Soil fertility management in Babati: A practical guide on good agricultural management practices in smallholder farming systems

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Foreword

Working with farmers and extension staff within the Ministry of Agriculture and interactions with broad range of researchers across national research and CGIAR Centers operating in Northern Tanzania resulted in a wealth of experience and knowledge that we bring forward in this guide. We have observed wide yield gaps across farms and experienced first-hand key challenges faced by farmers as we worked in their fields, interacted in field days, participatory technology evaluations, exchange visits and brainstorming meetings with farmers. High attainable yields observed by some individual farmers and researchers in experimental and demonstration trials clearly demonstrate potential of applying simple agronomic and other supporting practices to change fortunes of farmers. This is what inspired this guide. Although expressed through simple illustrations and language, most of the data and information are generated through rigorous scientific and data analysis approaches to ensure accuracy of the information. The guide, a knowledge intensive resource, brings together key messages from 6 years of International Center for Tropical Agriculture's (CIAT) operations in Babati and is a valuable management tool for farmers. It is also an essential reference tool for local agricultural extension and other stakeholders involved in the field of agriculture.

The agricultural extension staff reviewed this guide during a workshop held on 17 June 2019 in Babati. These staff included: Jetrida Kyekaka, the District Agriculture, Irrigation and Cooperative Officer (DAICO); Rose Pallangjo, Jonus Masamu and Paulo Tarmo, the District Extension Officers; and Adelta Macha, an extension officer in Gallapo village.

"The field guide brings awakening to all extension"

said Rose Pallangyo a local agricultural extension in Babati during the review of the guide.

"Our minds of agricultural and extension will remain even after we are gone"

added Jonus Masamu a field extension officer Babati.

"This guide is an essential reference tool for stakeholders involved in the field of agriculture and also extension agents posted from regions where different crops types such as cotton and rice are grown to the maize producing areas of Babati. In addition, the guide will help us in explaining appropriate technologies for use by farmers in Babati and elsewhere with similar agro-ecological zones".

DAICO

List of abbreviations

CA Conservation agriculture

CGIAR A global research partnership for a food-secure future

CIAT International Center for Tropical Agriculture

DAICO District Agriculture, Irrigation and Cooperative Officer

GAP Good agricultural practices

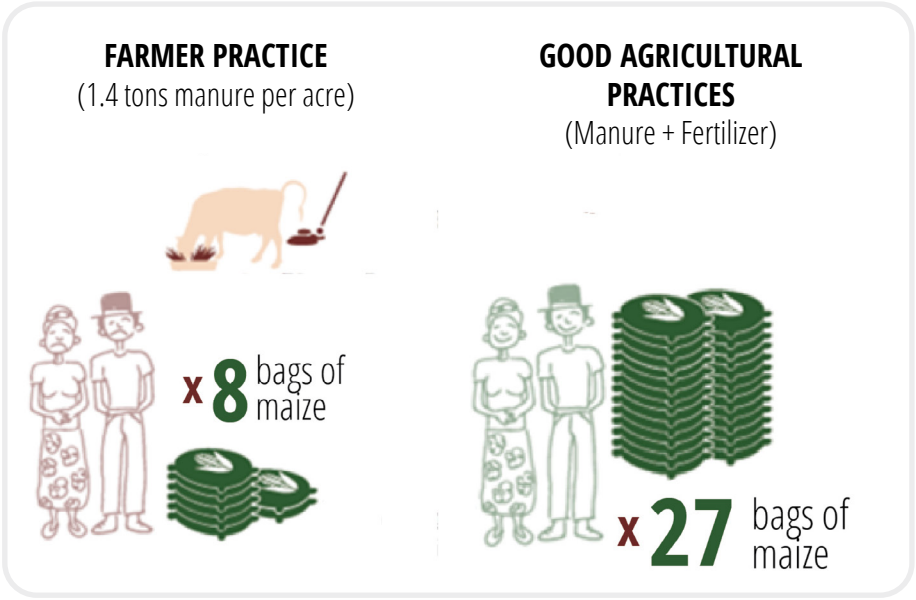
MoA Ministry of Agriculture

QDS Quality declared seeds

TARI Tanzania Agricultural Research Institute

Yield gap challenge

Babati has a huge agricultural production potential reaching up to 35-40 bags per acre for maize grain. However, production is still low due to soil fertility decline and use of poor soil management practices. For the last three years, variable weather, as a result of climate change, has been a major challenge to field crop production. For example, the onset of rains is experienced either earlier or later than the usual time. Employment of good agronomic practices in a time of changing weather can greatly enhance nutrient management and increase yields. It is through good management practices (GAP) that crop yields, for example maize, can be raised from the current 8 bags per acre in fields where manure is applied as the only fertilizer input to as much as 27 bags where GAP is practiced. Besides, adopting GAP can increase pigeon pea yields from the current 2-3 bags per acre under farmer practices to about 5-7 bags per acre under mixed cropping systems.

