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Technologies for Rabi and Summer Groundnut Cultivation

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Preface

Rabi/summer groundnut system with more or less assured irrigation has much higher productivity than the khafi groundnut. The average kharif groundnut productivity in the last decade was 800 kg ha-1, whereas it was 1500 kg ha-1 for rabi/summer groundnut. This system is also less prone to various stresses especially the bioatic stresses, including the aflatoxin production. Hence rabi/summer groundnut is more amenable to high-input agriculture with more assured returns. Moreover, there is a good potential of increasing area under rabi/summer groundnut especially in the residual moisture situations and paddy-fallows.

This publication summarizes and integrates the results of research and technologies developed for cultivation of rabi/summer groundnut in the research projects of All India Coordinated Research Project (Groundnut), Agricultural Universities, and National Research Centre for Groundnut. Authors have dealt with various problems of rabi/summer groundnut cultivation in the traditional and non-traditional groundnut growing areas including the North-Eastern regions, and proposed various remedies and future priorities. I hope this bulletin would help the extension workers, students and farmers in India.

Date: .May, 2001

(Dr A. Bandyopadhyay)
Director
National Research Centre for Groundnut

Contents

List of principal symbols and acronyms

CEC = Cation exchange capacity

$CaCl_2$ = Calcium chloride

CPE = Cumulative pan evaporation

DAS = Days after sowing

DOR = Directorate of Oilseeds Research, Hyderabad

EC = Electrical conductivity

FAO = Food and Agriculture Organization of United Nations

FYM = Farm yard manure

ha = Hectare

HPS = Hand picked selection (bold seed)

IAA = Indole acitic acid

IW = Irrigation water (to be given)

IPM = Intigrated pest management

Kg ha^{-1} =Kilogram per hectare

K_2O = Murate of potash

NRCG = National Research Centre for Groundnut, Junagadh

NAA = Naptheline acitic acid

NPK = Nitrogen, phosphorus and potassium

N = Nitrogen

PBDN = Peanut bud necrosis

PSM = Phosphorus solubilizing microorganism

SSP = Single super phosphate

VAM = Vsicular arbuscular mycorrhize

Introduction

In India, groundnut is cultivated in 7.1 million hectare (1999-2000) of which about 1.09 million hectare is cultivated in the rabi and summer seasons. The rabi (October-February) and summer (January-May) groundnut is usually grown either under irrigated or assured residual-soil-moisture conditions, gives almost double the yield (1621 kg ha^{-1}) of kharif (900 kg ha^{-1}) and large profits despite the high cost of production than the kharif season. Among the traditional groundnut growing areas, rabi/summer groundnut is grown in the states of Andhra Pradesh, Gujarat, Maharashtra, Karnataka, Orissa and Tamil Nadu under different agro-ecosystems. It is also grown in the non-traditional belt of West Bengal, Tripura, Assam and Manipur. In India rabi/summer groundnut is grown in four different ecosystems:

1. Summer-irrigated ecosystem
2. Rice-fallow ecosystem
3. Riverbed ecosystem
4. Spring-irrigated ecosystem

1. Summer-irrigated ecosystem

Summer groundnut is grown mainly in the six states of Andhra Pradesh, Gujarat, Maharashtra, Karnataka, Orissa and Tamil Nadu under irrigated conditions. Summer groundnut (bunch type) is generally sown from the first fortnight of January to the first fortnight of February. The farmers use to go for either dry sowing (with pre-sowing irrigation) or apply irrigation immediately after sowing. The maturity of the crop is often coinciding with the early rains, thus, resulting in pre-harvest sprouting of seed and deteriorating the quality of the produce. The summer groundnut is grown after pearl millet/sorghum in Maharashtra and sunflower in Karnataka.

2. Rice-fallow ecosystem

In Andhra Pradesh, Tamil Nadu, Karnataka and Orissa rice-fallow ecosystem occupies a major part. Because of shortage of irrigation water in the command areas of these states, of late, enterprising farmers have been utilizing rice fallows for growing groundnut. In rice based cropping system groundnut is grown either completely on residual moisture or with minimal supplemental irrigations. In the coastal belts of Orissa and West coast of North and South Kanara districts of Karnataka, groundnut is grown entirely on residual moisture throughout the growing period and does not receive any irrigation. However,

in the Konkan region of Maharashtra and rice fallows of Tamil Nadu and Andhra Pradesh, it is grown with irrigation. Among the non-traditional areas in West Bengal, Tripura and Manipur groundnut cultivation is gaining ground fast in rice fallows. Farmers of these states have been gradually adopting this sequence because of the problems of the rice-rice system like i) tillage problems because field remains wet throughout the year, ii) perpetuation of insect-pests particularly yellow stem borer of rice, iii) high water requirement (from 1800 mm to more than 2000 mm), and iv) depletion of nutrients like sulphur. For these reasons, productivity and profitability of the rice-rice cropping system has been declining. On the other hand including groundnut, a legume, in the rice based cropping system sustains crop production and even improves soil health, both inorganic and organic, breaks the build up of important insect-pests and pathogens, requires less number of irrigations and provides better nutritional and financial security. Sowing of groundnut depends on the harvest of rice hence, sowing is done from as early as October to as late as February. Again it is region specific, in Orissa sowing begins from October and continue upto February. In Karnataka the crop is sown during December to January. In the Konkan region of Maharashtra it is sown in the months of November and December.

3. Riverbed ecosystem

Cultivation of groundnut in riverbeds is common in Andhra Pradesh, Tamil Nadu, Karnataka and Orissa. In fact, because of deposition of silt due to occurrence of flood, almost every year, the riverbeds become ideal for groundnut cultivation under residual moisture situations. Sowing is usually done from September to October. Among the non-traditional areas, in Assam and Tripura, groundnut cultivation in riverbeds forms a major ecosystem.

4. Spring-irrigated ecosystem

Spring groundnut cultivation in Uttar Pradesh after harvest of potato or toria is done with irrigation in a very limited area. Spring groundnut after harvest of potato or toria is also gaining some ground in the Hooghly, Burdwan and Howrah districts of West Bengal without application of any fertilizer to the groundnut crop.

