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GUIDE FOR **GROUNDNUT, PIGEON PEA, SORGHUM AND FINGER MILLET** PRODUCTION IN MALAWI

For: Farmers Extension agents Researchers

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Production in Malawi

Introduction

Groundnut (Arachis hypogaea L.) is one of the world's fifteen leading food crops and cultivated throughout the world. It is among the most important foods in international trade. Popularly known as peanut in many countries, it is a leguminous plant considered as nut because of its high nutritional value. Besides being a food crop, majority of farmers also consider groundnut as a cash crop and useful rotation crop. It is easy to grow, withstands drought to some extent and being a legume crop it can fix atmospheric nitrogen. Thus maintains soil fertility.

All parts of this plant can be commercially used. For example, the plant stalks are fed to cattle in the form of green, dried and silage. Groundnut shell, haulms and hay are good fodder. Groundnut cake is a good feed for livestock and it is also used as manure. Kernels are used directly as food or snacks for human consumption. A large number of food products are prepared as well from groundnuts – Boiled nuts, roasted nuts, salted nuts, groundnut milk, groundnut yogurt, groundnut bars, groundnut butter, groundnut cheese, and bakery products etc.

In Malawi, groundnut is one of the widely grown grain legumes. The crop has potential to contribute to food and income security, but on-farmer yields are well below 0.8 t/ha. The low yields are due to a number of factors including:

- Low plant populations due to overly wide ridges;
- Delayed planting;
- Use of recycled seed for many years (limited access to improved varieties);
- Weed competition for water and soil nutrients;
- Low seed germination
- Poor soil fertility in fields where groundnuts are usually grown;
- Limited knowledge in pest and disease management;
- Challenges associated with aflatoxin contamination;
- Climate and weather related challenges (dry spells, water logging etc)
- Luck of knowledge on crop management practices by farmers
- Limited structured and profitable markets for groundnuts

Because of its nutritional and industrial significance, groundnut has been singled out as one of the crops whose production and consumption will be vigorously promoted in the country; evidenced by its inclusion in government Farm Input Subsidy Programme (FISP). The crop is also being targeted as one of the legumes to replace tobacco grown for export earnings. Therefore, adoption of improved crop production practices is needed for smallholder farmers in Malawi to avert some of the challenges outlined in this guide.

Agroecologies for Cultivation

Malawi has three main agroecologies based on climatic conditions and differences in altitude: the high-altitude areas (>1300 masl), the mid-altitude or plateau areas (760- 1300 masl), and the lakeshore (200-760 masl) and the Shire Valley (<200 masl), under low altitude areas. High altitude 2 areas receive 1000-1200 mm of rainfall, 600-1000 mm in mid-altitude, 500-600 mm in lowaltitude and less than 500 mm of rainfall in the rain shadow areas of the Shire valley. Groundnut is grown from sea level up to >1500 masl and therefore suitable for all districts in Malawi as seen
in the groundnut production area map (Fig. 1 and 2). Although groundnuts are grown in nearly all of Malawi's 28 districts, 70% of the crop in grown in the Central Region. The main groundnut growing areas are the plains of the following districts: Lilongwe, Kasungu, Mchinji, Mzimba, Salima, Balaka, Ntchisi, Dowa and Thyolo. About one in every five farmers in Malawi grows groundnuts. However, most small-scale groundnut farmers use little or no fertilizer or pesticides. The Department of Agricultural Research Services (DARS) in collaboration with International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) released improved varieties that are available and suitable for each of the agro ecological zones.

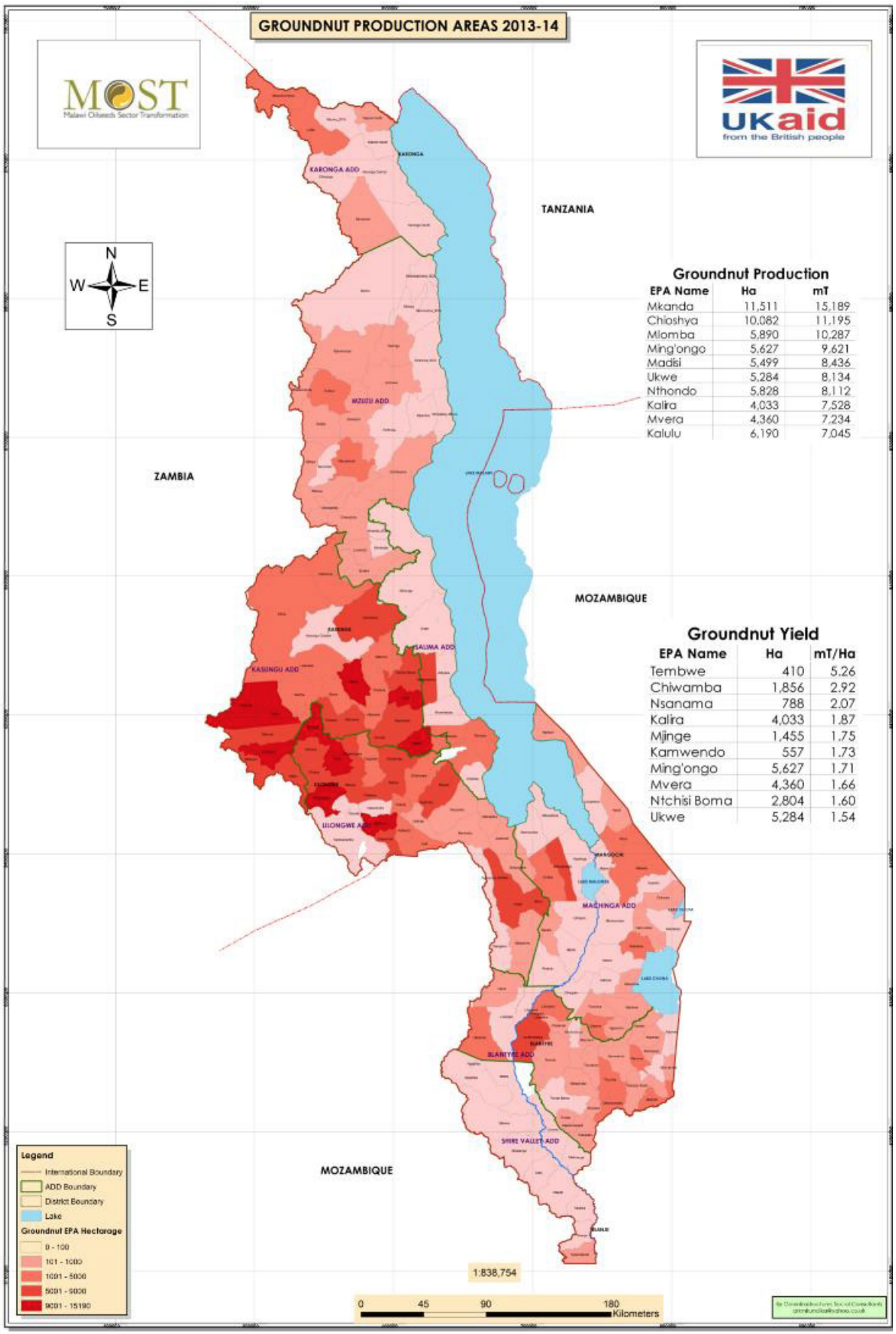

Fig. 1. Groundnut production areas as of 2013/2014 cropping season (Source: Malawi Oilseeds Sector Transformation, 2017)

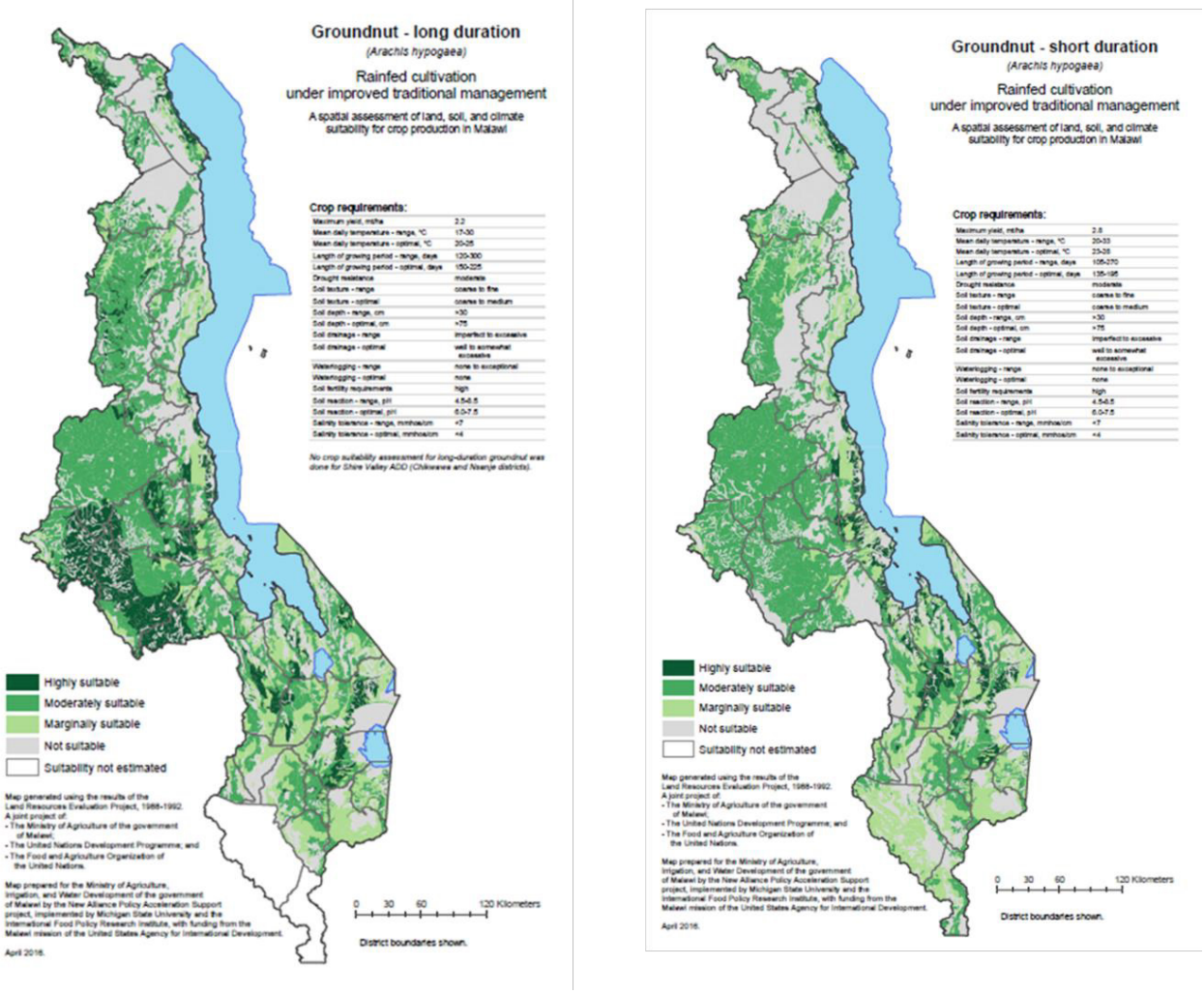

Fig. 2. Groundnut production areas as per land suitability under improved management (source: NAPAS, 2016)

Recommended varieties in Malawi and descriptors

Most of smallholder farmers use seeds saved from the previous harvest. Others buy seeds from vendors, or receive them from NGOs and through Farm Input Subsidy Program (FISP). Four major
types of groundnut varieties are differentiated - Spanish, Valencia, Runner and Virginia types (Fig. 3).

Fig. 3. Major types of groundnut varieties grown across the World

The groundnut varieties recommended for cultivation in Malawi belong to two botanical types on the basis of their growth habit. These are Virginia and Spanish type of groundnut.

Virginia type: In Virginia group groundnuts, the main stem does not have reproductive axes and but have alternate pairs of vegetative and reproductive branches and inflorescences/flowers are borne on the lateral and other n+1 branches (alternate branching). The Virginia type of groundnut as, compared to the other types of groundnuts, tend to have large kernel size in general. One of the major benefits of its large kernel is that they are good to use for in-shell roasting. They are also suitable for salting and confections and are therefore quite often used as a snack. Improved varieties in this category are: CG 7 and CG9 (red in colour), CG 8, CG 10, CG 11, Chalimbana 2005 and Nsinjiro (tan in colour), Table 1.

