Groundnut Production Guide for Uganda:

RECOMMENDED PRACTICES FOR FARMERS

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Foreword

Groundnut is one of the staple crops in the Uganda rich in protein, oil and essential minerals. The crop is increasingly becoming a cash crop and both production area and productivity are increasing. This is evident by the significant expansion of the industry in Uganda and with spillovers in the neighbouring countries. The end-users' preferences of groundnuts vary and are dynamic. The crop also suffers from numerous pests and diseases and erratic weather that affect production. The National Groundnuts Improvement Programme responded to these challenges by developing groundnuts varieties to meets these challenges.

The manual contains valuable scientific information about crop management topics such as land preparation, varietal selection, seed management, crop protection and postharvest management under Ugandan conditions. The appendices contain a catalogue of groundnut varieties released since 1966 with their yields and botanical classifications. This is in addition to the summarized poster of recommended practices at major growth stages covering pre- and post harvest operations

The manual is carefully written in comprehensible language while making no scientific compromises. I believe that this production manual will become an essential source of ideas and information for any farmer, extension staff, and researchers interested in cultivating groundnuts in Uganda.

NARO as a leader of quality agricultural research and development in the country and the region furnishes the users with practical technologies and the accompanying packages. Publication of this production manual is thus timely, and will help the wide spectrum of industry stakeholders (agricultural researchers, extension people, smallholder producers, agricultural consultants and commercial producers) by providing information on best management practices that will improve groundnut productivity and quality.

I sincerely thank the development partners for their contribution towards the production of this manual. The management of NARO applauds this effort by the authors and hope that the messages in the manual reach the intended users as we strive towards a sustainable quality groundnut production and productivity, and improvement of livelihoods.

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Acronyms

DAP	Days after planting
EU-IFAD	European Union International Funds for Agricultural Development
MRL	Maximum Residual Limit
NARO	National Agricultural Research Organisation
NaSARRI	National Semi-Arid Resources Research Institute
PCRSP	Peanut Collaborative Research Support Program
SMK	Sound Mature Kernel
SSA	Sub Saharan Africa
TL2	Tropical Legume Phase 2 project
USA	United States of America

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Introduction

Groundnut (*Arachis hypogaea* L.) also known as peanut, is cultivated in the semi-arid tropical and sub-tropical regions of nearly 100 countries in six continents between 40˚ N and S of the equator. It is an important legume grown and consumed globally and in particular in sub-Saharan African countries (Okello *et al.*, 2010a). For people in many developing countries, groundnuts are the principal source of digestible protein (25 - 34%), cooking oil (44 - 56%), and vitamins. These qualities make groundnut an important nutritional supplement to mainly cereal diets of maize, millet and sorghum of many Ugandans. In many countries, groundnut cake and haulms (foliage, straw/stems) are used as livestock feed. Groundnut is also a significant source of cash income in developing countries that contributes significantly to livelihoods and food security.

As a legume, groundnuts improve soil fertility by fixing nitrogen and thereby increase productivity of other crops in the semi-arid cereal cropping systems. Groundnut requires little input, making it appropriate for cultivation in low input agriculture by smallholding farmers. Groundnuts are grown in most of SSA by smallholder farmers as a subsistence crop under rain-fed conditions. Yields per hectare are generally low compared to those from developed countries like the USA, because of a combination of factors such as unreliable rains, mostly non-irrigated cultures, traditional small-scale farming with little mechanization, outbreaks of pest infestations and diseases, the use of low-yielding seed varieties, increased and/or continued cultivation on marginal land, poor adoption of agronomic practices and limited extension services. Insecurity instability and the frequently unsupportive oilseed policies have also played their role in low groundnut productivity. Therefore, there is excellent potential for yield improvement.

This production guide seeks to address salient issues in groundnut production in order to maximize groundnut productivity.

Groundnut Agronomic Practices

Land Selection: Groundnut is not suited to growing in very dry areas or at altitudes higher than 1500 metres above sea level (around 5000 ft). Generally higher altitudes with cooler climates are not suitable for groundnut production.

Climatic conditions: Optimum temperatures are 27 - 30 °C for vegetative growth and 24 - 27 °C for reproductive growth. Between 450 mm and 1250 mm of evenly distributed rainfall is required annually for good growth and yield. Early maturing small seeded varieties require 300 - 500 mm while medium to late maturing large seeded varieties need 1000 - 1200 mm rainfall.

Soils: All soils, other than very heavy ones are suitable for growing groundnut, but the best are deep, well drained sandy, sandy loam or loamy sand soils. The latter facilitate the forcing of the developing fruit into the soil (pegging). Groundnut will not grow well or fix nitrogen in acidic or infertile soils. Groundnuts grow best on soils limed to a pH of 5.8 to 6.2, provided other essential elements are in balance and available to the plant

Fertilizer requirements: Groundnuts respond better to residual fertility than to direct fertilization. If a well-fertilized crop precedes groundnuts, direct fertilization may not increase the yield or quality of the groundnuts. If fertilizer is needed, broadcast and incorporate it with the soil during the land preparation.

A soil test is the best way to determine whether fertilizer or lime is required in groundnut growing. Liming is necessary only when the soil pH is below 5.8. However if soil test results are not available, the general fertilizer recommendation is: **NPK kg /ha: 25 kg of N - 50 kg of P_2O_5 - 100 kg of K_2O**

Do not apply potassium fertilizers after the groundnuts have emerged. Foliar sprays of nutrients are generally ineffective or not economically feasible, except to prevent or correct some micronutrient deficiencies.

Rotation: A well planned, crop rotation system can ensure good yields of high quality. In order to reduce risk in the farming system, groundnuts should be grown in rotation with other crops, especially grass type crops. Groundnuts have been shown to improve the yield of subsequent maize and other grain crops up to 20%. One of the best crop rotation systems is one in which a grass fallow is followed by groundnuts. Fewer diseases are also present in groundnuts following a grass crop. Usually groundnuts also produce a better crop on fields that have been fallowed. To avoid the build-up of pests and diseases, groundnut should not be grown continuously on the same land. A rotation of 3 years or longer can usually reduce disease, pest and weed problems. Because of the incidence of pests and soil-borne diseases, groundnut should not be grown after cotton, although cotton can be used in rotation after groundnut. Crops such as soybean, tobacco, tomatoes and certain other vegetables may cause a build-up of nematodes and soil-borne diseases and, therefore, should be avoided in rotation with groundnuts. Cereals, such as maize, sorghum and millet are good rotational crops, and other clean-weeded crops such as cassava, sweetpotato and sunflower can also be used. Circumstances may force a farmer to plant groundnuts in succession in which case disease problems can be expected, especially leaf and pod diseases. This can be improved by deep ploughing which may reduce the disease problem.

Intercropping: Although a number of crops are used as intercrops with groundnut, results from intercropping research have been inconsistent, so any advantages or disadvantages are not known.

Land Preparation: Land should be prepared early, before the rains start, so that sowing can take place early in the rains (Fig. 1). A uniform seedbed with sufficient planting depth and spacing, good germination, weed control and good moisture retention is imperative for good yields. All previous crop residues and weeds should be completely removed or well incorporated into the soil, and seed beds should be smooth to provide good soil-to-seed contact after sowing. While opening land using hand hoe or ox plough, one should adhere to the above recommendations. Those who can afford tractors for land preparation, deep turn the soil to bury residue and weeds, using a disc plough, 3 - 4 weeks before planting. In wet, low lying areas it may be worth considering using ridges in which to plant groundnuts. The use of ridges can prevent waterlogging, and improve weed control and harvesting. Ridges should be made at, or just before, sowing and they should be flat-topped.

Seed selection: A uniform stand of healthy, vigorous plants is essential if growers are to achieve the yields and quality needed for profitable groundnut production. It is important for growers to plant high quality seed of varieties adapted to their farm situations, management

Box 1: Summary of recommended practices

Agronomy aspect	Recommended practice
Climate	Rainfall: 450-1250 mm per year Temp: 24-30^{0}C
Region in Uganda	Low to mid-altitude
Soils	Sandy or sandy loam, or loamy sands
Fertilizer	60 kg ha^{-1} NPK
Rotation	With cereals or cassava, sweet potato, sunflower
Land preparation	Before on-set of rains
Planting	When moisture is adequate and stable in soil Sow 5-6 cm deep
Seed dressing	With fungicide
Spacing	*Semi-erect types*: 45 X 10-15 cm e.g Serenut 1R, Serenut 2, Serenuts 7T, Serenut 8R *Bunch types*: 45cm X 7.5-10 cm e.g Serenut 4T, 5R, 6T
Weeding	2-3 times
Irrigation	Where possible and necessary

styles, and intended market uses. Yield and quality are two major factors that influence variety selection. Growers with significant disease history may need to choose a variety with disease tolerance or resistance. Use high quality seed of a recommended variety. Several factors must be considered when deciding on variety. First, it is extremely important to evaluate varieties based on regional performance (western, central and southern region prefer red types whereas northern and eastern regions prefer tan/white varieties). Certainly, yield and grade attributes (Appendix I) must be given top priority, but disease tolerance, growth habit, maturity, and seed quality and availability should also be considered. The "perfect variety" possessing all the necessary traits for diverse environments does not exist, so it makes good sense to plant a couple of different varieties to reduce the production risk.