Analysis of present area and production

Decrease in area and production of rabi/summer groundnut in recent years has been observed. Area and production has decreased from 1.29 million hectare and 1.90 million tonnes (1992-93) to 1.09 million hectare and 1.77 million tonnes (1996-97), respectively. The yields, however, have shown an upward trend and increased from 1473 kg ha^{-1} in 1992-93 to 1621 Kg ha^{-1} in 1996-97. The area, production and productivity of rabi/summer groundnut in different states (mean of 5 years from 1992-93 to 1996-97) is as follows:

States	Area (million hectare)	Production (million tonnes)	Yield (kg ha^{-1})
Andhra Pradesh	0.375	0.573	1527.6
Gujarat	0.106	0.177	1674.5
Karnataka	0.214	0.270	1242.6
Maharashtra	0.126	0.184	1448.0
Orissa	0.048	0.054	1136.2
Tamil Nadu	0.284	0.571	2037.1
West Bengal	0.023	0.031	1297.4
Tripura	0.007	0.006	1500.1
Manipur	0.002	0.0021	1432
Others	0.009	0.0016	-
All India	1.180	1.858	1580.0

The highest area and production of post-rainy season groundnut is in Andhra Pradesh, but productivity is highest in Tamil Nadu. Almost in all the six traditional states, area (million ha) under post-rainy season groundnut has been fluctuating during the last five years as given below:

State	1992-93	1993-94	1994-95	1995-96	1996-97
Andhra Pradesh	0.410	0.424	0.358	0.337	0.346
Gujarat	0.122	0.101	0.133	0.088	0.091
Karnataka	0.231	0.257	0.240	0.185	0.162
Maharashtra	0.122	0.156	0.129	0.088	0.136
Tamil Nadu	0.336	0.302	0.291	0.220	0.270
Orissa	0.051	0.045	0.043	0.054	0.049

In fact, area under rabi/summer season groundnut in these states is highly related with the success of monsoon. In many areas in the years of erratic monsoon, the farmers prefer wheat/mustard to grow, as these crops require only 3-4 irrigations during the whole growth period. In contrast, in West Bengal, a non-traditional state of groundnut area has increased from 0.021 million ha (1992-93) to 0.035 million ha (1996-97). The reasons for increase in area of post-rainy groundnut here is the shift from boro-rice (winter-rice) to groundnut.

Major constraints

The major constraint is the inadequate research and development, specifically for the systems with high potential have received much less than the due attention. Ecosystem specific major constraints are as follows:

Summer-irrigated ecosystem

General

- Lack of cultivars with high water use efficiency
- Lack of fresh-seed dormancy in Spanish type as the harvesting of the crop often coincides with early rains and provide congenial environment for *in situ* sprouting of seed.
- Poor plant stand on account of quick loss of seed viability
- Lack of high and low temperature tolerance in groundnut cultivars
- High incidence of peanut bud necrosis, and foliar diseases
- Nutrient deficiency particularly iron-deficiency-chlorosis
- Lack of suitable moisture conservation measures, thus, high cost of cultivation due to more and frequent irrigation applied.

Specific

States	Major constraints
Andhra Pradesh	• Lack of improved Spanish cultivar • Lack of information on dates of appropriate sowing
Tamil Nadu	• Lack of fresh-seed dormancy in Spanish cultivar • Problem of leaf miner, rust and late leaf spot
Karnataka	• Quick loss of seed viability • Lack of early maturing Spanish cultivar • Lack of fresh-seed dormancy • Problem of leaf miner
Orissa	• Quick loss of seed viability • Calcium deficiency in soil • Excessive vegetative growth

Tripura	• Lack of photo-thermo-insensitive early maturing cultivar • Loss of seed viability • Excessive vegetative growth • Lack of supply of quality seed
West Bengal	• Lack of supply of quality seed

Rice-fallow ecosystem

- Release of land for groundnut is usually delayed due to long duration rice cultivars
- Difficulty in achieving good tilth due to short time available for land preparation after harvest of rice which results in poor plant stand
- Likelihood of low population of native *rhizobium* in rice fallow because of change of soil microclimate from anaerobic to aerobic
- Nutrient dynamics and soil flora in rice-fallow soil in relation to groundnut is not properly known
- Lack of cultivars specifically bred for rice-fallow cultivation
- Poor soil drainage
- Rapid loss of seed viability
- Excessive vegetative growth particularly in Tripura and the Konkan region of Maharashtra

Riverbed ecosystem

- Lack of early maturing cultivars
- Lack of cultivars having high water use efficiency
- Low nutrient status especially of calcium in soil
- Rapid loss of seed viability

Spring-irrigated ecosystem

- Lack of low and high temperature tolerant cultivars (with tolerance to cold at the early stage and high temperature tolerance at later stage of the crop growth)
- Lack of early maturing cultivars which fit in the cropping system
- Lack of cultivars having fresh-seed dormancy, hence many a time *in-situ* germination of seed takes place when the crop is caught in early monsoon.

Major Strategies

A. Components of all ecosystems

Management Practices

Some of the management practices like weed control, calcium and sulphur application, use of mulch, appropriate harvesting and drying methods and management of disease-pests are more or less common among all the four ecosystems. These components are discussed below in brief.

Weed control

Post-rainy season groundnut requires optimally about 60 days weed free condition. Weeds can effectively be controlled by the application of pendimethalin @ 1.0 kg ha^{-1}or alachlor @ 1.0 kg ha^{-1} or oxyflurofen @ 0.2 kg ha^{-1}. However, the effective weed control would be obtained when these herbicides are combined with one or two hand weedings at 25 and 45 days after sowing.

Calcium and sulphur requirements

Besides the major nutrients, N, P and K, calcium requirement of groundnut is quite high especially during pod-formation stage. It is required for the stabilization of newly synthesized membranes, in activation of a number of enzymes and is the major requirement for groundnut shell and pod development. The developing pod directly absorbs calcium from the soil. At least 40 kg Ca is required through out the crop season to provide at least 1 milli- equivalent exchangeable Ca 100 g^{-1} soil in the root zone and 3 meq 100 g^{-1} soil in pod formation zone. Sulphur is directly involved in the biosynthesis of oil and in the process of biological nitrogen fixation. Therefore, 30-40 kg of S ha^{-1} is required. Gypsum being cheaper may fulfill the requirement of Ca and S and 500-750 kg gypsum ha^{-1} is recommended depending upon soil conditions. Gypsum should be applied to the base of the plant or pod zone to facilitate Ca diffusion from soil solution to developing pods.

Moisture conservation

Soil moisture conservation is an important aspect to be given due attention looking into the water availability, quality and the cost of irrigation involved. Some of the components like mulch use of anti-transpirants and growth hormones and soil amendments can reduce the number of irrigations by conserving water either in the plant or in the soil.

Mulching: Research conducted at the NRCG showed that application of wheat-straw @ 5 t ha^{-1} on the soil surface minimizes the temperature fluctuation by raising soil temperature by 2-3°C at seedling stage and by lowering soil temperature by 3-5°C during pod development phase. This mulch can also reduce the number of irrigation by about 3-4. Groundnut crop under wheat straw mulch thus maintains good vigour and growth and ultimately gives high yield. Also the organic and micronutrient enrichment of soil due to the mulch should be kept in view. (Plate 4)
Mulch-wheat straw + criss cross, further improvement in soil moisture conservation and yield.

