Guide to Groundnut Production in Malawi

Best Management Practices for a High Quality Crop

August 2023

Malawi Groundnut Production Guide

Best Management Practices for a High-Quality Crop

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Table of Contents

Introduction

Groundnuts are an important crop in Malawi and contribute to food security and farm income. To produce groundnuts successfully, farmers need to consider each of the following steps found in this production guide. The guide also includes three production packages that growers can select based on the yield potential and quality they want, the resources that are available to buy and their ability to afford these inputs and technologies.

Section 1. The Groundnut Plant

Groundnuts (*Arachis hypogaea* L., or peanut) originated on the eastern side of the Andes Mountains in South America. This plant was slowly domesticated and transported across the world by traders. The plant is unique in that the above-ground flowers produce fruit or pods that migrate on pegs to the soil surface and develop underground into what we know as a groundnut. Pod size can vary considerably among varieties.

Figure 1.1. *Representation of the groundnut plant showing both vegetative and reproductive structures.*

Spanish, Valencia, and Virginia botanical type groundnuts are grown throughout the world depending upon market demand and feasibility of production. Spanish and Virginia types are the major variety types grown in Africa including Malawi for both domestic consumption and regional trading.

Groundnuts express an indeterminate growth habit which reflects both vegetative and reproductive growth at the same time. *[Figures 1.1 and 1.2]*

Figure 1.2. *Time-lapse photos show the reproductive stages of groundnut (NC State Extension)*

This growth habit results in a wide range of pod maturity on a single plant at harvest. This habit creates an advantage by increasing resilience and allowing groundnuts to compensate for stresses during the growing season. It also creates a disadvantage because pods do not mature at the same time, making the decision of when to dig difficult. While the length of major growth stages or development stages can vary, Table 1.1 provides estimates that may be used for groundnuts in Malawi.

Days after Planting		Growth Stage	Description
Spanish	Virginia		
5	5	Emergence	Seedling “cracking” the ground and cotyledons visible
35	40	Flower (R1)	One-half of the plants with a bloom
45	50	Beginning Peg (R2)	First visible peg observed
55	65	Beginning Pod (R3)	Peg tip swollen at twice the peg diameter
60	70	Full Pod (R4)	Fully-expanded pod characteristic for the variety
65	75	Beginning Pod-Fill (R5)	Seed within pod is visible in cross-section
75	85	Full Size Seed (R6)	Seed is filling the pod cavity
80	110	Beginning Maturity (R7)	Pods having interior hull color with orange to brown mesocarp
90	120-130	Digging Maturity (R8)	70% of harvestable pods have an orange to light brown and brown to black interior hull color (mesocarp layer)
110	140	Over-mature (R9)	Kernels in oldest pod develop tan-brown seed coat and pegs may have deteriorated; over-mature pods have coal-black internal pod color.

Table 1.1. *Growth stage descriptions show the estimated number of days after planting for Spanish and Virginia cultivars need to reach these stages of development. Actual pace of movement through growth stages is influenced by weather patterns, such as rainfall and temperature. (Modified from Boote, 1980)*

Section 2. Site Selection and Field Preparation

Plant Groundnuts on Suitable Soils

Groundnuts grow best in soils that contain enough organic matter and soil structure but are relatively well drained and do not constrain root growth and pegging or break off pods during digging and lifting. Soils with adequate water-holding capacity can retain soil moisture into dry periods of the season, increasing yield potential and reducing potential growth of aflatoxin-producing molds. Groundnuts are sensitive to high salinity and acidic soils (<5.5 pH) which could contribute to problems with aluminum toxicity. Proper soil pH is 6.0 or higher.

Prepare Land Adequately

Land should be prepared as early as possible, and residues from the previous crop incorporated into the soil.

Most groundnut fields are prepared with either a tractor and disc harrow or by hand. Some farmers use less invasive tilling, preparing the field by controlling vegetation with a non-selective herbicide (glyphosate or paraquat), then planting seed into the soil with minimum disturbance. Both practices can be effective as long as fields are free of weeds when groundnuts begin to emerge. Still other farmers avoid disturbing the soil at all, which often requires the farmer to apply herbicide to control weeds. If weeds are not controlled completely, they can compete with groundnut seedlings and reduce groundnut yield, even if the farmer removes the weeds later in the season.

Groundnuts may be planted on ridges or flat ground. Ridges promote drainage that can reduce water logging of soils. However, this requires additional labor for land preparation. Planting on flat ground requires less labor for land preparation but can allow water to pool and can reduce groundnut stands in low areas during the rainy season. If groundnuts are planted on ridges, it is important to prepare the ridges shortly before planting and make the ridges flat on top. Beds are often spaced about 75 cm from the centers of each bed. Establishing groundnuts on ridges or beds can also make digging or lifting plants from soil easier.

Soil pH will be discussed in more detail in Section 4. How and when land is prepared can affect the efficiency of lime that is applied and distributed into the root zone. Lime requires several months to reduce acidity and increase pH. The soil should be prepared a minimum of one month before seeding so that soil pH is higher when groundnuts begin growing.

Rotate Groundnuts with other Crops

As a legume crop, groundnuts fit well into crop rotation programs in most farming systems that include cassava, maize and tobacco. Growing groundnuts in the same field each year can lead to higher concentrations of pathogens and plant parasitic nematodes, which can reduce yield or require greater inputs to suppress in order to maintain yield. Also, growing groundnut continuously in the same field can mine soil nutrients and cause an imbalance among nutrients. Rotations may also reduce aflatoxin contamination, however, groundnut production following maize often suffers from higher aflatoxin contamination. It is important to plant crops that are not hosts for pathogens and nematodes that also affect groundnuts.

Groundnuts do contribute to fertility of other crops in the rotation through biological nitrogen fixation (BNF). A well-balanced and diverse cropping system leads all crops in the rotation to realize higher yields and often decreases production costs and increase financial return for the farm. Groundnuts can also produce good yields in new fields and in fields where appropriate grass or broadleaf crops were grown.

Establish the Most Effective Sequence of Crops

The order or sequence of crops in the rotation is important. Planting groundnuts after legumes such as soybean may contribute to pest problems; it is better to alternate non-legume crops, such as tobacco, with groundnut. A good rotation sequence in Malawi would be tobacco-groundnuts-maize. If tobacco is not available, planting one or two crops of maize between groundnut plantings would be a good choice.

However, while maize is a good agronomic choice because it can reduce pest problems and take advantage of the nitrogen groundnuts contribute to the soil, maize may increase aflatoxin contamination levels in the subsequent groundnut crop. There is a bit of a trade-off in the maize to groundnut rotation, which reduces the threat from pests and diseases, but may increase aflatoxin in the groundnut crop. When groundnut follows maize in a rotation, it is critical to harvest on time to minimize aflatoxin contamination. If soybean is an option, planting a rotation of soybean-maize-groundnut-maize can be effective for pest suppression. When a farmer wants to plant groundnut more frequently, it is best to plant groundnuts before soybean rather than following soybean. Plant groundnut in a field that grew a non-legume crop the season before.

The economic value of each crop in the rotation determines what will be planted each year, but regardless of economic drivers, a poor rotation will eventually result in lower groundnut yields or will require greater inputs to suppress pests that have become entrenched. The value of specific rotations will be further examined in the risk management tool at the end of this guide.

Section 3. Variety Selection, Seed Quality, and Plant Populations

Select Improved Varieties from a Known Source

Assets to consider when selecting a variety include:

- pest resistance, which is essential to optimize yield and quality.
- predictability and durability of yield across environments for risk management.
- drought and disease resistance, such as resistance to leaf spot disease and rosette.
- short maturity times, which allow a farmer to adapt to early or unpredictable dry seasons
- consumer preference and market demand

Commercially available varieties and key characteristics in Malawi are listed in Table 3.1. Several improved groundnut varieties (both Spanish and Virginia types) have been released by DARS through research with CGIAR and other partners in Malawi. The latest varieties combine high yield, disease resistance and other preferred market traits. Understanding how these varieties interact with planting date, plant populations and other available inputs can help optimize yield of these varieties.

Agro-ecologies for Groundnut Cultivation

Malawi has four main agro-ecologies based on climatic conditions and differences in altitude: the high altitude areas, the mid-altitude or plateau areas (900-1200 m), the lakeshore, and the Shire Valley. The lakeshore and the Shire Valley are often regarded as a lowland agro-ecology (up to 899 m). Groundnut is grown from near sea level to >1500 m, but over 70% is produced in the mid altitude and plateau areas, covering Lilongwe and Kasungu in central Malawi, and Mzimba district in northern Malawi. Groundnuts are mainly grown as a rainfed crop; however, off-season production is possible in some parts of Nkhatabay and Karonga districts. The crop is either grown as the sole crop or intercropped with maize, sorghum, millets, soybean, pigeon peas or other plants.

The Virginia-type varieties are promoted in the mid altitude agro-ecology while the Spanish-type varieties are promoted in the lowland agro-ecology.

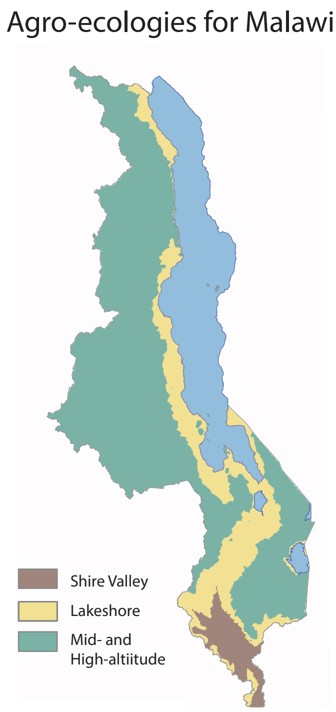


Figure 3.1

Importance of Seed Quality

Regardless of the variety, a farmer should use quality seed with high germination and seedling vigor. Seed that is produced under poor growing conditions, dried too quickly or to a low moisture level, has pest damage or is stored under warm and humid conditions often will have low germination and seedling vigor. Seed grown in soil lacking adequate nutrients, especially calcium and boron, are less likely to germinate and may produce plants with less vigor. Drought stress during the previous year also limits kernel development and subsequent germination and growth of seedlings. Growers should know the source of their seed and the quality of seed before purchase. Seed damaged through improper mechanical shelling can reduce germination. Kernels that are split or have damage to the seed coat will not germinate.

Table 3.1. *List of released varieties in Malawi.*

Table 3.1
VB = Virginia bunch, VR = Virginia runner, SB = Spanish bunch

Table 3.1

Varieties in Malawi

Variety	Market type	Year	Maturity (DAS)	Agro-ecology	Attributes and Use	Potential Yield under Good Management
Baka	SB	2001	90-120	Low-lying areas, lakeshore, Shire Valley	High yield, Rosette resistant, confectionery	1500 kg/ha
CG 7	VB*	1990	130-150	All groundnut growing areas	High-yield, wide adaptation, confectionery, oil, red seed colour	2500 kg/ha
CG 8	VB	2014	120-130	Mid-altitude	High pod yield, Rosette tolerant	2500 kg/ha
CG 9	VB	2014	120-130	Mid-altitude	High pod yield, Rosette tolerant	2500 kg/ha
CG 10	VB	2014	120-130	Mid-altitude	High pod yield, Rosette tolerant	2500 kg/ha
CG 11	VB	2014	120-130	Mid-altitude	High pod yield, Rosette tolerant	2500 kg/ha
CG 12	SB	2014	90-100	Low-lying areas, lakeshore, Shire Valley	High pod yield, early maturity, drought tolerant, Rosette resistant, good grain filling	1500 kg/ha
CG 13	SB	2014	100-110	Low-lying areas, lakeshore, Shire Valley	High pod yield, early maturity, drought tolerant, Rosette resistant, good grain filling	2000 kg/ha
CG 14	SB	2014	100-110	Low-lying areas, lakeshore, Shire Valley	High pod yield, early maturity, drought tolerant, Rosette resistant, good grain filling	2000 kg/ha
Chalimbana	VR	1968	140-150	Mid-altitude	High yield, confectionery	1500 kg/ha
Chalimbana 2005	VB	2005	130-140	Mid-altitude	High yield, confectionery	2500 kg/ha
Chitala	SB	2005	90-110	Low-lying areas, lakeshore, Shire Valley	High yield, confectionery	2000 kg/ha
Kakoma	SB	2000	90-120	Low-lying areas, lakeshore, Shire Valley	High yield, confectionery	1500 kg/ha
Nsinjiro	VB	2000	120-140	Mid-altitude	High yield, Rosette resistant, confectionery	2000 kg/ha
Mphatso	SB	2020	95	Low-lying areas	High yield, confectionary, drought tolerant, extra early maturing	2000 kg/ha

VB = Virginia bunch, VR = Virginia runner, SB = Spanish bunch
(Some legacy varieties, such as Chitembana, Malimba, Mani Pintar, Mawanga and RG1, are not listed because they are not commonly grown.)

Source of Seed

To realize high yields, farmers should use good quality seed from known and reliable seed sources such as International Crops Research Institute for the Semi-Arid Tropics (ICRISAT), Department of Agricultural Research Services (DARS) or a registered body of certified seed traders. A farmer who obtains seed of an improved variety may opt to save some of the crop to use as seed in subsequent seasons, but groundnut, like other legumes, should be harvested and saved as seed only three times. After three years of recycling, fresh seed should be obtained from known and registered seed sources for optimum production. Saved seed should be kept in shells until shortly before planting. Storing seed in the shell protects seed from physical damage and pests. Handle seed gently to avoid physical damage and negative impact on germination and seedling vigor.

Conducting a Seed Germination Test

Prior to planting seed in the field, growers should determine the germination rate so that they can adjust seeding rates, if necessary, to achieve an optimum plant population. Germination and plant density can have important implications for a farmer trying to reach a certain yield per hectare or needing a total amount of production from the farm.

To test germination, shell approximately 20-25 pods, sow 40 seeds in soil and water well enough to germinate. If 30 plants emerge, the seed is considered high quality and no adjustment at planting is necessary. If 20-30 plants emerge, you should plant a bit closer or put 2 seeds together in the row. If fewer than 20 plants emerge, the seed is poor quality and you will need to plant 3 seeds together in the row or purchase new seed.

The proper plant density is important to get the best yield, so it is better to sow seed to achieve the proper plant density than to spread the crop over a larger land area. If you have additional area available for planting, either purchase more seed to sow for the proper density or plant another crop on the additional land. A farmer should keep some seed in order to plant where seeds failed to emerge. This will establish greater uniformity of groundnut stands and can reduce weed interference and rosette disease.

Seed Preparation and Treatment

Groundnut to be used as seed should be selected carefully and graded before sowing. Before sowing, pods should be hand-shelled and sorted to eliminate skinned, immature, moldy, and small or disfigured seeds. Farmers may choose to treat seeds with an insecticide/fungicide mixture to minimize the impact of insects and pathogens that cause seedling disease and stand loss. The most common fungicide is Thiram which can be sourced from agricultural chemical companies such as Chemicals and Marketing, Agricultural Trading Company, Farmers' Organization, Crop Serve and other registered agro-dealers. Farmers should use caution when using Thiram to treat seed and in handling the treated seed.