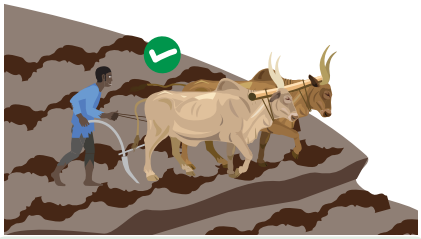


Improving the agronomic practices requires knowledge to ensure that the management practices applied in the field enhance nutrient conservation and crop growth. Observe the following specific management to achieve the increased yields.

Land preparation

Prepare your land on time to ensure other field operations like planting are not delayed. Timeliness also enhance better utilization of soil moisture. If the field has to be tilled, it's important to consider the alignment of the slope. Plowing across the contour (up and down) should be avoided to minimize soil erosion. Plowing down the slope transfers essential plant nutrients and deposits them on fields located down the slope i.e., flat fields and sometimes to dams, lakes and the ocean. Ploughing along the contours helps to increase water infiltration and resist soil erosion. If the breadth of your field is narrow and ploughing along the contour is uneconomical, adopt conservation agricultural practices (CA) or use hand hoe instead of tractor to plough. It is important to avoid land degradation because it requires great effort and time to correct. In a season, agricultural fields experiencing soil degradation may produce 4 bags per acre lower than non-degraded maize fields.

Tilling the land along the slope (up and down) is a bad practice that encourages soil degradation

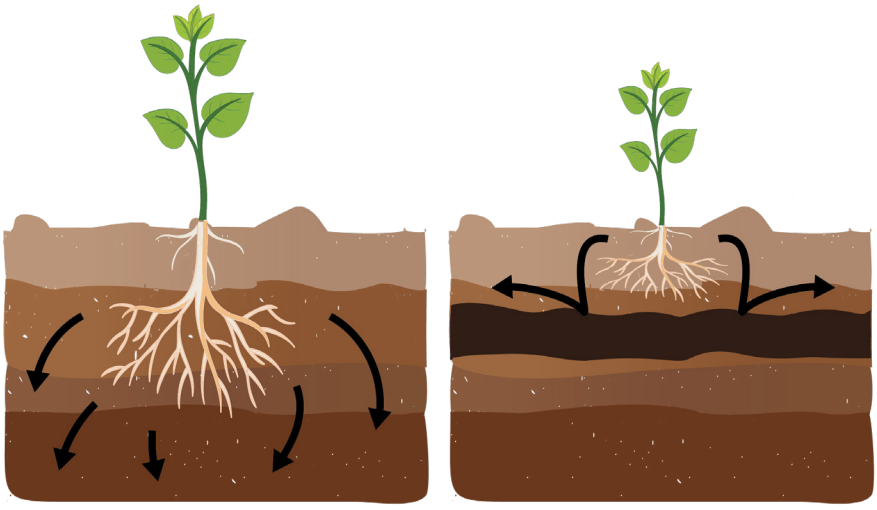


Tilling the land across the slope is a good practice that controls land degradation

Avoid tillage of soils during wet conditions. Tilling wet soils and post-harvest grazing increases soil compaction by the heavy weight of the machines and/or trampling by animals. This may prevent plant roots from reaching out for nutrients deposited in the lower soil layers.

Plants growing on soil that allows root penetration to the lower soil depth

Plants growing on a hard pan that prevents downward growth of roots



Seed choice

Use certified maize seeds to improve crop production and increase income. Seeds obtained from grains of the previous season's crop and those from local seeds reduce maize grain yield by up to 2 bags per acre compared to improved seeds. Besides they may carry pest and disease causing vectors which could later attack the growing plants. Such attack can result to crop loss and damage.

Plants improved seeds increases maize yields by 2 bags per acre compared to recycled seeds

Shelling maize cobs derived from the previous season's harvest leads to 2 bags lesser grain than certified seeds

For pigeon pea and beans, contact your extension agent for advice on where to get quality planting seeds. Quality declared seeds (QDS) have better growth and yields higher than local seeds. If you use QDS for beans, recycle for maximum 2 years. This is due to increase in pests and diseases, inter-variety mixing and loss of seed viability. Avoid using seeds from fields that had symptoms of pest and disease attack to avoid spreading and experiencing yield losses. To easily access QDS, hybrid seeds and other inputs, you will succeed better in groups (see section on "Working in groups").

Spacing

Maintain correct spacing to achieve higher productivity of land, labour and other inputs. Plant spacing will vary depending on the technology being practiced, crop variety, field characteristics and cropping systems i.e., whether pure crop or intercrops. For appropriate spacing, please contact your local extension officer. Planting behind a tractor or animal-drawn plough results to lower plant densities with maize grain yield reduction of approximately 4 bags per acre. This is because of the difficulty in controlling the amount of soil covering the seeds hence reduced germination.