Anti-transpirant: Alachlor @ 20 ppm, sunguard 0.2% and Kaoline 3% spray as anti-transpirants are found effective maintaining higher relative water content in post-rainy season groundnut.

Growth hormones: With limited water supply, withdrawal of two irrigations during the early crop growth followed by spraying of 50 ppm Indole butyric acid (IBA) at 40 and 60 DAS is economical.

- Foliar spray of the combination of DAP 0.5%, $(NH_4)_2SO4$, 0.2%, boric acid 0.1% and NAA 40 ppm at 25 and 35 days after sowing can improve the relative water content in groundnut.

Soil-amendments: Application of coconut coir improves the available soil moisture before or after irrigation.

- Application of 3 t paddy husk or 3 t powdered groundnut shell reduce the bulk density of vertisol by 0.04-0.01 g/cc, reduce soil strength and improve the infiltration.
- Application of FYM, biogas slurry, green leaf manure improves the soil moisture status.

Diseases and Pest

The losses due to diseases and pests are comparatively much less in the post-rainy season than in the rainy season. However, the major insect-pests during post-rainy season groundnut yield are leaf miner, thrips, jassids, aphids, spodoptera and helicoverpa. Affecting among the diseases, collar rot and peanut bud necrosis diseases (PBND) are of common occurrence.

Insepct-pests

Thrips: Although considered a minor pest, its infestation results in higher incidence of a deadly disease the PBND. Spray of monocrotophous or dimethoate @ 0.05% is recommended for the control of this pest.

Aphids: Spray of monocrotophous or dimethoate @ 0.05% is recommended for the control of this pest.

Jassids: Jassid is an important pest and causes reduction in early crop growth. Spray of Monocrotophous or dimethoate @ 0.05% is the recommended for the control.

White grub: It is the major pest of groundnut in areas having light textured soils. In fact in the prospective spring groundnut belt it is important. They cause damage by feeding on the roots, the pest symptoms are realized on only after the plants dry. It can be controlled by seed treatment with chloropyriphos @ 1.25 l/100 kg seed. However, collection and later destruction of the larvae in and around the fields can effectively control this pest.

Diseases

Peanut bud necrosis disease: It is a viral disease transmitted by thrips. The disease is visualized by ring spots developed on leaves and browning/blackening of the vegetative buds resulting in severe yield losses. An early stage infection results in total yield loss while the late stage infection causes substantial yield losses. The cultural methods, timely sowing, closer spacing may help in reducing the disease incidence. The cultivars with some field resistance identified for this disease are reported in this bulletin elsewhere.

Collar rot: It is a soil-borne fungal disease causing death of the plants at the collar region. In severe cases even cultivation becomes difficult. Seed dressing with thirum @ 2 g or dithane M 45 @ 3g kg^{-1} of seeds has been found to be effective. All these chemicals are effective but cause environmental pollution. Thus, the more effective, less expensive and environmentally sound means of controlling these pests would be the use of resistant cultivars and use of the concept of Integrated Pest Management (IPM). Some of the components of IPM effective in controlling various pests are mentioned below though it must be made clear that the description of IPM would require more extensive discourse (Plate 5).

- 2-5% crude neem leaves extract at two weeks interval control the foliar diseases.
- Application of soil amendments like castor cake @ 1 tonne ha^{-1} and biopesticides like *Trichoderma viride* @ 25 kg ha^{-1} found to control stem and root rots.
- Pheromone traps are effective in proper monitoring of the pest population of leaf miner.
- Planting of castor, pearl millet and pigeonpea as trapcrops for Spodoptera and *helicoverpa*

Fresh seed dormancy

Seed dormancy in groundnut, whether a desirable or undesirable characteristic, depends mainly on the agronomical practices followed. In India groundnut is cultivated in three different seasons i.e. the rabi, summer, and rainy and prolonged seed dormancy is an undesirable character, however, a short period (10-15 days) dormancy is desirable. Untimely rains immediately prior to harvest can cause the seed of Spanish and Valencia types to sprout in the field while being intact with the plant (*in situ*), and losses in the yield and quality can be substantial. Field experiment on *in situ* sprouting of seed showed large genotypic variations in pod loss. Cultivars with low DI (≥10%) showed more pod loss than the cultivars with high DI. The cultivar SB XI did not show any *in situ* sprouting or pod loss, thus could be source of traits contributing to no pod loss due to in situ sprouting of seed. A direct relationship (r=0.86) between fresh seed germination in the laboratory and plants having percent sprouted seed in the field at the final harvest was found (Nautiyal et al. 2001).

Harvesting

Pre-mature or delayed harvesting affects quality and viability of seed apart from pod loss during harvest. Irrigation to the crop must be stopped before about at least 8-10 days of harvest to bring down the pod moisture level without, of course, any risk of pod loss in the soil in the process of uprooting. The crop may be mature when more than 75% of the pods show the black or the dark tannin colour on the inner part of the shell.

Curing and drying

Quick loss of seed viability is a serious problem in the rabi/summer season produce. If the pods are kept for seed purpose for the next rabi/summer season, proper drying and storage is required. At the time of harvest pods contain about 40-60% moisture. The rate of loss of moisture from the seed and temperature required for drying depends mainly on the weather conditions of a particular location. Under humid conditions, the rate of removal of seed moisture will be too slow and seed become more susceptible to fungal and micro flora also. If pods are exposed to direct sunlight the temperature of the pods may go as high as 42°C and seed membrane is damaged to lose its permeability, thereby, cause quick loss of seed viability.

DOR Method: Immediately after harvest equal sized heaps of preferably 1 m diameter can be made. A heap is placed over the other in an inverted manner i.e. pods of the lower heap up ward and pods of the upper heap down ward, so that the haulm of the upper heap protects the pods at the middle from the direct exposure of sun light. Seed obtained from the pods dried by this method retains viability for a longer period (6-8 months) as compared to the conventional (2-3 months) methods (Nautiyal and Zala 1991) (Plate 6).

Shade drying: Plants after harvest may be tied into small bundles, the bundles can be dried for 2-3 days under shade of trees or any other objects in an inverted position "Pods upward and haulm downward".

