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Maize production manual for smallholder farmers in Tanzania

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The *Enhancing partnership among Africa RISING, NAFAKA, and TUBORESHE CHAKULA Programs for fast tracking delivery and scaling of agricultural technologies in Tanzania* is an interdisciplinary and inter-institutional project that aims to address smallholder farmers' needs in the semi-arid and sub-humid zones of Tanzania. The 3-year project is funded by the USAID Mission in Tanzania as part of the U.S. Government's Feed the Future initiative.

Through participatory and on-farm approaches, candidate technologies are being identified and evaluated for scaling by the project team. This is being achieved through the already established networks by Tanzania Staples Value Chain (NAFAKA), Tuboreshe Chakula (TUBOCHA), and other institutional grassroots organizations, creating an opportunity for mainstreaming into wider rural development programs, beyond Africa RISING's current zones of influence.

The project is led by the International Institute of Tropical Agriculture (IITA) and the USAID Tanzania mission-funded 'Feed the Future' programs NAFAKA and TUBOCHA. Developmental activities addressing the project objectives are being implemented in Manyara, Dodoma, Morogoro, Iringa, and Mbeya Regions in Tanzania.

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List of acronyms

ACDI/VOCA	Agricultural Cooperative Development International / Volunteers in Overseas Cooperative Assistance
Africa RISING	Africa Research in Sustainable Intensification for the Next Generation
CGIAR	Consortium of International Agricultural Research Centers
FAW	Fall Army Worm
FTF	Feed the Future
GAP	Good Agricultural Practices
GDP	Gross Domestic Product
IITA	International Institute of Tropical Agriculture
MOA	Ministry of Agriculture
OPV	Open Pollinated Varieties
TMA	Tanzania Meteorological Agency
USAID	United States Agency for International Development

Introduction

Maize (*Zea mays* L.) is the most important food crop in Tanzania, cultivated on over 45% of total arable land and generating close to 50% of rural cash income, at an average of 100 USD per maize producing household in 2018 (FAOSTAT, 2019). Maize production in the country is mostly under low-input rain-fed conditions. Use of simple farm equipment, recycled seeds, minimal use of agrochemicals and minimal weeding is the most common technological package. The result is frequent crop failure.

The objective of this production manual is to guide farmers on how to apply good agricultural practices (GAPs) as an important step towards increased productivity of maize, among other crops. GAPs offer benefits to farmers to achieve increased crop production levels, food security, production efficiency, and environmental protection. Key elements of GAPs include the use of appropriate crop varieties, proper spacing (including gap filling and thinning), application of fertilizers, weed management, protection of fertile soils and pest and disease management/control. Other key practices include proper harvesting, shelling and storage.

Cropping seasons and crop calendar

The concept of cropping seasons takes into account the seasonality and length of potential growing periods during the year. The growing periods are determined based on the start of the rainy season, potential evapotranspiration and temperature. The country's different agro-ecological zones experience great variability in rainfall with some areas receiving bimodal type (e.g. the Western highlands, Northern highlands, and Eastern highlands) and others receiving mono-modal type (e.g. the Central, Southern and Southern Highlands). Maize in Tanzania is almost grown under rain-fed conditions, and the crop calendar varies depending on agro ecological conditions, as shown in Table 1.

Table 1. Maize crop calendar for areas experiencing bimodal and unimodal patterns of rainfall in Tanzania (Source: FEWS, 2017).

Rainfall type / farm operation	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sept	Oct	Nov	Dec
Bimodal												
		Short dry season	Masika rains				Long dry season			Vuli rains		
Land prep.												
Planting												
Harvesting												
Marketing												
Unimodal												
	Musimu rains (cont.)					Dry season					Musimu rains start	
Land Prep.												
Planting												
Harvesting												
Marketing												

Notes:

In areas receiving bimodal rainfall, land preparation for maize planting in vuli rains has a short window (1 month) compared to that in Masika rains (1.5 month). This is because soils are much drier and difficult to work in the long dry season. Working on land becomes possible after first Vuli rains which are also good for planting. Harvesting and marketing of maize grown in Masika rains have a wide window as permitted by the long dry season.

In areas with unimodal rainfall pattern, farmers have at least 2 months to prepare the land and planting continues for at least 2 months depending on the location. Harvesting is done in the first 2.5 months of dry season while marketing can be extended throughout the dry season.

Agronomy

Site selection

Maize performs best on soils which are deep, loamy, fine-structured, well-aerated good drainage, with adequate amount of organic matter and well supplied with nutrients. Maize does not perform well in waterlogged soils implying that sites prone to waterlogging should be avoided. If such areas cannot be avoided, then soils must be drained by digging channels to direct water away from the field. Proper drainage allows for early cultivation, better weed control and reduces the likelihood of nutrient leaching.

Maize is grown successfully on soils with pH of between 5.0 and 7.0, but a moderately acidic environment of pH 6.0 to 7.0 is optimum. Outside this pH range results in nutrient deficiency as a result of unavailability of nutrients and mineral toxicity.

For good yields, maize has to be grown in open areas that are receiving full sunlight to allow for maximum photosynthesis. Yield will decrease with reduction in the amount of sunlight that reaches the plant. Therefore, land with many trees and shady areas should be avoided.

Checking the fertility of soils

Visual symptoms

Leaf coloration of the maize crop will tell if the soil is nutrient deficient. During routine inspection of your field, yellow, brown, purplish, striped, or desiccated maize leaves may be found. These symptoms can be foliar signs of a nutrient deficiency. Maize has a high requirement for nitrogen (N), phosphorus (P) and potassium (K). Thus, when in short supply, deficiency symptoms develop on plant leaves as shown on Figure 1. A Generalized explanation of visual symptoms on leaf and plant for N, P and K deficiencies is provided in Box 1.

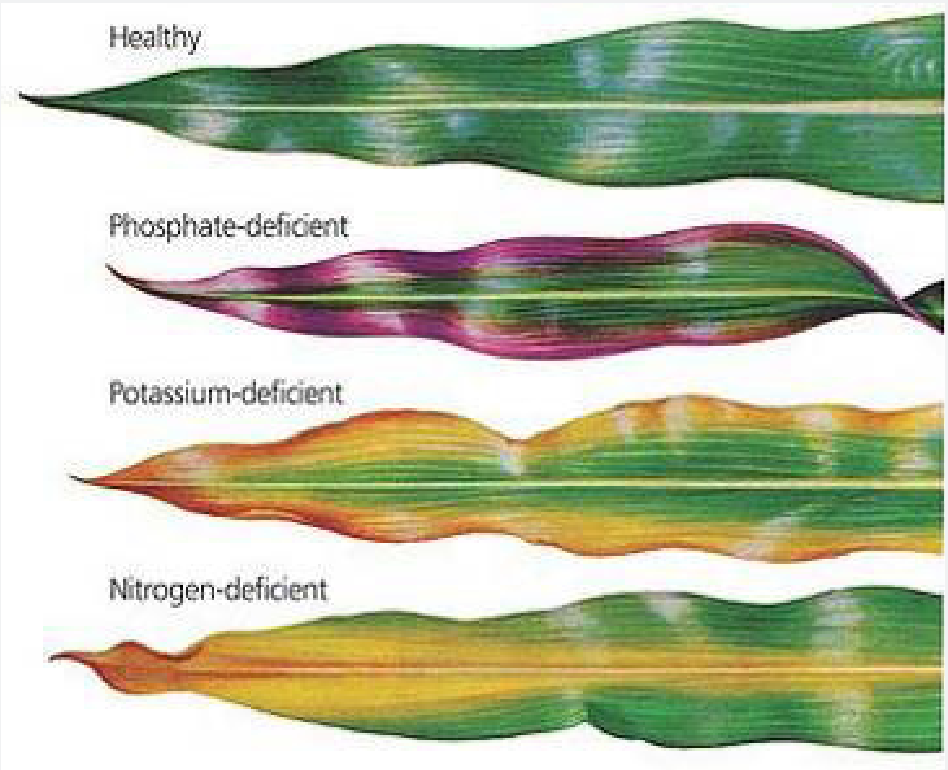


Figure 1. Common nutrient deficiency symptoms of maize. Photo credit: Pinterest.com.