Pods should be shelled 1 - 2 weeks before sowing and only good quality seed should be selected for sowing. Damaged, small or shrivelled seeds should be discarded Fig. 2. It is good practice to purchase certified groundnut seed at regular intervals, preferably every 2 - 3 years. The seeds must be free from contamination, irrespective of the sources of supply.

It is always recommended to test the germination capacity of seed prior to planting. Planting two or more varieties with different maturity dates permits efficient use of limited harvesting and curing equipments. Additionally, planting varieties with different genetic pedigrees reduces the risk of crop failure because of adverse weather or unexpected disease epidemics.

Seed dressing: Groundnut seed is susceptible to blights and rot in the soil. A fungicidal seed treatment will limit this decay and increase the stand in the field. It is therefore recommended that all seed be treated before planting. Two seed coating agents are currently registered for use on groundnuts, namely Mancozeb and Thiram. Comprehensive directions for the use of these agents are indicated on the label. Complete coating of the seed is essential and the use of a mechanical mixing apparatus is strongly recommended. This will reduce seed borne infections during seedlings germination and allow initial vigorous growth.

Dormancy: This is the period after maturity/harvesting that is required for the seed of certain varieties to continue developing before it can germinate even though the normal environmental factors conducive for germination are available. For instance Serenut 3R has a dormancy of at least 45 days; Serenut 5R has a dormancy period of at least 30 days. The other commercial varieties (Appendix I) have no dormancy period and sprout in the field when harvesting is delayed.

Time of planting: With the current weather changes globally, the planting date is difficult to standardize. However, farmers should plant as soon as there is adequate and consistent moisture in the ground to ensure good germination and the subsequent plant growth. Timely planting dates should take advantage of periods of higher rainfall and avoiding end of the season drought effects.

Sowing: Sow groundnut seed in rows and at the right spacing (Fig. 3). Sowing at 5 - 6 cm depth ensures that the plant develops and produces optimally. Seed that germinates slowly as a result of deep planting, takes longer to emerge and a substandard plant will be produced. Shallow planting of seed (less than 5cm) can only be considered when enough moisture is available and the climate is moist. In situations where moisture is not limiting 5 cm to 6 cm is the ideal planting depth. Seeds must not be sown immediately after heavy rains since they imbibe too much water, which causes rotting. This also results in excessive soil compaction which may hinder germination. Long duration varieties (120 days and above e.g. Igola) should only be planted with the first rains in the first season. Short to medium duration varieties can be planted in either season. Early planting generally improves yields and seed quality.

Plant density/Spacing:
Groundnut spacing depends on the growth habit of the variety, botanical type, and the seed mass germination rate of the seed-lot. The recommended space between rows is 45 cm while the recommended spacing between plants within a row is:

Fig. 1: Fine seed bed ready for planting

Fig. 2: Sorting groundnut for planting

Fig. 3: Pajule farmers planting groundnuts in rows

Fig. 4: Correct row spacing for planting groundnuts

Fig. 5: Clean weeded groundnut garden

Fig. 6: Nice groundnut crop

- Semi-erect types: 10 - 15 cm (e.g. Igola 1, Serenut 1 and Serenut 2)
- Bunch types: 7.5 - 10 cm (e.g. RedBeauty, Serenut 4T, Serenut 6T)

Row spacing can be reduced from 45 cm to 30 cm, if desired, and this will allow earlier ground cover and help prevent serious weed problems. Generally, 150,000 plants/ha are recommended for dry land production and for irrigated land 300,000 plants/ha. Planting groundnut plants closer together results in individual plants setting fewer pods, but over a short period of time. Overall, this will ensure that the pods will be of a similar age and stage of development and, therefore, make it easier to decide when to harvest (Okello *et al.*, 2010b). Wider spacing will produce fewer yields per unit area. It is important to sow groundnut seed in rows and at the right spacing as this helps to achieve the correct seed rate, reduce the incidence of rosette disease, ensures a more uniform pod maturity, better quality seed and maximizes yield. Row planting eases operations like: weeding, spraying, disease & pest identification, estimation of plant population/yield per unit area, uses less seed/Easy to determine seed rate, easy supervision and harvesting. Therefore plant at the recommended plant population based on a given row spacing and seed count (Fig. 4).

Weeding: Weeds compete with the crop for moisture, nutrition, light and space. Groundnuts cannot compete effectively with weeds, particularly 3 - 6 weeks after sowing; therefore, effective early weed control implies good control of weed throughout the growing season and this will translate into higher yields (Fig. 5). Weeds can be controlled by using cultural, mechanical, physical and chemical means. A combination approach provides the most successful results.

However, the ultimate choice depends on the species of weeds involved and the level of infestation. Generally, 2 - 3 weedings are recommended, the first before flowering and at least one other during pegging. Once pegging begins, soil disturbance near the plant should be avoided or kept to a minimum, so as not to interfere with the developing pods. Instead weeds at this stage can be controlled by hand-pulling. Weed by hand pulling to avoid earthing up and damaging the pegs. Crop rotation may reduce certain species of weeds. Pre- and post-emergence herbicides may be used to eradicate weeds.

Considerations for cultural and mechanical weed control include:

- Remove spotty infestations by hand hoeing or spot spraying to prevent spreading weed seed, rhizomes, tubers or roots. This is particularly important for perennial weed species.
- Use high quality, weed-free seed
- Clean all tillage and harvesting equipment before moving to the next field, or from weedy to clean areas within a field.
- Use herbicides to remove initial weed flushes prior to planting to ensure a weed-free seedbed.
- Keep the boundaries areas adjacent to fields clean.
- Practice crop rotation.

Weed management is critical to groundnut production from both yield and quality perspectives. Weeds reduce grower profits in several ways. Weed/crop competition for sunlight, water and nutrients can significantly lower yields. Weeds also disrupt digging and harvesting operations and cause pods to be stripped from vines, making them unharvestable. In addition, weed problems can lower grades because plant fragments and fruits are classified as foreign material contamination. Some weeds are reserviors of pests and diseases (alternate/alternative hosts).

Earthing up of groundnuts is not recommended as it limits yields. Earthing up of groundnuts (where soil is piled up around the main stem of the groundnut plant) is an important yield limiting factor as it influences pod formation of the lower highly productive nodes, and promotes disease development. Earthing up, especially in the early stage, has an influence on plant development leading to deformed plants with poor

or no production at the lower nodes. Flowers cannot develop at the nodes, and thus no pegs or pods are formed. Earthing up later in the season normally does not lead to deformed plants (as in the previous instance) but does lead to lower yields.

Irrigation: Groundnuts are considered to be a relatively drought tolerant crop though there are varietal variations to drought tolerance. Groundnuts have various physiological mechanisms for avoiding the effects of drought and an extensive root system which is able to exploit moisture reserves at depth. Even during drought, groundnuts will nearly always produce some yield. However, few farmers can afford average yields because of the high level of input costs. Groundnuts are best grown where the rainfall is reliable and/or where access to irrigation is available.

There are critical times during the growth of the groundnut plant that a soil moisture deficit can severely limit yields and/or diminish quality. The response of groundnuts to moisture stress depends on the stage of growth (Table 1).

Table 1: Groundnut growth stages and response to moisture stress

Plant growth stage (Duration)	Plant Indicators	Relative Drought Susceptibility	Irrigation Requirements
Germination (1 - 2 weeks)	Planting to emergence	High	Good moisture conditions are required. Irrigation can ensure you plant on time.
Early vegetative growth (5 - 6 weeks)	Emergence to pegging	Low	Groundnuts can tolerate mild water stress at this stage. Stress at this stage may be beneficial.
Nut development / fruiting (8 - 9 weeks)	Flowering/ pegging to pod formation	High	No water stress at this stage, very sensitive. Use irrigation where possible.
Maturation (5 - 6 weeks)	pod formation to harvest	Moderate	Decreasing water use as the crop matures.

Source: VT, 2012.

While adequate moisture during the germination stage is necessary for a good, uniform stand, the mid-season nut development, or fruiting stage, is the most critical time for irrigation if there is a shortage of rainfall. In addition to being the stage in which the groundnut plant is most susceptible to drought stress, it is also the stage of maximum water use by the plant.

The amount of water to apply depends on the different developmental stages, soil texture, root zone depth, and the plant-available water level when irrigation is begun as well as the sprinkler irrigation efficiency. In general, water use is low in the early season, but is at its peak during the reproductive period. Consumption then starts to decline as pods begin to mature. Drought stress reduces flower production and pollination, and extreme soil surface temperatures cause peg abortion.

The table below demonstrate how moisture stress at various periods during the season can affect production.