NRCG method: In this method a tripod type structure was erected by three bamboo poles (6 feet length) and groundnut plants immediately after were arranged on the rope tied over the structure in circular fashion. Plants were arranged in such a way that the pods of the bottom row get covered with the haulm of its upper row. This method of drying is very helpful in the region where rain showers are expected while curing/drying. Pods dried by this method retained seed germinability upto 80% even after 10 months of storage (Plate 7 and 8). The basic principle involved in this method to prolonging the viability of seed is to avoid high pod drying temperature and rain-water, if any, during the drying in the field (Nautiyal et al. 2001).

Storage

After drying the pods by any of the above method thorough drying of the produce can be judged by the following test:

- The pod should give rattling sound when shaken
- When a kernel is pressed between thumb and index finger it should easily split into two cotyledons

After thorough drying of the pods (5-6% moisture content) the produce meant for seed purpose should be stored in polythene-lined gunny bags, or polyethylene bags of 0.5 mm thickness, along with calcium chloride @ 250 g for a 30 kg pods in plastic container maintains the seed germinability about 80%, even after 10 months of storage (Nautiyal and Joshi 1989).

Cultivars: Some of the important cultivars suitable for various purposes are as follows:

Purpose	Name of the cultivar
High seed viability	TMV 2, RSHY 1, Jyoti, ICGS 44, S 206, SB XI, KRG 1, Girnar 1
Earliness (100-105 days)	TAG 24, TG 26, VRI 1, TG 26, TG 17, GG 2
High water use efficiency	Kadiri 3, ICGS 76, ICGV 86031, TAG 24, GG 2, ICGS 44, CSMG 84-1

B. Components special to each ecosystem

The scope of increasing area is limited; the strategies should be based more on increasing productivity. The strategies appropriate to the individual ecosystems on the basis of technologies available are discussed in this section. The strategies common to all the four ecosystems have been discussed in the section IV.

1. Summer-irrigated ecosystem

Management practices

Sowing period: Sowing of summer groundnut depends on prevailing air and soil temperatures. Therefore, sowing dates varies with location. The sowing date has to be chosen in such a way that favourable soil and air temperature prevail during the crop period. The minimum temperature in the top 10 cm soil should not be less than 18°C. The suggested sowing periods of groundnut for different states is as follows:

States	Sowing date
Maharashtra	Should not be beyond 30th January
Gujarat	First week of February
Andhra Pradesh	First week of December
Karnataka	Early December
Madhya Pradesh	December to end of January
Tamil Nadu	1st fortnight of April

Spacing and seed rate: In the summer season mostly bunch type are grown. In general, closer spacing and higher seed rate are required for summer groundnut to realize high yield, quality and profit. A spacing of 30 cm x 7.5 cm is suitable for the cultivation of groundnut in most of the states. However, a spacing of 22.5 cm x 10 cm is also recommended for sandy soil to establish a plant population of 4.4 lakh ha^{-1}. This closer spacing is optimum for the interception of solar energy and efficient use of water in pod zone. A seed rate of 125 kg ha^{-1} is optimum below which the consumptive use of water may increase due to higher evaporation rate at lower seed rate.

Seed hardening: Soaking of seeds with 0.5% $CaCl_2$ for 6 hours and then keeping the soaked seed in moist gunny bags for 24 hours followed by shade drying improves field emergence by overcoming the effects of low temperature and promotes accumulation of higher dry matter, deeper root system and thereby increase pod yield under water deficit condition.

Planting methods: The groundnut is generally sown in flat beds. Some of the improved methods give higher yield over the conventional method is discussed below:

i. **Criss-cross sowing:** Criss-cross sowing of groundnut can improve yield by about 18% as compared to conventional sowing by maintaining uniform distribution of seed and optimum number of plants/unit area. The seed rate used in this method is same as in conventional method. In this method, total seed lot is divided into two equal halves, first half of the seed is sown in one direction adopting 30 cm spacing between rows and then the remaining half in the perpendicular direction with the same spacing.

ii. **Broad-bed and furrow method:** This method is useful in areas having deep vertisol with high rainfall. This system consists of raised beds of 1.2 m width and 15 cm height with two furrows of 30 cm width on either side. Each raised bed would accommodate four rows with 30 cm spacing between rows. On an average 15% higher yield of groundnuts has been reported from the medium black soil over the flat bed or narrow bed and furrow methods. In Gujarat this method is not popular due to the non-availability of suitable implements for seed bed preparation and inter-culturing.

iii. **Furrow method:** Summer groundnut is generally sown on flat beds using a seed drill but sowing in furrow is more advantageous as it increases moisture recharges in the soil by collecting water for re-absorption and simultaneously increases water use efficiency by draining away excess water.

Nutrient management

Nutrient deficiencies are one of the reasons for low yields of groundnut. Visual symptoms of nutrient deficiency may not be always expressed. Thus, for obtaining high yield and high fertilizer-use efficiency, chemical analysis of plant and soil is the pre-requisite which allows

- Application of right quantity of nutrients
- Choice of right source of fertilizer, and application at the right time

In general, nitrogen, phosphorus and potassium requirement of summer groundnut is higher than the kharif groundnut because of better water management and high solar radiation interception. The recommended doses vary with region and soil type. NPK recommendation for different states is as follows:

State	N (kg ha^{-1})	P_2O_5 (kg ha^{-1})	K_2O (kg ha^{-1})	Soil types
Andhra Pradesh	30 25	40 30	50 30	Black soil (vertisol) Sandy loam soil
Gujarat	25	50	-	Medium black soil
Karnataka	40 25	75 75	25 37	Medium black soil Sandy soil
Maharashtra	50	50	0	Medium black soil
Tamil Nadu	17	34	54	Sandy loam to loamy sand with a single grain structure and deep
West Bengal	24	60	60	Sandy soil
Orissa				Red lateritic soil, acidic in nature, low CEC, high phosphate fixing capacity

Generally 10-12.5 tonnes of farmyard manure (FYM) per hectare is the recommendation for all the states, however, application of gypsum varies with the soil types. In Andhra Pradesh, Gujarat and Karnataka and application of 500 kg gypsum ha^{-1} and in Tamil Nadu 400 kg ha^{-1} are recommended whereas in West Bengal the recommended dose is 250 kg ha^{-1}. Application of gypsum in two splits, one as basal and other at 30 days after sowing is beneficial. In red and lateritic soils of Orissa application of 2 tonnes of lime was found useful. Some specific aspects of some nutrients, which are very important for achieving high fertilizer-use-efficiency, are given below:

Nitrogen: The deficiency symptoms are stunted growth and yellowish green foliage, yellowing first appears in the older leaves.

