MAXIMIZING GROUNDNUT PRODUCTION

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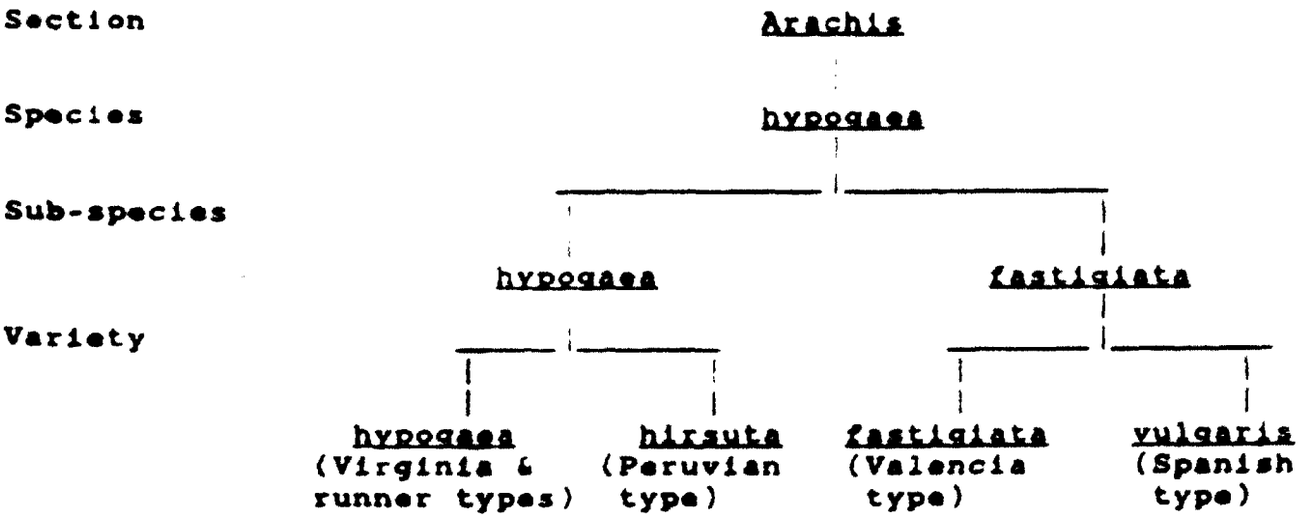
I. INTRODUCTION

1. Origin and botanical types:

The cultivated groundnut (*Arachis hypogaea* L.) probably originated in Bolivia or Argentina at the base of the Andes (Krapovickas 1968). Groundnut belongs to the family Fabaceae of the tribe Aeschynomeneae. The cultivated groundnut belongs to the section *Arachis* and series amphiploides (Gregory *et al.* 1973). The species *A. hypogaea*, consists of two sub-species, ssp. *hypogaea* and *fastigiata*. Each sub-species contains two botanical varieties. The section, species, sub-species, and varieties are:



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The morphological characteristics of the three major botanical varieties are given in Table 1.

The virginia groundnut varieties have high yield potential, but they require a longer season to mature. Spanish varieties are shorter in duration and tend to be more determinate.

2. Area, production and productivity of groundnut:

It is estimated (Table 2) that the world production was 20.1 million tons of groundnut pods from 18.7 million hectares with an average productivity 1077 kg ha^{-1} (FAO 1985). The maximum groundnut production areas are in India and China. The average yield in India is 862 kg ha^{-1} which is lower compared to that in China, Indonesia, Burma, the other Asian countries. The main reason for low productivity of groundnut in India is that 80% of the groundnut area is rainfed, with low inputs and with sowing starting in June or July after the onset of the South-West rains. Groundnut grown during postrainy season (November to April) is irrigated in Andhra Pradesh, Tamil Nadu, Maharashtra, Karnataka and Gujrat.

Groundnut in Andhra Pradesh is mainly cultivated on alfisols (red soil) with predominantly virginia runner varieties (50%) and the remaining under spanish, virginia and valencia bunch varieties (Reddy 1983). Groundnut is also cultivated in vertisols (black soil) in Gujarat, Tamil Nadu, Maharashtra and Andhra Pradesh. These soils are mostly low in organic matter content and available phosphorus with poor water retention capacity.

The objective of the present article is to discuss the factors which could help in maximization of groundnut yield based on the available literature and on experiences of ICRISAT groundnut scientists and the authors.

The main requirements for maximization of groundnut production are timely preparation of the seedbed and proper method of sowing, an adequate and balanced nutrient supply, use of good quality seed of adapted high yielding cultivars, supplemental irrigation with proper drainage, timely control of weeds, diseases, and pests, and harvesting at optimum maturity.

II. PRODUCTION PRACTICES

1. Preparation of land:

Groundnut requires fine tilth and a seedbed free from weeds. Therefore, one deep plowing (18-20 cm) followed by 2-3 disk harrowings may be necessary.

2. Preparing a broadbed-and-furrow:

The broadbed-and-furrow (BBF) system has an advantage over flat planting in prevention of runoff and draining of excess surface water, thus providing increased root aeration for plant growth. The BBF system is easier to hand weed, with less damage to pegs, and easier to conduct mechanical harvesting operations or for manual lifting. The groundnut grown on the broadbed-and-furrow system are more vigorous, have large leaves and dark green foliage, good nodulation, and yields higher than those flat planted (Amin et al. 1987). The broadbed-and-furrows can be

prepared by a bullock drawn ridger or tractor drawn implements. Raised beds (1.2 m wide and 15 cm high) are prepared with two furrows of 30 cm width on either side. The total width occupied by each broadbed-and-furrow would be 1.5 m. Such a bed (Fig.1) accommodates four rows of groundnut (30 cm between rows). The broadbed-and- furrows are formed across the slope with a grade of 0.6 to 0.8% and the furrows should lead to a common drainage system.