Table 2: Effect of Moisture Stress on Yield of groundnuts

Stress Period (days after planting)	Yield Losses (kgs)
30 to 65	1796
65 to 100	1315
100 to 135	1869
Optimum moisture	2059

Having adequate water available throughout the life cycle of groundnut is important for optimal plant growth and development. Drought or flood can have tremendously negative impacts on yield and quality of groundnut. Likewise, pest infestation and severity of damage from these pests is influenced by available water, either in the form of rainfall or irrigation. Understanding how environmental conditions, and in particular irrigation, affect pest complexes is important in developing appropriate management strategies. Irrigation is a powerful production tool. Irrigation minimizes risk and enhances consistency of yield. Additionally, irrigation improves consistency of pesticide performance and in many ways, the predictability of pest complexes. Groundnut yields will be reduced if the upper soil zone becomes dry from flowering through pod development. A water deficit may lead to the following consequences (Boote *et al.*, 1982):

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

Table 3: Impact of Irrigation on Groundnut Production and Pest Management Strategies

Agronomic Practices	Benefits of Irrigation or Optimum Rainfall
Land Preparation	Helps in establishment of seedbeds, either conventional or reduced tillage.
Seed Germination	Ensures germination of seed when existing soil moisture is marginal for complete stand establishment.
Weed Management	Irrigation or adequate rainfall activates pre-emergence herbicides and minimizes plant stress. Less moisture stress often enhances control by post-emergence herbicides and enables groundnut to recover more rapidly from herbicide damage.
Insect Management	Important for activation of in-furrow insecticides. Improves plant growth and root establishment, which is important in absorption of in-furrow insecticides. Improves groundnut recovery from early-season insect damage and insecticide phytotoxicity. Minimizes potential damage from corn earworms and armyworms by establishment of a dense canopy that can withstand damage from feeding. Reduces the likelihood of spider mite damage by keeping spider mite populations low.
Disease Management	Wet conditions early in the season can minimize potential for crown rot. Irrigation increases likelihood of having a favorable microclimate for development of foliar and soil-borne disease. Symptoms associated with tomato spotted wilt of groundnut are often more pronounced when groundnut are growing under dry and especially hot conditions. Timely irrigation will reduce plant stress and possibly enable plants to withstand tomato spotted wilt more effectively than non-irrigated, water-stressed plants.
Pod Maturation	Irrigation buffers against extremes in moisture and reduces stress (heat and drought), which allows normal flower production and kernel development. Maturation is more predictable and generally earlier. Limited rainfall during reproductive growth often causes delays in maturation and establishment of “multiple crops” or “split crops” on the same plant. Sufficient rainfall is critical for complete kernel development and pod fill.
Supplemental Calcium	Kernels need adequate calcium to become mature and completely developed. Irrigation buffers against drought, which reduces calcium concentration in soil water and mass flow movement into developing pegs
Digging	Ability to supply soil water to improve digging conditions (reduces hardness of soil), improves digging efficiency and minimizes pod loss during the digging process.

Source: David L. J., 2011 with modifications.

Harvest Management Practices

Groundnuts show indeterminate growth, which means that from about four weeks onwards the crop will continue to flower and grow vegetatively throughout the growing season. This characteristic makes it difficult to determine when optimum maturity occurs.

It is very common for the crop to still be flowering at harvest. As a result, the crop does not mature evenly and it can be difficult to determine exactly when to harvest. Therefore, at harvest, seeds on a single plant will be at differing levels of maturity. Harvesting is one of the most critical operations in groundnuts production. Weeds can make efficient harvesting impossible by interfering with digging or lifting. Determining when to harvest is important. Groundnut may gain 300 - 450 kg/ha and 2 - 3% in grade during the 10-day period before optimum harvest. Losses greater than 300 - 450 kg/ha may occur if the crop is not harvested at

optimum maturity. In order to determine the best harvest date a farmer must scout his crop on a regular basis. Maturity affects flavor, grade, milling quality, and shelf life. Not only do mature groundnuts have the quality characteristics that consumers desire, they are worth more to the producer. Damage to pods at the time of harvest should be avoided as much as possible since this can lead to rapid invasion of the pods by *Aspergillus flavus* / *Aspergillus parasiticus* which leads to aflatoxin contamination. Remove excessive moisture from the pods after harvesting through shaking.

i) Timing of pulling /Harvesting

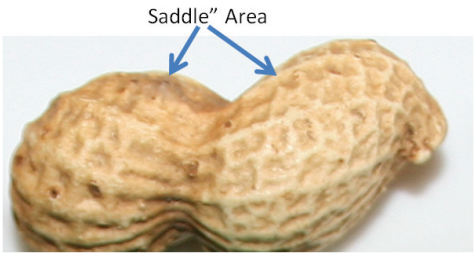
The groundnut plant usually gives an indication when to harvest. In order to determine the correct harvest date, the development of the plant must be considered. The groundnuts should be harvested when approximately 75% of the pods have reached maturity. Harvesting at the right time gives the farmer the maximum yield and grade. If harvesting is too early, grading factors will be lower. If harvesting is too late, over-mature pods can lose peg strength resulting in yield loss. There are several methods to determine the optimum digging time (see below). It is therefore very important to harvest the crop at optimum maturity, as excessive numbers of over-mature or very immature pods at harvest can be reflected in high levels of aflatoxin in the product. Also delays in harvesting will result in poor quality seed due to mould infections and subsequent aflatoxin contamination of the seeds/pods.

ii) Harvest Indicators

As pods mature, the inside portions become brown to black, while immature pods retain a fresh white appearance. The cellular layer just below the outer layer of the pod undergoes several colour changes during the maturation phase. This cellular layer is called the mesocarp. It changes in colour from white to yellow to orange to brown and finally black as the pod matures. This colour distinction can be used to estimate crop maturity with the 'hull scrape' method.

Method 1: ***Hull scrape method***; Hold the pod with the beak pointing down and away from you. With a pocket knife, scrape away the outer hull in the area from the middle of the pod to the peg attachment point. This region is known as the saddle. Pods should be moist when the colour determinations are made. To get accurate representation of the field, collect three (3) adjacent plants from 3 - 5 locations in the field. Collect an adequate sample is necessary for good results.

It is important to note the colour in the saddle area of the pod. This is where the colour changes first occur on the pod.



The colours which occur are:

Colour	Implication to harvest
Black	Mature to Overmature
Dark Brown	Mature
Orange / Light Brown	Close to Mature
Yellow	Immature
White	Immature to Underdeveloped

Method 2: ***Shell interior method.*** The most dependable guide to determine when to harvest is to look for pods with shells turning dark brown inside and the seed coat will be thin and tight on the kernel (Fig.7). The best time to harvest is when the crop has the highest percentage of sound mature kernels (SMK). Pull 3 - 5 plants, strip the pods, shell and examine the insides of the shells. If the majority of the pods (70% upwards) have dark markings inside the shell and the seed are plump and the true colour of that variety, then the groundnut is mature and ready for harvest.

Method 3: ***Seed weight.*** The mean seed mass plant is determined to estimate the maturity at successive intervals. It reaches a constant value, when the crop is mature.

Fig. 7: Shells with dark interior shows physiological maturity

Fig. 8: Serenut 8R (Achieng) remains green even at harvest. Maturity dates given by reaserch is the best harvest indicator.

Fig. 9: Under severe leafspot attack, the crop should be harvested regardless of maturity

Fig. 10: Hoe harvesting

Fig. 11: Hand harvesting

Example: Suppose 3 plants harvested on 20th July gave an average seed mass of 30g, and others harvested on 21st July also gave the same mass, then the crop is mature.

Method 4: ***Days after Planting:*** This and other guides include information on the number of days after planting (DAP) that each variety needs to mature. Use the estimated period of maturity of the varieties as provided by breeder / research institution. For example, Serenuts 1R, 2, 7T, 8R, 9T, 10R, 11T, 12R, 13T, 14R matures in 100 - 110 days. Serenuts 3R, 4T, 6T matures in 90 - 100 days. Acholi White and Red Beauty matures in 85 days. However, DAP is a general estimate of maturity and it should never be used alone for determining the harvesting date. The DAP information should rather be used to schedule approximate planting date. On large acreages, it is suggested that multiple varieties be selected to allow for varying harvest dates.

Groundnut varieties e.g Serenut 8R (Achieng variety, Fig. 8), which Stay-green (a new trait associated with high drought tolerance makes the variety remains green) even at physiological maturity requires a different harvest management from the other non-stay green types. The estimated maturity date from research is the ideal harvest indicator.

Diseases can also have an influence on the determination of harvest date. Plants in which the leaves have been lost due to leaf spot diseases, have weak and withered stems. In such a case, the farmer will be forced to harvest at an earlier stage (Fig. 9).

With experience farmers will become more adept at picking the maturity differences. Farmers must consider the other factors listed below in determining when to dig, but as a general guide the crop is ready for digging when the following maturity levels are reached:

Virginia Varieties: Harvest when 60 to 65% of the pods are brown and black.

Valencia and Spanish Varieties: Harvest when 65 to 80% of the pods brown and black.

