Groundnut Production Technology for Kharif (Rainfed)

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P.B. 5, JUNAGADH - 362 001, GUJARAT, INDIA

December 2003

Published by : DIRECTOR,
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GUJARAT, INDIA

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Printed at : NEW PRAGATI PRINTERS
2/10, Bhaktinagar Station Plot,
Near Meladi Maa Mandir,
Rajkot-360 002.
Phone:0281-2461965. 094260 40829

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1. Introduction

Groundnut is an important food legume world wise and grown in about 25 million hectares between 40° N - 40° S over 85 countries with a total production and productivity of 30.2 million tones and 1314 kg/ha, respectively. India is the leading groundnut producing country since it accounts for about 34.5 % world's groundnut area and about 27.3% production (second to China). However, India ranks tenth in productivity of world groundnut and average productivity hovers around 1100 kg/ha. The low yield levels are mainly due to its rain fed nature of cultivation where plethora of pests and diseases usually take a heavy toll.

India has an unique distinction of growing groundnut in major four seasons namely: kharif (80% area), rabi (11% area), summer (5% area) and spring (4% area). Thus kharif groundnut (June- December, depending upon the south-west monsoon) is the most important crop for the country. About 88% of the area and the production of kharif groundnut are confined to five states, namely, Andhra Pradesh, Gujarat, Tamil Nadu, Karnataka and Maharashtra. The remaining area is scattered in the states of Madhya Pradesh, Chhattishgarh, Uttar Pradesh, Rajasthan Punjab, Jharkhand and Orissa. However, productivity of kharif groundnut is the lowest (1041 kg/ha) among the four seasons. Groundnut being the premium oilseed in India contributes nearly 33% of the total oilseed production in the country. Substantial amount of multi-discplinary research in the areas of basic, strategic and applied area have resulted in development of Technology Treasure. If adopted by the farmers, these technologies are capable of substantially enhance the productivity of kharif groundnut. In this bulletin, implementable and economically viable agro-production and protection technologies for kharif groundnut are given for the use of extension workers, groundnut farmers and all other interested in groundnut farming.

2. Scope for Improving the Productivity-the Rationale

The results of one thousand and odd Front Line Demonstrations conducted on whole package of practices, cropping system and on key components of the package conducted during 1988-89 to 1997-98 in different production areas revealed that the productivity enhancement was substantial in whole package (38%), plant protection (36%), improved variety (32%), balanced use of fertilizers (22%) and weed control (20%). Even adoptiaon of biofertilizer could increase productivity by 9%. This amply suggests that there is vast untapped reservoir of yield, which can be exploited by adopting improved technologies developed for groundnut.

3. Critical Production Factors

Full yield potential of groundnut cultivar is realized when all the recommended package of practices are adopted in a favourable environment. However, the relative importance of individual components has been found to vary from region to region. However, adoption of improved variety followed by weed control and balanced use of fertilizers were found to be the most important critical production factors for rain fed kharif season in majority of the locations. The relative importance of critical production factors in different states/regions is given in Table1.

Table 1: The critical production factors in groundnut cultivation

State/region	Critical production factor
Andhra Pradesh-	
Rayalseemai	Protective irrigation, plant population and weed control
Telengana	Row spacing, seed treatment, plant population, and weed control
Jharkhand	
Chhotanagpur Plateau	Improved variety, weed control and fertilizer
Gujarat- Saurashtra	Protective irrigation, fertilizer
Karnataka- Dharwad region	Improved variety, seed treatment, weed control
Madhya Pradesh-	
Vimar valley	Weed control, fertilizer, seed treatment
Maharashtra-Sangli	Improved variety, protective irrigation, row spacing and plant population
Khandesh	Improved variety, row spacing, plant population and fertilizer
Orissa- Inland districts	Improved variety, fertilizer
Punjab	Weed control, plant population
Rajasthan	Weed control, fertilizer, plant population
Tamil Nadu	
South arcot	Improved variety, fertilizer, weed control and plant population
Uttar Pradesh-Manipuri	Improved variety, weed control and plant population
Eastern and NEH regions	Improved variety, fertilizer

4. Groundnut Based Cropping Systems

Mainly three types of cropping systems viz; mono cropping of groundnut, sequential cropping where kharif groundnut is rotated with another crop in rabi or summer and groundnut in intercropping systems are prevalent in different parts of the country.

Mono cropping

Most of the kharif groundnut area is under mono cropping where the farmers take up only one crop of groundnut in a year. This cropping system is dominant in rain fed areas of Saurashtra region of Gujarat, Rayalseema region of Andhra Pradesh, and in some parts of Karnataka. In Saurashtra region of Gujarat, farmers do not disturb the line furrows in the field spaced at 90/45 cm apart where they sow the crop in the same furrow year after year. This practice is however, slowly being replaced by recommended spacing. Continuous cropping of groundnut results in build up of soil insect-pests and pathogens (like increasing stem rot and collar rot), depletion of specific nutrients from rhizosphere and thus, reduces yield. Gradual decline in organic carbon and humus content of soil is also a result of mono cropping of groundnut because there is very little recycling of groundnut plant residue into the soil as groundnut uprooted at the time of harvest. Interestingly, an experiment at NRCG has shown that continuous cropping of groundnut may increase the harmful hydrocyanic acid producing bacteria in the soil.

Sequential cropping

Kharif groundnut is rotated with cereals, pulses, vegetables and fibre crops in different parts of the country. Among different crop sequences, groundnut followed by cereals (wheat, rabi sorghum, pearl millet) is the best while considering crop sustainability and nutrient balance in the soil. The promising cropping sequences for different states are given in Table 2.