A farmer planting behind an animal drawn plough often leads to poor crop spacing

Low and uneven plant density a characteristic of many farmer fields

Appropriate plant spacing results to achieving the right plant densities, reduces light, moisture and nutrient competition and increases crop yields. Planters can be used to achieve the required density. If you have no access to a planter for hire, increase the number of persons planting so they do not work in a hurry and miss the spacing. Seeds can be carefully placed on the upper surface of the ploughed soil to ensure a light soil cover that eases germination. Also, use drivers of tractors and animal ploughs with capability to maintain spacing of rows consistently. In addition, more seeds can be applied and latter thinned to attain the appropriate plant density after germination. Seeds are expensive so be careful with the use of multiple seeds per hole.

A farmer discussing plant distances with the extension officer

Planting

Plant across the slope and not along the slope. This is because during weeding, soil on fields planted along the slope is moved downslope. Timely planting is important to enhance germination and increase overall production. Early planted crops are able to utilize nitrogen flush (nitrogen available in the soil after rains succeeds a long dry period) which is mostly used by weeds in late planted fields.

A farmer planting while the neighboring fields have maize almost knee high

Besides, late planting can cause up to 100 kg per acre loss or even total crop loss depending on the season.

Delayed planting leads to reduced grain yields of up to 100kg per acre

Early planting leads to increased yields

Plant different species and varieties of crops to minimize the risk of weather variability. Stagger planting dates to reduce the threat of crop failure. Instead of just pure beans, use the new technology of doubled-up legume. In this system, you get 3 bags of pigeon pea on top of your normal beans, and you have benefits of extended soil cover.

Crop diversification and use of doubled up legume technology, intecropping pigeon pea with beans, to increase legume production

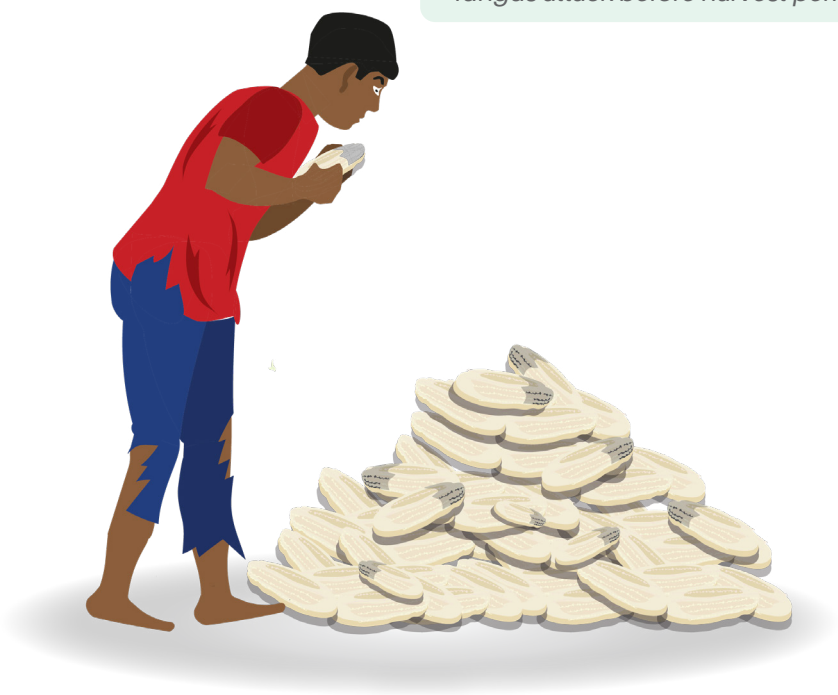
Beware of maize lethal necrosis. Maize lethal necrosis is a disease that causes complete yield loss on late planted crops. To evade the attack by maize lethal necrosis (MLN) avoid late planting.

Timely planting leads to vigorously growing plants

Late planting exposes the crop to attack by diseases i.e., Maize Lethal Necrosis

Delayed planting also increases maize vulnerability to cob rot, pest (i.e., stalk borers) and disease (i.e., maize smut) attack associated to stress during growth. Affected maize may result to yield loss of up to 1 bag per acre.

Late planted maize with several rotten cobs due to opportunistic fungus attack before harvest period



Make use of weather forecasts in farming. Utilizing the meteorological information on the local weather forecasts helps in making decisions on seed variety choice for a specific season. You also make better choices of planting time and best period for top dressing when you use forecasts.