Box 1. Generalized visual leaf and plant nutrient element N, P and K deficiency

Nutrient element	Visual symptoms
Nitrogen (N)	Light green leaf and plant color with the older leaves turning yellow, leaves that will eventually turn brown and die. Plant growth is slow, plants will be stunted, and will mature early.
Phosphorus (P)	Plant growth will be slow and stunted, and the older leaves will have a purple coloration, particularly on the underside.
Potassium (K)	On the older leaves, the edges will look burned, a symptom known as scorch. Plants will easily lodge and be sensitive to disease infestation. Fruit and seed production will be impaired and of poor quality.

Note: Apparent visual deficiency symptoms can be caused by many factors other than a specific nutrient stress, for example environmental interactions, insect feeding, herbicide injury, soil compaction, and other factors. Soil testing can help determine if a true nutrient deficiency exists. If you require assistance to diagnose symptoms, ask your extension officer.

Soil testing

It is desirable to check the fertility of your soils every after 3 - 4 years for pH levels (how acid or alkaline your soil is), organic matter and plant nutrients. To do so, take a representative soil sample from the field after you have evaluated it in terms of topography, soil texture, drainage, color of topsoil and past management. Where the above features are uniform throughout the field, take a composite soil sample to represent the soil in the field. Where differences are large, then take one composite soil sample from each of reasonably uniform area of the field. The procedure to collect soil samples for analysis is as follows:

- Dig a hole 15-30 cm deep in such a way that a "V" shaped hole is made, cut out a thin slice (approximately 2.5-5.0 cm) and put it in a clean container (Figure 2).
- Continue doing the same until you have whole field sampled.
- After all the sample cores are taken, mixed the soil thoroughly, and remove any stones or debris.
- Dry the soil samples on the clean surface under the shade.

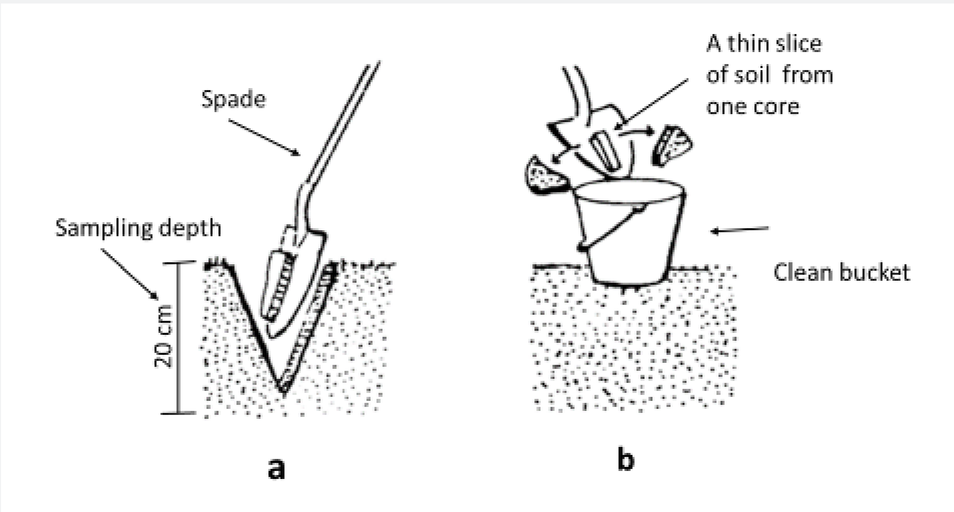


Figure 2. Illustration on how to take a soil sample at a specified depth (a) and a thin slice of one core sample transferred to a clean bucket (b). Figure credit: Frederick Baijukya/IITA.

- In the field, if available, soil testing kit (Figure 3), can be used for rapid tests of some soil properties including pH and nutrients (N, P and K) levels.
- If test kits are not available, take about 0,5-1kg of separate soil sample, label it by date of sampling, the farm name and send to the recommended agricultural service laboratories (for example at Tanzania Agricultural Research Centers Uyole, Mlingano and Selian; IITA-Dar es Salaam or Sokoine University of Agriculture) for analysis in order to inform on nutrient deficiency.
- Always consult the local agricultural extension agent for advice on when, how and where to analyze your soil samples.

Figure 3. An example of a soil test-kit developed by Eijkelkamp RM 5,690.00 MYR-Netherlands; It uses nutrient specific reagents for testing of soil pH, macro and micronutrients. Photo credit: lfarm.org.

Land preparation

For rapid emergence, maize seeds need a soil that is warm, moist, well supplied with air, and fine enough to give good contact between the seed and soil. Good seed-to-soil contact is necessary so that the seed can absorb moisture. A good seedbed should consist of fine firm soil that is free from weeds. The soil should not contain hardpans and compacted layers, which can reduce moisture penetration and root growth. Land clearing and tillage therefore aim at a field free of weeds and a loose, deep soil with a sufficiently fine tilth to allow an even seeding and uniform emergence.

Land clearing

Before tilling the land, ensure that the field is free of vegetation by either slashing or applying herbicides. To make the right decision on whether a field requires slashing and herbicide application, you must consider the type of fallow vegetation in your field. If your field has bushy vegetation with trees or woody shrubs, taller than 50 cm (about the height to your knee or slightly above) you will need to slash the vegetation before tillage. Grass fallows can prove more difficult to control since grasses grow quickly. Because of this quick regrowth, grasses are best controlled with herbicides. First, check whether the grass is taller than 50 cm. If it is, slash the grass, and allow it to regrow for about 2 weeks, then apply a recommended glyphosate-containing herbicide like Touchdown Forte, Sarosate, or Force-Up. If the vegetation is less than 50 cm tall, do not slash it. Instead, directly spray it with a glyphosate-containing herbicide before tillage. Check the label for proper application, and always wear protective equipment while applying herbicides to ensure safety. The vegetation must have green and fresh leaves for the herbicides to work effectively. Wait 2 weeks after spraying to allow the herbicide to complete a total kill, then clear the land.

A field that has very little vegetation generally does not present a need to slash or spray, so you can proceed directly to tilling operations. However, if the field has difficult weeds like spear grass (Imperata spp), Guinea grass (Panicum spp), or Couch grass (Cynodon spp), first spray them with a glyphosate-containing herbicide or they will prove difficult to control once your maize has been planted. Do not burn plant residues as this destroys plant nutrients from the residues which cannot easily be replaced!

Tillage

Seedbeds for maize production are prepared either using the conventional tillage procedures or conservation tillage. Tillage can either be performed manually or by tractor. It loosens the soil and facilitates penetration of the roots. Tillage also speeds up the release of nutrients from organic matter and plant residues in the soil. Convention tillage is commonly done using equipment shown in Figure 4, namely hand hoes (a), animal traction (b), walking tractors (c) and conventional tractors (d). The hand hoe is the most commonly used equipment by small holder farmers though it is slow and labour intensive. Animal traction involves use oxen to plough land, although it is not suitable under heavy soils and steep terrain. However, this method is the most appropriate, affordable, reliable and proven technology for small and medium scale farmers. Conventional tractors open extensive land for commercial farming while walking tractors (power tillers) can be used by small and medium scale farmers.

Figure 4. Common equipment used to in conventional land tillage. Photo credit: Africa Conservation Tillage Network (ACTN).

On land which has been cropped the previous season, in case a tractor is accessible, tillage should be done once and supplemented with harrowing before planting. In areas where shallow hard pans exist, subsoiling compacted soils through ripping is needed to raise the maize yield potential (Figure 5). Ploughing by oxen disturbs the soil less than by tractor. Therefore, where available, ploughing using oxen is highly recommended.