Table 2. Important groundnut based cropping sequences in different states

State	Residual moisture double cropping	Irrigated double cropping
Andhra Pradesh		
Telangana region	Groundnut-chickpea	Groundnut-maize
	Groundnut-safflower	Groundnut-wheat
Rayalseema region	Groundnut-safflower	Groundnut-maize
Coastal region (Srikakulam &Vishakhapatanam)	Groundnut-sesame	Groundnut-sesame
Maharashtra	Groundnut-safflower	Groundnut-rabi sorghum /maize
	Groundnut-fodder maize	
Karnataka	Groundut-safflower	Groundnut-wheat
	Groundnut-rabi sorghum (fodder)	Groundnut-maize
		Groundnut-sunflower
Tamil Nadu	Groundnut-sesame	Groundnut-maize
		Groundnut-rice/ finger millet, sorghum
Uttar Pradesh	Groundnut-mustard	Groundnut-mustard/ wheat/barley
Rajasthan (Ganganagar)	Groundnut-barley	Groundnut-mustard/wheat
	Groundnut-mustard	
Jharkhand	Groundnut-maize	Groundnut-maize
		Groundnut-wheat
Madhya Pradesh	Groundnut-safflower	Groundnut-wheat/mustard
	Groundnut-chickpea /linseed	
Orissa	Groundnut-chickpea	Groundnut-wheat/mustard
	Groundnut-sesame	Groundnut-rice/fingermillet
Gujarat	Groundnut-fodder sorghum	Groundnut-coriander/cumin
		Groundut-garlic/onion
Punjab and Haryana	Groundnut-mustard	Groundnut-wheat-green gram
		Groundnut-mustard -greengram

Intercropping systems

The system of intercropping is traditionally practiced in dry lands of India since component crops in intercropping system give higher yield and land use efficiency per unit time, provide greater stability, improve soil fertility and use resources more efficiently than sole cropping systems. Although groundnut is grown generally as sole crop in rain fed conditions, its wide row-to-row spacing and short stature make it ideally suited for intercropping system. It is estimated that about 25% of 7 m ha area under rain fed groundnut is under intercropping system. In this system, 1-6 rows of groundnut are intercropped with 1-3 rows of other companion crops. Some of the most promising intercropping systems for important groundnut growing states are given in Table3.

Table 3. Remunerative intercropping systems with groundnut for various

State	Region	Intercropping	Row ratio of base crop (G'nut) and intercrop
A.P.	Telangana	Groundnut + Pigeonpea	6:1
		Groundnut + Pearlmillet	3:1
		Groundnut + Cowpea	6:1
	Rayalseema	Groundnut + Pigeonpea	3:1 or 5:1
		Groundnut + Castor	5:1
Jharkhand		Groundnut+ Maize	6:1
		Groundnut+ Sesame	4:1
Gujarat	Saurashtra	Groundnut + Castor	3:1
		Groundnut + Pigeonpea	3:1
		Groundnut + Pearlmillet	1:1 or 2:1
		Groundnut + Sesame	1:1
		Groundnut + Cotton	1:1
	Rajkot region	Groundnut+ Castor	3:1
		Groundnut+ Pigeonpea	3:1
Karnataka		Groundnut + Sunflower	1:1
		Groundnut + Pigeonpea	4:1
		Groundnut + Cotton	3:1
		Groundnut + Sunflower	4:2
		Groundnut + Sorghum	6:1
		Groundnut + Chilli	4:2

Kerala		Groundnut+Tapioca	3:1
Maharashtra		Groundnut + Pigeonpea	6:1
		Groundnut + Pearlmillet	4:1
		Groundnut + Sorghum	4:1
		Groundnut+ Sunflower	3:1
Madhya Pradesh	Rewa region	Groundnut + Maize	3:1
		Groundnut+ Pigeonpea	3:1
Rajasthan		Groundnut+ pearlmillet	4:1
		Groundnut+ Sesame	4:1
Tamil Nadu		Groundnut + Pigeonpea	6:1
		Groundnut + Cotton	5:1
		Groundnut + Castor	7:1
		Groundnut + Sorghum /Pearlmillet	6:1
		Groundnut + Sesame	4:1
		Groundnut + Blackgram	6:1
		Groundnut + Rice	2:2
Uttar Pradesh		Groundnut+Pearlmillet	4:1
		Groundnut+Sesame	4:1
		Groundnut+Pigeonpea	6:1
Orissa and West Bengal		Groundnut+ Rice	2:2
NEH region		Groundnut+ Maize	3:1
		Groundnut+Rice	3:2
		Groundnut+Soybean	2:1

5. Management Practices for Different Cropping Systems

Mono cropping system

5.1 Selection of land and field preparation

Well drained, light coloured, loose and friable soil, well supplied with Calcium and moderate amount (0.3-0.7%} of organic carbon are best suited for groundnut cultivation. Red soil with fine texture and the soil with high density and stiff clay are not suitable for groundnut. Groundnut prefers slightly acid soils with pH of 6.0-6.4. When the pH is 7.5-8.5, yellowing of leaves and blackening of pods occurs. Beyond pH 8.5, it is very difficult to grow groundnut. The soils with following characteristics are suitable for groundnut cultivation.

- Good drainage
- Electrical Conductivity of soil less than 4.0 mmhos/cm
- Exchangeable sodium percentage less than 5,
- pH less than 8
- Calcium carbonate equivalent less than 4%

Field should be prepared to a fine tilth so that proper soil physical environment is obtained for good seed germination and seedling emergence. Generally, proper tilth is obtained by 1 and 2 ploughings (15-30 cm) followed by 2 or 3 harrowings. Deep ploughing up to a depth of 30 cm is advantageous in rain fed areas because of better retention of moisture, improved porosity of soil, better management of soil borne diseases and enhanced nutrient availability. Pod yield increases by about 15% by deep ploughing over shallow tillage generally practiced by the farmers.

5.2 Choice of improved varieties

Among different components of recommended package of practices, improved variety contributes up to 30% to the overall yield improvement. The groundnut varieties recommended for major kharif groundnut growing states are given in Table 4.