A household listening to news on seasonal weather

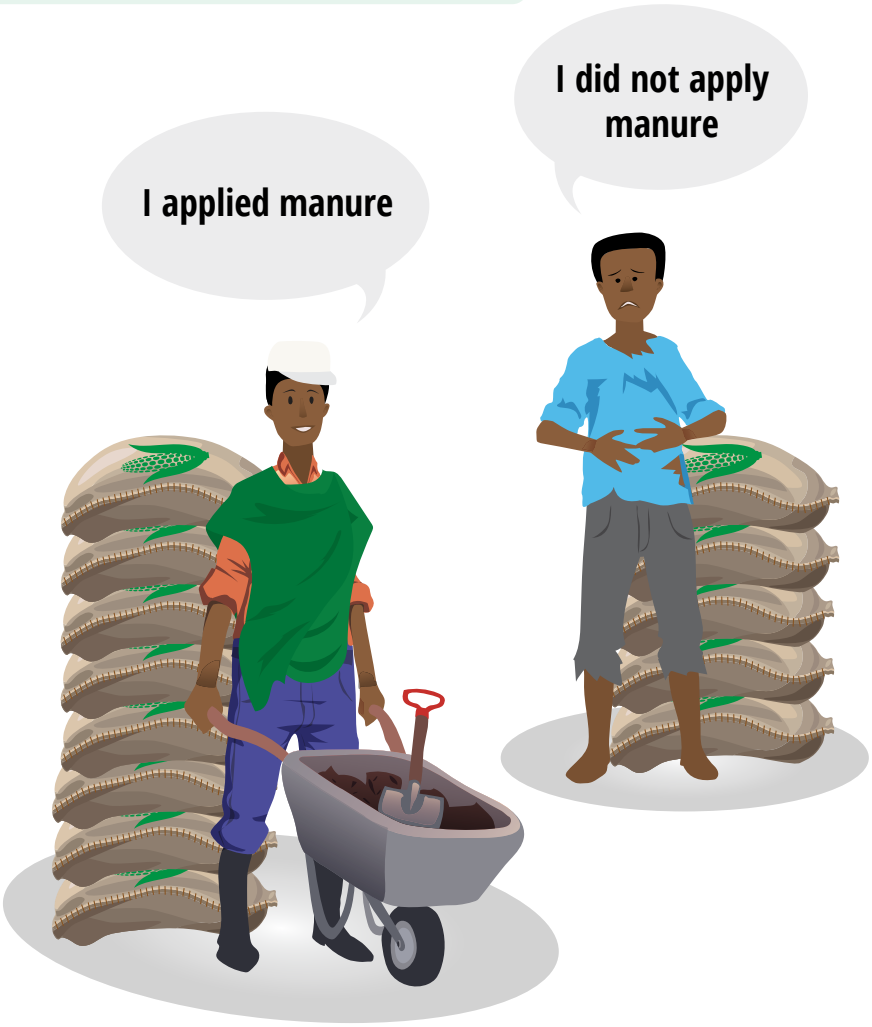
Use early maturing maize varieties in fields where planting is delayed. The early maturity trait of such varieties ensure that growth, maturity and yields are not affected by reduced rainfall amounts and distribution. If attack by maize lethal necrosis is foreseen, due to delays in planting, substitute maize with legumes like beans, cowpea, green grams, chick pea and lablab.

A field with maize of a height slightly above the knee adjacent to a portion of field having young beans.

Manure application

A well composted manure is important for increasing soil fertility through enhanced ability to hold beneficial plant nutrients, improves soil moisture holding capacity, structure and the soil health i.e., enhanced soil biodiversity. Manure application is not only important for resource poor farmers with limited ability to purchase inorganic fertilizers but also the resource endowed farmers. To improve crop productivity, always apply a well composted manure (See section on composting tips). A ton of well composted manure contains 28 kg of nitrogen and 11.2 kg of phosphorus. This is way higher than a ton of poorly composted manure which contain 4.2 kg of nitrogen and 1.4 kg of phosphorus. Contact of seeds and manure that is not well composted can result to destruction/ "burning". During a good crop season, manure applied fields obtain as much as 3 bags per acre more maize grain yield than those without manure. During the application process, ensure that manure is evenly broadcasted and immediately incorporated to avoid nutrient losses. If the manure is to be applied in the planting hills, as a precaution, avoid its contact with the seeds *(see illustration on fertilizer application).*

Manure applied fields produce up to 3 bags more than those without manure



It is not just manure application but also the application frequency that is important. Increased manure application frequency can be achieved through splitting manure doses over time. For example, applying 1.4 tons of manure per acre for two successive years is better than onetime application of 2.8 tons of manure per acre for only one year. If you have manure amounts above 1.4 tons, spread the extra manure to the other portions of the field. This will help to increase manure application frequency rather than quantity. Fields applied with manure more frequently (e.g. at least two times for every five seasons) produce about 3.6 bags per acre more than those with lesser intervals.

Splitting manure doses to increase application frequency

Organic resource transfer

Conserve soil nutrients in the cultivated fields by improving the organic matter content. Fields located far away from the homestead are disadvantaged because resources are extracted with little return. In addition, farmers with few or no livestock give away crop residues to those with more livestock. The manure generated, after crop residue imports, is applied to home fields of high livestock owning farmers. Such fields produce 5 bags per acre more grain than the distant fields. To avoid compromising your fields through residue transfers, remove the quantities sufficient to feed the livestock and leave the rest to help in improving field fertility.