- Two split applications of N, half at sowing and half at 25-30 days after sowing are better than single dressing, particularly in light soils.
- Combination of nitrate and ammonium forms of N gives a better result than a single form. During the reproductive stage, groundnut prefers ammonium form since at this stage it is directly available for protein synthesis.
- Foliar application of N in the form of urea (2%) in few splits during 4-6 weeks of crop growth improve groundnut yield in light soils.
- When low doses of N fertilizer are used, it is better as a side dressing in the row but at higher doses, method of application has little effect.

Phosphorus: The phosphorus deficiency symptoms are, bluish green to dark green colour of the older leaves, which further turns to bronze tinted and red colours.

- Summer groundnut may respond upto 120 kg P_2O_5. In the soil where available P is 11 kg it responds to 120 kg applied P_2O_5 but when the availability is 11-22 kg, the response is upto 60 kg. Groundnut may be grown even with soils of low P status if inoculated with Vsicular Arbuscular Mycorrhizae (VAM) and Phosphate Solubilizing Microorganisms (PSM) especially if the pH is non-acidic.
- Single superphosphate (SSP) is a more efficient source of P fertilizer because it contains Ca (19.5%), S (12.5%), traces of Zn and Mg in addition to P_2O_5 (16%) of which more than 90% is water soluble P. Calcium is important for pod formation and sulphur for oil biosynthesis.
- It should be applied before sowing, by placement.
- It can also be used in foliar spray and should be placed close to the root zone so that it becomes readily available to the root.

Potassium: Chlorosis along the leaf margin, scorching and browning of tip of older leaf are the peculiar deficiency symptoms of potassium.

- Although a general recommendation is yet to come, its application has been reported to impart general resistance to the crop to biotic and abiotic stresses, improves the pod filling and quality and thus, increases the groundnut yield.
- The ratio of K:Ca:Mg is more important than total amount of any of them. In soils rich in K, groundnut absorbs more K than needed and known as luxury consumption. This phenomenon upsets K:Ca:Mg ratio and pod filling gets affected. Thus, K should not be applied unless available K is less than 150 kg ha^{-1}.
- Potassium sulphate is a better fertilizer than potassium chloride as it contains S (18%). Moreover, the S ions are retained by the soil more strongly than chloride particularly in soil with high Ca content. Thus, application of potassium sulphate will be more appropriate in calcareous and alkaline soils. Under wet condition also it is better to apply potassium sulphate than the potassium chloride, as leaching loss will be less. It is also more effective in light soils.
- Entire quantity of K fertilizer may be applied in the soil prior to or at the time of sowing by adopting furrow method since it is not a mobile nutrient.

Iron: The deficiency of iron causes inter-veinal chlorosis of young leaves but the veins remain green. In severe cases the leaves become almost pate-white.

- Summer groundnut is highly susceptible to Fe deficiency. Iron chlorosis in groundnut has been reported from all major groundnut growing areas, especially

in the areas with calcareous soil (black soil) having free carbonates and bicarbonates. Three sprays of 0.5% $FeSO_4$ + 0.1% citric acid solution or 2% ferric citrate at 25, 40 and 75 days after sowing reduce the Fe chlorosis. Single superphosphate is more effective than DAP in improving Fe nutrition and chlorophyll synthesis. The amelioration of chlorosis with SSP than DAP indicates a role of S in preventing inactivation of Fe, possibly caused by excessive P accumulation. About 10 ppm indole acetic acid (IAA) foliar spray also tends to improve Fe nutrition. Foliar spray of 0.2% citric acid also controls Fe chlorosis to some extent.

Zinc: Due to zinc deficiency the top portion of the young leaflet becomes dark green but the middle and bottom portions remain light green. Bleached spots, chlorotic bands on either side of the mid-rib and brown yellow hollow heart of the seedlings are also the typical symptoms of the zinc deficiency.

- Zinc deficiency is common in the Saurashtra region of Gujarat and in the sandy soils of Andhra Pradesh and Tamil Nadu. Application of about 15-20 kg $ZnSO_4$ to soil or two sprays of 0.5% $ZnSO_4$ + 0.25% lime at 40 and 60 days after sowing corrects the Zn deficiency.

Aluminium toxicity: Aluminium (Al) and Manganese (Mn) toxicities are major deficiencies symptoms in the acid soils. On many acid soils high concentration of Al is harmful to plants especially to root growth. Root tips and lateral roots become thick and turn brown. Whereas the symptoms in the foliage are often similar to phosphorous deficiency as it affects the phosphate uptake and translocation also. The application of lime has been found to be the most effective means of controlling Al toxicity in acid soils. In general 2-4 tonnes lime per hectare depending upon the intensity of the acidity should be applied one month before sowing. Attention is also required towards the screening of genetic materials for tolerance to Al and Mn toxicity.

Water management

Water is no more a luxury and the increasing global demand for oilseeds and other agricultural products calls for urgent measures to increase water use efficiency which is, with plant nutrient avability, one of the two main limiting factors in crop production. In May 1990, FAO organized a consultation of experts and researchers in collaboration with the International Commission for Irrigation and Drainage and with the world meteorological Organisation, to review the FAO methodologies on crop water requirements and to advise on the revision and update of procedures. The panel of experts recommended the adoption of the Penman-Monteith combination method as a

new standard for reference evapotranspiration and advised on procedures for calculating the various parameters (FAO, 1998). In irrigation scheduling a climatologically approach based on IW/CPE ratio (Irrigation water/cumulative pan evaporation) was found appropriate. This approach is taken into account, all the weather parameters that determine the water use by the crop and may increase the water use efficiency. Total water use by the groundnut crop is controlled by climate, agronomic, and varietal factors. Water use by the groundnut crop in different cropping season in different parts of the world varies between 250 mm under rainfed conditions (Angus et al. 1983) to 831 mm under irrigated conditions in rabi/summer seasons. In general, summer groundnut requires 8-18 irrigation based on location and soil types. Groundnut pod yields was increased by imposing a transient soil-moisture-deficit stress in the vegetative phase for 25 days, followed by two irrigations at an interval of 5 days. Thus stress in the vegetative phase was found beneficial for groundnut growth and pod yields, but was highly detrimental when imposed at flowering and pod development (Nautiyal et al. 1999). Imposing a drought of 20 days after sowing followed by releasing water stress helps in the early development of deeper root system, synchronized flowering, higher biomass production and higher harvest index.