3. Application of manures and fertilizers:

The rate of fertilization should be based on soil tests and targetted yield levels. Adequate levels of nitrogen, phosphorus, potassium, sulfur, calcium, iron, zinc, and magnesium are essential for high yields. Application of organic manure (farm yard manure) along with fertilizers is essential to meet the nutritional requirements of groundnut. Farm yard manure 20 tons per hectare could be applied a month before planting and thoroughly mixed in the soil. Chicken manure is another good source of organic matter. It may be applied 10 to 12 tons ha^{-1}. The chicken manure contain approximately 1.5% N, 2.0% P and 1.7% K. Beside this 10 kg N and 17 kg P per hectare could be applied as a basal dose before sowing as ammonium sulphate and single super phosphate. The application of single super phosphate is advantageous as it contains 7% phosphorus, 19.5% calcium and 12.5% sulfur, these nutrients are usually required for high yield and good kernel quality in groundnut.

Application of zinc is essential in the areas where its deficiency has been identified, especially in the rice belts viz Visakhapatnam, and Krishna districts and parts of Guntur and Nellore districts in Andhra Pradesh. The deficiency symptoms for the essential nutrients in groundnuts are described in Table 3.

4. Sowing:

a) Time of sowing: Usually the rainy season groundnut sowing starts with the onset of the rains. In early planting to obtain optimum soil moisture and ensure good germination a presowing irrigation can be provided or the seed is planted in dry soil followed by a sprinkler or perfo sprayer irrigation. Research carried out by the AICORPO in India and at ICRISAT Center have shown that the advancement of sowing by "pre-monsoon planting", after one presowing irrigation, increased the yield significantly (Yadava 1985). During postrainy season sowing in November or later with an early maturing cultivar give higher yields (Sankara Reddi 1988).

b) Selection of seed: Bold and well filled pods are to be shelled by hand or a decorticator. Shelling should be completed just a few days before sowing to maintain the viability of the kernels. It was observed that under rainfed conditions plants from bold-kernels were superior to plants from smaller kernels in terms of rate of emergence, number of successful seedlings, number of primary branches, number of leaves, dry weight of roots and shoots, total dry matter and pod yield (Dharamlingam and Ramakrishna 1981). However, use of graded uniform medium size seeds were also useful for early germination.

c) Seed rate and spacing: The seed rate depends upon growth habit of the variety, the weight of 100 seeds, the desired plant population, and the viability of the seed lot. The common spacing recommended for spanish bunch varieties is 30 x 10 cm with a plant population 330,000 ha^{-1}. In case of semispreading and spreading varieties an optimum plant population of 220,000 ha^{-1} is recommended (30x15 cm or 40x10). It is necessary to sow 20% more seed to ensure a full plant stand. However, any excess seedlings should be removed within 15 days after germination.

d) Seed treatment: To control pathogens which cause seed and seedling diseases, it is necessary to treat the seed before planting with thiram @ 3 g kg^{-1} seed or carbendazim (Bavistin®) @ 2 g kg^{-1} seed

e) Application of carbofuran (Furadan®): The application of carbofuran granules with the seed (40 kg ha^{-1}) in the seed furrow is useful to control termites, white grubs and leafminers during early stages of crop growth. It was observed during 1987 rainy season trainee experiments at ICRISAT that the plots which were treated with carbofuran at the time of soving were free from leafminers at the early stage of crop growth. Therefore, where these pests are a problem, an application of carbofuran at the time of sowing may be considered.

f) Sowing: It is necessary to sow the seed uniformly 5-6 cm deep and compact the soil below and around the seed to conserve soil moisture for rapid germination. Sowing with a seed drill having press wheels will ensure uniform depth and good soil-seed

contact for rapid and uniform seedling emergence. The use of drills without compaction wheels or hand sown plots should be compacted by using a weighted roller or by walking on each row.

5. Weed control

Maximum weed competition usually occurs during the first 15 to 45 days of groundnut growth. Therefore, it is necessary to keep the crop weed free during this period. Two or three manual weedings with a Khurpi is often required. When wide row spacing is adapted a wheel hoe could be used. Disturbance of the soil near the plants after 45 days or after the peg formation stage results in yield loss due to peg damage (Yadava 1985).

Application of herbicides, listed in Table 4, could control the early weeds. It is necessary to uniformly spray the herbicide on the soil followed by sprinkler irrigation, if rain fails. The herbicide application could control the early weeds and reduce the number of manual weedings. The mid to late season weeds when left in the plot could cause yield losses and also interfere with harvest operations. Therefore, it is recommended that late weeds be carefully removed by hand pulling periodically without damaging the pegs and the pods.