Figure 5. A ripper working on compacted soil. Photo credit: Agromaster Agricultural Machinery.

In semi-arid areas, land can be prepared by slashing and planting directly into the resulting mulch (zero tillage or no ploughing). Burning should be avoided because the decaying weeds and crop residues act as mulch for the crop. The mulch keeps the soil cool, reduces soil surface crusting, conserves moisture, increases water infiltration, and reduces soil erosion as well as weed emergence. In humid environment, zero-tillage is only recommended when the soil is light in texture with good water infiltration in combination with stubble retained from the previous crop. The field should also be relatively even and kept free from weeds by hand weeding or spraying with herbicides.

Maize can be planted on flat beds or on ridges depending on the soils, land terrain and climatic conditions. Planting on flat bed should only be practiced on non-slopping land with deep well-drained soils. Planting on ridges, especially when they are tied, is recommended on sloping land to minimize runoff. Planting maize on ridges also provides longer water availability and improved soil physical conditions which lead to enhanced root growth, and higher maize yield. In semi-arid areas and areas with erratic rains, drought during the four-week period spanning flowering (tasseling and silking) through grain filling growth stages, can cause serious yield losses, and therefore some form of water conservation is important e.g. tie-ridges. Tie ridges (Figure 6), increase surface water storage and allow more time for rainfall to infiltrate in the soil.

Figure 6. Rain water trapped by tie ridges (in maize-Pigeon peas intercrop); the water percolates into the soils and becomes available to growing plants over a longer period. Photo credit: Sigmond Mujuni/IITA.

Choice of variety to grow

Variety choice, if correctly planned, can make a great contribution to risk reduction and should constitute an important part of production planning. Varieties' characteristics differ from one another, especially in terms of adaptability and yield potential. The differences between varieties provide a farmer with alternatives that can be utilized fully. For example, an early maturing variety, tolerant to drought and diseases (like maize steak virus and grey leaf spot) may give good yields in low rainfall areas. Similarly, a late maturing variety, capable of producing more than one ear, and tolerant to cob and tassel smut, may give good yields in the cooler areas. Therefore, for good yields, it is necessary to plant improved varieties that have the right agronomic advantage for a given agroecology. Always consult the local agricultural extension agent for information on recommended varieties. Some of maize varieties suitable for different areas are presented in Table 2.

There is both locally adapted seed of *hybrid maize* and *open-pollinated varieties* (OPV). Hybrids seeds are produced by crossing two different parent plants that contain improved genetics, such as high yield potential and unique trait combinations to tolerate adverse growing conditions. In contrast, open pollinated seeds are produced when two parent of same genetics self-pollinate. The resulting seeds will produce plants roughly identical to their parents. Overall, Hybrids are well suited to favorable production environments, respond well to high management levels, and result in higher yields than open-pollinated varieties. In addition, hybrids are uniform in maturity, plant height, and other plant characteristics, enabling farmers to carry out certain operations, such as harvesting, at the same time, particularly appropriate for large scale farming. To maintain the greatest yield advantage of both hybrids and OPVs, new seed should be purchased every planting season. Hybrid seed should never be used for seed in subsequent seasons. Always get improved seeds from a known source.

Table 2. Agronomic characteristics of some of the recommended maize varieties for cultivation in Tanzania (Source: Ministry of Agriculture- Tanzania, Registrar of Plant Breeders). Varieties market with * are OPV. Source: MOA(2018).

Variety	Optimal production altitude range (Masl)	Average grain yield (t/ha)	Maturity days	Special attributes
MERU H600	1,000 -1,600	10	129	Resistant to Maize Streak and Gray Leaf Spot diseases
NATA H 104*	500 -1,700	8.5	120	Resistant to Leaf rust, Leaf blight and Gray Leaf Spot
PAN 4M-21	400 -1,200	7.5	125	Drought tolerant, resistant to Leaf rust, Maize streak and Gray Leaf Spot
WE 3117*	0 - 1,500	6.7	125	Resistant to Leaf rust, blight and Maize streak virus diseases
MERU SB 507	800 -1,200	7.2	115	Resistant to Leaf rust, Maize streak, Gray Leaf spot diseases, Resistant to drought
MAMSH 591	900 - 1,500	7.8	110	Resistant to Leaf rust, Gray leaf spot and Maize streak virus diseases
SC 719	800 - 1,500	8.5	150	Resistant to Leaf rust, Gray leaf spot and cob rot diseases; good for animal feed
LUBANGO HYBRID	900 -1,500	10.0	110	Resistant to Leaf rust, Gray leaf spot, Maize streak virus
MERU LISHE* 503	800 -1,200	4.3	99	High levels of Lysine and Tryptophan, tolerance to Grey leaf spot and Maize streak virus diseases, suitable for roasting
NATA K8*	0 - 1,600	4.5	115	Tolerance to Grey leaf spot, Leaf blight, and Leaf rust diseases
MAMSH458	900 -1,500	8.5	100	Tolerance to Leaf blight, Grey Leaf Spot, Maize Streak virus
MERU VAH 519	800 - 1,200	6.7	65	Tolerance to Grey Leaf Spot and leaf Rust, High content of Vitamin A of 14.9µg/g, Carotene color Intensity score of 3.1
TH 617	800 -1,500	8-9	70	Tolerance to Leaf blight, Grey Leaf Spot and Maize Streak virus
UH6303	1,200 - 2,000	9-10	150-160	Good resistant to Leaf blight (*Helminthrosporium turcicum*), and Grey Leaf Spot
UH615	1,200 - 2,000	8-9	155-160	Tolerant to grey leaf spot (GLS) and leaf blight

Planting

Germination test

Once seed is purchased, it should be stored in a cool, dry place and safe from rodents prior to planting. A germination test should be conducted, at least 10 days before planting to prevent poor stand due to poor damaged seeds. To conduct a germination test the following steps should be followed:

- Randomly select 100 seeds and sow at a depth of 5 cm in a prepared area of the field or in a container at home (placed in the sun).
- Count the number of seedlings that emerge after 8 days.

Take decision based on the results of the germination test, as shown in Box 2.

Box 2. Decisions to take after a seed germination test

Number of plants counted	Number seed to be planted
85 or more	2 seeds per hole
70- 84	3 seeds per hole
<70	Get better seeds

Timing of planting

Planting at the beginning of rain season is associated with higher yields when rainfall is normal. Planting maize early is important for the crop to utilize the entire growing season moisture and consequently, maximize yield. Early planting with the right maize variety will make a large difference to the productivity of farmers' fields. The recommended planting window is given in Table 1, but the timing will depend on the onset of rains. It is always safe to plant after rains have established. Because onset of rain is becoming less reliable, the experience of farmers in each area coupled with weather forecast information from Tanzania Meteorological Agency (TMA) is the best guide. Planting one month later in the rain season will lead to low yields, and is very risky, because the crop may suffer from mid-season drought stress. Moreover, pests (e.g. stalk borer) and diseases (e.g. maize streak virus) are more prevalent on late planted maize crops.

Optimum plant population in a mono-cropping system

The recommended population of maize plants per hectare varies from 37,000 to 53,333 depending on the environmental yield potential and the variety to be grown. Higher plant populations are appropriate for early-planted crops under high rainfall conditions where management is of a good standard. Lower plant populations should be used under dryland conditions, especially in drought prone areas. Some varieties may be susceptible to lodging under high plant populations. Generally, the taller the variety, the lower should be the plant population. Short maize varieties may be grown at higher plant populations. In the above cases, the seed rate ranges from 8 kg to 10 kg per acre or 20 kg to 25 kg per hectare depending on the size of the seed.

To achieve the optimum population in humid and semi-arid conditions for tall and short maize varieties, plant in rows using spacing indicated in Table 3. Keeping two (2) plants per station reduces lodging because the plant anchor strongly in the soil.

