

Groundnut Production Practices

Compiled by

Faujdar Singh and D.L. Oswalt



Skill Development Series no. 3

Revised



ICRISAT

Training and Fellowships Program

**International Crops Research Institute for the Semi-Arid Tropics
Patancheru 502 324, Andhra Pradesh, India**

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Introduction

The cultivated groundnut (*Arachis hypogaea* L.) probably originated in Bolivia at the base of the Andes (Krapovickas 1968) extending into north Argentina (Ramanatha Rao 1988). Groundnut were sown in 20.09 million ha spread over 85 countries with the production of 22.59 million tonnes (t) and an average productivity of 1.12 t ha⁻¹ (FAO 1989). The cultivated groundnut belongs to the section *Arachis* and series amphiploidies and the family Fabaceae (Gregory et al. 1973). The species *A. hypogaea* consists of two subspecies, ssp *hypogaea* and ssp *fastigiata*. Each subspecies has two botanical varieties.

The four cultivated types according to Krapovickas and Rigoni (1960) are:

1. *Arachis hypogaea hypogaea hypogaea* Linn.
2. *Arachis hypogaea hypogaea hirsuta* Kohler.
3. *Arachis hypogaea fastigiata fastigiata* Waldron.
4. *Arachis hypogaea fastigiata vulgaris* Harz.

The morphological comparison of subspecies *hypogaea* and *fastigiata* and varieties of both subspecies are discussed in Management Procedure 1 (MP 1).

Production Practices

Soil

Groundnut is grown in a well-drained sandy loam, or sandy clay loam soil. Deep well-drained soils with a pH of 6.5-7.0 and high fertility, are ideal for groundnut. Runner and Spanish types are better suited to heavy textured soils than the Virginia types. The loss of pods is usually high in heavier soils. An optimum soil temperature for good germination of groundnut is 30°C. Low temperature at sowing delays germination and increases seed and seedling diseases.

Crop Rotation

A crop rotation of groundnut-cereal-cereal helps in efficient nutrient utilization and reduces soilborne diseases and nematodes. It also helps to reduce the incidence of weeds. Maize, sorghum, pearl millet or small grain crops can be grown following groundnut. To reduce the incidence of soilborne diseases it is recommended not to grow groundnut after groundnut, or tobacco, or cotton (Henning et al. 1982; Allison 1981).

Manures and Fertilizers

A balanced fertilizer application, based on soil tests, should provide adequate levels of especially phosphorus, potassium, calcium, sulphur, and magnesium. Nutrient availability depends on soil pH, organic matter content, and rate of release of nutrients from the soil minerals. The availability of other essential ions such as copper, boron, iron, manganese, and nitrogen may be low in alkaline soils (pH >8.5); while an acid soil (pH <6) may be deficient in molybdenum, manganese, sulphur, nitrogen, phosphorus, potassium, and calcium. Therefore, depending on soil nutrient status and targeted yields, the needed quantities of nutrients should be applied (Table 1).



Manures

Application of 10-12 t ha⁻¹ of chicken manure or 20 t ha⁻¹ of well decomposed farm yard-manure should be completed at least 1 month before sowing. This should be mixed into the soil for good plant development and to improve the soil structure.

Table 1. Estimated nutrients required to produce selected pod yields of groundnut.

Pods t ha ⁻¹	Nutrients kg ha ⁻¹									
	N	P	K	Ca	Mg	S	Fe	Mn	Zn	B
1	58	5	18	11	9	4	2	0.09	0.08	0.05
2	117	10	36	23	18	9	4	0.19	0.16	0.11
3	174	15	54	34	27	13	6	0.29	0.24	0.16
4	232	20	73	45	36	18	8	0.38	0.32	0.22
5	290	25	91	56	45	22	10	0.48	0.41	0.27
6	348	30	109	68	54	26	12	0.58	0.49	0.33
7	406	35	126	77	63	30	14	0.68	0.56	0.38
8	464	40	144	88	72	34	16	0.78	0.64	0.44
9	522	45	162	99	81	38	18	0.88	0.72	0.49
10	580	50	180	110	90	42	20	0.98	0.80	0.54

(Source: Calculation based on Sahrawat et al. 1988.)

Fertilizers

Nitrogen (N). Groundnut fixes atmospheric nitrogen with the help of *Rhizobium* in the root nodules. This helps to partially fulfill its nitrogen requirement. However, it takes about 25-30 days to develop root nodules. Therefore, some available nitrogen is required in the early stages for plant growth. An application of 10 kg N ha⁻¹ as ammonium sulphate at the time of sowing is recommended for soils with moderate to low nitrogen content.

Phosphorus (P). The requirement for phosphorus in nodulating legumes is higher compared with non-nodulating crops. If available soil phosphorus is less than 15 kg ha⁻¹, there is need to apply phosphatic fertilizer. Single superphosphate is recommended because it contains phosphorus (7.0 %), calcium (19.5%), and sulphur (12.5%) that are required by groundnut (Yadava 1985). At ICRISAT Asia Center, 17 kg P ha⁻¹ is applied at sowing as single super phosphate.



Potassium (K). A potassium application may not be required unless there is less than 125 kg K ha⁻¹ available in the soil.

Calcium (Ca). The groundnut requirement of calcium is high during the pod filling stage. Calcium is taken up directly by the developing pods from the top 5-7 cm of soil. Gypsum is a cheap source of calcium (19-24%) and sulphur (15-18%). The critical limit of calcium is 1 meq 100 g⁻¹ of soil in the root zone and 3 meq 100 g⁻¹ of soil in the pod zone (Dayal et al. 1987a). Depending on the soil test, 300-500 kg ha⁻¹ of gypsum should be applied at a depth of 3-5 cm prior to pegging.

Sulphur (S): Sulphur helps in biological oxidation and reduction processes, and chlorophyll formation. Acid soils are often deficient in sulphur. In soils where available sulphur is less than 10 ppm, sulphur application is necessary. However, additional sulphur is not required when gypsum is applied because it also contains 15-18% sulphur.

Iron (Fe): Groundnut grown in soils with a high pH often show iron chlorosis. Spraying of 0.5-1.0% ferrous sulphate (FeSO₄) with 0.1% citric acid, 3% ferrous ammonium sulphate, and 0.2% urea solution can correct iron deficiency. When iron chlorosis is severe three or more sprayings are required (Joshi et al. 1987).

Zinc (Zn): Zinc increases the chlorophyll content in the leaves, the number of nodules, and pod yield. Zinc deficiency occurs when the soil is alkaline or low in organic matter, under high levels of soil P, or when soils are cool and wet during the vegetative phase. An application of zinc sulphate at 10 kg ha⁻¹ to the foliage or 15 kg ha⁻¹ to the soil should correct the zinc deficiency (Joshi et al. 1987).

Deficiencies of boron (B), copper (Cu), molybdenum (Mo), manganese (Mn), and magnesium (Mg) can be corrected by soil application of these nutrients when symptoms appear, depending on soil type and agroclimatic conditions (Table 2).

Table 2. Nutrient deficiency symptoms in groundnut.

Element	Symptoms of nutrient deficiency
Nitrogen	Younger leaves become lighter green than normal. In severe cases the entire leaf becomes pale yellow. Stems are thin and elongated. In mature plants older leaves fall. Growth is stunted, and the stem becomes reddish. Poor pod and kernel development.
Phosphorus	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 the entire leaf becomes brown and finally drops.
Calcium	It results in localized pitted areas on the lower surface that turn into dark brown necrotic spots. Severe deficiency causes death of leaf tips and terminal buds. Roots become short, stubby, and discolored. Wilting of young leaves and death of apical buds occur 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 deficiency results in marginal chlorosis of leaves or sometimes interveinal chlorosis. Older leaves show marginal yellowing, and scorching at maturity, leaf margins curl upward, and the leaf 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.
Sulphur	Sulphur deficiency restricts root development and new leaves become pale green or yellow. Leaf chlorosis occurs mainly at the growing point. It decreases the number of pods per plant and quality of kernels. It decreases nodulation, interferes with the plant's nitrogen uptake, and results in lower oil content of the kernels. Sulphur-deficient plants have less branches thus they are upright.
Manganese	Young leaves turn yellow and then brown. Manganese deficiency causes interveinal chlorosis and brown spots on the leaf margin. The yellowing begins at margins and extends towards the 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	Severe boron deficiency causes leaves to turn deep green. Plant growth is reduced. Terminal leaves are 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". Such kernels do not develop properly, leaving a depressed area in the center that is often brown.
Iron	Young leaves initially develop 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 spots or necrosis on the lamina.
Copper	Copper deficiency leads to deformation of young leaves that are greenish yellow or chlorotic. Plants are stunted and rosetted. The stunted plants are dark green and wilt 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 and become chlorotic. Under high temperature, leaves appear bronze due to development of small necrotic spots. Growth of internodes are reduced, and plants are stunted. Stems and petioles become purplish.