Spanish types: In the Spanish type of groundnuts, reproductive branches are borne on both the main stem and the lateral stems. So, reproductive branches are borne in a continuous series on successive nodes of the cotyledonary and other lateral branches, on which the first branch is always reproductive (Sequential branching pattern). The kernel size of the Spanish groundnut is a bit smaller than the Virginia types. Improved varieties in this category are: Baka, Kakoma (JL24), Chitala, CG 12, CG 13, and CG 14 (Table 1). *So far, there has been no Spanish variety released for the purpose of oil but as confectionery. CG7 is the only Virginia type variety currently released for both uses for confectionery and oil. The new varieties are yet to be tested for oil usage.*

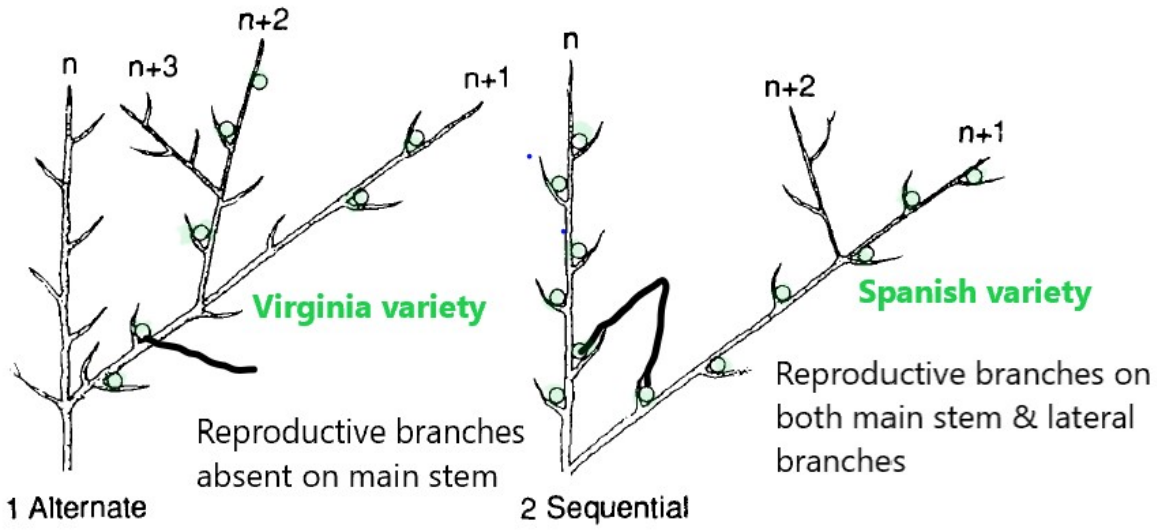

Fig. 4. Distinct features of Virginia and Spanish type groundnut varieties

Table 1. Description of improved groundnut varieties recommended for cultivation in Malawi

Variety	Type	Grain colour	Days to maturity	Yield potential (kg/ha)	Other descriptors
CG 7	Virginia	Red	120 - 140	2000 - 2500	Dark-green leaves, Orange-yellow flowers Reaches 50% flowering after 40 days. Susceptible to rosette
CG 8	CG 8	Red	120 - 140	2000 - 2500	Dark-green leaves, Orange-yellow flowers Reaches 50% flowering after 40 days. Resistant to rosette
CG 9	Virginia	Red	120 - 140	2000 - 2500	
CG 10	Virginia	Light Red	120 - 140	2000 - 2500	
CG 11	Virginia	Tan	120 - 140	2000 - 2500	
Nsinjiro	Virginia	Tan	120 - 140	2000 - 2500	
Chalimbana 2005	Virginia	Tan	130 -150	2000 - 2500	Moderately resistant to early leaf spot and rosette Recommended for higher altitudes (1000 -1500 masl)
CG 12	Spanish	Pale Tan	90 - 100	1500 - 2000	Erect growth Light green leaves, Yellow flowers Reaches 50% flowering after 30-35 days.
CG 13	Spanish	Pale Tan	100 - 110	1500 - 2000	
CG 14	Spanish	Pale Tan	100 - 110	1500 - 2000	
Chitala	Spanish	Pale Tan	90 - 110	1500 - 2000	Drought tolerant
Kakoma	Spanish	Pale Tan	90 - 110	1500 - 2000	
Baka	Spanish	Pale Tan	90 - 110	1500 - 2000	

Physiology and climate requirements

The knowledge of crop physiology is important for three reasons: (i) For optimal crop yield in an environment the life cycle of the crop must match with the length of growing season, (ii) The introduction of an improved genotype into a new region is largely determined by temperature and phenology, and (iii) Phenololgy is an essential component of whole crop simulation model, which can be used to specify the most appropriate rate and time of specific developmental process to maximize yield. In simple terms, Phenology is the study of organisms as affected by climate.

Environment plays a vital role in the development of seed from the flower to seed maturity. The advantages of producing groundnut in areas specifically suitable for groundnut production are that seed set, seed yield and recovery in harvesting are high and relatively stable; seed germination and seed vigour are consistently high; and seed borne diseases can often be avoided and are more easily controlled.

Rainfall is the most significant climatic factor affecting groundnut production and accounts for 50% variance in groundnut yields. Low rainfall and prolonged dry spells during the crop growth period are reported to be the main reasons for low average yields in groundnut production. It is difficult to have a concrete impression of where groundnuts would be best adapted in Malawi as a function of only rainfall distribution. Variety selection could also be a key in addition to the amount of rainfall that falls in a particular area. Soil water deficits occurring during the flowering to the start of pod growth phase significantly reduce pod yields (range 17–25%) relative to the wellwatered control plots for both Spanish and Virginia varieties.

The reduction in yield is greatest when severe stress occurs during the pod-filling phase. As a guide, between 500 mm and 1200 mm of evenly distributed rainfall is required annually for good growth and yield. Early maturing small seeded varieties require 400 – 650 mm while medium to late maturing large seeded varieties need 700 – 1200 mm rainfall.

Temperature is identified as a dominant factor for controlling the rate of development of groundnut. Every crop has its cardinal temperatures (i) base (Tb;), (ii) optimum temperature (To) and (iii) maximum temperatures(Tm). These are defined respectively as: (i) temperatures above which growth and development begins, (ii) temperatures at which growth and development are maximum, and (iii) temperatures above which growth and development ceases. Groundnut in Malawi does well at Tb range of 18ºC), To of 20–30ºC and Tm of 36–41ºC. Higher temperatures promote greater vegetative growth and higher photosynthesis in groundnuts, but the reproductive potential is decreased, due to greater flower abortion and decreasing seed size.

It is now well established that long days promote vegetative growth at the expense of reproductive growth and increase crop growth rate, decrease partitioning of photosynthesis to pods and decrease duration of effective pod filling phase in groundnuts.

Crop production practices

Variety selection

The choice of a groundnut variety for any particular area depends on matching the variety with the length of the growing season. Groundnut varieties whose growth cycle is longer than the duration of growing season at a particular location either fail to mature or mature at a time soil is too hard to dig the pods. Spanish varieties like Kakoma, Chitala and Baka are best suited low-altitude agroecological zones and Virginia type varieties (CG 7, Nsinjro, Chalimbana, Chalimbana 2005, CG 9, CG 10,) in areas with longer growing seasons (mid- and high altitude agro-ecological zones).

Fig. 5. Examples of groundnut variety seeds available in Malawi

Seed source

The seed source should be reliable. The seed should not be broken, shriveled, or diseased; and should not contain off-types. Use high quality seeds of the selected variety. Groundnut seeds easi lose their viability. It is common for groundnuts, even when stored properly, not to germinate after 3 - 6 months in storage when shelled. Therefore, use seeds that were not stored more than 12 months old after shelling to ensure good germination. Sort out the good seeds for planting to ensure that they are free from insects, disease infestation, and weed seeds. Do not purchase seeds from the open market as the germination potential is not guaranteed. Planting poor quality seeds will not produce a good yield. Always buy groundnut seeds from accredited seed companies or seed producers nearest to you.

Site selection and soil fertility

Good site selection is a recipe for increased groundnut yields. The groundnut pod is produced underground, thus the top-soil must have a low clay content (less than 20%) with a loose structure so that the reproductive roots may penetrate the soil freely. Therefore, sandy loam soils with sufficient drainage are good for groundnut.

Avoid:

- Steep sloping land
- Land which is near a swamp or likely to have water logging conditions
- Very sandy soil and areas with shallow surface soil to avoid drought stress
- Areas with a lot of couch grass.
- Areas with a lot of shade to the groundnut crop like under the trees
- Soils that easily compact and form a crust as the hypocotyls (neck) break easily under pressure

Substantial evidence exists that shows that groundnut responds to addition of fertilizer even though this is not imperative. Groundnuts are adapted to a soil of pH (H20) of 5.3 or higher. If soil pH is less than 3.5 or higher than 8.0, certain elements become unavailable e.g. iron and zinc .

Select productive land suitable for groundnut production. A fertile soil ensures that nutrients are available for the groundnut crop and therefore minimizes the need for inorganic fertilizer inputs. Poor, low fertile soils result in stunted plant growth, leading to low yields per unit area.

Field preparation

Proper land preparation ensures good germination and reduces weed infestation and timely field preparation facilitates timely sowing, which in turn, ensures higher yield. Land preparation for groundnut fields should ensure that all crop residues and weeds are completely buried. In this stage, the field is cleared, after which, plowing and harrowing are carried out to make seedbeds of fine tilth for proper germination and growth of crops. As for farmers without farm machinery, land can be prepared manually using hoes to make ridges or flat beds.

Those farmers planting on ridges, they need to make sure that ridges are spaced at 75 cm apart; each ridge should have a width of 50 cm where two shallow grooves will be made during planting. Ridges that are spaced at 75 cm apart and 50 cm wide, leave a space of about 25 cm between them.

Two rows per ridge (instead of only one) ensure high plant population > 180,000 - 250,000 plants per hectare depending on the variety used. This results in good yields. If planted on flat beds, rows should be spaced at 37.5 cm apart.

Note: Groundnut needs a soil that is warm, moist, with good supply of air, and with a good contact between the seed and soil for rapid germination.

Seed rate

Generally, 179,380 plants per hectare are recommended for dry-land production of Virginia varieties in Malawi e.g. CG 7, CG 8, CG 9, CG 10, CG 11, Chalimbana 2005, Nsinjiro using double row planting pattern at 75cm x 15cm while 268,935 plants per hectare are ideal for Spanish varieties e.g. CG 12, CG13, CG 14, Kakoma (JL 24), Baka and Chitala using double row planting pattern at 75 cm x 10 cm. In order to achieve these plant populations, the farmer is required to use 160 kg of seed for the Virginia type varieties and 120 kg seed for the Spanish varieties per hectare.

Planting

Planting time:
Planting date is linked to rainfall distribution in the area and length of the crop season. Soil moisture must be sufficient to guarantee good germination. The normal planting time for groundnuts in Malawi is when there is effective rains (November–December); ≥ 30 mm of cumulative rainfall. Several factors, however, will determine the precise date; the most important being rainfall. Groundnuts planted late, usually produce lower yields, poor seed quality and also have higher risks in terms of foliar diseases, control and build-up of aphids that lead to a viral disease , rosette . Seeds must not be sown immediately after heavy rains since they imbibe too much water, which causes rotting. This also results in excessive soil compaction, which may hinder seedling emergence.

Planting depth:
Groundnuts should be planted at a depth range of 5–6 cm. The planting depth should be uniform to ensure that the plant develops and produces optimally. To ensure uniform sowing depth, germination and crop stand, it is suggested that a groove 5-6 cm in depth is made along the rows for planting and, once the seed has been planted at the right depth and spacing, the soil is pressed down to ensure good contact with the seeds, enabling them to extract moisture more effectively.

Planting methods/planting pattern:
The current recommendation is to plant groundnut seeds in twin rows per ridge (two rows per ridge) that are spaced at 20–30 cm apart on the top of the ridge.

The advantage of using twin rows (some refers to it as 'double row planting) is that it increases groundnut yield by over 50% compared to single row planting pattern. Economically, twin rows increases economic benefits by over 60% compared to single row planting pattern. However, if planting is on flat ground without ridges, groundnuts should be seeded in rows that are spaced at 37.5 cm between them in order to achieve the same plant population as in groundnuts planted on ridges.

Fig. 6. Twin row planting pattern versus single planting pattern of groundnuts

Plant nutrition and fertilization

The structural and textural status of the soil, its fertility level, pH, microbial environment determine the growth and development of groundnut. In the nutrition of seed crops, nitrogen, phosphorus, potassium and several other elements play an important role for vigorous crop growth and productivity. It is advisable to know and identify the nutritional requirements of seed crops and apply adequate fertilizers. Adequate fertilization results in good seed development and maturation. Groundnut is energy rich crop, so its energy requirements need to be met with the application of optimum quantities of plant nutrients through application of manures and fertilizers. As a guide, groundnut requires key nutrients like nitrogen, phosphorus, potassium, calcium, boron and molybdenum.

Being a leguminous crop, groundnuts can fix atmospheric nitrogen (N) with the aid of soil bacteria thus, it does not depend on nitrogen fertilization. However, nitrogen supply can be boosted by the application of rhizobia inoculant in soils with low native rhizobia associated with the groundnut crop. Groundnut with effective root bacteria does not need additional nitrogen

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Use of inoculants: An inoculant is a culture of Rhizobia species that nodulate (through nodules) the legume crop. Inoculants form a relationship with a legume plant by forming nodules/swellings

that act as small factories for producing nitrogen that is found in fertilizers like Urea. Where inoculants are required, the farmer is advised to use recommended groundnut inoculants that are commercially available on the market with accredited dealers. This is because rhizobia species are live organisms that can die if not properly handled or stored thereby rendering them ineffective when applied to groundnut seed. Whilst there may be cross-inoculation of strains compatible with any given legume, the wide diversity of rhizobia requires more precise matching in symbioses. This specificity of an association enables maximization of nitrogen fixation. The procedure for inoculation is as follows:

- Put groundnut seed into a plastic pail.
- Tear the inoculant pack and mix with groundnut seed
- Spray 200 ml of water on approximately 10–15 kg of seed and mix thoroughly without damaging the seed coats. You can use a 300 ml bottle to get the 200 ml of water i.e. ¾ of 300 ml bottle
- 50 g pack of inoculant is enough to inoculate 10–15 kg of groundnut seed
- After thorough mixture of the seed with the inoculant, spread the inoculated seed on a tarpaulin or other clean surface under a shade (a tree) and leave for about 10 to 20 minutes to dry. This is now ready for planting.

Hints:

- The inoculated seed should be planted within 24 hours of inoculation in order to avoid killing the rhizobia.
- Inoculated seeds should not be in direct contact with sunlight.
- Keep the inoculated seed under shade (under the tree)
- Strong heat or direct sunlight may kill the live bacteria (rhizobia)
- The inoculant once purchased should be kept in a cool place (conditions) inside the house (under room temperature). If farmers have refrigerators, they can store the rhizobia in the fridge but not in the deep freezer compartment.