Establish Adequate Groundnut Population

In order to get the best yield, it is critical to have an adequate plant population. A final plant stand of 220,000 plants per hectare is optimal for the greatest yield. Historical recommendations in Malawi indicated that optimum yields could be obtained if groundnut is planted on ridges spaced at 60 cm for Spanish (133,300 plants/ha) and 75 cm for Virginia varieties (89,000 plants/ha). However, more recent research indicates growers should sow seed closer. A higher seeding rate and denser plant population can result in less groundnut rosette, suppress weeds, bring a higher yield, and result in less aflatoxin contamination at harvest, in some instances.

Recommended ridge and plant spacing for varieties differs. Table 3.2 gives maximum plant stand at different seed and row spacings. Regardless of row spacing, growers should plant seed no more than 10 cm apart for Spanish (5 cm along the twin/double row) and 15 am apart for Virginia varieties (7.5 cm along the twin row).

Though farmers sometimes choose to plant seed farther apart, it is important to follow spacing guidelines in order to establish a canopy and optimize photosynthesis early in the growth cycle. The recommended spacing may be different for different types of groundnut. For example, Virginia varieties often have a more prostrate or running growth habit and will produce pods further away from the crown of the plant, while Spanish varieties often grow more upright requiring plants to be established closer together.

Spacing and Seeding

Market Type	Varieties	Planting Pattern	Spacing between row centers (cm)	Rows per bed	Spacing between rows on bed (cm)	Spacing between seed in row (cm)	Seeding Rate (kg/ha @ 1 seed per hill)	Target Population (plants/ha)
Virginia	CG 7, CG 8, CG 9, CG 10, CG 11, Chalimbana 2005, Nsinjiro	Single 75/15	75	1	-	10	80-100	133,000
		Double 75/15	75	2	25	10	180-200	267,000
Spanish	Baka, CG 12, CG 13, CG 14, Chitala, Kakoma	Single 75/10	75	1	-	15	50-70	89,000
		Double 75/10	75	2	25	15	110-130	178,000

Table 3.2. *Recommended spacing and seed rate per market type of variety.*

The use of double rows, especially for Spanish types, is recommended. Seed should be planted in two lines on top of the bed following a zig-zag pattern, so that each seed in a line is 10 cm apart for Spanish varieties and 15 cm apart for Virginia types. This will result in spacing of 5 cm and 7.5 cm along the double row, and result in optimal plant densities and good ground cover. Double rows have been shown to increase yield, but it does increase the amount of seed sown per unit area. However, the goal is to optimize yield.

The actual seeding rate (kg per ha) depends on seed size (100 seed weight) and should reflect the germination percentage. After the groundnut plants emerge, growers should fill in gaps in plant stands as quickly as possible. Establishing plants no more than 10 or 15 cm apart not only increases yield potential but also minimizes the impact of rosette disease. The guidelines for plant spacing apply to all planting dates and for all commercially-grown varieties in Malawi. When seedling rate and plant density are optimum, the groundnut canopy will close more quickly, decreasing soil temperatures in the pegging zone which can increase the likelihood that pegs will survive in soil. Weed control is often enhanced when the groundnut canopy is closed more quickly.

Planting Configurations

Some farmers may choose to use broadcast planting because they have limited time and labor when the rains begin, but this approach can lead to erratic stands and poor stand establishment. Weed management is also more challenging when groundnut seeds are broadcast rather than planted in rows. Flat-sowing in rows or on raised beds is recommended in areas where the soils are loose to prevent losing pods to the ground (pod retention) during harvesting. When groundnut is grown on flat, the spacing between rows should be reduced to 45 cm. Replanting in areas that have not germinated should be done within one week of seedling emergence.

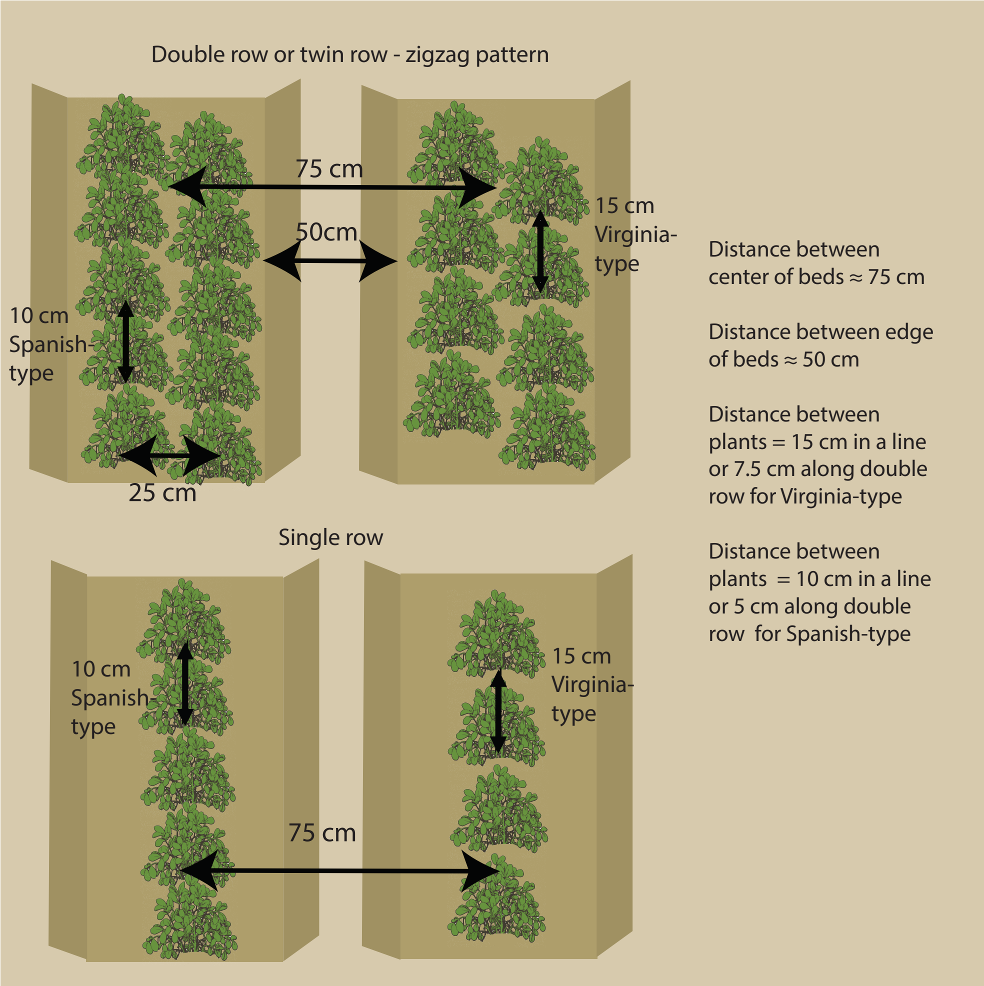


Figure 3.2. *Spacing is important to achieve good plant density for yield and weed control.*

Intercropping versus Monocropping

Many farmers choose to use intercropping, an approach that allows maize to benefit from BNF and can increase overall diversity of crops. Intercropping can also mitigate risk and can allow farmers with limited land to expand production in a different dimension, upward rather than laterally across landscapes. However, intercropping results in competition of the taller crop in the canopy (maize and cassava, for example) with lower-growing crops like groundnuts.

Intercropping rather than monocropping limits mechanization and presents challenges in synchronization of the crops in this system. If crops are not synchronized, one crop can be damaged when the other crop is harvested. Incorporating pesticides into an intercropped system is also difficult, especially with herbicides that may damage sensitive crops growing close to tolerant crops.

Land Preparation

This should start early enough (July or August) to ensure that residues from the previous crop are decomposed before the rains come and the growing season begins. This will also give ample time for the farmer to plant when the first effective rains begin. Ensure that all residues are buried, plowing is deep enough and soils are loose and friable which is important for rooting, water penetration, and pegging.

Sowing

In Malawi, planting should be initiated when the first effective rains begin. There has been some success with dry planting when it occurs within 2 weeks prior to the first rains, but this can be risky, since seeds can deteriorate if they remain in the ground for an extended period prior to germination. If seed is treated with inoculant for BNF, the bacteria in the inoculant does not survive if exposed to hot and dry conditions for a prolonged period of time. The suggested dry planting dates are based upon rainfall patterns for that area.

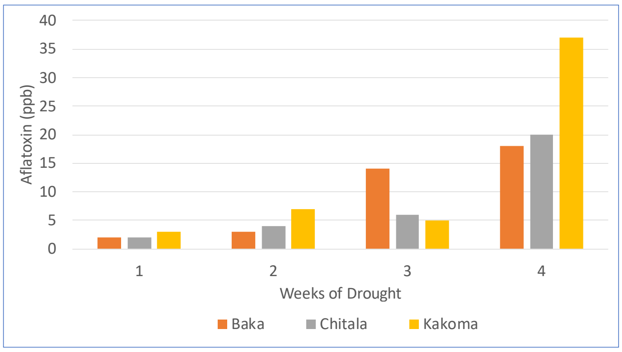


Figure 3.3. Influence of variety and duration of drought on aflatoxin contamination.

Groundnuts should not be planted after January 15 because of relatively high populations of aphids that transmit groundnut rosette virus. Planting this late will result in dry conditions during the latter part of the growing cycle. Prolonged drought during pod fill and near harvest causes lower yields and greater potential for aflatoxin contamination compared with early plantings that generally have more abundant rain throughout the growing cycle.

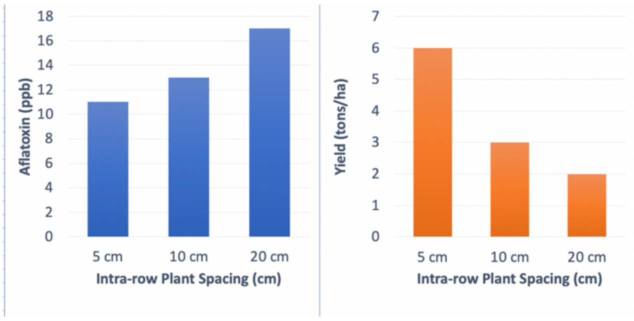


Figure 3.4. Influence of intra-row spacing on yield and aflatoxin contamination.

The first step in planting is to make a one or two (if planting double rows) grooves that are 5-7 cm deep along the top of the ridge. The amount of seed dropped in dependent upon germination of seed. In most cases, germination of seed will not exceed 75%. If the germination rate is 75% or higher, plant one seed per hole. If the rate is between 50% and 75%, plant two seeds per hole. If the rate is less than 50%, plant three seeds in each hole (or obtain better seed). The farmer should place the seed, then cover the groove with soil and press firmly to ensure adequate soil-seed contact and uniform seedling emergence. It is also important to replant in areas where seeds do not germinate within the first week after seedling emergence.

Plant as Soon as Rains Begin

The optimum planting date in Malawi for groundnuts coincides with the first predictable and sustained rains. This can occur in late November or early to late December, but can vary from year to year and across geographies in the country. Planting on time allows good germination and quick groundcover to suppress weeds and reduce rosette disease. Planting as early as possible also reduces the risk the crop will face drought later in the season (February/March) which can affect pod filling and increase the risk of infection by molds that cause aflatoxin contamination. Dry planting, within 2 weeks of the onset of rains, can also lower rosette pressure, increase yields, and reduce aflatoxin, but it comes with the risk that if the rains are delayed, the farmer will have poor germination and fewer plants. Finally, it is important not to wait until all maize is planted to start planting groundnut as it likely will be too late and result in a poor crop.

Planting date	Rain during final 30 days of the season (cm)	Aflatoxin (ppb)
December 31	9.9	4
January 8	2.7	37
January 15	0	89

Table 3.3. *Relationship of planting date, rainfall and aflatoxin contamination.*

Section 4. pH and Soil Fertility

Soil pH

Groundnut yield potential is often greatest when soil pH ranges from 5.8 to 6.2. Many soils in Malawi have pH much lower than optimum, and yield and quality of groundnuts will not reach full potential regardless of other inputs unless soil pH is raised to the recommended level. When soil pH is too low, groundnuts won't respond well to *Bradyrhizobia*-containing inoculant involved in BNF or to supplemental calcium in the form of gypsum (calcium sulfate).

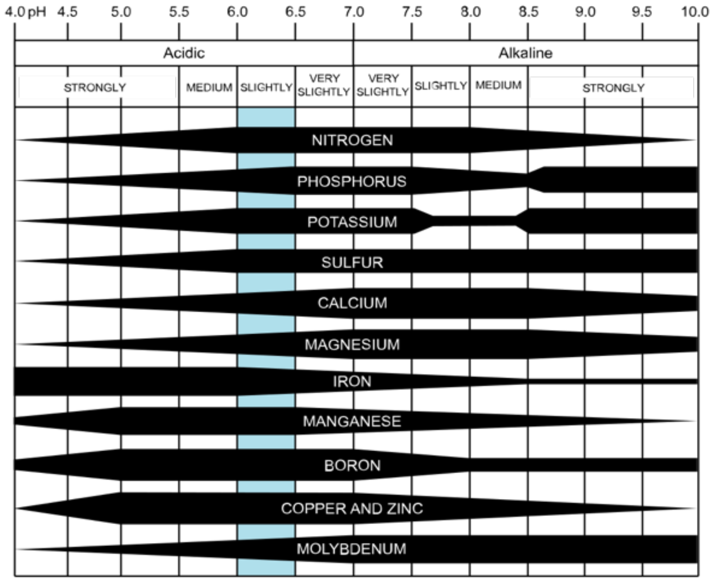


Figure 4.1. *Groundnut can best absorb and use necessary minerals when the soil pH is between 6.0 and 6.5.*

Elements such as boron, manganese, molybdenum, and zinc can be affected by soil pH. The proper balance of all elements requires a soil pH around 6.0 for groundnuts. When soil pH is lower than 5.5, the bacteria in inoculant often does not survive.

Lime should be applied several months in advance of sowing groundnut to reduce acidity. The rate of lime needed to raise pH to 5.5 or higher depends on the current pH level and ability to incorporate lime into the upper 25 cm of soil. Although groundnut roots can grow deeper than 25 cm, neutralizing acidity of soils in the rooting zone is important. To increase soil pH by a factor of 0.5 units (for example, increasing soil pH from 5.0 to 5.5) requires approximately 1,000 kg/ha of dolomitic lime on a broadcast basis. To increase soil pH from 5.0 to the desired level of 6.0 requires approximately 2,000 kg/ha.

Soil samples taken in 2021 from more than 850 maize, groundnut, and soybean fields in five selected districts (Lilongwe, Salima, Ntchisi, Kasungu, and Mzimba) showed a range of pH levels, but the vast majority were between 4.0 and 6.0. Initial observations indicated that the average soil pH was approximately 5.2 which is lower than optimal. Inputs such as inoculants perform poorly under low soil pH and are most effective when the pH is close to 6.0.

Soil Fertility and Plant Nutrition

Groundnut can benefit from residual fertility and in some cases no additional fertilizer may be required if the crop is grown on well-managed land previously treated with a balanced fertilizer. However, if native fertility is low added fertilizer will increase yield. Most soils in rain fed agriculture contain very little phosphorus, so to ensure good plant establishment and high yield, farmers are encouraged to apply superphosphate before or at sowing. Use of single super phosphate, provides the crop with phosphate, sulphate and calcium which are all essential for crop growth and development.