6. Gypsum application

The calcium present in the podding zone (7-9 cm depth of soil) is absorbed directly by the developing pods (Burkhart and Collins 1942). Gypsum is an inexpensive source of calcium (19-24%) and sulfur (15-18.6%). The critical limits of calcium and

sulfur in soils are 2 meq/100 g of soil and 10 ppm respectively. If the soil tests have indicated low values of these two elements, then the application of gypsum would be beneficial. Gypsum is applied at the early pegging stage (40-45 days after germination in rainy season, and 55-60 days in postrainy season). Finely powdered gypsum @ 300 to 500 kg ha^{-1} should be incorporated into the soil as close to the plants as possible. The responses to gypsum application under rainfed conditions are often erratic due to applied gypsum lying on the soil surface without reaching the pod zone and/or the drying of soil in the pod zone. Therefore, an irrigation is recommended when rain fails to ensure utilization of applied gypsum.

7. Irrigation

Groundnut requires moist conditions in the pod zone from pegging to maturity without becoming water logged. Water deficiency during crop growth leads to the following consequences (Boote *et al*. 1982):

i) Reduces dry matter production of vegetative components as well as the crop growth rate.
ii) Leaves are fewer and smaller in size with compact cells and short stems.
iii) Deficiency during mid season of crop growth delays the period of rapid pod development and reduces yield.
iv) Water deficiency in the soil surface during pegging and pod development reduces pod number and pod uptake of calcium.

v) A water deficit in the fruiting zone results in unfilled pods (pops), less calcium in the hull, and seed with a hollow heart.

vi) Finally, water dificiency reduces groundnut seed quality, the shelling percentage, number of mature pods, germination per cent of seed, and total yield.

The optimum water management scheme in groundnut is to schedule sprinkler irrigations to maintain a less than 50% soil water depletion (SWD) (or a soil water potential above -0.6 bars) in the top 30 cm of soil during early growth stages of crop and irrigation at 25% SWD (or soil water potential above -0.25 to -0.5 bars) during pegging, pod formation and kernel development stages (Boote et al. 1982).

To maximize groundnut yield, a sprinkler irrigation system is superior to flooding or furrow irrigation. Sprinklers can be adjusted to run for specific periods to keep the pod zone moist and avoid water stagnation in the field.

A general schedule for irrigation during the rainy season would be at intervals of 10 to 15 days from the initiation of flowering to pod filling to keep the soil at 25% SWD, depending on frequency and amounts of rainfall. It may be sufficient to run the sprinkler 3 to 4 hrs per irrigation or provide 3-5 cm of water per application. The podding zone should not be water logged. The broadbed-and-furrow system helps to assure more aeration in the pod zone under rainfed as well as irrigated conditions. The last irrigation should be about 10 days before

harvesting depending on the soil type. This will avoid water stress at maturity, reduces the chance of yellow mold (Aspergillus flavus) infection and facilitate in digging.

8. Plant Protection Measures

A. Diseases:

A number of soil and seed borne fungal and viral diseases infest groundnut. The most severe diseases are rust (Puccinia arachidis) and late leaf spot (Phaeoisariopsis personata). These diseases can be effectively controlled with a spray of 0.15% chlorothalonil (Subrahmanyam et al. 1984), starting from the 30th day after germination and continuing at 10 to 15 days interval for up to 90 days. The other chemicals which are effective to control foliar diseases are carbendazim (0.1%) sprayed at 10 to 15 days interval (Amin et al. 1987). The spraying schedule can be adjusted depending on the appearance of disease symptoms and weather conditions. Under cloudy and humid conditions more frequent spraying is required. Therefore, regular monitoring of the disease incidence provide effective disease control and may reduce the cost of control measures.

It is advisable to follow a recommended crop rotation to reduce diseases, insects, and weeds in groundnut. It was recommended that groundnut be grown once in a three year rotation (Henning et al. 1982). A rotation of cereal - cereal - groundnut, can avoid most of the groundnut soilborne diseases problems.

The use of disease resistant or tolerant genotypes (like IGC(FDRS)10, and ICG(FDRS)4 developed at ICRISAT) could reduce fungicide requirements and the cost of spray in groundnut production.

B. Insect Pests:

Several insect pests attack groundnut. Those inhabiting soils are termites (Odontotermes obesus Rambur), white grubs (Holotrichia spp.), false wire worms, and ear wigs. The aerial insects are leafminer (Aproaerema modicella Dev.), red hairy caterpillar (Amsacta albistriga), hairy caterpillar (Diacrisia obliqua Hb.), tobacco caterpillar (Spodoptera litura F.), weevil and boll worms (Heliothis armigera) (Amin, 1987). Aphids (Aphis craccivora Koch), thrips (Frankliniella schultzei Trybom), and jassids (Empoasca kerri Pruthi) are vector of groundnut viral diseases. Thrips are vectors of tomato spotted wilt virus causing bud necrosis disease, a serious problem in Andhra Pradesh. A careful monitoring of insects by regularly surveying throughout the growing season is required for good insect management. Damage caused by soil inhabiting and seedling insect can be controlled by the basal application of carbofuran @ 40 kg ha^{-1}.

Spraying of an insecticide is a waste unless it is done at the correct time. Therefore, it is necessary to monitor the insect populations and spray only when necessary. In Table 5 insects and effective pesticide controls are listed.

9. Determining physiological maturity:

During the rainy season many erect bunch varieties mature in 100-110 days, most semi-spreading and spreading varieties mature in 120-135 days. Some early types mature in 90-100 days. However during the postrainy season, maturity may be prolonged by 25-30 days due to low temperature during the initial crop growth. To determine the optimum degree of maturity for harvesting, the following symptoms are useful:

i) General yellowing of the foliage.

ii) The mature pods become hard and tough. The inner surface of the shell becomes rough with a net-like veination. A dark brown coloration develops on the inner side of the pod shell.