(Sources: Feakin 1973; Cox et al. 1982; Reid and Cox 1973; and Cox 1984.)

Field Preparation

Land preparation should ensure that all crop residues and weeds are completely buried. One plowing, to a depth of 15-20 cm, followed by two to four disk harrowings may be required to make a seedbed with a fine tilth.



Three systems of groundnut sowing are followed, sowing on a flat surface, on a broadbed-and-furrow system, or sowing on a ridge-and-furrow system. The broadbed-and-furrow system has an advantage over flat sowing in draining off excess water, providing more soil aeration for plant growth, and greater in-situ moisture conservation. It may be easier for weeding and mechanical harvesting. The procedures for preparing a broadbed-and-furrow system are given in MP 2.

Preparations for Sowing Experiments

Plot design

1. When testing for yield and quantitative characters, treatments are to be randomized and arranged in the plots in blocks.
2. Yield trials (breeding) at ICRISAT Asia Center are conducted in a triple lattice design, consisting of 25, 36 or 49 entries. The plot size is four rows of 4m length, with 30cm between rows and 10 cm between plants. However, in the Training and Fellowships Program six to eight genotypes are evaluated in a randomized block design on a broadbed-and-furrow system. Each plot has two beds each of 1.5m width and eight rows of 5m length. Each trial is laid out in 3 or 4 replications.

Layout and seed preparation

1. Initial steps. The experimental field maps indicating the randomization of treatments, blocks, direction of rows, number of rows, row width, row length, and alley width are prepared. Next, the seed and fertilizer packets for each row are prepared.
2. Selection of seed. Bold and well-filled pods are selected for shelling about one week before sowing. The viability of the kernels may deteriorate after being shelled and stored for a long time and are more subject to storage pest damage. The plants produced from bold kernels were found to be superior to those from correspondingly smaller kernels in their rate of emergence, number of successful seedlings, number of primary branches and leaves, and dry mass of roots, shoots, total dry matter, and pod yield (Dharmalingam and Ramakrishna 1981).
3. Seed treatment. To control pathogens causing seed and seedling diseases, it is necessary to coat the seed before sowing with either Thiram® (a.i. 50% @ 3 g kg⁻¹ seed) or Bavistin® (a.i. 50% @ 2 g kg⁻¹ seed). Seed may be inoculated at the time of sowing by field inoculation to ensure good nodulation where a soil has been found to contain few rhizobia (MP 3).
4. Seed rate and spacing. The seed rate depends on the variety (Spanish, Valencia, or Virginia), runner or bunch type, the seed mass, and germination rate of the seed-lot (MP 4). The recommended population for bunch varieties is 330 000 plants ha⁻¹ (about one plant per 30 x 10 cm). In case of semispreading and spreading varieties the recommended population is 250 000 plants ha⁻¹ (one plant per 40 x 10 cm).
5. Seed packets. When sowing by hand is done the calculated amount of seed for each row is separately packeted and the packets for each plot are temporarily fastened together. In case of machine sowing, seed packets are arranged by groups of rows for



continuous sowing (MP 5).

Sowing

1. Groundnut sowing during the rainy season start with the onset of the rains, usually by the 3rd week of June. The research carried out under the All India Coordinated Research Project on Oilseeds (AICORPO) and at ICRISAT Asia Center have shown that advancement of the sowing date with one premonsoon irrigation can substantially increase the yield (Yadava 1985).
2. Examine the soil before sowing for an optimum moisture content after rainfall or give a presowing irrigation to ensure good germination. At ICRISAT Asia Center, sowing may be done in dry soil followed by sprinkler or purfo irrigation.
3. At the time of sowing, place the seed at 5-6 cm depth in the soil. Compact the soil around the seed to ensure there is firm contact with soil moisture for rapid and uniform germination. Use of a seed drill with packing wheels is useful to ensure uniform germination.
4. When sowing manually, make sure that plots in each block is completed by the same person to reduce within-block variation due to uneven sowing caused by human differences.

Irrigation

Groundnut yields will be reduced if the upper soil zone becomes dry from flowering through pod development. A water deficit may lead to the following consequences (Boote et al. 1982):

- Reduction in the dry matter production of vegetative components as well as the crop growth rate.
- Fewer and smaller leaves with small compact cells and shorter stems.
- Water deficit from sowing to 67 days delays the period of rapid fruit growth by 10 days and decreases yield.
- Water deficit during the flowering and pegging stages results in higher yield losses than stress at any other growth stage; This deficit reduces the number of flowers plant⁻¹.
- Water deficit in the soil surface during peg formation and pod development reduces pod number and pod yield.
- Water deficit in the fruiting zone results in unfilled pods, and less calcium concentration in the hull and seed.
- Water deficit reduces groundnut quality, shelling percentage or percentage of sound mature seeds, seed mass, and germination of seed.

The aim of irrigation is to prevent soil water deficit and to supply the crop's upper rooting zone with sufficient moisture without waterlogging the root zone.



Adequate available water in the upper 60 cm layer of soil is important for high yield and good quality groundnut seeds. Most soils when at field capacity will hold about 3.1 cm of water at 30 cm of depth. The highest groundnut yields are observed when available soil moisture is kept above 50% of field capacity. Therefore, sprinkler irrigations are recommended when the moisture has been depleted to 50% of field capacity in the top 60 cm. During peak water-use periods (0.6-0.7 cm day⁻¹) the field may require 3.0-3.5 cm of water every 5 days. Irrigation intervals can be prolonged for 7-10 days during periods of low daily water requirements.

An optimum water management scheme is to schedule sprinkler irrigations to maintain a less than 50% SWD (soil water depletion) level in the top 30 cm of soil during early growth stages. Imposing a moderate water deficit during pre-flowering phase followed by irrigation can increase pod yields by 18-20% (Nageswar Rao et al. 1985, 1988). However, irrigation should be made at 25% SWD during the pod-formation and seed-development stages. If the soil water potential is measured, irrigation should maintain the soil water potential above -0.6 bars. When long, dry, hot, periods occur at the sensitive growth stages, such as pegging, pod formation, and early pod filling, sprinkler irrigations are necessary to maintain the soil water potential above -0.25 to -0.50 bars (Boote et al. 1982). This means that the upper 30 cm of soil should appear and feel moist and the plants should not wilt from lack of moisture during the afternoon. A procedure for measuring soil water deficit is discussed in MP 6.

Weed Control

Weeds (Table 3) cause much damage to the groundnut crop during the first 45 days of its growth. The most critical period of weed competition is from 3-6 weeks after sowing. The average yield loss due to weeds is about 30%, whereas under poor management yield loss by weeds may be 60% (Dayal et al. 1987b). At ICRISAT Center 100% yield loss has been observed. Therefore, it is advantageous to mechanically and chemically control weeds during the initial 6 weeks of groundnut growth (MP 7).



Table 3. Common weeds in groundnut.

