INTEGRATED *STRIGA* MANAGEMENT AND MICRODOSING IN SORGHUM: A HOPE PROJECT MANUAL FOR INCREASING SORGHUM PRODUCTIVITY IN EASTERN AFRICA

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PART 1: INTEGRATED STRIGA MANAGEMENT

Introduction

Sorghum is grown in the semi-arid zones of Africa and is an important crop for millions of resource poor farmers in parts of Africa. The crop has several production constraints such as drought, diseases, insect pests, birds and *Striga* weed. *Striga* is one of the major parasitic weeds affecting cereal crops and can cause crop losses of 60-90% depending on infestation. *Striga* is also called a ‘witch weed’ because its damage can be seen even before it emerges above ground. The parasite is very difficult to control because one *Striga* plant has potential to produce more than 20,000 seeds that are capable of remaining dormant and viable in the soil for over 20 years. The fact that seeds come out of dormancy at short and long intervals, makes *Striga* control even more difficult. The most appropriate approach to *Striga* management is use of a combination of control methods and a variety of options are available. These options include cultural, chemical, biological, physical and use of resistant crop varieties.

The biology of *Striga*

Striga thrives in low soil fertility, light sandy soils, low rainfall areas and temperature ranges of 18-40 degrees Celsius. Striga seeds, capable of remaining dormant and viable for up to 20 years, germinates after a short period of moist conditions and is induced by a stimulus produced by the host crop (plant). The *Striga* seed germinates and produces haustoria (root like structures) that penetrate the host roots. The haustoria suck water and nutrients from the host plant to feed the *Striga* plant. Attachment of the *Striga* haustoria to the host plant may start as early as two weeks after sorghum germinates (see Annex 3 for life cycle). It takes about 5 to 8 weeks after germination for the *Striga* plants to start emerging above ground. Not all shoots of *Striga* emerge hence the actual degree of infestation may remain invisible until most damage has already been done. *Striga* does not only release phytotoxins to host plant as it germinates, but also drains photosynthates and siphons off nutrients and water from the host plant causing the crop to wither and produce low yields.

The *Striga* plant is a hairy, single stem or branched annual herb that may grow from a few centimeters to over a meter. All species have opposite leaves and a reduced root system. Flowering occurs about one month after emergence with seeds maturing in 2-4 weeks. Flowers are red, yellow, white, pink or bluish depending on species. The most common *Striga* species parasitic to sorghum and finger millet in eastern and southern Africa, *S. asiatica* and *S. hermonthica* have red and pink flowers, respectively (Annex 1). Flowering and fruiting may continue until the host plant dies and the full life cycle of *Striga* is 3 to 4 months. The small *Striga* seeds (270 million in 1 kg) are easily spread by wind, water or animals and through use of infested tools and contaminated seed. A single plant may produce 20,000 seeds (VASATwiki 2007). Plants affected by *Striga* are stunted with wilted yellow leaves (Annex 2). Most of the damage is done before *Striga* emerges from the ground.

Integrated *Striga* Management (ISM)

Integrated *Striga* management involves using a combination of complimentary cultural, chemical, biological, physical and resistant crop varieties as measures for *Striga* control. To select suitable combination of practices for *Striga* control, the following have to be taken into consideration:

- Knowledge of *Striga* species popular in the region, their development and invading behavior
- Monitoring and mapping *Striga* spread and damage
- Control decisions based on potential damage, cost of control methods and effectiveness
- Evaluation of the effectiveness of the available control methods
- Importance of combining control methods to reduce *Striga* population and damage

A diversity of control measures that have been known to be effective in control of *Striga* weed are described below.

Preventive control

This strategy aims at preventing the introduction of *Striga* seeds into the cropping fields and include the following measures.