The virginia type groundnuts should be harvested when more than 60% of the pods are mature and the spanish bunch type when more than 70% of the pods have reached the maturity. After a variety attains 50% maturity, a close monitoring is required to determine the optimum date of harvest.

10. Harvesting:

Harvesting of groundnut before its maturity lowers the yield, oil percentage, and quality of kernels. Delay in harvesting after physiological maturity results in sprouting of non-dormant varieties, the development of stem rots and weakening of pegs, thus causing pods to be left in the soil. Over maturity increases the chances of yellow mold (Aspergillus flavus) infection which can result in aflatoxin production in the kernels.

There are three ways to harvest groundnut.

i) Irrigate the field with 2-2.5 cm of water if sprinkler irrigation is available. After one hour or so, the plants could be pulled out by hand while the soil is moist.

ii) Provide light furrow irrigation a week or ten days before harvesting and use of a blade type digger which would cut the tap roots 10 cm below the soil surface and will help for easy pulling out the plants.

iii) When the field is dry and irrigation is not available, bullock or tractor drawn digger can be used to cut the roots and loosen the soil for collection of the uprooted plants and pods.

The spanish bunch varieties (nondormant types) may start germinating in the soil, if harvesting is delayed. Therefore, they should be harvested when 70% of the pods are mature. The bunch and semispreading varieties are usually harvested manually while there is some moisture in the soil. The spreading types are usually harvested by using a blade harrow or by digging with a spade.

The harvested plants are stacked for drying in the field for 2-3 days before stripping the pods. The pods should be dried immediately and continuously to 8% moisture content to reduce the development of aflatoxin caused by yellow mold (Aspergillus flavus). On rainy days, pods should be removed immediately and put into a drier at 80°F-100°F for two days or until the seeds attain a constant weight at 8% moisture.

III. SOME YIELD OBSERVATIONS

The effect of suggested practices to maximize groundnut production were reflected in the trials conducted by the training participants during the 1987 rainy season (June to November) at ICRISAT (Table 6 & 7).

Thirteen replicated trials were conducted for maximization of yield under high fertility (HF). Each trial was with 6 genotypes replicated four times. The gross plot size was 15 m^2 (8 rows of 5 m length) and the net plot size was 12 m^2 (8 rows of 4 m length). These trials were planted on 23 June 1987 by a tractor drawn planter on broadbed-and-furrows at a plant density of 330,000 ha^{-1}. Chicken manure @ 12 t ha^{-1} was incorporated into the soil at the time of preparing the broadbed-and-furrows. In addition, Gromor (R) (28N and 13P) was applied @ 100 kg ha^{-1} at the time of sowing. Alachlor (Lasso (R)) was sprayed @ 4 L ha^{-1} as preemergence spray to control the weeds. The field was irrigated a day after sowing using sprinklers Subsequent irrigations were given 27, 38, 79 and 87 days after sowing, to supplement the rains (Fig.2). These trials were sprayed with chlorothalonil (Daconil (R)) 0.15% @ 1.5 kg ha $^{-1}$ each spray, 45, 57, 66, 77, and 91 days after sowing. This schedule kept the crop free from rust, early leafspot and late leafspot. Three sprays of monocrotophos (Nuvacron (R)) @ 1 L ha^{-1} each spray, were used to control the spodoptera, leafminers, aphids and other insects. In another trial in the same field, 16 genotypes were planted on 24 beds of 5 meter length each. Out of 24 beds 12 beds were given all the inputs mentioned earlier in high

fertility (HF) The other 12 beds were with low fertility (LF) as chicken manure and Gromor(R) were not applied.

In addition, 22 unirrigated varietal trials were conducted, each with 6 genotypes including released Indian cultivars in 4 replications. These trials were planted manually between 27 and 30 June 1987. In these trials 10 kg N and 17 kg P per hectare as ammonium sulphate and single super phosphate respectively were applied. Plant protection was followed as in the irrigated HF and LF trials. Since no irrigation was given, these trials are referred to as unirrigated (UI) trials. The mean yield of 6 genotypes released for cultivation in India were pooled from replicated high fertility (HF) and unirrigated (UI) trials for comparision.

The mean yield of 16 genotypes in high fertility trial was 3480 kg ha^{-1}, where as in low fertility trial, the yield was 2980 kg ha^{-1} (Table 6). This indicated that a high yield of groundnut could be achieved in the rainy season with the use of manures and fertilizers, optimum plant density, timely sprinkler irrigation, plant protection and weed management on broadbed-and-furrows. The average difference between 16 genotypes grown under high fertility and low fertility was 500 kg ha^{-1}

The highest average yield of 4430 kg ha^{-1} was observed for ICGS 44 (Table 6), followed by ICGS 6 (4170 kg ha^{-1}), and ICGS 35 (4080 kg ha^{-1}). Kadiri 3 gave a yield of 3700 kg ha^{-1}. Cultivars like TMV 2, JL 24, and J 11 yielded 2000 to 3000 kg ha^{-1} revealing that these genotypes did not respond to the application

of manures and irrigation as the ICRISAT varieties ICGS 44, ICGS 6 and ICGS 35. This exemplified that in addition to management, the use of varieties with high yield potential suitable for high fertility and irrigation is important, to achieve high yields of groundnut.

