		A	Medium and deep black soil	Guntur	*Rice* (24), *Jowar* (19), Tobacco (9), *Bajra* (6), Groundnut (15)
		B	Red soil	Hyderabad, Anantapur	*Jowar* (21), Groundnut (13), Rice (10), *Bajra* (5), Castor (5), Cotton (3), Gram (2)
		B	Grey brown soil	Mehsana, Surendranagar, Kaira, Ahmedabad	Cotton (26), *Bajra* (18), *Jowar* (15), Wheat (9), Rice (5), Groundnut (4), Tobacco (3)

		B	Mixed red and black soil	Jalaun, Hamirpur, Ratlam, Mandsaur, Medak, Bellary, Chitradurga, Coimbatore.	*Jowar* (22), Gram (10), Cotton (10), Wheat (9), Groundnut (7), Rice (5), *Til* (4), *Bajra* (3), *Ragi* (3), Maize (3), Cane (2), Linseed (2), *Tur* (2).
	60—40	B	Medium and deep black soil	Bhind, Datia, Shivpuri, Kotah, Sabarkantha, Panchmahals, Jhabua, Dhar, West Nimar, East Nimar, Baroda, Dhulia, Jalgaon, Buldana, Akola, Amravati, Parbhani, Aurangabad, Nasik, Ahmednagar, Bhir, Sholapur, Osmanabad, Bidar.	*Jowar* (25), Cotton (16), Wheat (9), Groundnut (8), *Bajra* (8), Gram (7), Rice (4), Maize (3), *Tur* (2)
		C	Red soil	Mysore	*Ragi* (25), *Jowar* (16), Rice (11), Groundnut (5), *Tur* (2), Tobacco (2), *Til* (2)
4	40—20	C	Mixed red and black soil	Chittorgarh, Dharwar	*Jowar* (19), Cotton (16), Wheat (16), Maize (10), Groundnut (8), Gram (5), Rice (4)
		A	Red soil	Vishakhapatnam, Srikakulam, Chittoor, Ganjam, North Arcot, South Arcot, Chingleput.	Rice (48), Groundnut (14), *Ragi* (8), *Bajra* (6), *Jowar* (3), *Til* (2)
		A	Mixed red and black soil	Karimnagar	Rice (24), *Jowar* (23), *Til* (11), Maize (11), Groundnut (10)
		B	Red soil	Kolar	*Ragi* (45), Groundnut (10), *Jowar* (8), *Tur* (3), *Bajra* (3)
		B	Shallow black soil	Betul	*Jowar* (17), Wheat (16), Gram (10), *Tur* (8), Groundnut (5), Rice (4), Maize (3)
		B	Medium and deep black soil	Jhalawar, Wardha, Yeotmal, Nizamabad, Nanded, Baroda, Broach.	Cotton (30), *Jowar* (27), Rice (9), Wheat (6), Gram (3), *Tur* (3), Maize (3), Groundnut (2)
		C	Red soil	Chikmagalur, Hassan, Mandya, Tumkur, Bangalore.	*Ragi* (32), Rice (15), *Jowar* (4), Groundnut (3)

Note : Figures in bracket show the area under different crops expressed as percentage of the total cropped area in the region.

The sorghum-groundnut crop complex zone covers most of the black cotton soil and red soil area.

The groundnut-growing districts included in each such zone along with thermal index, soil group and distribution of crops expressed as per cent of the total crop and area in the region are given in Table 2.7.

3. NUTRIENT UPTAKE AND NUTRITION OF GROUNDNUT

A. NITROGEN, PHOSPHORUS AND POTASSIUM

NITROGEN, phosphorus and potassium are the three major nutrients for most of the plants and are applied in the form of fertilizers and groundnut is no exception. In this chapter the role of N, P and K in the nutrition of groundnut has been discussed. The responses to fertilizers are discussed in Chapter 4. For a study of fertilizer requirements of groundnut, information on the total nutrient removal by the crop from the soil would be very much helpful. Nijhawan (1962) analysed the results of fertiliser trials on groundnut conducted at Samrala (Punjab) from 1952 to 1955 and computed average figure for total amount of nutrients uptake by various parts of groundnut plant, viz., kernel, shell, leaves and stalk except the roots which remain in the soil. Results are given in Table 3.1.

Similar study was made by Collins and Morris (1942) for which the results are given in Table 3.2.

TABLE 3.1. NUTRIENT UPTAKE (KH/HA) BY DIFFERENT PARTS OF GROUNDNUT (NIJHAWAN, 1962)

Parts of the plant	Yield	Nutrient uptake				
		N	P_2O_5	K_2O	CaO	MgO
Kernels	1777	85.1	14.5	16.7	1.6	4.0
Shells	892	11.3	0.9	8.1	2.0	1.2
Leaves and stalk	5781	112.2	12.7	35.3	105.3	32.9
Total	8450	208.6	28.1	60.1	108.9	38.1

TABLE 3.2. NUTRIENT UPTAKE (KG/HA) BY DIFFERENT PARTS OF PLANT (COLLINS AND MORRIS, 1942)

Parts of the plant	Yield	Nutrient uptake				
		N	P_2O_5	K_2O	CaO	MgO
Hay	4484	88.3	11.9	92.2	61.7	28.2
Kernels	1435	63.1	14.5	12.2	1.2	4.5
Hulls	807	5.2	0.9	11.1	3.1	1.2
Total	6726	156.6	27.3	115.5	66.0	33.9

The results from Punjab showed that the total uptake of nutrients by an average crop yield of 2670 kg of groundnut pods was 208 kg N, 28 kg P_2O_5, 60 kg K_2O, 108 kg CaO and 38 kg MgO per hectare. Simular results were reported by Collins and Morris (1942) as presented above. It is, therefore, evident that groundnut is a heavy feeder on nitrogen, potassium and calcium. It is also clear that about 54 per cent of total nitrogen, 59 per cent of potash and 76 per cent of calcium is removed by the leaves and stalks. If these are ploughed back an additional supply of 112 kg nitrogen, 13 kg P_2O_5, 35 kg K_2O and 105 kg Ca per hectare will be available annually to the soil. As the soil is not depleted by groundnut cultivation due to symbiotic fixation of nitrogen as described earlier, such additional supplies will be of great help in maintaining the soil fertility. The groundnut plant could thus function as a soil builder if the vegetative parts are ploughed back into the soil.

Nitrogen. Being leguminous plant, groundnut may not respond to large applications of nitrogen. Nitrogen is, however, a major limiting factor in the proper growth of groundnut plant. The data presented in Tables (3.1 and 3.2) regarding nitrogen content of different parts of the crop indicate that relatively large quantities of nitrogen are translocated from the leaves to the developing fruit pointing to the need for maintaining groundnut at a high level of nitrogen metabolism prior to the fruiting period. However, considerable experimental evidence is available to indicate that applications of nitrogen in large quantities is not necessary, when the leguminous plants are inoculated with a good strain of nitrogen-fixing micro-organism. Response to added nitrogen has been reported when groundnut crop was not inoculated or the soil was rather poor. The effect of nitrogen application as a starter also needs to be appreciated. There is also not much experimental evidence whether the crop could effectively utilize the previous inoculum present in groundnut soils and increase its yield. Symbiotic nitrogen-fixation may be inhibited in acid soils, hence response to nitrogenous fertilisers might be more pronounced on such soils. Most of the data on response to nitrogenous fertiliser available in the country is not accompanied with the soil data and information on inoculation, Some authors have indicated that application of nitrogen to soils which are very low in organic matter may be useful. Nitrogen status in groundnut soils is no doubt as important as for any other crop but as far as response to added nitrogen is concerned, the previous history of the field and presence of bracterial cultures or proper *Rhizobia* is essential Nitrogen status of the soil is also correlated with the disease infestation. Experiments at Georgia Experiment Station showed that nitrogen applied to Spanish peanuts caused a marked reduction in Southern root-rot (*Sclerotium rolfsii*) and the reduction in yield was directly related to the intensity of the disease. These results suggest that in some cases the beneficial effect of nitrogen may be due to its secondary influence in reducing the severity of the disease. In some cases the

beneficial effect of nitrogenous fertilisers, like ammonium sulphate, is attributable to the supply of sulphur which is very important nutrient for this crop.

Phosphorus. Young meristematic tissues contain considerable phosphorus which is utilised in the growing region in the formation of nucleoproteins and a number of other constituents. There is considerable inconsistency regarding the responses of groundnut to phosphorus. Some workers have reported that phosphorus stimulates the setting of fruit and decreases the number of unfilled pods whereas others think that phosphorus hastens the maturity of groundnuts. Phosphorus requirement of the crop are not so high, as only a relatively small amount of this element, about 23 kg (Table 3.1) is absorbed by the peanut plant. But realising that availability of phosphates applied to the soil hardly varies between 10-20 per cent even in most soluble sources of phosphate, the need for early soluble sources of phosphate becomes evident particularly on soils extremely low in available phosphorus. The supply of calcium by phosphate fertilisers is also very important factor in the nutrition of this crop and cannot be ignored particularly in soils of low pH with low calcium supply status.

Potassium. Large amount of potassium is required by the groundnut crop. Though comparatively large amount of it is absorbed by the crop, the yield responses to applications of potash have been reported in very few cases in Indian soils. There are some reports that potash applied to groundnut may even be harmful if it is not applied properly. Experiments in North Carolina, USA, have shown that stand of the crop was adversely affected when muriate of potash or potassium metaphosphate was applied in the furrow beneath the seed. When potash was applied in the pegging zone or top-dressed, the yields decreased and a large number of unfilled pods or 'pops' were produced. The practice of applying potash to the top after the plants were grown has been found to be satisfactory in some areas in Virginia. It has been observed that no reduction in the stand of the crop occurred when K was applied in bands at least two inches to the side of the plant.

B. CALCIUM

Calcium requirements of the groundnut plant are quite heavy. An average crop removes about 97 kg Ca per hectare, therefore availability of this nutrient in the soil in adequate quantities is very essential for meeting the nutritional requirements of the crop especially in the case of acidic soils. Even in neutral and alkaline soils of sandy texture, calcium deficiency may become serious. The most redeeming factor in calcium nutrition of groundnut crop is that responses to applications of calcium have been very consistent. Besides its requirements for good growth, a major function of calcium in groundnut nutritrion is the improvement in the quality of

the nuts, as evidenced by lighter, firmer shells and fewer unfilled pods.

Factors Affecting Responses of Groundnut to Calcium

Effect of Soil Characteristics

(i) Ca Content of Soils

Calcium content of the soil and response to added calcium have been reported to be negatively correlated. Colwell and Rogers conducted trials at North Carolina Agricultural Experimental Station in USA. The soils contained low, medium and high amount of calcium. They observed that Ca content of the soils were directly correlated to the responses obtained to calcium. Greater the calcium content of the soil greater the yield. It will be seen that large increases in yields were obtained by the addition of gypsum to soils low in calcium and lowest in soils high in calcium. The results further showed that there was great need of application of gypsum to soils low in calcium. It is also evident from these results that increases in yield obtained from gypsum on low calcium soil may in part be due to the favourable effect of calcium on the shelling percentage which was very low in groundnuts grown in these soils without the application of gypsum. Colwell and Brady (1945) indicated that the Ca-deficient soils produced a large number of unfilled pods and that the yield increases with the applications of Ca are due to the greater number of two cavity fruits and least number of unfilled pods formation. They also obtained very high responses by the application of lime to soils low in calcium. When the calcium content of the soil was increased from approximately 448 kg per hectare of $CaCO_3$ to 896 or 1008 kg by the application of lime the yield increased by 500 per cent. They recommended a dose of 3360 kg of lime on soils low in calcium. However when the soil pH is increased beyond a certain point by liming, the micronutrient deficiencies may occur. Fred Asams and R.W. Pearson in a series of experiments conducted in USA concluded that a strongly acid (pH 5.0) sandy loam subsoil had no detrimental effect on the yields of groundnut crop. The roots appeared to be unaffected by the acidity. The experiments with acid subsoil in growth chambers also showed no apparent detrimental effect on the roots. Experiments with nutrient solution showed that the groundnut crop had a greater propensity for preferential absorption of lower valency ions to the exclusion of higher valency ions. Either or both of these phenomena could explain the greater tolerance of groundnut to lower pH.

A review on groundnut fertilization indicates that very little work has been done on the effect of responses to Ca in Indian soils. It is surmised that responses to Ca may be most effective only if needs of NPK are fully met. On the other hand, a high concentration of potassium in the soil especially in the fruiting zone may be harmful because of its effect on fruit

quality, especially at low calcium levels. Groundnut plant is heavy feeder of potassium and the plant may absorb considerably more of this element than is needed if soils are rich in this nutrient and thus affect the pod filling due to lower availability of Ca and imbalance of Ca and K. There may be a synergetic effect of phosphate addition on responses to calcium also.

Study of effect of lime at Bangalore. Experiments were conducted at Bangalore Hebbal Agricultural Farm (Venkata Rao, 1960) for seven years from 1931 to 1937 to ascertain the influence of Ca in combination with the major plant nutrients, such as nitrogen, phosphoric acid and potash, which were applied at the rate of 11.2, 67.2 and 33.6 kg per hectare respectively. The soil in the experimental area was a red loam typical of the red loamy soils of Bangalore and kolar districts, where groundnut is grown. The soils were nearly neutral in reaction, low in exchangeable calcium and available phosphorus and contained moderate amounts of potash. The results are summarized in Table 3.3.

TABLE 3.3. EFFECT OF LIME ON GROUNDNUT PODS (KG/HA)

Years	Control		NPK		PK		P	
	Lime	No lime	Lime	No lime	Lime	No lime	Lime	No lime
1931	1100	1095	1113	1186	1153	1053	1053	1233
1932	750	800	790	880	946	860	840	813
1933	926	930	1020	1120	1086	1080	1040	1046
1934	1155	800	1306	952	1226	960	1240	900
1935	295	245	372	286	466	320	400	292
1936	460	480	540	500	560	672	592	620
1937	740	455	766	592	712	560	812	520

The results show that treatment with lime alone increased the yield of groundnut pods by over 10 per cent. Similarly phosphate treatment alone increased the yield by a similar amount. The combined application of lime and phosphate increased the yield by over 20 per cent while the additions of nitrogen and potassium did not appear to enhance the yield to any appreciable extent over the effect of phosphate application. These results clearly show the effect of calcium through liming on groundnut yields. This practice would appear to be necessary, particularly in the red sandy and sandy loam soils of Bangalore, Kolar and Tumkur districts where groundnuts are widely grown and which are reported to be low in exchangeable calcium.

Results of similar experiments were reported by Venkata Rao and Govinda Rajan (1954) from Hebbal (Table 3.4). In these experiments, started in 1954, the effect of liming and superphosphate was studied on shelling percentage and oil content besides yields.

TABLE 3.4. EFFECT OF LIME ALONE AND IN COMBINATION WITH PHOSPHATE ON THE YIELD, SHELLING PER CENT AND OIL CONTENT

Treatment	Yield of pods (kg/ha)	Shelling (%)	Oil (%)	Yields of oil (kg/ha)
Control	569	76.5	48.6	171.2
Lime at 112 kg/ha	604	77.8	47.3	183.1
Lime at 112 kg/ha + superphosphate at 136.6 kg/ha	904	78.7	48.2	193.0
Superphosphate alone at 136.6 kg/ha	739	77.5	47.5	227.0

These results show that application of lime alone did not increase the yield of groundnut pods significantly, when it was combined with phosphate which was a limiting factor, the yield increased by nearly 50 per cent. Application of superphosphate alone also benefited the crop significantly but the combination of phosphate and lime produced the best results. It also improved the shelling percentage and total oil yield though oil percentage did not change much.

(ii) Exchangeable Calcium Level of Soils

Rogers (1948) pointed out that lime responses were more closely correlated with the exchangeable calcium level than with percentage calcium saturation in the soil. Colwell and Brady (1945) also found better correlation between response to calcium additions and exchangeable calcium levels than with percentage calcium saturation of the soil. Rogers (1948) indicated that the critical level of exchangeable calcium for groundnut on Norfolk soils in Alabama, USA, was between 0.6 and 0.8 me per 100 g of soil. It was also found that the availability of given amount of exchangeable calcium increased with decrease in the base-exchange capacity of the soil.

Response to added calcium at Alabama to soils containing more than 0.7 me of calcium per 100 ceased but, at North Carolina, lime application gave responses in the soils containing up to 1.40 me exchangeable calcium. The exchangeable calcium of the soil in Alabama is lower because of the lower exchange capacity than those of North Carolina. It was concluded that increased availability of a given amount of

exchangeable calcium in soils depends upon base-exchange capacity of the soil and responses to added calcium are, therefore related to percentage Ca in the base exchange.

(iii) Effect of Type of Clay Mineral

Mehlich and Colwell found that with equal concentrations of calcium in sand-clay systems more calcium was absorbed from the kaolonite or 1:1 type mineral than from the 2:1 type bentonite. The effect of type of clay on calcium availability was also evidenced by the quality of the fruit produced. A high percentage of filled pods was produced on kaolonitic colloids even at relatively low calcium levels. In the bentonite systems large amounts of calcium required to produce fruit of similar quality. These workers observed that the uptake of calcium from kaolonite systems was more directly related to the total calcium present than to the degree of saturation. In the systems of 2:1 type mineral the absorption of calcium was found to be more directly related to the percentage calcium saturation than to the total amount present. Mehlich and Reed (1947) using the percentage of filled nuts as a criterion of calcium availability, found that a small amount of calcium is much less effective in a soil high in organic colloids than in a soil in which the cation absorption capacity arises from kaolonitic type minerals. Greater amounts of calcium were needed for the production of good quality groundnut in soils high in organic matter or in those containing a large percentage of 2:1 type minerals.

Mehlich and Reed studied correlation systems with organic and mineral colloids, kaolonite, bentonite and mica. It was found that for any given level of exchangeable calcium, the quality of fruit was lower when produced in bentonite or mica and at any given cation-absorption capacity the percentage of well-filled pods increased with an increasing degree of calcium saturation. When the percentage calcium saturation was the same in two systems the higher the calcium better was the quality of fruits produced. These workers, therefore, pointed out that both the percentage calcium saturation and total calcium are important in determining the need of calcium in groundnut soils. Percentage of filled nuts has been used as a criterion of calcium availability. They also reported that a small amount of calcium is much less effective in a soil high in organic colloids than in soil in which the cation-absorption capacity arises from kaolonitic type mineral. Greater amounts of calcium, therefore, may be needed for the production of good quality pods in soils high in organic matter or in those containing a large percentage of 2:1 type minerals. As indicated in the relevant chapter, the soil differences in the nature of the colloidal material are found in groundnut soils in different

agroclimatic regions of India. Responses to added Ca have to be studied in the context of their relationships.

Calcium Sources

Important calcium-bearing materials most commonly used for groundnut are gypsum ($CaSO_4.2H_2O$), calcitic limestone or slaked lime and dolomitic limestone. Paper mill waste and blast furnace surface stage could also be used. Brady (1947) emphasised the specificity of calcium as a nutrient for groundnut and showed that cations of a similar nature such as magnesium, cannot be effectively substituted for calcium. If the primary objective in using lime for groundnut is to supply the nutrient calcium it is important to select a material which is most effective in meeting the calcium needs of various soil types and soil conditions. Ordinarily the calcium needs of groundnut should be adequately met by simple liming material. Neutral calcium salts such as gypsum supplies calcium as well as sulphur. It has been reported that on very acid soils (below pH 5.0) groundnut may respond more to liming material than to additions of gypsum. Mann (1935) reported that the addition of lime to acid soils (pH 5.3 and 4.5) resulted in large increase in nodulation while gypsum application reduced the nodulation. Groundnut may absorb considerably more of K than is needed if the soil is rich in this element. In such soils it is very desirable to reduce this luxury consumption of potash to offset the ill effect of potassium on fruit filling. The addition of lime to soils results in a decreased absorption of potash by the plant. On the other hand there is evidence that gypsum may increase the uptake of K (Reed and Brady, 1948). Limestone, theoretically, therefore, may be more useful than gypsum for groundnut. This point may be taken into consideration while applying calcium to K-deficient soils. Limestone may be more useful in K-rich soils. Luxury consumption of K and subsequent accompanying ill effect on fruit filling have to be avoided. However, on soils of extremely low-exchange capacity, it may be necessary to apply a soluble source of calcium in addition to lime in order to supply adequate amounts of calcium. Dolomitic limestone contains about 22 per cent magnesium but it adds less than one-half amount of calcium to the soil to bring to a given pH as would be added when calcitic limestone is used. Therefore, when meeting the calcium requirements of groundnut is the aim, it should be more desirable to use a form of calcitic limestone rather than the one high in magnesium. When soils are low in magnesium content dolomitic limestone may be applied. However, magnesium may be added from a fertilizer source or a mixture of calcitic and dolomitic limestone could be used in these soils. If such a mixture is used, it has been recommended that the ratio of Ca to

Mg in the liming material may be kept relatively high. Numerous trials have been conducted in USA to determine the most satisfactory materials for groundnut. Rogers (1948) studied the effect of six sources of calcium on the yield of Spanish and runner type groundnut grown in a rotation with vetch. The lime materials were applied broadcast at two rates, 1680 and 3360 kg/ha to sandy soil.

The results show that all of the calcium sources were found to be approximately equal in value when applied at the rate of 3360 kg/ha except the calcium silicate slag, which got comparatively low increase in yield but it was also economical. Dolomitic limestone was found to be superior to calcitic lime in doses of 1680 and 3360 kg/ha. Addition of paper mill waste gave maximum yield. The pH of the soil also increased maximum in this case.

Placement of Calcium

A review of trials on groundnut fertilisation showed that very little work has been done on the placement of fertilisers as related to yield responses. Studies by Burkburt and Collins (1941) on the placement of Ca have shown that very high percentage of the calcium absorbed by the groundnut roots is immobilised in the leaves and very little is translocated to the gynophores. Brady (1947) also demonstrated the importance of proper placement of calcium. He showed that large number of well-developed pods were formed on the side of the plant to which calcium was supplied but only few healthy fruits were produced on the other side, in a medium, which had not been supplied directly with calcium. This clearly indicated that calcium is not freely translocated from one part of the plant to the other. As discussed earlier, groundnut has a special feature as to the mode of translocation of Ca and some other nutrients. Harris (1949) using radio-active elements showed that phosphorus, calcium and cobalt are directly absorbed by the developing fruits and are then translocated to other vegetative parts, the movement of nutrients in this case being to the opposite direction. It was found that translocation of calcium was more from pods to vegetative parts and less from the latter to the former. Experiments conducted by Bledsoe (1949, 1950) show that radio-active calcium taken up by the roots moved to the various parts of plants but only a trace of it got translocated to the gynophores and the fruits while calcium applied to the fruiting zone was readily absorbed and a substantial portion also moved back into other parts of the plant. Wiersum (1951) stated that the cause of the absence of transfer of calcium from the stem to the fruit could be that under normal field conditions the water or the nutrient solution in groundnut does not move through the xylem from stem to fruit. A good supply of calcium

is, therefore, very necessary in the zone of pod development as nutrients particularly calcium required for pod development are absorbed directly by the pegs and developing fruits. Calcium also plays an important role in the development of kernel. When calcium is absent from the fruiting medium only one per cent of the gynophores were produced. Haris (1949) and Brady *et al.* (1948) stated that out of the various nutrients added to the fruiting zone only Ca increased fruit filling. Vegetative growth, fruit production and increased fruit production and mineral composition of plant parts all were adversely affected when any of the major nutrient was lacking in the root zone but when Ca was withheld from the fruiting medium only fruit production was affected. Application of the various nutrients to the fruiting zone only withholding from the roots, never the less, manifested in all the important deficiency symptoms. Presence of nutrients in fruiting as well as rooting zone is, therefore, necessary. Burkhurt and Collins (1941) found that the presence of calcium in the fruiting medium had a definite favourable effect on fruit filling, and size and weight of kernel. The presence of potassium alone in the fruiting medium had a definite unfavourable effect on the fruit quality irrespective of the nature of the rooting zone. The quality improved when calcium was also added alongwith potassium (Harris 1949). Results of experiments to study the effect of application of calcium to soil giving low yields on account of production of a very high percentage of unfilled fruits have been reported by Shibuya and Suzhuki (1954). They showed that withholding Ca resulted in 70 per cent unfilled pods. Calcium applied to the fruiting and rooting zones of plants gave 100 per cent filled pods. When calcium was applied to the fruiting zone alone and the rooting zone alone, the percentage of unfilled pods was about 20 per cent and 30 per cent respectively of the total number. The percentage of light groundnuts harvested has been stated to be an index to the lime requirements of the soil. Harris (1949) observed that application of gypsum, between 15 and 35 days after the penetration of the gynophores into the soil, in the top layer of 3 cm where most of the pods are formed had the greatest effect on the percentage of developed pods. Ca also encourages root growth. The effect on the root development studied by Ali Mohammed *et al.* (1932) has already been discussed. Adequate amount of calcium in the fruiting as well as root zones, therefore, is very important for development of the plant, high yield and good quality crop. Colwell and Brady (1945) emphasised the importance of proper placement of calcium containing materials for groundnut in soils low in calcium when gypsum was applied to the fruiting and root zone.

The results show that increase in well-filled pods, shelling percentage and yields was greater when gypsum was applied to the fruiting zone.

When it was applied to rooting zone only it did not meet the demands of developing fruit. It was because calcium was absorbed directly by the developing gynophores and, therefore, for proper kernel development it is very important that sufficient quantities of calcium are present in the fruiting as well as in root zone.