Prevailing weather conditions can also influence the determination of the harvest date, as it influences quality. Drought determines the harvest date when the soil is desiccated to such an extent that the plant withers and the seeds in the pods begin to shrivel and take on a ripe appearance. Such groundnuts must be harvested immediately.

iii) Harvesting techniques

Two major harvesting techniques are used in Sub Saharan Africa; hand and hoe/ox drawn plough (Fig. 10 and 11). Whichever method is used care should be taken not to injure the seeds and pod.

- ***Hand harvesting/ hand pulling:*** Most suitable for erect/semi erect groundnut varieties (e.g. Serenut 4T and Serenut 6T) in sandy, loam soils which are well drained. Commonly used during the rainy season when the soils are moist and soft. Hold the entire group of branches as the plant is being lifted. Hand harvest only when there is enough moisture in the soil (Fig. 11).
- ***Hoe/Ox - drawn plough:*** Used for spreading groundnut varieties (Serenut 3R), on heavy soils and during dry conditions. This method is effective in lifting the entire crop from soils with a reduced pod loss. Avoid injury to pods and seed during harvesting using this method. The blades should be passed away from the pods as much as possible. A forked hoe/plough causes less pod/seed damage than unforked ones. This harvesting technique is practiced mainly during the second rains when drought usually sets in at harvesting time. Mechanical damage during harvesting with a hoe is a big problem in groundnuts. When pods are damaged, moulds will enter and produce aflatoxins. The situation becomes worse when drying takes place on bare ground.

iv) Cleaning and selection at harvests

Freshly harvested groundnuts should be cleaned and sorted to remove damaged nuts and other foreign matter. It is important to shake the plant after lifting/harvesting to remove soil from pods and avoid forming optimum conditions for aflatoxin development. Damage to pods at the time of harvest should be avoided as much as possible since this can lead to rapid invasion of the pods by *A. flavus*/A. *parasiticus* that produce aflatoxins which are poisonous. Every effort should be made to minimize physical damage at all stages of harvesting and transportation procedures. Individual plants that die from attack by pests (e.g. termites, nematodes Fig. 12 and 13) and diseases (wilts, pod rots, rosette) should be harvested separately as their pods will likely be contaminated with aflatoxin.

Fig. 12: Groundnut attacked by termites

Fig. 13: Groundnut attacked by nematodes

Major Pests and diseases of groundnuts and their control measures

Groundnuts are exposed to pests and diseases that reduce yield and quality and increase the cost of production wherever the crop is grown.

Major Diseases of Groundnuts

A large number of fungal, viral, nematode and bacterial diseases have been reported on groundnuts, most of which are widespread, but only a few of them are economically important on a regional basis. Major diseases in this region include groundnut rosette, early leaf spot (*C. arachidicola*), late leaf spot (*Phaeoisariopis personata*), Rusts (*Puccinia arachidis*) and aflatoxin (caused by *Aspergillus niger*, *Aspergillus flavus*)

A. Groundnut rosette disease

Groundnut rosette disease is a very serious viral disease of groundnuts widespread in sub-Saharan Africa and its off-shore islands (Waliyar *et al*., 2007). It is the major disease of groundnut in Uganda. It is transmitted by aphids feeding on the crop. There are two types of symptom seen in the crops: green and yellow or (chlorotic). The plants affected by this disease look stunted and presents a bushy appearance. There is a marked reduction in the size of the leaflets and mottling becomes visible (Fig. 14). Yellow (chlorotic) rosette symptoms initially develop a faint mottling on young leaves (Fig 15). Subsequently, leaflets are yellow with green veins. Plants infected when young produce progressively smaller distorted, curled and yellow leaflets. When older plants are infected the symptoms are generally restricted to a few branches or the apical portion of the plant. Green rosette disease shows middle mottling on young leaflets with some leaf curling, but leaves are not distorted. Plants infected when young are severely stunted and dark green in colour. Total yield losses have been reported in susceptible varieties. Uganda has 3 known hotspots (at NaSARRI Serere, Nakabango in Jinja and Ikiiki in Budaka) where disease appears as early as 2 weeks post emergence. Early infected plants produce no yield and there is no control once a plant is infected. A 100% loss in pod yield due to either chlorotic or green rosette disease may result if infection occurs before flowering. Control of aphids will prevent further spread of the disease.

Fig.14: Green Rosette Virus. This plant was infected early and will not produce any yield

Fig.15: Yellow Rosette Virus. No yield will come from the infected plant

Fig. 16: Resistant variety (left) and susceptible variety (right): on-station NaSARRI 2011B season

Management

1. ***Chemical control:***
   - Spray whole plant with insecticides, such as dimethoate 14 days after emergence (usually 5mls per 2 litres of water, but read the label for instructions) and then at 10-day intervals for a total of four sprays.
2. ***Cropping practices:***
   - Timely planting as soon as there is enough moisture in the soil
   - For erect/bunchy types (Serenut-4T, 6T, RedBeauty) plant 45 cm between the rows and 10 - 15 cm between the plants. For spreading types plant 45 cm between the rows and : 7.5 - 10 cm between the plants (e.g. Serenut 2, Serenut 8R, Serenut 7T).
   - Early sowing and close spacing of rows reduce disease
   - Intercropping with beans or sorghum is effective in reducing the disease incidence
3. ***Host plant resistance:***

Resistant varieties exist such as Serenut 2-14 series, Igola 1. These are available from NARO/NaSARRI Serere, seed companies, and select farmers (Fig. 16)

B. Early and late leaf spots

Early leaf spot (*Cercospora. arachidicola*) and late leaf spot (*Phaeoisariopsis personatum*) are the most damaging diseases of groundnuts worldwide. Besides adversely affecting the yield and quality of pod, they also affect the yield and quality of haulm. Although just one leaf spot pathogen usually predominates in a production region, both leaf spot species are generally found in a single field. Shifts in leaf spot species also have been observed over a period of years.

Early leaf spot (*Cercospora arachidicola* Hori) develops small necrotic flecks, that usually have light to dark-brown centers, and a yellow halo. The spots may range from 1 mm - 10 mm in diameter. Sporulation is on the adaxial (upper) surface of leaflets (Fig. 17). Late leaf spot (*Phaeoisariopsis personata* (Berk & Curt) develops small necrotic flecks that enlarge and become light to dark brown (Fig. 18). The yellow halo is either absent or less conspicuous in late leaf spot. Sporulation is common on the abaxial (lower) surface of leaves (Fig. 18). Farmers confuse leafspots with harvest indicators making mitigation measures difficult. The disease(s) maybe expressed on both the leaves and stems (Fig.29) and this results in poor crop stand and yields.

Fig. 17: Early Leafspot disease

Fig. 18: Late Leafspot disease

Fig. 19: Severely leafspot affected plants with both leaves and stems showing symptoms

Table 4: The comparisons of early and late leaf spot of groundnut.

Characteristics / Metrics	Early leaf spot	Late leaf spot
Stage of occurrence	Early infection 30 days after sowing	Usually late infection 55 - 57 days after sowing
Shape of spot	Circular to irregular	Usually circular
Leaf surface on which most spores are produced and their arrangement	Upper surface, Random	Lower surface, in concentric rings
Color of spot on upper leaf surface	Light brown to black, tending towards brown with some yellow halo	Brown to black, tending towards black
Color of spot on lower leaf surface	Brown	Black

Control Measures

- Crop rotation has been shown to provide partial control of leaf spots. When groundnut followed either maize or pasture, the disease development was slow and less severe.
- Early sowing has been shown to reduce the severity of leafspot diseases. Adjust the date of sowing to avoid conditions favourable for rapid disease development.
- Burying all groundnut crop residues by deep plowing will reduce initial inoculum.

Chemical control

- Multiple applications of a fungicide such as benomyl, captafol, chlorothalonil, copper hydroxide, mancozeb or sulphur fungicides may control early and late leaf spot (Smith, 1984) . However, carbendazim (0.05%) controls both leaf spots very effectively.
- Three sprays of 0.2% chlorothalonil at intervals of 10 - 15 days starting 40 days after germination up to 90 days provides effective control to early and late leaf spots, and rust.

Host plant resistance

- Grow cultivars tolerant to late leaf spot: Sources of resistance to both early and late leaf spot have been identified in *Arachis hypogaea* and used to develop breeding lines with resistance e.g. ICGV 87160, ICGV 86590, ICGV-SM 95741, ICGV-SM 95714, Serenut 8R, Serenut 12R and Serenut 14R.

C. Groundnut rusts

Rust (*Puccinia arachidis* Speg.) is one of the important foliar diseases that causes substantial losses to groundnut (*Arachis hypogaea* L.) production worldwide and reduces seed quality. Rust (*Puccinia arachidis* Speg.) and late leaf spot can together cause over 50% loss to groundnut production (Subrahmanyam *et al*., 1985; Waliyar, 1991), and affect seed quality.