Table 3. Recommended spacing (between and within rows) of maize with different heights and expected plant population in one ha assuming 100% germination.

Rainfall condition	Type of maize	Spacing between rows (cm)	Spacing between plants (cm)	Number of plants per station	Expected plant population /ha
Low rainfall (semi-arid areas)	All varieties	90	30	1	37,000
		90	60	2	37,000
High rainfall (sub humid- humid areas)	Tall varieties	75	30	1	44,444
		75	60	2	44,444
	Short varieties	75	25	1	53,333
		75	50	2	53,333

Spacing when intercropping

Maize can be intercropped with legume crops such as common beans and soybeans in areas with sufficient soil moisture.

Where intercropping is done, adjust the inter-row spacing as shown below:

a) two rows of maize at 90cm by 60cm with two rows of beans or soybean at 50cm by 20cm with two seeds per hole for each crop,

b) one row of maize with two rows of common beans or soybeans at a spacing 100cm by 25 cm for maize and 50cm by 10cm for beans with two seeds per hole for each crop (Figure 7) ,

c) one row of maize with three rows of common beans or soybean at 120cm by 60cm and two seeds per hole for each crop.

Plant spacing in a, b and c above will reduce maize the population of maize plants in the field by 10, 20 and 40, respectively.

Figure 7. Intercropping of maize and common bean in one row of maize with two rows of beans. Photo credit: Frederick Baijukya/ IITA.

Field inspection after planting

After planting, the maize field should be visited regularly, and seeds that did not germinate after 2-3 weeks replaced. Regular field visits also help to determine the type of crop management necessary to achieve high yield. Box 3 summarizes some of challenges that may be encountered when inspecting a maize field at an early stage and their possible causes.

Box 3. Challenges which may be detected at the early stage of seed germination and possible causes

Specific symptoms	Possible cause(s)
Seed not sprouting	Soil too dry Embryo was dead Too many clods during seedbed preparation Fertilizer burned the germinating seed Seed damaged by soil borne insects
Seed swollen but not sprouting	Soil too wet and cold for germination to proceed Fertilizer burnt
Rotten Seeds	Fungal seed rot Seed not viable
Seed hollowed out/dug up	Seed damaged by soil borne maize insects
Sprouts twisted, leaves expanding under ground	Seeds planted too deep Cloddy seedbed Soil crusting, compaction
Uneven emergence	Irregular planting depth Unfavorable soil temperature for germination
Seedling purple in color	Phosphorus deficiency

Fertilizers and application

Compost and animal manure

Maize responds well to the application of compost or animal manure. Apart from providing the required nutrients, compost and animal manure help to improve the physical conditions of the soil and its water retention capacity. Compost or animal manure should be added earlier after the first cultivation in land preparation to allow uptake of nutrients by the establishing plants. At second ploughing the manure is churned into the soil prior to planting. The rule of thumb is to apply compost or animal manure at a rate of 16 t/ ha (7 t /acre) on nutrient depletes soils or 8 t/ha (4 t /acre) on moderately fertile soil.

Mineral fertilizers

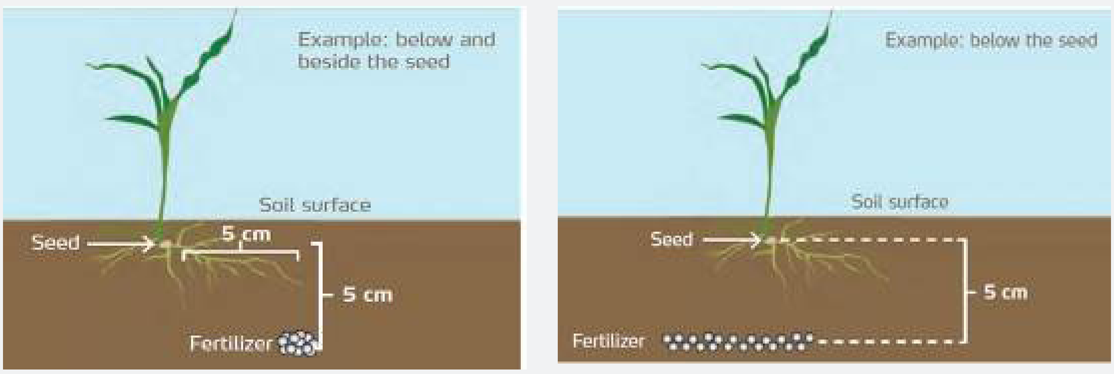
Common fertilizers for maize in Tanzania are; Minjingu Nafaka NPK (10:16:6), Di-ammonium phosphate N:P (18:46) and NPK (17:17:17) by YARA (YaraMila Cereal) for basal application, and Urea (46% N) or Calcium ammonium nitrate (CAN) (27% N) for topdressing. Recommended application rates of these fertilizers vary depending on the fertility of soils usually determined by the cropping history of the field, the climate and expected yield as summarized in Table 4.

Table 4. Recommended application rates of common basal and topdressing fertilizers by climatic Zone, cropping history and corresponding expected yield recorded in trials out plots conducted in farmers' fields by Africa Rising-NAFAKA project in 2016-2019. Source: Marandu et al., 2014.

Climatic Zone and cropping history	Basal fertilizer (in 50 kg bag /ha		Top dressing fertilizer (in 50 kg bag /ha)		Nutrient equivalent in kg/ha)			Expected yield (t/ha)§
	DAP	NPK*	Urea	CAN$	N	P	K	
Arid to semi-arid areas e.g. in Dodoma, Iringa and Morogoro regions								
Land fallowed for more than 5 years	2.5.	-	2.5	-	60	20	0	3.5-6.0
Land fallowed for less than 5 years	2.5	-	3.0	-	80	20	0	3.5-5.0
Land is continuously cropped	3.5	-	3.5	-	90	20	0	4.5-6.5
Sub-humid to humid areas in e.g. Iringa, Njombe, Mbeya and Songwe regions								
Land fallowed for more than 5 years	2.5	-	2.5	4.0	60	20	0	4.5-6.5
Land fallowed for less than 5 years	2.5	3.5	3.5	5.0	90	20	20	5.0-7.5
Land is continuously cropped	3.5	5.0	5.0	7.0	120	30	20	5.0-7.5
Land is continuously cropped with hybrids	3.5	5.0	6.0	10.0	150	30	20	6.5-9.0

*The fertilizer most suitable in humid and sub-humid highlands where soils are N, P and K deficient. $The fertilizer is most suitable in sub-humid and humid highlands where soils are deficient of N and Ca. §*The yield potential largely depends on the variety, expected rainfall and on the management applied to the crop.*

Apply the basal fertilizer at the time of planting. When planting by hand, place a teaspoonful or soda bottle cap of fertilizer into each planting hole 5cm away and below the seed (Figure 8a), or in a band 5cm below the seed (Figure 8b), mix the fertilizer well with soil and then plant the seed. When using a tractor planter, adjust the fertilizer hoppers to apply the right amount of fertilizer.



a b

Figure 8. Placement of basal fertilizers **(a)** 5 cm below at the side of the seed and **(b)** 5 cm below the seed. Photo credit: YARA.

After 4-6 weeks or when the crop is about 45cm high, top-dress your maize with CAN or Urea as recommended (see Table 5). If you are planting the maize in areas with high rainfall, apply the fertilizer in two splits. Apply the first split 4-6 weeks after plating and the second after 2 weeks or just before the maize flowers. Apply the fertilizer when the soil is moist by opening furrows 5 cm deep a circular way around the plant, then put one full-soda bottle cup of fertilizer and covered with soil to avoid fertilizer loss.