The best method of applying gypsum to groundnut is by dusting on the plant at the early flowering stage when it falls around the plant and reaches the zone of pod formation. This is also the time when the need for calcium is the greatest. It also ensures uniform distribution throughout the zone of fruit formation. Since there is little residual effect, normal application of gypsum, 336 to 672 kg/ha in acid soils is necessary for meeting the calcium requirement of groundnut. However, Colwell and Brady (1945) indicated that application of lime in rows during sowing operations is inferior to gypsum. They recommended 1120 to 1680 kg of lime applied broadcast every two to four years, depending upon soil and other characteristics. Lime is broadcast after the land has been ploughed before the crop is sown. Calcium gets concentrated on the surface layer where it is needed for the developing pods. In this way small amounts of lime every year immediately before the crop is sown should be applied in rotation. There is another advantage of yearly applications. Depending upon pH of the soil and Ca content yearly applications supply required quantities of calcium without increasing the pH beyond the level where certain minor element deficiencies are encountered. For acid soils which are low in exchange calcium doses varying from 448 to 672 kg/ha have been recommended in different soils depending upon the pH of the soil. Gypsum is usually applied broadcast and thoroughly mixed in the soil.

Effect of Application of Gypsum

In India very limited amount of work has been done on the effect of gypsum or other calcium salts on groundnut. The earliest experiments reported by Dalal, Kanwar and Saini (1963) have been discussed elsewhere. A number of trials were conducted at different places in 1968 to 1970 to see the effect of gypsum on yield, shelling percentage and other ancillary character contributing to yield. Important results are discussed below:

Gujarat State

Experiments were conducted in 1968-69 and 1969-70 to study the effect of gypsum on the crop on the medium black soils of Gujarat. The treatments were :

(A) Diammonium phosphate + Gypsum

(B) Ammonium sulphate + single superphosphate
(C) Diammonium phosphate
(D) Control

Doses of fertiliser were 30 kg and 74 kg of diammonium phosphate and 50 kg and 123.6 kg of gypsum in 1968-69 and 1969-70 respectively. Equivalent amount of ammonium sulphate and superphosphate were used on the basis of S and Ca. The results are given in Tables 3.5 and 3.6.

TABLE 3.5. RESULTS OF APPLICATION OF GYPSUM ON GROUNDNUT DURING 1968-69 (KHARIF)

Treatments	Yield (kg/ha)		Shelling (%)	Pods out of 100		Weight of	
	Pods	Kernels		Developed	Undeveloped	100 pods (g)	1000 kernels (g)
A	748	514	68.66	79	21	107	383
D	739	500	77.62	84	16	108	415
C	733	509	69.48	86	14	117	397
B	700	488	69.70	96	14	124	395
C.D.							

TABLE 3.6. RESULTS OF APPLICATION OF GYPSUM ON GROUNDNUT IN 1969-70

Treatments	Yield of pods (kg/ha)	Shelling (%)	1000 pods wt (kg)	1000 kernels wt (kg)	Pods out of 100	
					developed	undeveloped
B	498	69.5	1.125	0.391	87	13
C	467	70.2	1.082	0.375	82	18
A	420	69.0	1.083	0.380	84	16
D	395	69.4	1.079	0.398	85	15

The results in both the years show that no significant differences were observed between treatments on yield, shelling percentage and other ancillary characters. Information on the total exchangeable Ca and saturation percentage of Ca in the base exchange capacity of the soil was not available to interpret the results.

Karnataka State

An experiment was conducted in 1969 at Raichur (Karnataka) on black soil to find out the effect of calcium as gypsum on the pod for-

mation and yield of groundnut crop. The treatments were :

(A) Control
(B) 400 kg gypsum—every year
(C) 800 kg gypsum—every year
(D) 400 kg gypsum—alternate year
(E) 800 kg gypsum—alternate year
(F) 1200 kg gypsum—alternate year
(G) 1600 kg gypsum—alternate year

A basal dose of $N_{20}P_{40}K_{30}$ was used. The gypsum was incorporated into the soil by broadcasting. The yield data are presented in Table 3.7.

TABLE 3.7. YIELD DATA OF GROUNDNUT PODS IN KG

Treatment			Yield (kg/ha)
400	kg/ha of gypsum	Every year	570.97
400	,,	Alternate year	612.13
800	,,	Every year	456.43
800	,,	Alternate year	603.55
1200	,,	Alternate year	675.57
1600	,,	Alternate year	627.56
Control (Basal dose)			576.12

The results show that none of the treatments had any significant effect on the yield of crop though application of gypsum at the rate of 1200 kg/ha in alternate year gave the highest yield.

Madhya Pradesh

An experiment was conducted in black soils at Khargone, Madhya Pradesh, to study the response of gypsum in the presence of N and P. The following treatments were used:

(A) N_{10} $G_{14\cdot53}$ (10 kg N as urea, 14.53 kg Ca as gypsum)
(B) N_{10} P_{20} (Urea + superphosphate)
(C) N_{10} $Ca_{14\cdot53}$ $S_{11\cdot2}$ (Urea + $CaCO_3$ + Sulphur 11.2 kg)
(D) N_{10} $S_{11\cdot2}$ (Urea + Sulphur)
(E) Control

The results are given in Table 3.8.

It was observed that gypsum produced an additional yield of 488 kg/ha over control. The contribution by gypsum as a source of sulphur was 151 kg over the NP treatment. The differences however were not significant.

TABLE 3.8

Treatment	Average yield (kg/ha)
NG	22750.8
NP	2124.3
N CaS	2147.7
NS	2115.8
Control	1787.1
C.D. at 5%	219.626

C. SULPHUR

Sulphur is one of the 16 nutrient elements essential for growth of groundnut plants. Along with nitrogen and phosphorus, it plays an important role in the formation of proteins and is involved in the metabolic and enzymic processes of all living cells. Two sulphur bearing amino acids, cystine and methionine are of particular importance for the synthesis of plant proteins. It also forms biologically important compounds like thiourea and plant regulators like thiamin, biotin and glutamin which help in the biological oxidation-reduction processes. Likewise, it plays a vital role in chlorophyll formation since it has been observed that sulphur-deficient plants contain as little as 40 to 60 per cent chlorophyll in comparison with those receiving normal amounts of sulphur.

Oilseed crops, in general, have high sulphur requirements because oil storage organs are quite rich in proteins. The data available on the requirements of different crops for sulphur is scanty, especially information on the minimum sulphur content of groundnut soils required for high yield is lacking. Greenland and Nye found sulphur deficiency in groundnut in certain soils of Nigeria and Goldcoast (Ghana). They further showed that ordinary superphosphate consistently gave higher yields than ammonium phosphate and that sulphur content of the fertilizer accounted for the higher yields. They also indicated that chlorotic plants dusted with gypsum recovered the vigour.

Dalal and Kanwar (1963) while analysing the data of field experiments on groundnut concluded that responses to ammonium sulphate in the sandy soils of Samrala were mainly due to sulphate content of the fertilizer. The sulphur content of various fertilizers is given in Table 3.9.

Similar responses were obtained when gypsum which supplied sulphate and calcium both or single superphosphate which supplied P, S and Ca were applied. Sulphur deficiency in groundnut soils of Ludhiana

TABLE 3.9. SULPHUR CONTENT OF VARIOUS FERTILIZERS

Ammonium sulphate	23.7 per cent
Ammonium phosphate sulphate	15.4 ,,
Ammonium sulphate nitrate	15.1 ,,
Superphosphate (Single)	12.1 ,,
Potassium magnesium sulphate	22.7 ,,
Potassium sulphate	17.2 ,,
Gypsum ($CaSO_4$)	23.5 ,,
Gypsum ($CaSO_4\ 2H_2O$)	18.6 ,,

(Punjab) was reported by Kanwar and Mohan (1964). They found that the soils were mostly fine sandy loam or loamy-sand and in 75 per cent cases there was extreme deficiency of available sulphur. It was thus considered that there was a likelihood of good response of groundnut to sulphur application in these areas and field trials conducted later confirmed this view. The beneficial effect of sulphur as plant nutrient in fertilizers like ammonium sulphate and single superphosphate has been stressed by Mehring and Bennet (1950). Jordan and Ensminger (1960) reported that in Minnesota (USA) in sulphur-deficient areas the plots treated with gypsum yielded about 200 per cent more as compared to the plots receiving no gypsum.

The uptake of sulphur by groundnut plant from the soil is generally in the form of sulphate, though simple forms of organic sulphur in very small quantities are also taken up. The availability of sulphur to plants, therefore, depends on the ability of the soil to supply sufficient soluble sulphate, the rate at which other forms of sulphur become soluble and the rate of mineralisation of organic sulphur.

To assess the availability of various forms of sulphur to groundnut, pot-culture experiments were conducted by Chopra and Kanwar (1966) with Ludhiana sandy-loam soil. Correlation coefficients were calculated between different forms of sulphur, sulphur uptake and yield of groundnut and are given in Table 3.10.

TABLE 3.10. CORRELATION BETWEEN DIFFERENT FORMS OF SULPHUR, SULPHUR UPTAKE AND YIELD OF GROUNDNUT

Forms	Correlation Coefficient	
	Sulphur uptake	Yield
Sulphate sulphur	+0.74	+0.80
Water-solution sulphur	+0.80	+0.82
Heat-solution sulphur	+0.97	+0.96

These results show that heat-soluble sulphur, sulphate sulphur and water-soluble sulphur were correlated with the yield, the highest correlation being with heat-soluble sulphur. The relationship between yield and heat-soluble sulphur is of curvilinear nature.

An amount of less than 10 ppm of heat-soluble sulphur can be taken as a critical limit for available sulphur in soils for groundnut. Soils containing less than this amount are likely to respond to the application of fertilizers containing sulphur. Gypsum ($CaSO_4$. $2H_2O$) could be used as a source of supply of sulphur to plants if fertilizers supplying NPK do not contain any sulphur.

Effect of Sulphur on the yield of Crops

Very little work has been done in India on the yield responses to sulphur applied as fertilizer. In Punjab, Kanwar (1963) recorded that 75 per cent of soil samples collected from groundnut soils of six villages of Samrala (Ludhiana district) were deficient in available sulphur as would be seen from Table 3.11.

TABLE 3.11. SULPHUR STATUS OF SOILS OF GROUNDNUT-GROWING AREAS OF LUDHIANA

Range of available S	Available sulphur supply status	Mean percentage of soil samples
0-15 ppm	Highly deficient	22.5 per cent
5-10 ppm	Deficient	52.5 per cent
10-15 ppm	Satisfactory	17.3 per cent
20 ppm	Good	7.5 per cent

It is seen that groundnut soils in Punjab are mostly deficient in available sulphur. These soils therefore respond to application of fertilisers containing sulphur. The equal responses obtained to sulphur containing fertilizers such as ammonium sulphate and single superphosphate were explained on the basis of their sulphate content (Dalal *et al.* 1963). These authors observed that the yields of groundnut increase by 34 per cent with the application of ammonium sulphate, 46 per cent with superphosphate and 41 per cent with gypsum over the control (Table 3.12). They found that most economical source of sulphur was gypsum. They recommended the use of gypsum for fertilisation of groundnut in these soils where P is not deficient and superphosphate where P is also deficient.

TABLE 3.12. EFFECT OF DIFFERENT TREATMENTS ON THE YIELD OF GROUNDNUT

Treatment	Mean response over control	
	Average of 3 years (kg/ha)	Percentage
Control	1178	—
Ammonium sulphate	401	34
Ammonium chloride	247	21
Superphosphate (Single)	542	46
Superphosphate (Triple)	373	32
Gypsum	483	41
Calcium chloride	306	26

The uptake of various nutrients (including sulphur) as affected by application of different kinds of fertilizers is given in Table 3.13.

TABLE 3.13. EFFECT OF FERTILIZERS ON THE UPTAKE OF NUTRIENT IN GROUNDNUT CROP

Treatment	Percentage			
	N	P_2O_5	Ca	S
Control	1.51	0.734	2.19	0.132
Ammonium sulphate	1.61	0.923	2.17	0.152
Ammonium chloride	1.60	0.710	2.20	0.127
Superphosphate (Single)	1.57	0.973	2.40	0.162
Superphosphate (Triple)	1.52	1.043	2.20	0.141
Gypsum	1.58	0.943	2.40	0.187
Calcium chloride	1.49	0.826	2.30	0.139

These data show that application of ammonium sulphate, single superphosphate and gypsum increased sulphur content in the plants, the highest amount of sulphur becoming available to the crop when gypsum was applied. Likewise, the percentage of N was higher in plants with nitrogenous fertilizers, phosphorus with phosphate fertilizers and calcium with superphosphate (single), gypsum and calcium chloride. Thus, it is evident that higher yield responses with gypsum and superphosphate (single) were mainly because S, Ca, and P requirement of groundnut had been fully met.

Pot-culture experiments were carried by Chopra and Kanwar (1966) on Ludhiana sandy-loam soil (pH 7.8) with 100 ppm (S_1) and 200 ppm

(S_2) sulphur applied alone and in combination with N, P and K. The results are given in Table 3.14.

TABLE 3.14. EFFECT OF DIFFERENT TREATMENTS ON YIELD AND SULPHUR UPTAKE OF GROUNDNUT

Treatment	Weight of groundnut (g) (Mean of 4 replicates)			Sulphur uptake (mg/pot)		
	S_0	S_1	S_2	S_0	S_1	S_2
No fertilizer	34.5	35.0	35.6	15.2	15.4	16.1
N (50 ppm)	38.9	39.0	45.2	17.3	17.8	18.0
N+P (50, 100 ppm)	40.8	45.0	50.5	28.5	20.9	24.0
N+P+K (50, 100, 50 ppm)	43.9	48.2	52.8	20.5	22.5	26.1

The results show significant yield increase by the application of sulphur with N, NP and NPK. The response increased with higher dose of sulphur. The response to nitrogen and sulphur was, however, not significant. Sulphur uptake was also higher when it was applied with the treatments NP and NPK, the increase being greater with higher dose of sulphur. The application of sulphur and nitrogen alone did not show significant effect on the uptake of sulphur. This is possibly on account of higher production of groundnut resulting from the application of NP and PK which in turn led to increase in the requirements of sulphur. There is thus a need for application of sulphur while applying higher doses of fertilizers to ensure that sulphur deficiency does not become a limiting factor under conditions of high fertility.

Chopra and Kanwar (1966) also observed that sulphur fertilization not only increased the yield but also improved the quality of groundnut as is evident from the data in Table 3.15.

TABLE 3.15. EFFECT OF SULPHUR IN YIELD AND CHEMICAL COMBINATION OF GROUNDNUT

Sulphur applied	Weight of nuts (g/pot)	Protein (%)	Cysteic acid (mg/g N)	Methionine (mg/g N)	Oil (%)
Control (NPK)	43.9	29.7	145.2	52.2	46.2
50 ppm	48.9	30.3	147.3	54.2	48.8
100 ppm	52.8	30.6	151.0	55.0	49.6

These results clearly indicate the beneficial effect of sulphur on protein, oil content, cysteic acid and methionine content of groundnuts.

D. MICRONUTRIENTS

Groundnut like other legumes is also very responsive to the application of micronutrients, The response is high in soils deficient or marginal in some of the micrountrients like zinc, boron, molybdenum and copper. The deficiencies of maganese and iron are generally moderate to low, depending upon the soil.

Not much systematic work has been done on the responses to micronutrients in groundnut in India but some of the results reported by the All-India Co-ordinated Micronutrient Project and available from different centres which are very pertinent are reported here.

Responses to Zinc

In a replicated experiment on wheat-groundnut rotation in a sandy loam soil of Punjab Agricultural University, Ludhiana, zinc was applied in the form of zinc sulphate at the rate of 0, 2.8, 5.6 and 11.2 kg/ha directly to wheat and the residual effect was studied on groundnut. The yield data of 5 years from 1972-76 is given in Table 3.16.

TABLE 3.16. RESPONSE OF GROUNDNUT TO RESIDUAL LEVELS OF ZINC APPLIED TO WHEAT IN WHEAT-GROUNDNUT ROTATION (LUDHIANA 1972-76)

Year	Zn added (kg/ha)			
	0	2.8	5.6	11.2
1972	15.3	18.5	20.7	21.8
1973	13.3	15.5	16.9	17.0
1974	23.0	24.9	22.2	21.4
1975	22.0	20.5	18.7	19.0
1976	21.5	22.3	20.6	19.6
Mean	19.02	20.34	19.82	19.76

Source: *Annual Reports*, All-India Co-ordinated Micronutrient Scheme

From these results it may be observed that in the first and second years the response to 2.8 kg zinc was 3.2 and 2.2 q/ha and it also increased further with higher rate of zinc application. In subsequent years, however, the differences became smaller though still the effect of zinc was noticeable.

In 49 field trials conducted in Andhra Pradesh on cultivators. fields, it was observed that 50 kg $ZnSO_4$, on an average, gave a yield increase of 1.9 to 6.2 q/ha.

TABLE 3.17. RESPONSE OF GROUNDNUT TO ZINC APPLICATION (ANDHRA PRADESH 1972-73)

Place	No. of experiments	Increase in yield over control (q/ha)	
		Range	Mean
Nizamabad	8	3.1—5.9	4.4
Nargonda	8	2.7—7.6	6.2
Kurnool	5	2.6—8.3	5.1
Anantapur	15	1.6—12.1	4.1
Guntur	8	1.6—6.7	3.9
Chittoor	5	1.0—3.1	1.9

Source: *Annual Reports*, All-India Co-ordinated Micronutrient Scheme

Takkar and associates (1975) reported that in another experiment conducted from 1970 to 1972 on Ludhiana sandy loam soil the residual effect of zinc on groundnut was highly significant as is evident from the data in Table 3.18.

TABLE 3.18. DIRECT AND RESIDUAL EFFECT OF APPLIED ZINC ON YIELD, ZINC CONCENTRATION AND TOTAL UPTAKE OF ZINC BY GROUNDNUT CROP AND AVAILABLE ZINC STATUS OF SOILS

Level of Zn applied (kg/ha)	Yield (q/ha)	Zn concentration (ppm)	Zn uptake (kg/ha)	Available Zn in soils
0	4.4	16.9	31.9	0.41
11	7.7	25.6	58.3	1.70
22	9.2	25.7	68.2	2.92
33	10.1	25.9	69.2	5.26
44	10.3	26.8	73.1	6.84
55	10.4	27.2	78.9	7.38
LSD @ 5%	2.3	3.7	15.7	14.2

The zinc content in the plants and zinc uptake also showed the same beneficial effect. The available zinc content of the soil also showed the beneficial residual effect. The authors concluded that application of zinc to wheat and its residual effect on groundnut is highly beneficial.

Responses to Other Micronutrients

Sekhon and associates (1978) studied the nutrient status of groundnut from 5 selected villages of Ludhiana and Kapurthala districts of Punjab. They observed that major nutrient deficiencies were B>K>S >Zn>P>Mn>Cu. The inherent deficiency of these nutrients explained the low nutrient status in the plants (Table 3.19).

TABLE 3.19. DISTRIBUTION OF GROUNDNUT SAMPLES COLLECTED FROM LUDHIANA AND KAPURTHALA DISTRICT OF PUNJAB INTO VARIOUS CATEGORIES OF NUTRIENT DEFICIENCY (TOTAL SAMPLES 360) (SEKHON AND ASSOCIATES, 1978)

Nutrient	Percentage of samples in each category		
	Deficient	Sufficient	High
P	66	34	—
K	94	6	—
Ca	5	87	8
Mg	—	79	21
S	74	25	1
Zn	71	29	—
Cu	47	52	1
Fe	13	87	—
Mn	55	45	—
B	95	5	—

The same authors reported the following ranges of nutrient concentration at different stages of crop growth (Table 3.20).

TABLE 3.20. RANGES AND AVERAGE CONCENTRATION OF NUTRIENTS AT DIFFERENT STAGES OF CROP GROWTH

Nutrient	Vegetative stage		Fruiting stage	
	Range	Mean	Range	Mean
P (%)	0.10 — 0.46	0.23	0.10 — 0.41	0.20
K (%)	0.30 — 2.9	1.08	0.3 — 2.45	0.99
Ca (%)	0.70 — 2.34	1.61	1.06 — 2.92	1.95
Mg (%)	0.35 — 1.10	0.66	0.29 — 1.19	0.75
Zn (ppm)	5.0 — 55.0	17.7	7.0 — 40.5	17.2
Cu (ppm)	1.25 — 18.0	6.3	1.25 — 12.50	5.6
Fe (ppm)	33.0 — 150.0	70.0	66.0 — 226.0	111.0
Mn (ppm)	19.0 — 183.0	52.0	12.0 — 260.0	68.0
B (ppm)	6.5 — 24.0	19.0	4.0 — 30.5	18.0

It shows very widespread deficiency of K, P, S, Zn and B in groundnut in both these districts. The responses to the application of these nutrients are evident from the data of field experiments (Table 3.21).

TABLE 3.21. EFFECT OF DIFFERENT NUTRIENTS ON GROUNDNUT IN SIDHWAN SONA, KAPURTHALA DISTRICT, AND KEDDON, LUDHIANA DISTRICT

Sidhwan Sona, Kapurthala district		Keddon, Ludhiana district		
Treatment	Pod yield (q/ha)	Treatment	Pod yield (q/ha)	
P K Zn B	13.9	B P Zn K	14.4	B = 0.5 kg borax/ha
P Zn B	13.8	B Zn	11.6	P = 40 kg P_2O_5/ha
P K Zn	11.0	B K	11.5	K = 25 kg K_2O/ha
P K B	5.5	B P	9.1	Zn = 25 kg $ZnSO_4$/ha
K B Zn	7.4	B	8.6	
B K	7.2	Control	8.2	
Control	8.5			

From these results it is evident that response to Zn, P, B, and K are very marked. Good responses to boron have also been reported from Gujarat and Maharashtra.

Saini and associates (1975) reported that 3 years data of field experiments from Ludhiana showed that molybdenum, manganese and zinc increased the pod yield by an average of 8.6, 10.3 and 12.3 per cent. They also improved oil content. Muthuswamy and Sundararajan (1973) from Tamil Nadu reported that boron treatment increased the yield of groundnut significantly. Yadahalli and associates (1970) reported that application of boron, zinc and Ca on red sandy soils of village Raddi Timmapur, Bijapur district of Karnataka on cultivators fields increased the yield of groundnut by 25.7, 32.7 and 35.9 per cent respectively. These increases were obtained over and above the effect of phosphate and manure.

4. FERTILIZER RESPONSES

Realising the importance of the groundnut crop in the economy of Indian agriculture and the inadequacy of the information on fertilizer responses particularly under farmers' conditions, ICAR planned simple experiments on cultivators' fields under the All-India Co-ordinated Agronomic Experiments.

These experiments were started from 1958-59. They can be grouped into six broad categories or series. The results of these experiments are presented and discussed in this chapter.

First Series of Experiments (1958-62)

This series consisted of three types of simple experiments to study the effect of N, P and K on groundnut. The experiments were conducted under cultivator's conditions:

Type A : O, N, P, K, NP, NK, PK, NPK
Type B : O, N_1, N'_1, N''_1, N_2, N'_2, N''_2
Type C : O, P_1, P''_1, P_2 P''_2, N_1P_1, N_2P_2

The levels of nutrients studied were 22.4 and 44.8 kg/ha for nitrogen, 33.6 and 67.2 kg/ha for phosphorus and 33.6 kg/ha for potash. In Type A trials only the lower level of N and P were included. These trials were conducted during 1959-60 to 1961-62 in 34 districts located in six soil types covering seven states.

Second Series of Experiments (1962-67)

Since the results of the above series of trials were found very useful, the scope of the trials was enlarged and a more elaborately planned series of trials were taken up in which certain selected combinations of three levels each of N, P and K were studied so as to enable estimation of response curves and surface of these nutrients. The types of trials and treatments in this series were as follows:

A-I : O, N_1, N_2, P_1, N_1P_1, N_2P_2, $N_2P_2K_1$
A-II : O, N_1, P_1, P_2, N_1P_1, N_1P_2, N_2P_2, $N_2P_2K_2$
A-III : O, N_1, K_1, K_2, N_1K_1, N_1K_2, N_2K_2, $N_1P_1K_1$

The levels of fertilizers studied were 0, 15 and 30 kg/ha of nitrogen while for P and K, the levels tried were 0, 30 and 60 kg P_2O_5 and K_2O per hectare under irrigated conditions and 0, 20 and 40 kg/ha under unirrigated conditions. This series of trials was conducted during 1962 to 1967.

in 46 districts located in nine soils covering eight states. Apart from determining the responses to N, P and K, a study of economics of fertilizer application and the optimum fertilizer requirements of the crop in the different regions was also made with the help of the data so obtained.

Third Series of Experiments (1967-70)

In the trials of this series, 2 levels of N, 2 levels of P_2O_5 and 2 levels of K_2O were tried using one check plot.

Treatments: O, N_1, N_2, P_1, N_1P_1, N_2P_1, N_1P_2, N_2P_2, $N_2P_2K_1$, $N_2P_2K_2$

The levels of N were 15 and 30 kg/ha and those of P_2O_5 and K_2O each were 30 and 60 kg/ha. The trials in this series were initiated in 1967-68 and continued till 1969-70. These trials were conducted in 16 districts in nine soil types covering nine districts.

Fourth Series of Experiments under Dry Farming (1970-72)

The programme of trials in this series was initiated in *kharif* 1970-71 with the following treatments under dry farming conditions:

Treatments: O, N_1, N_2, P_1, P_2, N_1P_1, N_2P_1, N_1P_2, N_2P_2, $N_2P_2K_1$

The levels of N and P were 0, 20, 40 kg/ha respectively while potash was tried at 40 kg K_2O/ha. These experiments were continued in 1971-72 and covered five districts in as many soil types and states.

Fifth Series of Experiments Under Dry Farming (1972-77)

The programme of experiments on groundnut grown under dry farming conditions was modified in 1972-73 to study response to nitrogen and phosphorus and their various combinations over a wide range of doses. It was also intended to determine whether application of potash over N and P was beneficial to groundnut under dry conditions. The treatments were as follows:

Treatments: O, N_2, P_2, N_1P_2, N_2P_2, N_3P_2, N_2P_1, N_2P_3, N_3P_3, $N_2P_2K_1$ where levels of N were 15, 30 and 45 kg, P_2O_5, 20, 40 and 60 kg/ha and K_2O only 30 kg/ha. This series of experiments was continued up to 1976-77 covering ten districts in five soils.