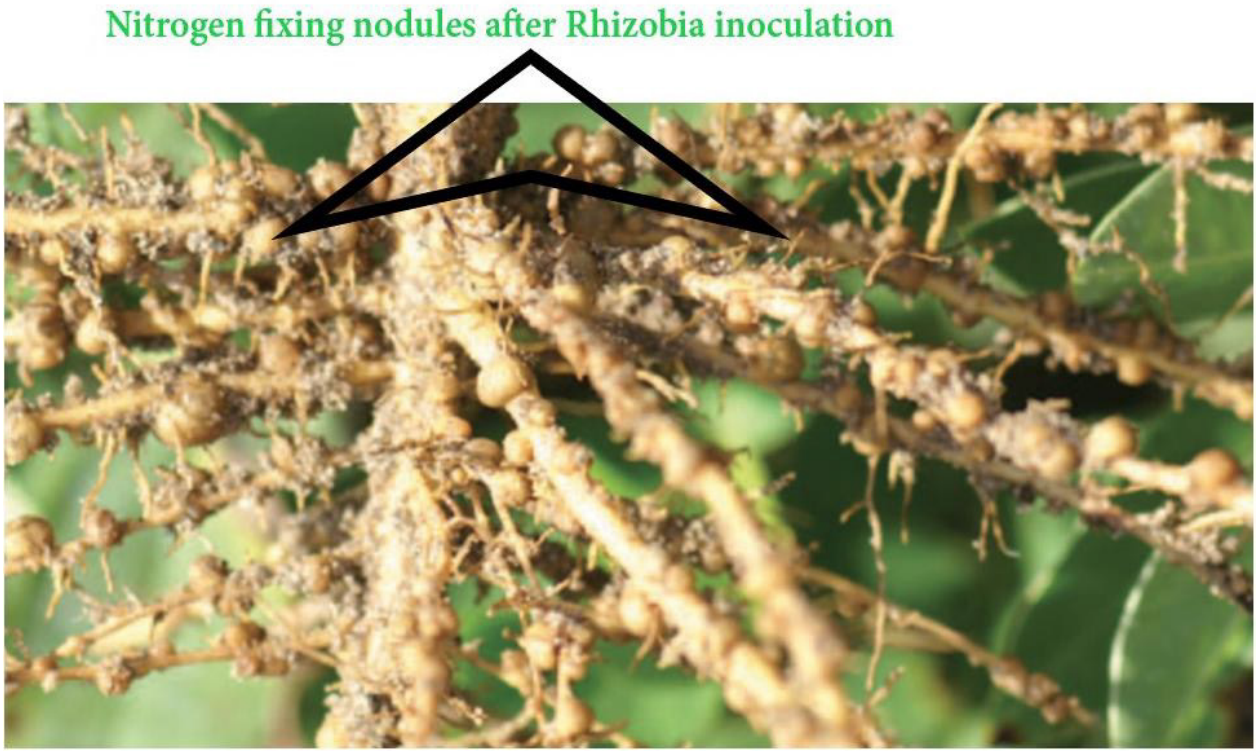

Fig. 7. Nitrogen fixing nodules in groundnuts after successful Rhizobia inoculation

Groundnuts prefer residual phosphorus (P) to freshly applied phosphorus. However, in fields where the level of phosphorus is low, it should be applied. An application of Single Super Phosphate (SSP) at the rate of 100–125 kg/ha or Triple Super Phosphate (TSP) at 80–90 kg/ha will boost groundnut yield.

Like other crops, groundnut plant requires sufficient levels of potassium (K) for normal growth and development. However, an oversupply of potassium in the soil can induce a calcium deficiency. In situations where the soil potassium level is low, additional potassium can be applied using K containing fertilizers. It helps in synthesis of proteins and fat in oil crops. In areas where there is high incidence of empty pods ('pops'), there could well be a shortage of calcium in the soil. Calcium is very important for seed development. Where a crop is grown on calcium deficient soils, the producer will have a direct seed loss as well as indirect damage to the seed which is not always visible. To rectify this, a treatment of gypsum at the rate of 200–400 kg/ha at early flowering will reduce the incidence of pops in situations where less than 100 mg kg1 of calcium is present in the soil. Of these particular nutrients, high dose of nitrogen reduces development in seed due to accumulation of germination inhibitors and prolong the growing period and delays the seed maturity.

Boron (B) deficiency symptoms occur in very sandy soils and can affect quality. In cases where boron deficiency symptoms have been observed 1 kg ha–1 of boron may be applied with or after planting. In acid soils in which the pH (KCl) is lower than 4.8, molybdenum may not be available. In these situations, it is advisable to treat the seed with molybdenum by applying 50 g sodium molybdate per 50 kg seed. Molybdenum can also be applied to the plant row 10–14 days' post emergence.

Groundnut and pigeonpea intercropping (Doubled up legumes)

Intercropping 2 legumes that have different growth habits is a relatively new practice. It is an approach that takes advantage of beneficial interactions between the 2 legume crops. Currently approved doubled-up legume intercropping systems mostly involve pigeon pea and groundnut. It has been established that pigeon pea grows very slowly for the first 2 months after planting. It follows that pigeon pea can be intercropped with groundnuts, without too much competition for water, nutrients and sunlight. Pigeon pea only starts rapid growth when groundnuts are approaching maturity. Groundnuts mature first in about 4 months and are harvested during May. After this pigeon pea continues to grow on its own in the field, forms pods, and will be harvested later. This way we 'double' crops and 'double' soil fertility benefits as both legume crops will contribute to soil fertility to the farmer's field.

Steps to establish groundnut-pigeonpea doubled-up cropping

There are two groundnut-pigeon pea double up options recommended for farmers in Malawi and these are explained below (Fig. 8):

First option: Plant groundnuts at full population in the field and then 1/2 population of pigeon pea. For every ridge of groundnuts, pigeon pea is planted at 180cm apart, three plants per plant station. Groundnuts should still be planted in twin or double rows per ridge.

Second option: Plant groundnuts and pigeon pea in alternative ridges or rows. After every two ridges of groundnuts, the third ridge is planted to pigeon pea at 90 cm apart (2:1), three seeds per

plant station. This achieves 1/3 population of pigeon pea. Groundnuts should still be planted in twin or double rows per ridge.

Step 1: Plant groundnut first

- Remember to use rhizobia inoculants on groundnuts if you are in an area that requires inoculation.
- Groundnut seed needs moist soil for germination. They must not be dry planted and should not be planted until it is clear that the rainy season has properly started (plant after a few days of rainfall!).
- Planting and planting pattern requirements should be done as indicated earlier, including the seed rate and management.

Step 2: Plant pigeon pea - on the same day or within seven days of planting groundnuts

- On the ridges already planted with groundnuts (first option), plant 3 pigeon pea seeds per planting station at 90 cm spacing. This results in about 44,000 plants/ha
- This single row of pigeon pea must be at the centre (top) of the ridge
- Only 3–5 kg pigeon pea seed is required to plant 1 ha of groundnut/pigeon pea doubled up system.

What benefits can be expected from double up legumes?

- Improves soil fertility through biological nitrogen fixation and leaf fall from both groundnut and pigeon pea that adds soil organic matter to the soil.
- Pigeon pea roots can help break hardpans (biological plough), and tap moisture and nutrients from deep soil layers
- Leaf fall from pigeon pea forms a dense mat that smothers weeds
- Labour savings since a farmers uses labour for weeding two crops on same piece of land
- Woody stems from pigeon pea are used as fuel wood
- Increased soil biological activities leading to improved soil aeration, water infiltration and rate of decomposition
- Significant reduction in witch weed (Striga asiatica L.) for the following maize grown in rotation with double up legumes
- Increased net benefit per unit kwacha invested

Fig. 8. Double up groundnut and pigeon pea intercropping technologies released for farmers' use in Malawi

Weed control

Weeds compete with the crop for moisture, nutrition, light and space. Unfortunately, groundnut cannot compete effectively with weeds, particularly 3-6 weeks after sowing; therefore, early removal of weeds is important. Generally, 2 weeding regimes are recommended, the first before flowering and at least another during pegging but with proper care so that flowering and pegging is not disturbed. Once flowering and pegging begins it is advisable to weed by hand by pulling, rather than by using a hoe, as this is less likely to disturb any developing pods. If early weeding is done well, and crop spacing recommendations followed, then the weeds that come up later are smothered with the vigorous growth of the crop. Remove spotty infestations by hand hoeing or spot spraying to prevent spreading weed seed, rhizomes, tubers or roots. This is particularly important for perennial weed species. Crop rotation also helps to control weeds in the field.

Weeds can be controlled chemically (both pre- and post-emergence herbicides), mechanically or with a combination of the two. However, the ultimate choice depends on the species of weeds involved and the level of infestation. If chemical use is the choice, follow the manufactures' 16 instructions on the label for safe use and dosage.

Crop rotation

Grow groundnuts in rotation with grain crops to reduce risks of pest and disease infestation. Groundnuts have been shown to improve the yield following maize and other grain crops by up to 20%. Grow groundnuts after the main crop such as maize, small grains, sorghum or millet, but not after cotton or soya beans due to the risk of weeds, pests and diseases.

Pest and disease management

Major pests

Major insect pests in groundnut are: termites (Odontotermes), whitegrubs (Lachnosterna consanguiea), thrips, aphids (Aphis craccivora) and leaf miners (Aproaerema modicella).
Termites (Chiswe): Termites can damage groundnut roots and stems, and bore holes in the pods, thereby damaging nuts. When termites damage pods, they also provide an entry point for the fungi that produce aflatoxin. To control termites:

- Incorporate crop residues of cereal crops like maize early enough. As they decompose, the residues produce heat which repels termites.
- Destroy termite mounds and remove queen termites: It's important to completely destroy the mounds. Partial destruction is not effective.
- Plant early: Groundnuts will then mature before late-season droughts. Early planting leads to healthier, more vigorous plants which can better tolerate termite attack.
- Correct plant spacing is also important. It can result in yields which are high enough to offset termite losses.
- Harvest promptly: Delaying the harvest increases termite damage.
- Apply appropriate chemicals such as Dursban in infested spots and neighboring plants
- Avoid banking and weeding at the same time. This should be done at two separate times.

Aphids *(Nsabwe)*: Yield losses due to aphids are not available however, the following management options can be used to control aphids.

- Remove and destroy volunteer groundnut plants.
- Sow early and at optimum plant population. Early planting allows plants to start flowering before aphids appear. Dense planting provides a barrier to aphids penetrating in from field edges and discourages population build-up of aphids and reduces incident of rosette disease
- Apply chemicals if necessary e.g. dimethoate or neem seed or leaf extracts.
- Conserve natural enemies: Ladybug beetles are important natural enemies in groundnuts

Leaf miners: The conditions favourable for the leaf miners' growth are long dry spells resulting in high temperature and low humidity (more than 21 days of no rain). Three or four attacks per 17 groundnut leaflet can cause so much distortion that a leaf exposes as little as 30% of the potential photosynthetic area to the sun. Later, when the caterpillar becomes too large to occupy the mine, they emerge to the leaf surface and either fold over a single leaf and hold it down with silk, or web together two or more leaflets. Leaf miners live and feed in the shelter they have constructed. Pupation takes place inside the webbed leaflets. Damaged leaves become brownish, rolled and desiccated, which results in early defoliation and affects the growth and yield of the plants.

Leaf miner control recommendations:

- Plant during the first short rains when normally the leaf miner population is low;
- Avoid drought stress by irrigating or sowing so as to avoid periods when drought is likely. Plants that are water-stressed are much more susceptible to leaf miner attack than irrigated plants;
- Use tolerant/resistant varieties.

Thrips: Several species of thrips attack groundnuts. Thrips are small slender insects that jump or fly when disturbed. Thrips larvae are similarly shaped and are usually yellow. They feed in buds or plants on young, folded leaflets. The flower thrips (Frankliniella schultzei and Megalurothrips sjostedti) infest mainly buds and flowers. Attacked flowers are discolored and scarred; terminal leaf buds are blackened and distorted after unfolding. In severe infestations, young leaves are severely deformed, plants are stunted and leaves are blighted.

Thrips control measures include:

- Ploughing and harrowing before transplanting. This can be useful in reducing thrips attacks by killing pupae in the soil;
- Conserve natural enemies to thrips, such as lacewings and other predatory bugs;

White grubs: White grubs are the larvae of scarab beetles. There are about 200 known species. Mature grubs are about 1.3-2.5 cm long with six prominent legs. The rear of the body is smooth, shiny, and usually black. They have curved C-shaped bodies. They live in the soil and feed on the underground parts of the groundnut plant. Their life cycle varies in length from 1-4 years, depending on the species.

White grubs attack groundnut plants at all stages of growth. They eat the roots and damage the pods. White grubs feed mainly on the taproots and/or peripheral roots leading to plant stunting or death. They inflict cuts in the crown region of taproots; these lesions are often invaded by rotcausing fungi. White grubs also cut out pods from the base of groundnut pegs and destroy larger, soft pods. Plants are often attacked in a row. The pests seem to prefer soils with sandy or

loamy sand textures and are seldom observed in clay soils. Control measures include:

- Allow enough time between manure application and groundnut planting. Note that the excessive use of organic manure in groundnut farms has been observed to increase the incidence of white grubs, especially when manure is applied during the cropping season; Plough deeply and hand hoe tillage as it exposes soil pests to desiccation and to predators, thus helping to reduce their numbers and damage

Major diseases

Diseases in groundnuts can be classified as leaf, stem and pod diseases and in addition to these particular viral diseases are also encountered. These cause large losses in both yield and quality of groundnut seeds.