Fig. 20: Groundnut Rust disease

Damage: Rust (*Puccinia arachidis*) is identified by the appearance of orange pustules (uredinia) on the abaxial (lower) surface of leaves and reddish-brown urediniospores (*uredospores*) (Fig.20). Symptoms are mainly confined to leaflets but pustules can be seen on all the aerial parts of a plant except the flower and pegs. Brown to dark reddish-brown pustules appear on the lower surface with the upper surface developing yellow, chlorotic spots with necrotic brown areas in the center. Severely infected leaves turn necrotic and desiccate but are attached to the plant. In addition to the direct yield losses, rust disease can lower seed quality by reducing seed size and oil content

Survival and Favourable Conditions: Wet weather coupled with a temperature of 22-25^{o}C favours the disease.

Cultural Control

- Crop rotation and field sanitation.
- Strict plant quarantine regulations should be enforced to avoid the spread of rust on pods or seeds to disease free areas.
- Early sowing to avoid disease incidence.
- Intercropping pearl millet or sorghum with groundnut (1:3) is useful in reducing the intensity of rust.
- Use resistant/tolerant varieties

Mechanical Control

Destroy volunteer (self sown) groundnut plants and crop debris to reduce / limit primary source of inoculum.

Biological Control

Foliar application of aqueous neem leaf extract at 2-5% is useful and economical for the control of rust.

Chemical Control

- Spray chlorothaalonil 0.2%; or mancozeb 0.25% or Hexaconazole/propaconazole to reduce disease incidence.

Resistant varieties

- Grow resistant cultivars: ICGV 87160, ICGV 86590.

D. Aflatoxin

Aflatoxins are a group of toxic metabolites produced by *Aspergillus flavus* and *Aspergillus parasiticus.* Aflatoxins are some of the most potent toxic substances found in foods and feeds. Scientific research shows that aflatoxin B1, M1, and G1 can cause various types of cancer in both animal species and humans. Evidence of acute aflatoxicosis in humans has been reported from many parts of the world with grim morbidity and mortality. Chronic intake of aflatoxin in animals can lead to poor food intake and weight loss.

Fig 21: Aspergillus infected groundnut at harvest

Aflatoxin contamination can occur in the field, during postharvest drying and storage, and shipment (Fig. 21). Crop husbandry practices, mechanical damage, insect and bird damage, climatic conditions (drought, stress or excessive rainfall), and soil factors, in addition to host-plant susceptibility, significantly influence aflatoxin contamination.

Aflatoxins are not visible neither do they have a particular flavour. Therefore, it is not easy to convince consumers about their existence in food. The majority of farmers, traders and consumers in the region are not currently aware of the aflatoxin contamination of food and feed and their implications on commerce, human and livestock health.

Due to their demonstrated potent health effect to both animals and humans, aflatoxins regulations have received great attention in food policy design and debates. Although some good practice based on current scientific knowledge and technical improvements can effectively reduce the level of contamination, the entire elimination of the presence of aflatoxin in foodstuffs is not possible. Therefore, certain Maximum Residue Limits (MRLs) are commonly adopted as the policy instrument to control for aflatoxin contamination in the food supply.

Table 5: Maximum level of total aflatoxin in foodstuffs

Country	Product	Maximum tolerable limit (ppb)
EU1	Groundnuts – Ready to eat,	4
	Groundnuts – for further processing	15
USA	Groundnuts (all products)	20
India	Groundnuts (all products)	30
Kenya	Groundnuts (all products)	10
Uganda	Groundnuts (all products)	10

Source: Okello et al., 2010b

Recommended harvesting practices

- Timely harvesting is very important to avoid delays when groundnuts have reached maturity. The non-dormant groundnut varieties, e.g. Serenut 1R, Serenut 2, Serenut 3R, Serenut 4T, Serenut 6T can sprout/ germinate (Fig. 22) in the field especially if it rains, thus splitting the pods allowing moulds to enter.
- Immediately after harvesting, pluck the pods off the haulms and place to dry as soon as possible
- Avoid field drying of groundnuts when attached to haulms. Aflatoxins increase with delays of produce in the field (Kaaya *et al.*, 2006).

- Careful harvesting to avoid mechanical damage. This is particularly important if hand hoes are used to harvest the pods.

Fig. 22: Non dormant groundnut sprouting after delayed harvest

Recommended drying practices

- Do not dry produce in contact with soil. Use clean sheets, for example polythene sheets, or tarpaulin or mats made of papyrus, cemented grounds or raised structures
- Dry groundnuts as soon as possible (in developed countries, drying is within 48 hours)
- Sun dry grain to bring down its moisture below 13%
- Do not dry diseased/infected produce along with health ones

Recommended shelling practices

- Separate out immature pods as well as those infested with pests and diseases
- Do not shell by beating or trampling on groundnut in shells
- Manual or motorised shelling is recommended but the shellers should not damage the pods.
- Use hand or motorised shellers specifically designed for groundnuts
- Do not sprinkle water on dry pods while using mechanical shellers. Instead, adjust (where possible) the space between blades and the sieve according to pod size to reduce breakage.
- Remove shriveled, discoloured, mouldy and damaged grains from the lot including groundnuts with damaged testa and dispose them.
- Remove dust, and foreign material which can provide a source of contamination.

Recommended storage practices

- Properly dry groundnuts for safe storage moisture content to less than 13%.
- Groundnuts should be placed in packages that will maintain suitable environment and prevent or restrict moisture pick-up and insect/rodent infestation.
- Use new/clean gunny or polybags to store the groundnuts.
- Put only clean sorted kernels into the bags
- Bags should not be placed directly on floor
- Do not heap groundnuts in shells/pods on the floor/ground inside storage structure
- Maintain proper storage facilities (well-ventilated, dry and low relative humidity) and care not to expose produce to moisture during transport and marketing.
- Control insect and rodents during storage
- Do not mix new with old stock produce

Recommended practices for traders

- Always purchase new or current season produce. Avoid purchasing produce stored for more than six months.
- The company should establish its own purchasing system rather than dealing with middlemen. This may involve purchasing groundnuts directly from farmers.
- Always check groundnut quality condition before acceptance. These include:
  - Moisture content (not more than 7%); use moisture meters
  - Presence of diseased/mouldy and discoloured grains
  - Presence of broken kernels

- Presence of soil contaminated grain
- Presence of foreign matter (soil, dust, chaff and stones)
- Presence of insects and insect damaged grain.

- Sorting and cleaning to remove the above - mentioned poor condition kernels should be done prior to processing. Do not process poor quality kernels because garbage in, garbage out. This behaviour is common for groundnut processors and hence their products are heavily contaminated with aflatoxins
- Unshelled groundnuts (those still in shells/dry pods) are better to purchase than shelled nuts since the shell protects them against mould invasion.
- If kernel moisture content of delivered nuts is greater than 13%, (but should not be more than 15%) then immediately dry produce on a clean surface, to reduce moisture content to 7%.
- Groundnuts purchased should not be stored for more than three months.
- The nuts should be stored in new interwoven polypropylene bags stacked in a moisture and rodent proof store (no rodents and insects)
- The store must be routinely cleaned to remove spilled kernels and other foreign materials.
- Proper packaging of the products in moisture-tight containers is recommended.
- On-spot mould and aflatoxin tests of the raw and finished products must be carried out.
- Processors should strive to get the Quality Mark from the Uganda National Bureau of Standards.

Major Pests of Groundnuts

The majority of insects of groundnuts can be grouped as: soil inhabiting insects (e.g termites, white grubs, earwigs, subterranean ants); foliage feeding insects (leafminer, caterpillars, armyworm, bollworm); those that transmit virus disease (thrips, aphids); and insects that damage flowers and growing parts (blister beetle). Of all these termites, aphids, thrips and leafminer are most important.

Fig.23: Aphids on a groundnut plant

A. Aphids: *Aphis craccivora*

These are brownish-gray polyphagous insects. They are vectors of groundnut rosette disease, peanut mottle virus and peanut stripe virus in Asia and Africa. Aphids can cause yield losses upto 40% (Khan and Hussain, 1965). They can cause serious damage in drought situations when the crop is still young. Aphids are sporadic pests and attack crops at all stages. Both adults and nymphs feed mostly on growing tips and young foliage by sucking sap (Fig.23)

Symptoms of damage

- Nymphs and adults inject toxins resulting in whitening of veins and chlorotic patches especially at the tips of leaflets, in a typical 'V' shape.
- Heavily attacked crop looks yellow and gives a scorched appearance known as 'hopper burn'.
- Adult: Elongate, active, wedge shape, green insects

Management

- Timely sowing of the crop and field sanitation.
- Crop rotation with non host crop.

- Intercropping with pearl millet
- Destroy volunteer groundnut plants and weeds
- Avoid groundnut-castor inter crop, it increases the infestation.
- Irrigate to avoid prolonged mid season drought to prevent pre-harvest aflatoxin.
- Spray dimethoate 30EC at 650ml/ha or monochrotophos 36WSC at 600ml/ha in 600 liter water

B. Leafminer

Groundnut leaf miner (*Aproarema modicella* Deventer), a defoliator from the order Lepidoptera, is a very serious pests of groundnuts attacking in both the rainy and post rainy season crops and is regarded as the most important pest threatening groundnut production whenever outbreaks occur. It is much more damaging during the short rainy cycle when long drought precedes rains. In Uganda, total crop losses have been reported by some farmers. No resistant variety is yet available in Uganda though tolerant variety Serenut 10R was released in 2011.