Table 4. Improved groundnut varieties recommended for different states of Kharif

State	Habit group	Variety
Andhra Pradesh	Spanish bunch	Tirupati 3, ICGV 86590, Kadiri 4, Apoorva , JCC 88, Vemana, DRG 12
	Virginia bunch	Kadiri 4, ICGS 76
Jharkhand	Virginia bunch	BG 3, BAU 13, Birsa bold, TG 22
Gujarat	Spanish bunch	GG 4, GG 5, GG 7,TG 26, LGN 2
	Virginia bunch	GG 20
	Virginia runner	GAUG 11, GG 13, Somnath
Haryana	Spanish bunch	ICGS 1, MH 4
	Virginia bunch	Prakash, HNG 10, Mukta
	Virginia runner	DRG 17
Karnataka	Spanish bunch	ICGV 86590, Apoorva, DRG 12, DSG 1
	Virginia runner	DSG 1
Kerala	Spanish bunch	TG 3
Madhya Pradesh	Spanish bunch	TG 26, ICGS 11, ICGS 37
	Virginia bunch	Jawahar Groundnut 3
Maharshtra	Spanish bunch	TG 26, Phule Vyas , Manikya, Manjira
Orissa	spanish bunch	Smruti , TG 3
Punjab	Virginia runner	M 522, Amber,
	Virginia bunch	HNG 10,Prakash, Mukta
Rajasthan	Virginia bunch	HNG 10, Prakash, Mukta
	Virginia runner	DRG 17
Tamil Nadu	Spanish bunch	VRI 4, ICGV 86590, Apoorva, ALR 2, BSR 1, ALR 3, CO 3, DRG 12, Vemana
	Virginia bunch	ALR 1,ICGS 76
Uttar Pradesh	Virginia bunch	Kaushal, HNG 10, CSMG 884, Mukta
	Virginia runner	DRG 17
West Bengal	spanish bunch	ICGS 44, ICGS 76
NEH region	spanish bunch	Girnar 1, ICGS 44, TG 26, R 8806, TAG 24
	Virginia bunch	ICGS 76

5.3 Quality seed and its treatment

Seed should be genetically pure, viable and free from external damage and disease infestation. Seed should have a minimum of 90% germination. After shelling, all shrivelled, immature and damaged/infested seeds should be removed and only well-filled and healthy seed should be used for sowing.

Immature seeds produce weak seedlings, encourage fungal attack in seedlings and this reduces plant stand. Spreading and semi-spreading types of groundnut have dormant seed, which generally require a resting period of 30 to 60 days depending up on variety. If seeds are to be sown before 30 days, dormancy needs to be broken by treating the seed with ethrel solution of 250ppm (0.05% volume/volume). Before planting, dormant seeds are soaked in ethrel solution for 12 hours and the soaked seed is kept in an airtight container/sealed polythene bags. The seed loses dormancy after treatment and becomes germinable. Bunch type generally has non-dormant seed and can be used for sowing immediately after harvest. Shelling of pods should be done 2-3 days before sowing. It is usually done by hand or hand operated sheller. Seed must be treated preferably at least 2-3 days before sowing so that the chemicals/treatment agents have sufficient time to act. Three gram of mancozeb or 2 g of carbendazim for every one kg of seed to control seed borne fungi are recommended.

5.4 Optimum sowing time

Groundnut is sown in between the second fortnight of June and the first fortnight of July, depending upon the onset of monsoon. Pre-monsoon sowing with one or two irrigations was found advantageous in Gujarat and Punjab. The optimum time for sowing groundnut in different states is given in Table 5.

5.5 Seed rate, spacing and plant population

Maintenance of optimum plant population is the key to success in groundnut cultivation. The seed rate depends upon the variety and spacing. The most common spacing recommended for Spanish (erect) cultivar is 30 cm x 10 cm. At this spacing, the seed rate requirement works out to be 100-110 kg/ha to obtain a plant population of 3.33 lakh/ha. In case of virginia bunch (semi spreading) and Virginia runner (spreading) cultivars, the most common recommended spacing is 45 cm x 10 cm which requires seed of 95 100 kg/ha to get a plant population of 2.22 lakh/ha.

In the Saurashtra region of Gujarat where wide row spacing and set row cultivation is still in practice in about 50% of the area, the farmers sow in set furrows spaced at 90 or 75 cm apart. Paired row system of planting conserves moisture by suppressing weeds infestation and minimizing evaporation losses

Table 5: Optimum time of sowing groundnut in different states

State	Time of sowing
Andhra Pradesh	
North coastal Andhra	First fort night of June
Telangana	First fort night of June
Rayalaseema	First fort night of June
Bihar	Last week of June
Gujarat	Second fortnight of June to first fortnight of July
Haryana	Third week of June to first week of July
Karnataka	Bunch type: Fist fortnight of June Spreading: June-July
Madhya Pradesh	Third week of June to first week of July
Maharashtra	Third week of June to first week of July
Orissa	June-July
Punjab	Second fortnight of June to first week of July
Rajasthan	Middle of July
Tamil Nadu	
Pollachi,Cumbum valley and Tenkasi	April-May
Northern districts: Salem, Dharmpuri and parts of North Arcot	June- July
Southern districts	July-August
Uttar Pradesh	Last week of June
West Bengal	Last week of June
NEH regions	August to September

owing to faster canopy coverage on the seedling zone and thus improves yield by about 27% over conventional method (90 cm spacing). In the paired row method, four rows in two pairs are sown in the same 90 cm spacing. The distance between pair is 60 cm and between rows within the pair, the distance is 30 cm. The same quantity of seed placed in one single row of 90 cm is distributed in 2 rows spaced at 30 cm apart and hence no extra seed is required (Fig 1). The recommended spacing for different states is given in Table 6.

Table 6 : Spacing recommended for groundnut in different states

State	Bunch type Row to row x plant to plant (cm)	Spreading type Row to row x plant to plant (cm)
Andhra Pradesh	30x8/10	30x15
Bihar	--	45x10
Gujarat	45x10	75/60x10
Haryana	--	22.5/30x10
Karnataka	30x10	45x10
Madhya Pradesh	30x8/10	-
Maharashtra	30x8/10	45x15
Orissa	30x10	--
Punjab	-	45x10
Rajasthan	30x10	45x10
Tamil Nadu		
Aliyarnagar	30x10	22.5x15
Tindivanum	30x8	30x20
Uttar Pradesh	-	45x10
West Bengal	30x10	30x10
NEH Regions	45x10	60x10

5.6 Nutrient management

Groundnut being a legume needs more phosphorus, being an oilseed crop requires more sulphur, and it needs more calcium for proper shell formation and filling. To produce 1 t/ha of pods, groundnut requires about 58 kg of N, 5 kg of P, 18 kg of K, 11kg of Ca, 4 kg of S and 9 kg of Mg. For realizing the potential yield and for sustaining soil fertility, integrated nutrient management practices involving microbial, organic and inorganic fertilizers should be adopted.

5.6.1 Bio-fertilizers (microbial fertilizers)

Rhizobium culture

Groundnut being a leguminous crop can fix atmospheric nitrogen through symbiotic nitrogen fixation by bradyrhizobium bacteria present on the root system. Seed inoculation with efficient strains of rhizobium can partially meet the nitrogen requirement of crop. Inoculation of groundnut seed with

strains of bradyrhizobium is not a complete substitute to nitrogenous fertilizer.