Use of agricultural lime

Agricultural lime is itself not a fertilizer but it is added to the soil to neutralize the acidity of soil for optimum plant growth. About 26 % of soils in the Southern Highlands of Tanzania are naturally acidic (pH 4.2- 5.6), thus need lime to neutralize the acidity. Soil-test summaries and field records compiled by YARA Fertilizer Company emphasize that poor management of soil pH accounts for a high percentage of the "crop problems" in the Southern Highlands of Tanzania. One option to reduce soil acidity is the use of agricultural lime. Maize grow better in slightly acidic to neural soils (pH 6.0 - 7.0), so the goal of liming is to raise the pH to this range, so as to avoid crop problems related to excessive acidity.

Several liming materials are available in Tanzania but the most recommended is the finely ground limestone rock containing ($CaCO_3$), and calcium oxide (CaO), that is supplied by the Dodoma Cement Company.

Rate and method of application

There is no established rate of lime application yet, but applying agricultural lime at 1.2 tons per acre or 3.0 t per ha has shown to increase maize yield from 300 – 600 kg per acre in the first year of application, in selected fields in Kilolo, Wanging'ombe and Mbozi districts.

If soils are regularly limed so that the pH never gets too low, then the timing of maintenance liming is not very critical. Thus, regular liming provides maximum flexibility to lime when you have time and the conditions are right. In our soils, liming every 3-4 years will usually meet this goal. This also fits with our normal soil testing frequency. The lime should be applied in dry soils, at least 2 weeks before planting in order to give it time to react with the soil. Lime can be applied by hand or with manual tractor spreaders. The best way to achieve uniform application at the appropriate rate is to measure the amount needed to cover a given area of the field, then spread it evenly on the soil surface followed by shallow tillage.

Proper liming provides a number of benefits:

- Plants develop healthier roots because they are exposed to less potentially toxic aluminum. Better root growth may enhance drought tolerance.
- Lime is a source of calcium (as well as magnesium if dolomitic limestone is applied).
- Nutrient solubility is improved at higher pH, so plants have a better nutrient supply.
- Increased soil nutrient exchange between the soil and plants as well as reduced leaching of basic cations, particularly potassium.
- Nodulation of legumes is enhanced, which improves nitrogen fixation.

Intercropping and rotations with legumes

Maize-legume systems come in the following two major configurations.

i. Intercropping, in which maize and legumes are planted simultaneously in the same or alternating rows, particularly suitable for farmers with small farms.
ii. Rotation, with maize being planted in the same field after the legume harvest.

Legumes that are common intercropped with maize are common beans, pigeon peas, cowpeas, groundnuts and soybeans. All legumes fix and add nitrogen to the soil, reducing the need for nitrogen fertilizer for the subsequent crop, and especially so if residues are retained in the field. For example, common beans grown preceding maize, could lead to 5-15 % increase in yields of subsequent maize as a result of improved soil organic matter and nitrogen (Baijukya et al., 2016). Intercropping or rotation or maize with legumes also helps to minimize disease, pest and weed incidences.

When maize and legume like common beans are intercropped, their yields of individual crops are generally lower than when the crops are grown monoculture, but land productivity is usually higher. Under intercropping, production costs per unit of output are usually lower and, because legumes sell for up to four times the price of maize, farmers' income is higher and more stable. When intercropping maize with legumes, there are three things to consider. First, the maize and legumes varieties must be compatible. Second, soil fertility and the need for fertilizer must be addressed to ensure a profitable crop yield. Lastly, maize and legumes must be planted in the right arrangement and crop densities.

Crop management

Weed management

Weeds compete with maize for light, nutrients, soil moisture and space resulting in yield losses, lower grain quality and increased production costs. Weeds also harbor insects and diseases. Delayed weed control may result in reduction of yields by 50% to 90%. Therefore, weeds must never be allowed to out-grow maize plants. Weeding during the critical 3-4 weeks after planting greatly enhances grain production as it helps the established maize plant to grow rapidly and become highly competitive compared to late weeding (Figure 9).

Figure 9. Maize plot clean weeded on time (left) and maize plot lately weeded after competing with weeds. Photo credit: Frederick Baijukya/IITA.

There are three main methods of weed control: manual weeding by hoe or cutlass, mechanical weed control with a mechanical weeder, and the use of post-emergence herbicides. For manual weed control, two weedings should be implemented, the first at 3 to 4 weeks after planting and the second at 6 to 8 weeks after planting. These weedings coincide with the time when mineral fertilizers are to be top dressed. A third weeding may be required 10- 12 weeks after planting in fields with high weed pressure.

If you opt for the herbicides method, look at the type of weeds in your field. If they are mainly grasses, choose a herbicide made specifically to control grasses like Fusillade Forte at 1.5 L per acre. For all other weed types, herbicides containing glufosinate ammonium, like Lifeline, Basta, and Facinate, or those containing glyphosate, like Round-Up Turb Touchdown Forte, Sarosate, Force-Up, and Delsate may be used at a rate of 1.5 l per acre. However, the herbicides should not be used during the first 4 weeks of crop growth as they will affect the maize if sprayed on the leaves or green stems. Instead, use manual or mechanical weed control. After the 4 weeks the above herbicides can be used to control weeds, but always use a sprayer with a shield so as not to spray the green parts of maize. Alternate between different herbicides to avoid build-up of resistance.

The effectiveness of herbicides is enhanced by good land preparation. Moisture is also required for activation of the herbicides. Herbicides lead to good management of annual grasses and broadleaf weeds but usually need to be supplemented by manual weeding to control perennial weeds or weeds emerging after the herbicides have dissipated. Successful use of herbicides depends on proper calibration of the sprayer, quantity of herbicide used, method and time of application, weather conditions and type of weeds. When using agrochemicals, the following precautions should be observed:

- Read the label on the package before using.
- Only apply chemicals obtained from recognized sources.
- Adhere to manufacturer's instructions and recommendations on the label.
- Use correct kind, dosage and application technique and appropriate safety precautions.
- Determine calibration rate and go by it.
- Seek technical advice when in doubt.
- Do not use expired agrochemicals.

- Wash your hands thoroughly with soap and water after using agro-chemicals.
- Do not eat while applying agro-chemicals.
- Dispose agrochemicals containers in a secure place.
- Wear protective equipment while you apply to ensure safety. You must wear goggles, nose mask, overalls, gloves and closed gumboots
- If the herbicide accidentally touches the skin and sensitive organs such as the eyes, wash the affected part with soap and clean water. If you feel some pain seek medical attention.

Management of major insect pests

Major pests of maize in Tanzania are the stem borer, fall army worm, termite and large grain borer. Storage insects such as larger grain borer (LGB) and maize weevil, cause grain losses after harvest. Main diseases of maize include gray leaf spot, fusarium ear rot, corn leaf blight and head smut. Below are some useful tips for managing pests and diseases in maize;

- be aware of pests and diseases common in the area where the crop is to be grown, and plant varieties that are tolerant to them;
- start scouting the field for pest infestation immediately after emergence of the seeds and monitor their levels regularly to determine whether they are causing economic damage to warrant their control;
- plant early to avoid the high pest pressure that are experienced with late planting;
- rotate maize and legumes to reduce weed, insect and disease pressure, enhance soil fertility and improve yields;
- under severe pest infestation, use pesticides judiciously;
- integration of all the methods above is critical for effective control.