The replicated trials conducted under high fertility with irrigation (HF) and normal fertilizer (10 N, 17 P) without irrigation (UI) showed wide differences in the pod yield between HF and UI trials (Table 7). Most of the genotypes without irrigation (UI) yielded around 1000 kg ha^{-1} where as their yield with irrigation (HF) was around 4000 kg ha^{-1}. ICGS 11 had the highest yield (4787 kg ha^{-1}), followed by Kadiri 3 (4440 kg ha^{-1}). The initial populations were almost equal in the irrigated and unirrigated experiments but in the unirrigated trial there were reductions in plant populations, mature pods per plant, plant height and yield (Table 7). This further indicated that adequate water is an important component in groundnut cultivation.

IV. ECONOMICS OF GROUNDNUT CULTIVATION UNDER HIGH FERTILITY MANAGEMENT

The costs of cultivation were based on the inputs used in the above trials (Table 8). The net return from groundnut ranged from Rs. 5500 at yield of 3500 kg ha^{-1} to Rs. 11500 when a yield of 4500 kg ha^{-1} was achieved in high fertility and sprinkler irrigation. Therefore, it is profitable to cultivate groundnut during the rainy season with the practices discussed in this text. The groundnut haulm value was not included, but it was

estimated that 4000 to 5000 kg ha^{-1} of usable haulms would have had a value of Rs. 1000 to 1200 ha^{-1}. The yield obtained was high in comparison to normal yield achieved by the farmers (862 kg ha^{-1}) or even in the unirrigated trials (Table 7).

The calculated costs have been based on a yield insurance package with maximum plant protection, and applications of carbofuran and chicken manure. Some of the cost inputs could be reduced depending on soil types, agroclimatic conditions and facilities available to the farmers. For instance farm yard manure is a less expensive source of organic manure than chicken manure. One may omit a carbofuran application in those areas where nematodes, white grubs, termites and other soil inhabiting insects are not a problem. The cost of insecticide and fungicide application could also be reduced, when the pest incidence is less.

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Table 1: Typical characteristics of the three major groundnut botanical varieties

Character	*hypogaea* (virginia)	*fastigiata* (valencia)	*vulgaris* (spanish)
Growth habit	Procumbent or decumbent	Erect	Erect
Branching	Alternate	Sequential	Sequential
Leaf color	Dark green	Light green	Light green
Number of branches	Numerous n+1,n+2 n+3	Very few n+1	Few n+1,n+2
Flowers on main axis	Absent	Present	Present
Inflorescence	Simple	Compound	Compound
Seeds per pod	2-1-3	3-4-2-1,2-3	2-1
*Maturity (days)	130-160	90-160	90-110

*The maturity will increase by 20-30 days during postrainy season in spanish and 25-30 days in virginia varieties.
(n = main axis; n+1 = primary branches; n+2 = secondary branches; n+3 = tertiary branches).
(Source: Based on Gibbons *et al*. 1972 and V.Ramnath Rao, ICRISAT, personal communication 1988).

Table 2: Area, production, and productivity of groundnut in the world (Three year averages i.e. 1979-81 and 1983 to 85)

Continents/ Countries	Area (million ha)		Production (million tons)		Productivity (kg ha^{-1})	
	1979-81	83-85	1979-81	83-85	1979-81	83-85
World	18.50	18.70	18.50	20.10	1003	1077
Africa	6.2	5.65	4.63	3.80	748	675
NC America	0.77	0.76	1.73	1.98	2263	2614
South America	0.64	0.40	0.96	0.63	1507	1590
Asia	10.91	11.87	11.21	13.69	1027	1153
China	2.34	2.75	3.50	5.22	1492	1891
India	7.13	7.49	5.99	6.47	841	862
Burma	0.49	0.56	0.39	0.58	797	1036
Indonesia	0.50	0.51	0.76	0.78	1534	1525

(Source: FAO 1985)

Table 3: Nutrient deficiency symptoms in groundnut.

Element	Symptoms of nutrient deficiency
Nitrogen	Younger plants become lighter green than normal. In severe cases the entire leaf becomes pale yellow, stems are thin and elongated. In adult plants older leaves fall. Growth is stunted, and stem become reddish. Poor pod and kernel development.
Phosphorus	Phosphorus deficient plants are stunted; leaf size is reduced. Initially affected plants become bluish green later a dull and dark green. Older leaves turn orange yellow. Later entire leaf becomes brown and finally drops.
Calcium	It results in localized pitted areas on the lower surface of leaves which turn into dark brown necrotic spots. Severe deficiencies results in the death of leaf tips and terminal buds. Roots become short stubby and discolored. Wilting of young leaves and death of apical buds occurs in severe deficiency. Calcium deficiency in addition to aborted, shrivelled fruit, include darkened plumules and production of 'pops' i.e. pods without seed.
Potassium	Potassium dificiency results in marginal chlorosis of leaves or sometime interveinal chlorosis. Older leaf show marginal yellowing, and scorching at maturity, leaf margin curl upward and leaves dries.
Magnesium	The first deficiency symptom is interveinal chlorosis of the terminal leaves and stunting of plants. Older leaves develop necrotic spots and drop off. Stems are slender and weak.
Sulfur	Sulfur deficiency restricts root development and new leaves become pale green or yellow. Leaf chlorosis occurs mainly at growing point. It decreases the number of pods per plant and quality of kernels. It decreases nodulation and interferes with the plant's nitrogen uptake, and results in lower oil content of the kernels. The sulfur deficient plants have reduced branches thus appear quite upright.
Manganese	Young leaves turn yellow and then brown. Manganese deficiency produces interveinal chlorosis and brown spots on the leaf margin. The yellowing begins at margins and extends towards midrib. The edges may become orange and crinkle or curl. Older leaves develop necrotic areas and fall off.