Sixth Series of Experiments to Study Crop Substitution with Groundnut (1972-77)

An important aspect of cultivation of groundnut crop is the feasibility of its being more remunerative to the cultivator compared to other

oilseeds like sunflower under dry farming conditions. This aspect was studied by a simple two-crop trial with recommended fertilizer practices. Another treatment included was groundnut crop grown with cultivator's own practice. These trials were conducted during 1972-73 and 1973-74 in 14 districts covering six soil types.

The scope of the crop-substitution experiment with groundnut was modified during 1974-75 to include different combinations of N, P and K for a study of comparative responses of groundnut and other alternative crops. A cereal crop was also included in the latter category in a few districts. The fertilizer treatments studied for each of the two crops were as follows:

O, N, NP, NPK

The levels of N, P and K were as per the state recommendations for the respective crops in the area. This series of experiments was conducted in 11 districts covering six soils and was continued up to 1976-77.

The yield as well as response data from different manurial treatments tried in experiments in different series were examined with the following objectives:

1. Determination of response of groundnut to N, P and K.
2. Relative efficiency of nitrogenous and phosphatic fertilizer.
3. Estimation of response curves and surfaces to N, P and K applied singly and in combination.
4. Formulation of optimum fertilizer recommendations based on the study of economics of fertilizer application to groundnut so as to maximise returns per rupee of investment on fertilizer.

It may be mentioned that the information on interaction between responses to various nutrients was available from all the series of trials except that pertaining to crop substitution aspect.

For a study of aspects 3 and 4 above, the fertilizer response was assumed to follow the law of diminishing returns which can be appropriately described by polynomial of second degree. The optimum doses were estimated so as to maximise net profit received from the use of fertilizer.

Besides these trials under the co-ordinated project of ICAR, a large number of experiments were planned and conducted at different regional research stations and experimental farms in the various states for the study of effect of various factors like fertilizers, cultural practices, improved varieties, etc., on the yield and quality of groundnut. The data of these experiments are collected and compiled at the Indian Agricultural Statistics Research Institute under the project 'National Index of Agricultural Field Experiments' and analysed with appropriate statistical techniques. The results are brought out in the form of compendia for six-year periods. The results of these experiments on groundnut conducted during the period 1960-71 have been suitably pooled and are presented in this chapter.

In addition to the above series of trials conducted in cultivators' fields on an all-India basis and experiments at research stations in different states, data of experiments conducted by other agencies in the various states were also available. In a majority of these experiments, the effect of different doses of the major nutrients like nitrogen, phosphorus and potash under different soil and agro-climatic conditions in various states was studied. However, apart from the fertilizer response, these experiments covered a number of other aspects such as (*i*) effect of other nutrients (calcium, groundnut-cake, F.Y.M. etc.), (*ii*) effect of different types and methods of fertilizer application, (*iii*) effect of cultural practices, (*iv*) effect of fertilizer application on characters other than yield, e.g., vines, number of pods per plant, shelling percentage, oil percentage, etc.

The results of these experiments generally conducted under controlled conditions at research stations or experimental farms have also been reported.

RESULTS AND DISCUSSION

First series of trials (1958-62)

A stated earlier, the first series of trials on groundnut was conducted during 1958-59 to 1961-62. The results pooled over years and districts in the various soils (state-wise) are presented in Table 4.1. The main conclusions are:

(*i*) Application of nitrogen at 22.4 kg/ha was beneficial to the crop in most of the soils, the notable exception being alluvial soils in Tamil Nadu and Haryana.

(*ii*) Application of phosphorus at 33.6 kg/ha showed slightly-better response compared to that of nitrogen in most of the soils. In alluvial soil of Haryana both nitrogen and phosphorus when applied individually did not show marked response but their joint application produced good response.

(*iii*) The best responses were obtained with the application of N, P_2O_5 and K_2O at 22.4, 33.6 and 33.6 kg/ha respectively in almost all soils, being particularly marked in red and yellow soil of Orissa, coastal alluvium soil of Pondicherry and red sandy soil of Tamil Nadu

Thus, the results of this series of trials gave conclusive evidence as to the beneficial effect of N, P and K, particularly when applied jointly in most of the groundnut-growing areas. It may be mentioned here that the crop was mostly unirrigated, irrigation being given only in areas where such facility existed and when the rains failed.

TABLE 4.1. RESPONSE (KG/HA) OF GROUNDNUT TO NITROGEN, PHOSPHORUS AND POTASH (1959-60 TO 1961-62)

State	Broad soil class	No. of districts	No. of years	No. of trials	Control yield	Response to nutrients (kg/ha)							C.D. (5%)
						$N_{22\cdot4}$	$P_{33\cdot6}$	$N_{22\cdot4}$ $P_{33\cdot6}$	$K_{33\cdot6}$	$N_{22\cdot4}$ $K_{33\cdot6}$	$P_{33\cdot6}$ $K_{33\cdot6}$	$N_{22\cdot4}$ $P_{33\cdot6}$ $K_{33\cdot6}$	
1	2	3	4	5	6	7	8	9	10	11	12	13	14
Andhra Pradesh	Red sandy	10	3	159	1283	225	175	201	247	230	259	510	23
Tamil Nadu	Alluvial	1	1	7	1700	70	150	140	70	140	180	250	31
	Red sandy	6	3	30	2227	269	422	472	456	488	586	859	72
Karnataka	Red loamy	3	3	29	1189	152	288	168	297	254	327	450	36
	Red sandy	3	2	20	920	117	194	131	68	59	151	226	71
Maharashtra	Medium black	5	1	110	747	141	157	131	280	224	242	334	19
Orissa	Red and yellow	1	3	13	1741	495	636	458	1299	751	1126	2159	147
Punjab	Alluvial	3	3	28	1157	117	213	330	108	288	336	477	41
Haryana	Alluvial	1	1	4	1210	−190	−100	290	180	70	90	370	178
Pondicherry	Coastal alluvium	1	2	8	2920	700	510	960	485	755	915	1335	129
	Red loamy	3		29	1189	152	288	168	297	254	327	450	
						(6.8)	(8.6)	(3.0)	(8.8)	(4.5)	(4.9)	(5.0)	
	Red sandy	19		209	1384	221	212	233	260	251	296	533	
						(9.9)	(6.3)	(4.2)	(7.7)	(4.5)	(4.4)	(5.9)	
	Medium black	5		110	747	141	157	131	280	224	242	334	
						(6.3)	(4.7)	(2.3)	(8.3)	(4.0)	(3.6)	(3.7)	

(Contd)

TABLE 4.1 (*Contd*)

1	2	3	4	5	6	7	8	9	10	11	12	13	14
	Alluvial	5		39	1260	77 (3.4)	170 (5.1)	292 (5.1)	109 (3.2)	239 (4.3)	283 (4.2)	425 (4.7)	
	Red and yellow	1		13	1741	495 (22.1)	636 (18.9)	458 (8.2)	1299 (38.6)	751 (13.4)	1126 (16.8)	2159 (24.1)	
	Coastal alluvium	1		8	2920	700 (31.2)	510 (15.2)	960 (17.1)	485 (14.4)	755 (13.5)	915 (13.6)	1335 (14.9)	
	Average/ all soils	34		408	1228	199 (8.9)	218 (6.5)	228 (4.1)	291 (8.7)	269 (4.8)	321 (4.8)	531 (5.9)	

Figures in brackets are response per unit nutrient.

The comparative yields of groundnut for different combinations of N, P and K are graphically presented for soils for which results were available for three or more districts (Fig. 4.1).

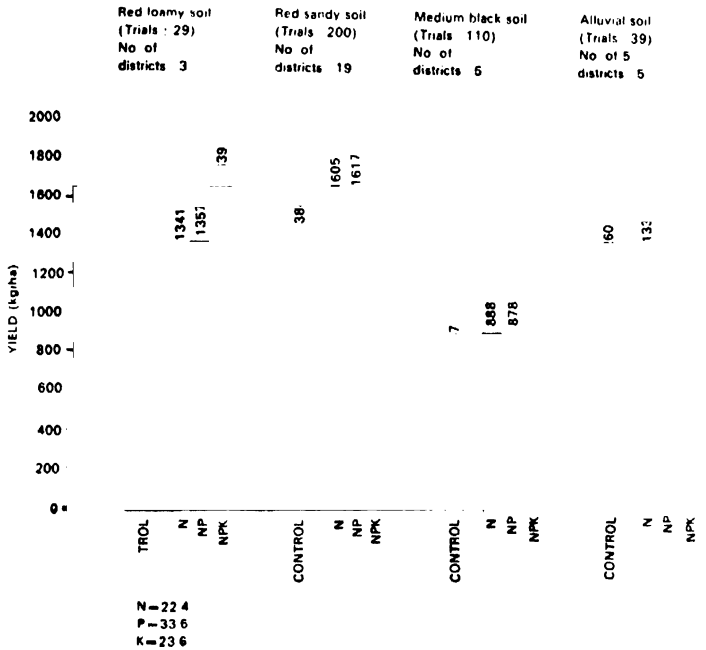

Fig. 4.1. Mean yields (kg/ha) of groundnut obtained under N, NP, NPK treatments on different type of soils in experiments conducted from 1959-62

Second series of trials (1962-67)

The second series of trials was initiated in 1962-63 and continued up to 1966-67. The results are presented separately for irrigated groundnut crop in Tables 4.2a, 4.2b, and 4.2c and for rainfed groundnut crop in Tables 4.3a, 4.3b, and 4.3c.

Groundnut (Irrigated). The responses to N, P and K on groundnut (irrigated) were available from 160 experiments conducted on four soil groups covering five states, viz. Andhra Pradesh, Tamil Nadu, Punjab, Uttar Pradesh and Pondicherry (Tables 4.2a, 4.2b and 4.2c). The results show that:

TABLE 4 2a. RESPONSE (KG/HA) OF GROUNDNUT (IRRIGATTD) TO DIFFERENT LEVELS OF NITROGEN (1962-63 TO 1966-67)

State	Broad soil class	No of dist-ricts	No. of years	No. of trials	Control yield	Response to nutrients (kg/ha)							C.D. (5%)
						N_{15}	N_{30}	P_{30}	$N_{15}P_{30}$	$N_{30}P_{30}$	$N_{30}P_{60}$	$N_{30}P_{60}$ K_{30}	
Andhra Pradesh	Red sandy	6	3	57	1393	110	172	140	216	302	354	457	40
Tamil Nadu	Coastal alluvium	1	3	11	2676	215	212	209	322	327	464	500	143
	Red sandy	5	3	46	1947	155	264	225	367	418	628	694	112
	Red loamy	1	1	8	1946	356	414	438	698	828	1150	1394	257
Pondicherry	Coastal alluvium	1	4	18	2543	470	743	536	894	1050	1108	1363	311
Punjab	Alluvial	2	2	15	1046	77	242	288	383	448	714	851	85
Uttar Pradesh	Alluvial	1	1	5	937	157	289	176	246	368	488	603	110
	Red sandy	11		103	1640	130 (8.7)	178 (5.9)	213 (7.1)	283 (6.5)	354 (5.9)	476	563	55
	Coastal alluvium	2		29	2593	373 (24.9)	412 (13.7)	542 (18.1)	677 (15.0)	776 (12.2)	864	1036	200
	Red loamy	1		8	1946	356 (23.7)	438 (14.6)	414 (13.8)	698 (15.5)	828 (13.8)	1150	1394	257
	Alluvial	3		20	1019	97 (6.5)	260 (8.7)	254 (8.5)	324 (7.8)	428 (7.1)	656	789	69
	Mean response over all the soils			160	1750	181 (12.0)	244 (8.1)	288 (9.6)	383 (8.5)	463 (7.7)	603 (6.7)	719 (6.0)	93

Figures in brackets are response per unit nutrient.

TABLE 4.2b. RESPONSE (KG/HA) OF GROUNDNUT (IRRIGATED) TO LEVELS OF PHOSPHORUS (1962-63 TO 1966-67)

State	Broad soil class	No. of dist-ricts	No. of years	No. of trials	Control yield	Response to nutrients (kg/ha)							C.D. (5%)	
						N_{15}	P_{30}	P_{60}	$N_{15}P_{30}$	$N_{15}P_{60}$	$N_{30}P_{60}$	$N_{30}P_{60}K_{60}$		
Andhra Pradesh	Red sandy	6	3	55	1373	147	127	190	225	271	368	444	38	
Tamil Nadu	Coastal alluvium	1	3	21	2336	108	146	227	316	371	343	325	260	
	Red sandy	5	3	47	1941	230	189	370	454	488	580	728	41	
	Red loamy	1	1	8	2162	115	106	381	480	522	801	1031	210	
Punjab	Alluvial	2	2	17	1700	141	297	585	348	582	619	808	70	
Pondicherry	Coastal alluvium	1	4	18	2756	435	533	912	747	1127	1223	1643	213	
Uttar Pradesh	Alluvial	1	1	4	1250	134	166	225	308	406	604	779	98	
	Red sandy	11		102	1629	185	156	273	331	371	466	575	27	$\frac{K_2O}{109}$
						(12.3)	(5.2)	(4.55)	(7.4)	(4.9)	(5.2)	(3.8)		
	Coastal alluvium	2		39	2530	268	325	543	515	720	749	933	172	184
						(17.9)	(10.8)	(9.05)	(11.4)	(9.6)	(8.3)	(6.2)		
	Red loamy	1		8	2162	115	106	381	480	522	801	1031	210	230
						(7.7)	(3.5)	(6.4)	(10.7)	(7.0)	(8.9)	(6.9)		
	Alluvial	3		21	1614	140	272	516	340	548	616	802	61	186
						(9.3)	(9.1)	(8.6)	(7.6)	(7.3)	6(.8)	(5.3)		
	Mean response over all the soils				1859	195	207	370	381	480	565	707	73	141
						(13.0)	(6.9)	(6.2)	(8.5)	(6,4)	(6.3)	(4.7)		(0.94)

Figures in brackets are response per unit nutrient.

TABLE 4.2c. RESPONSE (KG/HA) OF GROUNDNUT (IRRIGATED) TO LEVELS OF POTASH (1962-63 TO 1966-67)

State	Broad soil class	No. of dist-ricts	No. of years	No. of trials	Control yield	Response to nutrients (kg/ha)							C.D. (5%)
						N_{15}	K_{30}	K_{60}	$N_{15}K_{30}$	$N_{15}K_{60}$	$N_{30}K_{60}$	$N_{15}P_{30}K_{30}$	
Andhra Pradesh	Red sandy	6	3	54	1231	121	103	137	272	322	401	451	48
Tamil Nadu	Coastal alluvium	1	3	28	1944	150	164	203	214	243	215	446	203
	Red sandy	5	3	45	2029	190	175	278	308	417	532	591	54
	Red loamy	1	1	7	1888	194	646	329	661	690	605	941	177
Punjab	Alluvial	2	2	14	1489	249	1	117	232	282	452	516	109
Pondicherry	Coastal alluvium	1	4	18	2674	438	453	920	682	887	1128	1207	142
Uttar Pradesh	Alluvial	1	1	4	1157	257	58	77	307	380	567	422	110
	Red sandy	11		99	1594	152	136	228	288	365	465	515	35
						(10.1)	(4.5)	(3.8)	(6.4)	(4.9)	(5.2)	(6.9)	
	Coastal alluvium	2		46	2230	263	277	484	397	495	572	744	135
						(17.5)	(9.2)	(8.1)	(8.8)	(6.6)	(6.4)	(9.92)	
	Red loamy	1		7	1888	194	646	329	661	690	605	941	177
						(12.9)	(21.5)	(5.5)	(14.7)	(9.2)	(6.7)	(12.5)	
	Alluvial	3		18	1415	251	14	108	249	304	488	495	88
						(16.7)	(6.5)	(1.8)	(5.5)	(4.1)	(5.4)	(6.6)	
	Mean response over all the soils				1759	194	182	289	329	407	502	592	74
						(12.9)	(6.1)	(4.8)	(7.3)	(5.4)	(5.6)	(7.9)	

Figures in brackets are response per unit nutrient.

(*i*) Application of nitrogen at 15 kg/ha gave a high response of more than 400 kg/ha in coastal alluvial soil of Pondicherry. In the other soils also the response to N was fairly good varying between 100 to 350 kg/ha. At double the level, the response to nitrogen increased significantly in red sandy soil of Andhra Pradesh and alluvial soil of Punjab and U.P.

(*ii*) Application of phosphorus at 30 kg/ha generally gave a higher response compared to the 15 kg dose of nitrogen. Increase in the level of phosphorus to 60 kg P_2O_5/ha improved the yield of groundnut in all soils.

(*iii*) Joint application of nitrogen and phosphorus at 15 and 30 kg/ha respectively generally gave the same order of response as the sum of the responses to their individual application.

(*iv*) There was not much evidence of interaction between nitrogen and phosphorus at the levels studied in most of the soils.

(*v*) Application of potash at 30 kg/K_2O/ha gave a response of more than 100 kg/ha in all soils except alluvial soils of Punjab and U.P.

(*vi*) The average response per unit nutrient was 5.9, 12.9, 13.8 and 7.1 kg in case of red sandy, coastal alluvium, red loamy and alluvial soils respectively when 30 kg N and 30 kg P_2O_5 were applied together.

Rainfed Groundnut. The trials on rainfed groundnut crop (Tables 4.3a, 4.3b and 4.3c) were conducted on eight soils covering seven states. Data were available from 952 experiements. The following conclusions can be drawn:

(*i*) The response to nitrogen at 15 kg/ha was moderate to good in all soils except black and grey-brown soils in Gujarat and red sandy soils in Orissa. At the higher level of nitrogen (30 kg/ha), the response increased significantly in a number of areas (Table 4.3a).

(*ii*) Application of phosphorus at 20 kg P_2O_5/ha showed a response of the same order or higher compared to 15 kg N/ha in most of the soils. At the higher level of phosphorus, the response increased considerably in number of soils (Table 4.3b).

(*iii*) Combined application of nitrogen and phosphorus gave responses of the same magnitude as the sum of their individual responses.

(*iv*) Application of potash at 20 kg/ha gave a response of more than 100 kg/ha in a majority of areas. At the higher level of potash (40 kg K_2O/ha) the response increased in red and

TABLE 4.3a RESPONSE (KG/HA) OF GROUNDNUT (RAINFED) TO LEVELS OF NITROGEN (1962-63 TO 1966-67).

State	Broad soil class	No. of dist-ricts	No. of years	No. of trials	Control yield	Response to nutrients (kg/ha)							C.D. (5%)
						N_{15}	N_{30}	P_{20}	$N_{15}P_{20}$	$N_{30}P_{20}$	$N_{30}P_{40}$	$N_{30}P_{40}K_{20}$	
Andhra Pradesh	Red sandy	9	5	192	1091	151	240	167	289	351	438	494	27
Gujarat	Deep black	2	2	24	784	54	126	86	175	226	226	267	55
	Medium black	3	4	60	829	25	107	96	182	240	315	356	43
	Grey-brown	2	2	25	544	64	140	113	130	172	284	350	58
Karnataka	Laterite	1	2	13	1862	134	325	182	477	506	742	804	120
	Red loamy	1	2	8	2359	350	382	308	414	472	654	776	169
	Medium black	1	3	14	1046	149	254	250	304	379	495	709	69
	Red sandy	1	1	4	849	192	285	114	282	364	415	533	120
Orissa	Red loamy	1	1	3	1533	620	826	—13	566	740	780	882	182
	Red sandy	1	1	4	790	—77	—15	200	120	135	490	535	223
	Red and yellow	1	4	20	1329	234	407	312	537	731	811	1052	295
Punjab	Alluvial	2	1	14	1521	399	392	564	686	704	835	1013	369
Tripura	Red and yellow	1	2	32	1532	474	595	422	654	784	916	1162	195
Uttar Pradesh	Alluvial	3	2	23	1257	224	384	236	422	535	680	818	46
	Red sandy	11		200	1080	147 (9.8)	236 (7.9)	167 (8.35)	285 (8.1)	347 (6.9)	439 (8.37)	496 (5.5)	27
	Deep black	2		24	784	54 (3.6)	126 (4.2)	86 (4.3)	175 (5.0)	226 (4.5)	226 (3.2)	267 (3.0)	55
	Medium black	4		74	870	48 (3.2)	135 (4.5)	125 (6.3)	205 (5.9)	266 (5.3)	349 (5.0)	423 (4.7)	37
	Greybrown	2		25	544	64 (4.3)	140 (4.7)	113 (5.7)	130 (3.7)	172 (3.4)	284 (4.1)	350 (3.9)	58

TABLE 4.3a (*Contd*)

Laterite	1	13	1862	134 (8.9)	325 (10.8)	182 (8.1)	477 (13.6)	506 (10.1)	742 (10.6)	804 (8.9)	120
Red loamy	2	11	2134	424 (28.3)	503 (16.8)	220 (11.0)	455 (13.0)	545 (10.9)	689 (9.8)	805 (8.9)	67
Red and yellow	2	52	1454	382 (25.5)	523 (17.4)	380 (19.0)	609 (17.4)	764 (15.3)	876 (12.5)	1120 (12.4)	84
Alluvial	5	37	1357	290 (19.3)	387 (12.9)	360 (18.0)	522 (14.9)	599 (12.0)	739 (10.6)	892 (9.9)	73
Mean response over all the soils		436	1115	167 (11.1)	264 (8.8)	196 (9.8)	325 (9.3)	397 (7.9)	496 (7.1)	588 (6.5)	47

Figures in brackets are response per unit nutrient.

TABLE 4.3b. RESPONSE (KG/HA) OF GROUNDNUT (RAINFED) TO LEVELS OF PHOSPHORUS (1962-63 TO 1966-67)

State	Broad soil class	No. of dist-ricts	No. of years	No. of trials	Control yield	Response to nutrients (kg/ha)							C.D. (5%)
						N_{15}	P_{20}	P_{40}	$N_{15}P_{20}$	$N_{15}P_{40}$	$N_{30}P_{40}$	$N_{30}P_{40}K_{40}$	
Andhra Pradesh	Red sandy	9	5	194	1112	153	138	210	277	318	412	495	24
Gujarat	Deep black	2	2	24	828	61	50	73	109	66	119	237	71
	Medium black	3	4	54	608	98	108	201	215	278	337	422	43
	Grey brown	2	2	24	527	124	120	175	136	210	248	311	79
Karnataka	Laterite	1	2	12	1676	198	196	347	490	586	751	842	60
	Red loamy	1	2	7	1870	184	245	562	450	710	492	903	79
	Medium black	1	3	14	947	137	171	234	319	328	579	669	95
	Red sandy	1	1	4	750	238	338	414	414	477	537	590	90
Orissa	Red loamy	1	1	3	1466	493	253	186	626	733	760	888	259
	Red sandy	1	1	4	570	—20	180	440	187	265	392	367	131
	Red and yellow	1	4	24	1063	353	354	511	774	895	940	1172	241
Punjab	Alluvial	2	1	12	1260	314	409	552	578	490	664	882	322
Tripura	Red and yellow	1	2	34	1352	312	244	368	435	704	828	1038	174
Uttar Pradesh	Alluvial	3	2	25	1272	237	178	262	364	454	621	778	33
	Red sandy	11		202	1094	151	143	218	278	320	414	494	24
						(10.1)	(7.15)	(5.5)	(7.9)	(5.8)	(5.9)	(4.5)	
	Deep black	2		24	828	61	50	73	109	66	119	237	71
						(4.1)	(2.5)	(1.8)	(3.1)	(1.2)	(1.7)	(2.2)	
	Medium black	4		68	678	106	121	208	236	288	387	472	39
						(7.1)	(6.1)	(5.2)	(6.7)	(5.2)	(5.5)	(4.3)	
	Grey brown	2		24	527	124	120	175	136	210	248	311	79
						(8.3)	(6.0)	(4.4)	(3.9)	(3.8)	(3.5)	(2.8)	

TABLE 4.3b (*Contd*)

Red loamy	2	10	1749	277	247	449	503	717	572	898	96
				(18.5)	(12.4)	(11.2)	(14.4)	(13.0)	(8.2)	(8.2)	
Red and yellow	2	58	1232	329	290	427	575	783	865	1093	159
				(21.9)	(14.5)	(10.7)	(16.4)	(14.2)	(12.4)	(9.9)	
Alluvial	5	37	1268	262	253	356	433	466	635	812	106
				(17.5)	(12.7)	(8.9)	(12.4)	(8.5)	(9.1)	(7.4)	
Laterite	1	12	1676	198	196	347	490	586	751	842	60
				(13.2)	(19.8)	(8.7)	(14.0)	(10.7)	(10.7)	(7.7)	
Mean response over all the soils		435	1047	175	166	255	318	386	476	592	60
				(11.7)	(8.3)	(6.4)	(9.1)	(7.0)	(6.8)	(5.4)	

Figures in brackets are response per unit nutrient.