Some of the important methods of scheduling irrigations are discussed below:

- In irrigation schedule a climatologically approach based on IW (Irrigation water)/ CPE (cumulative pan evaporation) ratio is the most appropriate. This approach takes into account all the weather parameters that determine the water use by the crop and is likely to increase the productivity. Irrigation at 0.5 IW/CPE from 10-40 DAS and 0.75 ratio from 40 DAS to harvest is essential to ensure good nodulation and higher pod yield in summer groundnut. Further, the soil and irrigation water-use efficiency decreases when irrigation scheduling is done beyond 1.0 IW/CPE ratio. Though it is a simple method, the field level adoption by the farmers is poor. The extension agencies need to advocate this system by their sincere efforts either through field demonstrations or through organizing farmers' trainings so that the limited water is used more efficiently and economically.
- The method of irrigation is also important. For example, the border strip method is the most common surface irrigation method. But, this method causes water loss (through percolation beyond the reach of root zone) to the tune of 27-42%. Therefore, the feasibility of minimum irrigation through the use of sprinkler irrigation system should be explored since water requirement in this system is about 33% less, maintains high water use efficiency and less consumptive use of water than the border strip or check basin methods. However, this method requires high initial cost and the grass root adoption in large scale has to be fine-tuned.

Therefore, the subsidies now available for the purpose of these systems should be fully explored by the groundnut farmers.

Resources management through intercropping

Unlike in Kharif season groundnut, intercropping of groundnut in the summer season is not a common practice. But some of the recent observations obtained from experiments conducted at the NRCG and elsewhere are as follows:

With vegetables: Coriander and fenugreek, as leafy vegetables, could successfully be grown as intercrops (harvested in 30-35 days) between two rows of groundnut spaced at 30 cm without putting any additional inputs without affecting groundnut yield. Both vegetables and groundnut can be sown simultaneously. It may be noted that only necessary plant protection, irrigation, fertilizer and other management practices for groundnut crop was sufficient. A high return from groundnut and chilli intercropping has also been reported at Dharwad in the state of Karnataka. The concept can be tested with different vegetables in different regions (Plate 1, 2 and 3).

With cereal fodder: Summer groundnut is generally irrigated through border strip method where 3-4 lines of groundnut are maintained in each strip. Trials conducted at the NRCG indicated that growing bajra on the bunds of border strips along with summer groundnut would provide an additional income of upto Rs.10,00,0 ha-1 to the farmers by supplying upto 16.5 tonnes of green fodder from two cuttings during the lean period. It may be noted that necessary plant protection, irrigation, fertilizer and other management practices have to be taken for groundnut crop only. Only recommended nitrogen dose (80 kg N ha^{-1}) has to be applied to fodder.

Cultivars: All the cultivars released for commercial cultivation during the kharif season may not necessarily be suitable for post-rainy cultivation. Usually Spanish bunch groundnut cultivars are grown during the summer season. However, early Virginia bunch cultivars may be tried. If successful they will be an insurance against in situ germination due to early monsoon rains. The popular cultivars either bred specifically for summer or suitable for summer season are listed below.

Cultivar	Suitable for regions	Salient features
TG 17	Maharashtra	Fresh-seed dormancy upto 4 weeks high harvest index
UF 70-103	Vidarbha and W. Maharashtra	-
AK 12-24	Orissa	-
Kadiri 3	Marathwada region	Resistant to peanut bud necrosis disease
KRG 1	Raichur, Bellary and Gulberga district of Karnataka	Medium sized, 2 seeded
VRI 1	Tamil Nadu	Fresh-seed dormancy for a week
VRI 2	Tamil Nadu	-do-
TG 26	Gujarat, Andhra Pradesh, N. Maharashtra	Earliness (100 days) and fresh seed dormancy (20 days)
ICGS 11	Andhra Pradesh, Maharashtra, Karnataka	Tolerant of peanut bud necrosis disease
TAG 24	Maharashtra	Earlier, tolerant of peanut bud necrosis disease
ICGS 44	Gujarat, N.Maharashtra, Andhra Pradesh, Tamil Nadu	Tolerant of peanut bud necrosis disease
ICGS 37	Gujarat, N.Maharashtra, Andhra Pradesh, Tamil Nadu	-
BSR 1	Tamil Nadu	Fresh-seed dormancy for 21 days suitable for summer cultivation

Increasing area

- Groundnut can successfully be taken as an intercrop with the plantation crops. In the southern states, it can be taken as an intercrop in plantation or wise spaced crops like cassava, banana and coconut while in the eastern states it can be raised with citrus and pineapple. It has been estimated that about 45 million hectare area available with wide spaced crops can efficiently be utilized by taking groundnut as an intercrop.
- In the Akola region of Maharashtra and in some parts of Gujarat, Bihar and Tamil Nadu, spring planting of sugarcane called "saru" sugarcane is common. Initial growth of sugarcae is very slow. Therefore, in between wide spaced rows of sugarcane, 2 rows of groundnut spaced at 30 cm x 15 cm may be planted. This

will not only increase area under groundnut but also provide higher net return. In this case single budded sets of sugarcane is better than three budded sets.

- In the Dharwad region of Karnataka, where sunflower is grown round the year, intercropping of summer groundnut in the four rows of sunflower one row of groundnut is common, and groundnut plant population of 75% of the sole groundnut may be attempted.

2. Rice-fallow ecosystem

Management Practices

Tillage: Preparing the soil, after the harvest of rice, to obtain a good seedbed is a problem in some areas. The soil does not dry thoroughly and ploughing is done only once or twice. The high soil moisture content leads to cloddy seedbed, poor germination and thereby low plant population. Seedbed preparation with a tractor dawn plough and followed by a rotavator is better than conventional tillage (ploughing twice with a country made plough) in rice fallows. The roto tiller is suitable for light texture soil due to its low cost.

Zero tillage: Wherever groundnut is grown in rice fallows, left over rice straw as such may act as organic mulch and zero tillage can be tried by dibbling groundnut seed at 20 cm x 20 cm spacing. Many times direct incorporation of straw in soil leads to decrease in crop yield due to production of microbial phytotoxin and immobilization of available N in decomposing microbes. Therefore, the rice straw must be supplemented with Trichoderma viride @ 2.5 kg ha-1 immediately after harvest of rice along with additional 20 kg N so that the straw is degraded before the planting of groundnut. It may be noted that a turn around period of 30-35 days between harvest of rice and sowing of groundnut is required to ensure proper decomposition of rice straw.

Planting methods: Since optimum plant density of groundnut in paddy fallows is one of the major problems, suitable planting technique is needed to maintain the optimum plant stand.

- Criss-cross method: Bi-directional sowing of groundnut with 20 cm x 20 cm spacing or 30 cm x 30 cm is found suitable in rice fallows to provide optimum plant stand.
- Broad-bed and furrow method: In Konkan region of Maharashtra broad-bed and furrow method of planting is recommended in rice fallows.