Molybdenum	Its deficiency decreases vegetative growth, effective nodulation and nitrogen content of foliage. Molybdenum availability increases under alkaline conditions
Boron	boron deficiency causes leaves to turn deep green. Plant growth is restricted. Terminal leaves become small and deformed. Internode length is reduced, due to secondary branching. Plants appear stumpy and short. It reduces flowering and fruiting and causes "hollow heart" i.e. kernels do not develop properly, leaving a depressed area in the center which is often brown.
Iron	Young leaves develop initially interveinal chlorosis on the terminal leaves and may have crinkled margins, later leaves turn yellow then white. Iron deficient plants have limited roots. Affected leaves develop brown spot or necrosis on the lamina.
Copper	Copper deficiency leads to deformation of young leaves with greenish yellow or chlorotic color. Plants are stunted and rosetted. The stunted plants are dark green and wilted in an early stage. All leaflets become cupped as the leaf margin turns upward. Necrosis develops in the tips and margins progressing inward, until the petiole drops.
Zinc	Young leaves turn bronze in color and become chlorotic. Under high temperature leaves appear bronze due to development of small necrotic spots. Internodal growth is reduced, plants are stunted. Stem and petiole becomes purplish.

(Source Table based on the Pest Controls in Groundnuts PANS Manual No.2 Page 84; Cox et al. 1982; Reid and Cox 1973 and Cox 1984).

Table 4: Recommended herbicides for groundnut.

Herbicide	Trade name	Rate (a.i. kg ha^{-1})	Time of application
Fluchloralin	Basalin(R)	1.25-1.50	Pre-planting soil incorporation
Pendimethalin	Stomp(R)	0.60-1 50	Pre-emergence spray
Metalachlor	Dual(R)	1.00-1.50	Pre-emergence spray
Oxyfluorfen	Goal(R)	0.25-0.50	Pre-emergence spray
Alachlor	Lasso(R)	1.50-2.00	Pre-emergence spray

Source. Yadava 1985 and A.Ramkrishna, ICRISAT Personal Communication 1988).

Table 5. Sample unit for insect survey and chemical to control infestation

Insect	Sampling unit	When to spray	What to spray
Seedling insects			
Aphids Thrips Jassid	30 terminal shoots ha^{-1}	8-10 aphids or thrips	Dimethoate (Rogor (R)
Foliage feeder			
Leafminer	100 leaflets ha^{-1}	When 5 mines/ plant at seedling stage; 10-15 mines/plant at mid stage and 20-30 mines/plant at maturity stage	Dimethoate 200 ml a.i. ha^{-1}
Tobacco caterpillar	Count egg 1.5 m^{-1} or larvae m^{-1} row	When 3 egg 1.5 m^{-1} or 10 larvae m^{-1} at seedling stage in rainy, and 20 larvae m^{-1} at pegging stage in postrainy season.	Monocrotophos (Nuvacron (R)) 200-300 ml a.i. ha^{-1} or endosulfan (Thiodan (R)) @ 400-500 ml a.i. ha^{-1}

(Source Information based on Amin 1987; and S.K.Pal and G.V.Ranga Rao, ICRISAT, personal communications 1988)

Table 6 Average performance of 16 groundnut genotypes under high fertility (HF) and low fertility (LF) with supplemental sprinkler irrigation at ICRISAT Patancheru, during rainy season (June-November) 1987.

Genotypes/ varieties	Pop (000 ha^{-1})		Shelling (%)		Yield kg ha^{-1}	
	HF	LF	HF	LF	HF	LF
ICGS 1	237	245	70	68	3520	2540
ICGS 4	296	276	78	72	3720	2910
ICGS 5	344	343	72	70	3310	3350
ICGS 6	297	288	63	64	3770	3580
ICGS 26	325	321	72	70	4170	3340
ICGS 35	311	345	65	68	4080	3910
ICGS 44+	258	369	70	68	4430	3440
ICGS 47	258	233	68	65	3640	2920
ICGS 51	291	265	58	44	3680	3130
ICG(FDRS) 1	343	338	66	58	3800	3160
ICG(FDRS)23	274	259	67	60	3090	2500
TMV 2+	327	270	68	69	2710	2630
JL 24+	371	269	70	68	3120	2560
ROBUT 33-1	306	235	74	68	2830	2470
KADIRI 3+	334	255	70	69	3720	2910
J 11+	294	240	66	65	2070*	2350
Mean	304	278	73	65	3480	2980
SEM	±16.7	±14.0	±3.3	±2.6	±235	±170
CV(%)	13.5	12.4	11.1	10.0	16.6	14.0

+ Released varieties

* High weed infestation at late stage of crop growth affected yield of this plot.

(Note: Kadiri 3 is released name of Robut 33-1, however, Robut 33-1 available with us has considerable variation may be due to different source of seed which was reflected in yield).