Early leaf spot *(Thomba yoyambilira)* and late leaf spot *(Thomba yochedwa*): Early and late leaf spots *(Cercospora arachidicola and Puccina personate)* are considered the most important fungal diseases of groundnut in Malawi due to severe leaf loss (defoliation). Yield reductions may approach 70% in the absence of proper management practices. Early leaf spot is recognizable by the brown spots on the leaves which are surrounded by a yellow halo whilst late leaf spot is recognizable by larger, circular black spots. Late leaf spot is very serious and destructive in low lying and lakeshore areas and yield losses range from 25 to 50 %. Remedies include: (i) reducing initial inoculum by crop rotation, early planting, and tillage, and (ii) reducing the rate of disease spread by cultivar selection and applications of fungicides 30–40 days after planting.

Rosette *(Kadukutu, Kaligwiti, khate*): Groundnut rosette is a viral disease transmitted by insects called aphids and white flies. Rosette is the most destructive disease of groundnut, and can cause 100% loss of yield in severe cases. If rosette occurs at flowering, yield losses are very large. Use rosette resistant varieties of groundnut e.g. Nsinjiro, CG 8, CG 9, CG 10, CG 11 to eliminate the need for spraying insecticides to control the aphids. Avoid late planting and wide spacing to reduce incidences of rosette disease. If a high yielding non-rosette resistant variety is grown (e.g. CG 7) then insecticides will be needed. Systematic insecticides such as dimethoate can be sprayed at 10- day intervals for a total of four sprays.

There are two forms of symptoms seen in the crops: 1) 'chlorotic' (yellow and stunted) and 2) 'green' (green and stunted).

Rust (Dzimbiri): Rust *(Puccinia arachidis)* has now become a disease of major economic importance in almost all the groundnut-growing areas of the world. It becomes devastating under conditions of high rainfall and humidity. The disease can survive in volunteer plants and spores can disperse over long distances to infect other areas. It is characterized by orange-red pustules on the leaves which later turn dark brown and cause curling of leaflets and defoliation. The disease is of little consequence if it appears 2-3 weeks before harvesting. The cultural practices and fungicidal control measures recommended for leaf spot should be used. The disease occurs 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 control the disease by:- Removing and destroying infected volunteer groundnut plants and early planting.

Aflatoxin (Chuku): Aflatoxin contamination of groundnut is a major problem in most of the groundnut production regions to humans and livestock and it is mostly influenced by the occurrence of drought during the late seed filling duration. It is caused by the growth of the moulds

Aspergillus flavus and/or Aspergillus parasiticus. The moulds are common saprophytic fungi found in soils throughout the major groundnut producing areas.

Aflatoxin is more serious during and following alternating dry and wet periods i.e. droughts following showers. Groundnut varieties should be chosen, when possible, that are genetically more resistant to the growth of fungus and the production of aflatoxin (unfortunately no variety released in Malawi is genetically resistant to aflatoxin contamination). Drought tolerant varieties also have found to have greatly reduced aflatoxin contamination. Additionally, choosing varieties which are resistant to diseases and pests can help reduce aflatoxin contamination.

Other remedies for aflatoxin include:

- Harvest the crop as soon as it is mature, any delay will encourage the development of fungus
- Avoid damaging pods during cropping
- Remove soil from the pods before leaving to dry
- Ensure that the correct drying procedures are used and that damaged, shrivelled, or rotten pods are removed before storage
- Store the pods under dry, well ventilated conditions to ensure the moisture content remains low, thus discouraging fungal growth
- Avoid damaging the seed during shelling and destroy any discoloured, shrivelled or mouldy seed

The government of Malawi, through the ministry of Agriculture, Irrigation and Water Development (MoAIWD) has released a new product composed of microorganisms that counter effect (feed and compete with microorganisms responsible for development of aflatoxin) aflatoxin development for use by farmers in Malawi. The product is called Aflasafe that can be applied in both groundnuts and maize crops.

Harvesting

Harvesting, drying, and shelling procedures can greatly affect the quality of groundnuts. In areas where mechanical and drying procedures are not standard, seeds are often damaged and germination is poor.

Two things should be considered when thinking about harvesting groundnuts in the field:
Timing: Groundnuts need to be harvested at the correct time. Harvest groundnut at the right time of seed maturity to avoid harvesting of immature seed or conversely, over maturity through delayed harvesting. This is so because groundnut flowering is indeterminate and therefore the proportion of mature and immature pods is variable at the end of the crop cycle. Most of the legumes seed (Groundnut, soybean, common beans, and cotton) attain physiological maturity at moisture content ranging from 50-55%. Following maturation, the seeds continue to dry down until they reach harvest maturity. Climatic conditions during this post-maturation pre-harvest period have a great influence on the quality of seed harvested. Adverse weather conditions during the pre-harvest period cause seed quality problems. Delays in harvest will lead to mold infections and subsequent aflatoxin contamination.

Indicators for harvesting time imply the removal of at least 5 plants in the field at random and the pods removed and shelled to assess maturity. The insides should be examined. If >70% of the pods 20 have dark markings inside the shell and the seeds have the right colour for the variety, then the groundnuts are mature and ready to harvest. The estimated period of maturity for each variety can be used as a rough guide. Late harvesting also reduces yield because higher proportions of pods are left in the ground due to the pegs being weak and the pods breaking off. If harvested late, some non-dormant varieties like the Spanish type (Chitala, Baka, Kakoma, CG 12, CG 13 and CG 14) will begin to sprout in the field resulting in yield losses.

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

Sometimes diseases can also have an influence on the determination of harvest date. Plants in which the leaves have been lost due to leaf spot diseases, do not lead themselves to the making of a professional stack, as water easily penetrates the stack. In such a case, the farmer will be forced to harvest at an earlier stage. It is not advisable to use leaf drop as a sign of maturity because leaf drop can be the result of diseases.

Methods of harvesting: Harvesting by hand is more suitable for the bunch/erect groundnut varieties in sandy, loam soils which are well drained. When the soil is wet and heavy or very dry, it is much more difficult to pull up the whole plant without losing pods and therefore other methods should be used. Hold the entire group of branches as the plant is being lifted. Hand harvest only when there is enough moisture in the soil. Hand lifting with a hoe is also possible to lift plants out of heavy or dry soil with a reduced pod loss. Spreading varieties can also be more easily lifted with a hoe. Care should be taken not to damage the pods with the hoe as damage makes the pods susceptible to fungal attack. The blades should be passed away from the pods as much as possible.

Drying methods

The harvested groundnuts have a moisture content of approximately 25%. As groundnuts with such a high moisture content tend to rot easily, it is necessary that they be subjected to a conditioning or drying process as soon as possible. Once plants have been uprooted, they must be allowed to dry for a few days with the pods exposed to the air. Good drying requires plenty of air circulation. Poorly dried groundnuts enhance fungal growth and aflatoxin contamination. Drying of seeds to a safe moisture content before storage is essential to minimize deterioration due to microorganisms and endogenous respiration during storage.

There are different ways of drying the pods, some of which are better than others. It is particularly important to note that if the pods are exposed to the sun for too long the seed quality can deteriorate considerably and germination can be affected. The different methods of drying are explained below.

Field drying: In Malawi, sun drying is the conventional method for reducing moisture level in the seed. Most of farmers use windrows to dry groundnut which varies from place to place. If the

harvested groundnut plants are left to dry on the soil surface where they have been lifted, the pods are likely to be in contact with the soil, which can contain moisture. In this case, it can easily affect the quality of the seed, particularly if there is rain during the drying period. Slow drying in the windrow or which involves bundling plants and inverting them over other bundles to cover pods from direct sunlight and then exposing all pods to open air during the night is a common practice in Malawi (Fig. 9 and 10) and is mostly subject to mold proliferation which subsequently degrades seed germination ability. Apart from being weather-dependent and slow, sun drying often results in non-uniform drying.

Fig. 9. Windrows where groundnuts face south or north, west or east

Fig. 10. Windrows where groundnuts pods face upwards in a cyclic ring

To improve the practice, windrows of groundnut plants should be laid in rows to dry more quickly for 3-5 days before picking or stripping. When picked from the rows, plants should be laid out in a thin layer in the sun on a dry surface for another 2-5 days. Pods should be covered or taken indoors during wet weather. If not using windrows, pods could be picked from the plant after lifting and placed in the sun on a dry surface for 6-8 days. Mandela cock: Some farmers have minimized using windrows and adopted Mandela cocks mode of drying groundnuts after harvest. In this method, plants are laid, with foliage, directly on the

ground in a circle 1-2 m in diameter, the pods placed towards the inner part of the circle. Layers are built-up gradually decreasing the inner part of the circle. The opening can be closed by grass. The cock should also be built on raised ground. Important to note is that "no polythene should neither be used as the base of the cock nor as to cover the opening on top of the cocks." A-Frame: When using A-Frame to dry groundnuts, plants are stacked on an A-frame with the pods facing inwards and away from the soil. A-frames are easy to construct using three thick poles as a base. The lowest shelf should be about 30 cm above ground. Excellent air circulation and the pods are protected from rainfall. In both cases (Mandela cocks or A-frames) groundnut should be left to dry for 3-4 weeks before picking.

Groundnuts are ready for picking once the pods can be removed from the stems without causing long shreds to form. At this stage, the groundnut seeds clearly rumble when the pods are shaken and the seed already has a nutty taste. Picking should commence when the moisture content of the seeds is approximately 10% when shelling is to be done on the farm, otherwise it should be 8%. After picking do not dry further into the sun to avoid killing the groundnut seed. Drying on mats: The plants can be picked/ plucked from the windrows and then laid out in a thin layer in the sun on dry ground, mats or other dry surfaces for a further 2-5 days after stripping which would normally dry the pods to the required moisture content for storing. Pods should be covered or taken indoors during wet weather. They can also be picked immediately after lifting and then dried in the sun as above for 6-8 days. Once again excessive exposure to the sun can affect the quality of the seed. Do not dry groundnut seeds on top of iron sheets to avoid killing the embryo of the seed.

Artificial drying: On the other hand, artificial drying in an elevated temperature (up to 50 0C) and low relative humidity ensure quicker and more uniform drying of seeds. Unless carefully controlled, artificial drying may cause a detrimental effect with respect to physical damage and germination parameters. Wherever possible, only naturally dried groundnuts should be utilized for seed purposes.

Stripping

This operation consists of separating the pods from the vegetative parts of the plants (vines). Pods are individually detached from the vines and therefore dry very quickly stabilizing at 6-8% moisture content. If you have enough labour, stripping can be done right away after lifting the groundnut plants. But the activity is mostly done after plants are thoroughly dried. Stripping can be done by hand or mechanically. It is advisable to strip by hand groundnuts meant for seed purposes.

Shelling

Shelling only when seeds are required for consumption, marketing or planting. Seeds can be shelled by hand or by mechanical shelling machines. During shelling, seeds should be checked where immature pods, discoloured, mouldy or shrivelled seeds as well as those infested with pests and diseases, should be thrown away

Hand shelling: Labour intensive and good for smaller quantities and seed selection for planting. Do not shell by beating or trampling on groundnut in shells as this may damage the seeds and enhance fungal infections.

Mechanical shelling: Various types of shelling machines are available on the market that aim to reduce drudgery in shelling groundnuts. Manual or motorized shelling is recommended but the 'shellers' should not damage the pods. Do not sprinkle water on dry pods while using mechanical 'shellers'

Seed storage practices

Seeds have to be stored because there is usually a period of time between harvest and planting. During this period, the seed have to be kept somewhere. While the time interval between harvest and planting is the basic reason for storing seed, there are other considerations, especially in the case of extended storage of seed. The purpose of seed storage is to maintain the seed in good physical and physiological condition from the time they are harvested until the time they are planted.

Groundnut seed storability differs depending on storage environment and groundnut genotype. Groundnuts are prone to various types of deterioration during storage which renders them unsuitable for consumption and trade resulting in large economic losses. The rule of thumb is

that
groundnuts should be stored in pods in order to provide a quality product and to ensure profitability.

On-farm storage of groundnut seed: Farmers only keep limited quantities of groundnuts because of financial and logistical reasons. They rarely distinguish between seed and grain. Protective chemicals are rarely used since farmers consume some of the groundnuts themselves. Due to dangers of poor storage practices for seed management, the following good storage practices should be adhered to:

- Pods should be stored under dry, well ventilated conditions to ensure moisture content remains low; thus discouraging fungal growth.
- Remove poor, damaged, shrivelled, and rotten or fungus infected pods before storage.
- Do not bag groundnuts when pods are still damp.
- Store must be dry and well ventilated to reduce fungal growth.
- Storage of pods can be in gunny bags, clay pots or woven baskets to allow air circulation.
- Check seeds regularly during storage (every 15 days or once a month depending on storage period)

Warehouse storage of groundnut seed: Storability can be improved by controlling storage environment. Several of the deteriorations are caused by storage moulds which result in decrease of germination ability, loss in kernel weight, discoloration of kernels, heating and mustiness, chemical and nutritional changes, and mycotoxin contamination. Of the environmental factors affecting seed storage in warehouses, relative humidity and temperature are the most important. Relative humidity directly influences seed moisture. Increasing temperature increases the amount of moisture air can hold and the rate of cellular metabolism. Ideal conditions for storage of groundnut seed are 10 0C and 65% RH. The resulting seed moisture content is approximately 8%. Maintaining these conditions is not possible when groundnuts are stored in warehouses without climate control.

Groundnut seeds should be kept in the shell until as near to the time of planting as possible since viability declines rapidly after shelling and the testa is easily damaged

Do not use polythene, polypropylene bags and do not use plastic or tarpaulin to cover the bags as they will promote fungal growth and enhance aflatoxin contamination

Sanitation in storage warehouse is key. There are several other recognized procedures for good seed storage that most farmers already know. Seeds should be stored in a seed warehouse, not a fertilizer, chemicals, herbicide, or feed warehouse. Good sanitation should be a continuous practice. It will minimize storage insect infestations. If storage insects are a problem, the judicious use of insecticides and fumigants, combined with sanitation, will alleviate the problem. The best procedure is not to place insect infested lots in storage with other lots unless all the insects have been killed by fumigation or insecticide treatment.