The cultures of bradyrhizobium like NC 92, IGR 6, IGR 40, TAL 1000 and TNAU 14, which fix nitrogen efficiently, have been recommended for groundnut. The following method of seed inoculation is recommended.

- Inoculation with bradyrhizobium is done about 1 hour before commencement of sowing.
- Solution of 10% jaggery or molasses is prepared in water. For treating 100 kg seed of groundnut, approximately one litre of this solution is sufficient.
- Two hundred grammes of carrier based culture of bradyrhizobium containing 10^{9}-10^{10}-cells/g carriers is added and mixed with 10% cold solution of jaggery or sugar to make slurry.
- Seed should be spread on a floor or polythene sheet and thoroughly mixed with slurry of inoculant's strain. For uniform application of inoculum, small batches of seed may be treated at a time.
- Then the seed are dried in shade to avoid mortality of bradyrhizobium. The seed are then sown immediately avoiding exposing them to the sun.

Phosphate solubilizing microbes (PSM) culture.

Inoculation of efficient strains of PSM species like, *Pseudomonas striata* and *Bacillus polymixa* with seed increases availability of phosphorous from the soil and thus improves yield especially in soils with alkaline pH. Inoculation of seed with PSM should be done as has been described for bradyrhizobium inoculation and both PSM and bradyrhizobium can be mixed and applied.

5.6.2 Organic manures

To sustain the overall health of the soil and continued good yields, a desirable level of organic carbon in the soil (0.3-0.7%) must be maintained. Application of organic matter (organic manure, green manure or crop residues) to the soil is a must for supplying organic carbon. Well decomposed FYM or compost, 10 15 t/ha should be applied well before sowing and should be incorporated into the soil (Fig 2). Organic manures are good source of

micronutrients also.

5.6.3 Inorganic fertilizers

For obtaining high fertilizer use efficiency, inorganic fertilizer should be applied on the basis of soil test results. However, based on field experiments, the N P K fertilizer doses recommended for the major groundnut states are given in Table7.

States	N	P_2O_5	K_2O	Gypsum
	(active nutrients kg/ha)			
Andhra Pradesh	20	40	20	-
Jharkhand	25	50	20	-
Gujarat	12.5	25	0	-
Karnataka	15	30	25	250
Maharashtra	20	40	0	-
Madhya Pradesh	20	40	20	-
Orissa	8	16	15	-
Punjab	15	40	25	125
Rajasthan	20	60	0	-
Tamil Nadu				
a) Aliyarnagar-Polachi tract	11	22	33	250
b) Tindivanam	10	20	45	250
Uttar Pradesh	15	30	45	200
West Bengal				
a) Alluvial soil	20	40	-	250
b) Red soil	40	80	60	250

Macronutrients

(a) Primary nutrients

Nitrogen: Nitrogen requirement of groundnut is much higher than cereals as the protein content of its seed (25-30%) is one and half times more than that in cereals. As groundnut takes up about 180 kg/ha nitrogen from the atmosphere, the demand for mineral nitrogen is not very high. However, the nitrogen fixation process of the plant starts working at about 25-30 days after sowing when the nodule apparatus is fully formed. Till that time to give the plant growth an initial boost, about 10-30 kg N/ha basally applied as a starter dose has been recommended for different areas. Nitrogen should be applied

preferably in the form of ammonium sulphate because it supplies sulphur required by groundnut to produce oil in addition to nitrogen.

Phosphorus: Phosphorus promotes root growth and multiplication of rhizobium, stimulates the setting of pods, hastens maturity of the crop and also helps the crop to tide over moisture stress. Though the amount of phosphorus requirement is very small (0.4 kg phosphorus required to produce one quintal of pods), but higher quantity of phosphatic fertilizers need to be applied because a large proportion gets fixed in the soil and becomes unavailable to the plant. Unless the available phosphorus in the soil is less than 35 kg P_2O_5/ha, response to applied phosphorus may not be evident.

Kharif groundnut responds to the applied phosphorus in the range of 20-80 kg P_2O_5/ha in different soils. Phosphorus should be applied fully before sowing in the furrow. Farmers generally use DAP as a source of phosphorus and nitrogen. However, single super phosphate (SSP) is the best source of phosphorus as it contains phosphorus (16%), calcium (19.5%) and sulphur (12.5%) and traces of zinc and manganese. In acidic soils of the NEH region, use of SSP + rock phosphate in a ratio of 25:75 was found to be effective for prolonged phosphorus availability in the soil

Potassium: Groundnut needs potassium throughout the growing period. Most of the Indian soils are rich in potassium. Response to potassium is evident only when available K_2O in soil is less than 150 kg/ha. Where soils are deficient in potassium, 17-34 Kg K_2O/ha may be applied in the soil. Among the sources of potassic fertilizers, potassium sulphate should be preferred as it also contains sulphur (18%) besides potassium (K_2O 50%). Potassium is not a mobile nutrient. Therefore all the potassium should be applied in the furrow before sowing. The best ratio of K: Ca: Mg for groundnut has been found to be 4:4:2 for higher production. Upsetting this balance towards K may be harmful.

(b) Secondary nutrients

Calcium and sulphur: Besides N, P and K, calcium (Ca) and sulphur (S) are the major secondary nutrients required by groundnut. Calcium requirement is very high especially during the peg development and the pod-filling phenophases. Calcium is taken up directly from the soil by pods and inadequate supply results in pods without seeds called 'pop" or darkening of plumules of the embryo. About 1 meq/100g of soil in the root zone and 3-

meq/100 g of soil in the pod zone (5cm) are considered to be the threshold values of calcium sufficiency. Sulphur is directly involved in the biosynthesis of oil. It improves nodulation, prevents premature leaf fall and increases pod yield. Sulphur deficiency is moderate to high in Bihar, Gujarat, Punjab, Madhya Pradesh, Uttar Pradesh some parts of A.P.and Karnataka (Fig 3). About 10-ppm heat soluble sulphur is the critical limit of available sulphur for groundnut. The requirement of Ca and suphur can be met through application of gypsum (Ca 24%, sulphur 18.6%). Well-powdered gypsum (30 mesh) should be applied to the crop, as close to the base of the plant as possible, when it is in its peak of flowering. Availability of sufficient moisture is necessary at the time of application of gypsum for its efficient uptake.