Table 7: Pooled mean performance of groundnut varieties in different trials under high fertility irrigation (HF) and unirrigated(UI) conditions at ICRISAT during rainy season (June-November) 1987

Genotype	Trial (number)	Population (000 ha^{-1})	Height (cm)	Mature (Pod/pl)	Pod Yield (kg ha^{-1})
ICGS 44	HF(3)	251	32	24	4144
	UI(2)	245	18	13	1486
ICGS 11	HF(2)	284	36	21	4787
	UI(1)	201	23	8	1125
KADIRI 3	HF(4)	279	31	19	4440
	UI(2)	202	17	9	843
JL 24	HF(3)	284	41	17	3216
	UI(2)	165	29	12	661
TMV 2	HF(3)	310	44	19	3143
	UI(2)	107	30	9	806
J 11	HF(3)	301	46	18	3047
	UI(1)	190	34	10	885

CV(%) for irrigated trials were below 20 for all the characters
CV(%) for unirrigated trials were very high.

High fertility (HF) Chicken manure 12 t ha^{-1}; Gromor 100 kg ha^{-1}; Sprinkler irrigation (6 times), Carbofuran, and Plant protection

Unirrigated(UI) = 10-17-0, N-P-K and plant protection measures without irrigation.

Net plot size = 12 m^2 with four replications in each trial.

Table 8: Estimated cost of cultivation for groundnut under high fertility at ICRISAT in rainy season 1987:

Items		Approx. Cost (Rs ha^{-1})
A. **INPUTS**:		
1. 4 disk plowings and BBF formation @ Rs. 200 per operation	=	1000
2. Chicken manure @ Rs. 400 t^{-1} for 12 tons	=	4800
3. Gromor(R) @ Rs. 360 for 100 kg	=	360
4. Seed @ Rs. 16 kg^{-1} for 120 kg	=	1920
5. Lasso(R) @ Rs. 120 per L. for 3.5 L.	=	420
6. Carbofuran @ Rs. 25 kg^{-1} for 40 kg	=	1000
7. Thiram @ Rs. 70 kg^{-1} for 300 g	=	21
8. Chlorothalonil @ 1.5 kg ha^{-1} per spray for five spray @ Rs. 253 $spray^{-1}$	=	1265
9. Cost of Monocrotophos for three sprays one L each @ Rs. 194 per L	=	582
10. Sowing, weeding, spraying, and harvest labor	=	2000
11. Sprinkler irrigation @ Rs.100 per irrigation for 6 irrigations	=	600
12. Rental value of the land	=	1000
13. Interest on working capital	=	500
14. Miscellaneous	=	32
Total cost a. with chicken manure		15500
b. without chicken manure		10700

B. NET RETURNS:

1. Gross income for a yield of 4500 kg ha^{-1} pod		
@ Rs. 6 kg^{-1}	= Rs.	27000
Net gain ha^{-1} Rs. 27000 - 15500	= Rs.	11500
2. Gross income for a yield of 3500 kg ha^{-1} pod		
@ Rs. 6 kg^{-1}	= Rs.	21000
Net gain ha^{-1} Rs. 21000 - 15500	= Rs.	5500
3. Gross income for a yield of 3000 kg ha^{-1} Pods (without chicken manure) @ Rs. 6 kg^{-1}	= Rs.	18000
Net gain ha^{-1} Rs. 18000 - 10700	= Rs.	7300