In storage warehouse the following should also be considered:

- Cracks and crevices around corners have to be brushed to eliminate hiding pests. All debris should be removed. Provision of wire meshes to windows, ventilators, drains to prevent entry of rats, squirrels, birds, etc.
- Reduce the moisture content of seed to prevent insect build up (usually below 10%). Previously used bags, bins, etc. should be dried in the sun repeatedly.
- Elimination of conditions which favour storage pests. Uniformly graded seeds should be used, broken seeds should be removed before bagging since they favour pest build up. Stitching of all torn bags, filling bags up to the brim, no loose packing.
- Surface treatment of storehouse before storage with appropriate chemicals
- In warehouse with concrete floors, seed bags should be stacked on wooden pallets to keep them from contact with the floor as considerable moisture can be transmitted through concrete floors and do not stack higher than 15 bags and provide adequate space between the roof and the seed bags.
- Seed warehouses should also be adequately ventilated (unless they are conditioned) and protected against rodents. When pests damage pods or seeds, they will enhance fungal growth.

Principles of seed storage

Storage of seed should embrace the following seed storage principles:

1. Seed storage conditions should be dry and cool
2. Effective storage pest control
3. Proper sanitation in seed stores
4. Before placing seeds into storage they should be dried to safe moisture limits.
5. Storing of high quality seed only i.e., well cleaned treated as well as high germination and vigour.

Factors affecting seed longevity in storage

1. Kind (or) variety of seed Seed storability is considerably influenced by the kind or variety of seeds. Some seeds are short lived. Groundnut seeds like soybeans are short lived because of their proteinaceous or oily nature (hygroscopic nature) compared to starchy seeds.
2. Initial seed quality Seed lots having plumpy, vigorous undamaged seeds store longer than that of deteriorated. Even seed lots having good germination at the beginning of storage period, may deteriorate at a faster rate depending upon the severity of weathering damage, mechanical injury or otherwise in the field. The low-quality seeds should invariably be rejected. Even at best storage conditions, the initial quality of the seed

cannot be improved (except for the dormant seed) but can only be maintained

3. Moisture content The most important factor influencing seed viability during storage is the moisture content and the rate of deterioration increases, as the seed moisture content increases. The drier the seed the higher will be the storage life. It is well known that higher moisture content enhances the biological activity in the seeds and causes excessive heating, besides promoting mould and insect activities.
4. Relative humidity and temperature during storage Seeds are hygroscopic. They attain rather specific and characteristic moisture content when subjected to given level of atmospheric humidity at a particular temperature (equilibrium moisture content). The equilibrium moisture content for a particular kind of seed at a given relative humidity tends to increase as temperature decreases and the deterioration starts. Equilibrium moisture content varies among seed kinds. In general, the equilibrium moisture content of "oily" seed is lower than that of "starchy" seed at the same relative humidity and temperature. This phenomenon can be accounted for by the fact that fats and oils do not mix with water. Thus, in a seed with 50% oil content, the moisture has to be concentrated in half the seed, while in a seed containing 10% oil, the moisture is distributed throughout 90% of the seed.
5. Provenance The seeds harvested in different climates (or) at different times show differences in viability because they are subjected to different pre-harvest conditions which will have caused different amounts of deterioration by the time, the seeds are harvested.
6. The activity of organisms associated with seeds in storage. The bacteria, fungi, mites, insects, rodents and birds may do harm to seeds in storage.

Protection or management of stored seeds

Management of established infestation: The principle storage pests of groundnut are the seed bug *(Heteroptera sp)* and the groundnut seed beetle *(Caryedon Serratus)*; these can cause significant damage. Other insects, particularly Khapra beetles *(Trogoderma granarium E.)*, as well as flour beetles, *(Tribolium castaneum H. and T. confusum)* are also important, especially on shelled groundnuts. The groundnut seed beetle is the most important storage pest. The larva develops inside the pods and is therefore difficult to control.

Groundnut bruchid beetle, Caryedon serratus (Olivier): Groundnut bruchid also known as groundnut bruchid beetle, groundnut borer, seed beetle is a serious pest of stored groundnuts, particularly when these are still in their shells. The damage caused is particularly significant when the groundnuts are destined for confectionery purposes. The translucent milky-white eggs are attached to the pod wall. After hatching, the larva burrows straight through the egg shell and the pod wall, and start eating the seed. The first sign of attack is the appearance of 'windows' cut into the pod wall by the larva to allow the adult to leave the pod after emerging from the pupal cacoon. Fully grown larva sometimes come out through the exit holes made by the previous generations. They often live in the storage sacks and pupate in large numbers at the bottom of the pile of sacks. By this stage, the groundnut seeds are too severely damaged for human consumption or oil expulsion.

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

Pod sucking bug, Elasmolomus sordidus (Fabricius): On groundnut, the initial infestation starts when the harvested plants are placed for drying in the field. The infested pods are discoloured and
show oily spots on the outside. In case of severe infestation, the produce is unfit for seed as well as human consumption. This causes seed shrivelling and increases the free fatty acid content of the oil, producing a rancid flavour.
The adult is dark brown, approximately 10 mm long and 2 mm wide. Each female lays about 100 eggs in its lifespan of about 30–40 days. In the field, the females lay their eggs in the soil or on groundnut haulms, but under storage conditions, eggs are laid loosely among the groundnuts or on sacks. The first instar nymphs have a bright red abdomen; later instars become progressively darker. All stages of the pest feed on seeds, perforating the pod with their rostrum.

Treatment/Control: Groundnuts should be stored unshelled. If groundnuts are stored as seed, care should be taken to avoid breakage. Broken seeds should not be stored for long periods. Fumigation of pods and covering the sacks with polythene sheet for 5 days can effectively control bruchids without affecting the seed viability. Fumigation should be done only in well aerated places outside the residential areas or in seed warehouse, under the supervision of plant protection specialist.

Monitoring of insect pests in storage

It is very important to monitor regularly (once in a fortnight), insect populations in harvested produce and stores so that remedial measures can be taken as soon as infestation is noticed. Stored bags should be monitored for insect damage frequently. In large consignments, the condition of storage may vary markedly among the sacks, for example, the temperature at the centre of the stack may be different from that of the surface. These differences should be taken into account by following a stratified sampling procedure to monitor the insect damage. To make it easy and effective, the division of a single stack into a number of layers, each containing the same number of sacks will help in drawing representative samples. In a given number of sacks in each layer,

samples must be drawn at random without bias.
If there are ten sacks or less, sample each sack, if there are between 11 and 100 sacks, sample 10 sacks at random. When stacks are broken down while sampling, the sacks must be replaced in their original position, so that the disturbance within the stack is minimum. To minimize pest damage to groundnut seed, storage areas, containers, drums, bags and storage equipment (conveyors, etc.) should be treated before storing groundnuts. Cleaning of these areas can be followed by fumigation or spraying with insecticides.

Guide for Pigeonpea

Production in Malawi

Introduction

Pigeonpea is the most versatile grain legume grown by smallholder farmers in Malawi for both local consumption and export. It ranks third among the important legume crops after groundnut and beans. It accounts for about 53% of the total pulse production in Malawi. By the year 2011 the crop was planted on a 300,000 ha of land and it rose to 375,000 ha in 2017 (Gumma et al., 2019). These statistics clearly show that there is a great potential to increase production and expand area of pigeonpea in Malawi (see fig 1). Although the crop is now grown in all the agricultural development divisions (ADDs), Blantyre and Machinga ADDs remain major growing areas accounting for more than 90% of the total area under pigeonpea cultivation. Farmers prefer growing pigeonpea either as an intercrop or pure stand because it provides food at the time when all the other legumes have been harvested from the field. Most of the pigeonpea is grown as an intercrop with maize, sorghum, groundnuts, soybean, or cotton. Available estimates indicate that 65% of the pigeonpea produced is consumed on-farm, 25% is exported, while 10% is traded on the domestic markets. The crop is deep rooted as such it is adapted to withstand the intermittent or terminal droughts depending on the type of varieties grown.

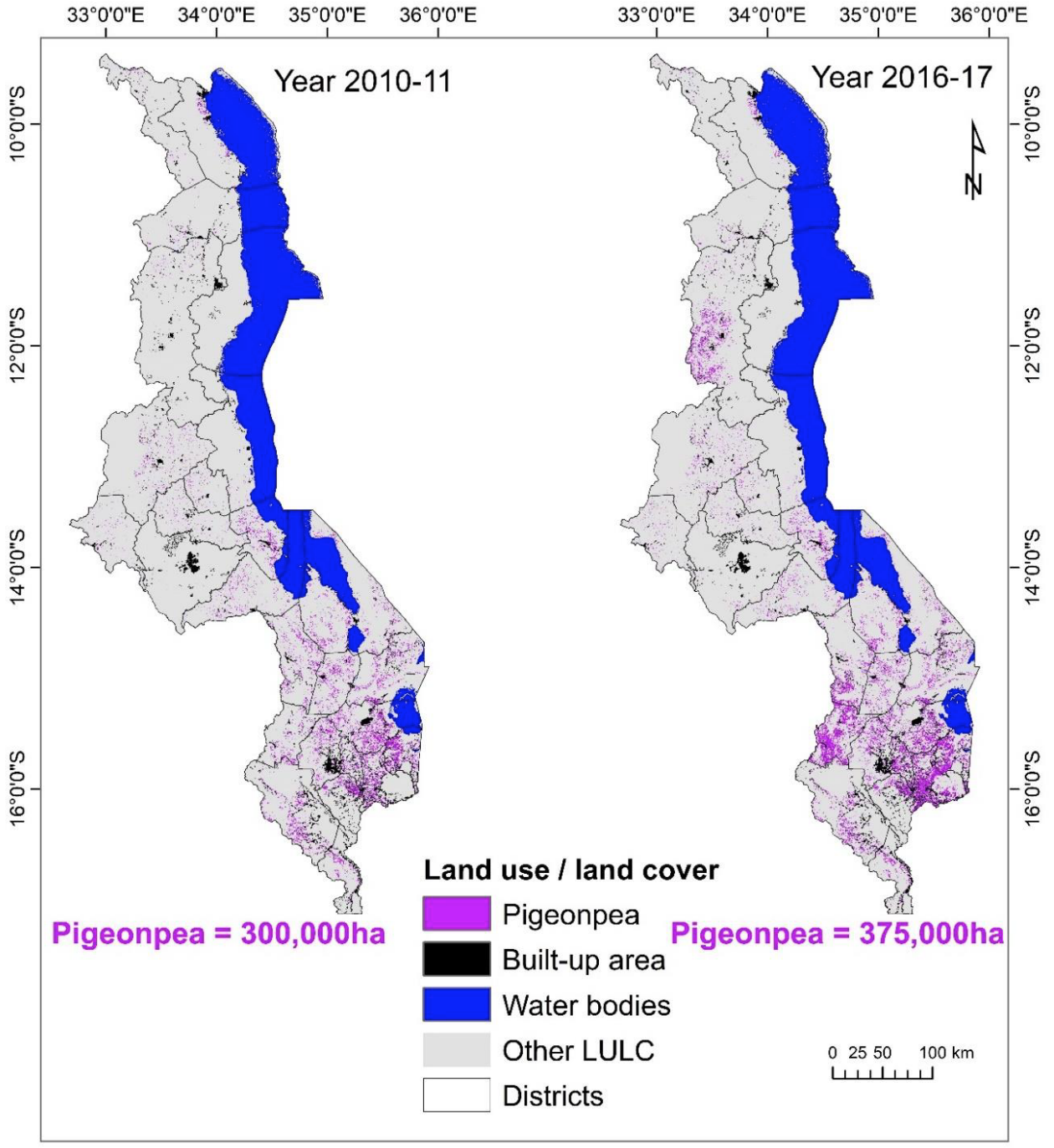

Figure 1: Area of pigeonpea cultivation in Malawi (source: Gumma et al., 2019)

Importance of Pigeonpea

- It is used for consumption
- It provides cash to the farmers and
- It is one of those legumes that can be produced with fewer inputs
- It also provides fodder/feed for livestock and
- Has the potential to improve soil fertility.
- It breaks the soil hard pan

Figure 2: Pigeonpea Field

Agroecologies for Cultivation

With the development and release of the medium duration pigeonpea varieties introduction and expansion of pigeonpea production in non-traditional pigeon pea areas is now possible. Central and northern regions have now taken up the growing of medium duration pigeonpea varieties.

Recommended varieties in Malawi and descriptors
These include old and new;
Old (Long duration)

- Sauma
- Kachangu

Figure 3: Sauma (Top) and Kachangu (Bottom) long duration pigeonpea varieties

New (Short duration)

- ICPL 87105
- ICPL 93026

Figure 4: ICPL 87105 (Top) and ICPL 93026 short duration pigeonpea varieties

New (Medium duration)

- Mwaiwathualimi,
- Chitedze pigeon pea 1 and
- Chitedze pigeon pea 2

Figure 5: Mwayiwathualimi (Top) and Chitedze 2 medium duration pigeonpea varieties

Crop production practices

Pigeonpea variety selection

When selecting the pigeonpea variety the following steps must be considered;

i. Agroecology - Know the area where you want to grow in terms of the rainfall pattern. Some varieties such as Kachangu take time to mature as such it needs to be grown in areas which receive high rainfall. Due to high livestock production in the mid and low altitude areas it is recommended that farmers choose varieties that mature earlier (almost same time with cereal crops). In these areas, just after cereal crops harvest, livestock farmers normally release the livestock to graze freely. As such long duration varieties may be damaged by the grazing livestock.

ii. Usage- choose the best variety depending on what you are growing for; if it is for subsistence or commercial then you go for high yielding, for soil fertility improvement you select the one that produces more biomass or good for ratooning?

iii. Compatibility with other crops- if you intend to grow as an intercrop choose a variety that flourishes and yields well when exposed to the intercrop such as Kachangu.