- *Striga* seeds, which are tiny and dusty, are easily blown by wind from one place to another and sometimes from field to field. Wind speed can be reduced by use of wind breaks.
- *Striga* seed that falls onto the soil after crop harvesting may be carried on the feet of humans and draught animals from one field to another and this way introduce the seed to *Striga* free fields. This can be avoided by cleaning feet before people enter uninfested fields. Livestock should not be allowed to move from infested fields to *Striga* free fields when soils are wet.
- Sowing only certified/clean crop seed with most minimum level of allowable tolerance to weed seeds, including *Striga* seed. Where farmers use own seed, seed should be harvested separately and be processed in a way that does not allow contamination by *Striga* seed.
- Before farm machinery, tools and vehicles are moved from *Striga* infested fields, they should have all soil and clogs washed off to avoid moving weed seed to an un-infested field.
- *Striga* weeds should be removed from the field before they produce seed.
- If animal manure is used, it should be left to rot well to kill any weed seeds in it. To expedite this process some N fertilizer can be sprinkled on it. The manure should also be turned now and then and water sprinkled on it in dry years.

Physical *Striga* control

This control method refers to physical removal of *Striga* plants through ***manual and mechanical methods***. *Striga* control using these methods need to be done repeatedly.

Manual control

This involves using hands or hand tools to remove *Striga* plants. It is a useful method where farms are small and in medium and large size farms where labor is readily available. Hand pulling should be done prior to flowering of *Striga* plants and should continue through to harvest period of the affected crop.

Benefits of *Striga* control by hand may not be realized in the season as damage is done before emerging above ground but benefits may be realized in subsequent seasons as the below ground *Striga* seed bank is gradually depleted.

Mechanical control

This involves use of hand tools, machinery, such as mowers and tractor slashers to remove weeds. This method also includes some types of cultivators that bury the *Striga* plants deep under the soil to prevent their re-growth.

Mulching

In using mulch care should be taken regarding the type of mulch to be used and how it should be applied. Most mulches are organic in nature, so they will nourish the soil while suppressing weeds and maintaining good soil moisture level. The mulch can be in form of straw or compost. A layer of 20-30 cm thick mulch is necessary to prevent light from reaching the germinating *Striga*.

Burning

Burning, done after the sorghum crop is harvested, is a traditional form of ***thermal weed control,*** which is effective in reducing the number of viable *Striga* seeds that return to the soil after harvesting. There should be enough stubble to create an excess of 200°C for about 20 to 30 seconds. Burning can reduce the viability of *Striga* seeds in the soil by up to 70 %.

Cultural control

This refers to use of one or more field management practices to control *Striga* in a sorghum field.

Crop rotation

This is one of the most important *Striga* control strategies. This strategy avoids long runs of cropping sorghum or other cereals on the same field. Cultivation of same host cereal or related host cereals on the same field in succeeding seasons sustains *Striga* establishment. Different crops, therefore, are used in a rotation to disrupt *Striga* weed germination and to break growth cycle of the parasitic weed. Cereal rotation with field legumes such as soybean, desmodium, cotton, groundnuts, sesame, pigeonpea, sunflower and lablab, which are able to suppress *Striga* by inducing its germination but do not facilitate root attachment to the false host (Khan et al. 2005), result in death of the parasitic weed.

Crop establishment

A well-managed crop has the ability to compete well with *Striga* and produce a good yield. For a crop to establish well, it has to come from certified or healthy seeds, which give a good start. Good seed from a recommended variety, planted at the right time, using a recommended seed rate, gives a vigorous good start. A resulting vigorous crop is able to compete well with *Striga*. It is reported that crop shading can restrict *Striga* growth when generous fertilizer is applied. In areas of high rainfall, use of high plant populations, recommended fertility levels, and good weed control encourage lush crop growth and shading despite the presence of the parasitic *Striga* weed (VASATwiki 2007). This, however, is not feasible in moisture stressed rain fed areas.