Fig 24: Severely attacked groundnut garden appearing burnt.

Fig 25: Leafminer

Leafminer larvae mines the leaves and feed inside the leaflets. Eggs are laid singly on the underside of the leaves of groundnut, soybean and other leguminous plants. Young larvae mine the leaves and later instars exit the mine to web together several leaflets. Damaged leaves become brownish, rolled and desiccated, which results in early defoliation and affects the growth and yield of the plants (Fig. 24 and 25).

A*proarema modicella* has been recently discovered in various regions in Africa. First in 1998 in Kumi District, Uganda (Epieru, 2004; Page *et al*., 2000), then in Malawi, South Africa, Mozambique and Democratic Republic of Congo (DRC) (du Plessis, 2004; Munyili, 2003). The pest is spreading rapidly, causing serious damage to groundnut, particularly in Mozambique and Uganda. Most of the African groundnut production is considered at risk. The pest also feeds on soybean, cowpea, alfalfa, pigeon pea, other legumes and cotton.

Control methods

- Spraying with Monochrotophos 36SL 600ml/ha or Dimethate 30 EC at 650ml/ha in 600 liter water
- Growing groundnut - cereal rotation reduces the leafminer incidence
- Manipulation of planting dates to avoid the pest buildup
- Growing resistant genotypes e.g. Serenut 10R gives better yields under heavy leafminer infestation
- Use of trap crops
- Botanical pesticides and *Bacillus thuringiensis* Berliner

C. Thrips: *Scirtothrips dorsalis*

Groundnut plants are usually attacked by thrips 6 - 8 weeks after planting. Thrips may complete several generations per season under favourable conditions. Thrips feed primarily in terminal leaf clusters between folds of young leaflets by rasping the tender leaf surface and sucking plant juices. The symptoms from thrips result in dwarfing and malformation of leaves, causing a condition called pouts (Fig. 26). Blackening of the small leaflets can be mistaken for chemical injury. Under favourable conditions, plants normally outgrow this injury with no reduction in yield or grade. However, the delay in vine growth from early-season thrips injury may retard maturity. This in combination with other injuries, such as herbicide burn, can reduce yield. Thrips cause serious crop stunting and yield loss from both direct feeding and virus transmission (tomato spotted wilt virus) in groundnuts, cowpea, greengram, blackgram, soybean and tomato. Thrips are carried, to a large extent, by wind; therefore, it is important to plant late groundnuts upwind from earlier planted fields. Secondary spread occurs when immature thrips develop on virus-infected plants then mature to the adult stage and feed on other groundnut plants within the same field. The virus can only be acquired by immature thrips feeding on infected plants. As the thrips mature they move to other plants nearby thus spreading the virus from plant to plant.

Fig 26: Thrips affected plant (left) is stunted with very small leaves nearing a healthy plant (right)

Symptoms of damage

- Tender leaves showing yellowish green patches on the upper surface and brown necrotic areas and silvery sheen on the lower surface.
- Severe infestations cause stunted plants.

Management

- Spray monochrotophos 36 WSC 600 ml/ha or dimethoate 30 EC 650ml/ha or methyldemeton 25 EC 600 ml in 600 litres of water.
- Spray per acre monocrotophos 320 ml mixed with neem oil 1litre and 1kg soap powder mixed in 200 litres of water twice at 10 days interval.
- Grow resistant/tolerant varieties e.g Serenut 7-14 series from Uganda

D. Termites: *Odontotermes and Microtermes spp*

Termite damage to groundnuts are common in light (red and sandy) soil when rainfall is moderate. The Microtermes and Odontotermes species seriously attack groundnuts. Microtermes kills plants directly by destroying the roots. These are social insects, live in termataria, in distinct castes, workers, king and queen. Workers' are small (4 mm) and have a soft, white body and a brown head.

Symptoms of damage

- Wilting of plants in patches
- Termites penetrate and hollow out the tap root and stem thus kill the plant.
- Bore holes into pods and damage the seed (Fig.27).
- It removes the soft corky tissue from between the veins of pods causing scarification, weaken the shells, make them liable to entry and growth of *Aspergillus flavus* that produces aflotoxins.

Management

- Digging the termataria and destruction of the queen is most important in termite management.
- Use well rotten organic manure.
- Harvest the groundnut as soon as they are matured, early removal of the produce from the field will reduce the chances of termite damage to pods.
- Clean cultivation
- Irrigate the crop frequently
- Thorough ploughing and frequent intercultural operations reduces termite damage.
- Apply chlorpyriphos 20 EC or lindane 1.3% to control termites.
- Dust chlorpyriphos at 30 - 40 kg/ha in soil before sowing in endemic areas
- Seed treatment with chlorpyriphos at 6.5ml /kg of seed may reduce termite damage.

Figure 27: Termite damage on groundnut pods

Storage pests of groundnuts

Groundnuts are stored both as unshelled pods and as kernels for different uses. Both forms are vulnerable to attack by a plethora of insect pests after harvest. More than 100 insect species are known to live and feed on stored groundnuts, some of which are of economic importance. However, groundnut kernels are more susceptible to insect attack than pods in storage. The amount of damage inflicted by insect pests during postharvest processing and storage depends on several factors such as moisture content in the product, the form in which it is stored, level of maturity at harvest, sanitation of storage space and the quality of the material itself. In addition, the storage structure also influences the rate of groundnut deterioration through its physical environment. Post-harvest processing of groundnuts (threshing, drying and cleaning) has significant influence on insect behavior and establishment in the storage facility. Mature pods are less susceptible to insect pests than immature pods. Damage to pod shells also increases susceptibility to insect pests. Pre-storage processing of groundnut varies from country to country and region to region. Insect infestation in groundnut is well known for causing direct loss, but indirect loss in terms of quality of the produce also impacts its trade and use. The heat and moisture generated by a large insect population in storage also increases the risk of mold growth, which indirectly spoils the quality through mycotoxin contamination, rendering the stock unfit for human and animal consumption.

Postharvest losses due to storage pest are on the increase in Africa due in greater part to the recent extension of areas where the groundnut seed-beetle, *Caryedon serratus*, attacks groundnuts. The reasons for the high level of damage inflicted by insects to groundnut stocks in Africa are: deficient collecting networks, inadequate basic road equipment, lack of economic incentives for a better grain quality, inadequate storage structures and management, and lack of hygiene and insect control measures at farm level. Groundnuts often reach the storage facility with high infestation levels and are frequently left without attention to address further insect attack.

A. Peanut bruchid beetle (*Caryedon serratus* Olivier*)*

Groundnut bruchid *Caryedon serratus* also known as peanut bruchid beetle, groundnut borer, seed beetle is a serious pest of stored groundnuts, particularly when these are still in their shells. The damage caused is particularly significant when the groundnuts are destined for confectionery purposes. *Caryedon serratus* is of Asian origin, but is distributed to many tropical and subtropical regions of the world (Southgate 1979).

Symptoms

The translucent milky-white eggs are attached to the pod wall. After hatching, the larva burrows straight through the egg shell and the pod wall, and start eating the seed. The first sign of attack is the appearance of 'windows' cut into the pod wall by the larva to allow the adult to leave the pod after emerging from the pupal cacoon. Fully grown larva sometimes come out through the exit holes made by the previous generations. They often live in the storage sacks and pupate in large numbers at the bottom of the pile of sacks. By this stage, the groundnut seeds are too severely damaged for human consumption or oil expulsion (Wightman and Ranga Rao 1993).

Fig. 28: Peanut Bruchid Beetle (Caryedon serratus) of groundnut: (A) milky-white eggs on the pod; (B) windows cut into the pod wall by the larvae and (C) adult (photos: ICRISAT)

Host includes: *Arachis hypogaea* (groundnut), stored products (dried stored products), *Elaeis guineensis* (African oil palm), *Gossypium* (cotton), *Phaseolus* (beans), *Theobroma cacao* (cocoa) and *Tamarindus indica* (Indian tamarind).
Detection/indexing: Dry seed examination using magnifying lens and X-ray radiography are used.

Treatment/control

- To prevent primary infestation from alternate hosts (Tamarind, Acacia and Pongamia) avoid drying groundnuts near these host trees.
- Incase of positive test remove the infested seeds followed by the seed treatment.
- Storing groundnut kernel with dried neem leaves (about 500 g of leaves for 10 kg kernel) in any sealed container can be effective.

B. Red flour beetle (*Tribolium castaneum* herbst).

Red flour beetles also known as Rust red flour beetle attack stored grain products such as flour and nuts. These beetles have chewing mouthparts, but do not bite or sting. The red flour beetle may elicit an allergic response, but is not known to spread disease and does not feed on or damage the structure of a home or furniture. These beetles are the most important pests of stored products in the home and grocery stores.