Variety description

Table 1 summarizes the information on the available varieties and their description

VARIETY	ATTRIBUTES
Long	
Sauma (ICPL 9145	Long duration variety (220-270 days to maturity)
	It is resistant to fusarium wilt and Cercospora leaf spots
	The yield potential is 2500 kg/ha
	It is large seeded (19g/100 seed weight)
	The seed colour is creamy white
	Produces bright-yellow flowers
	Can be grown as an intercrop
Kachangu (ICEAP 0040)	Long duration variety (190-240 days to maturity)
	Has considerable degree of resistance to Fusarium wilt
	Has an average yield of 1.7 tonnes per hectare
	It is large seeded (22g/100 seed weight)
	The seed colour is creamy white
	Seed coat easier to remove hence good for dehulling
	Produces ivory- cream flowers
	Can be grown as an intercrop
Medium	
Mwaiwathualimi (ICEAP 00557)	It is a medium duration variety
	It takes between 159 -180 days to mature
	Plant height is influenced by temperature, under warm environment, it grows tall
	The growth habit is non determinate and semi-spreading
	It produces yellow flowers with dense streaks
	The immature pods are green with light to dense stripes, long and sickle shaped
	Each pod contains 6 -7 seeds
	Seed size is between 17-19g/100 seed weight
	Yield potential is 2000 kg/ha
	It is resistant to fusarium wilt and soil borne diseases
Chitedze 1	It is a medium duration variety
	It takes between 151 -190 days to mature
	The growth habit is non determinate and semi-spreading
	The crop remain semi spreading when grown in low population and remain tall when intercropped
	Its base flower colour is red ; immature pods are green with light stripes, long and sickle shaped

	The variety is good for ratooning
	Seed size is large (14g/100 seed weight0
	Each pod contains 6 -7 seeds
	Grows well with annual rainfall of 400-900 mm and an altitude of 400-1800 m above sea level
	It is easy to dehul hence preferred by agro-processors
	It is resistant to most leaf diseases but susceptible to Fusarium wilt
	Yield potential is 2500 - 3000 kg/ha
	It has wider adaptation in Malawi
Chitedze 2	It is a medium duration variety
	It takes between 151 -190 days to mature
	It is erect branching
	Its base flower colour is yellow, green pods, long and sickle shaped
	The variety is good for ratooning
	Seed size is large (14g/100 seed weight0
	Each pod contains 6 -7 seeds
	Grows well with annual rainfall of 400-900 mm and an altitude of 400-1800 m above sea leve
	It is easy to dehul hence preferred by agro-processors
	It is resistant to most leaf diseases but susceptible to Fusarium wilt
	Yield potential is 2500 - 3000 kg/ha
	It has wider adaptation in Malawi
Short	A high yielding (2000 kg/ha) and early maturing variety with stable grain yields.
ICPL 87105	It is adapted to a wide range of environments; matures in 126 days;
	Has large seed size (17g/100) with cream seeds and has a high market value.
	Because of its earliness in maturity, it tends to escape the Fusarium wilt
ICPL 93026	This variety has same characteristics as the above varieties except that it is slightly taller (137 cm and matures earlier (120 days) than ICPL 87105

Seed source
There are different sources where you can get pigeonpea seed. There include among others; seed companies, agro-dealers, farmer associations or/ cooperatives, agricultural research centres.

Site selection
Pigeon pea is sensitive to water logging hence requires a well-drained soil for good root and nodule development. It does not grow well in saline soils but can withstand drought reasonably.

Cropping systems
Pigeon pea can be grown both under sole and intercropping systems. The most important intercrops include those with sorghum, pearl millet, maize, groundnut and soybean.

Land Preparation
Prepare ridges at 75 cm or 90 cm apart. Fields should be properly tilled to conserve soil and water. Manure can be applied 2-4 weeks before planting.

Planting
All farmers are encouraged to use treated seed that should be done with a recommended fungicide (Thiram) before planting to prevent seed-borne and soil borne seedling diseases. Planting should be done with the first planting rains or soon after the main crop has emerged where inter-planting is practiced. · Plant spacing depends on duration to maturity and cropping system followed.

Short duration pigeon peas

- Short duration pigeon peas are best produced as sole crop.
- Plant on the ridges which are spaced at between 75 or 90 cm apart on double or single row.
- Planting on single row requires 2 plants per station, 20 cm apart.
- Planting on double rows which are spaced at 30 cm apart require one plant per station, 10 cm apart.
- In either case, 75 cm ridge spacing gives a plant population of 111, 110 plants per hectare and a seed rate of 16 to 25 kg per ha.
- Seed yields of the short duration pigeon pea varieties are reduced when intercropped with maize on the same ridge due to shading by the maize plants.
- The only way to plant short duration pigeon peas with maize is where the maize and the short duration pigeon pea are planted on alternate ridges or in strips of 2 or more ridges.

Medium and long duration pigeon peas

- Plant 2 seeds per station spaced at 60 cm on ridges of either 75 or 90 cm apart. This requires a seed rate of 8 kg per hectare and the expected plant population is 37,000 and 44,444 plants per hectare at 90 cm and 75 cm ridge spacing respectively.

Planting Methods

Planting in intercrops
Successful intercrop systems in Malawi mostly involve pigeon pea. It has been established that pigeon peas grow very slowly for the first two months after planting. When intercropped with groundnut or soybean, it only starts rapid growth when either of these are approaching maturity.

Steps to establish soyabean-pigeonpea intercrop

Step 1: Plant soyabean first

- Remember to use if you are using varieties that require innoculation (see how to grow soybean guidelines for details)
- Soybeans need. They must not be dry planted and should not be planted until it is clear that the rainy season has properly started (plant after a few days of rainfall!). Make apart, just as for maize, so that the normal ridging system is not disrupted by the production of soybeans. Avoid ridges wider than 75 cm as this is wasting our precious land
- Plant soybean on (3 cm deep at most) that can be made with a stick on each side of the ridge. Two rows per ridge (instead of only one) ensure high plant population > 250,000 plants per hectare. This results in good soybean yields.
- Within a row, drop (sprinkle) the soybean seeds at about 5–8 cm apart. These seeds must be planted no more than 3 cm deep, otherwise germination will not be good.

Step 2: Plant pigeonpea –on the same day

- On the ridges already planted with soy bean, plant 3/4 pigeonpea seeds per planting station at 90 cm spacing. This results in about 44,000 plants/ha. This single row of pigeonpea must be at the centre (top) of the ridge.
- Only 8 kg pigeonpea seed is required to plant 1 ha of soybean/pigeonpea doubled up system
- A farmer planting 30 x 40 field size requires only 1 kg pigeonpea seed
- In this intercrop, soybeans are harvested earlier, and then the pigeonpea remains as the only crop in the rhizobia inoculants moist soil for germination ridges that are 75 cm 2 shallow farrows.

Steps to establish groundnut–pigeonpea intercropping

Figure 6: Intercropping Groundnuts and Pigeonpea in a Double-up legume cropping system

Step 1: Plant groundnut first

- If maximum yields are to be realized, groundnuts must be planted early, with the first effective rains – a delay in planting will cause a marked drop in yield
- Make ridges that are 75 cm apart (just as for maize and soybean), so that the normal ridging system is not disrupted by the production of groundnuts.Avoid ridges wider than 75 cm as this is wasting of your precious land
- Plant 2 rows of groundnut on either side of each ridge, at about 5–8 cm depth. Too shallow planting will result in patchy germination as the surface soil can dry out if there is no further rainfall after planting. Too deep planting will delay germination
- Within each row, plant groundnut seeds at 10–15 cm apart. Double rows on each ridge and using this seed spacing will ensure high plant populations (>200,000 plants/ha), and good harvests
- Seed requirements per hectare range from 80–100 kg, depending on the groundnut variety and seed size

Step 2: Plant pigeonpea– on the same day

- On the ridges already planted with groundnuts, plant 3/4 pigeonpea seeds per planting station at 90 cm spacing. This results in about 44,000 plants/ha
- This single row of pigeonpea must be at the centre (top) of the ridge
- Only 8 kg pigeonpea seed is required to plant 1 ha of soybean/pigeonpea doubled up system
- In this intercrop, groundnuts are harvested earlier, and then the pigeonpea remains as the only crop in the field.
- The benefit of the pigeonpea to next year's crop on that field (usually maize) is due to the large amount of pigeonpea leaves that fall to the ground as the crop matures and adds a lot of organic mulch that enriches soil fertility

Weed Management

It is important to keep pigeon pea field free from weed infestation during the early growth period (4–6 weeks). Weeds can be controlled by applying chemicals or using a hoe in the initial stages. When herbicides are not applied two or three hand weedings are required for the 1 to 6 week of crop growth.

Management Options

- All early maturing pigeon pea varieties have to be sprayed twice between 50% and full flowering and twice between 50% and full pod to control insect pests.
- Cut worms, white grub, elegant grasshopper and aphids feed on young seedlings.

Pests Management

- The field should be weed free especially in the initial stages of establishment. This is crucial for pigeon pea because initial growth is slow, consequently the crop may not withstand any competition for water nutrients or light.

Insects

- Leaf eaters, pod borers, jassids, thrips (Fig 8) can cause up to 70% losses in yields. Flower beetles or blister beetles cause serious damage to flowers.
  Without exception, all early maturing pigeon pea varieties have to be sprayed twice between 50% and full flowering and twice between 50% and full pod to control insect pests.

Figure 8: Insect pest feeding on pigeonpea flowers

Table 2: Chemical control in pigeon peas
Insect pest

Insect pest	Chemical	Formulation	Rates	Method
Aphids	Dimethoate	20 WA	34g/litre Spraying	
	Dimethoate	40EC	17ml/14 litre	Spraying
Cutworms/ whitegrubs	Carbaryl	85g/14litres	85g/14litre	Drenching
Flower/leaf eaters	Carbaryl	85 WP	85g/14litre	Spraying
Pod suckers	Dimethoate	40 EC	5g/ha	Spraying
Pod borers	Carbaryl	85 WP	12ml/14 litres	Spraying
	Karate	5EC	25g/50kg	Spraying
Storage pests	Decistab	2.5 EC	25g/50kg	Spraying
	Actellic			
	super	Dust	25g/50kg	Dusting
	Super			
	Guard	Dust	25g/50kg	Dusting

Harvesting and threshing

- Harvesting should be done when 75-80% of the pods are at physiological maturity
- Delayed harvest leads to damage in mature seeds.
- Mature pods are identified as they are brown and have a dry testa.
- Pigeon peas can be harvested by cutting the stem at the base and tying the stems in bundles and transported for threshing. The pods and grain are separated by beating the dry plants with sticks or by using a thresher.
- Pigeon pea can also be harvested by hand picking the mature pods which allows the crop to flower for second or third harvest.

Guide for Sorghum
Production in Malawi

Introduction

Sorghum [Sorghum bicolour (L.) Moench] is an indigenous crop to Africa. Although it has both domestic as well as commercial uses, it remains an important staple food for many rural communities, especially in the semi-arid tropics and drought prone areas. The crop is more resilient to a number of biotic and abiotic stresses compared with maize and therefore forms an important household food security crop for rural communities.

Agro-ecologies

Sorghum cultivation is concentrated in drier areas, especially on shallow and heavy clay alluvial soils. In Malawi, Sorghum production is concentrated in Shire Valley with isolated pockets in Phalombe plain and along the lakeshore (Fig 1).

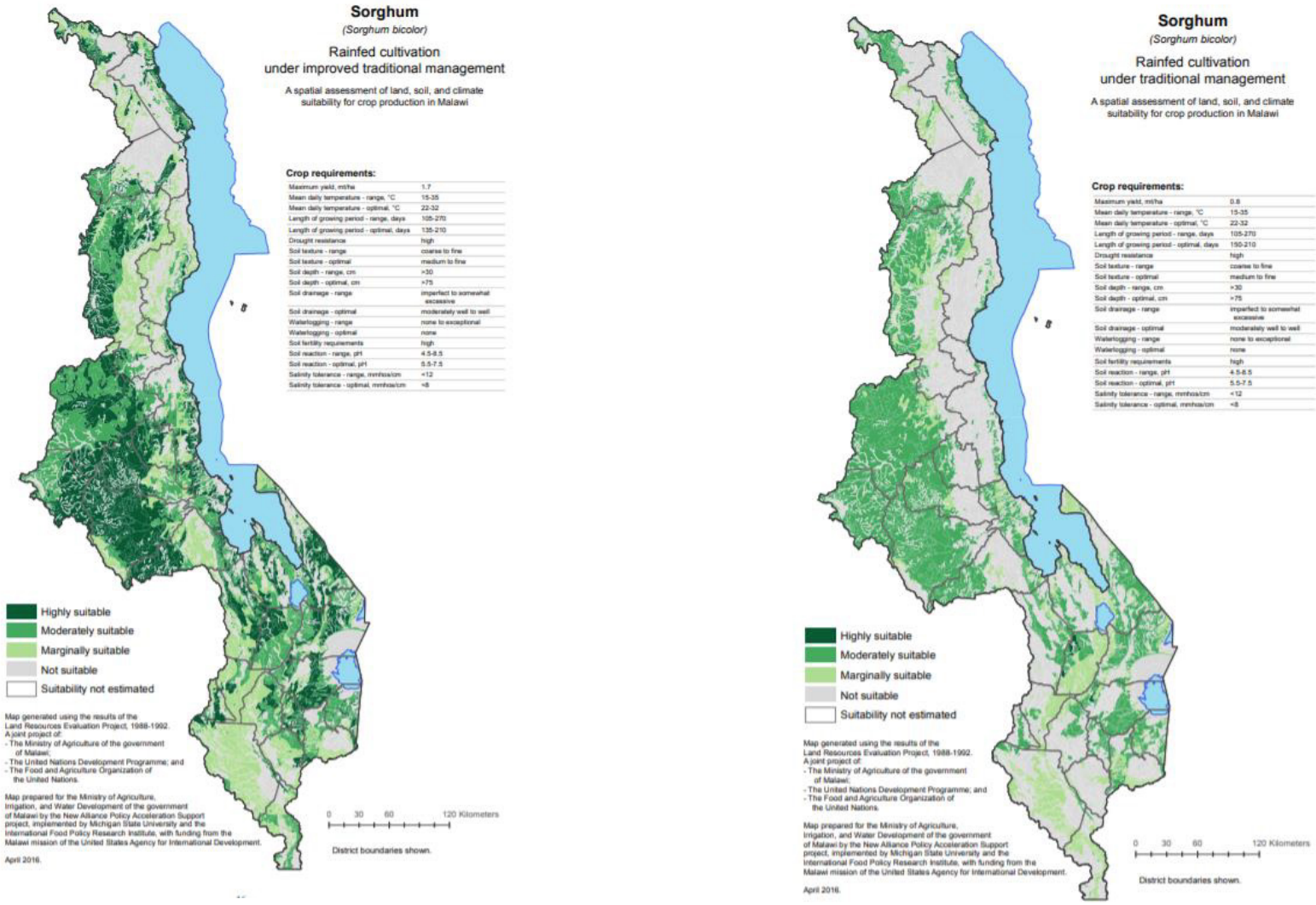

Fig 1. Maps showing suitable areas for sorghum production in Malawi under rainfed cultivation under improved traditional (right) and
traditional management (left)

Morphology, Growth and Development

Sorghum is in a genus of flowering plants in the grass family Poaceae. It comprises the root system, leaves, stem, inflorescence (Panicle) and seed.