Intercropping

Intercropping refers to the inclusion in the cropping system of crops that are not related to sorghum. The intercrops included usually disrupt the life cycle of the parasitic weed by inducing germination of *Striga* seed but do not support its growth (trap crops of false hosts). Some of the intercrops have the ability to smother *Striga*, while others produce root exudates that prevent germination of *Striga* seed. The following intercropping systems are recommended depending on rainfall and the objective of the farmer.

1. Sorghum: pigeonpeas in 2:1 row ratio
2. Sorghum: soybeans in 2:4 row ratio
3. Sorghum: groundnuts in 2:4 row ratio
4. Sorghum: sunflower in 4:2 row ratio

Nitrogen fertilizer and manures

Crops grown in soils with high fertility are usually more vigorous and resistant to *Striga* attack. Use of fertilizers and manures rich in nitrogen help minimize *Striga* effects. Reduced forms of N, such as urea and ammonium are also capable of tricking *Striga* to germinate in the soil leading to death of *Striga* plantlet as it does not find host roots to attach to (Woldeyesus 2001). Sorghum varieties that are resistant to *Striga* seem to respond better to fertilizer or manure application than susceptible sorghum types.

Resistant varieties

One of the best, reliable and cost effective methods of *Striga* control is the use of sorghum varieties that are resistant to the parasitic weed. A number of sorghum varieties resistant to *Striga* have been developed including Wahi and Hakika, in Tanzania; MALISOR 84-1, SAMSORG 41 , SRN 39, Framida and Wasa in Nigeria and Mali; Hormat, Gubiye and Abshir in Ethiopia and ICSV111IN in Eritrea.

Suicidal germination

In fields not yet planted with a crop, *Striga* seed is induced to germinate by injecting ethylene gas into the soil, which mimics the natural physiological response linked to host recognition. Because no host roots are available, the *Striga* seedlings die (Kamal et al.

2001). Unfortunately, each *Striga* plant can produce tens of thousands of tiny seeds and these can remain dormant in the soil for many years. Thus, such treatments do not remove all seeds from the soil. Moreover, this method is expensive and not generally available to resource poor farmers.

Chemical *Striga* control

Herbicides *Striga* control, considered as a cultural method, is expensive for the resource poor farmer and should only be used where other options have failed or are difficult to use. Herbicides are classified according to their selectivity, mode of action and timing of application.

Pre-emergence herbicides

These are applied into the soil before sorghum is sown or one to two days after it is sown but before weeds emerge. These herbicides have the advantage that they control *Striga* early and minimize competition. It is, however, important to apply them when the soil is moist for greater effectiveness. Examples of pre-emergence herbicides that are able to control *Striga* in sorghum: ***Atrazine, Prometrine***, ***Propazine*** and ***Trifluralin****.* All these herbicides do not kill emerging sorghum seedlings but are effective in pre-emergence control of annual grasses and broad-leaved weeds.

Post-emergence herbicides

These are applied after both the crop and weed seeds have emerged. The advantages of using such herbicides are that they are applied when the type and density of weeds have been observed and they usually do not leave residues in the soil. However, these herbicides are effective when weeds are young and lush. Any new flush of weeds coming out after such a herbicide is applied, are not controlled and application should not be done under rainy and windy conditions. Examples of post-emergence herbicides are*:* ***Bromoxynil*** also called ***Buctril****;* ***2,4-D.*** Post-emergence herbicides are effective against *Striga* that has already emerged out of the soil. By this time *Striga* will have caused some damage to the crop.

Summary of good *Striga* control practices

Use of recommended crop rotation systems and plant populations, *Striga* resistant sorghum varieties, improved soil fertility and soil moisture conservation practices help to maximize crop vigor and shading and minimize effects of *Striga*. Timely and effective weeding of sorghum field in combination with hand pulling of *Striga* prior to flowering will minimize the effect of *Striga* on sorghum production. Further, care should be taken to avoid physical spread of *Striga* seeds through animals, fodder, manure and contaminated soil on tillage tools.