Generally, groundnuts perform well following a well fertilized maize or tobacco crop. Phosphorus, calcium and sulfur-containing fertilizers such as 23:21:0+4S can increase groundnut yields even when applied to the previous crop. Superphosphate at 100 kg/ha applied at planting is recommended for groundnut in fields that have low native fertility levels. The fertilizer should be applied in a band on the ridge, or broadcast onto the soil and ploughed under before sowing. Studies in 2020 and 2021 indicate inconsistent, but often significant yield increases from the use of inorganic fertilizers. These inputs did not appear to be consistent across varieties and more research is needed.

Biological Nitrogen Fixation (BNF)

Many leguminous plants, including groundnut, can form a symbiotic relationship with specific bacteria (Bradyrhizobia spp.) that are commonly found in the soil. The bacteria infect the roots of the plant and take nitrogen from the air and make it available to help the plant grow (BNF) in exchange for nutrients from the plant. This exchange happens in small nodules found on the roots of the plants. Active BNF can be confirmed by slicing open a nodule to see if there is a red or rust color, indicating the active conversion of nitrogen. Specific strains of Bradyrhizobia have been identified to maximize this production for groundnut and are available as commercial inoculants that are usually coated to the seed prior to planting.

Unlike soy, which requires a specific strain of bacteria for BNF, groundnut may or may not benefit from inoculant. Inoculant can increase nodulation and nitrogen-fixing, leading to higher yield. However, in fields where groundnuts have been grown in the past, bacteria populations may already be adequate, making inoculant unnecessary. Or, if the soil pH is too low, inoculant may be ineffective until the pH is adjusted (a process described elsewhere in the guide). Recent trials conducted in Malawi indicate a benefit from the use of inoculants and increased biological nitrogen fixation and yield, but this was not true at every location or with every variety. Data trends do indicate value in using inoculant, particularly if soil pH is higher (above 5.5).

Figures 4.2 and 4.3. *These images show nodulation and the deep red or rust color that indicates proper nodule activity. (Figure 4.2 photo by Bridget Lassiter)*

Since inoculants are living organisms, they can also be damaged by poor handling, such as storing in extreme heat. When using an inoculant, farmers should acquire their supply from a reputable dealer, follow the manufacturer's directions carefully, apply the inoculant immediately before planting and purchase a new supply every year to ensure the maximum number of living bacteria. Pesticide seed treatments may harm inoculant performance, so farmers who use both should follow manufacturer's directions closely. Direct contact with synthetic fertilizers in the soil also may harm inoculant health, so farmers should consider how fertilizers are applied at planting. Do not apply fertilizer in-furrow where it can contact the seed.

Apply Calcium at First Flowering

Calcium is the most limiting nutrient in sandy soils and where medium- to large-seeded varieties such as the Virginia-types are grown. The large-seeded Virginia types have larger kernels which often require more calcium to ensure kernel formation and seed development than small-seeded Spanish varieties do. Topdressing with gypsum when 30% of the plants have flowered will help to correct calcium deficiency and reduce the number of groundnut pods without kernels or malformed kernels. Gypsum should be applied at the rate of 200 kg/ha directly at the base of the plant where the pegs will enter the soil. Under low soil pH conditions, which is common in Malawi, the application of gypsum may reduce yield. For example, data from the USA showed that a positive response to gypsum occurs when soil pH is around 6.0. At pH around 5.5 a decrease in yield was noted when gypsum was applied, at pH 5.2 there was no response to gypsum, and at pH 4.5 gypsum increased yield. Other results indicated that increasing gypsum rates above those currently recommended also reduced yield when pH was 5.5. These results indicate that a clear description of gypsum rate and application methodology is needed when determining if gypsum will play a positive, negative or neutral role relative to soil pH.

Studies conducted in the 2020-2021 growing season on the impact of boron and calcium applications demonstrated a strong positive impact on yield across two locations, both Chitala and CG9 varieties, and when applied at different dates in fields with soil pH near 6.0.

Section 5. Protect Groundnuts from Weeds and Pests

Impact of Weeds on Groundnut Yield

Weeds can compete with groundnuts for light, nutrients in soil, and water causing major yield losses if they are not controlled. Weeds can also interfere with digging and lifting plants at harvest. Broadleaf weeds, annual and perennial grasses, and sedges are present in many fields and if left uncontrolled, can result in significant yield reduction. When and how often a farmer controls weeds will influence the final yield of groundnuts. To ensure the highest yields, growers need to begin the first weeding (usually by hand, using hoes) no later than 3 weeks after planting. Additional weeding at 6 and 9 weeks after planting will also protect yield from weeds that emerge later. The first 30 days is the most important time to weed and is often referred to as the critical period of weed interference. Once flowering and pegging begins, weeds should be pulled by hand to avoid destroying flowers and developing pods or disturbing the soil.

Planting in rows rather than broadcast seeding or intercropping increases efficiency of hand-weeding. Intercropping limits the use of herbicides to control weeds because of the potential for damage to crops other than groundnut. A thick and uniform stand of groundnuts can improve weed control by allowing groundnut plants to shade the soil and minimize growth of weeds. By establishing a groundnut population of 222,000 plants per hectare and using an appropriate herbicide at planting or hand-weeding within 30 days of planting, a farmer can avoid an additional weeding later in the season and preserve yield.

Herbicide Guidelines for Suppression of Weeds

Some farmers may choose to buy herbicides. Use of herbicides, especially immediately after planting, can reduce the time required for hand removal and protect groundnuts from weed interference. For example, research in Ghana indicated that 40 or more hours were required to hand weed a single hectare of groundnuts (Figure 5.4). Using herbicides at planting decreased this time commitment dramatically, and even though the herbicides were expensive, the weed control they provided was cost effective and brought documented financial benefits. When labor to remove weeds by hand is limited, herbicides can be an effective tool for farmers to minimize weed interference during the first month of the season.

Trials conducted in Malawi in 2020 and 2021 at two locations show a benefit from the use of herbicides in terms of reduced labor and increased yield. This was true for both the use of preemergence and postemergence herbicides.

It is important to make sure any herbicides used in groundnuts are approved by regulatory agencies in Malawi and that they are used in accordance with the manufacturer's product label.

Several herbicides can be applied to groundnut fields before sowing or just after sowing but before groundnuts and weeds emerge. Glyphosate and paraquat and other herbicides containing the active ingredient acetochlor, alachlor, diclosulam, pendimethalin, *S*-metolachlor, and trifluralin are available in Malawi and provide good suppression of weeds during the first 30 days of the season. These herbicides control weeds that might emerge for several weeks after application, but do not kill weeds that already are growing when the chemical is applied.

Glyphosate is a relatively safe herbicide to handle and apply. However, paraquat is highly toxic to humans and animals and should be applied only when people use all safety precautions. If adequate personal protection equipment is not available, paraquat should not be used.

Consistent control requires application several weeks before sowing if a disc is not used and then a second application immediately after sowing. If a disc is used to prepare field for sowing, these herbicides can control weeds that begin to emerge after disking, especially if sowing is delayed because of labor issues or excessive rain. Do not apply these herbicides if soil begins to crack due to groundnut emergence. These herbicides are considered non-selective and will kill not only groundnuts but also weeds once they have emerged.

Once groundnuts have emerged, herbicides such as bentazon and fluazifop-p-butyl can be used. Bentazon controls broadleaf weeds and sedges while fluazifop-p-butyl will control grasses. Make sure the correct adjuvant is added with the herbicide. These herbicides control only the weeds that have emerged, and the herbicide comes in contact with. There is no residual weed control in the soil from these two post-emergence herbicides.

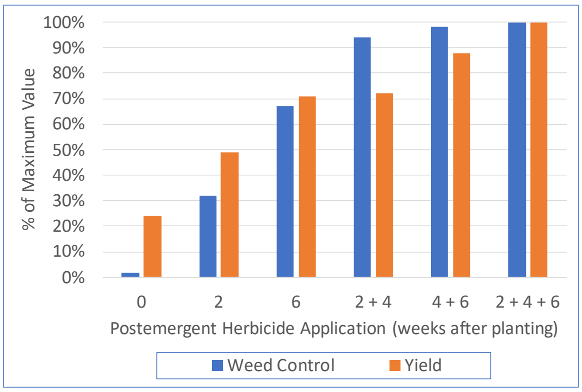


Figure 5.1. *Percent weed control (100% denotes no weeds at harvest) and groundnut yield (percent of maximum yield) when postemergence herbicides were applied at various after planting. Data are from research in the USA.*

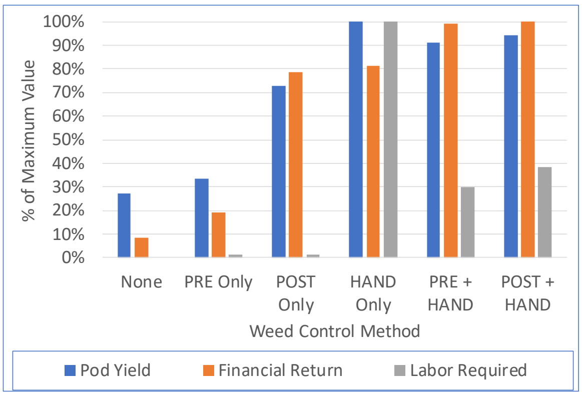


Figure 5.2. *Percent of maximum groundnut yield, financial return and number of working days required for weed control when a combination of preemergence herbicides (PRE), postemergence herbicides (POST), and hand weeding (HAND) were used in Ghana.*

Figures 5.3 and 5.4. *Weeds can compete with groundnuts for light, nutrients, and water, making weeding necessary to optimize yields.*

Practicing Integrated Pest Management (IPM)

Integrating pest management strategies is important in protecting groundnut yield from pests. While there are many definitions and approaches for IPM, The Southern IPM Center (http://www.sripmc.org/) defines IPM as:

Integrated pest management (IPM) is socially acceptable, environmentally responsible, and economically practical crop protection. Traditionally, a pest is defined as any organism that interferes with the production of the crop. Wegenerally think of pests as insects, diseases, and weeds, but there are many other types, including nematodes, arthropods other than insects, and vertebrates. We now also deal with pests in many non-crop *situations, such as human health and comfort.*

The Southern IPM Center also suggests the following approach to protecting peanut and other crops from pest injury by using the PAMS approach (Prevention, Avoidance, Monitoring, Suppression):

Adoption of integrated pest management (IPM) systems normally occurs along a continuum from largely reliant on prophylactic control measures and pesticides to multiple-strategy biologically intensive approaches and is not usually an either/ or situation. It is important to note that the practice of IPM is site-specific in nature, with individual tactics determined by the particular crop/pest/environment scenario. Where appropriate, each site should have in place a management strategy for Prevention, Avoidance, Monitoring, and Suppression of pest populations (the PAMS approach). In order to qualify as IPM practitioners, growers should be utilizing tactics in at least three of the four PAMS components. The rationale for requiring only three of the four strategies is that success in prevention strategies will often make either avoidance or suppression strategies unnecessary.

***Prevention** is the practice of keeping a pest population from infesting a field or site and should be the first line of defense. It includes such tactics as using pest-free seeds and transplants, preventing weeds from reproducing, irrigation scheduling to avoid situations conducive to disease development, cleaning tillage and harvesting equipment between fields or operations, using field sanitation procedures, and eliminating alternate hosts or sites for insect pests and disease organisms.*

***Avoidance** may be practiced when pest populations exist in a field or site but the impact of the pest on the crop can be avoided through some cultural practice. Examples of avoidance tactics include crop rotation such that the crop of choice is not a host for the pest, choosing cultivars with genetic resistance to pests, using trap crops or pheromone traps, choosing cultivars with maturity dates that may allow harvest before pest populations develop, fertilization programs to promote rapid crop development, and simply not planting certain areas of fields where pest populations are likely to cause crop failure. Some tactics for prevention and avoidance strategies may overlap in most systems.*

***Monitoring** and proper identification of pests through surveys or scouting programs, including trapping, weather monitoring and soil testing where appropriate, should be performed as the basis for suppression activities. Records should be kept of pest incidence and distribution for each field or site. Such records form the basis for crop rotation selection, economic thresholds, and suppressive actions.*

***Suppression** of pest populations may become necessary to avoid economic loss if prevention and avoidance tactics are not successful. Suppressive tactics may include cultural practices such as narrow row spacing or optimized in-row plant populations, alternative tillage approaches such as no-till or strip till systems, cover crops or mulches, or using crops with allelopathic potential in the rotation. Physical suppression tactics may include cultivation or mowing for weed control, baited or pheromone traps for certain insects, and temperature management or exclusion devices for insect and disease management. Biological controls, including mating disruption for insects, should be considered as alternatives to conventional pesticides, especially where long-term control of an especially troublesome pest species can be obtained. Where naturally occurring biological controls exist, effort should be made to conserve these valuable tools. Chemical pesticides are important in IPM programs, and some use will remain necessary. However, pesticides should be applied as a last resort in suppression systems using the following sound management approach:*

1. *The cost benefit should be confirmed prior to use (using economic thresholds where available);*
2. *Pesticides should be selected based on least negative effects on environment and human health in addition to efficacy and economics;*
3. *Where economically and technically feasible, precision agriculture or other appropriate new technology should be utilized to limit pesticide use to areas where pests actually exist or are reasonably expected;*
4. *Sprayers or other application devices should be calibrated prior to use and occasionally during the use season;*
5. *Chemicals with the same mode of action should not be used continuously on the same field in order to avoid resistance development; and*
6. *Vegetative buffers should be used to minimize chemical movement to surface water.*

Not all of these approaches are available for groundnut farmers in Malawi. As the groundnut industry increases and *more resources and technologies become available for pest management, it will be important to integrate tools into production systems. A farmer who follows a control practice may expect a pest or group of pests to be suppressed and yield to be protected, but groundnuts and the environments in which they grow are dynamic and can be unpredictable. When we control one pest, we can affect the ecology of the growing environment and another pest may become a problem. In some cases, the second pest may be more injurious to groundnuts than the first pest. Insecticides can be very effective in controlling insects and protecting yield, but depending on the product used, insecticides can be very disruptive to groundnut ecology.*

Scouting Fields

It is important to look for pests in the field and track any change in numbers over time. By documenting the number and type of pests over time, a farmer can see changes that happen within a season or over many years, which can help him choose when and how to apply an intervention. It is important to identify both the pest and the damage the pest causes. A common method of scouting is using a Z-shaped pattern across fields.

Figure 5.5. *A typical Z-shaped pattern is used to scout groundnut fields.*

Pesticide Use in Groundnuts

Pesticides can be effective tools for pest control but can be harmful to human health and the environment when used inappropriately. Individuals applying these products need to wear protective clothing, gloves, boots, goggles and a respirator depending on the product they are applying. The correct rate should be applied to prevent leaching into groundwater or movement from fields into sensitive areas and ensure pest control and prevent unnecessary injury to groundnut.

Pesticides should be placed in a cool and dry space away from stored seed and harvested crops. It is especially important to store pesticides in a way that people, especially children, are not exposed to them. Keep the pesticide tightly sealed in the original container and do not store pesticides in containers that could be confused with those used for cooking, drinking and food storage. Every year many people around the world are poisoned by pesticides, most often due to accidental exposure in storage areas or in households. Using pesticides that are sanctioned by the Malawi government and used in the appropriate way will also ensure that residues of pesticides do not contaminate foods consumed by people.