Fig. 29: Red Flour Beetle (Tribolium castaneum) of groundnut: (A) adult and (B) damaged seed (photos: ICRISAT)

Symptoms

Infestation by adult beetles can be readily observed by the tunnels they leave when they move through the flour and other granular food products. When infestation is severe, these products turn grayish-yellow and become moldy, with a pungent odour (Fig. 29). Infestation may also be apparent by the appearance of adults on the surface of the seeds (Whiteman and Ranga Rao, 1993).

Hosts includes: *Arachis hypogaea* (groundnut), *Avena sativa* (oats), *Bertholletia excelsa* (Brazil nut), *Hordeum vulgare* (barley), *Juglans* (walnuts), *Lens culinaris* (lentil). *Oryza sativa* (rice), *Phaseolus* (beans), *Phaseolus lunatus* (lima bean), *Pisum sativum* (pea), *Prunus dulcis* (almond), *Secale cereale* (rye), *Triticum* (wheat), *Triticum spelta* (spelt), *Zea mays* (maize).

Geographic distribution

The rust-red flour beetle, originally of Indo-Australian origin, has a cosmopolitan distribution but occurs more in warmer climates. Its distribution is mainly in Africa, Australasian - Oceanian, Central and South America, Europe, Northern Asia, Mediterranean Basin, South and South-east Asia, USA and Canada (Teetes *et al*. 1983).
Detection: X-ray radiography is used for suspected samples because it offers a non-destructive method. Dry seed examination using magnifying lens to separate the infested seed.

Treatment/control

- Fumigation of the samples with methyl bromide by 32 g/m^3 for 4 hour followed by treatment with chlorpyriphos at 3-g/kg seed (Ghanekar *et al*. 1996).
- Rejection of positive samples

General Conclusion on storage pests

A rational control strategy against stored groundnut pests is a global one: it must take into account the different categories of pests mentioned earlier. It should be based upon the following considerations:

(1) In areas where groundnut is prone to termite and myriapod attack (roughly in areas with less than 1000 mm annual rainfall), heavy infestation by secondary pests seems unavoidable without a chemical protection of the stock; any progress in termite and myriapod control in groundnut fields will greatly improve groundnut keeping quality.

(2) Elsewhere, the shell (as long as it is perfectly sound and undamaged) protects groundnuts against all insects except the groundnut seed-beetle *C. serratus*.

(3) The seed-beetle is a pest of groundnut only in certain geographic areas, which should be precisely defined. Priority should be given to the interruption of the infestation cycle, which passes through wild hosts and/or the tamarind tree. Anywhere else groundnut pods will escape field infestation if drying and pod are picked are performed far away from wild host plants in order to avoid invading beetles. Shelling is sometimes advocated as a way to avoid beetle infestation. In fact, usual storage conditions in subsistence farming are such in Africa that unprotected nuts will immediately become the target of various secondary pests;

(4) In all cases, primary infestation originating from *C. serratus*-infested groundnut residues or from various other food products infested by secondary pests must be avoided thanks to a thorough cleaning-up of stores and houses. Granaries and bags must be treated before the new crop is stored;

(5) Preliminary investigations (Mital, 1969; Mapangou-Divassa, 1985) on resistance mechanisms identified in some groundnut varieties should be continued. Research programmes aiming at the selection of new varieties resistant to *C. serratus* should be included in groundnut selection programmes.

Postharvest Management Practices of Groundnuts

Drying: Drying, together with harvesting, have the greatest influence on groundnuts quality and marketing. Do not leave harvested groundnuts in windrows for too long especially during wet weather. Remove as much soil and trash from pods during drying as soon as possible. Drying must begin immediately after lifting to prevent moulding and spoilage. Special care must 'be taken when drying in bad weather as this encourages pod loss, splitting shell discolouration and attack by moulds and insects

Fig 30: Drying groundnuts on bare ground; **bad practice.**

Drying of unshelled nuts

In most instances, aflatoxins are formed after harvest, particularly when harvesting takes place during end-of-season rains. The drying stage is all-important to reduce attack and damage from insects and fungi. Traditional drying techniques involving bare ground drying (Fig. 30) are a major source of fungal contamination. They are slow, time consuming and labour intensive involving lots of crop handling, and due to rains that normally persist at harvesting, it is difficult to achieve the recommended moisture level for safe storage. Some farmers do not dry groundnuts immediately after harvest, due to labour constraints needed for plucking. Thus, they heap the groundnuts either in the field or in houses (Fig. 31). Sometimes farmers store wet groundnuts in bags for a few days waiting for sunshine (Fig. 32) These practices, coupled with inefficient and slow drying process under the humid conditions enhance aflatoxin contamination greatly and are not recommended.

Fig 31: Groundnuts heaped in the house after harvest; **bad prcatice**

Fig. 32: Soiled fresh groundnuts stores in bag prior to drying: **bad practice**

Fig 33: A farmer drys her groundnut on a tarpulin

Fig. 34: Drying groundnuts on a rack constructed from local materials: **recommended practice**

Recommended practices

- Do not dry produce in contact with soil. Use clean sheets, for example polythene sheets, or tarpaulin or mats made of papyrus, cemented grounds or raised structures (Fig. 33 and 34)
- Dry groundnuts as soon as possible (in developed countries, drying is within 48 hours)
- Sundry grain to bring down its moisture to 7% or below for proper storage of groundnuts
- Do not dry diseased/infected produce along with health ones

Ideally pods should be dried with plenty of air circulation and in the shade. After 2 - 3 days of wilting in the field in windrows, the plants should be dried using either A-frames or cocks (Fig. 35 and 36) for 3 - 4 weeks and then pickoff the pods.

Fig.35: A-frame used for plant/pod drying (Source Page *et al.*, 2002)

Fig. 36: Cocks used for plant/pod drying (Source Page *et al.*, 2002)

Postharvest Storage

The fundamental reason why groundnuts should be stored dry is to increase storability and prevent growth of storage fungi. If groundnuts are stored incorrectly, that is, in an improperly dried state or under high humidities with inadequate protection, fungi will inevitably grow. Duration of storage is an important factor when considering aflatoxin formation. The longer the storage period the greater the possibility of building up environmental conditions conducive to fungal proliferation and production of aflatoxin.

Generally, groundnuts are stored in two forms: Inshells/pods (unshelled) and in shelled form (as kernels). The former method of storage is mainly at farm level, while the latter form of storage is at retail level since groundnuts are delivered to wholesalers and retailers as kernels. Storing groundnuts in shells/pods is recommended because shells offer protection against mould infection. When stored in kernel form, groundnuts deteriorate very fast because they pick-up moisture and are easily invaded by moulds, insects and rodents.

Fig 37: Granary, a common storage strucrture among farmers

In most parts of Africa, however, traditional means of crop storage are not optimal as evidenced by the storage structures (Fig 37). Whether traditional or modern, storage conditions should maintain an even, cool and dry internal atmosphere; they should provide protection from insects, rodents, and birds; should be easy to clean and should be water proof and protected from flooding. These recommendations were made in view of *A. flavus* infection and aflatoxin production in stored groundnuts.

The maximum moisture content for storage of groundnuts (unshelled) is 9% while that for shelled groundnuts is 7% (Odogola, 1994; Waliyar *et al*., 2007; 2008). At these moisture contents, if the relative humidity is maintained at 70% and temperature 25˚C - 27˚C, groundnut can safely be stored for approximately one year. Whether groundnuts are kept on the ground, in the granary or in commercial warehouses e.g. of seed production units, the principles of good storage are the same. Storage requires good sanitation, ventilation and pest control. Groundnuts should be stored in their shell. Farmers with large quantities of groundnuts should avoid using plastic or canvas covers that may cause increased moisture/condensation and lead to mould growths.

Storage of processed products

Storage of all processed groundnut products should be in a cool dry place. In retail markets, locally processed peanut butter and other products are usually not stored properly and are often exposed to sunshine. Hot conditions accelerate rancidity and also encourages growth and multiplication of micro-organisms including moulds and bacteria like Salmonella. It is therefore important to improve the quality of the nuts used to produce the products and also maintain recommended packaging and storage procedures.

Packaging

The packages or containers used to store groundnut products should be able to exclude air and moisture. If air enters, it will accelerate the process of rancidity, which induces off-odours and off-flavours, while moisture will encourage mould growth and subsequent aflatoxin production (Okello *et al.*, 2010b).

The containers may be plastic or glass, which should be covered thoroughly to avoid entry of air and moisture. For peanut butter, plastic or glass jars are recommended. These should be sealed tightly to avoid

leakage of oil. Oil separation is common in this product and, quite often, if not well-sealed, containers leak and the oil affects the appearance of the product including the label. Locally processed peanut butter or paste in retail markets of Uganda is commonly packaged in polyethylene bags which are manually tied. This does not offer maximum protection against moisture entry and leakage. Some traders use plastic containers of different shapes with tight covers which is a good practice (Okello *et al*., 2010b). It is important that the containers are well-labeled to include all the important information desired by the consumer and Uganda National Bureau of Standards.