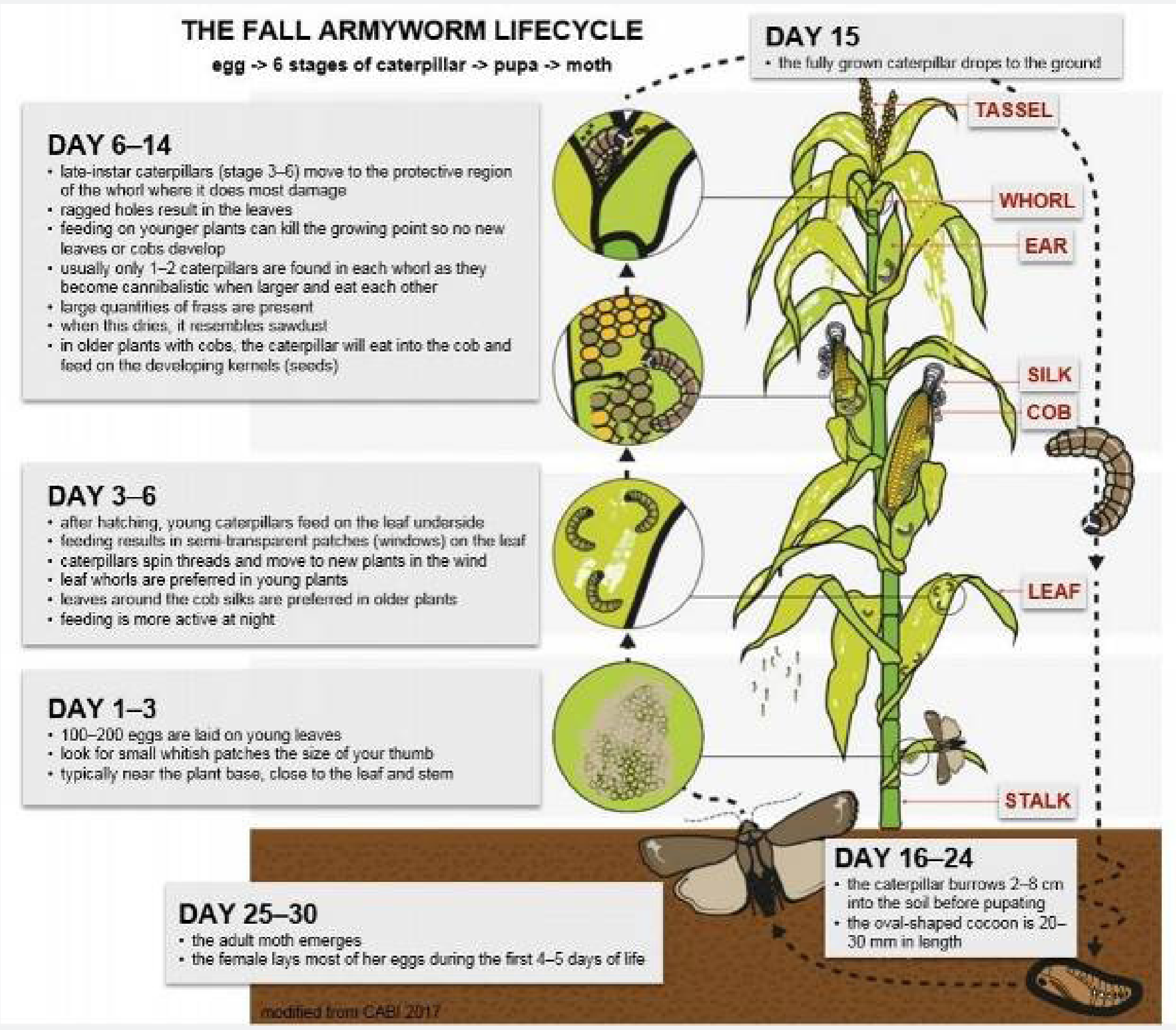


Figure 10. Life cycle of the Fall Army Worm. Source:CABI.

Maize stem borer

The maize stem borer, *Busseola fusca*, is the most serious insect pest of maize in Tanzania and causes enormous crop losses (estimated at more than 10% of the national crop). Stem borer infestation is higher in the later part of the cropping season. Most of the damage by this pest is caused by the larvae which feed on young leaves and later enter and tunnel inside the stem of the plant.

Symptoms

Maize plant parts affected are leaves, stems and cobs. First instar larvae feed on young terminal leaf whorls producing characteristic patterns of small holes and "window panes" (patches of transparent leaf epidermis) where tissue has been eaten away (Figure 11 A, B). Later, they eat into the growing points which may be killed so that the dead central leaves form characteristic dry, withered "dead hearts" (Figure 8D). Older larvae tunnel extensively into stems and eat out long frass-filled galleries, which may weaken stems and cause them to break (Figure 11 C). Some larvae bore in the cobs. When larvae feed on grains in the cob, frass deposits are visible (Figure 11 E, F).

Figure 11. Symptoms of maize stalk borer, Busseola fusca, damage on leaves: (A) characteristic "window panes," (B) shot holes where tissue has been eaten away, and (D) dead heart. Symptoms of damage to stems and cobs: (C) galleries filled with frass, (E) cobs showing frass, and (F) deposits and empty grains. Photo credit: ICIPE.

Management

Cultural methods: Stem borers multiply in crop residues left on the field after harvest. So, turn all the crop residues under the soil immediately after harvest. This practice helps to kill the pupae left in the residues thereby preventing the carry-over population and consequently limiting the establishment of the pest on the following season's crop. Trap crops e.g. elephant grass or early planted maize, reasonably spread around the proper maize field, will entice moths to lay their eggs before the main crop is up.

Chemical control: Although threat patterns will differ from area to area, it is advised to watch the maize for "shot-hole" symptoms early after crop emergence and onwards. Insecticides such as Karate (Orthene and Rimon) should be applied at the funnel stage, when small shot-holes are evident in the youngest leaves and borers have not yet migrated into the stalks. Spray Karate at 30 ml per 15 liters of water for every 100 m^2 beginning at 2 weeks after planting and repeat at 2-week intervals till tasseling stage.

Fall army worm (FAW)

The fall armyworm [FAW] (*Spodoptera frugiperda*) is a moth, native to tropical and subtropical regions of the Americas, but it is the caterpillar or larva that causes damage. Almost 100 different crops and other plants are susceptible to attack, but there is a preference for maize, rice, sorghum and sugarcane. A detailed description of FAW life cycle and activity at each stage is summarized in Figure 11, using an example of a maize plant to feed on the leaves. In young plants, the stem may be cut. Older larvae stay inside the funnel and so are protected from spray applications and predators. In older plants the larger larvae can bore into the developing reproductive structures, such as maize cobs, reducing yield quantity and quality.

Figure12. A maize plant attacked by fall army worm. Photo credit: CABI.

Identification of FAW

Half-grown or fully grown caterpillars are the easiest to identify. FAW caterpillars have a characteristic pattern of dark pimples (spots) on their backs; each spot has a short bristle (hair) (Figure 13). Although the skin looks rough, it is smooth to the touch. Look out for four dark spots forming a square on the second to last segment. The head is dark and shows a characteristic upside down Y-shaped pale marking on the front.

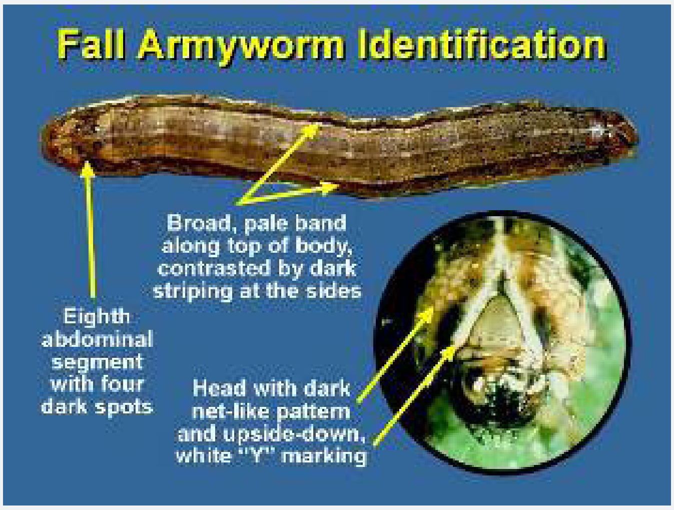


Figure 13. Distinctive features of Fall Army Worm. Source: CABI.