When pests are present and active, pesticides can be very effective in protecting groundnuts and minimizing yield loss. They can suppress pest populations quickly and reduce the labor needed for pest management, especially in the case of weeds. However, pesticides do pose a risk to people, the environment and the food system if they are used improperly. Pesticides should be respected and used in manner that protects people and the environment.

Impact of Arthropods on Groundnut Yield

Groundnuts can be affected by multiple pests including termites, aphids, Hilda spp., white grubs and leafminers. Crop rotation typically helps to prevent or reduce all insect pests. Early planting, higher plant densities, and practices that ensure a healthy plant (proper soil pH and fertility) reduce the impact of pest problems. Before implementing any specific control practices, a farmer must scout the field, measure the level of infestation and find where the pest is in the field to determine if action is warranted. Some pests such as groundnut rosette can be partially managed through the selection of resistant varieties.

Termites: Termite can damage groundnuts at all stages of growth but are usually most serious close to harvest when the soil is dry. These pests occur anywhere groundnuts are grown in Malawi, but infestations usually are in patches. Termite damage can reduce yield and quality and makes the kernel more susceptible to mold and aflatoxin contamination. Termite infestations can be reduced by deep ploughing and incorporating crop residues into the soil and using chlorpyrifos on infested areas.

Groundnut aphids: Aphids are vectors of groundnut rosette disease and can significantly hurt yield, especially during drought. They suck sap and plant juices from the plant's growing points. Aphid damage and the transmission of groundnut rosette can be minimized by planting early, destroying volunteer groundnut plants, and using resistant groundnut varieties (e.g., Baka).

Hilda species: This pest is associated with black ants, and is found most often in early- or late-planted fields. Damage usually begins along the field edge and is most serious in drought years. Areas if infestation are often seen in patches of wilted and dead plants.

White grubs: Insect larvae (grubs) feed on roots and pods, causing wilting and exacerbating drought stress. They are most common in the light sandy soils of the Lilongwe plateau. Crop rotations help reduce all insects.

Leafminers: This insect tunnels or "mines" through the leaf tissues and produces blister-like lesions on the leaves. Severe infestations can cause the leaflet to become brown, shriveled and will dry up. Whole plants can die from severe infestation. Leafminers are not able to move long distances and local infestations can usually be controlled. They are most common in northern Malawi.

Insecticides Guidelines for Groundnuts in Malawi

There are many trade names for pesticides. In this listing, they are referred to by the common name for the active ingredient and a few examples of trade names listed in parenthesis. When purchasing any insecticide, look beyond the common name to make sure the product contains the active ingredient you are seeking. Read and follow all label directions and make sure the product is registered for use on groundnuts. There are three main groups of insecticides: organophosphate, pyrethroid, and neonicotinoid insecticides.

Organophosphate Insecticides

Insecticides in this group are highly toxic to humans and animals as compared to the other products. The common names often end in "fos" or "phos". These products are typically very broad spectrum (i.e., control a number of insect species) and are very effective. These products usually have relatively long residual activity (except acephate) and many are effective against soil insects. Typically, they work well on ants, aphids, caterpillars, jassids, leafminers, and some work on termites, white grubs, and nematodes.

Active Ingredient (Common Name)	Active Against
Fenamiphos (Nemacur)	Nematodes
Terbufos (Counter)	Nematodes
Fenamiphos (Nemacur)	Nematodes
Oxamyl (Vydate)	Nematodes, aphids, caterpillars
Dimethoate	Aphids, leafminers, jassids, some caterpillars
Chlorpyrifos	Aphids, jassids, caterpillars, leafminers, termites
Acephate	Caterpillars, aphids

Table 5.1. *Target pests for organophosphate insecticide active ingredients.*

Pyrethroid Insecticides

These insecticides are typically used at lower doses and are very effective against caterpillars and aphids. Products that are pyrethroids all have common names that end in "thrin". They are less toxic to people and animals than organophosphates are. They have shorter residual activity and are generally not effective against insect pests in the soil.

Active Ingredient (Common Name)	Active Against
Deltamethrin (Decis)	Caterpillars, aphids, jassids
Cypermethrin	Caterpillars, aphids, jassids
Zeta-cypermethrin	Caterpillars, aphids, jassids
Lamda-cyhalothrin (Novathrin)	Caterpillars, aphids, jassids

Table 5.2*. Target pests for pyrethroid insecticide active ingredients.*

Neonicotinoid Insecticides

These insecticides are among the safest products and have a relatively broad spectrum of control, good residual activity, and good protection against many soil insects.

Active Ingredient (Common Name)	Active Against
Imidacloprid (Confidor)	white grubs, aphids, leafminers
Thiamethoxam	white grubs, aphids, leafminers

Table 5.3. *Target pests for neonicotinoid insecticide active ingredients.*

Seed treatments

Treatment of seed prior to planting can provide value for groundnut production programs in Malawi. These may contain only a fungicide such as Thiram to protect the seed and seedling against various soil-borne diseases. Some seed treatments also contain an insecticide usually imidacloprid or thiamethoxam. These can help protect the seed and seedling against a variety of pests such as white grubs, millipedes, ants, wireworms and as the plant emerges offer some control of aphids and jassids. Common trade names include Cruiser 350 FS (insecticide only), Apron Star (thiamethoxam, metaxyl, and difencomazole), and Gaucho T (imidacloprid, Thiram).

As with all pesticides, users must wear appropriate protection and follow proper handling recommendations. Any seed treatment should be applied to the seed just prior to planting, and any seed that is not planted should be destroyed so that no one eats it.

Impact of Diseases and Viruses on Groundnut Yield

Leaf spot diseases, rust and crown rot are fungal diseases that affect groundnut yield in Malawi. Rosette, which is caused by viruses spread by aphids, also can be a problem.

Figure 5.6

Figure 5.7

Figure 5.8

Figure 5.9

Figure 5.10

Figure 5.11

Figure 5.6. *Early leaf spot (ELS) causes brown spots with a yellow halo.*

Figure 5.7. *Late leaf spots (LLS) forms dark brown or black spots with a less brilliant halo.*

Figure 5.8. *Rust forms reddish-brown pustules on the underside of the leaf.*

Figure 5.9. *Crown rot causes the main stem of seedlings to rot, killing the plant.*

Figure 5.10. *In chlorotic rosette, young leaves turn yellow.*

Figure 5.11. *In green rosette, plants are severely stunted.*

Disease Pest Management in Groundnut

Several diseases may attack groundnuts throughout the growing cycle. The most common diseases in Malawi include early leaf spot and late leaf spot, rust, and groundnut rosette disease.

Cultural practices can help to prevent diseases. When farmers also plant resistant varieties, they have the greatest control of diseases and virus, and the best potential for high yield. For example, early planting can reduce aphids which in turn reduce transmission and expression of rosette virus.

Leaf Spot Disease

Early leaf spot is a fungal disease that attacks the groundnut crop soon after emergence. The disease is characterized by lesions (spots) produced on all above-ground parts of the plant (leaves, petioles, stems, and pegs). The lesions are sub-circular and dark brown on the upper surface and light brown on the lower surface of the leaves. In severe cases, the disease causes premature defoliation and has the potential to cause yield loss of up to 50%. This disease is widespread in all groundnut growing areas and is particularly serious in the central region (Lilongwe–Mchinji to Kasungu plain).

Farmers can manage the disease by removing or burying infected crop residues.

Late leaf spot is a fungal disease that occurs late in the season. It is characterized by lesions that are nearly circular and black. In severe cases, affected leaves become chlorotic, then necrotic and lesions coalesce, resulting in premature defoliation. It can cause yield losses ranging from 25% to 50%. This disease occurs sporadically in several parts of Malawi but is widespread in the warm and humid low altitude areas of the Kasungu, Mzuzu, Salima and the Shire Valley ADDs.

Both early and late leaf spot can cause rapid defoliation of the groundnut canopy. Once lesions appear near the base of the plant, compete defoliation can occur within a few weeks. Leaf spot epidemics expand rapidly, as shown in Figure 12. From just a few lesions in the bottom of the canopy, the disease spreads and lesions appear throughout the canopy. Ultimately, significant defoliation is noted 14 days later and then almost complete defoliation in another 7 days. In this example, only 21 days separated the time when lesions first appeared at the base of the plant to almost complete defoliation. Using a leaf spot-resistant variety or an effective fungicide regime can offer protection from leaf spot.

Trials conducted in Malawi in 2020 and 2021 showed a positive effect of fungicide applications on groundnut yield with moderate disease pressure for all varieties. Yield increases of 400kg/ha were observed.

Figure 5.12 a, b, c, d. *Groundnuts can often lose 30-40% of leaves without sacrificing yield. However, canopy defoliation happens rapidly, and leaf drop can double within just one week.*

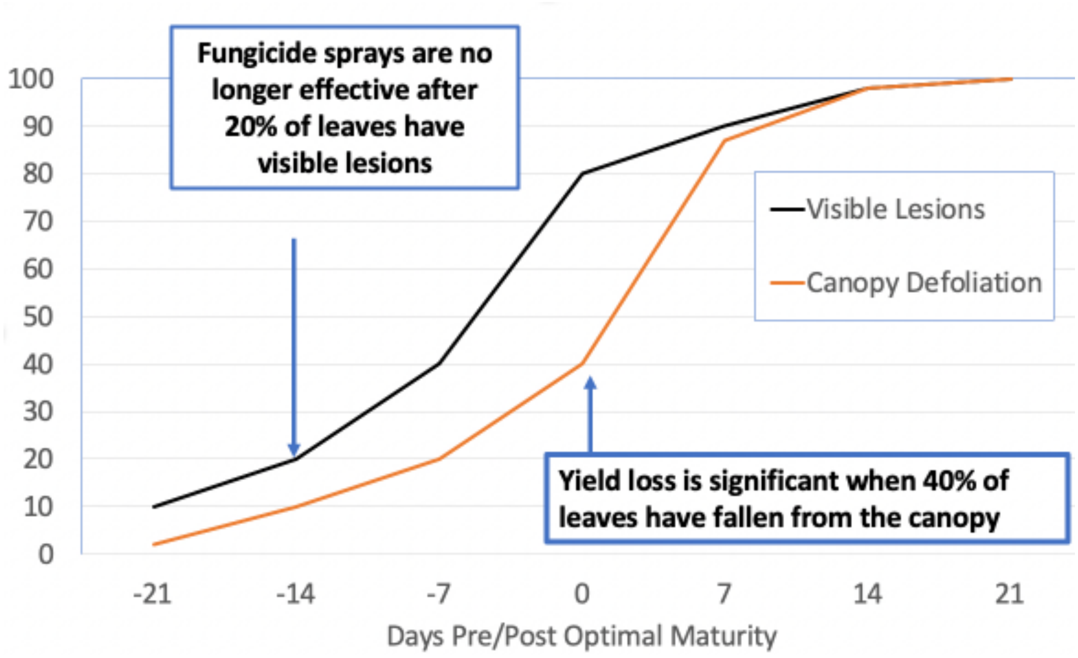


Figure 5.13. *Typical progression of leaf lesions and canopy defoliation due to leaf spot disease.*

Rust

Rust is a fungal disease that usually appears at the same time as leaf spot (late in the season). It is characterized by orange-coloured pustules (spots) on the lower surface of leaves which rupture to release masses of reddish-brown spores. The lesions affect all above-ground parts of the plant except flowers. Infected leaves become necrotic and dry up; however, they remain attached to the plant. Rust in combination with late leaf spot can cause yield loss of about 30% to 40%. The disease appears sporadically in Malawi and is common in warm and humid low altitude areas and destructive in parts of Karonga, Mzuzu, Salima and the Shire Valley ADDs.

Farmers can minimize the incidence and severity of leaf spot and rust diseases by adhering to the following management practices:

- Plant a leaf spot- or rust-resistant variety, if available;
- Develop a sequence of crops in the rotation that are not hosts for the pathogens that cause early and late leaf spot (e.g., maize, sorghum, millet);
- Remove or bury infected crop residues;
- Remove and destroy infected volunteer groundnut plants that are present in rotation crops;
- Sow groundnuts early in the rainy season; and
- Apply appropriate fungicides in a timely manner, if they are available.

Groundnut Rosette Disease

Groundnut rosette is the most destructive disease in Malawi groundnut fields. The disease, which is transmitted by aphids, shows up in two forms in Malawi: chlorotic (yellow) and green rosette. Chlorotic rosette is characterized by yellow, twisted and distorted leaves while green rosette is characterized by mild mottling of younger leaves, older leaves appear dark green and reduce in size. In both forms of the disease, the plants are severely stunted and early infected plants do not produce any pods. The disease is present in all groundnut growing areas; however, it occurs sporadically. Total loss can result when the disease occurs in epidemic proportions.

Famers can reduce the impact of the disease by:

- Sowing early and at an ideal plant population (dense planting provides benefits);
- Removing and destroying all volunteer groundnut plants after harvest to reduce harboring aphids; and
- Using resistant varieties such as Nsinjiro (medium duration) and Baka (short duration).

Fungicide Guidelines for Suppression of Diseases

Seedling Diseases

Seed can be treated with the combination of thiamethoxam, metalaxyl-M, and difenoconazole to minimize the negative impact of soil pathogens on seeds and seedlings. This treatment can be especially important on soils that can remain wet after sowing.

Leaf Spot and Rust

Several fungicides are registered for use in Malawi after groundnuts have emerged. These are applied beginning 45 days after sowing and are often applied every two weeks until about two weeks before harvest. Three applications spaced 2 weeks apart will generally provide effective control of leaf spot and rust, but the fungicides available for use in groundnuts are protective and are not curative. They prevent lesions from forming, and for this reason, the first application should be applied no later than 45 days after sowing.

Fungicides available in Malawi include: azoxystrobin, boscalid, chlorothalonil, copper oxychloroide, mancozeb, maneb plus zinc oxide, propiconazole, pyraclostrobin, sulfur, tebuconazole, tebuconazole plus trifloxystrobin. These vary in effectiveness, expense, and availability. For leaf spot and rust disease, commercial fungicides that contain azoxystrobin, chlorothalonil, propiconazole, pyraclostrobin, and tebuconazole are the most effective. If a fungicide program of 2 or more sprays is used, rotate fungicides in order to minimize resistance and ensure the long-term viability of these products. For example, a spray program of azoxystrobin or pyraclostrobin followed by tebuconazole or propiconazole followed by chlorothalonil can be very effective in controlling these diseases and preventing resistance from developing.

Once lesions appear, treatment will not prevent the plant from shedding the leaves. Approximately three times as many leaves are infected as show visible lesions. For example, when 20% of leaves have lesions about 60% of the leaves on a plant are infected and will produce lesions and defoliate regardless of whether a fungicide is applied. For this reason, fungicides need to be applied early in the season to prevent epidemics from beginning. When leaf spot disease is widespread and severe in a field, a farmer may opt to harvest groundnuts before they reach optimum pod maturity. Protecting groundnuts from leaf spot disease so that canopy defoliation is minimized can give farmers more control over when to harvest. Using a variety with resistance to leaf spot or an effective fungicide program will increase yield because healthy plants will give the pods more time mature.