Micronutrients

Deficiency of micronutrients in groundnut has been reported from several major groundnut-growing states. Application of micronutrient especially should be decided on the basis of soil test. Among all the micronutrients, iron deficiency is most commonly observed especially in groundnut grown in calcareous soils (Fig 4). The micronutrient deficiencies observed in different states and their corrective measures are given in Table 8a and 8b.

Acid soils having pH less than 5.5 show aluminium toxicity in groundnut. To correct the acidity of the soil, application of lime @ 2-4 t/ha depending upon the intensity of the acidity of the soil is required. Once pH is brought to the desirable level of 5.5 to 7.5, gypsum may be applied in the root zone at pegging and pod development stage so that sulphur is also available to groundnut. In the NEH region, furrow application of lime @ 0.2 t /ha once in three years has been recommended for acid soils.

Table 8a: Deficiencies of micronutrients prevalent in different states

Micronutrient	State
Zinc	Gujarat, Andhra Pradesh, Tamil Nadu and Punjab
Boron	Punjab, Tamil Nadu, Madhya Pradesh and Maharashtra
Iron	Tamil Nadu, Gujarat, Karnataka and Maharashtra
Copper	Uttar Pradesh
Molybdenum	Mostly in acidic soils
Manganese	Mostly in alkaline soils of U. P. and Karnataka

Table 8b: Schedule for correcting micronutrient deficiencies

Micronutrient	Rate of application to soil In furrows	Application to the crop as a spray
Boron	Borax 5-20 kg/ha	0.2% Borax
Copper	Copper sulphate 10-15 kg/ha	0.1% copper sulphate+0.5% lime
Manganese	Manganese sulphate 10-15 kg/ha	0.6% manganese sulphate + 0.3% lime
Zinc	Zinc sulphate 10-20 kg/ha	0.5% zinc sulphate + 0.25% lime
Molybdenum	Sodium molybdate 15-25 kg/ha	0.5% sodium molybdate
Iron	Ferrous sulphate 10 kg/ha	0.15% ferrous sulphate + 0.15% citric acid

5.7 Weed management

Weeds cause maximum damage to the crop up to 45 days after sowing. Improper weed control is a critical constraint-affecting yield of groundnut in the states of Rajasthan, Madhya Pradesh, Punjab, Karnataka, Tamil Nadu and Andhra Pradesh. Application of herbicide along with one or two intercultures controls the weeds effectively. Pre-sowing soil incorporation of Alachlor or Fluchloralin @1.5 kg ai /ha, or pre-emergence application of Pendemethalin @ 1.0 kg ai/ha along with 2 intercultures at 30 and 45 days after sowing have been recommended for effective and economical control of weeds in groundnut. Frequent interculturing is very common in the Saurashtra region of Gujarat where spacing between rows is wider than other states. This practice, besides weed control also helps in conserving soil moisture and pulverizing the soil (Fig 5 and 6).

5.8 Efficient moisture management

On an average, groundnut crop requires about 550-650 mm of water depending upon the soil type. The kharif groundnut is usually exposed to mid or late season drought. The most critical stages of groundnut when adequate moisture must be available are i) flowering and ii) peg penetration/pod formation and pod filling. If there is a moisture deficit during these critical stages, pod yield is reduced substantially.

Broad Bed and Furrow (BBF) method of sowing in deep vertisols is advantageous in rain fed conditions as it helps to conserve soil moisture (Fig 7). Opening of a furrow at about 20-25 days after sowing in between two rows of groundnut also help in conserving *in-situ* rain water that could be utilized by the groundnut plant during moisture stress period. If irrigation water is available, providing life saving irrigation during critical growth stages can increase pod yield substantially. Water being a scarce commodity in rain fed agriculture; judicious use of water preferably through sprinkler/drip is also advised. When technical advice is available, irrigating at irrigation water (IW)/ cumulative pan evaporation (CPE) ratio of 0.8 is recommended. Determining IW/CPE ratio is not at all a complicated and costly affair.

5.9 Plant Protection Measure

5.9.1 Control of insect pests

The major insect-pests and their control measures are given below.

a. Major sucking pests like aphids, jassids and thrips can effectively be controlled by spraying 0.05% Monocrotophos or 0.05% Dimethoate (Fig 8).

b. Setting up light traps for destroying the moths may control leaf miner. The economic threshold studies indicated that chemical control should be adopted when the larval population reaches 61-70 per 100 leaflets. Carbaryl 50 WP 0.2% spray is most economical.

c. Red-hairy caterpillars may be controlled effectively by spraying Monocrotophos 40 EC @ 1000 ml/ha before the caterpillars develop hair. Egg masses and larvae, which can easily be detected, may be collected and destroyed. A biological control measure through spraying of Nuclear Polyhedrosis Virus (NPV) developed at Tamil Nadu Agricultural University (TNAU), Coimbatore is found effective and economical.

d *Spodoptera, Helicoverpa*, *Anarsia* and *Plusia* pests are nocturnal in habit and hence control measures have to be taken up either in the early morning hours or in the late evening hours. To control these pests spraying Quinalphos @ 0.05% @ 400 ml/ha may be undertaken. Other insecticides like Carbaryl 0.2%, Endosulfan 0.04%, Parathion 0.05% are also effective. Planting of castor, pearl millet and pigeonpea as trap crops in groundnut has been found to be effective

e. White grub a menace in the light soils of Rajasthan, Uttar Pradesh, Punjab and Haryana can be controlled effectively by treating the seed with Chlorophyriphos 20 EC @ 12.5 ml/kg of seed. Soil treatment with Thimet 10g @ 20-25 kg/ha is recommended for the control of white grub wherever the population is high.

f. Storage pests: Among the storage pests, the groundnut pod borer (bruchid beetle) is the most devastating storage pest in groundnut, which can cause pod damage to the extent of 90-100%. So far, no single control measure has been successful for controlling this pest.

Therefore, the following integrated approach is suggested.