Nutrient management

- Groundnut grown in rice fallows responds to high NPK. It responded upto 60 kg N and 90 kg P_2O_5 ha^{-1} in the light soils in Andhra Pradesh; up to 51 kg P_2O_5

and 68 kg K_2O Tamil Nadu; 25 kg N, 72 kg P_2O_5 and 37.5 kg K_2O in the coastal sandy soil of Karnataka, and 24 kg N, 60 kg P_2O_5 and 60 kg K_2O in sandy loam soil of West Bengal. The high response to fertilizer in rice fallows possibly due to the adverse soil physical environment in the rhizosphere caused by the flooding in rice field.

- Application of 7.5 tonnes FYM ha^{-1} is needed to realize optimum yield of groundnut in rice fallows.
- Acid soil of coastal Karnataka, Tamil Nadu, Andhra Pradesh, red lateristic soils of Orissa and West Bengal where groundnut follows rice, pH ranges from 5.1 to 6.4. In these soils, response of groundnut to liming is high up to 2 tonnes ha^{-1}. In the absence of lime, a mixture of single superphosphate (SSP) and rock phosphate (RP) (1:2) appeared to be the most economical.
- In rice fallows, response of groundnut to S is high. Sulphur from gypsum has no effect on rice during kharif but has significant effect on groundnut in rice fallows. Generally, 500 kg gypsum, ½ as basal and ½ at flowering advocated. Seed palliating of 2 g elemental S kg^{-1} seed and 45 kg S ha^{-1} at flowering is equivalent to gypsum application.
- Application of DAP to either rice or groundnut even if, gypsum is added to any one of the crops.
- When groundnut succeeds rice, it is essential to treat the seed with rhizobium as the native rhizobia may get destroyed due to anaerobic condition in flooded rice soil. Rhizobium inoculum without adequate P application, however, is not beneficial.
- Since Molybdenum is a costly input, its seed dressing @ 0.4 kg ammonium molybdate/kg seed of groundnut is effective and economical in rice fallows.
- Acid paddy soils are also deficient in boron. Borax @ 2.5 -5 kg/ha as soil application at 40 days after sowing or 0.5% spray at 50 days after sowing is recommended to correct the deficiency.
- Proper nitrogen management may be required for optimum vegetative growth of groundnut grown in rice fallows. Again it is cultivar specific, for example in the medium black soil of North Konkan areas, the recommended doses of 25 kg N and 50 kg P_2O_5 led to excessive vegetative growth in SB XI and ICGS 1 but not in the cultivars like UF 7013 and JL 24. Excess growth in SB XI and ICGS 1 did not occur when they received 12.5 kg N and 50 kg P_2O_5 and zero N and 50 kg P_2O_5 ha^{-1}, respectively.

Cultivars suitable for residual soil moisture in rice fallows recommended for different locations are as follows:

Cultivars	Suitable areas
R 8804, DRG 12, ICGS 11 (102-109 days)	Rice fallow in Orissa
ICGS 5, TG 23, ICGS 11 (105 days)	Sand loam soil of West Bengal in rice fallows
VRI 3	Rice fallow of Tamil Nadu
ICGS 44, ICGS 5	Rice fallow of Tripura

Possibilities of increasing area

In the traditional belts, growing groundnut as the second crop after rice epecially in the southern states like Tamil Nadu, Karnataka, Andhra Pradesh and Orissa is expected to give a tremendous boost to the production of groundnut in the country in the immediate future. The returns from rice-groundnut sequence are higher (Rs.23, 08, 7 ha^{-1}) than rice-rice sequence (Rs.13, 19, 5). Diversion of area from high water duty crops to low water duty crops is needed where availability of water is uncertain. Winter rice in the irrigation command areas of these states quality for such diversion and groundnut is a potential replacement. It may be noted that replacement of winter rice may not be feasible unless groundnut yield is 2.5 - 3.0 tonnes to compensate for replaced rice crop even though it improves the soil fertility.

- A part of the future demand may also be met by increasing area under groundnut in non-traditional belt. It is estimated that in Tripura about 8,000 ha area in the riverbeds could be brought under groundnut cultivation simply by installing deep tube wells. In West Bengal about 7 lakhs ha can be brought under groundnut mainly in paddy fallows for which a strong extension wing should work to make the farmer aware of the profitability of the system and supply of quality seed is assured. Similarly, in Manipur about 20,000 ha area could be brought under groundnut cultivation, provided marketing facilities are assured.

3. Riverbed ecosystem

Management approaches

- Identification of cultivars with early vigour and rapid canopy cover to check evaporation and to ensure crop growth under residual soil moisture conditions.
- The cultivar should be early maturing so as to escape late season drought.
- Establishment of small farm reservoirs for water harvesting e.g. Khadin system followed in Rajasthan, so that necessary protective irrigation may be given.

- Riverbeds may prove to be ideal for the cultivation of bold-seeded (HPS) groundnuts because good fertility from deposition of silt due to occurrence of flood, almost every year and light textured soil. Thus, identification of suitable bold-seeded groundnut cultivar will be of prime importance.

The cultivars recommended for different locations for this ecosystem area as follows

Cultivars	Suitable areas
ICGS 44, J 11	Coastal region of Mahandi delta
RSHY 1	Coastal belt of Andhra Pradesh
ICGS 44, ICGS 5	River bed of Tripura

4. Spring Irrigated ecosystem

Management approaches

- Use of locally available organic mulch specially in this system will be useful
- Sowing of groundnut cultivars tolerant to cold and high temperature from the second fortnight of February to the first fortnight of March.
- Maximum benefit can be obtained when seed is sown in furrows with 45 cm x 10 cm spacing.
- It has been reported that first irrigation after germination can be delayed to the time of flower initiation followed by irrigation at cumulative pan evaporation (CPE) of around 60 mm until the onset of monsoon.
- Need of short duration groundnut cultivar maturing in 100-105 days so that the crop can be harvested before the onset of the monsoon.

Cultivars: The following cultivars are found suitable for spring season

Cultivars	Suitable for specific environmental conditions
ICGS 1, SG 84	Uttar Pradesh (after the harvesting of Toria)
TG 23, ICGS 65, ICGS 11 (100-105 days)	West Bengal (after the harvesting of potato/toria)
GG 2, Dh 3-30, ICGS 11, Dh 39, Kadiri 3, GG 11	Salinity tolerant (EC 4-8 ds/ml)
R 8806, R 9021	Moderately tolerance to salinity (EC 4-8 ds/ml)
Girnar 1	Cold tolerant

Possibilities of increasing area

In the command area of the Indira Gandhi Nahar Pariyojana of Rajasthan, characterized by high temperature (up to 55°C) during summer, about 2-3 lakhs hectare land area can be brought under rabi groundnut cultivation. The crop at present in these areas is sown in the month of April and harvested in the months of September-October and requires frequent irrigations at every 5-8 days interval (30-31 irrigations in all). This is leading to the gradual development of soil salinity. An alternative way is the advancement of the sowing date to early February with cold tolerant cultivars so that the crop gets early establishment and is escapes the adverse effects of high temperature at pod development stage in May-June. This will also help in reducing the number of irrigations because of the shortening of total crop duration. However, suitable cold tolerant cultivars are yet to be developed.