Impact of Nematodes in Groundnut Yield

Nematodes are small microscopic worms that can infect roots and pods causing galling, knots on the root that hurt the plant's ability to move moisture and nutrients through its vascular system. There are many non-plant parasitic nematodes in soil that do not affect groundnuts. And, not all plant parasitic nematodes affect crops to the same degree. Nematodes prefer sandy, well-drained soils. The only way to suppress nematodes is through effective crop rotation as chemical control is cost prohibitive and marginally effective.

Figure 5.14. *The effects of rootknot nematodes in groundnut.*

Impact of Vertebrates in Groundnut Yield

Birds and mammals consume groundnuts in the field and during drying and in storage. These pests can be difficult to control. Keeping groundnut fields free of weeds and establishing a buffer area around fields can reduce these pests. Harvesting in a timely manner can also decrease the length of time groundnuts are exposed to pest damage. In storage, place groundnuts in durable bags off the floor and away from walls to decrease hiding areas and entry points for vertebrate pests.

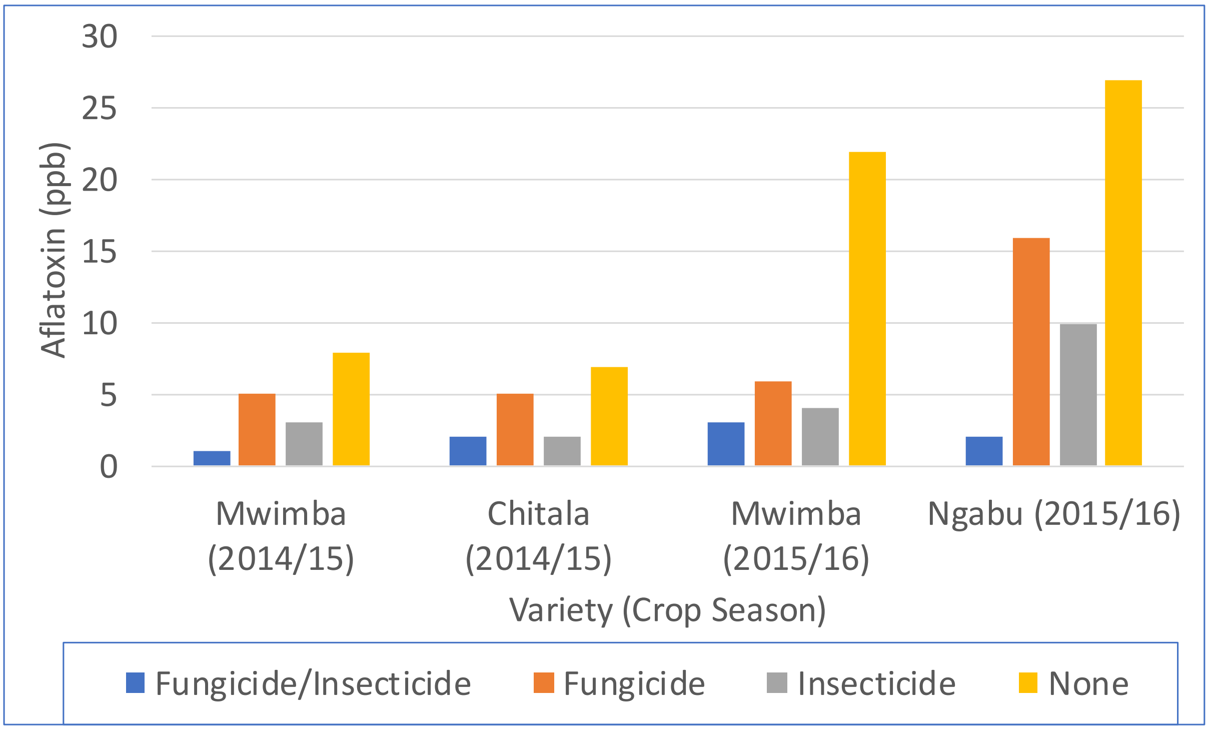


Figure 5.15. *Influence of different pest management options applied to four groundnut varieties on aflatoxin contamination.*

Section 6. Harvest Groundnut at Optimum Maturity

Kernel Maturity and Yield

Deciding when to dig or lift groundnuts is one of the most important management decisions farmers make. Pod yield and kernel quality and economic value improve as maturity increases. Research in Zambia and Mozambique has demonstrated the importance of allowing groundnut to reach maturity to optimize yield.

However, at some point pods will naturally shed from the plant or in the case of Spanish varieties seed can sprout. The longer groundnuts remain in soil, the greater the risk they will be infected by mold and aflatoxin. The timing of harvest impacts yield and quality, as well as seed viability, if the groundnuts were grown for seed.

Since all of these factors interact, farmers should carefully consider the optimum time to lift or dig peanuts.

Optimizing Groundnut Yield and Minimizing Aflatoxin Contamination

Since groundnut is an indeterminate crop (i.e., it flowers continually throughout its life cycle), every pod on an individual plant will be at a different maturity. In addition, plants in different parts of the field can also be at different stages of growth due to environmental and other factors.

A farmer can evaluate the maturity of groundnuts from the field by looking at a layer of the skin on the pod. Groundnut pods have three layers of skin: the outer exocarp, the inner endocarp and a middle layer, the mesocarp. The color of this middle layer (mesocarp) can be used to determine the maturity. As the pod matures, the mesocarp will darken in color, from an initial white color (immature) to brown (intermediate) to black (mature). In a mature crop, the majority of the pods will show the reddish brown/dark black color in the mesocarp.

There are three basic methods to see the mesocarp and evaluate the maturity of groundnut (see below), but all the methods begin with taking a sample of 3 to 4 plants randomly selected throughout the field. Strip all pods from the plants and take a random sample of around 50 pods.

Once the mesocarp is exposed, a farmer can arrange a groundnuts by color, estimate the maturity of the majority of the nuts and approximate the number of days/weeks that remain before the crop will be ready to harvest. A maturity board (poster) has been developed and is used in the USA and other countries. The board provides a color chart for arranging the pods and then indicates the maturity.

Shell-out Method

The "shell out" method is one of the simplest ways to reveal mesocarp color differences. Shell the sample of 50 pods carefully so that the shell remains intact as two halves. Lay out the shells with the inside of the pods facing up. Group pods into three sections representing white to yellow, orange to light brown, and dark brown to black coloration. When only a few pods are in the white to yellow grouping and the remaining pods are evenly divided among the darker categories, groundnuts are at optimum maturity (Figure 6.1). Leaving groundnut in the field after this point does not increase yield and can reduce yield as plants shed pods and kernels sprout. The potential for aflatoxin contamination also increases when groundnuts are left in the field beyond optimum maturity.

Figure 6.1. *A ready-to-dig using the "shell-out" method.*

The shell-out method is one of the more practical approaches to determining pod maturity. A handout was prepared for farmers to see the relationship of pod maturity, yield and aflatoxin contamination. (See addendum.)

Hull-scrape Method

The “hull-scrape” method requires scraping the outside of the pod near the saddle (middle of the pod) with a knife to reveal the mesocarp color. Remove approximately 50 pods from plants across the field and carefully scrape the shell in the middle of the pod (near the saddle) with a small knife. You do not need to scrape away a lot of the outer layer, only enough to be able to see the color underneath (this will be visible on the older mature pods). Lay out the scraped pods into three sections representing white to yellow, orange to light brown, and dark brown to black coloration. When only a few pods are in the white to yellow grouping and the remaining pods are evenly divided among the darker categories, groundnuts are at optimum maturity (Figure 6.2). Leaving groundnut in the field after this point does not increase yield and can reduce yield as plants shed pods and kernels sprout. The potential for aflatoxin contamination also increases when groundnuts are left in the field beyond optimum maturity.

Figure 6.2. *A ready-to-dig crop using the “hull-scrape” method.*

Pod-blasting Method

For growers with larger land area and access to electricity, the exocarp can be removed using a pressure washer with a rotating nozzle to expose the mesocarp. As in the other methods, select 50 pods from plants across the field. Place the pods in a metal basket inside a larger plastic bucket. Power wash the pods for 2 to 3 minutes using a rotating nozzle and a power washer that generates around 1500 psi. Remove basket with pods, shake dry and lay out pods according to color. Examples of pod mesocarp color using the “pod blasting” method are presented in Figure 6.3.

Figure 6.3. *A ready-to-dig crop using the “pod-blasting” method.*

The change in pod mesocarp color over a 21 day period for two fields in the US are presented in Figures 6.4 to 6.9.

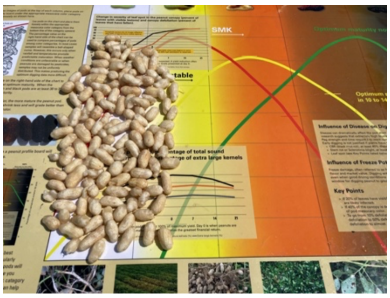


Figure 6.4. *Immature crop with no mature kernels.*

Figure 6.5. *Split crop with high percentage of yellow pods.*

Figure 6.6. *Split crop with almost equal number of immature and mature kernls.*

One field (*Figures 6.4, 6.5 and 6.6*) exhibit a “split crop” in that maturity of pods is generally in the yellow and early stages of the orange while a similar percentage in the brown and black categories. This scenario makes the decision on when to lift a challenge. Depending on weather conditions and disease severity, it is often available to dig when the first group is mature rather than waiting on the pods that are slowing more slowly to reach greater maturity. Damage for pests and greater aflatoxin contamination can occur the longer groundnuts remain in the field.

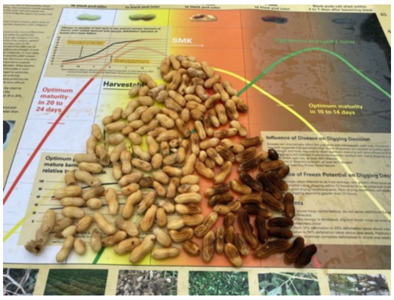


Figure 6.7. *Early maturity crop.*

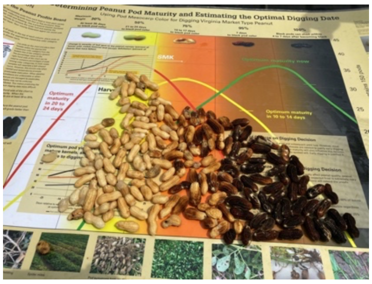


Figure 6.8. *Crop at about 2 weeks before optimal digging date.*

Figure 6.9*. Mature crop ready to dig.*

Figures 6.7, 6.8 and 6.9 present a more typical distribution of pod maturity. A stress much earlier in the season can cause pollination and pod set to be disrupted. When the stress is removed pollination and pod set may resume. A period of drought during the middle of the season is often the cause of a "split crop" making the decision of when to dig more challenging. In this case groundnut should be dug as soon as the dark brown to black color is reached even though this may only be only half of the pods. Yield will be lower than normal because there are no orange to light brown pods represented, however, yield would be even lower if digging is delayed because the more mature pods will shed or be damaged.

If groundnut plants are infected with leaf spot, a farmer should harvest the crop when 40% of leaves have fallen regardless of the maturity shown by the internal pod color. Groundnuts also should be dug early when drought has been excessive during the latter part of the season and no additional rain is forecast. Digging one week earlier than optimum maturity can decease aflatoxin contamination significantly without sacrificing yield since pods and kernels generally do not mature in drought-stressed plants. Dry soil conditions and brittle pegs may also make harvesting more difficult.

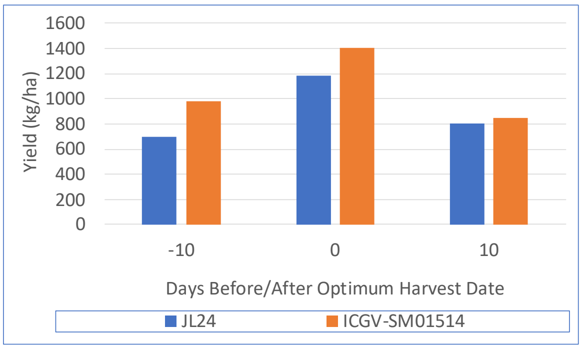


Figure 6.10. Effect of digging date on aflatoxin contamination

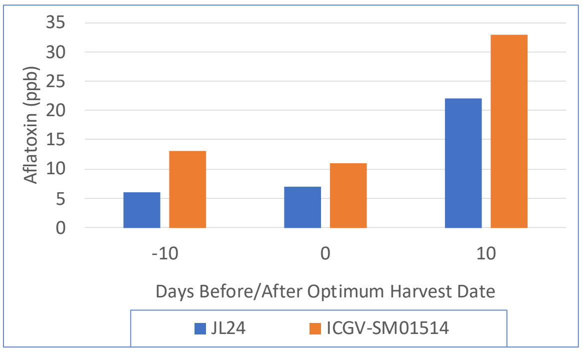


Figure 6.11. Effect of digging date on yield.

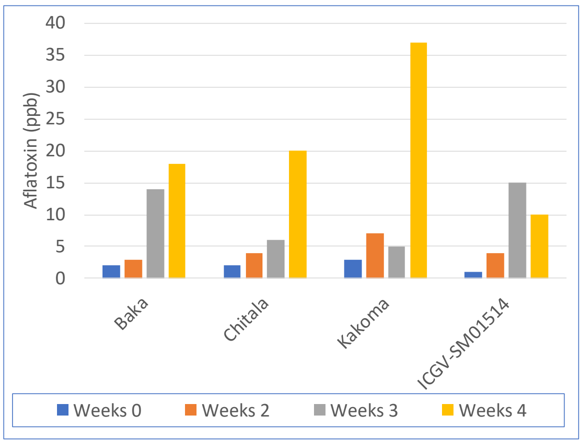


Figure 6.12. Influence of variety and drought duration on aflatoxin contamination (Sibakwe, et al., Malawi)

Section 7: Drying and Storing Groundnuts

Dry Groundnuts Quickly

In order to maintain quality of groundnuts and prevent growth of mold, groundnuts should be dried as quickly as possible. If groundnuts are not immediately removed from plants, pods should be turned facing the sky with soil shaken from the roots and pod as thoroughly as possible. This will allow air to flow across pods and will decrease the amount of time needed for drying (*Figure 7.1*). If groundnuts are dug and pods removed at the same time, pods should be placed on tarps or materials that provide a barrier between the pods and soil. This will also increase the speed of drying and will protect pods from insect damage and possible mold contamination.

Figure 7.1. *Freshly dug groundnuts should have the soil shaken off and laid with the pods up in the air, so they do not touch the ground.*

The drying step is often the most important step in managing aflatoxin contamination. Practices in the field can also affect contamination by aflatoxin, but poor drying can cause an explosion of mold and high contamination going into storage. Groundnuts should be dried to a moisture of less than 10% before placing in storage. Groundnuts in the field are often dried to approximately 10% before they are stripped from the vines. This stripped is often done with sticks which often damages the pods. For smallholder farmers this percentage can be difficult to estimate. Many farmers use a technique of shaking a handful of pods, which may make a rattling sound when dried. Pods that make this sound may need to be dried even a bit more to assure they are safe from mold growth. Moisture meters are available and could be used on a village or community level. It is important to dry pods more slowly and handle pods with care if they are going to be used for seed the following year.