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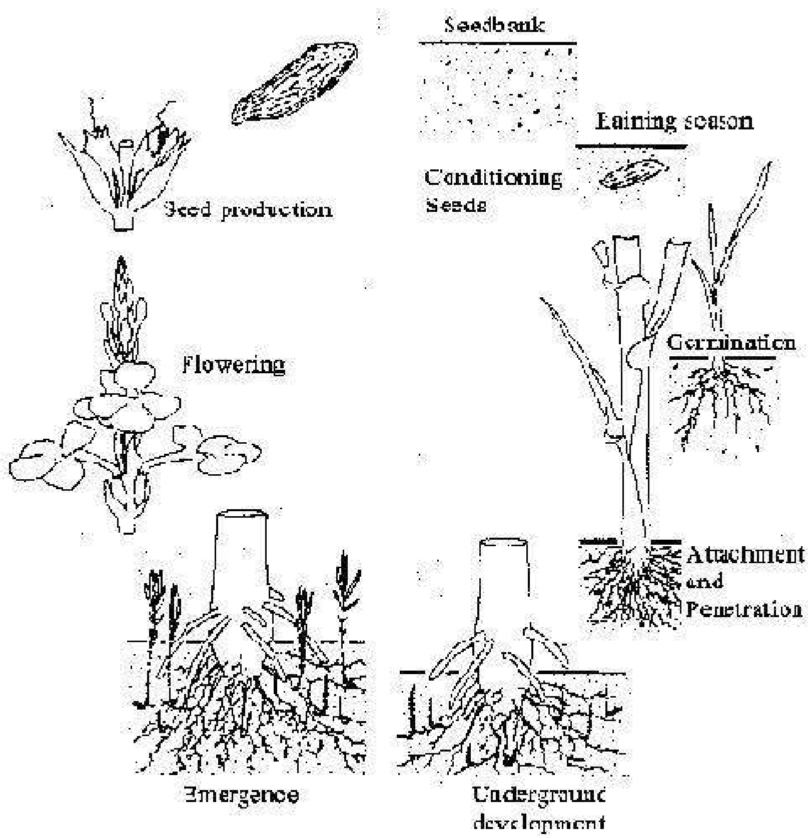
Annex 1: Types of *Striga*

a) Sorghum plant infested by *S. asiatica*

b) Sorghum plant infested by *hermonthica*

Annex 2: Effects of striga on sorghum

Annex 3: *Striga* Life-cycle



PART 2: MICRODOSING IN SORGHUM

Introduction

Sorghum is a coarse grain crop adapted to the dry, moisture deficient conditions of the semi-arid tropics. The crop survives well under these conditions because its well developed root system spreads wide and deep in search of water and nutrients.
Due to its ability to perform well under the above mentioned conditions, it has been accepted by farmers in these areas as the most important food security crop among the cereal crops.

Most soils in the semi-arid tropics are coarse and sandy, draining fast and consequently losing most of the much needed nutrients (N, P, K) for growth. Supplementing these nutrients in the poor soils is essential in order to improve the existing poor yields obtained by farmers. Conventional application of these nutrients, in the form of fertilizers, poses serious risks of crop failure to farmers due to frequent droughts occurring in the dry tropics. Additionally, farmers in these regions are resource poor and cannot afford to purchase and use large amounts of fertilizers. Furthermore, poor market infrastructure reduces farmers' access to input and output markets. Therefore, the combination of frequent droughts, poverty and poor markets has contributed to non-use of fertilizers for crop production by a majority of farmers in the semi-arid tropics. Therefore, scientists have developed more soil water- and nutrient-use efficient sorghum varieties in addition to a method of fertilizer application that ensures use of essential nutrients within the crop zone under low moisture conditions. This method uses small amounts of fertilizers applied into the sowing hole at a rate of a bottle cap full or three-finger pinch per hole. When the soil moisture is adequate, the fertilizer is placed near the seed or seedling and then covered. Application of such small amounts of fertilizer is called microdosing. Where soil moisture extends for longer periods, such small amounts of fertilizers can be as top dressing 20–45 days after sowing sorghum. Fertilizer should be placed 5 cm away from the plant. Microdosing, which has the potential to reduce food insecurity and increase farm incomes, has been able to double farmer sorghum yields in drought-prone tropics.