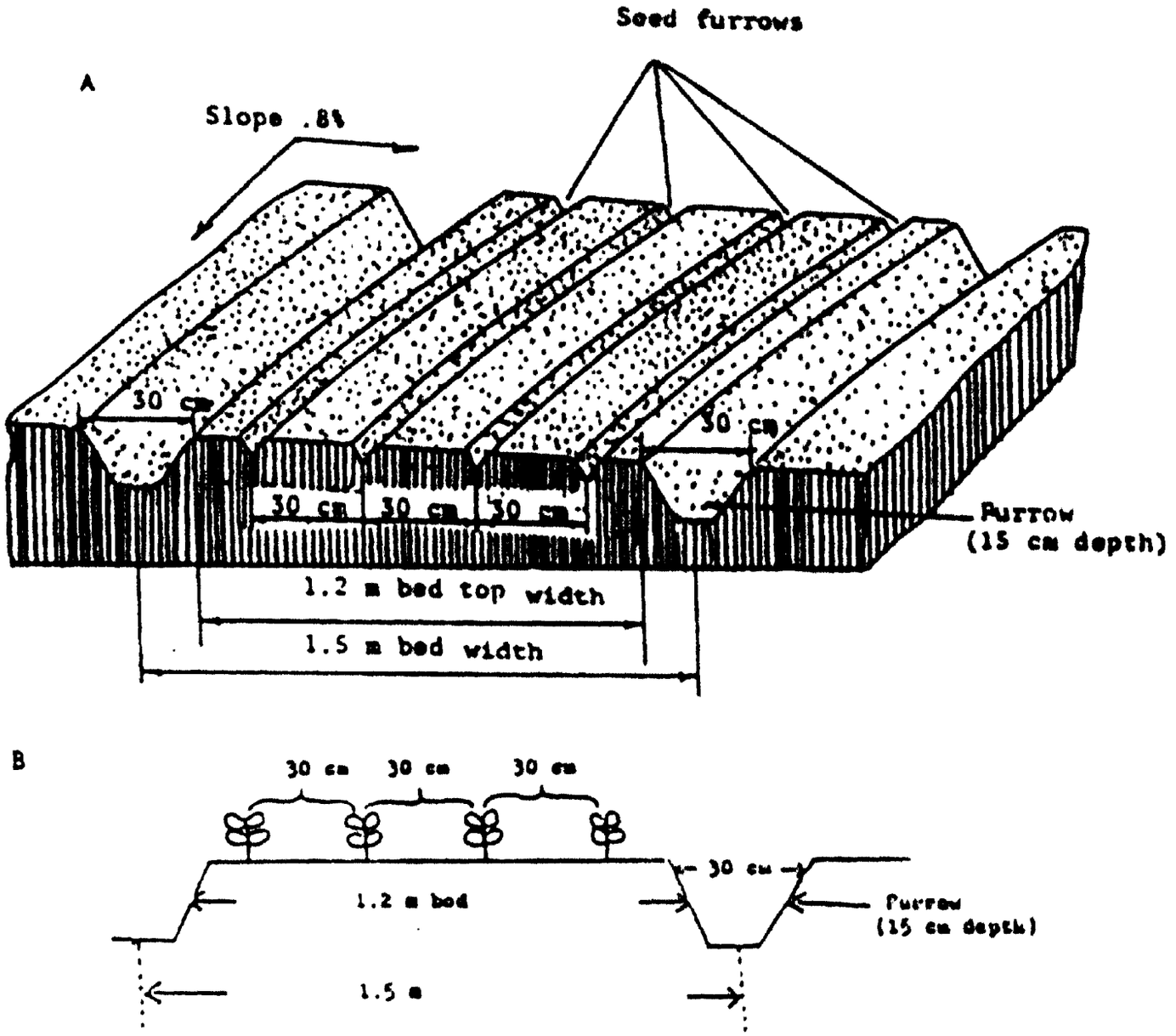

Fig 1. A. Cross section of broad-bed and furrow
B. Top of bed, sowing area and plants

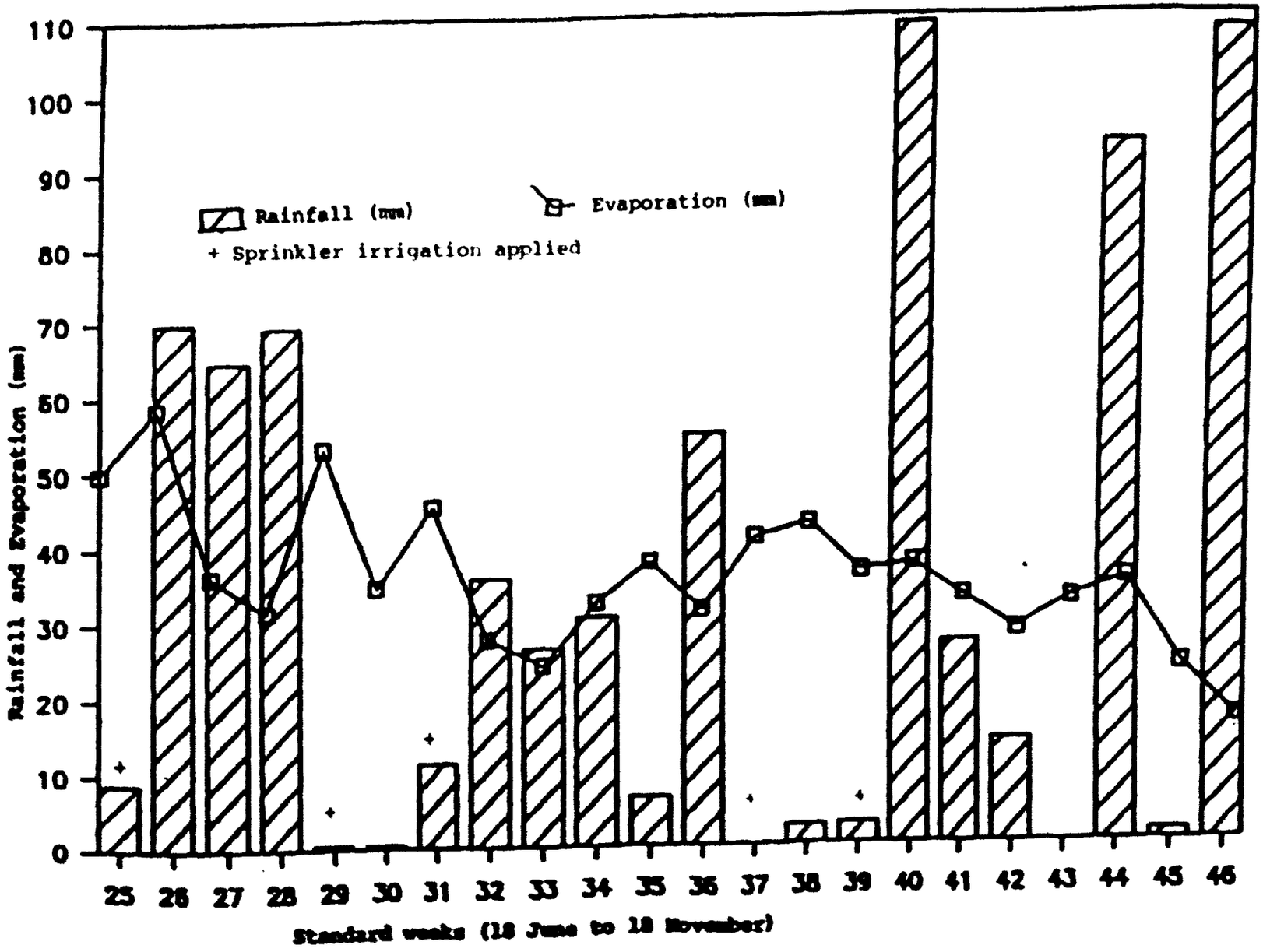

Fig 2. [illegible], weather data during crop season 1987