Store Groundnuts Properly

The first step in maintaining kernel quality and reducing the risk of aflatoxin contamination is to dry groundnuts to a low moisture content as quickly as possible and move the dried groundnuts into storage as quickly as possible. Storage of groundnuts remaining with the shell is recommended because the shell offers a protective layer against pests that are found in storage areas and can protect kernels from physical damage. While difficult to achieve, especially for small-holder farmers, storing groundnuts in protective bags placed away from walls and off of the floor promotes air flow and can keep relative humidity lower. Air flow in a shady area can also moderate temperatures. Decreases in groundnut kernel quality and increases in mold growth leading to possible aflatoxin contamination occur when relative humidity and temperatures are high.

Figure 7.2. *If further drying is necessary, groundnuts should be spread on a tarp.*

If plastic storage bags that can be hermetically sealed are available, the quality of groundnut kernels can be maintained and the potential for increased aflatoxin during storage minimized. If these are used it is important that moisture of groundnuts is 8% or less and that bags remain sealed. If groundnut moisture is high and bags are sealed, mold and subsequent aflatoxin contamination can increase at a high rate.

Importance of Minimizing Aflatoxin in the Field, During Drying and in Storage

Careful attention to management practices at pre-harvest and post-harvest steps is needed to provide a safe product that can be further processed, marketed to consumers and exported. Proper practices and care of groundnuts prior to storage can have a significant effect on the potential for an increase in aflatoxin contamination while in storage. Incorporating practices that improve plant health in the field not only increases yield but also decreases contamination by mold and subsequent aflatoxin contamination. Practices such as increased fertility and protection from pest damage in the field results in less mold going into the drying step. Pest-resistant varieties and good rotation sequences along with other practices improve plant health. Rapid drying and less exposure of groundnuts to soil where mold is often found can decrease the abundance of aflatoxin production molds going into storage. It is important to store groundnuts elevated off the ground (e.g., on a wooden pallet), and under cool and dry conditions if at all possible. Mold can grow exponentially when relative humidity and temperatures are high. NEVER moisten or add any water to the pods when shelling. This increases the likelihood of higher aflatoxin contamination. Sealed bags create a protected environment not only from moisture but also from arthropod and vertebrate pests. It is important that groundnuts are dried to the desired level before sealing bags. Sealing bags with groundnuts at higher moisture could lead to disaster.

Practices to Minimize Aflatoxin Contamination

In general, the growth of healthy groundnut plants in the field will reduce aflatoxin contamination of the crop prior to harvest. Stressed plants are more likely to suffer from higher levels of aflatoxin. Thus, the first step in aflatoxin management is the production of a healthy, high yielding crop which should also contribute to increased profits. This fact cannot be overstated in an overall aflatoxin management program that the cost-efficient production of high yielding and profitable groundnuts is the best approach to gain an initial advantage in this effort.

Figures 7.3 and 7.4 compare practices that improved plant health the field (e.g., fertilizer, minor suppression of disease and aphids, and extra weeding) with the traditional farmer practice. In this research conducted in rural villages, groundnuts following both practices in the field were dried on the ground or on tarps which protected groundnuts from soil and allowed groundnuts to be covered or moved to shelter quickly if rain occurred.

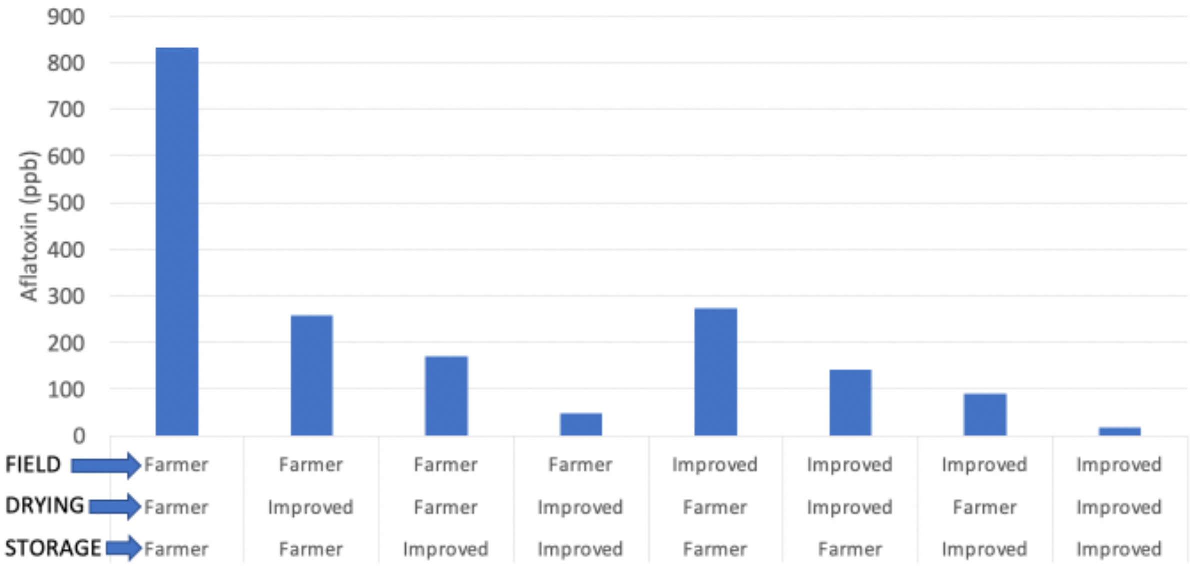


Figure 7.3. *Aflatoxin contamination after 4 months of storage when an improved practice was implemented at pre-harvest and post-harvest steps compared with a farmer practice.*

Groundnuts were then placed in poly bags or were placed in bags that could be sealed. The results from six villages revealed that improved practices at each step in the process contributed to reductions in aflatoxin when groundnuts were removed after 4 months of storage. Quality of shelled kernels was also higher when an improved practice was implemented. The highest quality and least amount of aflatoxin was observed when the improved practice was used at each step. While the increase in groundnut yield more than offset the costs of a tarp and sealed bags, farmers may not be able afford these inputs in full but may be able to incorporate at least one or two improved practices in the system. The result would be fewer damaged kernels and less aflatoxin for processors to deal with further down the value chain.

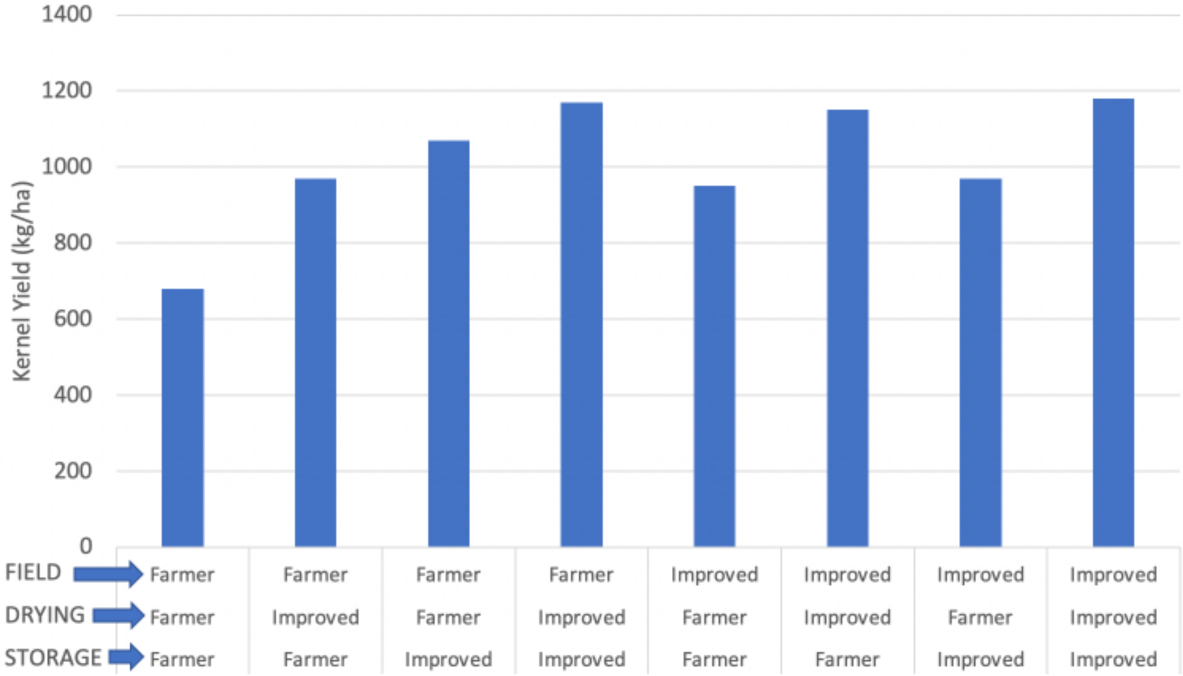


Figure 7.4. *Weight of good kernels after 3 months of storage when an improved practice was implemented at pre-harvest and post-harvest steps compared with farmer practice.*

Section 8. Production Packages for Growers

Based on the current knowledge from various field trials on research stations and farmers' fields, the following three packages are recommended for producing quality groundnuts. These provide a low, medium and high input options that farmers can follow depending on the available of resources and market opportunities. These are summarized in Table 8.1 and briefly describe below.

Low Input Package

Some farmers have limited access to inputs or simply do not have financial resources or credit to purchase inputs even if they are available. In this case there are fundamental steps farmers can implement that increase the likelihood that yield will be optimized under a low input system.

First, plant groundnuts in fields that were planted to crops other than groundnut the previous year. This will minimize the impact of some pests including leaf spot disease and nematodes. Second, plant high quality seed (either as saved seed for no more than 3 season or as recently purchased seed) as soon as the rains begin after conducting a germination test using the steps outlined earlier in this guide. This will enable you to establish plants at the correct spacing of 10 cm apart for Spanish types or 15 cm apart for Virginia types. In this package, we are assuming fertilizer and pesticides are not available to promote plant health and protect groundnuts from pest injury. Therefore, every attempt should be made to sow a variety with some degree of resistance to disease and rosette. Plant as early as possible to reduce the likelihood of groundnut rosette and to ensure the crop is mature before soil conditions get hot and dry (which can contribute to higher aflatoxin levels). Farmers should weed fields within the first 3 weeks after planting and follow up with an additional weeding no later than 6 weeks after planting. **Digging groundnuts at optimum maturity is important in this production system be sure to determine maturity using the shell-out or hull-scrape method**. Digging too early results in lower yield and quality because pods and kernels are immature. Digging too late can result in greater contamination by mold and aflatoxin, poorer kernel quality due to damage from pests and sprouting of seed. The result is much lower yield and poorer quality and marketability. If farmers sort prior to selling in the market, they will have much lower turnout of premium kernels for the market. Farmers should dry groundnuts as quickly as possible and store in a manner than protects groundnuts from mold production and damage from insect and vertebrate pests.

Low Input Package Take-Aways:

- Plant an improved variety of groundnut as early as possible in fields that did not have groundnuts the previous season
- Plant high quality seed with known germination as soon as the rains begin at a spacing of 10 to 15 cm for all varieties (5 to 7.5 cm along the twin or double row)
- Weed fields three and six weeks after planting
- Dig groundnut at optimum maturity or one week prior to optimum maturity if drought has occurred
- Dry groundnuts as quickly as possible
- Store groundnuts in a clean and dry building, off of the floor and away from walls

Medium Input Package

If farmers have access to inputs and resources or credit for purchasing inputs, a few key inputs can be added to the low input package for higher yields and quality. In most cases, these added inputs will deliver economic returns above investment cost, although careful selection of inputs is required. Throughout the season, a farmer using a medium input package should follow all the advice offered in the low-input package: Choose a site that is appropriate for groundnut and a variety with resistance to disease, conduct a germination test so that you can achieve optimum plant spacing, weed twice and at the correct time, harvest groundnuts at optimum maturity, dry as quickly as possible and store in a way that protects groundnuts from mold growth and damage from pests.

The most fundamental input to increase yield potential in the medium input system is applying lime to increase soil pH. When soil pH is established at 6.0, groundnuts have a greater capacity to respond to fertilizers and inoculant that promotes biological nitrogen fixation (BNF). In the medium input system, a general fertilizer with adequate phosphorus and potassium also will increase yield. Many blends of fertilizer contain nitrogen and can boost yield, especially if inoculant for BNF is not available or viability and quality are in question. A fertilizer blend that includes calcium will also increase yield and quality. Gypsum is also a good investment and often ensures proper kernel development and increases yield. If available, inoculant that has been handled well and is viable can also increase yield. An important note of caution on this recommendation is that groundnuts are often nonresponsive to inoculant for BNF and gypsum when pH is less than 5.8. In some cases when soil pH is low applying gypsum further decreases yield. A final input in the medium input system would be a single fungicide application 45 days after planting. This will slow epidemics of leaf spot disease and can protect yield.

Medium Input Package Take-Aways:

- Lime soil to obtain a pH of 6.0
- Plant an improved variety of groundnut as early as possible in fields that did not have groundnuts the previous season
- Apply inoculant for BNF
- Plant high quality seed with known germination as soon as the rains begin at a spacing of 10 cm for Spanish-types and 15 cm for Virginia-types for all varieties.
- Apply phosphorus with potassium fertilizer
- Weed fields three and six weeks after planting
- Apply gypsum at flowering
- Dig groundnut at optimum maturity or one week prior to optimum maturity if drought has occurred
- Dry groundnuts as quickly as possible
- Store groundnuts in a clean and dry building, off of the floor and away from walls

High Input Package

In the high input system farmers should include all recommendations associated with the low and medium input systems. Site selection, proper rotation, selection of high quality seed of an improved variety, establishing optimum plant stands, adjusting pH to 6.0, applying fertilizer including gypsum, applying inoculant for BNF with seed, digging at optimum maturity and drying quickly, and storing in a manner that reduces mold growth and injury from insects and vertebrates form a foundation for the high input system.

The next level of input includes pesticides. In the high input system, farmers should use pre-emergence and post-emergence herbicides to control weeds. Herbicides are more efficient than hand-weeding and often damage groundnuts less than removing weeds by hand. Farmers should also scout for insect pests, check to see if the number of pests surpass thresholds and, when possible, apply insecticides. In the high input system, farmers should apply fungicides 3 times during season beginning 30 days after planting with the second spray made 45 days after planting and the final spray 60 days after planting. It is important to use only those pesticides that are registered for use by the manufacturer for groundnuts grown in Malawi. Proper equipment should be used to deliver pesticides and those making pesticide applications must wear approved personal protection equipment and clothing to prevent injury. Fields should be marked so that people and livestock do not enter for the appropriate period of time outlined on the pesticide label and all applications should adhere to preharvest intervals that are provide by the manufacturer.