MICRODOSING SORGHUM

Microdosing is the application of small amounts of fertilizer to a crop by placing it next to a planting hole, seed or seedling when the soil moisture is sufficient. Timing of fertilizer application, with respect to availability of amount of soil-moisture, and placement is critical for success of this system.

Sorghum production and the state of fertilizer use

Sorghum (*Sorghum bicolor* (L.) Moench) is the fifth most important cereal crop after wheat, rice, maize and barley. The crop is grown in over approximately 45 million hectares, producing approximately 60 million tons of grain. It is one of the major food crops in Africa, South Asia and Central America. (Stenhouse JW 1997).

Sorghum, which performs better than maize in dry areas with frequent drought and inherent poor soils, will yield 3 to 4 times more in fertile soils. Poor soils require judicious fertility improvement by the use of fertilizer or organic manures. Ruminant and or compost manures are the best alternatives under the resource poor farmer conditions because they are readily available.

About 40% of farmers in the drought prone areas of sub-Saharan Africa keep cattle, which can supply 60% of the farmers manure requirements (Twomlow S et al. 2008). However, less than 10% of all resource poor farmers in the region use any mineral or organic fertilizers. The bulk of manure produced by their cattle remains unutilized while crop productivity and per capita food production continues to fall sharply due to poor soil fertility. The combined effect of drought and low soil fertility usually results in tremendous losses in crop and income.

Sub-Saharan farmers report bulkiness and un-affordability, respectively, as the main reasons for not using manure and fertilizers routinely. In addition, there are indications that lack of awareness also contributes to low use rate of manures and mineral fertilizers for soil and crop improvement (Hove et al. 2006). The other reason for non-compliance by farmers is that current recommended rates of manures and fertilizers, as high as 30 t ha^{-1} and 300 kg ha^{-1}, respectively, are based on high potential areas and are too high to use in semi-arid drylands where there is high risk of crop failure due to frequent drought. Furthermore, poor marketing infrastructure results in high transaction costs for both inputs and outputs resulting in poor accessibility by most farmers to input and output markets. Therefore, although some adoption of improved crop varieties have been recorded in sub-Saharan Africa, productivity increases have bean minimal due to non- or low-use of fertilizers (Twomlow et al. 2008). ICRISAT scientists, working with national research institution scientists, developed a microdosing system where less than a quarter of the recommended amount of fertilizer (making fertilizer more affordable) is used to increase yields under the conditions of resource-poor farmers.

Why Micro-dose

Soils in the sorghum-growing drought-prone areas of sub-Saharan Africa are deficient in nitrogen (N), phosphorus (P) and sometimes potassium (K). A majority of the farmers are poor and risk-averse and cannot afford to purchase the conventional recommended fertilizer rates. This deficiency, combined with moisture stress, results in very low sorghum productivity, household incomes and food security. Microdosing drastically reduces the amount and cost of fertilizer used in sorghum production while at the same time increases the soil nutrient- and water-use efficiency.