Latin name	Family	Common name (English)
A. Dicots		
<i>Abutilon indicum</i>	Malvaceae	Indian mallow
<i>Alysicarpus</i> sp.	Papilionaceae	One-leaf clover
<i>Argemone mexicana*</i>	Papaveraceae	Mexican poppy
<i>Celosia argentina</i>	Amaranthaceae	White cock's comb
<i>Corchorus acutangulus</i>	Tiliaceae	Wild jute
<i>Digera arvensis*</i>	Amaranthaceae	Crab grass
<i>Euphorbia purviflora*</i>	Euphorbiaceae	Spurge
<i>Leucas aspera*</i>	Labiatae	-
<i>Portulaca oleracea*</i>	Protulacaceae	Purslane
<i>Vernonia cinerea</i>	Compositae	Little iron weed
B. Monocots		
<i>Brachiaria eruciformis*</i>	Gramineae	Signal grass
<i>Commelina benghalensis*</i>	Commelinaceae	Tropical spiderwort
<i>Cynodon dactylon*</i>	Gramineae	Bermuda grass
<i>Digitaha sanguinalis*</i>	Gramineae	Crab grass
<i>Echinochloa colonum*</i>	Gramineae	Water grass
<i>Eleusine indica</i>	Gramineae	Goose grass
C. Sedges		
<i>Cyperus rotundus*</i>	Cyperaceae	Nutgrass
<i>Cyperus esculentus *</i>	Cyperaceae	Yellow nut sedge

* Common weeds at ICRISAT Asia Center.
(Source: Dayal, Devi et al. 1987b).

Determining Plot Yield

A procedure for estimating plot yield is given in MP 8. When replicated trials are conducted it is important to have the harvested area free from border effects. In a plot with eight rows of 5-m length, all eight rows with a length of 4-m could be harvested, this leaves a 0.5-m border on each end (MP 8). Alternatively, a circle containing 10 m² could be randomly harvested within a plot or field at locations away from the borders (MP 8).

Recording Observations

Observations to be recorded depend on the objectives of the experiment. When yield is evaluated, the emphasis is on pod mass and related characters. When the main objectives are related to genetic, biometrical, or statistical studies, then individual plant data are recorded.



When studying a segregating population, data are recorded on a large number of individual plants (MP 9).

Harvesting

Premature harvesting of groundnut pods lowers the yield, oil percentage, and quality of seeds. Delay in harvesting after physiological maturity can result in increased *Aspergillus flavus* infection, and aflatoxin contamination in pods/seeds, and many pods may be left in the soil due to weakening of pegs. The Spanish bunch varieties (nondormant types) start germinating if harvesting is delayed. Therefore, it is important to harvest at optimum maturity (MP 10).

There are three ways of harvesting groundnut:

- Apply sprinkler irrigation for an hour and manually pull the plants.
- Provide a light surface irrigation 2-3 days before harvest and use a blade harrow that cuts the plant roots 12-15 cm below the soil surface. Then manually pull the plants.
- When irrigation water is scarce, use a plow or tractor-driven digger to loosen the soil. Then manually remove the plants.

Harvested plants should be stacked in the field for a few days for air and sun drying (on bright sunny days) before stripping the pods. Thereafter, pods are continuously dried to reach a moisture content of 6-6% to avoid the development of aflatoxin caused by yellow mold (*Aspergillus flavus*). On cloudy days, pods should be removed and immediately placed in an air drier at 27-38°C for 2 days or until the pods dry to a constant mass (6-8% moisture).

Storage

After cleaning and grading, store the dry pods in gunny bags and stack them up to 10 bags high in separated stacks so that air freely circulates among them. The bags should be piled on wooden planks to avoid damage from dampness. Dusting the bags with 5% Lindane® will protect the pods from many storage pests.



MP 1. Comparison of Sub Species and Varieties of *Arachis*

The following morphological comparisons of genus *Arachis* subspecies, varieties, and the most widely cultivated varietal groups (Table 4) are based on Gibbons et al. 1972 and Ramanatha Rao 1988.

Table 4. Morphology of groundnut.

A. Morphological comparison of subspecies *hypogaea* and subspecies *fastigiata*

Character	ssp <i>hypogaea</i>	ssp <i>fastigiata</i>
Growth habit (Fig. 1)	Procumbent or decumbent	Erect
Branching (Fig. 2)	Alternate	Sequential
Foliage color	Dark green	Light green
Inflorescence	Simple (unbranched) but never on the main axis	Simple or compound branched, on main axis also
Pod diameter	10-20 mm	10-15 mm
Seed dormancy	Present	Absent

B. Morphological comparison of varieties of subspecies *hypogaea*

Character	var <i>hypogaea</i>	var <i>hirsuta</i>
Growth habit	Procumbent runner or bunch	Procumbent (runner)
Main stem	Short, less hairy	Long, very hairy
Pod constrictions	Slight	Prominent
Beak on pods (Fig. 3)	Present but small	Strongly beaked
Maturity	Medium to late	Very late

C. Morphological comparison of varieties of subspecies *fastigiata*

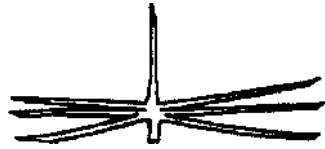
Character	var <i>fastigiata</i>	var <i>vulgaris</i>
Branching	Few branches	Many branches
Inflorescence	Simple	Compound
Constriction (Fig. 4)	May or may not be	Slightly constricted
Seeds pod ⁻¹	Two to four	Two
Testa color	Red, but tan and white forms also found	Tan, but red forms also found
Seed size	Small to medium	Medium

D. Morphological comparison of three major groundnut botanical varieties.

Character	<i>hypogaea</i> (Virginia)	<i>fastigiata</i> (Valencia)	<i>vulgaris</i> (Spanish)
Growth habit	Procumbent, decumbent or erect	Erect	Erect
Branching	Alternate	Sequential	Sequential
Leaf color	Dark green	Light green with bluish tinge	Light green
Number of branches	Numerous	Very few	Few
N-main shoot	N+1, N+2, N+3	N+1	N+1, N+2
Flowers on main axis	Absent	Present	Present
Inflorescence	Simple	Simple	Compound
Seeds pod ⁻¹	2,2-3	2-4,3-5,2-3	2

(Note: Procumbent plants lie prostrate, whereas decumbent plants trail on the ground and then tend to rise at their apex: Branches pattern N- main shoot, N+1 = primary, N+2 = secondary and N+3 = tertiary).

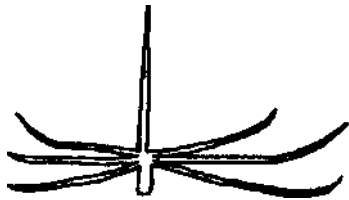




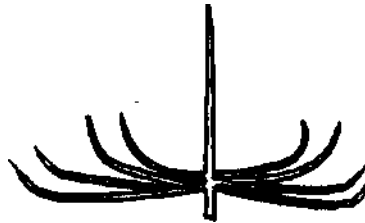
1. Procumbent 1



2. Procumbent 2



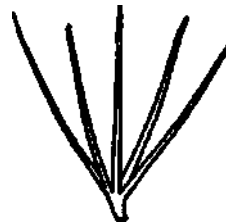
3. Decumbent 1



4. Decumbent 2



5. Decumbent 3



6. Erect

Figure 1. Growth habit of groundnut.
(Source: Ramanatha Rao 1988)