Future prospects

The future of groundnut appears to lies in its use as food rather than oil. With the changing agro-socio economic situation in the country, export of groundnut and its products have a very bright future. HPS groundnut is traditionally an export earner. HPS has to be treated as a high value crop to be grown in identified areas under high inputs and assured moisture. It has been found that in very light soils (sandy or sandy loam) in the area such as Hanumangarh in Rajasthan with assured irrigation from Indira Gandhi Canal and Kutch area of Gujarat, the expression of bold seeded groundnut is excellent. A proper tie up with the industry, the marketers and the exporters will be required. A contact farming approach will possibly be thought of, in which scientists, exporters, and identified farmers can form a contractual group. The exporter group may even participate in a system where quality seeds of exportable groundnut cultivars can be produced, distributed, at a accelerated speed under the guidance of qualified scientists.

REFRENCES

Angus, J.F., Hasegewa, S., Hsiao, Liboon, S.P., amd Zandstra, H.G., 1983. The water balance of post-monsoonal dry land crops. Journal of Agricultural Science (UK) 101: 699-710.

FAO, 1998. Crop evaporation, guidelines for computing crop water requirements. FAO irrigation and drainage paper No. 56.

Nautiyal, P.C., and Y.C.Joshi, 1989. Storage of rabi/summer groundnut (*Arachis hypogaea* L.) with calcium chloride for prolonged seed viability and vigour. Trop. Sci. 31, 21-26.

Nautiyal, P.C., and P.V.Zala, 1991. Effect of drying methods on seed viability and seedling vigour in Spanish groundnut. Seed Sci. Tech., 19, 451-459.

Nautiyal, P.C., V.Ravindra, P.V.Zala, and Y.C.Joshi, 1999. Enhancement of yield in groundnut following the imposition of transient soil-moisture-deficit stress during the vegetative phase. Experimental Agriculture, 35: 371-385.

Nautiyal, P.C., Y.C.Joshi, and Devi Dayal, 2001. Response of groundnut to deficit irrigation during the vegetative phase., FAO and IAEA collaborative publication, a booklet on different aspects of "Deficit Irrigation Practices" (In press).

Nautiyal, P.C., A. Bandyopadhyay, and P. V. Zala, 2001. In situ sprouting and regulation of fresh seed dormancy in Spanish type groundnut (*Arachis hypogaea* L.). Field crop research 70:233-241.

Nautiyal, P.C., V.Ravindra, and P.V. Zala, 2001. A new method for drying of groundnut pods for better seed viability. International Arachis Newsletter (ICRISAT) (in press).

Plate 1: Intercropping of groundnut with Spinach

Plate 2. Intercropping of groundnut with fenugreek

Plate 3. Intercropping of groundnut with sunflower

Plate 4. Application of wheat-straw mulch after groundnut sowing

Plate 5. Integrated pest management in groundnut

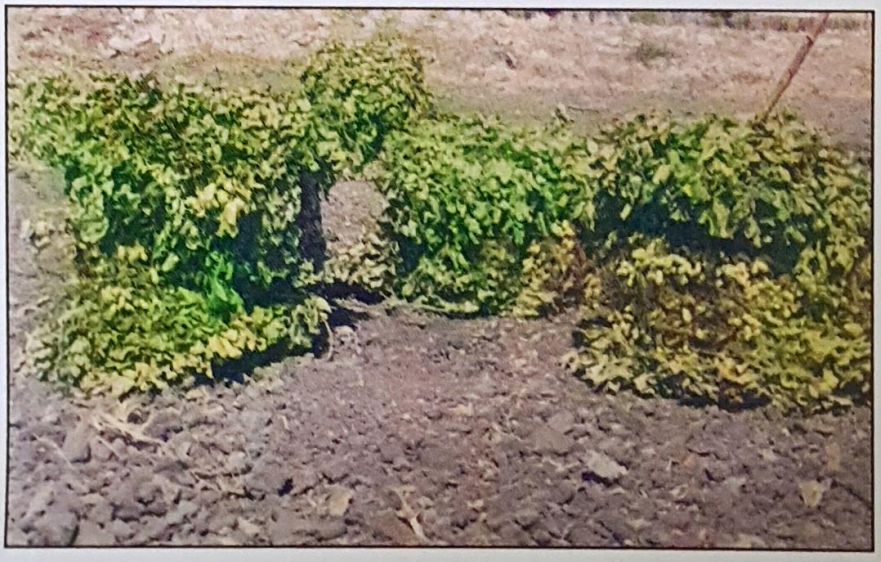

Plate 6. DOR method of drying of groundnut pods

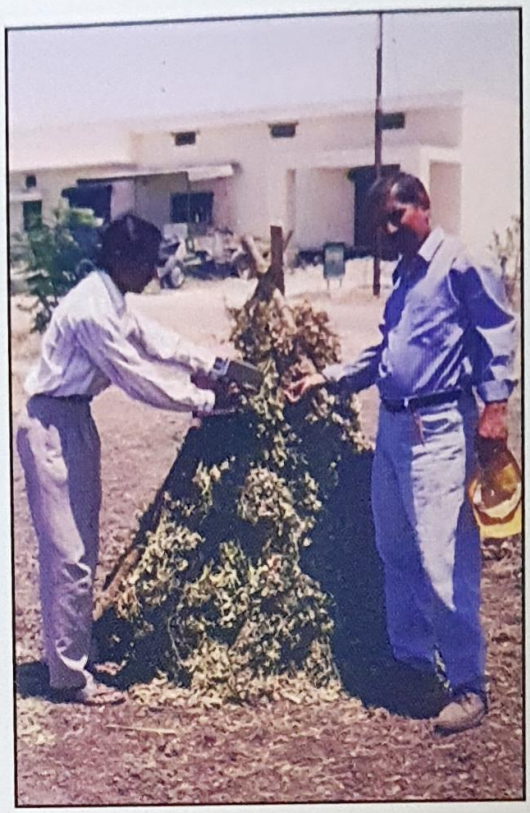

Plate 7. NRCG method of drying of groundnut pods

SPlate 8. Germination of the seed obtained from the pod dried by NRCG method