TABLE 4.3c. RESPONSE (KG/HA) OF GROUNDNUT (RAINFED) TO LEVELS OF POTASH (1962-63 TO 1966-67)

State	Broad soil class	No. of dist-ricts	No. of years	No. of trials	Control yield	Response to nutrients (kg/ha)							C.D. (5%)
						N_{15}	K_{20}	K_{40}	$N_{15}K_{20}$	$N_{16}K_{40}$	$N_{30}K_{40}$	$N_{15}P_{20}K_{20}$	
Andhra Pradesh	Red sandy	9	5	199	1038	138	63	134	231	261	346	414	64
Gujarat	Deep black	2	2	24	710	80	56	64	98	165	143	258	43
	Medium black	3	4	56	773	60	43	125	229	206	211	336	79
	Grey-brown	2	2	25	482	98	146	151	204	205	256	308	66
Karnataka	Laterite	1	2	13	1701	120	93	143	357	427	668	608	79
	Red loamy	1	2	8	1995	228	241	372	416	610	697	782	72
	Medium black	1	3	15	974	105	122	180	195	255	413	386	76
	Red sandy	1	1	4	819	215	107	123	319	296	482	502	90
Orissa	Red loamy	1	1	3	1373	576	140	260	833	903	950	1066	135
	Red sandy	1	1	4	590	210	—	260	25	140	215	187	300
	Red and yellow	1	4	18	1020	392	323	643	564	648	1046	1057	202
Punjab	Alluvial	2	1	12	1607	326	1	323	360	266	321	679	472
Tripura	Red and yellow	1	2	32	1300	298	256	441	482	662	805	734	201
Uttar Pradesh	Alluvial	3	2	23	1222	247	123	178	336	423	595	480	43
	Red sandy	11		207	1025	141	62	136	229	259	346	411	63
						(9.4)	(3.1)	(3.4)	(6.5)	(4.7)	(4.9)	(7.5)	
	Deep black	2		24	710	80	56	64	98	165	143	258	43
						(5.3)	(2.8)	(1.6)	(2.8)	(3.0)	(2.0)	(4.7)	
	Medium black	4		71	815	70	60	137	222	216	254	346	65
						(4.7)	(3.0)	(3.4)	(6.3)	(3.9)	(3.6)	(6.3)	
	Grey brown	2		25	482	98	146	151	204	205	256	308	66
						(6.5)	(7.3)	(3.8)	(5.8)	(3.7)	(3.7)	(5.6)	

TABLE 4.3c (*Contd*)

Laterite	1	13	1701	120	93	143	357	427	668	608	79
				(8.0)	(4.7)	(3.6)	(10.2)	(7.8)	(9.5)	(11.1)	
Red loamy	2	11	1825	322	213	341	530	689	766	860	65
				(21.5)	(10.3)	(8.5)	(15.1)	(12.5)	(10.9)	(15.6)	
Red and yellow	2	50	1199	331	290	514	411	657	882	850	149
				(22.1)	(14.5)	(12.9)	(14.6)	(11.9)	(12.7)	(15.5)	
Alluvial	5	35	1354	274	81	228	344	369	501	548	165
				(18.3)	(4.1)	(5.7)	(9.8)	(6.7)	(7.2)	(10.0)	
Mean response over all the soils		436	1029	160	99	189	274	314	410	465	81
				(10.7)	(5.0)	(4.7)	(7.8)	(5.7)	(5.9)	(8.5)	

Figures in brackets are response per unit nutrient.

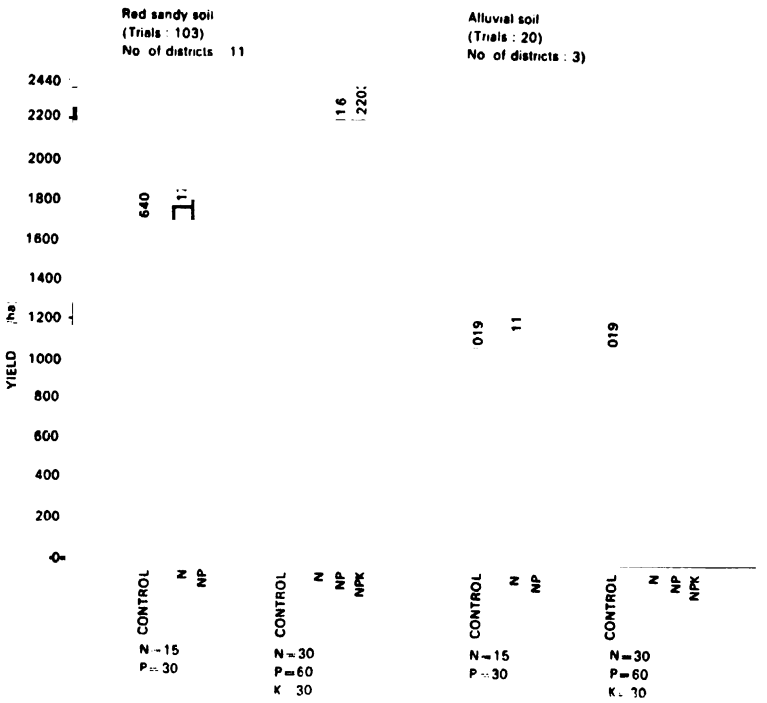

Fig. 4.2. Yields of groundnut (irrigated) as affected by N, NP, and NPK in different types of soils in trials on cultivators' fields (1962–1967)

yellow soil of Orissa and alluvial soil of Punjab (Table 4.3c).

(v) Combined application of nitrogen and potash generally gave a response slightly less than or equal to the sum of their individual responses.

The results of this series of trials both on groundnut irrigated as well as rainfed confirmed the earlier results that application of N, P and K is highly beneficial to groundnut in most of the areas. However, as against beneficial effects of joint application of N, P and K compared to their individual application as observed in the earlier series, the interaction between the nutrients when applied jointly was generally found absent in this series of trials.

The comparative yields of groundnut for different combinations of

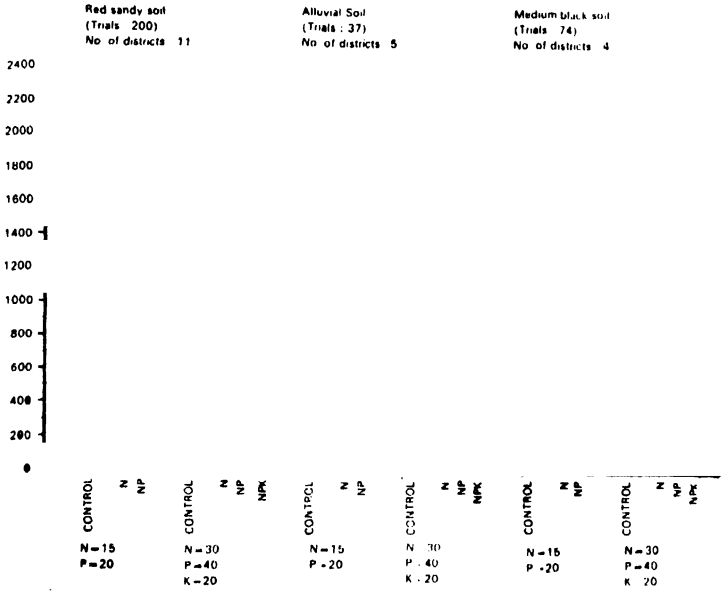

Fig. 4.3. Yield of groundnut (rainfed) as affected by N, NP, and NPK in different types of soils in trials on cultivators' fields (1962-63–1966-67)

N, P and K are graphically presented for soils for which results were available for three or more districts in Fig. 4.2 for irrigated crop and in Fig. 4.3 for rainfed crop.

Third series of trials (1967–70) with high-yielding varieties of groundnut

With the program of cultivators' field trials geared to study fertiliser requirements of the newly introduced high-yielding varieties of cereals, the trials on irrigated groundnut were taken up in nine districts located in three soils covering five states and Pondicherry while on unirrigated groundnut trials were conducted in 12 districts located in six soils covering seven states. The results for the period 1967-68 to 1969-70 are presented in Tables 4.4 and 4.5 for irrigated and rainfed crops respectively.

Irrigated crop. The variety commonly used was 'TMV-2', its average yield without fertiliser varied between 1300–2650 kg/ha in red sandy soil of Andhra Pradesh and Tamil Nadu. The response to 15 kg N/ha was more than 200 kg/ha in most of the soils indicating a response of more than

TABLE 4.4. RESPONSE (KG/HA) OF GROUNDNUT (IRRIGATED) TO NITROGEN, PHOSPHORUS AND POTASH (1967-68 TO 1969-70).

State	Broad soil class	District	No. of years	Variety	No. of trials	Control yield
Andhra	Red sandy	Warangal	1	'TMV-2'	8	1442
Pradesh	Red sandy	Warangal	3	'Local'	50	1649
Gujarat	Coastal alluvium	Jamnagar	1	'Local'	17	456
	Alluvium	Jamnagar	1	'Samrala	20	1106
	Deep black	Surat	1	'Local'	5	1192
Maharashtra	Medium black	Nasik	1	'SB-11'	8	1860
Rajasthan	Medium black	Kota	1	'Local'	9	1746
Tamil Nadu	Coastal alluvium	Chingleput	1	'TMV-2'	22	1542
	Red sandy	Salem	1	'TMV-2'	4	2649
	Red sandy	Tirunelveli	1	'TMV-2'	13	1284
Pondicherry	Coastal	Pondicherry	3	'TMV-2'	58	1640
	alluvium	Pondicherry	2	'Local'	29	1614
	Red sandy		2		75	1617
	Coastal alluvium		3		146	1409
	Black soils		3		22	1662
	Mean response over all the soils		8		243	1521

TABLE 4.4 (*Contd*)

Response to nutrients (kg/ha)							C.D. (5%)
N_{15}	N_{30}	P_{30}	$N_{15}P_{30}$	$N_{30}P_{30}$	$N_{30}P_{60}$	$N_{30}P_{60}K_{60}$	
172	441	22	315	485	554	649	117
175	213	162	195	404	494	640	79
42	69	77	100	116	140	214	17
91	171	191	421	596	722	972	52
204	436	9	160	442	630	775	202
264	364	108	358	674	593	868	265
112	213	182	284	554	722	913	167
162	224	180	356	454	535	877	170
151	300	101	300	550	600	801	174
346	465	230	457	650	853	1019	177
270	502	397	754	992	1229	1588	64
226	334	210	412	549	594	803	104
203	286	156	259	463	568	715	
(13.5)	(9.5)	(5.2)	(5.8)	(7.7)	(6.3)	(4.8)	
194	331	262	504	667	802	1081	
(12.9)	(11.0)	(8.7)	(11.2)	(11.1)	(8.9)	(7.2)	
188	319	116	283	572	654	865	
(12.5)	(10.6)	(3.9)	(6.3)	(9.5)	(7.3)	(5.8)	
196	316	216	408	595	716	948	
(13.1)	(10.5)	(7.2)	(9.1)	(9.9)	(8.0)	(6.3)	

Figures in brackets are response per unit nutrient.

TABLE 4.5. RESPONSE (KG/HA) OF GROUNDNUT (RAINFED) TO NITROGEN, PHOSPHORUS AND POTASH (1967-68 TO 1969-70).

State	Broad soil class	District	No. of years	Variety	No. of trials	Control yield
Andhra Pradesh	Red sandy	Warangal	1	'TMV-2'	5	585
			2	'Spanish improved'	15	1491
			1	'Local'	24	768
Bihar	Red and yellow	Santhal Parganas	1	'Local'	6	1397
		Hazaribagh	1	'AK-12-25'	12	768
Gujarat	Coastal alluvium	Jamnagar	1	'Local'	8	279
		Surat	1	'Samrala'	28	720
	Deep black	Ahmedabad	3	'Local'	147	788
			1	'Local'	7	1272
Madhya Pradesh	Medium black	Sehore	1	'Local'	3	620
Maharashtra	Medium black	Kolhapur	1	'Kopergaon'	86	2245
		Nasik	1	'SB-11'	77	1086
Orissa	Red and yellow	Mayurbhanj	1	'P. No. 1'	9	1529
	Red loamy	Dhenkenal	1	'AK-12-24' and 'TMV-3'	12	1265
Tripura	Red and yellow	Tripura	2	'T-28'	23	1519
		Tripura	1	'Local'	21	1410
	Red loamy		1		12	1265
	Red sandy		2		44	994
	Red and yellow		4		71	1351
	Black soils		4		313	1260
	Alluvial soils		1		36	622
	Gray-brown soils		1		7	1272
	Mean response over all the soils		13		483	1202

TABLE 4.5 (*Contd*)

Response to nutrients (kg/ha)							C.D. (5%)
N_{15}	N_{20}	P_{20}	$N_{15}P_{20}$	$N_{30}P_{20}$	$N_{30}P_{40}$	$N_{30}P_{40}K_{40}$	
168	276	56	284	528	643	846	169
66	126	46	98	241	288	438	54
32	65	92	172	253	380	4713	33
689	911	511	988	1352	1516	1743	173
91	290	1	313	502	578	706	65
59	103	90	127	174	217	287	66
38	81	89	209	288	264	430	30
77	187	45	136	263	351	448	16
72	60	76	102	85	231	282	178
168	496	252	330	500	746	883	—
112	148	155	174	342	402	422	112
142	279	124	255	393	499	549	64
479	1022	551	1283	1420	1803	2336	155
293	272	168	239	431	731	916	145
300	528	480	687	824	1178	1585	100
258	491	308	568	704	973	1026	214
293	272	168	239	431	731	916	
(9.5)	(9.1)	(8.4)	(6.8)	(8.6)	(10.4)	(8.3)	
59	110	72	160	280	379	503	
(3.9)	(3.7)	(3.6)	(4.6)	(5.6)	(5.4)	(4.6)	
308	572	360	690	854	1124	1380	
(20.5)	(19.1)	(18.0)	(19.7)	(17.1)	(16.1)	(12.5)	
103	202	97	178	308	405	470	
(6.9)	(6.7)	(4.8)	(5.1)	(6.2)	(5.8)	(4.3)	
43	86	89	191	263	254	398	
(2.9)	(2.9)	(4.4)	(5.4)	(5.3)	(3.6)	(3.6)	
72	60	76	102	85	231	282	
(4.8)	(2.0)	(3.8)	(2.9)	(1.7)	(3.3)	(2.6)	
129	239	134	253	382	503	610	
(8.6)	(8.0)	(6.7)	(7.2)	(7.6)	(7.2)	(5.6)	

Figures in brackets are response per unit nutrient.

13 kg per unit N. In coastal alluvial soil of Jamnagar (Gujarat), the response was low.

The response to 30 kg P_2O_5/ha was generally not significantly different from that to 15 kg N/ha. Combined application of 15 kg N and 30 kg P_2O_5/ha gave a higher response compared to their individual responses taken together in red sandy soil of Warangal (Andhra Pradesh) with variety 'TMV-2' and in coastal alluvial soil of Jamnagar (Gujarat) with variety 'Punjab-1 (Samrala)', indicating a positive interaction between these two nutrients. With the combined application of N and P at double the level, the response increased considerably in all soils.

Application of potassium at 60 kg K_2O/ha over 30 kg N and 60 kg P_2O_5/ha showed a significant increase in the yield of groundnut in almost all soils being particularly marked in coastal alluvial soil of Tamil Nadu and Pondicherry (350 kg/ha) for variety 'TMV-2' and in coastal alluvium soil in Gujarat and medium black soil in Maharashtra (250 kg/ha). The results thus showed that combined application of N, P and K at fairly high levels would be highly beneficial for groundnut crop under irrigated conditions particularly with the improved varieties.

Rainfed crop. The yield level without fertilizer was the highest with the variety 'Kopergaon-1', in medium black soil in Kolhapur (Maharashtra) being of the order of 2245 kg/ha. A yield level of about 1500 kg/ha was obtained with 'Spanish Improved' variety in red sandy soil of Warangal (Andhra Pradesh) and with 'P. No. 1' and 'T-28' in red and yellow soil of Mayurbhanj (Orissa) and Tripura respectively.

(*i*) Application of 15 kg N/ha showed a high response of 689 and 479 kg/ha in red and yellow soil of Santhal Parganas and Mayurbhanj respectively. In the red and yellow soil of Tripura as also red loamy soil of Dhenkenal (Orissa), the response was quite high varying between 250-300 kg/ha.

(*ii*) Application of phosphorus at 20 kg P_2O_5/ha gave a high response of 300-550 kg/ha in red and yellow soil in Orissa, Bihar, and Tripura. Combined application of N_{15} and P_{20} gave a response higher than the sum of their individual responses in red and yellow soil in Bihar and Orissa and coastal alluvium soil in Jamnagar (Gujarat), thus indicating a positive interaction between N and P in these areas. At the higher level of N, P application, the response was more than double in most of the soils.

(*iii*) Application of potassium at 40 kg K_2O/ha over $N_{30}P_{40}$ showed a significant increase in the yield of groundnut in most of the soils being particularly marked in red and yellow soils of Mayurbhanj (Orissa) with variety 'P. No. 1' and in Tripura with variety 'T-28'.

(*iv*) The relative yields of groundnut for different combinations of N, P and K for some of the important soil classes in the above series of trials are given in Fig. 4.4 for irrigated and in Fig. 4.5 for rainfed crop.

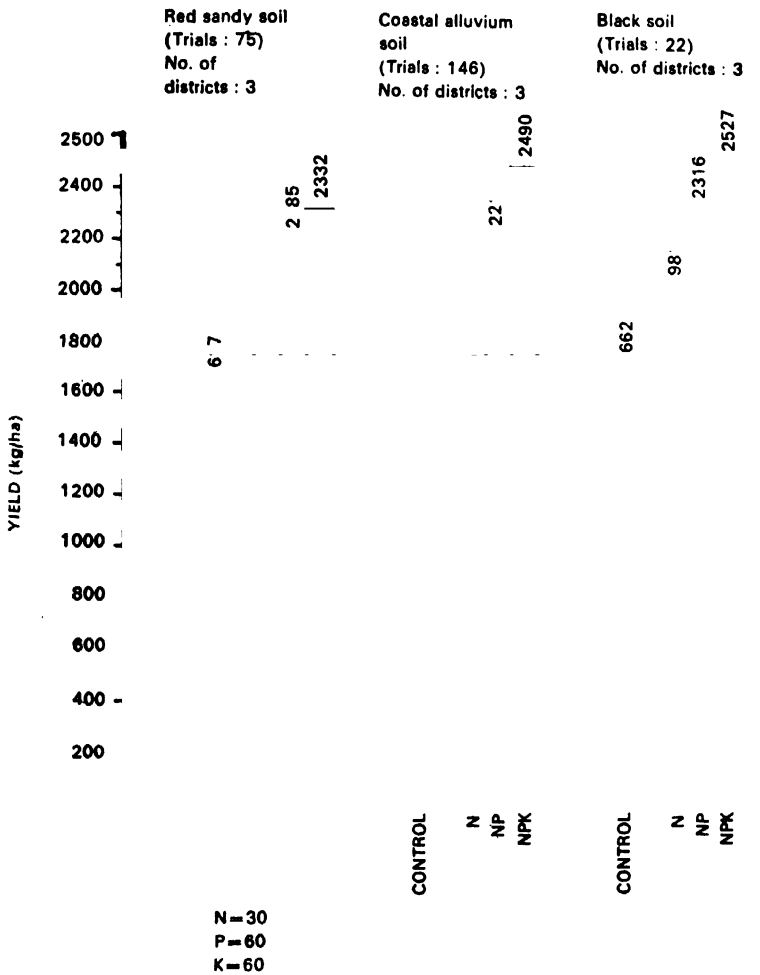

Fig. 4.4. Yield of groundnut (irrigated) as affected by N, NP and NPK on different types of soils in trials on cultivators' fields (1967-68–1969-70)

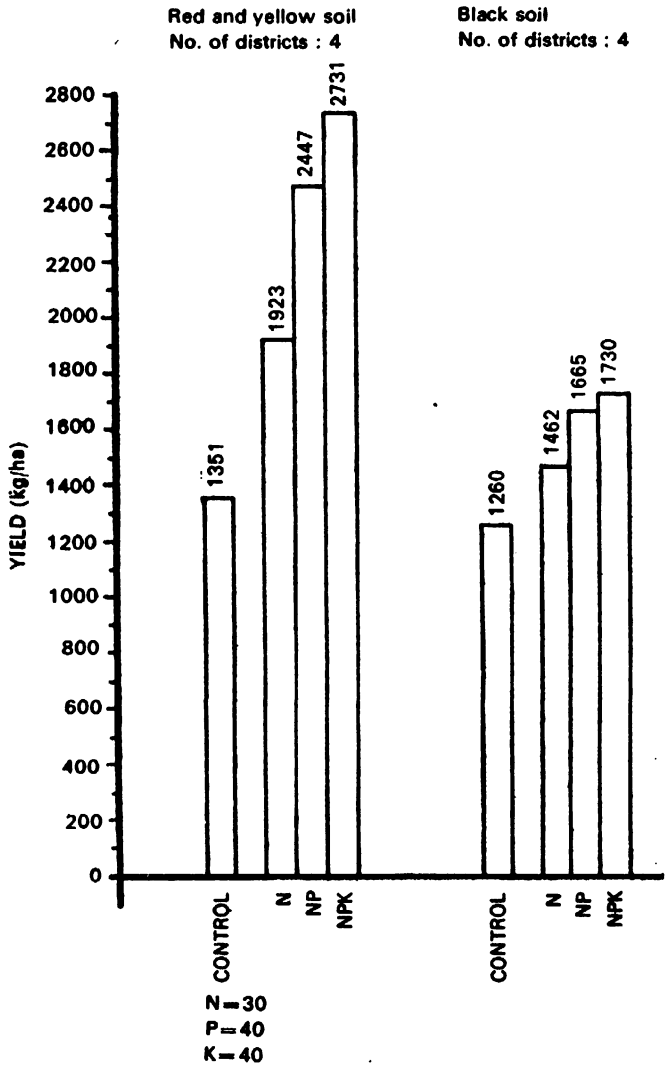

Fig. 4.5. Yields of groundnut (rainfed) as affected by N, NP and NPK in trials conducted on cultivators' fields (1967-68–1969-70)

Thus, as compared to groundnut irrigated, the yield of groundnut rainfed without fertilizer or with fertilizer at lower doses was generally lower. However, the yield increased considerably when higher levels of fertilizers were used. In fact, both for irrigated and rainfed crop the highest yields were generally obtained when N, P and K were applied together at higher levels. It may be noted that the improved varieties of groundnut were tried in cultivators' field for the first time in this series.

Fourth series of trials (1970-72)

The results of trials conducted in 1967-68 to 1969-70 served a very useful purpose in underlining the need for adequate application of N, P and K to groundnut even in unirrigated areas. However, since the basic yield rate with rainfed crop was smaller compared to irrigated crop, there appeared to be a need for investigating measures for raising the basic yield of groundnut in such areas. This aspect was studied in the another series of trials initiated in 1970-71 to study the extent to which the yield level could be raised by improved practices of moisture conservation like deep ploughing, bunding, etc. under dry farming conditions. These trials were conducted in 3 districts in as many soil classes and states during 1970-71 and five districts covering four states on four soils during 1971-72. No significant difference was generally observed between yield levels obtained in trials with cultivators' normal management practices and those with moisture conservation practices possibly because seeing that improved practices were being adopted in one series of trials, the cultivators in the former category also adopted improved practices of moisture conservation. The data from the two sets of trials were, therefore, combined. The results are presented in Table 4.6.

The average yield of groundnut without fertiliser was fairly good in red sandy and mixed red and black soils of Ramanathpuram (Tamil Nadu) and in red sandy soil of Koraput (Orissa) varying between 1281 and 1946 kg/ha for the different varieties tried. The local varieties also showed fairly high yield of 1423 kg/ha in Ramanathpuram during *kharif* 1970-71.

(*i*) Application of nitrogen at 20 kg/ha gave a high response of 378 kg/ha with variety 'TMV-2' in Kurnool. Increase in the dose of nitrogen to 40 kg/ha more than doubled the response. In Bijapur and Koraput districts also the response to nitrogen was quite good while in Ramanathpuram, nitrogen did not show much response.

(*ii*) Application of phosphorus at 40 kg P_2O_5/ha gave a good response in all soils except in mixed red and black soil of Ramanathpuram while in red sandy soil of this district a moderate response was obtained only with the varieties 'TMV-1' and

TABLE 4.6. RESPONSE (KG/HA) OF GROUNDNUT TO NITROGEN, PHOSPHORUS AND POTASH UNDER DRY FARMING CONDITIONS (1970-71 TO 1971-72).

State	Broad soil class	District	No. of years	Variety	No. of trials	Control yield
Orissa	Red sandy	Koraput	1971-72	'AK-12-24'	23	1452
Tamil Nadu	Red sandy	Ramanath-puram	1970-71	'TMV-2'	13	1283
				'TMV-1'	6	1946
				'Local'	19	1423
	Mixed red and black	,,	1971-72	'TMV-2'	10	1565
				'TMV-7'	7	1281
Orissa	Laterite	Mayur-bhanj	1971-72	'AK-12-24'	21	657
	Red and yellow	,,	1970-71	'AK-12-24'		526
Karnataka	Medium black	Bijapur	1970-71			
			1971-72	'Local'	47	978
Andhra Pradesh	Mixed red and black	Kurnool	1971-72	'TMV-3'	37	380
		,,		'TMV-2'	9	811
Pooled for soils:						
	Red and Yellow	1			32	526
	Red sandy	2			61	1456
	Laterite	1			21	657
	Medium black	1			47	978
	Mixed red and black	2			63	730
	Mean response over all the soils				224	944

Response to nutrients (kg/ha)									C.D. (5%)
N_{20}	N_{40}	P_{40}	P_{80}	$N_{20}P_{40}$	$N_{20}P_{80}$	$N_{40}P_{40}$	$N_{40}P_{80}$	$N_{40}P_{80}K_{40}$	
180	304	461	540	679	745	931	1149	1328	80
14	99	167	229	267	326	411	499	489	73
45	99	147	239	313	384	462	483	595	83
22	72	79	178	207	236	303	373	424	57
117	119	60	215	123	246	159	235	288	76
94	108	71	109	94	104	127	147	238	74
169	396	275	478	592	730	729	932	1104	120
168	259	325	444	452	547	691	772	930	123
264	292	332	476	444	542	554	654	744	78
86	136	160	183	233	247	291	338	413	39
378	822	656	1111	1011	1200	1036	1370	1492	441

TABLE 4.6 (*Contd*)

168	259	325	444	452	547	691	772	930	—
87	168	248	331	408	462	578	703	796	..
169	390	275	478	592	730	729	932	1104	..
264	292	332	426	444	542	554	654	744	
134	228	205	312	311	367	358	448	528	..
154	243	265	373	409	486	537	647	750	..
(7.7)	(6.1)	(6.6)	(4.7)	(6.8)	(4.9)	(6.7)	(5.4)	(4.7)	

Figures in brackets are response per unit nutrient.

'TMV-2'. Increase in the level of phosphorus to 80 kg P_2O_5/ha did not show much effect except for variety 'TMV-2' in Kurnool.

(*iii*) Joint application of nitrogen and phosphorus at 20 and 40 kg/ha respectively did not show any further increase over their individual responses in any soil. In fact, there was evidence of a decline in the yield of groundnut in medium black soil of Bijapur. At the higher level of $N_{40}P_{80}$, the responses were almost additive except in Koraput and Ramanathpuram (1970-71) where the response increased significantly indicating a positive interaction between N and P.