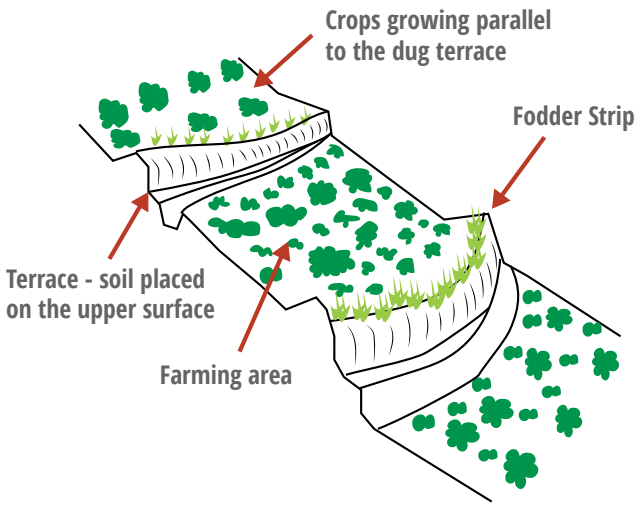
Ox-cart full of residues being transported off the farm

Adopt cereal-legume intercropping because after defoliation, a lot of biomass remains in the field as a soil cover. Cover crops like lablab, chick peas and pumpkins help to compensate for the residue removed after maize harvesting. Be careful not to allow animal grazing on the cover crops. This is because the expected soil conservation benefits derived from use of cover crops may not be achieved.

Soil conservation

Both gentle and steep slopes undergo continuous soil erosion if conservation measures are absent. The nutrient enriched soils are later deposited on bottom lands which are more fertile and produce up to 5 bags per acre more than fields on steep and gentle slopes. Preference for manure application should be given to sloppy lands over the bottom lands. Also, patches of land with signs of infertility require manuring.

Use soil and water conservation measures to reduce the amount of nutrients being lost from agricultural fields. The soil conservation measures include: terraces, grass strips, conservation agriculture and utilization of micro-catchments such as tied ridges. Construct terraces across the slope to obstruct surface runoff. To stabilize the bunds, combine "Fanya juu terrace" with strips of napier or agroforestry trees/shrubs e.g. leucaena, grevillea and acacia species with reduced canopy. Improved napier accessions are available in Babati.

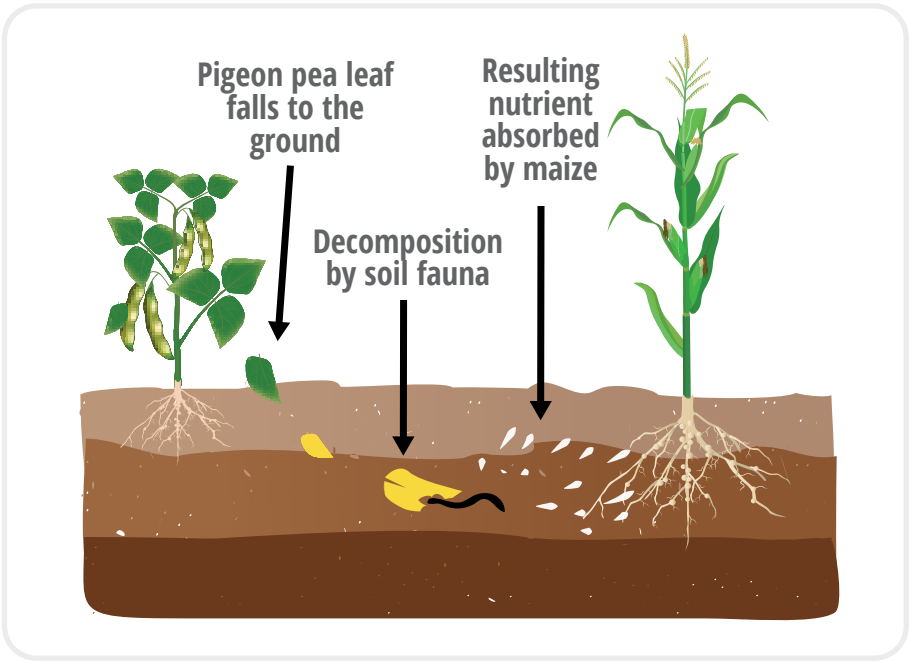


Adopt conservation agriculture for long-term stability of crop production and soil conservation. Conservation agriculture involves minimal soil disturbance, maintaining at least 30% of permanent organic mulch/cover crops and crop rotations. Supplement maize residues with cover crops such as cowpea and lablab for mulch/ soil cover.