Fertilizers used in microdosing

Fertilizers used in microdosing are those that contain N and/or P. In southern Africa, the following fertilizers have been test-evaluated with promising outcome (Hove et al. 2006):

1. Ammonium nitrate (NH_4NO_3)→ 34% N
2. Calcium Ammonium nitrate (CAN) → 28% N

3. Di-ammonium Phosphate (DAP) → 18% N
4. Urea → 46% N

Method of application

- A small quantity of fertilizer is placed into a hole where sorghum seeds have been dropped, the hole is then covered
- This method is labor intensive but it yields good results because the fertilizer is within the root zone where it can be absorbed by the germinating seeds.
- Alternatively, fertilizer, enough for a specific area of land, is mixed with seed enough for that area shortly before sowing sorghum seed.
- Mixing fertilizer with seed is only done when the soil has enough moisture to sustain germination or else the seed will be desiccated (Twomlow et al. 2006).
- Where a second fertilizer application is necessary, it is applied to sorghum plants 20 to 45 days after sowing.
- It is necessary to ensure that the fertilizer is placed 5 cm away from the plantlets to avoid scorching them.
- The second application of fertilizer is done when the crop has a good stand and is promising, otherwise it can be skipped if drought conditions exist
- In Zimbabwe, sometimes fertilizer is only applied 20 to 40 days after sorghum sowing and placed on soil surface 5 cm away from the plant when the soil is moist.

Application rates

- Rates of application depend on types of fertilizer in use as they possess varying levels of N and P
- Generally, however, a rate of a bottle cap full or three-finger pinch (about 2-3 g of fertilizer) per hill or planting hole planted with 2-4 seeds of sorghum has been known to give good results
- The same rate of fertilizer is applied to sorghum 2 to 3 weeks after sowing as a first application or as a second application
- The application done after planting is on soil surface, 5 cm away from the plants
- This post planting application practice is becoming common in southern Africa (Zimbabwe, Mozambique and Malawi) where good results were obtained by use of a three-finger pinch or bottle cap full of DAP or NPK(16:16:16) per hole at sowing or on the soil surface 20 to 40 days after sowing (Shapiro et al. 1998).
- Using the above prescribed rates, the actual fertilizers used are 60 kg ha^{-1} of AN ; 75 kg ha^{-1} CAN; and 50 kg ha^{-1} of Urea.
- Microdosing using the above rates was able to increase the yields of sorghum by 20% to 80% in the Sudano-Sahelian region of West Africa and in Zimbabwe.

Use of organic fertilizers

As mentioned above, farmers in the drought prone areas of sub-Saharan Africa have access to kraal or compost manures. As the majority cannot afford inorganic fertilizers, use of manure is recommended as it adds some nutrients to the soil as well as improving the general soil structure. Manure, which conserves moisture (Mamu et al. 1991, Bationo et al. 2008), is applied after seedbed preparation and 1-2 weeks before seeding. A handful of well-decomposed manure is placed into a hole where seed will later be dropped. When there is sufficient soil moisture, seeding is done by placing the seed in the hole where manure had been placed earlier followed by placement of inorganic fertilizers and then covering the planting hill. Techniques and type of fertilizer vary depending on soil and climate conditions. For example, where soil is hard, farmers dig planting holes before the rain starts, then fill it with manure. When the rains begin, then they apply fertilizer and sow seed in the hole. This method enhances crop yields dramatically.

Impact of microdosing

Microdosing as a system helps farmers to improve availability of plant nutrients in the soil and to increase crop yields. More than 25,000 farm families in the arid lands of West Africa have doubled their crop yields and incomes by use of improved seeds and strategically applied tiny doses of fertilizer. Microdosing has the potential to reduce widespread food insecurity in drought prone areas of sub-Saharan Africa, where the soil has been vastly degraded. Moreover, it is an innovative technique that could help poor farmers cope with the soaring prices of food and fertilizer.

The system entails timely and strategic application of small doses of inorganic fertilizers in the planting hole to enhance uptake. It, therefore, reduces the risk of fertilizer use. The rates used are small, less costly and therefore affordable to the resource poor farmers. Yield increases of 44% to 120% have been reported in Niger and Zimbabwe. Where microdosing involves the use of small quantities of organic manures, soil structure is improved and moisture conserved.