High Input Package Take-Aways:

- Lime soil to obtain a pH of 6.0
- Apply inoculant for BNF
- Plant an improved variety of groundnut as early as possible in fields that did not have groundnuts the previous season
- Plant high quality seed with known germination as soon as the rains begin at a spacing of 10 to 15 cm for all varieties (5 to 7.5 cm along the twin/double row)
- Apply herbicide with residual activity immediately after sowing and include glyphosate if weeds have emerged when sowing is complete.
- Apply phosphorus with potassium fertilizer

- Weed fields three and six weeks after planting
- Apply herbicide that controls emerged weeds three weeks after planting
- Apply fungicide 30, 45 and 60 days after planting to protect groundnuts from pathogens that cause leaf spot disease and rust.
- Apply gypsum at flowering
- Dig groundnut at optimum maturity or one week prior to optimum maturity if drought has occurred
- Dry groundnuts as quickly as possible
- Store groundnuts in a clean and dry building, off of the floor and away from walls

Intervention	Recommended Practices Low Input	Medium Input	High Input
Soil pH	Not determined	Test soil & apply lime to reach 6.0 pH	Test soil & apply lime to reach 6.0 pH
Soil fertility	Not determined	Apply phosphorus with potassium fertilizer	Apply phosphorus with potassium fertilizer
Variety	Improved	Improved	Improved
Seed	Quality seed	Purchase quality certified seed	Purchase quality certified seed
Planting density	Spanish: 15 cm plant double row x 75 cm row spacing (178,000 seeds/ha) Virginia: 10 cm plant double row x 75 cm row spacing (267,000 seeds/ha)	Spanish: 15 cm plant double row x 75 cm row spacing (178,000 seeds/ha) Virginia: 10 cm plant double row x 75 cm row spacing (267,000 seeds/ha)	Spanish: 15 cm plant double row x 75 cm row spacing (178,000 seeds/ha) Virginia: 10 cm plant double row x 75 cm row spacing (267,000 seeds/ha)
Planting method	Manual	Manual	Mechanical double-row planter
Planting date	As soon after rains begin	As soon after rains begin	As soon after rains begin
Inoculant	None applied	Apply as seed treatment	Apply as seed treatment
Aflasafe	None applied	(To be determined)	(To be determined)
Calcium application	None applied	Apply ~125 kg/ha gypsum along row at first flowering	Apply ~125 kg/ha gypsum along row at first flowering
Weed control	Hand weeding at 3 & 6 weeks post-planting	Hand weeding at 3 & 6 weeks post-planting	Apply herbicide treatment with residual activity immediately after planting + 2nd treatment to control emerged weeds 3 weeks post-planting
Pest management	None	None	Post-emergence insecticide treatment (if necessary)
Disease management	None	None	Post-emergence fungicide treatment 30, 45 & 60 days post-planting
Irrigation	None	None	Supplemental (if necessary at maturity)
Maturity determination	Shell or hull scape method	Shell or hull scape method	Shell or hull scape method
Harvest date	At optimum maturity or one week prior if under drought	At optimum maturity or one week prior if under drought	At optimum maturity or one week prior if under drought
Harvest method	Manual lifting	Manual lifting	Manual or mechanical lifter
Pre-drying	Inverted on ground for 7 days	Inverted on ground for 7 days	Inverted on ground for 7 days
Stripping	Manual	Manual	Mechanical
Drying (pods)	On tarps	On tarps	On tarps
Storage (inshell)	New burlap or poly-woven bags in clean & dry building, off floor and away from walls	New burlap or poly-woven bags, PICS bags in clean & dry building, off floor and away from walls	New burlap or poly-woven bags, PICS bags in clean & dry building, off floor and away from walls
Shelling	Manual (avoid wetting shells)	Manual or hand-cranked mechanical sheller/aspirator	Hand or motorized mechanical sheller/aspirator
Storage (shelled nuts)	Clean poly-woven bags	New poly-woven bags	New poly-woven bags

Table 8.1. *Recommended groundnut production practices for farmers in Malawi.*

Section 9. Groundnut Production Budget

Profitable farming requires knowledge about the cost of inputs and their contribution to yield and quality. Farmers make different choices whether to use inputs and have different budgets. Some inputs may not be available to farmers in some areas and other farmers may not have credit to purchase inputs. Regardless of how many inputs are included, developing a budget and recording all activities can help farmers be more efficient and profitable. Budgets can be relatively simple or complex depending on the resources available to farmers.

Item	Quantity and unit	Price or cost/unit	Total cost per hectare
GROSS RECEIPTS			
Groundnuts			
VARIABLE COSTS			
Seed			
Lime			
Inoculant			
Fertilizer			
Weed control			
Disease control			
Arthropod control			
Nematode control			
Digging			
Plucking			
Drying			
Storing			
Sorting			
Transport			
TOTAL COST			
NET RETURN			

Table 9.1. *This budget template can be used as a planning tool.*

Mechanization

Most farmers perform all operations by hand from land preparation to shelling after storage. As mechanization becomes more available and affordable, farmers may be able to become more efficient. Using a tractor for land preparation and a sheller that does not damage groundnuts are the two areas that farmers should consider incorporating into their operation.

Section 10. Managing Pest Risks in Groundnut

Managing pest risk in peanut can be complicated and is very important to maintaining a successful and sustainable peanut production system. A pest risk management tool has been developed to support farmers and their advisors in Malawi assess the risk of reduced yield or greater aflatoxin contamination. The risk tool allows users to determine if the production plan they have developed effectively minimizes yield lost to pests or other stresses. An action that may reduce risk in one way might cause a problem in another area.

The risk tool for Malawi considers the following practices:

Planting date	Land preparation
Plant density	Aphid spray
Seed inoculant	Fungicide
Variety	Gypsum
Crop rotation	Digging date
Fertilizer	Drying
Soil pH	Storing

To access the risk tool, follow the following steps.

1. Go to the website: https://davidjordan.wordpress.ncsu.edu/resources/.
2. Select Malawi and follow the screen commands.
3. Input data in all sections on the left side of the screen (see Figures 10.1, 10.2. and 10.3 for examples).
4. Consider the risk as shown in the red, yellow and green dots. The number of red, yellow, or green dots on the right side of the screen indicates the risk level to groundnut yield and contamination by aflatoxin.
5. If needed, change practices to minimize risk, but keep in mind that risk of other pests can be affected and that production costs will also change.
6. Remember the risk tool is for planning prior to the season. Almost all farmers start with a plan but need to make adjustments based on weather, pest outbreaks, and economic constraints. This risk tool was created to help farmers start the season by selecting practices that minimize pest risk and identify pests that might impact peanut yield during the season. The risk tool is currently being updated to reflect new varieties, production and pest management practices, and to include a weed management category.

Examples of Risk to Groundnut Yield and Aflatoxin Contamination

The risk tool assigns a range of points to a production or pest management practice in the field that affects groundnut yield and aflatoxin contamination. The tool also includes risk of aflatoxin contamination after harvest during drying and storing. The range of points is presented in Figures 10.1 and 10.2. The extremes of risk are presented in Figures 10.3 and 10.4. When a farmer follows agronomic and pest management practices that are not effective in optimizing yield, the harvest likely will be small (Table 10.3). While groundnut volume coming out of the field may be low, choosing a poor digging date and following poor drying and storage practices can also affect aflatoxin contamination. In the scenario associated with Figure 10.3, the farmer needs to change many of the production and pest management practices, as well as his approach to drying and storage, in order to produce and deliver high quality and safe groundnuts to the marketplace. It is obvious that smallholder farmers may not have access to all technologies that could protect yield and minimize aflatoxin contamination. However, there are some steps in the field and after harvest that could improve production.

The most effective approach to protect yield and minimize aflatoxin contamination is presented in Figure 10.4. It is unlikely all farmers can implement the best management practice at each step. However, farmers should strive to create a production scenario and a complementary post-harvest strategy based on a reasonable number of elements presented in Figure 10.4.

Three realistic examples are presented in Figures 10.5, 10.6, and 10.7. In one example, a leaf spot-tolerant variety is planted and one extra weeding is employed. Post-harvest, groundnuts are dried on a tarp to minimize aflatoxin contamination (Figure 10.5). However, this approach is hampered by the late planting date which endangers both yield and food safety because of aflatoxin. If the risk tool was used in planning, the farmer would be able to see that planting date is a critical factor and that he should do everything within reason to plant earlier in the season.

In the second example (Figure 10.6), the farmer chooses a late planting date, but employs other elements of production and pest management to protect yield. Fertilizer is applied, soil pH is higher, weed control is increased and digging occurs at the optimum timing. After harvest, pods are dried in a way that protects them from soil contamination and prevents cycles of wetting and drying. The groundnuts are dried to the optimum moisture level and stored in sealed bags. Even though this approach appears to protect yield and minimize aflatoxin contamination, considerable risk remains because of the likelihood that the dry season will return before the crop is mature.

In the final example (Figure 10.7), groundnuts are sown in early December rather than early February. This resulted in a reduction in risk to yield and food safety through a reduction in risk of aflatoxin contamination.

In all five examples, the farmer and agronomists who are making recommendations can assess the relative cost of practices. Financial constraints can limit what inputs can be used to protect yield and minimize contamination with aflatoxin. The risk tool provides an avenue to analyze the benefits and costs associated with a production package in a comprehensive manner that can potential minimize risk to both yield and food safety through aflatoxin mitigation.

Groundnut - Yield Risk Summary

LOW — MODERATE — HIGH — 565

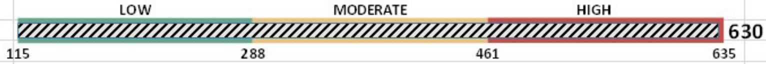
65 — 240 — 415 — 590

Crop Practices\Planting Date	**Risk Points**	
01 Feb or Later*	70	**70**
16 Jan to 31 Jan	50	
01 Jan to 15 Jan	40	
16 Dec to 31 Dec	30	
01 Dec to 15 Dec	20	
16 Nov to 30 Nov	10	
01 Nov to 15 Nov	5	
Crop Practices\Plants per 1m Row	**Risk Points**	
05 plants (20cm spacing)*	80	**80**
08 plants (15cm spacing)	40	
10 plants (10cm spacing)	15	
20 plants (5cm spacing)	5	
Crop Practices\Seed Inoculant	**Risk Points**	
None*	15	**15**
Yes	0	
Crop Practices\Variety	**Risk Points**	
Spanish, Virginia Type*	50	**50**
Spanish Rosette Resistant, Virginia Type Rosette Resistant	30	
Spanish Leafspot Resistant, Virginia Type Leafspot Resistant	20	
Spanish Leafspot and Rosette Resistant, Virginia Type Leafspot and Rosette Resistant	5	
Field Management\Crop Rotation	**Risk Points**	
Groundnut:Groundnut:Groundnut*	50	**50**
Soybean:Groundnut:Groundnut	45	
Soybean:Soybean:Groundnut	40	
Groundnut:Maize:Groundnut, Groundnut:Tobacco:Groundnut	25	
Soybean:Maize:Groundnut	20	
Maize:Tobacco:Groundnut, Tobacco:Maize:Groundnut	15	
Maize:Maize:Groundnut	5	
Field Management\Fertilizer	**Risk Points**	
000 kg/ha*	40	**40**
050 kg/ha	20	
100 kg/ha	15	
150 kg/ha	10	
200 kg/ha	5	
250 kg/ha	0	
Field Management\Gypsum Application	**Risk Points**	
None*	15	**15**
Yes	5	
Field Management\Land Preparation	**Risk Points**	
No ridging*	20	**20**
Hand dug and ridging, Tractor and hand ridging	10	
Field Management\Soil pH	**Risk Points**	
4.4 or Lower*	60	**60**
4.5 to 5.0	50	
5.1 to 5.5	30	
5.6 to 6.0	10	
6.1 or Higher	0	
Field Pest Mgmt\Aphid Spray	**Risk Points**	
None*	20	**20**
Yes	10	
Field Pest Mgmt\Fungicide Applications	**Risk Points**	
None*	50	**50**
1 Spray	25	
2 Sprays	15	
3 Sprays	5	
Field Pest Mgmt\Weed Control	**Risk Points**	
1 hand weeding during season*	50	**50**
2 hand weeding during season	25	
3 hand weeding during season	10	
Harvest\Digging Timing	**Risk Points**	
Early (21 days)	60	**35**
Late (21 days)*	35	
Early (14 days)	25	
Late (14 days)	15	
Early (07 days), Late (07 days)	10	
Optimum	0	
Harvest\Lifting	**Risk Points**	
Hand pulled*	10	**10**
Hand dug with hoe, Plow/Mechanical digger	5	

*** Selected options used in calculating pest risk.**
Note: Reduction in pest risk value by a control practice will be less under low risk conditions.

Figure 10.1. *Categories and range of points associated with risk to groundnut yield during the growing cycle. The higher the number of points the greater the risk.*

Groundnut - Aflatoxin Risk Summary



Crop Practices\Planting Date	**Risk Points**	
01 Feb or Later*	90	**90**
16 Jan to 31 Jan	70	
01 Jan to 15 Jan	50	
16 Dec to 31 Dec	40	
01 Dec to 15 Dec	20	
16 Nov to 30 Nov	10	
01 Nov to 15 Nov	5	
Crop Practices\Plants per 1m Row	**Risk Points**	
05 plants (20cm spacing)*	30	**30**
08 plants (15cm spacing)	15	
10 plants (10cm spacing)	10	
20 plants (5cm spacing)	5	
Crop Practices\Seed Inoculant	**Risk Points**	
None*	15	**15**
Yes	0	
Crop Practices\Variety	**Risk Points**	
Spanish, Virginia Type*	25	**25**
Spanish Rosette Resistant, Virginia Type Rosette Resistant	20	
Spanish Leafspot Resistant, Virginia Type Leafspot Resistant	15	
Spanish Leafspot and Rosette Resistant, Virginia Type Leafspot and Rosette Resistant	5	
Field Management\Crop Rotation	**Risk Points**	
Groundnut:Groundnut:Groundnut*	50	**50**
Soybean:Groundnut:Groundnut	45	
Soybean:Soybean:Groundnut	40	
Groundnut:Maize:Groundnut, Groundnut:Tobacco:Groundnut	25	
Soybean:Maize:Groundnut	20	
Maize:Tobacco:Groundnut, Tobacco:Maize:Groundnut	15	
Maize:Maize:Groundnut	5	
Field Management\Fertilizer	**Risk Points**	
000 kg/ha*	40	**40**
050 kg/ha	20	
100 kg/ha, 150 kg/ha	10	
200 kg/ha, 250 kg/ha	5	
Field Management\Gypsum Application	**Risk Points**	
None*	25	**25**
Yes	5	
Field Management\Land Preparation	**Risk Points**	
No ridging*	20	**20**
Hand dug and ridging, Tractor and hand ridging	10	
Field Management\Soil pH	**Risk Points**	
4.4 or Lower*	40	**40**
4.5 to 5.0	30	
5.1 to 5.5	20	
5.6 to 6.0	10	
6.1 or Higher	0	
Field Pest Mgmt\Aphid Spray	**Risk Points**	
None*	10	**10**
Yes	5	
Field Pest Mgmt\Fungicide Applications	**Risk Points**	
None*	20	**20**
1 Spray	10	
2 Sprays, 3 Sprays	5	
Field Pest Mgmt\Weed Control	**Risk Points**	
1 hand weeding during season*	30	**30**
2 hand weeding during season, 3 hand weeding during season	15	
Harvest\Digging Timing	**Risk Points**	
Late (21 days)*	70	**70**
Late (14 days)	50	
Late (07 days)	30	
Optimum	20	
Early (07 days)	10	
Early (14 days), Early (21 days)	5	
Harvest\Lifting	**Risk Points**	
Hand dug with hoe, Plow/Mechanical digger	10	**5**
Hand pulled*	5	
Post Harvest\Drying	**Risk Points**	
Ground*	80	**80**
Protected	20	
Post Harvest\Storage	**Risk Points**	
Traditional*	80	**80**
Sealed	20	

*** Selected options used in calculating pest risk.**
Note: Reduction in pest risk value by a control practice will be less under low risk conditions.