Integration of grass strips and conservation agriculture using cover crops and maize stubble

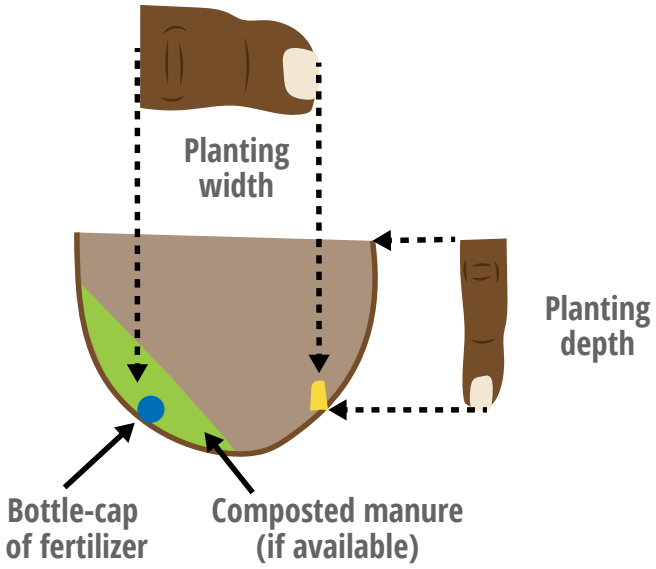
Utilizing locally available crops to improve soil fertility

Intercropping such as maize/pigeon pea system is important for improving soil nutrient content and crop yields. This is because pigeon pea leaves that fall during the growing period decompose and enrich the soil. Legumes fix nitrogen from the air which is used by consecutive cereal crop thus improving yields. Repeated use of same crop combinations such as the maize/pigeon pea intercropping may result to build-up of pests and diseases. However, rotations (even of intercropping systems) breaks pest and disease cycles. Exercise intercropping of cereals and legumes, and rotations, to achieve these benefits. If not possible to rotate, prepare the land early or plant a cover crop during the long fallow period.



Fertilizer application

Apply fertilizers to increase crop production. A rate of 50 kg N ha^{-1} and about 20 kg P ha^{-1} is recommended by Africa RISING for maize for soils in Babati. Sources of phosphorus include DAP and minjingu fertilizers while urea is a good source of nitrogen. After fertilizer application, apply a light soil cover to prevent nitrogen loss into the air. Fertilizer placement has to be away from seeds or seedlings for good germination. In soil that are not much depleted of fertility, foliar application of fertilizer blends containing micronutrients can improve crop yields.



While phosphorus is applied during planting, nitrogen is applied after germination, usually in splits at 4 and 8 week after planting i.e., after 6 and 11 fully expanded leaves. Splitting fertilizer

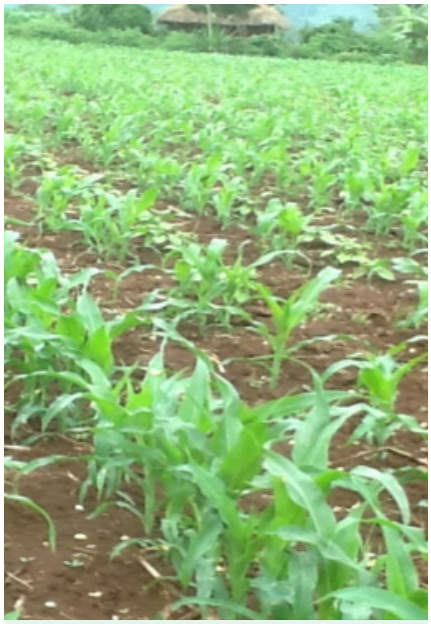
application enables better utilization of nitrogen. Nitrogen is quite mobile (meaning it can be easily lost in the soil), not like phosphorus and potassium that is available in the soil for a longer time, and that's why a split application is necessary. Apply nitrogen fertilizers when the soil is moist. Fertilizer applied to dry soils do not dissolve and nitrogen can be lost to the atmosphere. Application of nitrogen fertilizer needs to be timely. Late application may coincide with growth stages when crops may not utilize it.

Topdressing knee high maize with fertilizer placement being a few centimeters from the plants

Weeding

Ensure the fields are regularly weeded during the crop growing period. Weeds shade and compete for nutrients with the young developing crops. Besides, they act as breeding sites for pests and disease which may later cause crop damage and reduce yields. Timely weeding is important to avoid yield reduction or loss. Weeding twice is sufficient for a good crop in Babati especially when the season is good. If you decide to use herbicides, be careful not to damage the intercropped legumes.

A weed affected field with weak, yellowish plants



Weed free field with vigorous growing green plants

Slash the weeds after harvesting maize to reduce competition with pigeon pea. After slashing, leave the weeds on the soil surface to minimize the severity of pigeon pea damage by termite. The surface laid weeds act as alternative feed for the termites.

Pest and disease control

Pest and diseases reduce crop productivity. Different organic and inorganic measures can be applied to control attack and spread of pest and diseases in the crop fields. These measures include: application of pesticides which are readily available in Babati agro-vets e.g., Multi-alpha plus, Snow crone, Karate, Attakan C and Phytotech immediately the signs of attack are identified to control fall army worm, aphids and leaf miners in maize, beans and pigeon pea. Besides, spraying Karate and Ninja at the initiation of flowering can control damage by pod borers. Common diseases limiting crop yields include: fusarium wilt, maize smut and maize streak.