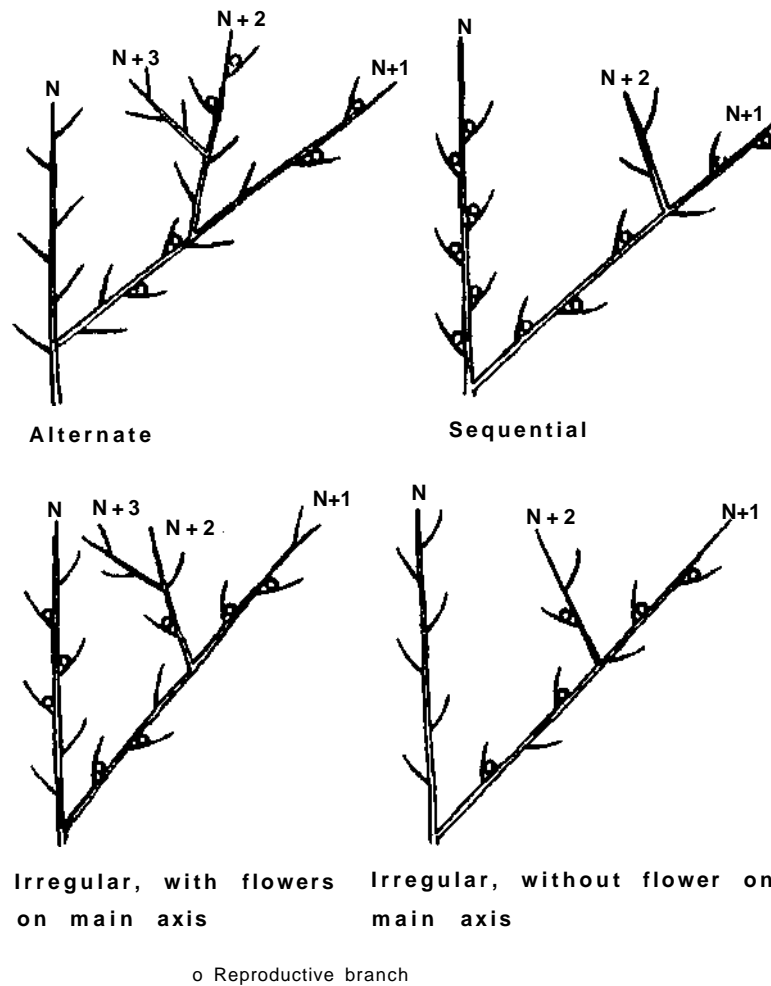
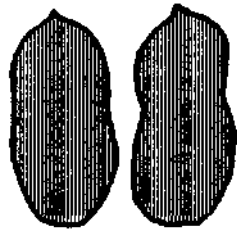
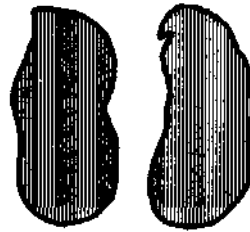


Figure 2. Branching patterns of groundnut.
 (Source: Ramanatha Rao 1988)

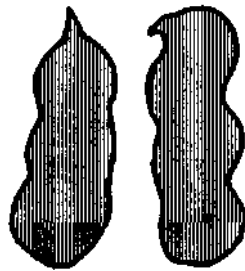




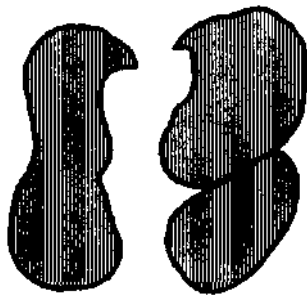
1. Absent



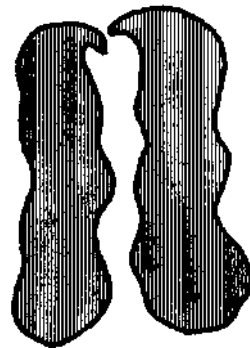
3. Slight



5. Moderate



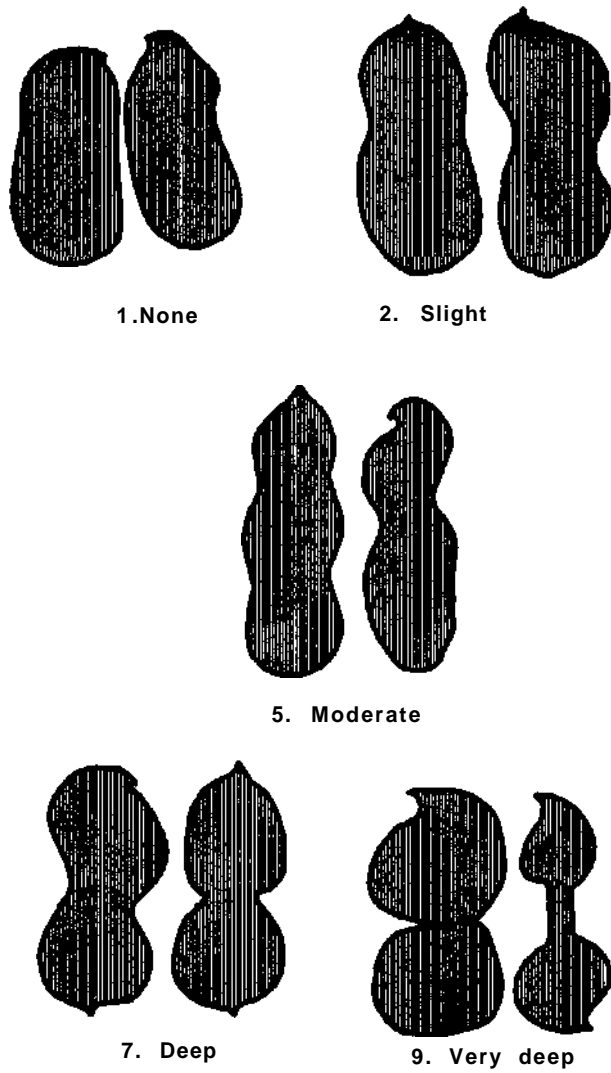
7. Prominent



9. Very prominent.

Figure 3. Pod beakness of groundnut (1-9 scale).
(Source: Anonymous 1981)





**Figure 4. Pod constrictions of groundnut (1-9 scale).
(Source: Anonymous 1981.)**



MP 2. Preparing Broadbeds-and-Furrows

Broadbeds and furrows are prepared by an animal-drawn ridger, mounted on a tool carrier (e.g., Tropicultor or Agribar), or by tractor-drawn implements with ridgers. Two ridgers may be fastened on a tool bar so that the top of the bed is 1.2 m wide and the distance from the center of one furrow to the center of the next furrow is 1.5 m. The depth of furrows should be 15 cm or more (Fig. 5). The broadbeds-and-furrows are to be prepared with a 0.6-0.8% graded slope. All furrows should end in an adequate drainage system.

To start making broadbeds-and-furrows, determine the slope of the field and lay out the keyline. Start by leaving a 30cm border in one corner of the field. Follow the keyline to the other end of the field and lift the tool bar before turning. Now place one wheel in the previous furrow and move back to the starting end of the field. Lift the tool bar again to turn and make another new broadbed-and-furrow. Repeat this process till all broadbed-and-furrows are completed in the field.

Bed cultivation before sowing can be completed by fitting a 1.2 m blade harrow with a ridger behind each wheel and fitting a heavy chain between the ridging plows. Machine sowing may be completed directly on the broadbeds. Hand sowing may be done by opening furrows on the broadbed (30 cm apart). To open furrows, four v-shaped (5 cm wide by 7.5 cm deep) openers (made of wood or angle irons) may be fitted on a wooden plank. The openers are adjusted to 30 cm between points. Seeds are sown at a distance of 8-10 cm in the row, depending on seed requirements for the desired population (MP 4).

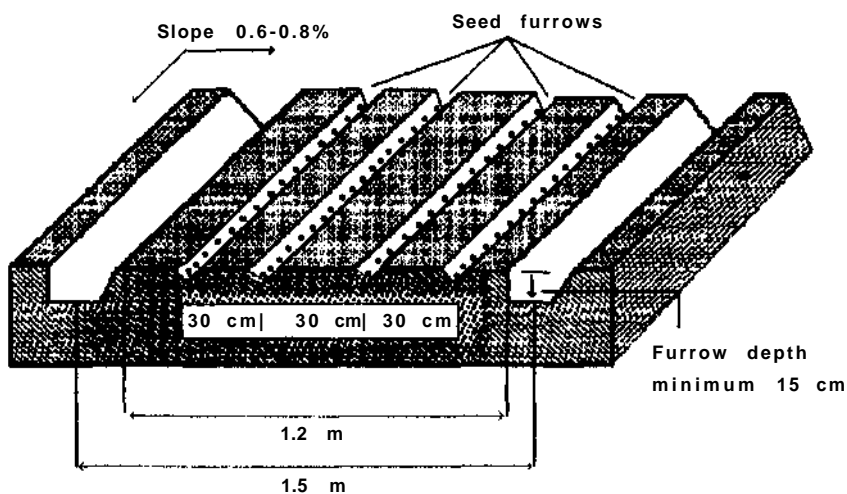


Figure 5. Cross-section of a broadbed-and-furrow system.