(*iv*) Application of 40 kg K_2O/ha over $N_{40}P_{80}$ proved beneficial in all soils except for variety 'TMV-2' in red sandy soil of Ramanathpuram.

It may also be observed that maximum response per unit of nutrient was obtained in laterite soil particularly for higher combinations of N and P being about 7—10 kg response per unit nutrient. The total response was further increased by the application of K but per unit nutrient the response decreased indicating lower response to K. The overall response in all the soils was 5.8 per unit of NP mixture and 4.7 per unit of NPK mixture. It may further be seen that although not much increase in the general yield level was observed on account of adoption of moisture conservation practices like bunding, deep ploughing, etc., the need for application of adequate doses of N, P and K for realising good yields of groundnut under dry farming conditions was clearly brought out by the results.

Fifth series of trials (1972-77)

The results of application of moderate doses of nitrogen and phosphorus to groundnut under dry farming conditions being found encouraging, the scope of this series of trials was modified to study closely spaced doses of both N up to 45 kg and of P up to 60 kg P_2O_5/ha and their various combinations as also a dose of potash at 30 kg K_2O/ha applied over $N_{30}P_{40}$. This series of experiments with 10 treatments was initiated in 1972-73 and continued

up to 1976-77 covering 11 districts in five states and on five soils. In 1973-74, a dose of zinc (as zinc sulphate) applied over $N_{30}P_{40}K_{30}$ was tried in place of $N_{45}P_{60}$ in three districts, namely, Kurnool, Jamnagar and Junagadh, the dose of zinc being 25, 25 and 50 kg/ha respectively. The results are presented in Table 4.7.

(*i*) Application of 45 kg N/ha was found beneficial in Dharwar (Karnataka) during 1972-73 and 1973-74, in Mehboobnagar (Andhra Pradesh) during 1975-76, in Dhulia (Maharashtra) during 1975-76 and 1976-77, and in Anantapur during 1974-75 to 1976-77. The response varied between 307 to 491 kg. In Junagadh and Jamnagar with the variety 'Punjab-1' and in Kurnool with variety 'TMV-7', the responses were 277, 235 and 214 kg respectively. Taking different soils, the best response was observed in red sandy soil in Anantapur and Mehboobnagar districts where all the three doses of nitrogen showed a good response. In Bijapur, Gulbarga and Madurai, response to nitrogen was observed only up to 30 kg N/ha.

(*ii*) Application of phosphorus showed a high response to 60 kg P_2O_5/ha in Dharwar during 1972-73 and 1973-74, in Jamnagar and Junagadh during 1973-74 and Dhulia during 1975-76 and 1976-77. Moderate response was observed to all the levels of phosphorus in Mehboobnagar.

(*iii*) Application of potash at 30 kg K_2O/ha over $N_{30}P_{40}$ showed a high response of 460 kg in Dharwar, 326 kg in Dhulia and 314 kg in Ramanathpuram. In some of the other districts, like Kurnool, Anantapur and Madurai, the response to this dose of potash was around 240 kg.

Response to N, P and K in different soils pooled over various series of trials

The effect of application of different levels and combinations of N, P and K on the yield of groundnut crop studied in various series of trials conducted in cultivators' fields during 1959 to 1976 has been discussed in earlier sections. It would be of interest to study the overall response to these nutrients in different soils pooled over the various series. Since different levels of nutrients were tried in different series, the responses obtained to the lowest levels of N, P and K tried were utilized to compute the response ratio per kg of N, P, NP and NPK for the various series before pooling the same. The pooled results are given in Table 4.8 for irrigated groundnut and Table 4.9 for rainfed groundnut, and are discussed below:

Irrigated

(*i*) The average response ratio of nitrogen was the highest in coastal

TABLE 4.7. RESPONSE (KG/HA) OF GROUNDNUT TO NITROGEN, PHOSPHORUS AND POTASSIUM (1972-73 TO 1976-77)

State	Broad soil class	District	No. of years	Variety	No. of trials	Unfertilised plot
Karnataka	Medium black	Bijapur	1972-73	'Spanish improved'	7	607
			1973-74	'Local'	2 o	1231
		Gulbarga	1975-76			
			1976-77	'Local'	49	599
			Pooled	'Spanish improved'	7	607
				'Local'	75	818
Gujarat	Mixed red and black	Junagarh	1973-74	'Punjab-1'	51	1344
Tamil Nadu	,,	Ramanath-puram	1972-73	'TMV-7'	54	1269
			1973-74	'TMV-2'	11	1341
			1974-75	'TMV-7'	24	1082
Karnataka	,,	Dharwar	1972-73	'Local'	50	1223
			1973-74			
Andhra Pradesh	,,	Kurnool	1973-74	'TMV-2'	15	651
			1973-74	'TMV-7'	10	473
			Pooled	'Punjab-1'	51	1344
				'TMV-2'	26	943
				'TMV-7'	88	1188
				'Local'	50	1223
Gujarat	Coastal alluvium	Jamnagar	1973-74	'Punjab-1'	31	284
Andhra Pradesh	Red sandy	Anantapur	1974-75 to 1976-77	'K-71-1'	86	612
		Mehboob-nagar	1975-76	'TVM-2'	6	1137
Tamil Nadu	Red sandy	Madurai	1976-77	'TMV-2'	17	1275
				'TMV-7'	17	1327
			Pooled	'K-71-1'	86	612
				'TMV-2'	23	1239
				'TMV-7'	17	1327
Mahara-shtra	Deep black	Dhulia	1975-76 1976-77	'SB-11'	22	829
Pooled for soils						
	Medium black				82	800
	Mixed red and black				215	1204
	Coastal alluvium				31	284
	Red sandy				126	823
	Deep black				22	892
	Mean response over all the soils				476	959

TABLE 4.7 (*Contd*)

Av. yield (kg/ha)			Response over P_{40} to			Response over N_{30} to			Response to K_{30} over	C.D. (kg/ ha)
$N_{45}P_{60}$	P_{40}	N_{30}	N_{15}	N_{30}	N_{45}	P_{20}	P_{40}	P_{60}	$N_{30}P_{40}$	(5%)
1041	696	871	94	200	160	93	24	148	190	87
1676	1355	1562	99	124	120	39	—82	73	167	86
1046	712	782	109	159	170	86	89	200	150	68
1041	696	871	94	200	160	93	24	148	190	—
1264	935	1052	106	147	153	70	30	156	156	
*	1511	1584	89	180	277	89	107	356	178	45
1728	1406	1520	108	124	132	24	10	72	314	63
1507	1388	1436	—23	106	116	—30	59	107	112	123
1305	1091	1135	88	69	130	118	25	52	189	77
2180	1420	1468	74	182	491	85	134	490	460	61
921	741	709	8	54	34	105	85	175	135	58
*	582	824	95	159	214	63	—82	105	239	51
*	1511	1584	89	180	277	89	107	356	178	...
1169	1015	1017	5	76	69	48	74	146	125	—
1598@	1226	1336	101	113	141	53	4	70	271	—
2180	1420	1468	74	182	491	85	134	490	460	—
*	462	367	85	121	235	114	216	435	103	24
1268	770	827	96	215	307	98	159	277	234	25
1777	1311	1350	104	235	418	143	195	265	89	104
1744	1438	1588	97	134	65	49	—15	174	189	116
1700	1540	1583	31	128	—18	3	84	265	246	113
1268	770	827	96	215	307	98	159	277	234	ND
1753	1405	1526	99	160	157	74	40	198	163	ND
1700	1540	1583	31	128	—18	3	84	265	246	ND
1735	1230	1393	77	233	380	104	70	316	326	96
1245	915	1037	105	152	154	72	29	155	159	
			(7.0)	(5.1)	(3.4)	(3.6)	(0.7)	(2.6)	(5.3)	
1715≠	1313	1387	79	140	246	68	67	245	275	
			((5.3)	(4.7)	(5.5)	(3.4)	(1.7)	(4.1)	(9.2)	
*	462	367	85	121	235	114	216	435	130	
			(5.7)	(4.0)	(5.2)	(5.7)	(5.4)	(7.2)	(3.4)	
1415	990	1057	88	193	236	81	127	261	223	
			(5.9)	(6.4)	(5.2)	(4.0)	(3.2)	(4.4)	(7.4)	
1735	1230	1393	77	233	380	104	70	316	326	
			(5.1)	(7.8)	(8.4)	(5.2)	(1.8)	(5.3)	(10.9)	
1517$	1100	1173	86	159	223	77	86	249	232	
			(5.7)	(5.3)	(5.2)	(3.8)	(2.2)	(4.2)	(7.7)	

@ Based on 78 trials ≠ Based on 154 trials $ Based on 384 trials

*In Kurnool, Jamnagar and Junagarh, in place of $N_{45}P_{60}$, zinc sulphate at 25, 25 and 50 kg/ha was tried respectively over a basal application of $N_{30}P_{40}K_{30}$. The response to zinc in these districts was 56, 30 and 91 kg/ha respectively.

TABLE 4.8. RESPONSE (KG/HA) OF GROUNDNUT (IRRIGATED) TO PER UNIT NUTRIENT OF N, P AND K.

Soil class	Period	No. of distr-icts.	No. of trials	Control yield	Response per unit nutrient			
					N	P	NP	NPK
Red sandy	1962-63 to 1966-67	22	205	1635	10.5	6.2	6.8	4.3
	1967-68 to 1969-70	3	75	1617	13.5	5.2	5.8	4.8
	Pooled	25	280	1626	12.0	5.7	6.3	4.6
Red loamy	1962-63 to 1966-67	2	16	2054	15.7	8.6	13.1	9.2
Black soils	1967-68 to 1969-70	3	22	1662	12.5	3.9	6.3	5.8
Alluvial	1962-63 to 1966-67	6	41	1316	7.9	8.8	7.7	6.0
Coastal	1962-63 to 1966-67	4	68	2557	20.9	13.9	12.9	7.2
alluvium	1967-68 to 1969-70	3	146	1409	12.9	8.7	11.2	7.2
	Pooled	7	214	1983	16.9	11.3	12.0	7.2

alluvium soil (16.9) followed by red loamy soil (15.7), and was 12 kg or more in all soils except in alluvial soil.

(*ii*) The response ratio for phosphorus application was also the highest in coastal alluvium soil (11.3) followed by alluvial and red loamy soil but was poor in black soil.

(*iii*) Combined application of N and P proved more beneficial compared to their individual application in red loamy soil and was also good in coastal alluvial soil. Combined application of N, P and K proved beneficial in red loamy soil and coastal alluvial soil giving a response ratio of 9.2 and 7.2 respectively.

Rainfed

(*i*) A high response of more than 16 kg per kg of nitrogen was obtained in red and yellow, coastal alluvium and red loamy soils.

(*ii*) In case of phosphorus, a response of more than 15 kg per kg P_2O_5 was obtained in red and yellow soil. In red loamy and coastal alluvium soils, a response ratio of more than 9 was obtained.

(*iii*) Application of both N and P showed a response rate of more than that of phosphorus alone in coastal alluvium, laterite and a few other soils although it was always less than that of nitrogen.

(*iv*) Combined application of N, P and K gave a response rate higher than that of N and P in deep black and red and yellow soils being more than 13 kg in the latter. In some of the other soils like coastal alluvium, laterite and red loamy soils, the rate of response to combined application of N, P and K was more than 7 kg per kg of the nutrients.

TABLE 4.9. RESPONSE (KG/HA) OF GROUNDNUT (UNIRRIGATED) TO PER UNIT NUTRIENT OF N, P AND K.

Soil class	Period	No. of districts	No. of trials	Control yield	Response per unit nutrient			
					N	P	NP	NPK
Red sandy	1959-60 to 1961-62	19	209	1384	9.9	6.3	4.2	5.9
	1962-63 to 1966-67	22	402	1087	10.0	7.8	8.0	5.0
	1967-68 to 1969-70	1	44	994	3.9	3.6	4.6	4.6
	1970-71 to 1971-72	2	61	1456	4.1	6.2	6.8	5.0
	1972-73 to 1976-77	3	126	823	7.8	4.2	5.1	6.2
	Pooled	47	842	1149	7.1	5.6	5.7	5.3
Red loamy	1959-60 to 1961-62	3	29	1189	6.8	8.6	3.0	5.0
	1962-63 to 1966-67	4	21	1951	23.6	11.7	13.7	8.6
	1967-68 to 1969-70	1	12	1265	19.5	8.4	6.8	8.3
	Pooled	8	62	1468	16.6	9.6	7.8	7.3
Medium black	1959-60 to 1961-62	5	110	747	6.3	4.7	2.3	3.7
	1962-63 to 1966-67	8	142	778	5.1	6.2	6.3	4.5
	1970-71 to 1971-72	1	47	978	13.2	8.3	7.4	4.6
	1972-73 to 1976-77	2	82	800	7.9	2.9	3.8	5.1
	Pooled	16	381	826	8.1	5.5	5.0	4.5
Deep black	1962-63 to 1966-67	4	48	806	3.8	3.4	4.0	2.6
	1972-73 to 1976-77	1	22	892	16.7	8.4	8.2	11.6
	Pooled	5	70	849	10.2	5.9	6.1	7.1
Black soils	1967-68 to 1969-70	4	313	1260	6.9	4.8	5.1	4.3
Red and yellow	1959-60 to 1961-62	1	13	1741	22.1	18.9	8.2	24.1
	1962-63 to 1966-67	4	110	1337	23.6	16.6	16.9	11.1
	1967-68 to 1969-70	4	71	1351	20.5	18.0	19.7	12.5
	1970-71 to 1971-72	1	32	526	8.4	8.1	7.5	5.8
	Pooled	10	226	1239	18.6	15.4	13.1	13.4
Alluvial	1959-60 to 1961-62	5	39	1260	3.4	5.1	5.2	4.7
	1962-63 to 1966-67	10	74	1312	18.4	15.3	13.6	8.6
	1967-68 to 1969-70	1	36	622	2.9	4.4	5.4	3.6
	Pooled	16	149	1065	8.2	8.3	8.1	5.6
Coastal alluvium	1959-60 to 1961-62	1	8	2920	31.2	15.2	17.1	14.9
	1972-73 to 1976-77	1	31	284	2.8	4.4	4.3	3.6
	Pooled	2	39	1602	17.0	9.8	10.7	9.2
Laterite	1962-63 to 1966-67	2	25	1773	11.0	9.4	13.8	8.3
	1970-71 to 1971-72	1	21	657	8.4	6.9	9.9	6.9
	Pooled	3	46	1215	9.7	8.2	11.8	7.6
Grey brown	1962-63 to 1966-67	4	49	536	6.3	5.8	3.8	3.4
	1967-68 to 1969-70	1	7	1272	4.8	3.8	2.9	2.6
	Pooled	5	56	904	5.6	4.8	3.4	3.0
Mixed red and black	1970-71 to 1971-72	2	63	730	6.7	5.1	5.2	3.3
	1972-73 to 1976-77	4	215	1204	6.1	2.7	3.6	5.7
	Pooled	6	278	967	6.4	3.9	4.4	4.5

It may thus be seen that application of chemical fertilizers was highly beneficial to groundnut crop in a number of soils both under irrigated as well as rainfed conditions, the response being particularly marked in red loamy and coastal alluvium soils for irrigated groundnut and red loamy, red and yellow, costal alluvium and laterite soils for rainfed crop.

Economics of fertiliser use and optimum doses of fertilisers

The results of all the fertilizer experiments with groundnut have conclusively shown the beneficial effects of fertilizers under both the rainfed and irrigated conditions, but the question is, what is the economical dose? It calls for the analysis of the data from economics standard. The most commonly used criterion for deciding upon the adequacy of fertilizer doses is the optimum dose or the level of fertilizer application which maximises the returns per rupee of investment. As stated earlier, this was one of the objectives of the second series of trials conducted in 1962-63 to 1966-67. The optimum doses of N, P and K were calculated from results of these trials assuming the law of diminishing returns and using second degree polynomial for the same. The normal price prevailing in important groundnut-growing areas was around Rs 2.00 per kg. However, since the prices vary in different areas, three prices of the crop, namely Rs 1.50, Rs 2.00 and Rs 2.50 per kg, were taken for calculating the optimum doses and profits. The cost of N, P_2O_5 and K_2O was taken as Rs 3.75, Rs 3.25 and Rs 1.50 per kg respectively.

As mentioned earlier, the doses of fertilizers tried in irrigated trials were 0, 15, 30 kg/ha for N and 0, 30, 60 kg/ha for both P and K, while in unirrigated trials, the doses were 0, 15, 30 kg/ha for N and 0, 20, 40 kg/ha for P and K. In a number of districts, the response to various doses of one or more of the nutrients was found linear (the coefficient of quadratic term being found non-significant). In such cases the maximum dose tried was taken as the optimum. In a few cases, when the linear coefficient just fell short of being significant at 5% level, the lower level tried was taken as the optimum dose (more or less as a basal application). In all other cases, the optimum doses were calculated from the second degree response surface of N, P and K. The optimum doses were rounded off to the nearest multiple of 5 before working out the net returns. The results are presented for irrigated crop in Table 4.10 and unirrigated crop in Table 4.11.

For irrigated groundnut, the optimum doses of N, P and K varied between 0—30, 40—60 and 0—60 kg/ha for the three nutrients respectively. But in majority of cases 30 kg N, 60 kg P_2O_5 and 0—60 kg K_2O was optimum even at the basic prices of the produce. The optimum dose of phosphate and potash improved with higher price of groundnut. For rainfed groundnut, the optimum doses for the three nutrients varied between 15—40 kg/ha for N, 20—45 kg/ha for P_2O_5 and 0—40 kg/ha for K_2O. In a majority of cases

TABLE 4.10. OPTIMUM DOSES OF N, P, K FOR GROUNDNUT (IRRIGATED) AND THEIR ECONOMICS

State	Broad soil class	Price of groundnut (Rs 1.50/kg)					Price of groundnut (Rs 2.00/kg)					Price of groundnut (Rs 2.50/kg)				
		Optimum dose (kg/ha)			Net profit (Rs)	Profit (%)	Optimum dose (kg/ha)			Net profit (Rs)	Profit (%)	Optimum dose (kg/ha)			Net profit (Rs)	Profit (%)
		N	P	K			N	P	K			N	P	K		
Andhra Pradesh	Red sandy	30	40	30	409	142	30	45	30	641	211	30	45	30	878	289
Tamil Nadu	Red sandy	25	60	60	767	202	25	60	60	1150	303	25	60	60	1532	404
	Red loamy	30	60	35	2045	568	30	60	35	2846	791	30	60	35	3648	1013
	Coastal alluvium	30	60	0	733	238	30	60	0	1080	351	30	60	0	1427	463
Punjab	Alluvial	0	60	60	1184	415	0	60	60	1673	587	0	60	60	2163	759
Pondicherry	Coastal alluvium	20	60	60	2182	606	25	60	60	2164	571	25	60	60	2800	739
Uttar Pradesh	Alluvial	30	60	60	785	197	30	60	60	1179	296	30	60	60	1574	395

TABLE 4.11. OPTIMUM DOSES OF N, P, K FOR GROUNDNUT (RAINFED) AND THEIR ECONOMICS

State	Board soil class	Price of groundnut (Rs 1.50/kg)					Price of groundnut (Rs 2.00/kg)					Price of groundnut (Rs 2.50/kg)				
		Optimum dose (kg/ha)			Net profit (Rs)	Profit (%)	Optimum dose (kg/ha)			Net profit (Rs)	Profit (%)	Optimum dose (kg/ha)			Net profit (Rs)	Profit (%)
		N	P_2O_5	K_2O			N	P_2O_5	K_2O			N	P_2O_5	K_2O		
Andhra Pradesh	Red sandy	35	35	20	478	174	35	35	20	729	266	40	40	20	978	315
Gujarat	Deep black	30	20	0	185	104	30	25	0	312	161	30	25	0	439	226
	Medium black	30	20	25	495	230	30	20	25	731	340	30	20	25	968	450
	Grey brown	30	40	20	227	83	30	40	25	396	141	30	40	25	565	202
Karnataka	Laterite	30	30	20	1094	456	30	35	20	1536	600	30	35	20	1984	775
	Red loamy	30	30	20	719	346	30	20	20	1028	494	30	20	20	1337	643
	Medium black	30	30	40	695	257	30	30	40	1016	376	30	35	40	1337	467
	Red sandy	30	40	40	533	176	30	40	40	812	269	30	40	40	1090	361
Orissa	Red sandy	15	40	20	370	171	15	40	20	566	262	15	40	20	762	353
	Red and yellow	30	30	20	1500	625	30	30	20	2080	867	30	30	20	2660	1108
	Red loamy	25	20	20	1286	680	30	20	20	1750	841	30	20	20	2240	1077
Punjab	Alluvial	30	20	20	1202	578	30	25	20	1682	751	30	25	20	2158	963
Tripura	Red and yellow	30	40	20	1204	443	30	40	20	1696	624	30	40	20	2188	804
Uttar Pradesh	Alluvial	30	40	40	926	307	30	45	40	1343	421	30	45	40	1759	551

30 kg N, 40 kg P_2O_4 and 0–20 K_2O was optimum even at the lowest price level. With the optimum doses, the profit was quite high in red loam and red and yellow soils and alluvial soils. The profits ranged from 142—606 per cent in irrigated soils and from 83—680 per cent in rainfed groundnut even at the lowest price of 1.50 rupees per kg of groundnut. The profits improved considerably with the rise in prices of groundnut.

Relative efficiency of nitrogenous fertilizers

The relative efficiency of different sources of nitrogen on groundnut was studied in trials on cultivators' fields during 1958-59 to 1961-62. The sources of nitrogen studied were ammonium sulphate, urea, ammonium sulphate nitrate and calcium ammonium nitrate each applied at two levels of 22.4 and 44.8 kg N/ha. The trials covered three soils located in four states. The results are presented in Table 4.12. Ammonium sulphate nitrate gave somewhat higher response compared to ammonium sulphate in red loamy as well as red sandy soils in Tamil Nadu at both the levels, while in alluvial soil in Punjab and Haryana this difference was observed only at the higher level. A few other differences were also observed but these were not consistent in favour of any particular source from area to area in the different states. Different sources of nitrogen, therefore, did not show any differential effect in the uptake of nitrogen by groundnut except in certain isolated cases, where the differences were explainable on the basis of sulphur content of the fertilizer.

Relative efficiency of sources of phosphorus

Two phosphorus carriers, namely, single superphosphate and monoammonium phosphate, were studied at two levels each, namely, 33.6 and 67.2 kg P_2O_5/ha. Trials were conducted in five soils covering four states. The results are presented in Table 4.13. No differences were observed in the responses for the two phosphate carriers in any soil.

Crop substitution experiments with groundnut

The last series of experiments in cultivators' fields reported here relates to the crop substitution aspect in which groundnut and another oilseed (mostly sunflower) were grown with recommended doses of N, P and K and the produce compared in terms of value received to study the relative returns from the two oilseeds. These experiments were conducted during 1972-73 and 1973-74 in 14 districts on six soils in nine states. The results are presented in Table 4.14 and conclusions discussed in the following paras:

(*i*) Groundnut proved more remunerative in chest brown soil in Ambala, medium black soil in Panchmahal and Bijapur, mixed red and black soil in Ramanathpuram, laterite soil in Mayurbhanj and red sandy soil in Dhenkanal.