Monitoring and management of FAW

Monitoring is the deliberate effort of checking for the presence of Fall Armyworm on maize growing in your garden. It is important to monitor your maize crop frequently after germination for presence of the pest and or signs/damage symptoms. Early detection of the pest allows quick and timely response which will help minimize damages to your maize crop and reduce harvest losses. The method used in pest monitoring is called Scouting. "Scouting" means rapidly and systematically determining overall crop health and estimating presence of certain organisms causing damage and potentially yield reduction.

Start scouting your field two weeks after planting and continuously visit your field every 3 days. In the field, walk a letter "W", covering the entire field: At the start, at every turn, and at the end, inspect 10 plants in a row. These ten plants are called "zones" (Figure 14).

Look carefully in the whorl of each plant for signs of recent leaf damage or fresh frass in the whorl. These indicate a live larva, probably FAW, in the whorl. Do NOT include plants with some damage to older leaves, but with no clear signs of current damage. Only currently infested plants need be counted. Keep track of the number of plants currently infested in this way (in this example FAW infested plants are marked with an "x") as indicate in the record sheet below.

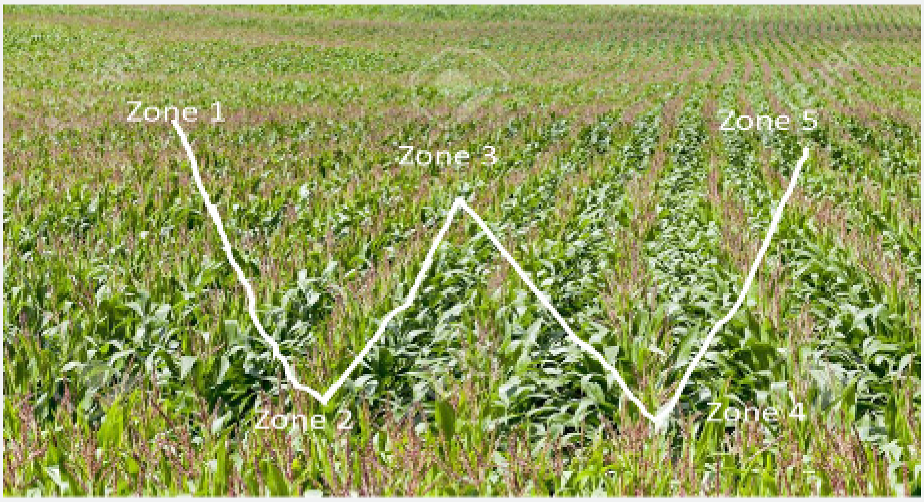


Figure 14. Procedure for monitoring of FAW in the maize field. Photo credit: FAO.

The total number of plants infested in the 50 plants counted is 6+4+4+5+7= 26. So, in 100 plants it would be double: 26 X 2 = 52, or 52% of the plants infested. Because we are looking for signs of FAW presence (fresh leaf damage or frass in whorl), the sampling doesn't depend of finding the larvae. So the sampling is fast, non-destructive and can be done any time of the day.

Pheromone traps can also be used for monitoring the presence of FAW in the field. If you notice the presence of the FAW moth in the trap, take appropriate control measures as described in the next section on FAM management.

Box 3. Record sheet of field FAW monitoring exercise

Zone 1		**Zone 2**		**Zone 3**		**Zone 4**		**Zone 5**	
Plant no	Infested?	Plant no	Infested?	Plant no	Infested?	Plant no	Infested?	Plant no	Infested?
1	x		x						x
2	x				x		x		
3	x								x
4							x		
5	x		x		x				x
6									
7	x				x		x		x
8			x		x				x
9	x						x		x
10			x				x		
Total number of plants infested									
	6		4		4		5		7

Management

The best and most effective strategy for managing FAW is taking preventive measures and immediate action when the Fall Armyworm is detected. The action taken will be guided by the extent of infestation.

Cultural methods/mechanical control methods

- Destroy the eggs, larvae and pupae in the crop residues after harvest by deep burying the plant residues in soil (at least 12 cm deep).
- Practice crop rotation; alternate maize with crops that are not attacked by the FAW e.g. cassava 3.
- Intercropping with pigeon pea, beans, groundnuts can attract more beneficial insects, and can help repel FAW from the maize field.
- If the number of eggs or caterpillars are few, handpick and crush them. This is only practical for small fields or few affected plants.
- FAW is food for certain birds and insects. Growing trees, hedgerows and a variety of crops in your field helps increase the number of these predators that can feed on the FAW and will help to reduce on infestation in the farm.

Use of insecticides

i. **When to apply:** Consider insecticide application when 20% of whorl-stage plants are infested with live larvae. For the pesticides to be effective you must spray early in the morning from 6:00-10:00am or late afternoon 4:00-7:00 pm provided the conditions are favorable for spraying.

ii. **How often to apply pesticides:**
   - Spray your crops and check for presence of caterpillars 4 days after spraying. Thereafter continuously monitor for the presence of caterpillars.
   - If after 7-14 days live caterpillars are identified in 10 out of 50 randomly selected plants, respray with the same pesticide.
   - Two to three (2-3) times of spraying may be adequate in a maize season,
   - Remember to alternate pesticides with different modes of action after every season to avoid development of pest resistance.

iii. **Which pesticides to use:** The pesticides listed in Table 5 have been recommended to control FAW in Tanzania. Always put on the protective wears when handling, mixing and applying the pesticides, as described before.

Table 5. List of some of insecticides registered for control of Fall Armyworm in Tanzania. Source MoA, (2020).

Trade name	Registration number	Common name	Registrant /supplier
Ecoterex 30 EC	IN/0927	Deltamethrin 0.005%+ Pirimiphos Methyl 0.025%	Anicrop Services Ltd- Tanzania
Diesel 5 EC	IN/0930	Lufenuron 10 g/l + Emamectin Benzoate 40 g/l	TAPAZOL Chemical Industries Ltd. - Israel
Hero 52% EC	IN/0948	Profenophos 500 g/l+Emamectin benzoate 20/l	Iffa Seed Co. Ltd - Tanzania
Benocarb 105 EC	IN/0953	Indoxacarb 85g/l + Emamectin Benzoate 20g/l	Kenagro E.A Ltd, Nairobi- Kenya
Radi Plus 160 SC	IN/0955	EmmamectinBenzoate 4% + Indoxicarb 12%	Anicrop Services Ltd- Tanzania
Evakan C344 SE	IN/0982	Imidacroprid 200g/l + Cypermethrin 144g/l	Fat P Investment ltd,T/A AgriChem
Twigamectin 50 EC	IN/0991	Emmamectin Benzoate 0.05%	Twiga Chemical Industries (T) Ltd Tanzania
Ampligo 150 ZC	IN/1002	Lambda cyhalothrin 50g/kg + Chlorantraniliprole 100g/kg	Syngenta Crop Protection AG - Switzerland
Lancer GOLD 55WG	IN/1005	Acephate 50 +Imidacloprid 5 WG	UPL Ltd – India
Baknock 27% C	IN/1021	Thiamethoxam14.1% + Lambdacyhalothrin 10.6%	Bajuta International (T) Limited Tanzania
Bamidacy Plus344 SE	IN/1022	Imidacloprid 200g/l + Cypermethrin 134	Bajuta International (T) Limited Tanzania
Bandocarb Plus 20 EC	IN/1023	Emamectin Benzoate 40g/L + Indoxacarb 160 GL	Bajuta International (T) Limited Tanzania
Banofos Super 520 EC	IN/1024	Profenofos 500g/L + Emamectin Benzoate 20g/L	Bajuta International (T) Limited Tanzania
Uphold 360 SC	IN/1026	Spinetoram 60 g/l + Methoxyfenozide300 g/l	Dow Agro Science, France

Termites

Termites are social insects that live together as a colony in a nest. Colony members belong to one of three interdependent groups with specialized form and function known as castes. The three basic castes present in the colony are workers, soldiers and reproductive forms (Figure 15). Workers and soldiers are wingless, sterile and blind. Workers construct the distinctive shelter tubes and collect food to feed the young and other members of the colony. The primary function of the soldiers is to defend the colony, usually against ants, which are their main enemies. The reproductive caste is usually referred to as the king and queen. They are responsible for the production of fertilized eggs for the colony and of specialized chemicals (hormones) important for managing the inhabitants of the colony. Mature colonies produce winged reproductive forms at certain times of the year. After the dispersal flight, they attempt to produce new colonies.