MP 3. Rhizobium Inoculation Procedures

Need for inoculation

Rhizobium or *Bradyrhizobium* inoculation is a cheap and effective way of providing nitrogen to legumes. Since the advantages of seed inoculation with *Rhizobium* in groundnut are not clearly established, it is necessary to assess the need for inoculation before undertaking this step (Nambiar 1990). In general *Rhizobium* inoculations are required under the following situations:

1. When groundnut is to be grown in a field where it has not been grown previously, *Rhizobium* inoculation may be effective in increasing pod yields.
2. In the fields where rhizobial populations are poor and nitrogenous fertilizers are not applied as basal dose for groundnut cultivation.

Several factors influence the success of *Rhizobium* inoculation and efficiency of nitrogen fixation; for example, different cropping systems such as intercropping with cereals causes reduction in nitrogen fixation by groundnut; deep sowing results in development of elongated hypocotyl, poor rooting, poor nodulation, and poor nitrogen fixation (Nambiar 1990).

Inoculation procedures

Bradyrhizobium population of 10^2 to 10^4 cells g^{-1} soil are usually detected in many soils; much higher rates or a minimum of 10^6 cells $seed^{-1}$ are needed for successful field inoculation (Nambiar 1990). Actually use of higher rates (10^6 - 10^8 cells $seed^{-1}$) for initial inoculations may help early establishment of the inoculant strain. Common inoculation procedures are:

Direct seed inoculation

a. *Seed coating with inoculum pastes.* The seeds are inoculated by directly coating the rhizobium (10^6 cells $seed^{-1}$). Seed inoculation is planned 48 hours prior to sowing. Before coating with *Rhizobium*, seeds may be moistened; or a paste of inoculum may be used. The carrier in the paste-like inoculum helps the rhizobial cells to stick to the seed. Jaggery or sugar solutions (10-15%) may be used as inoculum carriers.

Mix the inoculum and seed thoroughly. This should be done without handling the seed harshly. It is better to add half the required inoculum to the seed, mix and then add the second half and mix again. This will ensure black specks on each seed, indicating the presence of inoculum.

The amount of inoculum to be used is usually indicated on the container of most commercial products. Nine mL of slurry containing 4.4 g of peat inoculum per kg of seed has been suggested for seed of the size of soybean (Burton 1976).

b. *Pelleting.* Under this procedure the appropriate rhizobia are added to the seed at the factory or main distribution point. The seed is enclosed in a clump of lime or phosphate rock along with inoculum. This implies protection of the bacteria and seed, plus amelioration of adverse conditions in the soil adjacent to the seed.



Material used in this procedure are limestone or rock phosphate as a base with stickers such as gum-arabic (15% water solution) and methyl-ethyl-cellulose (1% solution). The procedure involves inoculation of seed using gum-arabic (40%) or methyl-ethyl-cellulose (50%); while the seed is still moist tumble it in an appropriate container with the chosen coating material like rock-phosphate or fine limestone powder (Meisner and Gross 1980).

Field inoculation

Nambiar and Dart (1982) prepared a granular inoculum for groundnut by mixing 70 g of peat containing *Rhizobium* with 800 mL of aqueous methyl cellulose (1.5% w/v), with subsequent addition of 5.5 kg washed river sand, until the sand was evenly coated with the peat. This mixture was air-dried for 8-12 h. One or two grams of this sand was placed below the seed before sowing to provide a minimum 10^6 rhizobial cells seed⁻¹.

Although the most common procedure of *Rhizobium* application is direct inoculation of seed, this causes problems for groundnut. Groundnut seeds are fragile and are often treated with fungicides (that may be toxic to *Rhizobium*), prior to sowing in order to control seedling diseases. When groundnut seeds coated with the *Rhizobium* strain NC 92 were treated with fungicides, the success of the strain in nodule formation was reduced (Nambiar 1990). Application of inoculum in the seed furrow in peat-based slurry form was found effective. Nambiar and Dart (1982) suggested mixing of peat in water (0.7 g L^{-1}) and pouring the mixture below the seed (4-5 mL seed⁻¹) into the furrow, to give a population of more than 10^6 rhizobial cells seed⁻¹.



MP 4. Determination of Seed Rate for a Given Plant Density

The seed is a major input in groundnut production. Therefore judicious use of seed requires careful calculation of seed required to ensure establishment of the desired plant population with minimum cost.

Seed rate depends on the row spacing, plant spacing (plants ha⁻¹), seed-mass, and percentage germination of the sample. In experiments, it may be desirable to increase the seed rate by 20% above the amount for the desired population of plants to ensure an adequate plant population.

Given: 100 seed mass = 32 g
Population: 333 000 plants ha⁻¹
100% germination

Find: Seed ha⁻¹ and 15 m² plot with eight 5 m rows.

Calculations:

$$\begin{aligned} 333\ 000\ \text{plants ha}^{-1} &= 33.3\ \text{seeds m}^{-2} \\ 32\ \text{g per 100 seeds} &= 0.32\ \text{g seed}^{-1} \\ \text{Thus } 33.3\ \text{seeds m}^{-2} \times 0.32\ \text{g seed}^{-1} &= 10.65\ \text{g seed m}^{-2}. \end{aligned}$$

or

$$\frac{10.65\ \text{g} \times 10\ 000\ \text{m}^2\ \text{ha}^{-1}}{1000\ \text{g kg}^{-1}} = 106.5\ \text{kg ha}^{-1}$$

Add 20% to meet unforeseen losses due to birds, insects, or diseases during germination.

$$106.5\ \text{kg ha}^{-1} + 20\% \text{ or } 106.5\ \text{kg ha}^{-1} \times 1.20 = 127.8\ \text{kg ha}^{-1}.$$

Seed plot⁻¹ equals:

If 10 000 m² requires 127.8 kg of seed then 1 m² requires:

$$\frac{127.8\ \text{kg} \times 1000\ \text{g kg}^{-1}}{10\ 000\ \text{m}^2} = 12.78\ \text{g m}^{-2}$$

A plot of 15 m² will require 12.78 g m² x 15 m² = 191.7 g.

Seed row⁻¹

The plot of eight rows requires 191.7 g.

Hence, one row requires:

$$\frac{191.7\ \text{g}}{8\ \text{rows}} = 23.96\ \text{g row}^{-1}$$



Answer: When the 100 seed mass is 32 g for 333 000 plants ha^{-1} with 100% germination and 20% oversowing, the seed requirement will be:

- a. 127.8 kg or 128 kg ha^{-1}
- b. 191.7 g or 192 g per plot with 15 m^2
- c. 23.96 g or 24 g per 5-m row x 30 cm (eight rows in 15 m^2).

Note: When the seed germination rate is known, the calculation needs adjustment to compensate for the dead seeds.

Example: A seed sample showed 80% germination, then the calculation for the above example will be:
(80 seeds will germinate out of 100 seeds)

$$\text{For 100 viable seed} = \frac{100 \times 100}{80} = 125 \text{ seeds should be sown.}$$

This means for each gram of seed, 1.25 will be the multiplying factor to compensate for 80% germination.

So the seed requirements in the above example will become:

- a. 128 kg ha^{-1} x 1.25 = 160 kg ha^{-1} .
- b. 192 g plot^{-1} x 1.25 = 240 g plot^{-1} .
- c. 24 g row^{-1} x 1.25 = 30 g row^{-1} .