TABLE 4.12. RELATIVE EFFICIENCY OF DIFFERENT SOURCES OF NITROGEN (1959-60 TO 1961-62)

State	Broad soil class	No of dist-ricts	No. of years	No. of trials	Control yield	Response to 22.4 kg N/ha				Response to 44.8 kg N/ha				C.D. (5%)
						A/S	Urea	ASN	CAN	A/S	Urea	ASN	CAN	
Andhra Pradesh	Red loamy	1	1	6	2829	312	308	220	—	626	395	476	—	241
	Red sandy	9	2	117	817	216	220	257	490	362	432	397	720	78
Punjab and Haryana	Alluvial	3	2	27	1262	90	68	70	57	183	105	340	103	123
Tamil Nadu	Alluvial	2	3	8	1235	170	100	140	212	267	169	210	212	102
	Red loamy	1	1	10	2460	47	54	750	—	510	610	880	—	274
	Red sandy	4	4	35	170	209	206	361	86	301	276	463	88	99
	Red loamy	2		16	2598	146	149	551	—	554	529	728		
	Red sandy	13		152	668	214	217	281	397	348	396	412	574	
	Alluvial	5		35	1257	108	75	86	92	202	120	310	128	
	Mean response over all the soils	20		203	921	190	187	269	340	339	359	419	491	

TABLE 4.13. RELATIVE EFFICIENCY OF DIFFERENT SOURCES OF PHOSPHATE (1959-60 TO 1961-62)

State	Broad soil class	No. of dist-ricts	No. of years	No. of trials	Control yield	Response to 33.6 kg P_2O_5/ha		Response to 67.2 kg P_2O_5/ha		C.D.
						Single super-phosphate	Mono ammonium phosphate	Single super-phosphate	Mono ammonium phosphate	
Andhra Pradesh	Red sandy	3	1	19	920	137	150	267	237	126
Tamil Nadu	Alluvial	1	1	6	1640	220	240	280	260	123
	Red loamy	1	2	14	2225	645	625	1050	880	135
	Red sandy	2	1	8	1435	345	370	405	515	143
Maharashtra	Medium black	5	1	111	540	146	132	218	208	35
Pondicherry	Coastal alluvium	1	2	12	2845	580	430	1120	1190	158
	Red soil	6		41	1309	291	302	444	437	
	Alluvial soil	2		18	2242	400	335	700	725	
	Medium black soil	5		111	540	146	132	218	208	
	Mean response over all the soils	13		170	1157	252	242	396	393	

TABLE 4.14. COMPARATIVE RESPONSES (KG/HA) OF GROUNDNUT AND ALTERNATIVE CROPS TO DIFFERENT FERTILIZER APPLICATIONS (KHARIF, 1972-73 AND 1973-74)

Soil group/ district	Year	Crop	Variety	No. of trials	Average duration (days)	Seed rate (kg/ ha)	Fertilizer dose (kg/ha)			Average yield (kg/ha)	Net return	% return
							N	P	K			
1	2	3	4	5	6	7	8	9	10	11	12	13
Chestnut brown												
Haryana	1972-73	Sunflower	'Sunrise'	13	104	25	60	60	60	603	922	158
Ambala	1972-73	Groundnut	'Local'	13	113	85	—	—	—	766	1234	415
	1972-73	Groundnut	'Pb-1'	13	113	85	30	40	30	1100	1615	276
Coastal alluvial												
Gujarat	1972-73 &											
Jamnagar	1973-74	Sunflower	'EC-68414'	46	92	12	60	60	60	603	962	176
	1972-73 &	Groundnut	'Pb-1'									
	1973-74	Groundnut	'Local'	46	98	125	30	40	30	485	245	34
	1972-73	Groundnut	'Local'	17	97	125	30	40	30	271	—183	—25
	1973-74			29	100	125	—	—	—	361	284	65
Medium black												
Gujarat	1972-73 &											
Panchmahal	1973-74	Sunflower	'EC-68414'	56	107	12	60	60	60	1000	1954	358
	1972-73 &											
	1973-74	Groundnut	'Local'	56	124	82	—	—	—	1398	2509	874
	1972-73 &											
	1973-74	Groundnut	'J-11	56	120	95	30	40	30	1536	2452	395
Maharashtra	1972-73	Sunflower	'EC-68414'	22	106	10	60	60	60	728	1280	237
Aurangabad	1973-74	Sunflower	'EC-68414'	36	109	10	60	60	30	1174	2440	493

TABLE 4.14 (*Contd*)

1	2	3	4	5	6	7	8	9	10	11	12	13
	1972-73 & 1973-74	Groundnut	'Local'	58	102	100	—	—	—	612	874	250
	1972-73 & 1973-74	Groundnut	'SB-11'	58	102	100	30	40	30	968	1298	204
Karnataka	1972-73 &											
Bijapur	1973-74	Sunflower	'EC-68415'	30	116	14	60	60	30	732	1323	261
	1972-73											
	1973-74	Groundnut	'Local'	30	130	88	—	—	—	948	1583	516
	1972-73 & 1973-74	Groundnut	'Spanish improved'	30	130	98	20	40	—	1188	1828	334
Madhya Pradesh	1972-73	Sunflower	'EC-68413'	11	116	15	60	60	60	1102	2200	396
Indore	1972-73	Groundnut	'AK-12-24'	11	113	110	20	40	20	737	854	138
	1972-73	Groundnut	'Jyoti-61-240'	11	114	112	30	40	30	845	1010	149
Rajasthan	1972-73	Sunflower	'EC-68414'	15	100	12	60	60	60	1076	2150	398
Jhalawar	1972-73	Groundnut	'Local'	15	99	75	—	—	—	814	1366	520
	1972-73	Groundnut	'AK-12-24'	15	99	75	30	40	30	1157	1764	321
Maharashtra	1973-74	Sunflower	'EC-68414'	27	114	17	20	30	—	1317	3069	1373
Sholapur	1973-74	Groundnut	'Local'	27	112	99	—	—	—	1330	2314	668
	1973-74	Groundnut	'SB-11'	27	112	99	20	30	—	1641	2763	532
Mixed red and black												
Karnataka	1972-73 &											
Dharwar	1973-74	Sunflower	'EC-68415'	39	96	10	60	60	30	1316	2795	565
	1972-73 & 1973-74	Groundnut	'Local'	39	120	86	—	—	—	1137	1973	655

TABLE 4.14 (*Contd*)

1	2	3	4	5	6	7	8	9	10	11	12	13
	1972-73 & 1973-74	Groundnut	'Improved'	39	120	86	20	40	—	1708	2912	578
Tamil Nadu	1972-73	Sunflower	'EC-68414'	14	96	17	20	40	40	144	46	15
Ramanathpuram	1972-73	Groundnut	'Local'	14	102	125	—	—	—	1096	1754	401
	1972-73	Groundnut	'Improved'	14	102	125	10	20	30	1469	2354	403
Andhra Pradesh	1972-73	Sunflower	'N.A.'	6	104	7	60	60	30	1042	2119	436
Hyderabad	1972-73	Groundnut	'Spanish improved'	6	117	80	—	—	—	724	1178	436
	1972-73	Groundnut	'TMV-2'	6	117	80	30	40	30	810	1062	191
Andhra Pradesh	1973-74	Sunflower	'EC-68415'	15	110	13	60	40	30	1080	2256	508
Kurnool	1973-74	Groundnut	'Local'	15	110	125	—	—	—	653	868	199
	1973-74	Groundnut	'TMV-2'	15	110	125	30	40	30	866	1007	139
Laterite												
Orissa	1972-73	Sunflower	'EC-68415'	24	111	8	30	40	15	237	304	105
Mayurbhanj	1973-74	Sunflower	'Sunrise'	17	112	12	60	60	30	395	486	97
	1972-73 & 1973-74	Groundnut	'Local'	41	132	106	—	—	—	1087	1803	486
	1972-73 & 1973-74	Groundnut	'AK-12-24'	41	116	118	30	40	30	1783	2866	409
Red sandy												
Orissa	1972-73	Sunflower	'Sunrise'	19	114	11	30	30	15	115	22	8
Dhenkanal		Groundnut	'AK-12-24'	19	112	200	30	40	30	1322	1659	168
	1973-74	Sunflower	'Sunrise'	26	105	15	50	60	30	965	1940	411
		Groundnut	'AK-12-24'	26	105	200	15	30	20	1592	2300	260
		Groundnut	'AK-12-24'	26	105	200	25	40	30	1925	2881	297

(*ii*) Sunflower on the other hand proved more remunerative in coastal alluvial soil in Jamnagar, medium black soil in Indore and Sholapur and mixed red and black soil in Kurnool. The yield of groundnut crop was thus much higher and brought in considerably larger income in a large number of districts.

In view of encouraging results and good returns from groundnut under dry farming conditions the scope of these trials was enlarged to include different combinations of N, P and K and further a cereal crop was also studied in some of the districts. The experiments were conducted during 1973-74 to 1976-77 and covered 11 districts in eight states and six soils. The results are given in Table 4.15.

It may be observed that groundnut outyielded sunflower, cereals like paddy and *bajra* and pulses like *arhar* in almost all districts except in black soil in Indore (Madhya Pradesh), and Gulbarga (Karnataka) while in Dhulia (deep black soil) during 1976-77 and in Anantapur (red sandy soil) during 1975-76, there was no difference in the two sets of crop studied. Another important result emerging from this series was the beneficial effect of joint application of N, P and K on groundnut in almost all districts except Gulbarga which clearly shows that combined application of chemical fertilisers (N, P and K) in adequate doses of 30—40 kg/ha each would prove quite remunerative under dry farming conditions. This is in agreement with similar results obtained in earlier series of trials.

Experiments at research stations in different states

As mentioned earlier, experiments to study the response of groundnut to one or more of the chemical fertilizers and other practices like irrigation, etc., are being conducted at research stations or experimental farms in different states. The data of these experiments conducted during the period 1960-71 and collected under 'National Index of Agricultured Field Experiments' at I.A.S.R.I. were appropriately analysed and pooled over different years at a centre. Since different levels of fertilizers were tried in experiments in different years, the responses were standardised to commonly used doses before pooling over years. The results pertaining to responses of N, P and K are presented respectively in Tables 4.16, 4.17 and 4.18 for irrigated groundnut and Tables 4.19, 4.20 and 4.21 for unirrigated crop.

Response of groundnut (irrigated) to N, P and K. A high response of 480 kg/ha was obtained in 20 kg N/ha at Seed Multiplication Farm, Piprakoth (Bihar) in sandy loam soil with variety 'AK-12-24' which, however, did not show further increase at the higher level of nitrogen. The variety 'TMV-2' showed a significant response to 20 kg N/ha at Amravati (black soil) and Tindivanam (red loam soil). Application of phosphorus showed a significant response at different levels at a number of centres being particularly

TABLE 4.15. COMPARATIVE RESPONSES (KG/HA) OF GROUNDNUT AND ALTERNATIVE CROPS TO DIFFERENT FERTILIZER APPLICATIONS (KHARIF, 1974-75 TO 1976-77)

Soil group/ district	Year	No. of trials	Crop	Variety	Treatment	Res- ponse	Net return	Crop	Variety	Treatment	Res- ponse	Net return
1	2	3	4	5	6	7	8	9	10	11	12	13
Alluvial	1974-75	12	*Bajra*	'HB-3'	Control	1066	1056	Ground-	'C-501'	Control	4848	9346
Delhi					N_{40}	310	160	nut		N_{30}	531	950
					$N_{40}P_{40}$	416	136			$N_{30}P_{40}$	1207	2171
					$N_{40}P_{40}K_{20}$	469	159			$N_{30}P_{40}K_{30}$	781	1274
Red loamy												
Orissa												
Dhenkanal	1974-75	23	Paddy	'Bala'	Control	552	492	Ground-	'AK-12-	Control	1399	2448
					N_{60}	152	—73	nut	24'	N_{30}	244	325
					$N_{60}P_{40}$	324	− 31			$N_{30}P_{40}$	456	670
					$N_{60}P_{40}K_{30}$	484	84			$N_{30}P_{40}K_{30}$	634	981
	1975-76	28	*Arhar*	'S-5'	Control	479	1138	Ground-	'AK-12-	Control	1249	1973
					N_{20}	260	575	nut	24'	N_{30}	395	678
					$N_{20}P_{40}$	592	1275			$N_{30}P_{40}$	765	1288
					$N_{20}P_{40}K_{20}$	729	1687			$N_{30}P_{40}K_{30}$	1006	1725
Red and yellow												
Bihar Ranchi	1974-75	16	Sunflower	'EC- 68.414	Control	261	628	Ground-	'AK-12-	Control	905	1460
					N_{60}	158	170	nut	24'	N_{30}	383	654
					$N_{60}P_{60}$	262	235			$N_{30}P_{40}$	631	1020
					$N_{60}P_{60}K_{30}$	294	270			$N_{30}P_{40}K_{30}$	717	1147

TABLE 4.15 (*Contd*)

1	2	3	4	5	6	7	8	9	10	11	12	13
	1975-76	34	Sunflower	'EC-68414'	Control	181	428	Ground-nut	'AK-12-24'	Control	966	1582
					N_{60}	184	235			N_{60}	313	401
					$N_{60}P_{60}$	410	670			$N_{60}P_{60}$	620	880
					$N_{60}P_{60}K_{30}$	461	753			$N_{60}P_{60}K_{30}$	761	1117
Red and yellow Ranchi	1976-77	35	Sunflower	'EC-68414'	Control	166	391	Ground-nut	'Early runner'	Control	1035	1720
					N_{60}	152	155			N_{30}	402	692
					$N_{60}P_{60}$	254	215			$N_{30}P_{30}$	757	1304
					$N_{60}P_{60}K_{30}$	336	375			$N_{30}P_{30}K_{30}$	1087	1919
Rajasthan Ajmer	1975-76 & 1976-77	47	Sunflower	'EC-68414'	Control	450	1050	Ground-nut	'AK-12-24'	Control	874	1398
					N_{60}	150	150			N_{30}	262	412
					$N_{60}P_{60}$	278	275			$N_{30}P_{40}$	438	634
					$N_{60}P_{60}K_{30}$	370	460			$N_{30}P_{40}K_{30}$	580	873
Medium black												
M.P. Indore	1974-75 to 1976-77	40	Sunflower	'68413'	Control	855	2062	Ground-nut	'AK-12-24' and 'Exotic'	Control	741	1045
					N_{60}	138	120			N_{30}	128	144
					$N_{60}P_{60}$	258	225			$N_{30}P_{40}$	232	222
					$N_{60}P_{60}K_{30}$	377	478			$N_{30}P_{40}K_{30}$	330	373
Maharashtra Satara	1975-76	28	Sunflower	'68414'	Control	206	440	Ground-nut	'K-4-11'	Control	630	910
					N_{60}	72	—45			N_{30}	158	204
					$N_{60}P_{40}$	149	17			$N_{30}P_{40}$	351	460
					$N_{60}P_{40}K_{30}$	224	160			$N_{30}P_{40}K_{30}$	490	693
	1976-77	36	Sunflower	'EC-68414'	Control	765	1882	Ground-nut	'K-4-11'	Control	1599	2848
					N_{60}	202	280			N_{30}	312	512
					$N_{60}P_{60}$	366	495			$N_{30}P_{40}$	622	1002
					$N_{60}P_{60}K_{30}$	535	872			$N_{30}P_{40}K_{30}$	903	1519

TABLE 4.15 (*Contd*)

1	2	3	4	5	6	7	8	9	10	11	12	13
Medium black												
Karnataka Gulbarga	1974-75	5	*Tur*	'C-28'	Control	389	958	Ground-	'Local'	Control	476	602
					N_{20}	160	325	nut		N_{30}	88	64
					$N_{20}P_{40}$	210	380			$N_{30}P_{40}$	162	82
					$N_{20}P_{40}K_{20}$	301	577			$N_{30}P_{40}K_{30}$	166	45
Gujarat Sabarkantha	1974-75	29	Sunflower	'EC-68414' 'EC-68404'	Control	678	1608	Ground-	'Pb-1'	Control	916	1482
					N_{30}	185	350	nut	'Samrala'	N_{30}	219	326
					$N_{30}P_{40}$	359	654			$N_{30}P_{40}$	400	558
					$N_{30}P_{40}K_{30}$	542	1067			$N_{30}P_{40}K_{30}$	533	779
Deep black												
Maharashtra Dhulia	1975-76	8	Sunflower	'EC-69874'	Control	681	1672	Ground-	'SB-11'	Control	1056	1762
					N_{30}	413	934	nut		N_{30}	606	1100
					$N_{30}P_{40}$	565	1185			$N_{30}P_{30}$	790	1338
					$N_{30}P_{40}K_{30}$	678	1422			$N_{30}P_{40}K_{30}$	1083	1879
	1976-77	13	Sunflower	'EC-68974'	Control	615	1508	Ground-	'SB-11'	Control	594	838
					N_{60}	116	65	nut		N_{30}	212	312
					$N_{60}P_{60}$	210	105			$N_{30}P_{40}$	295	348
					$N_{60}P_{60}K_{30}$	326	350			$N_{30}P_{40}K_{30}$	395	503
Red sandy												
Andhra Pradesh Nellore	1975-76 1976-77	10	*Bajra*	'HB-3'	Control	350	330	Ground-	'TMV-2'	Control	847	1396
					N_{40}	298	148	nut		N_{40}	342	534
					$N_{40}P_{40}$	476	196			$N_{40}P_{40}$	510	740
					$N_{40}P_{40}K_{20}$	493	183			$N_{40}P_{40}K_{20}$	780	1250

TABLE 4.15 (*Contd*)

1	2	3	4	5	6	7	8	9	10	11	12	13
Red sandy												
Andhra Pradesh	1975-76	22	Castor	'Aruna'	Control	770	1868	Ground-	'Kadiri	Control	720	1090
Anantapur					N_{30}	543	1244	nut	71-1'	N_{30}	253	394
					$N_{30}P_{40}$	762	1662			$N_{30}P_{40}$	509	776
					$N_{30}P_{40}K_{20}$	982	2282			$N_{30}P_{40}K_{20}$	752	1232
	1976-77	26	Castor	'Aruna'	Control	318	738	Ground-	'Kadiri	Control	400	450
					N_{40}	88	70	nut	71-1'	N_{30}	127	142
					$N_{40}P_{40}$	156	110			$N_{30}P_{40}$	257	272
					$N_{40}P_{40}K_{20}$	261	312			$N_{30}P_{40}K_{30}$	380	473

TABLE 4.16. RESPONSE (KG/HA) OF GROUNDNUT (IRRIGATED) TO DIFFERENT LEVELS OF NITROGEN AT EXPERIMENTAL FARMS

State	Soil type	Centre	Year	Variety	Control yield	Response to levels of N			C.D. (5%)
						20	40	60	
Andhra Pradesh	Red sandy loam	Oil Seed Research Station, Yemmiganur	1967	'TMV-2'	639	200	246		—
		Groundnut Research Station, Machilipatnam	1966	'TMV-2'	2822	—32	414	—	—
	Black	Agricultural Research Station, Amravati	1963-65	'TMV-2'	1665	150	216	—	56
Bihar	Clay	Agricultural Research Station, Patna	1961-62	'Ciriak local'	2156	38	42	11	—
	Sandy loam	Seed Mult. Farm, Piprakothi	1969	'AK-12-24'	1551	483	468	—	348
Karnataka	Slightly alkaline with calcium pebbles	Agricultural Research Station, Gangavati	1964	'TMV-2'	1100	86	58	—	—
Punjab	Sandy loam	Punjab Agricultural University, Ludhiana	1960	'P.G.No.4'	2108	100	—	—	—
				'P.G.No.1'	1636	59	—	—	—
		Phulawal Sadhar and Ghungarwali (CF)	1960	'P.G.No.1'	792	69	—	—	—
Rajasthan	Loamy sand	Government Agriculture Research Farm, Sriganganagar	1966	'AK-12-24'	1084	83	132	—	—
Tamil Nadu	Red loam	Oilseed Experimental Station, Tindivanam	1966-69	'TMV-2'	1549	104	—	—	85
Uttar Pradesh	Sandy loam	G.B. Pant University of Agriculture and Technology, Pantnagar	1969-70	'T-28'	2488	134	—	—	—

TABLE 4.17. RESPONSE (KG/HA) OF GROUNDNUT (IRRIGATED) TO DIFFERENT LEVELS OF PHOSPHORUS AT EXPERIMENTAL FARMS.

State	Soil type	Centre	Year	Variety	Control yield	Response to levels of P_2O_5			C.D. (5%)
						20	40	60	
1	2	3	4	5	6	7	8	9	10
Andhra Pradesh	Black	Agricultural Research Station, Amravati	1964-65	'TMV-2'	2622	65	105	120	—
	Red sandy loam	Groundnut Research Station, Darsi	1968-70	'TMV-2'	1416	123	95	—	—
Bihar	Clay	Agricultural Research Institute, Patna	1961-62	'Ciriak' (local)	2163	50	40	—30	—
Gujarat	Sandy loam	Trial-cum-Demonstration Farm, Thasra	1960-63	'AH-32'	708	88	211	—	55
	Medium black	Trial-cum-Demonstration Farm, Kum	1960-62	'AH-32'	972	84	153	—	147
Karnataka	Medium black	M.A.E. Centre, Gangavati	1960, 1962-64	'TMV-2'	668	116	161	—	62
	Slightly alkaline with calcium pebbles	Agricultural Research Station, Gangavati	1964	'TMV-2'	1032	165	196	95	135
Orissa	Sandy loam	State Agricultural Research Station, Bhubaneswar	1970-71 1968	'AK-12-24'	1141	123	238	345	57
Punjab	Sandy loam	Punjab Agricultural University, Ludhiana	1968-71	'M-145'	1869	164	188	—	93
		Phulawal, Sadhar and Ghungarwali (C.F.)	1960	'PG-1'	799	59	—	—	—

TABLE 4.17 (*Contd*)

1	2	3	4	5	6	7	8	9	10
		Oilseed Research Station, Samrala	1964	'PG-1'	2016	41	—	—	—
		Punjab Agricultural University, Ludhiana	1970-71	'M-145'	1350	89	157	—	—
Rajasthan	Sandy loam	Government Agricultural Research Farm, Sriganganagar	1965-68	'AK-12-24'	840	58	110	160	131
		Regional Agricultural Research Station, Sultanpur	1964	'RS-1'	1331	172	265	282	270
Tamil Nadu	Red soil	Agricultural Research Station, Bhavanisagar	1965	'TMV-2'	1204	58	—	—	—
	Red loam	M.A.E. Centre, Bhavanisagar	1960 64	'TMV-2'	2099	312	410	—	—
Uttar Pradesh	Sandy loam	Government Research Station, Bahraich	1967	'T-28' (late)	1416	111	140	88	—
		Jute Research Station, Bahraich	1969	'T-28' (late)	739	—29	10	117	103
		Government Regional Agricultural Research Station, Etawa	1968	'T-28' (late)	1179	509	672	488	141
		Fertilizer Research Farm, Pura (Kanpur)	1970	'T-64'	2368	94	125	94	—
		Government Research Station, Mainpuri	1970	'T-64'	564	105	—	—	—
	Loam	G.B. Pant University of Agric. and Tech., Pantnagar	1969	'T-28' (late)	2314	—49	—6	131	—
West Bengal	Sandy loam	State Agricultural Farm, Behrampore	1965	'B-31' (from AK-108-11')	1061	208	275	—	154

TABLE 4.18. RESPONSE (KG/HA) OF GROUNDNUT (IRRIGATED) TO DIFFERENT LEVELS OF POTASH AT EXPERIMENTAL FARMS

State	Soil type	Centre	Year	Variety	Control yield	Response to levels of K			CD
						20	40	60	
1	2	3	4	5	6	7	8	9	10
Andhra Pradesh	Black	Agricultural Research Station, Amravati	1964-65	'TMV-2'	2673	38	46	27	—
	Sandy loam	Groundnut Research Station, Machlipatnam	1960-62	'TMV-2'	1555	203	268	—	156
		Agricultural Research Station, Rudrur	1961-63	'Spanish improved'	853	—36	32	—	—
Karnataka	Medium black	M.A.E. Centre, Gangavati	1962-64	'TMV-2'	826	—40	50	—	—
	Slightly alkaline with calcium pebbles	Agricultural Research Station, Gangavati	1964	'TMV-2'	1087	– 72	64	—	—
Punjab	Sandy loam	Punjab Agricultural University, Ludhiana	1960	'PG-1'	1287	49	—	—	—
		Phulawal, Sadhar and Ghungarwali (C.F.)	1960	'PG-1'	802	55	—	—	—
Rajasthan	Sandy loam	Government Agricultural Research Farm, Sriganganagar	1968	'TMV-2'	1431	—30	52	—	—
Tamil Nadu	Red loam	Oilseed Experimental Station, Tindivanam	1970-71	'TMV-2'	1674	—35	—32	8	—
	Red soil	Agricultural Research Station, Bhavanisagar	1965	'TMV-2'	1140	81	161	242	122

TABLE 4.18 (*Contd*)

1	2	3	4	5	6	7	8	9	10
	Red clay loam (sandy)	Agricultural Research Station, Aliyarnagar	1967-68	'TMV-2'	1778	—44	—5	--	
Uttar Pradesh	Sandy loam	Government Groundnut Research Station, Mainpuri	1961-65	'T-28' (late)	1372	65	129	—	107
		Government Regional Agricultural Research Station, Etawa	1968	'T-28' (late)	1179	96	264	504	71
		Jute Research Station, Bahraich	1969	'T-28' (late)	739	260	282	70	206
		Groundnut Research Station, Mainpuri	1970	'T-64'	625	113	99	—41	—

TABLE 4.19. RESPONSE (KG/HA) OF GROUNDNUT (UNIRRIGATED) TO DIFFERENT LEVELS OF NITROGEN AT EXPERIMENTAL FARMS

State	Soil type	Centre	Year	Variety	Control yield	Response to levels of N			C.D. (5%)
						20	40	60	
1	2	3	4	5	6	7	8	9	10
Andhra Pradesh	Black	Agricultural Research Station, Amravati	1964	'TMV-2'	447	106	124	—	15
	Chalka	Agricultural Research Station, Warangal	1960-63	'Spanish improved'	300	72	169	291	158
		Government Agricultural Farm, Dindi	1960-63	'TMV-2'	627	11	97	—	—
	Sandy loam	Agricultural Research Station, Karimnagar	1971	'Spanish improved'	1296	22	204	—	58
Bihar	Red loam	Agricultural Research Institute, Kanke	1964-66	'AK-12-24'	912	68	—	—	—
Gujarat	Medium black	Agricultural Research Station, Amreli	1960-62	'AH-32'	991	82	—	—	53
		Agricultural Research Station, Jamnagar	1962 and 1964	'Punjab-1'	861	85	—	—	—
		Dry Farming Research Station, Targhadia	1967, 1969-71	'SB-11'	1338	83	—	—	—
	Sandy	Agricultural Research Station, Talod	1960, 1960-62	'AH-32' 'Samrala-1' (Punjab)	979 791	90 51	— 84	— —	— —
Karnataka	Light masouri	Agricultural Research Station, Bailhongal	1960-61	'Spanish improved'	694	33	—	—	—

TABLE 4.19 (*Contd*)

1	2	3	4	5	6	7	8	9	10
	Red loam	Agricultural Research Station, Hebbal	1961	'HG-10'	1118	164	140	--	161
Madhya Pradesh	Sandy loam	Government Agricultural Station, Jhabua	1960	'N.A.'	1794	410	—	—	—
Maharashtra	Medium black	Agricultural Research Station, Buldhana	1960-61	'Spanish improved'	2182	207	—	—	179
		Agricultural Research Station, Parbhani	1963-65	'K-4-11'	1240	64	—	—	—
		Agricultural College Farm, Parbhani	1970-71	'SB-11'	573	65	25	—	28
		Agricultural Research Station, Washin	1960	'AK-12-24'	2521	218	—	—	64
		Agricultural Research Centre, Amravati	1966-70	'AK-12-24'	1320	43	60	--	—
		Regional Research Centre, Amravati	1966-69	'AK-12-24'	1552	34	76	128	71
		Agricultural College Farm, Akola	1970-71	'AK-12-24'	581	54	39	—	—
	Black cotton soil	Agricultural Research Station, Akola	1960-62	'AK-12-24'	1030	117	—	—	95
		Agricultural Research Station, Jalgaon	1965-67	'SB-11'	531	57	74	104	72
		Agricultural College Farm, Nagpur	1962	'AK-12-24'	2346	268	—	—	181
	Light black	Agricultural Research Station, Badnapur	1965	'SB-11'	524	64	91	—	44
	Deep black cotton soil	Agricultural Research Station, Jalgaon	1960	'Faizpur-1-5'	1867	216	—	—	139