Shelling

Mechanical damage to foodstuff during shelling, threshing and winnowing makes them much more vulnerable to invasion by storage moulds, including *A. flavus*. Under any given environmental conditions fungal growth may be much more rapid in damaged compared to intact nuts. Cracks and breaks in groundnut pods and testa are caused mainly during shelling by trampling or use of machines. There are two types of groundnut shellers now. The hand operated (Fig. 38) and the motorised shellers. The latter normally uses electricity and can be a simple type of sheller that only handles small volumes of groundnuts or a big type that handles several bags of groundnut per hour.

Fig.38: Hand sheller for groundnuts

Fig.39: Hammer mill used to process groundnuts flour

(Source of pictures: Okello et al., 2010b)

Recommended shelling practices

- Separate out immature pods as well as those infested with pests and diseases
- Do not shell by beating or trampling on groundnut in shells
- Manual or motorised shelling is recommended but the shellers should not damage the pods.
- Use hand or motorised shellers specifically designed for groundnuts
- Do not sprinkle water on dry pods while using mechanical shellers. Instead, adjust (where possible) the space between blades and the sieve according to pod size to reduce breakage.
- Remove shriveled, discoloured, mouldy and damaged grains from the lot including groundnuts with damaged testa and dispose off unwanted materials.

Transportation of groundnut products

It is important that during shipping, containers of groundnut products are well-protected. They should not be damaged, which would allow air and moisture absorption and the environment should be cool. It is therefore important that rigid secondary packages/containers are used to hold primary containers. For example, the jars can be packed in paper cartons, which are then stacked in the vehicle for transportation. Under such circumstances, in-pack movements of the jars should be avoided.

Transportation of shelled groundnuts in Uganda is a serious problem. The nuts are packaged in polypropylene bags which quite often are not well-sealed. Thus, spillage is a common phenomenon. The trucks are not well-covered and subsequently the bags are soaked with rain. It is important that the trucks are well-covered with tarpaulins/canvas to avoid moisture and dust.

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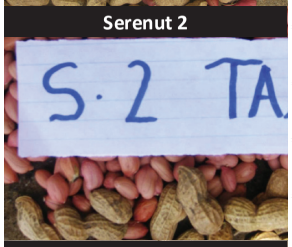
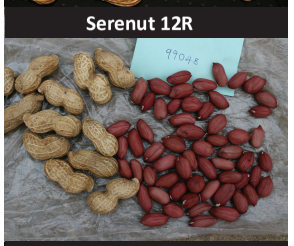
Appendices

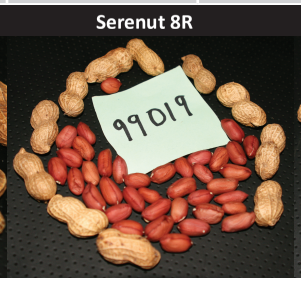
Appendix I: Variety releases 1966 - 2011

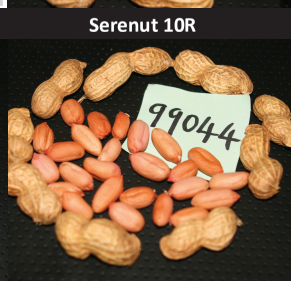
Recommended Commercial groundnut varieties for Uganda

Variety	Maturity Days	Yield (kg/ha)	Year of release	Potential market use	Other remarks
Serenut 1R	100-110	2500-3700	1998	Confectionery, butter	Virginia, tan
Serenut 2	100-110	2500-3700	1998	Condiment, flour	Virginia, Red
Serenut 3R	90-100	2500-2900	2002	Butter, oil	Spanish, Red
Serenut 4T	90-100	2500-2900	2002	Confectionery, butter	Spanish, Tan
Serenut 5R	100-110	2500-3000	2010	Butter, oil	Virginia Red
Serenut 6T	90-100	2500-3000	2010	Butter, oil, confec-tionery	Spanish Tan
Serenut 7T	100-110	2500-3700	2011	Confectionery, butter	Virginia, tan
Serenut 8R	100-110	2500-3700	2011	Confectionery, but-ter, oil	Virginia, Red
Serenut 9T	100-110	2500-3700	2011	Confectionery, butter	Virginia, tan
Serenut 10R	100-110	2500-3700	2011	Butter, butter	Virginia, Red
Serenut 11T	100-110	2500-3700	2011	Confectionery, butter	Virginia, tan
Serenut 12R	100-110	2500-3700	2011	Butter, oil	Virginia, Red
Serenut 13T	100-110	2500-3700	2011	Butter, oil	Virginia, tan
Serenut 14R	100-110	2500-3700	2011	Butter, oil	Virginia, Red



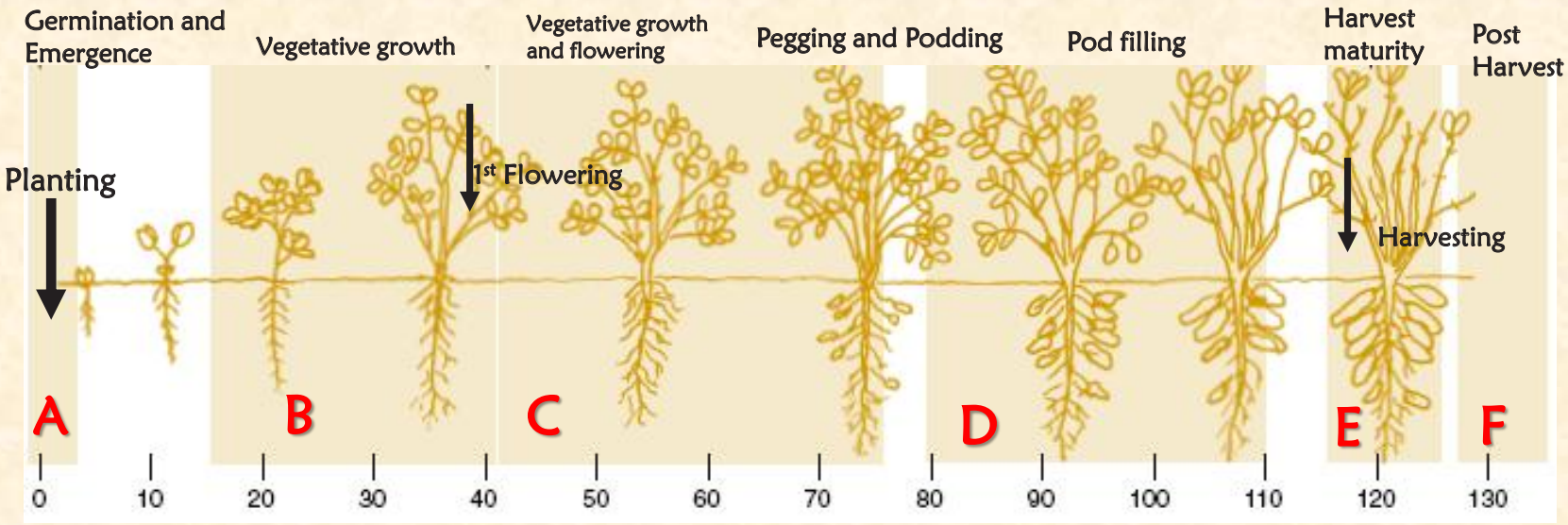






Appendix II: Groundnut growth stages and their managements

DEVELOPMENT STAGES GROUNDNUT AND RECOMMENDED PRACTICES



Days (For Long Duration Variety)

A

- Prepare land early so that seed can be planted early after first rains.
- If possible, fertilize with SSP or TSP before planting.
- Choose good quality seed.
- Dress seed with thiram to control fungal and bacterial growth.
- Sow at 5–6 cm depth.
- Space at 45 x 7.5–10 cm for bunch type varieties.
- Space at 45 x 10–15 cm for Semi-erect type varieties

B

- Ensure good weed control.
- Avoid earthing up plants when using hoe.
- Check for aphids or leaf miners and control if necessary.

C

- Ensure good weed control.
- Weed by hand pulling to avoid earthing up and damage to pegging.
- Check for pests and diseases and control where necessary

D

- If weeding is required use hand pulling.
- Check for pests and diseases and control where necessary.

E

- Harvest when 70% or more pods are mature.
- Use dark markings on inside of shell.
- Seeds should be plump and correct colour for variety.
- If crop is severely defoliated (95%) or sprouting has begun, harvest straight away.
- Clean excess soil from pods.
- Wilt/dry in windrows for 3–5 days.

F

- Dry pods on mats for a further 2–5 days.
- If A-frames or cocks used, dry for 3–4 weeks and then pickoff the pods.
- Do not dry any further after picking.
- Before storing remove poor, damaged, shrivelled, rotten or fungus-infected pods.
- Store pods in gunny bags in a cool, dry, well ventilated store.
- Do not store moist groundnuts.
- Do not use plastic or polyweave bags

Adapted from Page *et at*., 2002 with modifications





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