• • • •

"In 2017, up to 35% pigeon pea damage by fusarium in a farmer field in Babati was observed"

Jonus Julius, district agricultural officer.

Fusarium wilt attack on pigeon pea has increased in Babati in recent years. The disease can be controlled by application of fungicides e.g. Chariot and Gearlock Turbo. Application of Optimizer during the flowering stage can help in minimizing flower abortion.

Cultural methods that can help to control pests and diseases include: early planting to control fall army worm, stock borers, maize smut and maize streak, early thinning of sickly plants which act as refuge and breeding grounds to minimize spread, crop rotation to break pest and disease cycles and use of seeds that are resistant to pests and diseases. Moreover, using GAPs i.e.,

fertilizers, and timely weeding can help to avoid expenses on agrochemicals.

Generally, for pest and disease management:

- Use appropriate chemicals
- Ensure timely pests and diseases control (when signs and symptoms are identified)
- Follow the prescribed procedures during agro-chemical mixing

Maize attack by fall army worm

During chemical applications, beware to:

- Wear protective clothing
- Observe wind drifts i.e., spray facing away from the wind source
- Spray in early mornings or late evenings
- Don't smoke while spraying
- Wash hands before eating

Crop harvesting and post-harvest management

Timely harvesting is important to prevent pest attacks in the field. Crop varieties/species with open tops encourage fungus attack which may continue even after harvest. Harvest your crops when the moisture content is at manageable levels to prevent post-harvest damage. Reduced grain moisture (less than 13%) inhibits the development of moulds and growth of fungi such as *Aspergillus flavus* which causes aflatoxin poisoning. Aflatoxin is a

serious problem that affects the liver results in cancer in humans and contaminates animal products e.g. milk when consumed by livestock. Dispose of the affected grains because they are not fit for both human and livestock consumption. Besides, the affected grains must not be used for making local brews. If impossible to wait for grains to dry while in the field, the produce can be harvested and occasionally sun-dried to appropriate moisture content. After threshing and/or shelling of cereal and legumes, remove broken grains and treat clean grains to prevent pest damage during storage. The grains can also be stored in air tight containers or bags to avoid post-harvest attack.

Damaged cobs due to poor post-harvest handling

Delayed crop harvests may result to shuttering hence wastage of cereal and legume grains. Maize may suffer termite attack while in the field. Late harvesting of maize may also reduce canopy development hence reducing productivity of the intercropped pigeon peas. Besides the loss in quantity of the harvested grains, their quality can be compromised making them unsuitable for human consumption.