TABLE 4.19 (*Contd*)

1	2	3	4	5	6	7	8	9	10
	Medium to heavy black	Oilseed Research Station, Latur	1964-65	'Karad-4-11'	560	120	—	—	54
	Medium black clay loam	Agricultural Research Station, Digraj	1962-64	'Kopergaon-1'	747	94	—	—	40
Maharashtra	Med. Marund No. 2	Agricultural College Farm, Nagpur	1970-71	'AK-12-24'	2220	19	—42	—	—
	Black	Agricultural Research Station, Jalgaon	1970-71	'SB-11'	349	73	60	—	—
Punjab	Sandy loam	Oilseed Research Station, Samrala	1960	'C-145'	1148	44	—	—	—
Rajasthan	Sandy loam	Government Agricultural Research Farm, Sriganganagar	1964	'PG-1'	2263	369	600	692	311
Tamil Nadu	Sandy loam	Oilseed Experimental Station, Tindivanam	1967-71	'TMV-2'	783	12	262	—	61
Tripura	Sandy loam	Research-cum-Demonstration Farm, Arundhatinagar	1964-65	'Local'	1115	88	—	—	—
West Bengal	Sandy loam	State Agricultural Farm, Behrampore	1966-67	'B-31'	962	72	12	—	—
	Laterite	State Agricultural Farm, Midnapore	1965-67	'B-30'	687	56	—28	—	—

TABLE 4.20. RESPONSE (KG/HA) OF GROUNDNUT (UNIRRIGATED) TO DIFFERENT LEVELS OF PHOSPHORUS AT EXPERIMENTAL FARMS

State	Soil type	Centre	Year	Variety	Control yield	Response to levels of P			C.D. (5%)
						20	40	60	
1	2	3	4	5	6	7	8	9	10
Andhra Pradesh	*Chalka*	Government Agricultural Farm, Dindi	1962-63	'TMV-2'	606	92	—24	—	—
		Agricultural Research Station, Warangal	1960-63	'Spanish improved'	316	85	158	222	219
	Sandy loam	Agricultural Research Institute, Rajendranagar	1960-63	'Spanish improved'	973	24	51	—	—
		Agricultural Research Station, Karimnagar	1971	'Spanish improved'	1386	116	177	184	67
	Red loam	Regional Oilseed Research Station, Kadiri	1960-63	'TMV-1'	912	48	53	—	—
	Red sandy loam	Project Development Demonstration Farm, Garikapadu	1966	'TMV-2'	1226	45	60	—	—
Bihar	Red loam	Agricultural Research Institute, Kanke	1964-66	'AK-12-24'	1336	142	202	258	—
		Agricultural Research Institute, Kanke	1967-68	'Early summer'	730	93	138	135	—
	Calcarious loam	Agricultural Research Institute, Dholi	1963, 1965	'AK-12-24'	1225	10	45	---	—
Gujarat	Sandy	Agricultural Research Station, Talod	1960-61	'Samrala 1' (Punjab)	783	43	52	24	—

TABLE 4.20 (*Contd*)

1	2	3	4	5	6	7	8	9	10
	Medium black	Agricultural Research Station, Kothara	1961-62 1964-65	'AH-32'	1144	40	52	—	—
		Agricultural Research Station, Amreli	1960-62	'AH-32'	981	35	61	79	56
		Trial-cum-Demonstration Farm, Kholwad	1960-62	'AH-32'	2091	58	184	—	—
		Trial-cum-Demonstration Farm, Umrala	1960	'AK-12-24'	1329	36	65	87	—
Gujarat	Medium black	Agricultural Research Station, Jamnagar	1962, 1964	'Punjab-1	876	23	47	72	48
		Oilseed Research Station, Junagarh	1967	'J-11'	1736	97	176	237	—
		Oilseed Research Station, Junagarh	1966	'SB-11'	830	51	—	—	—
		Dry Farming Research Station, Targhadia	1966-71	'SB-11'	1065	52	73	60	65
Karnataka	Red loam	Agricultural Research Station, Hebbal	1961	'HG-10'	1128	163	194	—	161
	Red soil	Regional Research Station, Raichur	1971	'S-206'	1264	89	74	–44	—
	Medium black	Agricultural College Farm, Dharwar	1963-64	'Spanish improved'	1068	84	111	—	109
	Light masouri	Regional Sorghum Research Station, Bailhongal	1964	'Erect type'	794	64	134	208	84
Maharashtra	Black	Agricultural Research Station, Jalgaon	1971	'SB-11'	405	71	104	99	74

TABLE 4.20 (*Contd*)

1	2	3	4	5	6	7	8	9	10
	Medium black	Agricultural College Farm, Akola	1970-71	'AK-12-24'	798	44	58	—	—
		Agricultural Research Station, Achalpur	1960-62	'AK-12-24'	1060	47	73	—	—
	Medium Marund-2	Agricultural College Farm, Nagpur	1970-71	'AK-12-24'	2106	115	199	—	—
		Agricultural Research Station, Amravati	1966-70	'AK-12-24'	1298	61	139	—	41
		Agricultural Research Station, Chas	1960	'Karad 4-11'	1256	—10	—	—	—
		Agricultural Research Station, Parbhani	1970-71	'SB-11'	568	40	60	—	47
	Medium black	Agricultural Research Station, Washim	1960	'AK-12-24'	2423	235	372	—	107
Maharashtra	Medium deep black	Agricultural Research Station, Jeur	1960	'K-4-11'	1662	55	—	—	—
	Black cotton	Agricultural College Farm, Nagpur	1962	'AK-12-24'	2419	—26	26	—	—
Rajasthan	Red and black	Regional Research Farm, Barwat (Banswara)	1966-67	'AK-12-24'	772	34	85	152	127
	Sandy loam	Government Agricultural Research Farm, Sriganganagar	1964	'Punjab-1'	2556	66	133	200	—
	Clay loam	Government Agricultural Farm, Sawaimadhopur	1961-62	'Gangapur'	1206	179	46	—	—
	Loam	Janta College Farm, Dabok	1965	'AK-12-24	1071	61	103	125	—
Madhya Pradesh	Sandy loam	Government Agricultural Farm, Bhind	1967	'AK-12-24'	709	224	—	—	—

TABLE 4.20 (*Contd*)

1	2	3	4	5	6	7	8	9	10
	Medium black	Government Experimental Farm, Khandwa	1960	'AK-12-24'	1373	459	—	—	326
	Black cotton	Government Agricultural Research Farm, Bahadari	1962	'AK-12-24'	1300	124	—	—	—
Tamil Nadu	Red sandy	Regional Research Station, Tindivanam	1963-64	'TMV-2'	491	68	—	—	21
	Red sandy loam (strewn with pebbles)	Gingelly Research Station, Kanur	1961-63	'TMV-3'	533	46	59	—	55
Tripura	Sandy loam	Research-cum-Demonstration Farm, Arundhatinagar	1964-65	'Local'	1002	114	287	—	111
Uttar Pradesh	Sandy loam	Government Regional Agricultural Research Station, Hardoi	1964	'T-28' (late)	1240	100	—125	—	—
West Bengal	Laterite	State Agricultural Farm, Midnapore	1965	'B-33' (from AK-10)	598	251	362	—	113

State	Soil type	Centre	Year	Variety	Control yield	Response to levels of K_2O			C.D. (5%)
						20	40	60	
Andhra Pradesh	*Chalka*	Agricultural Research Station, Warangal	1962-63	'Spanish improved'	351	44	101	170	—
	Red sandy loam	Project Development and Demonstrations Farm, Garikapadu	1966	'TMV-2'	641	54	33	—	—
Bihar	Red loam	Agricultural Research Station, Kanke	1964-65	'AK-12-24'	692	38	111	—	—
	Calcarious loam	Agricultural Research Institute, Dholi	1963, 65	'AK-12-24'	1230	47	24	—	—
Gujarat	Medium black	Irrigation-cum-Demonstrations Farm, Kukda	1962	'AK-12-24'	666	44	58	44	—
		Central Experimental Station, Junagarh	1960-62	'Punjab-1'	1211	26	22	—11	—
Karnataka	Medium black	Agricultural College Farm, Dharwar	1963-64	'Spanish improved'	1216	108	114	—	99
Orissa	Sandy loam	Agricultural Research Station, Sambalpur	1962	'TMV-2'	1906	66	88	69	—
	Loamy sand	State Agricultural Research Station, Bhubaneswar	1962	'TMV-3' (late)	1199	21	36	44	—
Punjab	Sandy loam	Oilseed Research Station, Samrala	1960	'C 145'	1113	278	—	—	235
Tamil Nadu	Sandyl oam	Oilseed Experimental Station, Tindivanam	1967-70	'TMV-2' (early)	613	202	—	—	—
	Red sandy loam	Regional Research Station, Tindivanam	1963-64	'TMV-2'	613	28	55	—	—
Tripura	Sandy loam	Research-cum-Demonstrations Farm, Arundhatinagar	1964-65	'Local'	1110	36	96	—	—
West Bengal	Sandy loam	State Agricultural Farm, Behrampore	1966-67	'B-31' (from 'AK-11')	970	36	52	—	—

marked at Bhubaneswar, Thasra, Etawa and Behrampur all located in sandy loam soils. Application of potash at 20 and 40 kg/ha proved beneficial in sandy loam soil at Machlipatnam (Andhra Pradesh), Mainpuri (Uttar Pradesh), Etawa (Uttar Pradesh) and Bahraich (Uttar Pradesh), while at 60 kg K_2O/ha, the response was significant at Bhavanisagar (Tamil Nadu) in red soil and Etawa (Uttar Pradesh) in alluvial soil.

The yield response curves to N, P and K at some of the centres in sandy loam soil are presented in Figure 4.6.

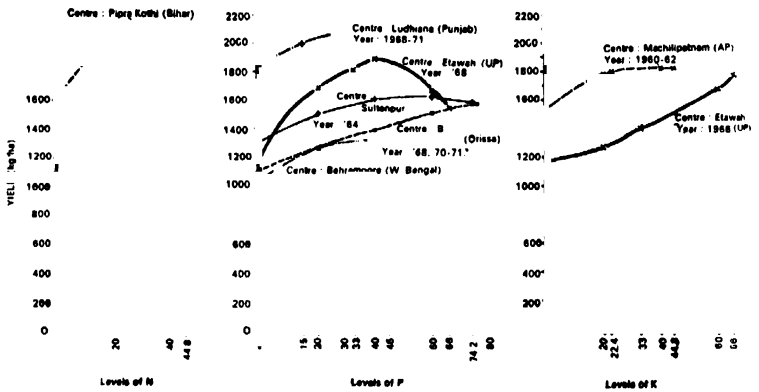

Fig. 4.6. Responses to different levels of N, P and K in irrigated ground at experimental station

Responses of groundnut (rainfed) to N, P and K. Response to nitrogen (Table 4.19) at 20 kg/ha was significant at Amravati (Maharashtra), Amreli (Gujarat), Buldhana, Washim, Badnapur, Jalgaon, Latur and Digraj (Maharashtra), all located in medium to deep black soil. At the higher level of 40 kg/ha, the response was significant in sandy loam soil at Karimnagar, Sriganganagar and Tindivanam. There was no significant increase in the response when the level of nitrogen was further increased to 60 kg/ha. It may also be observed that responses to N were much smaller in magnitude on research stations than on cultivators' fields. There also did not seem to be any case for the application of more than 20 kg N at most of the centres as the average response obtained to 20 kg N was about 100 kg or a response ratio of 1 : 5. The response to phosphorus (Table 4.20) at different levels was found significant in sandy loam soil at Karimnagar (Andhra Pradesh) and Arundhatinagar (Tripura), in red loam soil at Hebbal (Karnataka) and in black soil at Jalgaon, Amravati and Washim (Maharashtra). At the highest level of 60 kg P_2O_5/ha, the response was

significant at Warangal (*chalka* soil), Karimnagar (sandy loam soil), Belhangal (*masori* soil) and Banswara (red and black soil). The mean response to 20 kg P_2O_5/ha was 76 kg or a response ratio of 1 : 3.8. In the case of potash (Table 4.21), the response was significant to 20 kg K_2O/ha at Dharwar (medium black soil) and Samrala (sandy loam soil). Further increase in the level of potash did not show any improvement in the response. If the responses to 20 kg K_2O at all the research stations were averaged, the mean response comes to 69 kg for 20 kg K_2O indicating a response ratio of 1 : 3.5.

From these results at the experimental stations it is evident that the responses to N, P and K were generally low at most of the stations. This was in marked contrast to high responses observed in experiments in cultivators' fields. The yield response curves for N and P for a few centres in some of important soil classes are given in Figures 4.7 and 4.8.

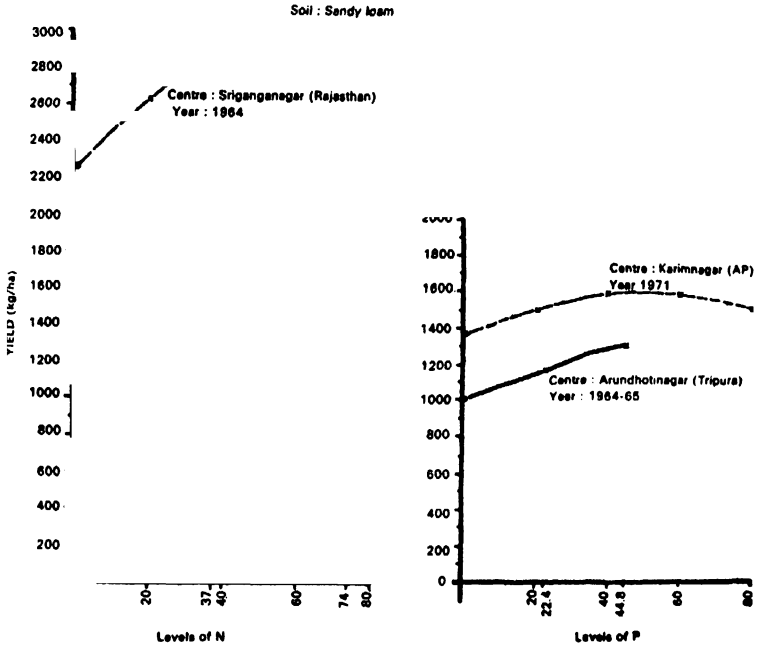

Fig. 4.7. Yield curves of groundnut (rainfed) showing effect of different levels of N or P

Interactions between N, P and K. The results of experiments in which two factor interactions were found significant are given in Tables 4.22, 4.23 and 4.24 corresponding to N×P, N×K and P×K respectively for irrigated groundnut and in Tables 4.25, 4.26 and 4.27 for rainfed groundnut.

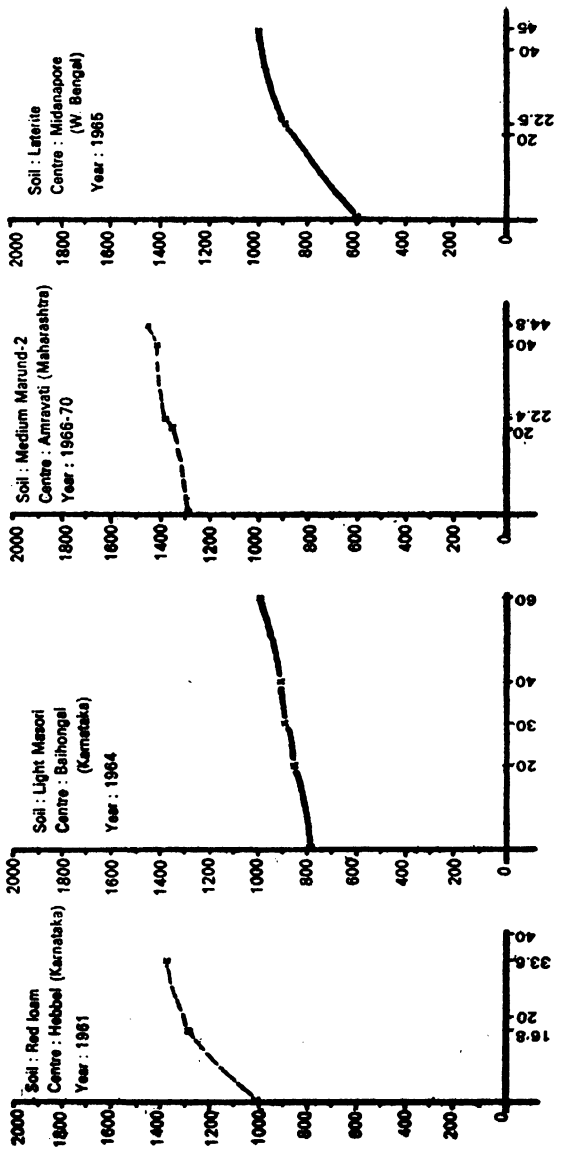

Fig. 4.8. Yield curves of groundnut (rainfed) showing effect of different levels of P in different soils

TABLE 4.22. EFFECT OF JOINT APPLICATION OF NITROGEN AND PHOSPHORUS ON GROUNDNUT (IRRIGATED)

State	Soil type	Centre	Year	Variety	Average yield for different combinations of N and P			C.D.
						$N_{(0)}$	$N_{(11\cdot2)}$	
Madhya Pradesh	Sandy loam	Government Agricultural Farm, Bhind	1965	'MV-3'	$P_{(0)}$	1097	1323	200
					$P_{(22\cdot4)}$	1123	1754	
						$N_{(0)}$	$N_{(150)}$	$N_{(300)}$
Utter Pradesh	Sandy loam	G.B. Pant University of Agriculture and Technology, Pantnagar	1970	'N.A.'	$P_{(0)}$	1503	1954	1603	286
					$P_{(50)}$	2050	1972	2343	
					$P_{(100)}$	2480	2226	2362	
					$P_{(150)}$	2440	2831	2069	

TABLE 4.23. EFFECT OF JOINT APPLICATION OF NITROGEN AND POTASH ON GROUNDNUT (IRRIGATED)

State	Soil type	Centre	Year	Variety	Average yield for different combinations of N and K				C.D.
						$K_{(0)}$	$K_{(33\cdot6)}$		
Uttar Pradesh	Sandy loam	Groundnut Research Station, Mainpuri	1961	'T-28' (late)	$N_{(0)}$	1244	1267		196
					$N_{(11\cdot2)}$	1004	1313		
						$K_{(0)}$	$K_{(34\cdot0)}$	$K_{(67\cdot0)}$	
Andhra Pradesh	Red soil	Project Development and Demonstrations Farm, Yemmiganur	1961	'TMV-2'	$N_{(0)}$	1151	1180	1107	144
					$N_{(11\cdot0)}$	1236	980	1256	
					$N_{(22\cdot0)}$	1004	1199	1101	

TABLE 4.24. EFFECT OF JOINT APPLICATION OF PHOSPHORUS AND POTASH ON GROUNDNUT (IRRIGATED)

State	Soil type	Centre	Year	Variety	Average yield for different combinations of P and K				C.D.
						$P_{(0)}$	$P_{(34\cdot0)}$	$P_{(67\cdot0)}$	
Andhra Pradesh	Red soil	Project Development and Demonstrations Farm, Yemmiganur	1961	'TMV-2'	$K_{(0)}$	1241	1091	1057	144
					$K_{(34\cdot0)}$	1259	1006	1095	
					$K_{(67\cdot0)}$	1134	1154	1176	
						$P_{(23)}$	$P_{(34)}$	$P_{(45)}$	
	Red clay loam	Agricultural Research Station, Aliyar Nagar	1968	'TMV-2'	$K_{(23)}$	1818	1687	1570	112
					$K_{(34)}$	1624	1610	1530	
					$K_{(45)}$	1439	1728	1754	

TABLE 4.25. EFFECT OF JOINT APPLICATION OF NITROGEN AND PHOSPHORUS ON RAINFED GROUNDNUT

State	Soil type	Centre	Year	Variety	Average yield for different combinations of N and P				C.D.
1	2	3	4	5	6	7	8	9	10
						$N_{(0)}$	$N_{(20)}$	$N_{(40)}$	
Maharashtra	Black	Agricultural Research Station, Jalgaon	1971	'SB-XI'	$P_{(0)}$	470	657	486	229
					$P_{(40)}$	647	674	579	
					$P_{(80)}$	489	589	742	
						$N_{(0)}$	$N_{(11\cdot2)}$	$N_{(22\cdot4)}$	
Gujarat	Medium black	Agricultural Research Station, Kothara	1961	'AH-32'	$P_{(0)}$	1719	2159	1996	113
					$P_{(22\cdot8)}$	2099	2173	2104	
					$P_{(44\cdot8)}$	2360	2275	2058	

TABLE 4.25 (*Contd*)

1	2	3	4	5	6	7	8	9	10
						$N_{(0)}$	$N_{(11\cdot2)}$	$N_{(16\cdot8)}$	
Karnataka	Medium black	Agricultural Research Station, Saundatti	1965	'Erect type'	$P_{(0)}$	802	968	889	111
					$P_{(11\cdot2)}$	1034	959	856	
					$P_{(16\cdot8)}$	947	1001	980	
						$N_{(0)}$	$N_{(20)}$	$N_{(40)}$	
Maharashtra	Medium black	Agricultural College Farm, Parashari	1970-71	'SB-XI'	$P_{(0)}$	516	621	596	49
					$P_{(20)}$	594	684	559	
					$P_{(40)}$	610	640	639	
						$N_{(0)}$	$N_{(11\cdot2)}$	$N_{(22\cdot4)}$	
Maharashtra	Medium black	Oilseed Research Station, Latur	1966	'Karod-4-11'	$P_{(0)}$	438	506	464	67
					$P_{(22\cdot4)}$	485	430	459	
					$P_{(44\cdot8)}$	486	474	411	
						$N_{(0)}$	$N_{(11\cdot2)}$	$N_{(22\cdot4)}$	
Gujarat	Sandy	Agricultural Research Station, Talod	1962	'Samrala-1' (Punjab)	$P_{(0)}$	978	955	1223	231
					$P_{(28\cdot0)}$	923	1147	1005	
					$P_{(56\cdot0)}$	1210	1029	1028	
						$N_{(0)}$	$N_{(22\cdot4)}$	$N_{(44\cdot8)}$	
Andhra Pradesh	Sandy loam	Agricultural Research Institute, Rajendranagar, Hyderabad	1961	'Spanish improved'	$P_{(0)}$	1248	1603	1560	
					$P_{(22\cdot4)}$	1475	1588	1503	
					$P_{(44\cdot8)}$	1062	1404	1915	
						$N_{(0)}$	$N_{(22\cdot4)}$	$N_{(44\cdot8)}$	
Andhra Pradesh	Sandy loam	Agricultural Research Institute, Rajendranagar, Hyderabad	1963	'Spanish improved'	$P_{(0)}$	1039	1211	1182	
					$P_{(22\cdot4)}$	1313	1266	1218	
					$P_{(44\cdot8)}$	1338	1234	1227	

TABLE 4.26. EFFECT OF JOINT APPLICATION OF NITROGEN AND POTASH ON RAINFED GROUNDNUT

State	Soil type	Centre	Year	Variety	Average yield for different combinations of N and K			C.D.
						$K_{(0)}$	$K_{(28\cdot0)}$	$K_{(56\cdot0)}$	
Gujarat	Medium black	Central Experimental State, Junagarh	1962	'Pb-1'	$N_{(0)}$	1210	1052	1182	130
					$N_{(11\cdot2)}$	1011	1233	1215	
					$N_{(22\cdot4)}$	1205	1096	1005	
						$K_{(0)}$	$K_{(28\cdot0)}$	$K_{(56\cdot0)}$	
		Agricultural Research Station, Jamnagar	1964	'Pb-1'	$N_{(0)}$	1225	1095	1194	114
					$N_{(11\cdot2)}$	1174	1327	1208	
					$N_{(22\cdot4)}$	1254	1266	1340	
						$K_{(0)}$	$K_{(20)}$	$K_{(40)}$	
Madhya Pradesh	Black cotton	Agricultural College Farm, Indore	1969	'AC-12-24' 'TMV-2' 'Kh-61-240'	$N_{(0)}$	306	346	335	45
					$N_{(10)}$	497	540	578	
					$N_{(20)}$	562	612	614	
						$K_{(0)}$	$K_{(20)}$	$K_{(40)}$	
			1970	,,	$N_{(0)}$	606	667	633	72
					$N_{(10)}$	939	892	1044	
					$N_{(20)}$	733	739	939	
						$K_{(0)}$	$K_{(28\cdot0)}$	$K_{(56\cdot0)}$	
Punjab	Sandy loam	Oilseed Research Station, Samrala	1960	'C-145'	$N_{(0)}$	1015	1143	1603	329
					$N_{(28\cdot0)}$	1211	1148	1195	
						$K_{(0)}$	$K_{(22\cdot4)}$		
Madhya Pradesh	Sandy loam	Government Agricultural Research Station, Jhabua	1961	'AK-12-24' 'R-4' 'Spanish improved'	$N_{(0)}$	522	655		173
					$N_{(11\cdot2)}$	655	1116		

TABLE 4.27. EFFECT OF JOINT APPLICATION OF PHOSPHORUS AND POTASH ON RAINFED GROUNDNUT

State	Soil type	Centre	Year	Variety	Average yield for different combinations of P and K			C.D.
Andhra Pradesh	Black	Agricultural Research Station, Amravati	1964	'TMV-2'		$P_{(0)}$	$P_{(33\cdot6)}$	$P_{(67\cdot2)}$	32
					$K_{(0)}$	442	548	573	
					$K_{(33\cdot6)}$	501	467	566	
					$K_{(67\cdot2)}$	556	556	482	
Gujarat	Medium black	Central Experimental Station, Junagarh	1960	'Pb-1'		$P_{(0)}$	$P_{(28\cdot0)}$	$P_{(56\cdot0)}$	141
					$K_{(0)}$	1426	1471	1269	
					$K_{(28\cdot0)}$	1429	1340	1484	
					$K_{(56\cdot0)}$	1446	1326	1408	
Madhya Pradesh	Black cotton soil	Agricultural College Farm, Indore	1969, 1970	'AK-12-24' 'TMV-2' 'Kh-61-240'		$P_{(0)}$	$P_{(30)}$	$P_{(60)}$	157
					$K_{(0)}$	542	637	643	
					$K_{(20)}$	535	674	689	
					$K_{(40)}$	631	657	799	
Maharashtra	Medium black	Oilseed Research Station, Latur	1966	'Karod-4-11'		$P_{(0)}$	$P_{(22\cdot4)}$	$P_{(44\cdot8)}$	67
					$K_{(0)}$	515	490	431	
					$K_{(44\cdot8)}$	465	468	444	
					$K_{(89\cdot6)}$	428	415	497	
Gujarat	Sandy	Agricultural Research Station, Talod	1961	'Samrala-1' (Punjab)		$P_{(0)}$	$P_{(28\cdot0)}$	$P_{(56\cdot0)}$	253
					$K_{(0)}$	968	1301	1281	
					$K_{(28\cdot0)}$	1250	1029	1243	
					$K_{(56\cdot0)}$	1210	1423	1083	
Madhya Pradesh	Sandy loam	Government Agricultural Research Station, Jhabua	1961	'AK-12-24' 'R-4' 'Spanish improved'		$P_{(0)}$	$P_{(22\cdot4)}$		173
					$K_{(0)}$	536	677		
					$K_{(22\cdot4)}$	670	1065		

Of the various interaction effects observed, only the joint application of N and P was found beneficial compared to the responses to their individual applications taken together at Bhind Agriculture Farm (Madhya Pradesh) and Pantnagar Agriculture Farm (Uttar Pradesh), both in sandy loam soil under irrigated conditions and at Jalgaon Research Station (Maharashtra) in black soil, Kothara Research Station (Gujarat) in medium black soil and Agriculture Research Institute, Hyderabad (Andhra Pradesh) in sandy loam soil under rainfed conditions. The other interactions namely N × K and P × K did not show substantial positive effect at any centre both in irrigated as well as unirrigated conditions. The results of experiments on state agriculture farms and research stations, therefore, showed that responses to the application of the three nutrients were more or less additive in most of the soils, and there was little interaction except in case of N × P.