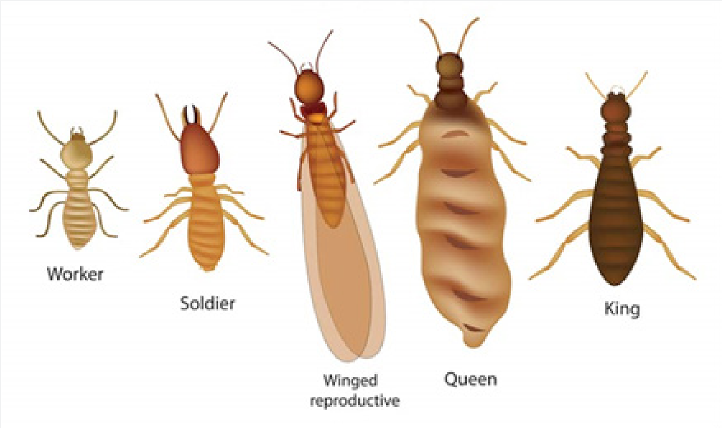


Figure 15. A picture showing five basic castes present in the termite colony. Photo Credit: ICIPE.

The most troublesome type of termites in agriculture is the fungus-growing termites. They harvest plant material to feed the fungus which they then feed on themselves. The termites chew maize roots and dry the plant out, usually resulting in patches of crop death. They may also tunnel up the inside of the stem, resulting in lodging and significant yield loss. Crop losses estimated at between 3-100% have been recorded.

Control measures

Cultural method

- Adding organic material (compost or well-rotted manure) to the soil: Termites prefer to eat dead plant material. Their attacks are thought to be related to soils with low organic matter content. This is because such soils do not contain enough food for termites to live and they resort to feeding on living plant material.
- Cultivating on ridges: Ridges are usually made along contours and the soil is finally shaped into a ridge form. In these operations, termite colonies are destroyed or exposed to predators such as birds.
- In dry areas, sow seeds at the beginning of the wet season to give the plants a chance to establish themselves and remain healthy in the field.
- Practice crop rotation to reduce the build-up of termites, especially with legume crops.
- Harvest at the right time, as termites often attack maize left in the field after maturity.

Physical method

- Mechanical Destruction: This consists of breaking the mounds of the termites and removing the queen and the king. The success of this measure depends on eliminating the queen, who may be hidden deep inside and is not easily found.

Chemical method

- The application of chemical pesticides against termites is generally aimed at creating a barrier to prevent termite access to plants.
- In areas where termites come early in the growing season, pesticides should be used in the form of seed dressing. Or applied to the planting hole. Insecticides such as Fipronil give some success either as a seed dressing, or as a furrow treatment at planting.
- In areas where termites come late during the growing season apply pesticides like Termidor SC, Ostrinia furnacalis or Imidachloprid as a high-volume spray to the plant bases at the appropriate time (when attack is likely).
- Note that pesticides are poisons so it is essential to follow all safety precautions on labels.

Management of diseases

Maize is vulnerable to a number of diseases that reduce yield and quality. Leaf diseases reduce the photosynthetic area of the plant and limit the production of sugars, which in turn reduces grain fill in the ears. Ear and kernel rots decrease both yield and quality and, in some instances, can produce harmful toxins such as aflatoxin, fumonisin, and vomitoxin. Root and stalk rots disease can cause premature dying of plants.

Diseases of maize, like those of other crops, vary in incidence and severity from year to year and from one locality or field to another. Overall, disease levels will depend on the presence of the pathogen, weather and soil conditions, and the relative resistance or susceptibility of the maize variety. Even when the proper combination of disease-causing organisms and favorable environmental conditions are present, only limited disease losses will occur if the maize variety is tolerant or resistant.

The potential for disease epidemics is always present. One cause is genetic uniformity, typified by single cross hybrids. Another potential is the intensive cultivation of maize resulting from continuous cropping, higher plant populations and heavy fertilizer applications to achieve maximum yields. Changes in tillage operations from conventional tillage to various reduced or no-till systems has also allowed some pathogens such as the one causing gray leaf spot to become more firmly established. Control and management methods of various maize diseases is as summarized in Table 6.

Table 6. Major maize diseases in Tanzania and their management.

Disease and Cause	Symptoms	Occurrence	Management
Gray leaf spot (GLS)  A foliar fungal disease caused by fungal pathogens *Cercospora zeae*-maydis and *Cercospora zeina*.	Symptoms develop on lowest leaves first and progress upward. Pinpoint lesions surrounded by a yellow halo appear first. These elongate into pale brown or gray rectangular lesions 0.2 to 2.0 inches in size. Entire leaves may become blighted.	The disease survives in infested debris. Initial infections occur in early in one to 2 months in the season. Cloudy weather, accompanied by prolonged periods of leaf wetness and high humidity favor disease development. Severe damage often occurs in low spots or in fields bordered by trees or streams where air circulation is poor.	Use a rotation long enough to eliminate corn debris or use tillage. Many partially resistant hybrids are available. Use fungicides when the economic threshold is exceeded.
Head smut ***Sphacelotheca reiliana***  Caused by soil borne smut fungus *Sporisorium reilianum*	Tassels and ears of infected plants are often replaced by smut sori. On tassels, individual spikelets may be infected. Ears are usually entirely aborted.	Infection occurs in seedlings and the fungus grows systemically into the reproductive parts of the plant. Temperatures of 70 to 82 degrees Fahrenheit and low soil moisture favor infection.	The disease is effectively controlled by resistant hybrids. Planting early and use of systemic fungicide seed treatments are partially effective.

Fusarium ear rot Caused by soil borne fungi *Fusarium verticillioides* 	Usually, individual or groups of infected kernels are scattered on the entire ear. A whitish fungal growth on kernels is typical. Infected kernels often exhibit a "starburst" pattern, i.e. white streaks radiating from the point of silk attachment at the cap of the kernel.	The disease is most common in continuous maize. *F. verticillioides*, produce large numbers of microconidia and macroconidia on crop maize debris and these asexual spores comprise the most important inoculum for Fusarium ear rot. Infection takes place through the silks.	Balanced moisture and fertility and control of insects that damage Kernels reduce the severity of the disease.
Maize leaf blight Caused by the fungus *Exserohilum turcicum* 	Gray green, elliptical or cigar-shaped lesions that are 1 to 6 inches long appear on oldest leaves first and progress upward. Lesions become tan as they mature.	The disease is most common in continuous maize where crop debris remains on the surface. Temperatures of 65 to 80 degrees Fahrenheit and extended periods of dew favor infection.	Resistant hybrids. Use rotation or tillage to eliminate crop debris.

Harvesting and post-harvest management

Maize should be harvested as early as possible to reduce in-field losses. In dry areas maize could be allowed to dry on the field before harvesting. If left in the field to dry, the crop is ready for harvesting when cobs start dropping as shown in Figure 16.

Figure 16. Maize cobs in a field of dried maize plants ready for harvesting. Photo credit: Frederick Baijukya/IITA.

Before harvesting, it is important to ensure availability of all the necessary equipment for harvest and post-harvest, shelling, shelling and drying. For more details on the best ways to harvest, shell, dry and store maize, please read our books in this series by Mutungi et al., 2019.

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