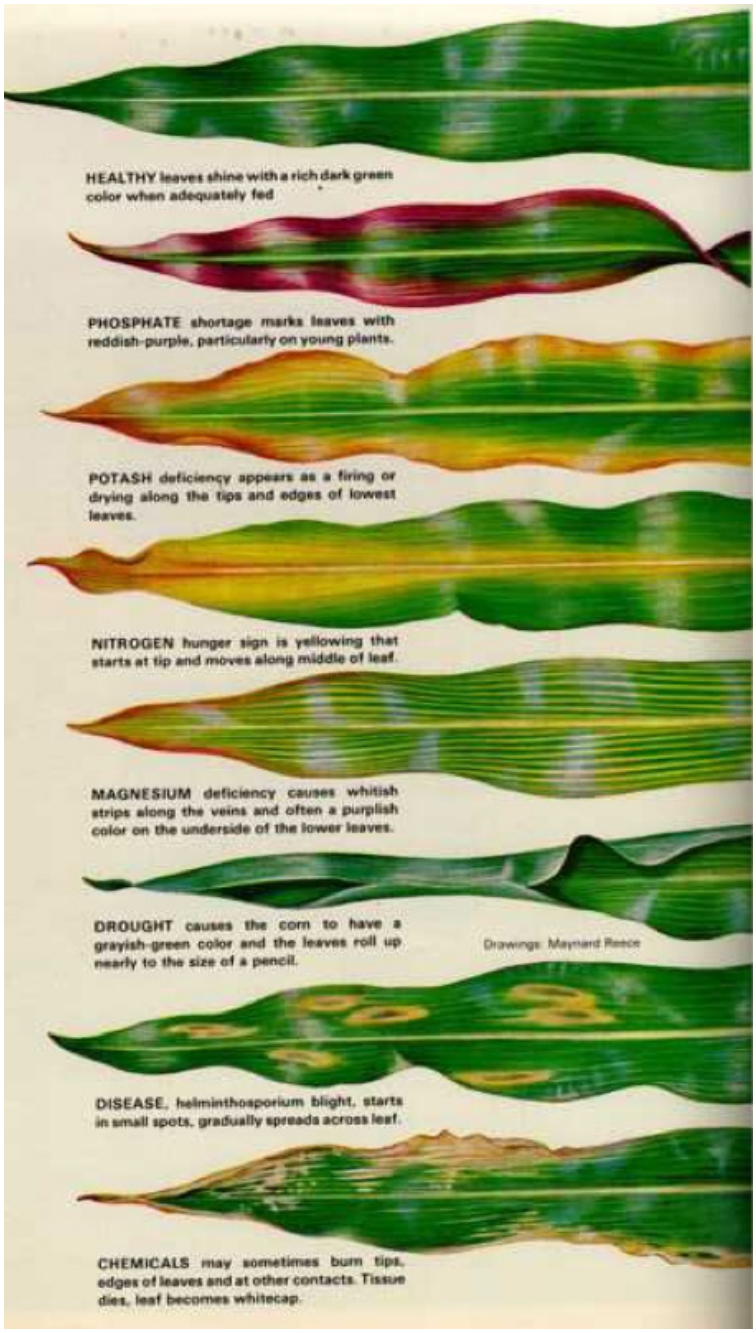
Working in farmer groups/organizations

Operate in farmer groups and local cooperative unions. If none of these exists, mobilize other farmers to form groups. Farmer groups helps to:

- Transform smallholder farming through improved production and incomes
- Increase farmer interaction and learning new innovations from peers
- Improve farmers' access by local agricultural extension for service delivery unlike the individuals
- Farmers share information and experiences on potential markets for their produce
- Improves farmer access to agricultural inputs, credits, government subsidies and donor funding
- Increases farmers' bargaining power for their produce
- Evade exploitation by brokers and middlemen due to direct access to market of produce
- Strengthen/build social capital

Visual limiting nutrient deficiency diagnosis

You can visually diagnose soil nutrient deficiency, moisture stress and disease attack by looking at the growth characteristics and patterns in vegetative organs of crops. Early detection of the symptoms helps to offer solutions before severe damage occur to crops. In maize, the colour of the leaves and the growth pattern may help to diagnosis the source of plant stress. Use the illustration below to guide you in detecting stress emanating from nutrient deficiency, drought and diseases in maize plants.


HEALTHY leaves shine with a rich dark green color when adequately fed
PHOSPHATE shortage marks leaves with reddish-purple, particularly on young plants.
POTASH deficiency appears as a firing or drying along the tips and edges of lowest leaves.
NITROGEN hunger sign is yellowing that starts at tip and moves along middle of leaf.
MAGNESIUM deficiency causes whitish strips along the veins and often a purplish color on the underside of the lower leaves.
DROUGHT causes the corn to have a grayish-green color and the leaves roll up nearly to the size of a pencil.
Drawings: Maynard Reece
DISEASE, helminthosporium blight, starts in small spots, gradually spreads across leaf.
CHEMICALS may sometimes burn tips, edges of leaves and at other contacts. Tissue dies, leaf becomes whitecap.

Manure composting tips

A well composted manure can be obtained through pit and heap methods of preparation. The following are some general tips for composting:

1. Make compost using the materials available to you. For details about the process, enquire from your extension agent
2. After gathering all the composting materials i.e., poultry droppings, cattle dung, vegetable residues, kitchen wastes, and maize stubble, make compost layers e.g.
    a. Spread the dry material evenly at the base to about 0.5–1 foot. Moisten by sprinkling water.
    b. Make a layer of fresh and moist (green) material such as leaves and weeds but for this do not sprinkle water
    c. Add a layer of fresh manure of about 5–10 cm thick
3. Continue adding more layers in the same arrangement as described above. The layers should make a gentle slope such that the middle is higher than the sides until the heap is 1–1.5 metres high
4. Stir up the pile on monthly basis, mixing all the layers, while sprinkling water to make it moist, but not wet
5. Drive a few ventilation sticks into the heap to test the level of heating and test if the heap is decomposing well
6. Cover the compost heap especially during hot weather to avoid volatilization and in rainy season to avoid excessive wetting that slows composting process
7. Check for compost maturity using a stick. Bad smell indicates decomposition is not going on well. Matured compost has a darkish brown colour and can be mistaken with soil.

The length of composting depends on the materials used. For continuity, make a series of heaps depending on the size of farmlands to be applied and to supply ready manure at different times.

Acknowledgement

The knowledge contained in this guide is generated during implementation of Africa RISING project in Babati. We appreciate all the partners such as CGIAR Centers working in Babati district, Selian Agricultural research institute (SARI) and the ministry of Agriculture, Babati. Appreciations to Mr. Isaac Savini, Stephen Limo and Luhenda Yangore for their support during the research. Thanks to CIAT technical staff Inot Songoyani and several district, ward and village level extension officers in Babati for their assistance during data collection and linking us with the farmers to work with. Furthermore, we acknowledge the contribution by our private partners Minjingu Mines & Fertilisers Ltd, Meru Agro-Tours & Consultant Co. Ltd, Aminata Quality Seeds & Consultancy Ltd (AMINATA Seeds) for provision of certified seeds and fertilizers and participation in farmer education forums.

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