MP 5. Seed Packeting and Arrangement for Sowing

The seed packet for each experimental row should be marked with row number, variety name, quantity of seed, and initials of the experimenter. When conducting a trial with six genotypes, four replications, and eight rows per plot, the following steps may be followed:

1. Prepare the field map and assign treatments at random to the plot in each block. Blocks (replication) could also be randomized.
2. Write the row numbers starting from the southwest corner and from left to right (Fig.6). When there are eight rows per plot and six plots per replication there will be 48 rows in each range and a total of 192 rows per experiment. The row numbers could be 101 to 148 for replication II, 149 to 196 for replication 1, 197 to 244 for replication IV, and 245 to 292 for replication III.
3. Mark the row number on each packet according to the field map (name of genotype, quantity of seed, and initials).
4. Separately calculate the amount of seed row^{-1} for each variety. Group the packets by genotype or quantity of seed in case of plant density trials. In this example there would be 32 packets of each genotype.
5. Now measure the required amount of seed for a genotype in each group of packets.
6. Arrange the seed packets, check row numbers, and temporarily fasten them as per the plots in the field map.

Arranging packets for sowing

When sowing by hand the numbered packet is placed at the beginning of each numbered row.

When sowing with a tractor-mounted seed drill (cone-drill machines that moves across the plots), the packets are arranged according to the number of rows sown by the machine and its direction of movement.

Example: An experiment consists of six genotypes with plots of eight rows and four replications to be sown with a four-row machine (Fig. 6).



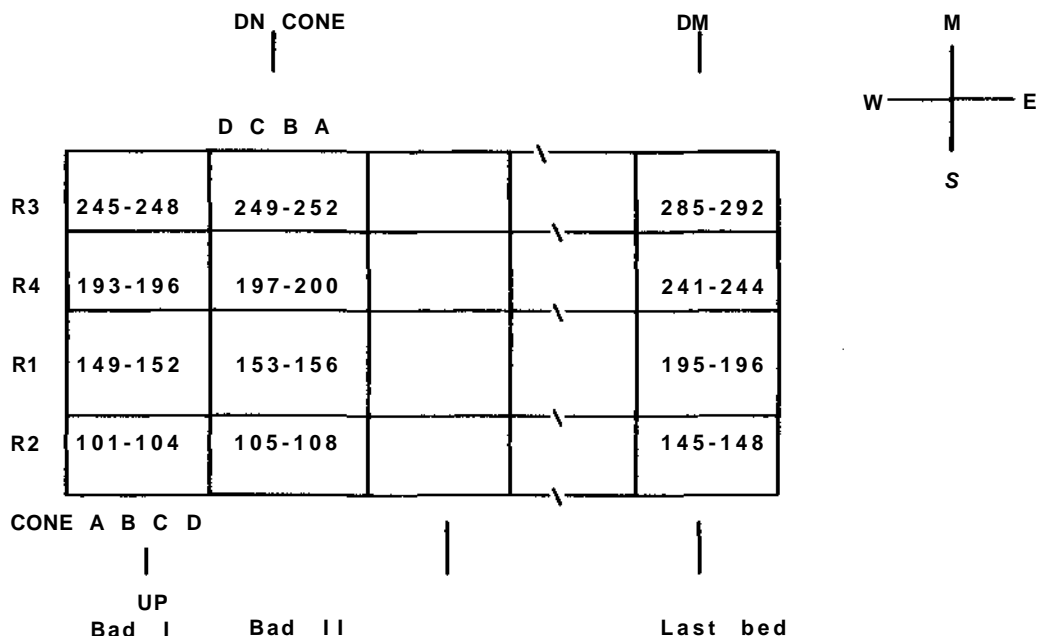


Figure 6. Packet arrangement for a four-row machine.

In this example, tie numbers 101, 149, 193, and 245 for the first machine row; 102, 150, 194, and 246 for 2nd row; 103, 151, 195, and 247 for 3rd row; and 104, 152, 196, and 248 for 4th row. These could be identified as machine rows A, B, C, and D. While returning (DN) fasten packets for rows 249, 197, 153, 105 for the 1st machine row; 250, 198, 154, and 106 for the 2nd; 251, 199, 155, and 107 for the 3rd; and 252, 200, 156, and 108 for the 4th row so that the correct seed is sown in the assigned plot. These could be assigned as E, F, G, and H, respectively.

Seed packets for the up (UP) direction can be arranged in one tray and the return (DN) direction in another tray to facilitate distribution. Keep the seed-packet trays at the starting side of the plots and at the point of turning for the reverse direction.

At the time of sowing pick up the bunches for A, B, C, and D together and give each to the person responsible for placing the packet contents in the cone for each row. At the turning point on the other end of the field, give the packets for the next four groups of rows (e.g., D, C, B, and A) for the order of sowing.

Care must be taken (by the persons operating the seed cones for sowing) not to disturb the sequence of packets while putting seed in the cones. Adjust the machine to fit the required row length and depth for precise sowing and compaction of the soil with seed.

MP 6. Measuring Soil Water Deficit and Irrigation Requirements

Soil water is measured with the help of a tensiometer. It consists of a plastic tube with a water-permeable ceramic cup at the bottom and a vacuum gauge at the top. When they are installed in the soil, water in the tensiometer and the soil water form a continuous film through the permeable tip (Fig. 7). When water is removed from the soil by evapotranspiration, a gradient is formed and water will permeate from the tensiometer into the soil to establish equilibrium. This will create a vacuum within the tensiometer that is measured by a gauge. The tensiometer vacuum gauge is calibrated in millibars or centibars so that soil water potential can be directly recorded.

A tensiometer should be installed at different depths to sample the rooting zone of a crop. Irrigation is given when the top soil reaches a soil water potential of -0.25 to -0.50 bars in order to replenish the soil water reservoir. Tensiometers installed in the subsoil indicate whether sufficient water is being applied by irrigation. For a large field, several instruments should be installed.

A frequent irrigation management strategy is to irrigate when the soil water in the 0-30 cm surface layer reaches a soil water depletion (SWD) characteristic of a given soil. Irrigation scheduling at 50% SWD is adequate in groundnut from "sowing to pegging" and at 25% SWD during "pegging to pod formation" and "pod formation to harvest" (Boote et al. 1982).

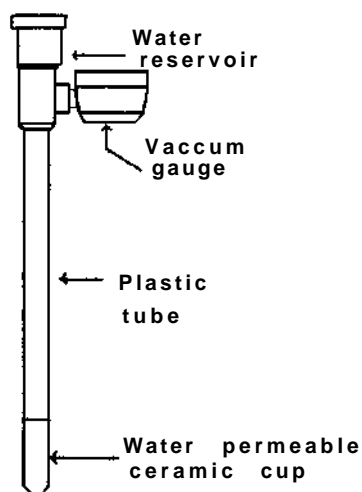


Figure 7. A vacuum-type tensiometer.
(Source: Boote et al. 1982.)



MP 7. Management of Weeds

Weeds in groundnut may be controlled by manual, mechanical, or chemical methods. However, a combination of methods could be more effective and economical. The most effective may be to apply a pre-emergence herbicide followed by one or two mechanical or hand weedings to keep the crop free of weeds after emergence.

Chemical control

A pre-emergence spray of a recommended herbicide (Table 5) provides effective control of weeds for the initial 2-3 weeks.

Table 5. Selected herbicides and recommended rates.

Herbicide scientific name	Trade name	Rate (a.i. kg ha ¹)	Time of application
Fluchloralin	Basalin [®]	1.25-1.50	Presowing incorporation into the soil
Nitrofen	Tok-E-25 [®]	1.50-2.00	Pre-emergence spray
Pendimethalin	Stomp [®]	0.60-1.50	-do-
Alachlor	Lasso [®]	1.50-2.00	-do-
Oxyflurofen	Goal [®]	0.25-0.50	-do-

A pre-emergence herbicide should be uniformly sprayed followed by a light sprinkler irrigation to facilitate uniform movement of the herbicide into the soil. When weeds are present at sowing it is recommended to mix Agrimine" (@ 1.5 kg a.i. ha⁻¹) with alachlor to kill them.

Mechanical or hand weeding

Weeds are manually controlled using a hoe, 'star weeder', or 'khurpi' within 1-3 weeks after crop emergence. When a wide row spacing is adopted, farmers may use a blade or 'Bakhar'. All manual weeding must be completed before the pegging stage (about 45 days after sowing). Further disturbance to the soil may damage the pegs and thereby reduce pod yield.