- Clean up the warehouse or godown inside and outside before storing groundnut.
- Spray insecticide (Malathion1.25% or Fenitrothion 2%) @ 5 litre spray solution for 100 m^2 on wall, floor and roof of the godown before storage.
- Bring down moisture content o of pod by 8% and for seed by 7%
- As eggs are laid in the field during drying of pods, the pods should be fumigated with Aluminium phosphide @ 3-5 tablets/tonne of groundnut before storage.
- If jute bags are used for storage, they should be impregnated with Malathion 0.25% or
- Fenitrithion 0.25% and should be dried before use.
- For already infested groundnut, fumigation with Methyl bromide + Chloropicrin (gas), 10-15 g/m^2 for 24 hours or phosphine (solid Aluminium phosphide) 3-5 tablets/tonne for 7-10 days should be undertaken under gas proof sheet/gas tight storage.

5.9.2 Control of major diseases of groundnut

Early and late Leaf spots and Rust: Bavistin 0.05% along with Dithane M 45 0.2% should be sprayed at 2 3 weeks interval for 2 3 times starting from 4-5 weeks after planting. Two to 3 spraying of Chlorothalonil 0.3% at 45,55 and 75 DAS controls the diseases effectively, Two to five percent crude neem leaf extract at two weeks interval can also control the foliar diseases. This practice,

besides eco-friendly, is cheaper and could be adopted by the small and marginal farmers.

Collar rot, stem rot and dry root rot: The seed should be treated with 5 g. of Dithane M-45 or 2 g. of Bavistin per kg of seed. Application of soil amendments like castor cake @0.5 t/ha and bio pesticide formulation of *Trichoderma viride* @ 25kg/ha have been found to be effective in controlling stem and root rots.

Peanut bud necrosis disease: This disease caused by Peanut bud necrosis virus cannot be controlled through chemical. Thrips which transmit the disease should be controlled by using Rogor @ 400 ml/ha. The cultural methods like early planting, closer spacing and intercropping with millets are advocated (Fig 9).

5.10 Harvesting & Drying

Groundnut is an indeterminate crop; hence synchronous maturity of its pods cannot be obtained. There fore, harvesting should be done when 75- 80% of all the pods are fully mature. The important indications of maturity are yellowing of foliage, spotting of leaves, dropping of old leaves, dark tan coloration inside the shell and full development of colour of the testa. Premature or delayed harvest affect quality and viability of seeds apart from pod loss during harvest. A portion of the harvest required to be kept for seed should be dried thoroughly till the moisture content comes down to 7-8% and should be stored in a polythene lined gunny bag.

5.11 Management of Aflatoxin

Aflatoxin production groundnut caused by *Aspergillus flavus* group of fungi is a problem mainly during post-harvest processing and storage. About 81% of the kernels are immediately crushed for oil and hence aflatoxin is not a major problem in the domestic market. However, it is of concern in respect of exportable commodities i.e., kernel, oil-cake etc.

The following are some of the measures to avoid aflatoxin contamination.

- Avoid mechanical and biological damage to the crop particularly during cultivation, harvesting and subsequent processing.

- Harvest the crop at peak maturity and use inverted wind-row method to optimize curing
- Dry the produce as rapidly as possible but the rate of drying must be controlled to prevent excessive skin slippage and splitting of kernel.
- Dry groundnut pods to a safer moisture of 8% before storage.
- Store the produce at a low humidity.

6. Management practices for groundnut based crop sequences

6.1 Varietal choice

Selection of sequence crop with kharif groundnut mainly depends on amount of annual precipitation, moisture storage capacity of the soil, duration of sequence crop and marketing facility for produce of the crop.

Very limited information is available on suitability of cultivars in a specific crop sequence involving kharif groundnut. At present, choice of cultivar of the crop in sequence mostly depends on duration of cultivar, its yield potential and availability of seed at the time of sowing. Short to medium duration of groundnut cultivar may be grown when rabi crops like wheat, mustard and rabi sorghum are to be sown. It has been observed that wheat yield was higher when it was grown after the spreading type of groundnut than when grown after the bunch type of groundnut. For groundnut sunflower sequence, short duration cultivars of sunflower like Morden, Co 1 and Co 2, BSH 1 and PAC 36 are better suited under residual moisture or limited irrigation situation. Under high input intensive irrigation conditions, sunflower hybrids like MSFH 8, MSFH 17 and Jwalamukhi may be better for realizing higher profitability in the system.

6.2 Time of planting

Time of sowing of the sequence crop should be adjusted in such a way that the reproductive period of the crop does not face adverse climatic conditions. Advancing sowing of groundnut by 15-20 days with one pre-sowing irrigation not only increases the pod yield of groundnut substantially but also facilitates timely sowing of rabi crops like wheat, mustard and rabi sorghum as harvesting of kharif groundnut advances by about 10-15 days. After harvest of kharif groundnut, field should be prepared immediately as per the need of sequence crop. In groundnut mustard sequence, sowing of mustard should not be delayed beyond middle of October, otherwise infestation by aphids is increased many folds.

6.3 Nutrient management

Since fertilizers do have residual and cumulative effects, application of recommended doses of fertilizer to one crop will have some effect on the next crop grown in a sequence. But fertilizer recommendations for a particular sequence of crops is generally lacking. The information available is given in the following Table9.

Table 9 Recommended fertilizer doses for important crop sequences in different states

Crop sequence	State/region	N, P, K, kg/ha	
		Groundnut	Sequence crop
Groundnut -wheat	Gujarat (Saurashtra)	12.5-25.0	120-60-0
	Maharashtra (Digraj)	15-30-0+ FYM 250	120-60-60
	A. P. (Jagtial)	10-20-10+500 kg FYM	Recommended dose
Groundnut -mustard	Rajasthan, M. P., Punjab	Recommended NPK+20 kg sulphur	80-40-40 (no sulphur)
Groundnut -rice	Orissa, A. P., Karnataka	NPK+rhizobium+20 kg sodium molybdate	Recommended NPK
Groundnut -sunflower	Gujarat (Saurashtra)	12.5-25-0	20-20-0
	A. P. (Hyderabad)	20-40-20	Recommended dose
	Tamil Nadu (Coimbatore)	11-22-33	Recommended dose

6.4 Weed management

Rotation of crops having dissimilar life cycles or cultural conditions like groundnut-wheat, groundnut-mustard, is an effective and practical weed control method. Residues from some herbicides used on preceding crops may persist in the soil and injure the subsequent crop. Atrazin and simazin commonly used to weed control on maize, sorghum and pearlmillet may remain in sufficient quantity to injure succeeding groundnut crop. Herbicides recommended for groundnut namely, Fluchloralin, Pendimethalin and Alachlor at recommended rate do not cause residual effect on succeeding crops like chickpea, green gram, black gram, sunflower, cowpea and pigeonpea.