The root system

Sorghum root system comprises primary and secondary roots. Primary roots refers to those,which appear first from the germinating seed. These roots are there to provide the young seedling with water and nutrients from the soil. Primary roots have a limited growth and secondary roots quickly take over their function. Secondary roots develop from nodes below the soil surface. The permanent root system branches freely, both laterally and downwards into the soil. Sorghum roots branch freely, both laterally and downwards into the soil and if no soil impediments occurs, they can reach a lateral distribution of one meter and to a depth of up to two meters early in the life of the plant.

Leaves

Sorghum leaves are typically deep green, smooth glasslike and flat elongated and narrower compared to maize leaves. Sorghum plants have a leaf area smaller than that of maize. The leaf blade is therefore long, narrow and pointed with a tendency to bend downwards as leaves mature leaving only the younger standing upright. Sorghum leaves have stomata on both surfaces of the leaf. Uniquely, sorghum leaves have rows of motor cells along the midrib on the upper surface of the leaf. These cells can roll up leaves rapidly during moisture stress making it tolerant to heat and moisture stress. The leaves have a thin waxy layer and develop opposite one another on either side of the stem. Environmental conditions determine the number of leaves, which may vary from 8 to 22 leaves per plant.

Stem

The stem of sorghum plant is solid and dry but sometimes succulent and sweet. If conditions are favourable, more internodes develop, together with leaves, producing a longer stem. The stem consists of internodes and nodes. A cross section of the stem appears oval or round. The diameter of the stem varies according to growth conditions. The stem responds to plant density and nutrient availability and it can grow as big as 30 mm in diameter. Internodes are covered by a thick waxy layer giving it a blue-white colour. The waxy layer reduces transpiration and increases the drought tolerance of the plants. The root band of nodes below or just above the soil surface develop prop roots. The growth bud develops lateral shoots. Sometimes the growth buds higher up the stem may also develop lateral shoots.

Inflorescence (Panicle)

The inflorescence of sorghum is a compact panicle. The shape and colour of the panicle varies between cultivars. Heads are carried on a main stem or peduncle with primary and secondary branches on which the florets are borne. The peduncle is usually straight and its length varies from 75 to 500 mm. Each panicle contains from 800 to 3 000 kernels which are usually partly enclosed by glumes. The colour of the glumes may be black, red, brown or tan. The flowers of sorghum open during the night or early morning. Those at the top of the panicle open first and it

takes approximately six to nine days for the whole panicle to flower. Due to the structure of the flower, mainly self-pollination takes place. A small percentage of cross-pollination (approximately 6 %) occurs naturally (Fig. 2).

Seed

The ripe seed (grain) of sorghum is usually partially enclosed by glumes, which are removed during threshing and/or harvesting. The shape of the seed is oval to round and the colour may be red, white, yellow, brown or shades thereof. If only the pericarp is coloured, the seed is usually yellow or red. Pigment in both the pericarp and testa results is a dark-brown or red-brown colour. The sorghum grain consists of the testa, embryo and endosperm.

Growth Requirement

Sorghum requires specific environmental conditions for its optimum growth and performance. Sorghum requires deep well-drained fertile soil, with good and fairly stable rainfall pattern during the growing season, temperate to warm weather (20 to 30 ºC) and a frost-free period of approximately 120 to 140 days.

Soil requirements

Sorghum is mostly grown on low potential, shallow soils with high clay content, which usually are not suitable for the production of maize. However, sorghum usually does not grow well on sandy soils, except where the sub soil is heavy textured. Sorghum tolerates alkaline salts than other grain crops and can therefore be successfully cultivated on soils with a pH (KCl) range of 5.5 to 8.5. It can better tolerate short periods of water logging compared with maize. The optimal soil needs to have a clay percentage of between 10 % and 30 % for optimal productivity.

Climatic requirements

Sorghum climatic requirements are divided into temperature, day length and water needs.

Temperature

As a warm weather crop, sorghum requires high temperatures for good germination and growth. The minimum temperature during germination varies from 7 to 10 ºC. If temperature is right, 80% of sorghum seed will germinate within 10 to 12 days. Plant sorghum at a depth of 2.5 cm when there is sufficient water in the soil and soil temperature is 15 ºC or higher. Temperature of 27 to 30 ºC is required for optimum growth and development. The temperature can, however be as low as 21 ºC, without a dramatic effect on growth and yield. Very high temperatures can cause a decrease in yield. Sorghum is photoperiod sensitive, hence flower initiation and the development of flower primordia are delayed with increased day and night temperatures. Plants with four to six mature leaves that are exposed to a cold treatment (temperatures less than 18 ºC) will form lateral shoots. However, in plants with or beyond the eight-leaf stage, apical dominance will prevent the formation of lateral shoots. Temperatures below freezing are detrimental to sorghum and may kill the plant. In general, plants older than three weeks are less tolerant to low temperatures and may be killed at 0 ºC.

Day length

Sorghum responds to day length. As a short day plant, it means that the plant requires short days (long nights) before proceeding to the reproductive stage. The optimum photoperiod to induce flower formation, is between 10 and 11 hours. Therefore photoperiods longer than 11 to 12 hours stimulate vegetative growth. The tropical varieties are usually more sensitive to photoperiod than the quick, short-season varieties. Sorghum plants are most sensitive to photoperiod during flower initiation.

Water requirements

Sorghum is produced on a wide range of conditions with fluctuating rainfall ranging between 300 mm in the drier areas to about 800 mm in wetter areas.

Drought tolerance

Sorghum can tolerate drought better than most of other grain crops. This behaviour is attributed to the following: (i) its well developed and exceptionally well branched root system, which makes it very efficient in the absorption of water; (ii) its small leaf area per plant, which consequently limits transpiration; (iii) the leaves fold up more efficiently during warm, dry conditions than that of maize; (iv) it has an effective transpiration ratio of 1:310, as the plant uses only 310 parts of water to produce one part of dry matter, compared to a ratio of 1:400 for maize; (v) the epidermis of the leaf is corky and covered with a waxy layer, which protects the plant from desiccation; (vi) the stomata close rapidly to limit water loss; (vii) during dry periods, sorghum has the ability to remain in a virtually dormant stage and resume growth as soon as conditions become favourable. Even though the main stem can die, side shoots can develop new shoots and form seed as the water supply improves.

Production potential

The production potential of sorghum is 3,000 kg/ha which is achieved by using correct plant population and densities, application of fertilizers and selecting adapted varieties for a particular area among others.

Crop Management Practices

Sorghum production meets several constraints that limit yield. Adoption of good crop and soil management practices is therefore key to the attainment of maximum productivity and to make the cropping system sustainable in the long run. This section therefore describes improved cultivars and recommended practices to realize other higher yields.

Recommended varieties

Currently, many farmers still use unimproved photoperiod sensitive sorghum land races which, have low yield potential. Therefore, in order to increase sorghum yield through genetic gains, a

number of improved varieties have been recommended for production in Malawi. These are divided into old and new varieties based on the year of release.

Old varieties

Two varieties of improved sorghum were released in 1995 for production in Malawi. These include Pilira 1 and Pilira 2.

Description of Pilira 1 (SPV351)

Pirira 1 is a high-yielding, medium-duration (110-115 days), drought-resistant sorghum variety recommended for general cultivation in Malawi, and specifically for the hot, humid, lower Shire river basin. It was released by the National Cultivar Release Committee of Malawi on the basis of its hard grains, to replace the soft-grained commercial variety, PN 3. It is photoperiod-insensitive and has medium- sized leaves. It grows to a height of 1.4-1.7 m and has elliptic, medium-sized, semi-compact, well-exerted panicles. It is resistant to downy mildew (Sclerospora sorghi) and sooty stripe Ramulispora sorghi, but is susceptible to shoot fly (Atherigona soccata) and stem borer (Chilo partellus) attacks if sown late. The seed of Pilira 1 is creamy-white medium-sized grains (100-seed mass 2.6 g) with white, pearly endorsperm and thin pericarps. The grains have no testa (seed coat). They are hard (3.7 on a 1-5 scale) with very good milling yield (83%). The flour is white (Agtron reading 73.2 dry and 48.4 wet), is acceptable as food, and has better storage qualities than PN 3 whose grain hardness is only 2.5.

Description of Pilira 2 (SPV475)

Pilira 2 is a medium-duration (110-120 days), photoperiod-insensitive variety and medium-sized leaves. It grows to a medium height of 1.5-1.8 m, and has an elliptic, large, open, well-exerted panicle. It is resistant to most leaf diseases in the Shire Valley, but is susceptible to shoot fly (Atherigona soccata) and stem borer (Chilo partellus) attack, if sown late. It has yield potential of 2,250 kg/ha. The seed of Pilira 2 has creamy-white, medium to large grains (100-seed mass 2.9g) with white, intermediate corneous endosperm and thin pericarp. The grains have no testa. They are medium hard (3.2 on a 1-5 scale) with flour milling yield of 78.10% (lower than Pirira 1, another high-yielding sorghum variety released in Malawi) and 13.3% water absorption. The grain is "sweet", because it does not contain tanin. Its flour is whiter (Agtron readings 77.7 dry and 58.6 wet) than that of Pilira 1, and is acceptable for food. The grain is harder than that of PN 3 whose grain hardness is 2.5.

New varieties

The Department of Agricultural Research Services (DARS) in collaboration with ICRISAT have recently released three varieties of sorghum that are high yielding, resistant to a number of diseases and are tolerant to drought. These varieties include: Pilira 3, Pilira 4 and PIlira 5.

Pilira 3 (Kari-Mtama 1)

Pilira 3 is a high-yielding medium-duration (120 days). It is photoperiodinsensitive and has medium- sized leaves. It grows to a height of 1.9 m and has elliptic, medium-sized, semi-compact, well-exerted panicles. It is resistant to downy mildew (Sclerospora sorghi), powdery mildew, head smutand tolerant to Grey leaf spot (Cercospora zea-maydis), rust (Puccinia spp) and is also tolerant to anthracnose. The seed of Pirira 3 is creamy-white medium-large sized grains (100-seed mass 3.0 g).

Pilira 4 (IESV 23010 DL)

Pilira 4 is a high-yielding, medium-duration (120 days). It is photoperiodinsensitive and has medium- sized leaves. It grows to a height of 1.9 m and has elliptic, medium-sized, semi-compact, well-exerted panicles. It is tolerant to Grey leaf spot (Cercospora zea-maydis), rust (Puccinia spp) and is tolerant to anthracnose, downy mildew, powdery mildew and head smut. The seed of Pilira 4 is of brown/red colour with medium-large sized grains (100-seed mass 2.9 g).

Pilira 5 (IESV 23006)

Pilira 5 is a high-yielding, medium-duration (after 120 days). It is photoperiod-insensitive and has medium- sized leaves. It grows to a height of 1.9 m and has elliptic, medium-sized, semi-compact, well-exerted panicles. It is tolerant to Grey leaf spot (Cercospora zea-maydis), rust (Puccinia spp) and is tolerant to anthracnose, downy mildew, powdery mildew and head smut. The seed of Pilira 5 is of brown/red colour with medium-large sized grains (100-seed mass 3.0 g).

Field preparation

Early land preparation is recommended. In dry areas such as the Shire-Valley and other marginal rainfall areas, soil moisture need to be retained by ridging and box ridging. During land preparation, ensure that all weeds, shrubs and stumps are removed. Loosen the soil by tillage, and attain a smooth soil by breaking clods to ensure good seedling emergence and establishment. Prepare ridges at 75 cm apart.

Seed rate

Sorghum planted with two seeds per station spaced 30 cm apart will require 5 kg seed per hectare.

Variety selection and seed source

Choosing the right variety is key to increasing sorghum yield. Agronomic characteristics such as disease and insect resistance, lodging and panicle/head placement should help in choosing a good variety. Seed source???

Planting and plant population

Timely planting is needed in order to take full advantage of the rainy season and nitrogen flush. Planting with the first planting rains in November leads to a good crop of sorghum. Planting is done by splitting each ridge 2.5 cm deep and planting 5 seeds into the groove at 30 cm apart. Sorghum is sensitive to low temperatures therefore, the ideal soil temperature for germination is 15 ºC at a depth of 2.5 cm. After planting, the seeding groove is then covered. After seedling emergence, thin the plants to 2 seedlings per station when plants are 15 cm high.