MP 8. Yield Estimation in Experiments and Demonstrations

Experimental plots

A recommended way to estimate yield of a plot or field is by using a circle with an area of 10 m² (Oswalt 1987). This eliminates the need to construct square corners to establish a rectangular area and it is easy to transport and set up the equipment in a farmer's field or small plot (Fig. 8a).

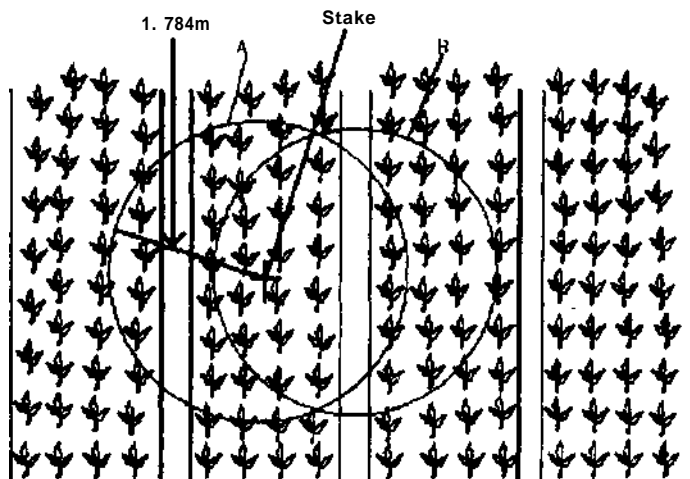


Figure 8a. Using a circle for outlining an area.

Materials

- A stake, equal to the crop height, to establish the center of a circle.
- A 1.784 m non-elastic cord or wire attached to the top of the stake.

Method

- Set the stake at a random location in the plot or field.
- Stretch the cord from the center of the stake. Count and harvest or record data for all plants with their main stem within the circle.
- Multiply the harvested yield by 1000 to estimate per hectare values.

Example: Number of plants harvested in 10 m² = 300.
Number of plants ha⁻¹ = 1000 x 300 = 300 000.
Pod yield in 10 m² = 2.5 kg.
Pod yield kg ha⁻¹ = 1000 x 2.5 = 2500.

Net plot determinations

The border effects in groundnut are negligible. Therefore, the net plot in experiments with rows of 5-m length (15 m^2) can be determined (Fig. 8b) by harvesting all eight rows leaving a 0.5m border on the end of each row.

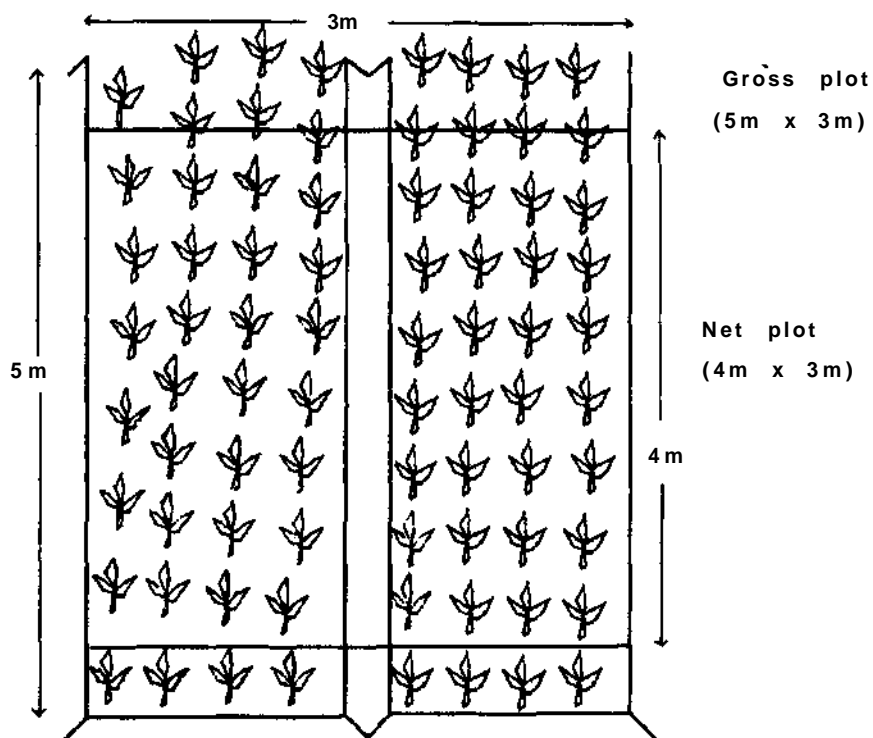


Figure 8b. Gross-plot and net-plot areas.



MP 9. Recording Morphological Characters

Days to emergence. Number of days counted from the date of sowing (irrigation or on first good rain if dry sowing is adopted) to the date when 80% of the seedlings emerge.

Days to 50% flowering. To record days to 50% flowering one should observe the crop every day when flower initiation starts and record the days after emergence when 50% of the plants have at least one flower.

Plant population (at harvest). Count of plants harvested in the net plot and expressed as population ha^{-1} .

Growth habit*. Scored on a 1-6 scale as illustrated in Figure 1.

Height of main axis (cm). Plant height is measured from the ground to top of the main axis (Fig. 9).

Number of primary branches. The branches directly emerging from the base of the main shoot are counted on five consecutive plants during harvest (Fig. 9).

Number of secondary branches. Branches arising from primary branches are counted on five consecutive plants during harvest (Fig. 9).

Number of nodes with pegs on primary branches. Count the nodes with pegs directly emerging from the base of main shoot and primary branches on five consecutive plants during harvest (Fig. 9).

Number of nodes with pegs on secondary branches. Count the nodes on secondary branches on five consecutive plants during harvest (Fig. 9).

Days to 75% maturity. This is determined by examining foliage, internal pericarp color, and color of pods (MP 10) and determining the number of days after emergence when 75% are mature.

Total number of pods plant^{-1} . The pods on five consecutive plants are counted during harvest to calculate the mean pods plant^{-1} .

Number of mature pods plant^{-1} . The mature pods on five consecutive plants are counted during harvest to calculate the mean number of mature pods plant^{-1} .

Total number of seeds plant^{-1} . The seeds from the pods of five consecutive plants are counted at harvest to calculate the mean kernels plant^{-1} .

Number of mature seeds plant^{-1} . The mature seeds from the pods of five consecutive plants are counted at harvest to calculate the mean seeds plant^{-1} .

Number of seeds pod^{-1} . Calculate the average number of seeds obtained from 10 randomly selected mature pods from five consecutive plants.



Seed color. The color of the seed (i.e., red, tan, dark red, brown or white) is recorded in the remarks column for identification purposes.

Net plot yield of pods (kg). From the net plot, mature pods are stripped, dried and cleaned, then yield is recorded in Kg plot⁻¹ nearest to the g.

100 seeds mass (g). A random sample of 100 seeds is taken from the harvested bulk and weighed to the nearest 0.01 g.

Shelling percentage. The mass of seeds obtained from the mass of pods that were randomly drawn from the bulk sample is used to calculate the shelling percentage.

$$\text{Shelling \%} = \frac{\text{Seed mass}}{\text{Pod mass}} \times 100$$

Example: Given pod mass = 50 g and seed mass = 30 g,

$$\text{then shelling (\%)} = \frac{30}{50} \times 100 = 60\%.$$

Reproductive efficiency of genotypes. This is based on the first five flowering nodes of the first-formed (N+1) branches as follows: The number of flowers are counted each day after initiation of flowering until the end of the reproductive phase on five selected plants.

$$a = \frac{\text{Number of pods} + \text{number of peas}}{\text{Number of flowers}} \times 100$$

$$b = \frac{\text{Number of pods}}{\text{Number of flowers}} \times 100$$

$$c = \frac{\text{Number of mature pods}}{\text{Number of flowers}} \times 100$$

a, b, and c indicate reproductive efficiency (%) measured at different stages of crop growth.