6.5 Insect-pests and disease management

There is very little carry over of the insect pests from season to season. There fore, the management practices recommended for sole cropping may be followed for groundnut based crop sequences also. However, crop rotation itself has an effect on controlling diseases and pests. Rotation of groundnut with chickpea and wheat are helpful in reducing the incidence of collar rot disease. Crops like maize, sorghum, pearl millet and rice may be rotated with groundnut to reduce the incidence of root knot nematode. Studies conducted at Junagadh indicated that incidence of stem/collar rot can be minimized by crop rotations like groundnut- rice and groundnut-wheat instead of groundnut-groundnut or groundnut-legumes.

7. Management practices for important groundnut based intercropping systems

System based approaches in terms of resource use is all the more important for intercropping systems. But the research efforts to deal with the systems as a whole have been made only recently. Recommended planting geometry, right choice of the varieties of the component crops, nutrient need of the system rather than individual crop, planting time of component crops is especially important.

7.1 Crops and varietal choice

The crops in an intercropping system should together utilize the available resources synergistically and efficiently. In a two crop intercropping system, a tall crop matches with short growing, and a deep-rooted crop with a shallow rooted one, so that both above and below ground resources could be exploited. There should be a difference of about 25% in crop duration among the intercrops in a system for effective complementarity.

Selection of suitable varieties of the component crop in an intercropping system is very important. However, not much information is available on suitable genotypes for groundnut based intercropping systems. The available information is given in Table10.

7.2 Plant population and row arrangement

Intercropping gives higher yield advantages when the total population in the system is higher than that of the individual sole crops. The optimum plant densities and row ratios recommended for various intercropping systems are given in the Table 3.

7.3 Time of planting

Under rain fed conditions, it is desirable to plant crops at earliest opportunity to allow maximum growth during the most favourable periods. In general, all the component crops may be planted simultaneously to achieve

Table 10 Recommended varieties for component crops in important intercropping system

Intercropping system	State/Region	Varieties of the component crops	
		Groundnut	Intercrop
Groundnut+Pigeonpea	Gujarat (Saurashtra)	M13/GG20	BDN 2
	Maharashtra		
	Jalgaon	JL 24/TAG 24	ICPL 87
	Rahuri	TG 26	BSMR 736
	A. P. (Kadiri)	K134	LRG 41
	M.P. (Khargone)	JGN 3	UPAS 120
Groundnut+Castor	Gujarat (Saurastra)		
	Rainfed	GAUG10 /GG20	DCS 9/DCS 32
	Irrigated	GAUG10 /GG20	GCH5
Groundnut+Maize	M.P.(Khargone)	JL 24/TAG 24	JM 8
Groundnut+Sunflower	Gujarat (Saurastra)		
	Rainfed	GAUG10 /GG20	Morden
	Irrigated	GAUG10 /GG20	MSFH 8, MSFH 17
	Maharastra		
	Rainfed	Phule Pragati	Morden
	Irrigated	TG26	MSHF 8, MSFH 17
	Karnataka		
	Rainfed	Dh 3-30	Morden
	Irrigated	Dh 3-30	APSH 11, PSFH 67
Groundnut+Sesame	Gujarat (Saurastra)		
	Rainfed	GAUG10 /GG20	Gujarat Til 1

higher yields. Staggered planting of component crops is found to be advantageous to safe guard drought against uncertain rainfall regimes to utilize late season rain fall and also to reduce competition between the component

crops. Staggered planting of pigeonpea, castor, sesame and sunflower (30 days after groundnut sowing) with groundnut has been recommended for Saurashtra region of Gujarat. This practice allows operation of bullock drawn implements for intercultivation in groundnut. However, staggered planting has limited application in semi-arid tropics because rainfall is uncertain in rain fed areas. Besides, the opportunity to establish a second component crop is risky; it is very difficult to establish a second component crop with mechanical equipment in an established crop. Simultaneous sowing is common practice in intercropping of cereals (pearlmillet, sorghum and maize), sesame and short duration pulses (green gram and blackgram) with groundnut. In case of cotton +groundnut, planting of groundnut is done 25-30 days after cotton sowing.

7.4 Nutrient management

In recent years, there has been an emphasis on working out the nutrient requirements on cropping system basis rather than based on individual crop but not much results and recommendations are available. Since the associated crops are invariably of differential nature in growth and nutrient needs, thus the understanding of the system as a whole is difficult. Some results obtained from different studies are presented below.

In groundnut + pigeonpea, 50% of recommended dose of fertilizers for both component crops gave the maximum productivity in Saurashtra region of Gujarat, while in Kolar region of Karnataka, application of DAP @ 50 kg/ha along with rhizobium and phosphorus solubilising micro-organisms (PSM) gave the maximum yield and monetary returns . In groundnut +castor, it is better to apply fertilizers in proportion to plant density of the component crop. If plant density of groundnut is 75%, then apply fertilizer only3/4th of the recommended fertilizers. In groundnut +cereals intercropping, half of the nitrogen of cereal component should be applied besides full doses of phosphorus and potassium. Application of one third of nitrogen as basal and remaining in three equal splits either as soil application or foliar spray to pearlmillet gave the maximum yield and monetary returns in groundnut+pearlmillet intercropping system. In groundnut+sunflower, maximum net returns were obtained when 100% recommended fertilizer dose for groundnut and sunflower were applied. In medium black soil, application of full-recommended dose of phosphorus for groundnut and full-recommended dose of fertilizers to sunflower recorded maximum yield monetary returns.

Method of fertilizer application is important when component crops have different requirement as with nitrogen in cereals+groundnut intercropping. In this case, nitrogen should be applied to cereal component as far away from the groundnut as possible so that nitrogen fixation of groundnut is not affected. Foliar application of nitrogen to cereal component may be advantageous in these conditions.

7.5 Weed management

It has been generally accepted that intercrops are better than either of the sole crops in competing with the weeds. However, mechanical weeding may be difficult or even impossible in certain spatial arrangements of intercrops or when the row spacing of the component crops are too close to each other. When applying herbicides for weed control in intercropping, care for selectivity of the herbicide must be taken.