Figure 10.2. *Categories and range of points associated with risk of aflatoxin contamination during the growing cycle and after harvest. The higher the number of points the greater the risk.*

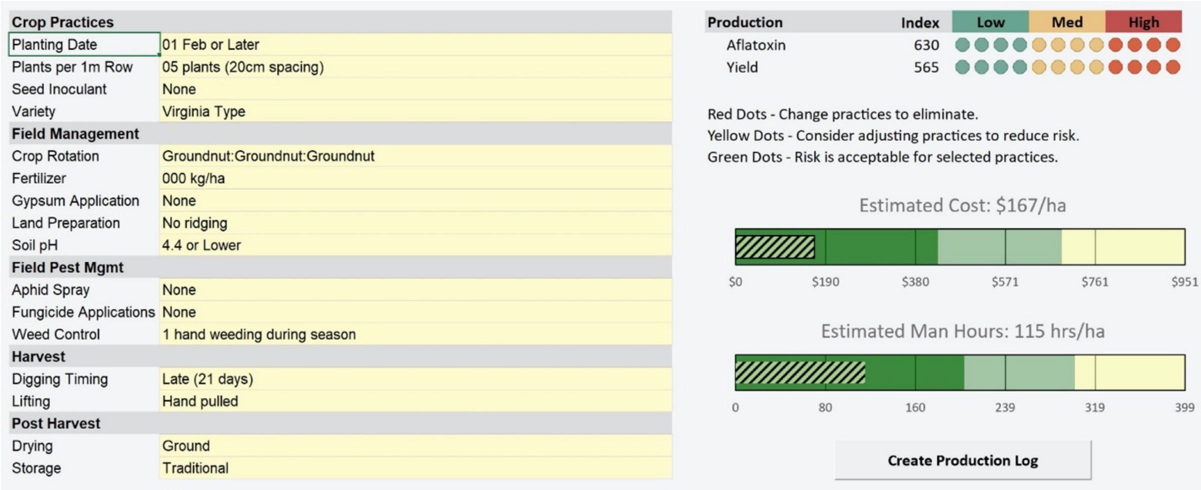


Figure 10.3. Risk to groundnut yield and aflatoxin contamination when the least effective production and pest management practices are implemented. The greater the number of yellow or red dots indicates greater risk.

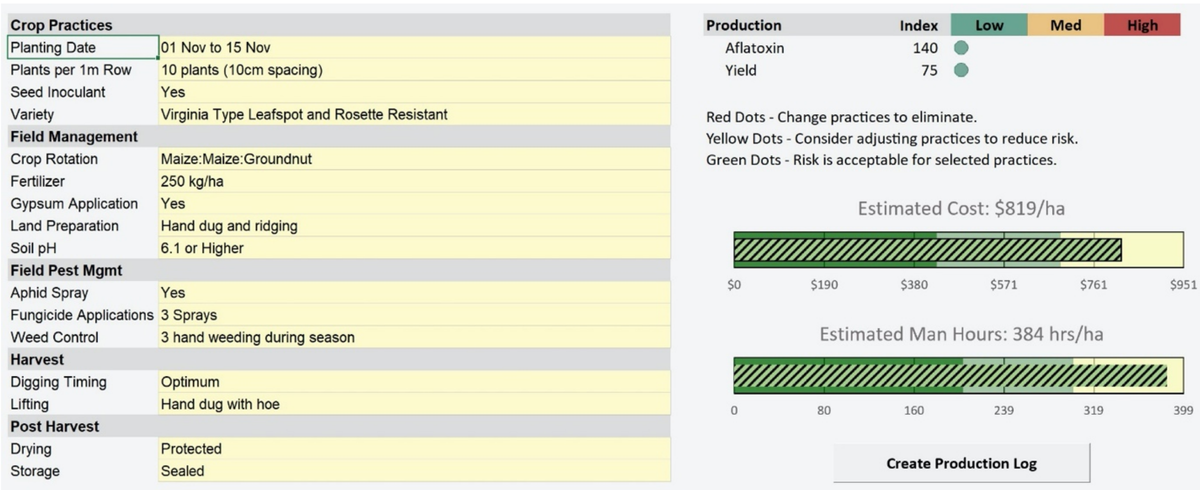


Figure 10.4. *Risk to groundnut yield and aflatoxin contamination when the most effective production and pest management practices are implemented. The greater the number of yellow or red dots indicates greater risk.*

Figure 10.5. Risk to groundnut yield and aflatoxin contamination when the planting date is delayed, and fungicides and insecticide are not used. The greater the number of yellow or red dots indicates greater risk.

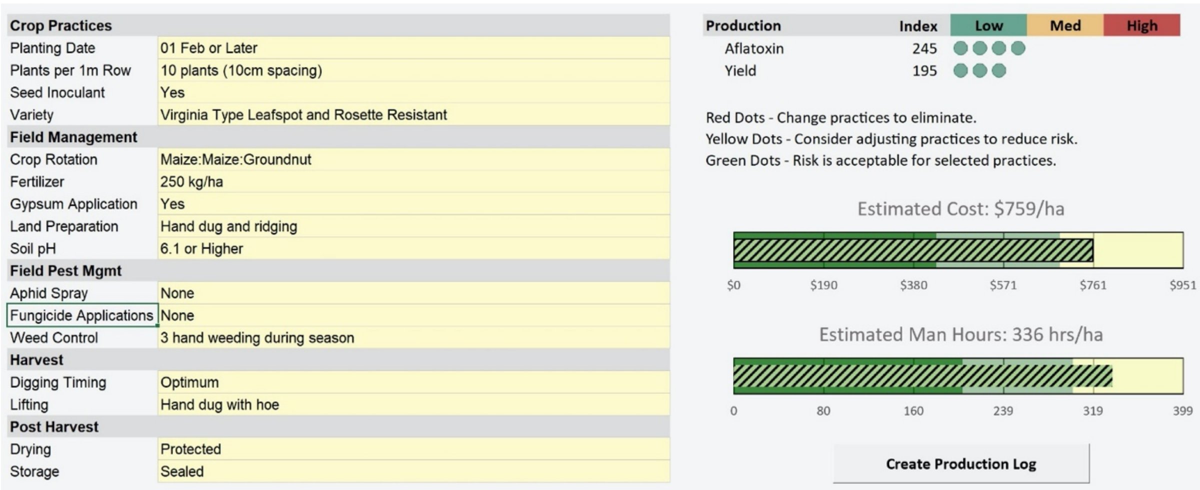


Figure 10.6. *Risk to groundnut yield and aflatoxin contamination when the planting date is delayed, and fungicides and insecticide are not used but a more effective fertilizer is applied and soil pH is higher. In this example, the most effective practices associated with digging time and drying and storing of groundnuts are used. The greater the number of yellow or red dots indicates greater risk.*

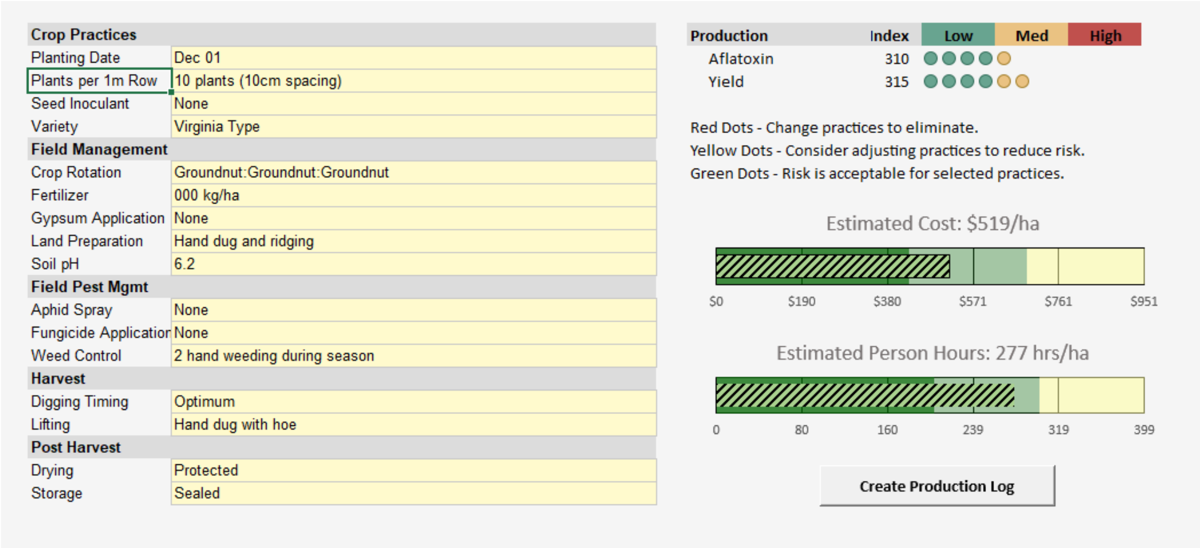


Figure 10.7. *Risk to groundnut yield and aflatoxin contamination when the planting date is early, but fungicides and insecticide are not used. Fertilizer is applied and soil pH is higher in this example. In addition to establishing a higher plant population, the most effective practices associated with digging time and drying and storing of groundnuts are used in addition to sowing earlier in the growing cycle. The greater the number of yellow or red dots indicates greater risk.*

Section 11: Evaluating Practices on the Farm

Evaluating

Each grower should develop an understanding of what practices work best on a particular farm. In some cases, research may have been conducted under different conditions or in another area and may not apply in a particular farmer's field.

However, simple comparisons in the field can help a farmer understand the value and the risk of different practices. These comparisons will show if an input (inoculant, fungicide or herbicide) contributes to yield and profitability. To evaluate these inputs under the real conditions of a particular field, a farmer must avoid biased tests and replicate the treatments to have confidence in the results.

On one field, apply inputs in one place and do not apply inputs in another, in order to compare the results. To avoid bias, select fields and areas within the field where the problem exists. In other words, herbicide should be tested in an area that has a history of weed problems.

Replicating results takes more effort and planning, but is important because the soil type, drainage and pest pressure can vary across a field. Repeat the treatments in multiple locations to account for that variation and avoid choosing an area that might have more pressure than others. For example, if the edge of the field has many more weeds than the rest of the field, testing there might not accurately demonstrate the overall effect of the herbicide.

While putting treatments out in multiple strips in a field is a good start, the preferred method is to replicate the treatments randomly. The figure below illustrates a good example of a randomized trial comparing one input. If possible, it is good to replicate at least four times for each treatment.

After the appropriate data are recorded, it is then important to analyze the data using appropriate statistical procedures. All treatments (such as planting an improved variety) need to have an equal chance of being placed at random somewhere in the experimental area. Likewise, all treatments need to be replicated a reasonable number of times (in most agricultural and pest management settings four replicates are sufficient). One should never draw major conclusions from a single experiment. Experiments should be repeated over space (locations) and time (growing cycles) to characterize consistently in response to variables. For example, many breeding programs require that a group of varieties be compared for three years at five locations before release.

Example of a replicated and randomized trial area for two inputs.

1 = Input #1, 2 = Input #2, 3 = Input 2 + 3, 4 = No Inputs or Untreated

3	1	4	2
2	4	3	1
4	2	1	3
1	3	2	4

Addendum

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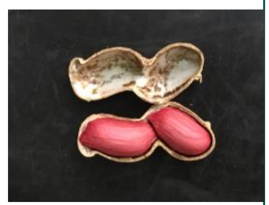
Optimizing Groundnut Yield and Minimizing Aflatoxin Contamination

Successfully Producing Groundnut

Select appropriate land
Rotate with other crops
Prepare land effectively
Plant high quality seed
Establish optimum plant populations
Provide adequate fertility
Protect from pest damage
Promote plant health
Lift and dry in a timely manner
Effectively store and transport

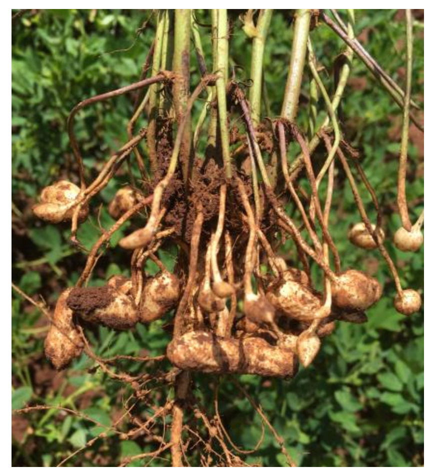


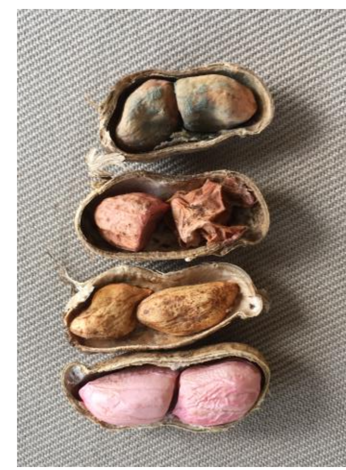
Minimizing Aflatoxin in Groundnut

Plant when rains begin
Plant viable seed 8 cm apart
Establish optimum pH and fertility
Apply calcium at peak flowering
Promote plant health
Protect from pest damage
Dig or lift 7 days early if drought exists
Dry pods as quickly as possible
Store pods optimum moisture content
Remove damaged pods and kernels

Groundnut Varieties in Malawi

Name	Type	Days to maturity
Chalimbana	Virginia	130-140
CG7	Virginia	130-150
Chitala	Spanish	90-120
Kakoma	Spanish	90-120
Nsinjiro	Virginia	120-149





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Relationship of Timing of Lifting and Pod and Kernel Maturity, Yield and Risk of Mold

Deciding when to dig or lift groundnuts is one of the most important management decisions farmers make. Pod yield and kernel quality and economic value improve as maturity increases. However, at some point pods will naturally shed from the plant or in the case of Spanish varieties seed can sprout. As groundnuts remain in soil after optimum maturity the risk of infection by mould (*Aspergillus flavus* and *A. parasiticus*) and contamination with aflatoxin increases. This chart provides information on how these factors interact and should be considered when deciding when to dig or lift groundnuts. The "shell out" method can be used to reveal color differences for the mesocarp pod layer. A darker mesocarp color indicates advanced maturity. The relationship of yield and distribution of pod mesocarp color for scenarios one might encounter is provided.

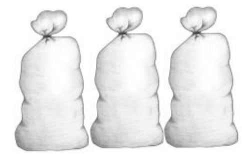
Darker pod color indicates advanced maturity

Split maturity
Dig Now

21 days early

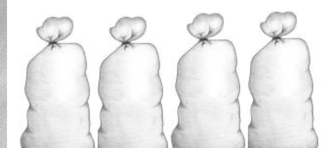
Mould Risk *Low*

14 days early



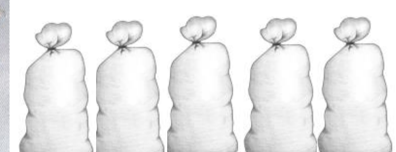
Mould Risk *Low to Moderate*

7 days early



Mould Risk *Moderate*

Optimum maturity



Mould Risk *Moderate to High*

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