***Note:** These data need transformation for statistical analysis.



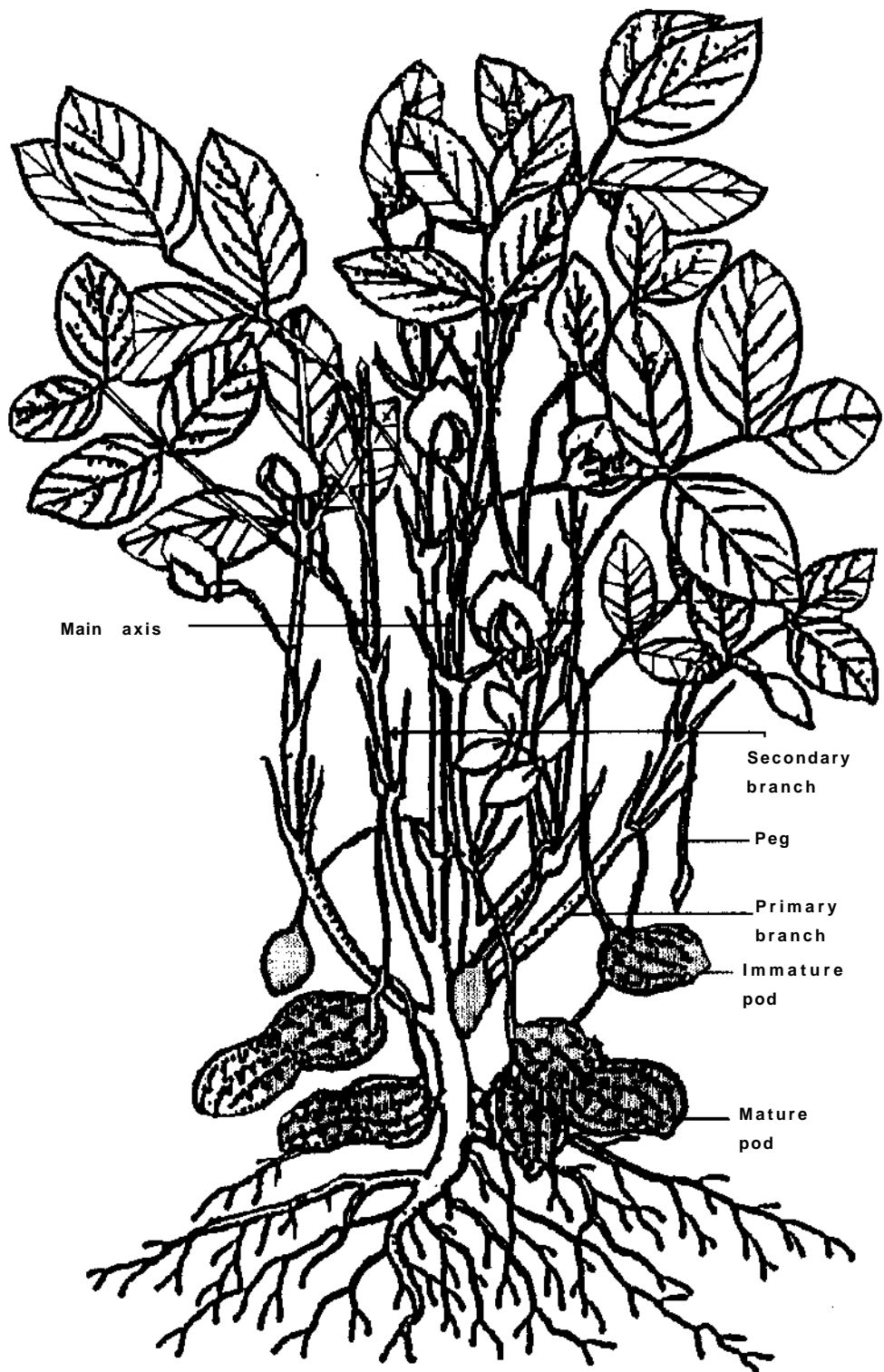


Figure 9. Illustration for recording observations.
(Source: Feakin 1973)

MP 10. Maturity Determination

The bunch varieties mature in 115-120 days. The semispreading and spreading varieties mature in 125-135 days. Some early types mature in around 90 days. The following symptoms reflect the stage of maturity:

1. Yellowing of foliage, and dropping of older leaves.
2. The mature pods become hard and tough. The inside shell surface becomes rough with visible net venation with a dark brown color.
3. The seed becomes smooth and the testa develops color typical of the variety.

Besides the above symptoms the following simple procedures can be useful for determining the maturity in groundnut (Sanders et al. 1982).

Shell out method. The pods of the groundnut from several plants in the field are picked and cracked or cut open to determine maturity. The percentage of pods with tan to brown color inside the hull and pink to dark pink seed coats is worked out. Harvesting is recommended when mature pods range from 60 to 80%, depending on the variety, presence of dormancy, and environmental factors.

Seed weight. The mean seed mass plant⁻¹ is determined to estimate the maturity at successive intervals. It reaches a constant value, when the crop is mature.

Example: Suppose 2-3 plants harvested on 3 November gave an average seed mass of 30 g, and others harvested on 4 November also gave the same mass, then the crop is mature.

Seed/hull ratios (maturity index). The ratios of seeds to hulls were found highly correlated with the various developmental stages of the physiological maturity index. All pods from plants selected for evaluation are removed, washed, towel-dried, and opened. Those pods at or beyond the maturity stage are characterized by cracks in the white internal pericarp. Such pods are separated into seed and hull. Less mature pods without such cracks are placed with the hulls. A fresh mass ratio (FMI) is determined by seed mass divided by the hull mass. The grouped kernels and hulls are forced air-dried or dried at room temperature to determine the dry mass ratio (DMI). When FMI or DMI of the two samples is constant, harvesting is recommended. After a variety attains 50% maturity a close monitoring is required to determine the date of harvest.



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Evaluation

Select the most appropriate answer.

1. The center of origin of groundnut is
 - a) Bolivia.
 - b) Brazil.
 - c) Northwestern Argentina.
 - d) USA.
2. Groundnuts are usually grown on a
 - a) poorly drained heavy soil.
 - b) well drained heavy soil.
 - c) poorly drained sandy loam or sandy clay soil.
 - d) well drained sandy loam or sandy clay soil.
3. Optimum pH suitable for groundnut cultivation ranges from
 - a) 5.5 to 6.5.
 - b) 6.5 to 7.0.
 - c) 7.5 to 8.5.
 - d) 8.5 to 9.0.
4. Heavy textured soils are suitable to grow
 - a) Spanish and runner types.
 - b) Virginia and runner types.
 - c) runner and Valencia types.
 - d) none of these.
5. Efficiency of nutrient utilization and reduction in soil-borne diseases in groundnut is possible through
 - a) heavy irrigation.
 - b) proper tillage.
 - c) weed control.
 - d) crop rotation.
6. A basal application of nitrogen (10 kg ha^{-1}) helps a groundnut plant to
 - a) meet its full nitrogen requirement.
 - b) meet its partial nitrogen requirement.
 - c) produce more nodules.
 - d) flower earlier.
7. Nodulation in groundnut starts _____ after germination,
 - a) 10 to 15 days
 - b) 15 to 20 days
 - c) 25 to 30 days
 - d) 40 to 60 days
8. Nitrogenous fertilizer recommended to groundnut for basal application is
 - a) urea.
 - b) ammonium sulphate,
 - c) diammonium phosphate.
 - d) organic manure.
9. Compared to cereals, legumes have a high requirement for
 - a) nitrogen.
 - b) phosphorus,
 - c) potassium.
 - d) zinc.
10. Calcium requirement in groundnut is highest at the
 - a) seedling stage.
 - b) flowering stage.
 - c) pod-filling stage.
 - d) time of maturity.
11. Groundnut pods directly absorb calcium from the soil at
 - a) the surface.
 - b) a 5-7 cm depth.
 - c) a 8-10 cm depth.
 - d) a 15-20 cm depth.