In case of staggered planting of pigeonpea, castor, sesame or sunflower with groundnut, weeds can be controlled in groundnut by interculturing or hand weeding since planting of intercrop is done 30 days after groundnut sowing. Mechanical weeding may not be possible in simultaneous planting. In that case, weeds can be controlled through hand and mechanical weeding. Pre emergence application of Pendimethalin @ 1-1.5 kg ai /ha followed by one hand weeding at about 25-30 days may control the weeds effectively in groundnut+sunflower, and groundnut+pigeonpea intercropping systems. In groundnut+castor, application of Fluchloralin @ 1.5 kg/ha as pre sowing soil incorporation may control weeds effectively.

7.6 Insect-pests and disease management

In intercropping with certain combinations of component crop, management of insect-pests and diseases is more efficient but in certain combinations the situation may be aggravated.

Late leaf spot was minimum in groundnut+cowpea followed by groundnut+pearlmillet and groundnut+blackgram. Incidence of rust was minimum in groundnut+sorghum intercropping. Intercropping of groundnut+cotton reduces the incidence of stem rot. Intercropping of pearlmillet with groundnut helps to minimize the incidence of Peanut Bud

Necrosis Disease (PBND). In root knot nematode affected areas, intercropping groundnut with cereals namely, pearlmillet, sorghum, maize and rice will help to reduce the nematode problem. However, where peanut mottle virus is a problem, intercropping of groundnut+ cowpea may be avoided. On the other hand, recently it has been found that intercropping of sunflower with groundnut may enhance spread of Peanut Stem Necrosis Disease(PSND) caused by tobacco streak virus. Thus, an integrated approach including need-based fungicides should be adopted to manage diseases in groundnut based intercropping system.

Intercropping of groundnut with cereals, especially maize and pearlmillet, reduces incidence of pests by 10% in groundnut. In groundnut+pearlmillet, lowering of incidence by 21% of leaf miner was observed. Intercropping of crops like, cowpea, soybean and castor attract leaf miner and jassids if not controlled properly. In groundnut+castor, population of Spodoptera may increase. In groundnut+sunflower intercropping system, high damage (35.%) by Spodoptera litura was noticed as compared to sole crop of groundnut (23%).

7.7 Harvesting, threshing and storage.

In intercropping systems, mechanical harvesting of both the crops by bullock or tractor drawn implements may some time not be possible because of different row ratios of component crops. Therefore, groundnut harvesting is done by hand uprooting. After harvest of groundnut crop, harvesting of intercrop may be done as per method adopted for sole cropping of component crop. When both the component crops are of similar duration, care should be taken to avoid crop mixture at the time of harvesting as well as during threshing. Threshing is done separately for groundnut and component crops.

Figure 1. Paired row planting technique in groundnut

Figure 2. Application of *murram* in set furrow made for sowing groundnut

Figure 3. Groundnut crop showing sulphur deficiency

Figure 4. Groundnut crop showing iron deficiency

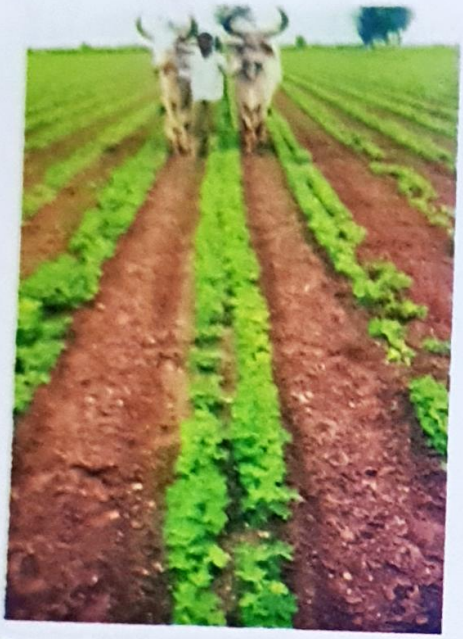

Figure 5. Intercultural operation through bullock drawn implement

Figure 6. Weeds are removed through hand weeding operation

Figure 7. Improved in-situ moisture conservation technique for rainfed groundnut

Figure 8. Spraying of insecticide for controlling insect-pests

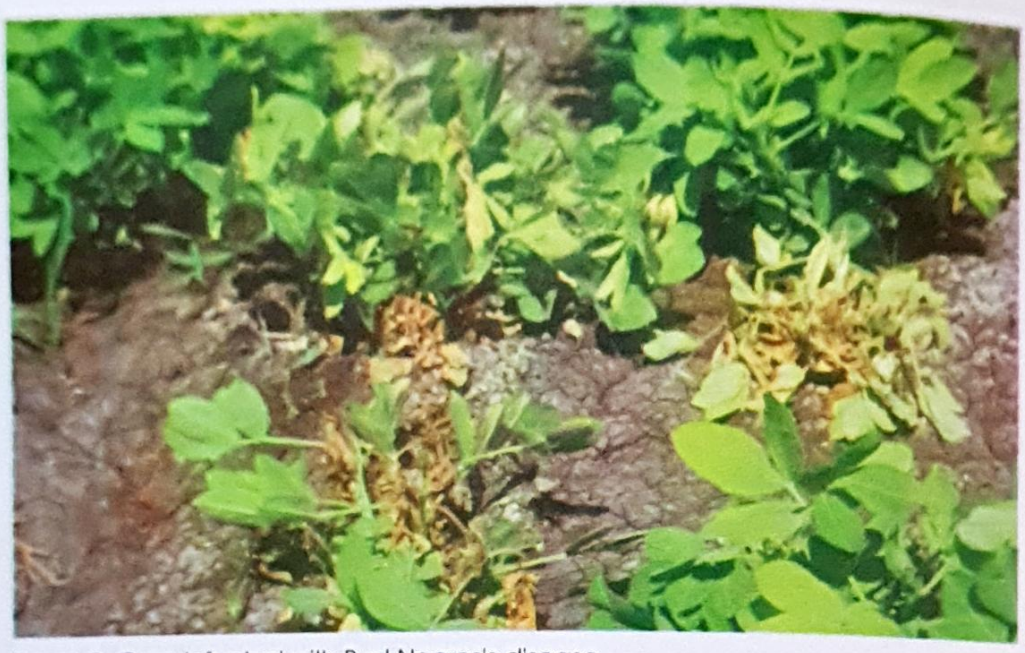

Figure 9. Crop infected with Bud Necrosis disease.

Figure 10. Intercropping of Groundnut with Maize.