Fertilizer application

Currently many farmers don't apply any fertilizer to sorghum especially when they use local varieties leading to low yields.. Current recommendation is to apply fertilizer to improved varieties at a rate of 69 kg N ha-1 supplied by applying 100 kg ha-1 of N:P:K (23:10: 5 + 1Zn + 6S) at seeding and 100 kg ha-1 urea (46% N) approximately 3 weeks after planting.. In both application, the fertilizer is applied in drills made on the side of the ridge or dolloping in between the sorghum stations. If fertilizer is not applied, the following symptoms will appear as follows:

Nitrogen (N) deficiency - young plants are light green or yellow-green, at a more mature stage the older leaves start yellowing first with a characteristic inverted V-shape.

Phosphorus (P) deficiency - under wet, cool conditions leaves of young plants may turn dark green with reddish-purple margins and tips.

Potassium (K) deficiency - a deficiency of K is initially noted as yellow or necrotic leaf margins, beginning at the lower leaves and spreading to the upper leaves.

Cropping systems

Sorghum can be grown as a pure stand or occasionally in intercropping systems with legumes.

Pure stand Under

pure stand, two cultivation methods are possible. These include planting on ridges and flat

planting

Ridges: Ridges are spaced 75 cm apart with planting spacing of 30 cm apart. Flat planting: Rows should 75 cm apart with spacing between plants of 30 cm apart. Due to the very close planting spacing between plants (30 cm), there is limited space for other component crops to be intercropped. Research is therefore under way to come up appropriate spatial arrangements for intercropping sorghum with legumes.

Weed control

Weeds compete vigorously with sorghum crop for nutrients and water during. Weed control during the first six to eight weeks after planting is crucial for a better crop establishment. The parasitic weed, Striga asiatia (L.) Kuntze or witchweed can damage sorghum crop. This is associated with low input farming conditions. The parasitic plants are single stemmed with bright red flowers. Most of the damage is done before the parasite emerges from the soil. The symptoms include leaf wilting, leaf rolling, and leaf scorching even when soil has sufficient water. The tiny seeds are disseminated by wind, water, and animals, and remain viable in the soil for 15- 20 years. Rotation with cotton, groundnut, cowpea and pigeonpea will reduce the incidence of Striga. Hand pulling the plants before flowering may also help.

Methods of weed control

Physical methods
Weeds can be removed mechanically, using hand labour or implements.

Cultural methods
Ploughing during winter or early spring is an effective method of controlling weeds.

Chemical methods
Care should be taken on use of herbicides. Some herbicides can affect the germination of sorghum. This means that verification of the right herbicides for sorghum should be done.

Pests and diseases and their control

Pests
Sorghum get attacked by a number pests at all stages. It has pests that attach it in the field and in storage. Some important pests for sorghum are as follows:

Birds: These attach sorghum at the milk stage during grain formation. This leads to empty grains and bird must be controlled by scaring them at all cost. This is serious with improved varieties that have their grain exposed outside the sheath. Local varieties are protected by spike -like sheath that pricks the bird when trying to feed on the developing grain and the high polyphenol content that gives birds un-palatable taste.

Shootfly and Stem borer: Shootfly (Atherigona soccata) and stem borer (Chilopartellus) will mostly attack late planted sorghum. Control is by planting early. Furadan granules can be applied in the ridge at planting to control shootflies systematically. Diptrex granules can be placed in plant whorls (funnels) 3 weeks after plant emergence to control stem borer.

Aphids: In the case of aphids, timely control is very important, but spraying at first indication of an infestation is not necessary. An indication that the aphid population is nearing economically important levels is, when virtually all plants are infested. Spraying at this stage will ensue that the crop is free from aphids for the greater part of the most sensitive period such as the grain filling stage.

Fall-Armyworm: This is a new challenge in the region and Malawi in particular. Fall-Amryworm is attacking all cereals including maize. Control methods currently include: Manual removal of the worms and Chemical control. Research is on-going to find the best control strategy. Sorghum has shown to be able to regenerate after attach and is able to produce panicles with grain intact. Integrated pest management (IPM): This is a system whereby various methods are applied to protect the crop by suppressing insect populations and limiting damage. These measures include the following: chemical control, biological control, plant resistance and cultural control. Storage pests: After harvest, sorghum in the store can be attached by weevils. Actellic Super dust is recommended for stored grain.

Sorghum Diseases
Experience in the shire valley is such that the recommended varieties are generally resistant to most diseases of economic importance.

Leafblight (HelminthosporiumTurcicum): This disease has been observed but this normally

occurs in the crop later in the season when improved varieties have formed grain.

Downy Mildew *(Sclerospora sorghi) and sootystripe (Ramulispora Sorghi):* The improved varieties of Pilira1 and 2 are resistant to both Down Mildew (Sclerospora sorghi) and sootystripe *(Ramulispora sorghi).* The three newly released varieties (Pilira 3, 4 and 5) are also resistant to these diseases while these diseases occur in the unimproved varieties. They can therefore be controlled by timely sowing and growing of improved varieties.

Grain Moulds: There are two types of grain moulds namely; Fusarium spp and Culvularia spp which are fungal diseases. These are normally experienced when harvesting is delayed. Farmers are therefore advised to harvest as soon as physiological maturity occurs where this disease is prevalent, particularly where rains are continuous.

Harvesting and threshing

Harvesting should be done as soon as the crop has reached physiological maturity. This may be 4 months after planting. At this stage the grain has 25% to 30% moisture content and forms a black layer at the hilum region. Timely harvesting minimizes weevil, bird damage and shattering. Cut the dried heads and put them in a bag. When threshing beat the bag to loosen the grain from the heads.

Post-harvest handling

Dry the grain well to about 12.5% moisture content and store in dry structures. Treat the grain with Actellic Super or Super Grain Dust at the rate of 25 g per50kg bag of sorghum and store in a dry clean place. The grain may also be stored into a crib (nkhokwe). Put into the crib treated grain. Before starting to fill the crib clean and remove all old grains. Sprinkle evenly some Actellic Super or Super Grain Dust on the side and floor of the crib thoroughly at the rate of one sachet (40g) for every square meter.

Commercialization

Although sorghum is used for food and is a staple food to people in Shire-Valley, the extra production can be used as a source of cash through processing into various products. These include: beer, sorghum rice and animal feed.

Beer

Preparation of beer involves three ingredients namely; malt, meal and yeast. Suitable varieties for beer are those with red colour in most cases. They must be those varieties that have good malting characteristics.

Sorghum rice

Sorghum rice or “Corn Rice” is whole, decorticated sorghum.

Livestock feed and other animal products

Livestock feed form sorghum is not yet a well-developed market for sorghum in Malawi but it is the most important market for surplus sorghum in other countries, as it competes effectively with other grain products in terms of price and quality. Sorghum is an important component in both livestock and poultry feed.

Guide for Finger Millet

Production in Malawi

Introduction

Among the millets of the world, finger millet ranks fourth after pearl millet (Pert. nisetum americanum L.), foxtail millet (Setario italics), and proso millet (Panicum miliaceum). Finger millet is the most important small millet in the tropics (12% of global millet area) and is cultivated in more than 25 countries in Africa (eastern and southern) and Asia (from Near East to Far East), predominantly as a staple food grain. The major producers are Uganda, India, Nepal and China. In Malawi, finger millet is an important alternative food and cash crop in the plateau areas about 1000 m above mean sea level (masl) especially in Chitipa, Mzimba, Rumphi, Kasungu and Nkhata-Bay. The slash and burn (Visoso) as practised in Chitipa and Karonga as well as Nthemera as practised in Mzimba destroys vegetation and land productivity and should therefore be discouraged.

The crop is abundant in nutrients such as calcium, iron, protein, fibre and other minerals and is a gluten-free food. It also helps in addressing health ailments such as liver diseases, high-blood pressure, diabetes, heart weaknesses and asthma among others. Millets are recommended to lactating mothers if they are unable to produce sufficient milk to feed their infants. Finger millet nutritional value: finger millet is often ground to a fine powder and the major portion of millet flour is carbohydrate, followed by protein and fibre. It has the least amount of fat in them. Other important traits of finger millet include resistance to pests and diseases, short growing season, and productivity under hardy and drought conditions when major cereals cannot be relied upon to provide sustainable yields. Millets are underutilized in most developed countries. There is an immense potential to process millet grains into value-added foods and beverages in developing countries.

Table 1. Finger millet flour nutritional value

Content	Range
Carbohydrate	71.3 - 89.5
Protein	5.8 - 12.8
Fibre	3.5 - 3.9
Fat	1.3 - 2.7

Source: FAO, 1995

Agro-ecologies for cultivation

Finger millet requires day temperatures of between 30 and 34 oC and night temperatures of between 22 and 25 oC for optimum growth along with good sunshine. It thrives best in the areas with annual rainfall of about 1000 mm. It thrives at higher elevations than most other tropical cereals and tolerates salinity (optimal range: <0.4 mmhos/cm) better than most cereals. It grows best in an environment with fertile, well-drained sandy loam soil with a pH between 5.5 and 7.5. Areas with low rainfall and low relative humidity during seed ripening and maturation are best for regeneration.

Accessions and improved varieties

Several accessions of finger millet exist at Chitedze Research Station genebank that were collected from farmers in various parts of the country. There are two distinct types based on the head characters. The open type has long thin ribbon like fingers that open outward. It is called Phazi-la-njobvu' which means elephant foot. The other type, in which short fingers fold inwards, is called 'Fumbata'. The landraces are classified into two maturity types. The early type which matures in about three months is called 'Nthanga' which is common around Mzimba. It has incurved heads and the seed is very small. The late maturing types which take more than 120 days to mature produce large heads and bold grain. Two improved cultivars include Dopalopa and Mavoli which are red and white grained, respectively.

Agronomic practices

In order to improve yields of finger millet the following husbandry practices are recommended:

Improved varieties

Plant improved cultivars such as Dopalopa and Mavoli which are red and white grained, respectively. Research has identified potential varieties of finger millet to be released for use by smallholder farmers in the country.

Field preparation and spacing

Traditionally finger millet cultivation involves clearing of forest land and burning the trees in a system called 'Chitemene' where the crop benefits from ash and fire burns weed seeds. However, due to population growth and land degradation concerns, less land is available for clearing for cultivation using the system described above. New methods of cultivating finger millet using existing crop land exist. However, these will require different levels of management to support crop growth if yield is to be optimized. Plough the field 2 or 3 times deeply to conserve the moisture content in the soil. When planting on ridges, prepare ridges at inter-row spacing of

75 cm and level top of ridge aiming to create a width of 50 cm. When planting on the flat, prepare grooves spaced at 37.5 cm apart.

Planting

Plant 2 to 4 weeks after first rains to allow Rapoko grass (Eleusine indica), a weed which looks like millet to emerge so that it can be controlled before millet is sown. On flat, prepare grooves 37.5 cm apart and sow millet seeds aimed at one plant per station, 5 cm apart. The spacing between rows should be 37.5 cm. Prepare two lines 30 cm apart on top of each ridge and plant one plant per station 5 cm apart within lines. Plant millet seeds at a depth of 3 cm into the soil. The seed rate is 5 to 7 kg per hectare.

Fertilizer application

Where manure is available incorporate 13 tonnes per ha into the soil. Apply 100 kg of 23:10:5+1Zn+4S per hectare. If planted on the flat, apply using one and half (1.5) cupfuls of cup No.5, and two and half (2.5) cupfuls of cup No.8 when planted on ridges.

Weed control

The crop should be free from weeds during the first 6 to 8 weeks as this is the period when the crop is least able to stand competition. In practice, the crop requires 2 to 3 inter cultivation operations.

Pest and disease control

Main pests found in finger millet are: pink stem borer, leaf folder, earhead bug, aphids, white stem, cutworm, finger millet leaf hopper and grasshopper. The most important diseases of finger millet are Head blast and Mosaic which cause premature drying of fingers. Control is by using tolerant cultivars such as Dopalopa and Mavoli. Literature lists some of the non-chemical pest and disease management options as follows:

(i) Neem solution is used to control sucking pests and mealy bug. Add 100 litres of water to a large container along with 5 litres of cow urine. Add also 5 kg of cow dung to this. Crush 5 kg of neem leaves, making a pulp from them, and add this into the pot. Stir the solution and let it stabilize for 24 hours. Stir this solution twice a day by any stick. Filter the liquid through a cloth and spray the filtered liquid (100 ml added to 5 litres of water) for controlling the above pests.

(ii) Multi-purpose solution for controlling sucking pests, pod borers, fruit borers. In a pot, add 10 litres of cow urine in it. Crush 3 kg of neem leaves, making a pulp, and add this into the pot. Then add the following tree or plant leaves, ground into a pupl: 2 kg of custard apple leaves, 2 kg of papaya leaves, 2 kg of pomegranate leaves, 2 kg of guava leaves, 2 kg of Lantana camara leaves, and 2 kg of Datura stramonium leaves (Lantana and Datura leaves if available). Boil the moisture until it is 1/5th of previous amount. When it is cooled, leave it for 24 hours. Filter the liquid through a clean cloth. Spray the filtered liquid (100 ml in 5 litres of water) for controlling the above pests.

More information on symptoms and control measures for these pests and diseases, can be solicited from the AEDOs.

Harvesting and storage

Finger millet will start flowering in 2 to 3 months and ready and mature in 4 to 5 months period. Harvest by cutting at ground level and dry them in the sun for 2 to 3 days. Harvest the crop when the heads are dry and store whole heads in dry structures such as nkhokwes. Bullocks or sticks can be used to separate the seeds from the plants.

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