Experiments with irrigation treatments on groundnut

Experiments with different irrigation treatments were conducted at various Agricultural Research Stations and Farms to study their effect on the yield of groundnut. The results are given in Table 4.28. Beneficial effect of irrigation given at 75 per cent depletion of available soil moisture at Rahuri (Maharashtra) and with two irrigations at Kholwad (Gujarat) located in black soil was observed, the response being about 300—500 kg/ha. In medium black soil, two irrigations appeared optimum giving a high response at Junagarh, Jamnagar and Kim (Gujarat) and Akola (Maharashtra). At Sultanpur (Rajasthan) in sandy loam soil, pre-sowing irrigation and at flowering gave a response of more than 400 kg/ha while at Sriganganagar two irrigations at 30 and 70 days after sowing gave a response of about 460 kg/ha. At Bhawanisagar (Tamil Nadu) in sandy loam soil the crop suffered considerably when irrigation was delayed beyond 40 per cent depletion of available soil moisture being the lowest when irrigation was given at 80 per cent depletion of available soil moisture. The best yield was obtained with irrigation at 40 per cent depletion of available moisture. At Garikapadu (Andhra Pradesh) in red soil, the best yield was obtained with irrigation at 50 per cent depletion of available soil moisture and any delay in irrigation with further depletion in soil moisture resulted in significant decline in yield.

It thus appears that two irrigations given at appropriate stage of crop growth or irrigation at 40—50 per cent depletion of available soil moisture proved highly beneficial for groundnut, while irrigation at a less or more frequent intervals generally showed adverse effect on the yield of groundnut.

TABLE 4.28, EFFECT OF IRRIGATION TREATMENTS ON YIELD OF GROUNDNUT IN EXPERIMENTS AT RESEARCH STATIONS

State	Soil type	Centre	Variety	Year	Treatments	Yield (kg/ha)	C.D. (5%)
1	2	3	4	5	6	7	8
Maha-rashtra	Deep black	Rahuri	'SB-11 (medium)	1970-71	I_1 (At 25 per cent depletion of available moisture)	1873	232
					I_2 (At 50 per cent depletion of available moisture)	1864	
					I_3 (At 75 per cent depletion of available moisture)	2133	
Gujarat	Black	Kholwad	'Punjab-1'	1965	I_0 (Control)	818	193
					I_1 (One irrigation)	913	
					I_2 (Two irrigations)	1116	
	Medium black	Junagarh	'AH-334'	1965	I_0 (Control)	233	211
					I_1 (Irrigated at 60 per cent available moisture — 3 irrigations)	1640	
					I_2 (Irrigated at 40 per cent available moisture — 2 irrigations)	1521	
					I_3 (Irrigated at 20 per cent available moisture — 1 irrigation)	688	
					I_4 (Irrigation at maximum peg formation)	891	
	Medium black	Jamnagar	'Punjab-1'	1963-65	I_0 (Control)	944	
					I_1 (One irrigation)	1003	
					I_2 (Two irrigations)	1409	
	Medium black	Kim	'Punjab-1'	1965	I_0 (Control)	623	366
					I_1 (One irrigation)	1054	
					I_2 (Two irrigations)	1351	

TABLE 4.28 (*Contd*)

1	2	3	4	5	6	7	8
Gujarat	Medium black	Umrala	'Samvalu-1' 'Punjab-1'	1963-65	I_0 (Control) I_1 (One irrigation) I_2 (Two irrigations)	1297 1460 1568	156
Mahara-shtra	Medium black	Akola	'AK-12-24'	1963-64	I_0 (Control) I_1 (Irrigation 35 days after sowing) I_2 (Irrigation 70 days after sowing) I_3 (Irrigation 35 and 70 days after sowing) I_4 (Irrigation as and when required)	861 926 837 1032 775	160
	Medium black	Akola	'AK-12-24'	1967-69	I_0 (Control) I_1 (Irrigation 35 days after sowing) I_2 (Irrigation 70 days after sowing) I_3 (Irrigation 35 and 70 days after sowing) I_4 (Irrigation after every 21 days) I_5 (Irrigation as and when required)	1393 1407 1464 1370 1450 1324	133
Rajasthan	Sandy loam	Sultanpur	'RS-1'	1964	I_1 (Pre-sowing irrigation) I_2 (I_1 + irrigation after 30 days) I_3 (I_1 + irrigation at flowering) I_4 (I_1 + irrigation after 30 days + irrigation at flowering)	1277 1283 1692 1746	296
		Srigan-ganagar	'AK-12-24'	1965	I_0 (Control) I_1 (Irrigation 30 days after sowing) I_2 (Irrigation 70 days after sowing) I_3 (Two irrigations 30 and 70 days after sowing)	856 718 1114 1312	314
Andhra Pradesh	Sandy loam	Karim-nagar	As per treat. (12 varieties)	1970	I_0 (Control) I_1 (5 irrigations)	584 769	135

TABLE 4.28 (*Contd*)

1	2	3	4	5	6	7	8
Tamil Nadu	Sandy loam	Bhavani-sagar	'TMV-2'	1968	I_1 Farmer's method of giving irrigation once in 7 days)	4464	458
					I_2 (40 per cent depletion of available moisture)	4490	
					I_3 (60 per cent depletion of available moisture)	4299	
					I_4 (80 per cent depletion of available moisture)	3793	
	Red sandy loam	Tindi-vanam	'TMV-2'	1963-64	I_1 (Irrigation every 7 days)	1721	223
					I_2 (Irrigation every 10 days)	1953	
					I_3 (Irrigation every 12 days)	1850	
					I_4 (Irrigation every 15 days)	1515	
Andhra Pradesh	Red sandy loam	Garika-padu	As per treat. (7 varieties)	1966	I_1 (2 irrigations)	842	
					I_2 (4 irrigations)	915	
					I_3 (6 irrigations)	885	
Tamil Nadu	Red soil	Bhavani-sagar	'TMV-2'	1965	I_1 (Irrigation every 15 days)	1341	159
					I_2 (Irrigation every 10 days)	1165	
Andhra Pradesh	Red Soil	Garika-padu	'AH-6279'	1971	I_1 (At 75 per cent depletion of moisture)	1188	293
					I_2 (At 50 per cent depletion of moisture)	1944	
					I_3 (At 50 per cent depletion of moisture in P_1 and 75 per cent depletion in P_2, P_3)	1344	
					I_4 (At 50 per cent depletion of moisture in P_2 and 75 per cent depletion in P_1, P_3)	1590	
					I_5 (At 50 per cent depletion of moisture in P_3 and 75 per cent depletion in P_1, P_2)	1258	
					I_6 (At 75 per cent depletion of moisture in P_1 and 75 per cent depletion in P_2, P_3)	1615	

TABLE 4.28 (*Contd*)

1	2	3	4	5	6	7	8
					I_7 (At 75 per cent depletion of moisture in P_2 and 50 per cent depletion in P_1, P_3)	1441	
					I_8 (At 75 per cent depletion of moisture in P_3 and 50 per cent depletion in P_1, P_2)	1266	
					Where P_1 = up to flowering, P_2 = flowering to pod formation P_3 = pod formation to ripening		
Tamil Nadu	Red gravelly loam	Bhavani-sagar	'TMV-2'	1969	I_1 (Farmer's method of giving irrigation once in 7 days)	3386	169
					I_2 (40 per cent depletion of available moisture)	3975	
					I_3 (60 per cent depletion of available moisture)	3905	
					I_4 (80 per cent depletion of available moisture)	3388	

SUMMARY AND CONCLUSIONS

The groundnut (*Arachis hypogaea* L.) is the most important oilseed crop in India. It occupies two-fifths of the world's acreage and the area has steadily increased from less than one lakh hectares in the beginning of the century to more than 73 lakhs in 1975-76. However its yields have remained virtually stagnant.

Gujarat, Karnataka, Tamil Nadu and Andhra Pradesh are the four largest groundnut-producing states in India, which contribute more than three-fourths of the entire production in the country.

Most of the groundnut crop in India is rainfed though about 8 per cent area is irrigated. Most of the crop is grown in *kharif* but the yields are higher in *rabi*. The scope for increasing groundnut yields is very large.

Groundnut has hitherto been considered a crop of poor sandy soils and it has not been much fertilized or irrigated. In fact the technology of groundnut production under good management and with fertilizers and other imputs is rarely practised.

The most important soils for groundnut production are red sandy soils, sandy loam, alluvial, coastal alluvial, mixed red and black soils and some laterite soils. It is also grown to a significant extent on medium black soils. The climatic zones 3 and 4 with short wet seasons and long dry seasons and semi-arid to arid climate and with 20 to 40 and 40 to 60 per cent moisture deficit are the important groundnut-growing regions in the country. Sorghum, millet, cotton and pulses are other common crops of these regions. A few typical important groundnut soils of India are described in this bulletin.

The role of fertilizers in increasing yields of groundnut has gained recognition only in recent years. The yield responses to fertilizer application at experimental stations have been rather low but the responses on cultivators' fields have shown spectacular differences.

It is not only the responses to N, P and K but the responses to micronutrients, such as sulphur and calcium have also been observed. There is an overwhelming evidence of significant responses to zinc, boron and other micronutrients particularly in the sandy soils of Punjab and red sandy loams in Tamil Nadu, Karnataka and Gujarat.

In the last two decades large number of trials on cultivators' fields have been done on this crop. This bulletin discusses the results of experiments conducted on cultivators' fields and leading experimental stations. These data have been obtained from the ICAR reports of the Co-ordinated Schemes and Compendia Volumes of National Index of Agricultural Field Experiments.

The results of experiments in cultivators' fields reported here pertain to the period 1958-59 to 1976-77. The results have been presented in different series according to the treatments and design adopted.

Responses to ferilizers in different soils

In the first series of experiments conducted during 1958-61, it was observed that application of N, P and K was beneficial in most of the soils, the response being particularly marked in the red and yellow soils and coastal alluvial soils. The average response to $N_{22\cdot4}P_{33\cdot6}K_{33\cdot6}$ was 531 kg/ha or 5.9 kg per kg nutrient. The results of second series of experiments conducted during 1962-66 showed that under irrigated conditions groundnut showed a good response to fertilizers in red loam and coastal alluvial soils, the response ratio for combined applications of $N_{30}P_{30}$ was 13.8 kg per kg nutrient in red loamy soil and 7.1 kg in alluvial soils. In 170 experiments it was observed that $N_{30}P_{60}$ combination gave a response of 6.3 kg per kg nutrient in all the soils. $N_{15}P_{30}K_{30}$ gave an average response of 7.9 kg per kg nutrient. Under unirrigated conditions also, combined application of N and P showed a fairly high response. Response of more than 10 kg per kg nutrient in red and yellow coastal alluvial and laterite soils was obtained with $N_{30}P_{20}$. The average response in 436 experiments was 7.9 kg per kg nutrient.

Fertilizers and varietal interactions

In the third series (1967-70), the effect of fertilizers using high yielding/ improved varieties of groundnut was studied. The results of 243 experiments show that combined applications of N and P at 30 kg each gave higher response in improved varieties than the locals. A ratio of 16.5 kg per kg nutrient was obtained in coastal alluvial soil of Pondicherry. The variety 'SB-11' gave a response of more than 11 kg in medium black soil. Under rainfed conditions the varieties 'Punjab No. 1' and 'T-28' showed a high response to joint application of N and P in red and yellow soil, the response to $N_{30}P_{20}$ was 28.4 and 16.5 kg per kg nutrient respectively. The response of other varieties was comparatively moderate. It may however be mentioned that the differences between different varieties were not very significant.

Effect of combined application of N and P at higher levels was studied in the fourth series of trials (1970-72). The variety 'AK-12-24' showed a good response in red soil in Orissa while 'TMV-2' showed a high response to combined application of N and P only in mixed red and black soil in Kurnool (Andhra Pradesh).

Responses to different levels of fertilizer applications

In the next series of trials designed to study response of groundnut

to closely spaced levels of N and P, the varieties 'TMV-2' and 'TMV-7' showed a good performance in red soil and mixed red and black soils. The response ratio was, however, moderate.

Under irrigated conditions application of nitrogen gave the best results in coastal alluvial soil followed by red soil. The response to phosphorus was the highest in coastal alluvial soil followed by alluvial and red soils whereas their joint application proved more beneficial in red loam soil followed by coastal alluvial soil. Combined application of N, P and K showed a good response in red and coastal alluvial soils.

Under rainfed conditions the application of nitrogen proved beneficial in red and yellow, coastal alluvial and red loam soils and that of phosphorus in red and yellow soils whereas their joint application showed a good response in coastal alluvial and laterite soils. Combined application of N, P and K was better than that of N and P in deep black and red and yellow soils.

Economics of fertilizer-use

On the economics of use of fertilizers on groundnut, the results showed that under irrigated conditions, the optimum doses of N and P varied between 20–30 and 40–60 kg/ha respectively, the profit varying between 200–800 per cent of the investment on fertilizer taking the price of groundnut at Rs 2 per kg. Under rainfed conditions the optimum doses of N and P generally varied between 25–30 and 20–40 kg/ha respectively, the profit varying between 140–860 per cent.

Comparison of sources of N and P

No difference was observed in the uptake of nitrogen by groundnut when different sources of nitrogen were tried except in soils where sulphur was deficient. In the latter case ammonium sulphate proved better. Similarly, different phosphorus carriers were also found equally effective.

Substitution of other oilseed crops

The results of experiments conducted to study substitution of other oilseeds by groundnut showed that the income accruing from groundnut was higher than other oilseeds in most of the areas even with the present yield levels.

Irrigation

The results of experiments conducted at research stations to study effect of irrigation given at different moisture depletion levels showed that irrigation was beneficial at 75 per cent depletion at Rahuri (Maharashtra) and with two irrigations at Kholwad (Gujarat) in black soil. Pre-sowing irrigation and again at flowering gave a response of 400 kg/ha at Sultanpur (Rajasthan)

in sandy loam soil while two irrigations at 30 and 70 days after sowing gave a response of 460 kg/ha at Sriganganagar. In red soil of Andhra Pradesh the best yield was obtained with irrigation at 50 per cent depletion of available soil moisture.

To sum-up

Groundnut is generally grown in light-textured soils mostly on red sandy, red loamy, alluvial and coastal alluvial soils. Mixed black and red and medium black soils also have considerable area under this crop.

Groundnut crop is fairly responsive to the application of moderate doses of fertilizers 20—30 kg N, 40—60 kg P_2O_5 and 20—40 kg K_2O in all the major soils.

The remunerative responses are obtained under irrigated as well as rainfed conditions.

Some varieties are more responsive than others but these differences are not of same magnitude as one finds in dwarf varieties of cereals. Really high-yielding and highly fertilizer-responsive varieties have not yet been developed.

The groundnut crop benefits from balanced use of N, P and K. The responses to zinc, boron, calcium and sulphur are also not uncommon. There is no doubt that simply by balanced use of fertilizers alone, groundnut production in India can be increased considerably.

REFERENCES

Ali Mohammed, Zafar Alam and Khanna, Kidar Lal. 1933. Studies on germination and growth in groundnut (*Arachis hypogaea* Linn.) *Agriculture Live-Stk. India* 3(2): 91-115.

Bledsoe, R.W. and Harris, H.C. 1950. Influence of mineral deficiency on vegetative growth, flower and fruit production and mineral composition of the peanut plant. *Pl. Physiol.* **25**: 63-77.

Bledsoe, R.W., Comar, C.L. and Harris, H.C. 1949. Absorption of radioactive calcium by the peanut fruit. *Soil Sci.* **109**: 329-330.

Brady, N.C. 1947. The effect of period of calcium supply and mobility of calcium in the plant on peanut fruit filling. *Proc. Soil Sci. Soc.* **12**: 336-341.

Brady, N.C. and Colwell, W.E. 1945. Yield and quality of large-seeded type peanuts as affected by potassium and certain combinations of potassium, magnesium and calcium. *J. Am. Soc. Agron.* **37**: 429-442.

Brady, N.C., Reed, J.F. and Colwell, W.E. 1948. The effect of certain mineral elements on peanut fruit filling. *J. Am. Soc. Agron.* **40**: 155-167.

Burkhart, Leland and Collins, E.R. 1941. Mineral nutrients in peanut plant growth. *Proc. Soil. Sci. Soc. Am.* **6**: 272-280.

Chopra, S.L. and Kanwar, J.S. 1966. Availability of sulphur in the sandy-loam soils of Ludhiana. *Indian J. agric. Sci.* **36**(5): 278-284.

Collins, E.R. and Morris, H.D. 1942. Soil fertility studies with peanut. *N. G. Agric. Exp. Stn Bull.* **330.**

Colwell, W.E. and Brady, N.C. 1945. The effect of calcium on certain characteristics of peanut fruit. *J. Am. Soc. Agron.* **37**: 696-708.

Colwell, W.E. and Brady, N.C. 1945. The effect of calcium on yield and quality of large-seeded type peanuts. *J. Am. Soc. Agron.* **37**: 413-428.

Dalal, J. L. 1950 Effect of manuring on groundnut. *Punjab Fmr* **2**: 4-6.

Dalal, J.L., Kanwar, J.S. and Saini, J.S. 1963. Investigations of soil sulphur. II. Gypsum as a fertilizer of groundnut in the Punjab. *Indian J. agric. Sci.* 33(3): 199-204.

Fourrier, P. and Prevot, P. 1958. Influence sur l 'arachide de la fumure minerale et du trempage des graines. *Oleagineux.* **13**: 805-809.

Harris, Henry C. 1949. The effect on the growth of peanuts of nutrient deficiencies in the root and pegging zone. *Pl. Physiol.* **24**: 150-161.

India, Ministry of Food and Agriculture. 1953. *Report of the Expert Committee on Manures and Fertilizers.* Delhi, Manager of Publications.

John, C.M., Seshadri, C.R., Bhavani Shankar Rao, M. and Krishna Marar, M.M. 1948. Manurial experiment on groundnut. *Madras agric. J.* **35**(5): 49-58.

Jordan, H.V. and Ensminger, L.E. 1958. Role of sulphur in soil fertility. *Adv. Agron.* **10**: 407-432.

Kanwar, J.S. 1963. Investigation on sulphur in soils. I. Sulphur deficiency in groundnut soils of Samrala (Ludhiana). *Indian J. agric. Sci.* **33**(3):196-198.

Kanwar, J.S. 1972 Cropping patterns, scope and concept. *In Proceedings of the Symposium on Cropping Patterns in India, New Delhi*, January 27-31, 1968. 10-38.

Kamwar, J.S. and Mohan, S. 1964. Dsitribution on forms of sulphur in Punjab soils. Symposium on fertility of Indian soil. *Bull. natn. Inst. Sci. India.* 20:31.

Krishnan, A. and Mukhtar Singh. 1972. Soil-climatic zones in relation to cropping patterns. *In Proceedings of the Symposium on Cropping Patterns in India, New Delhi*, January 27-31, 1968. pp. 172-185.

Kulkarni, G.N. 1967. Studies on few climatic factors in relation to groundnut at Raichur. *Indian J. Agron.* **12**(3): 298-302.

Lin, H. and Chen, C.C. 1967. Studies on the yield components of the groundnut. I. Analysis of yield components in varieties of different types. *J. agric. Ass. China* **57**: 35-48.

Mann, H.B. 1935. Relation of soil treatment to the nodulation of peanuts. *Soil Sci.* **40**: 423-437.

Mehlich, A. and Colwell. W.E. 1946. Absorption of Ca by peanuts from kaolin and bentonite at varying levels of calcium. *Soil Sci.* **61**: 369-374.

Mehlich, A. and Reed, J.F. 1947. The influence of type of colloid and degree of calcium saturation on fruit characteristics of peanuts. *Proc. Soil. Sci. Soc. Am.* **11**: 201-205.

Mehring, A.L. and Bennett, G.A. 1950. Sulphur in fertilizers, manures and soil amendments. *Soil Sci.* **70**: 73-81.

Muthuswamy, T.D. and Sundararajan. 1973. Effect of boron on bunch groundnut. *Madras agric. J.* **60**: 403.

Narasinga Rao, U. 1936. A note on preliminary physiological observations on the groundnut. *Proc. Ass. econ. Biol. Coimbatore.* 1-6.

Nijhawan, H.L. 1962. Effect of application of manures on the composition of groundnut crop. 1. Change in the important constituent of groundnut seed effecting its quality in trade. *Indian Oilseeds J.* **6**(2): 123-129.

Nijhawan H.L. 1962. Response of groundnut to fertilizers. *Indian Oilseeds J.* **6**(3): 185-192.

Panse, V.G., Dandawate, M.D. and Bokil, S.D. 1947. Summary of past experimental work on wheat, millets, oilseeds and pulses. Appendix II (*a*) *In Report on soil fertility investigations in India with special reference to manuring* by A.B. Stewart. New Delhi, ICAR.

Pathak, G.N. and Verma, G. 1964. Studies on the cultural and manurial requirements of groundnut in Uttar Pradesh. *Indian Oilseeds J.* **8**(2): 167-174.

Prevot, P. and Biliaz, R. 1962. Agro-physiological investigations on the problem of drought resistance in the groundnut. *Oleagineux* **17**: 911-917.

Reed, J. Fielding and Brady, N.C. 1948. Time and method of supplying calcium as factors affecting production of peanuts. *J. Am. Soc. Agron.* **40**: 980-996.

Rogers, H.T. 1948. Liming of peanuts in relation to exchangeable soil calcium and effect on yield quality and uptake of calcium and potassium. *J. Am. Soc. Agron.* **40**:15-31.

Seshadri, C.R. 1961. *Groundnut, a monograph.* Indian Central Oilseeds Committee, Hyderabad. 143 pp.

Seshadri, C.R., Bhavanishankar Rao and Muhamed, S. Varisai. 1958. Studies on root development in groundnut. *Indian J. agric. Sci.* **28**(2): 211-215.

Shibuya, T. 1935. Morphological and physiological studies on the fructification of peanut. *Mem. Fac. Sci. Agric. Taihoku imp. Univ.* **17**(1):1-120.

Shibuya, T. and Susuki. 1954. Studies on the formation of unfilled fruit in peanut. *Proc. Crop. Sci. Soc. Japan* **23**:87-91.

Sindagi, S.S. 1964. Effect of rainfall distribution on the yield of groundnut in Raichur tract of Mysore State. *Indian Oilseeds J.* **8**(1): 41-43.

Singh, M.P. and Lala Amarnath. 1958. Cultural and manurial studies in groundnut and castor. *Indian Oilseeds J.***2**(2): 82-88.

Sekhon, G.S., Arora, C.L., Soni, S.K., and Brar, M.S. 1978. Nutrient indexing of peanut in some selected villages of the Punjab. *Soil Sci. Pl. Analysis.* **9**(5).

Saini, J.S., Tripathi, M.P., Dwivedi, R.S. and Randhawa, M.S. 1975. Effect of micro nutrients on the yield and quality of groundnut. *Punjab J. Res.* **12**(3): 224-27.

Takkar, P.N., Mann, M.S. and Randhawa, N.S. 1975. Effect of direct and residual available zinc on yield, zinc concentration and its uptake by wheat and groundnut crops. *J. Indian Soc. Soil Sci.* **23**(1): 91-95.

Vaidyanathan, M. 1934. General review of the results of past experiments with fertilizers in India. *In Analysis of Manurial Experiments in India.* Vols 1-3. New Delhi, ICAR.

Venkata Rao, B.V. and Govinda Rajan, S.V. 1954. Effect of lime and phosphate on yield and pod filling of groundnuts. *Mysore agric. J.* **30**(4): 277-279.

Venkata Rao, B.V. and Govinda Rajan, S.V. 1960. Manuring of groundnut in Mysore—a review of experiments of the past thirty years. *Indian Oilseeds J.* **4**(4): 234-238.

Wiersum, L.K. 1951. Water transport in the xylem as related to calcium uptake by groundnuts (*Arcahis hypogaea L.*). *Pl. Soil.* **3**:160-169.

Yadahalli, Y.H., Raddar, G.D. and Patil, S.V. 1970. Response of groundnut to major and minor elements in red sandy soil of Badami. (Unpublished).