Crops microdosed perform better under drought conditions, with early season moisture availability. They develop a large root system capable of finding water and fertilizer, which help to hasten crop maturity and escape late season drought. In Kenya, a system was initiated to supply small packs of seed and fertilizer to first-time and women buyers so as to create fertilizer demand. This initiative yielded good results because demand for additional farm inputs from agro-dealers was created (Blackie and Albright 2005).

In Zimbabwe, 25 kg packs (enough for one acre) of AN were introduced for microdosing. Most farmers obtained 30-50 percent yield increases – a production boost that ended Zimbabwe’s grain shortage in 2004 (Hove et al. 2006). Malawi initiated a subsidized starter pack program to overcome famine in which small packs of fertilizers were supplied to farmers for use in microdosing techniques (Blackie and Mann 2005, Snapp et al. 2003, ICRISAT/MAY 2000). When the program stopped, Malawi got into a problem of food deficit again and a new program called Smart subsidies was later started that enabled Malawi to produce surplus food (Denning et al. 2009). This technique requires only about one-tenth of the amount typically used on wheat and one-twentieth of the amount applied on corn in the US. Due to existence of very poor soils that are deficient in N and P in sub-Saharan Africa, the tiny amount of chemical fertilizers applied in microdosing often doubles crop yields.

The ***'Warrantage'*** system practiced in Niger enabled farmers to increase their income by 50 to 134% (Pender et al. 2006, Dening et al. 2009). Farmers realized that by holding the major part of their produce for 10 months after harvesting, millet prices increased three-fold. They then initiated the ***'Warrantage'*** system, which was a society of their own where grain was stored and only sold when prices improved. During the grain-holding period they got credits, to purchase inputs for use in the next cropping season, using their grain as collateral. They repaid the credit after selling their produce. The ***'Warrantage'*** system combined microdosing with "inventory credit" that enables farmers to withhold their produce for higher prices and farm margins.

Promotion of microdosing

For greater impact of microdosing as a technology, a deliberate effort to up-scale the technique for wider adoption is necessary. For wider adoption of microdosing as soil fertility improvement method by farmers the following should be done:

Promotion at micro or farm level

- Using focus group discussion to identify priority sorghum production constraints and potential solutions including microdosing technique
- Farmers to make a work plan for use of microdosing techniques
- Organize for a practical training on the technique by gathering farmers in a host farm to demonstrate how the technique is applied
- Distribute quality seed of improved varieties and some fertilizer to trained farmers to apply the technique in their fields ensuring that each farmer has a check plot without the technique
- Organize field days when the sorghum crop has attained physiological maturity on a few selected farms where microdosing was applied
- During the field day organize the farmers present to evaluate the technique and document feedback
- Prepare pamphlets in the local language for wider distribution
- Upscale the technique to more areas in the subsequent season incorporating any improvements suggested during the field days
- Combine microdosing with improved output market linkages

Promotion at macro-level

- Encourage agro-dealers to stock small fertilizer packs
- Encourage linkages between sorghum farmers and agro-dealers
- Train agro-dealers on microdosing
- Distribute microdosing information through agro-dealer networks
- Develop other simple but practical application methods for microdosing
- Encourage farmers to engage in collective action for input and output marketing - the *'Warrantage'* system developed in Niger should be encouraged
- Promote use of organic manures to enhance the efficiency of inorganic fertilizers

Summary and conclusion

Soil mining and failure to replenish fertility of the soil results in a decline in productivity, which subsequently leads to widespread hunger and malnutrition. Microdosing in sorghum production responds to constraints related to low productivity, poverty, low soil moisture and high cost of fertilizer especially when applying the conventional recommendation rates. Microdosing is a technique to apply small doses (usually ¼ of the recommended rates) of chemical fertilizers at seeding or 15-45 days after emergence of the sorghum crop. A three-finger pinch or a bottle cap full of the fertilizer is placed in the planting hole after seed placement and then covered. Post seeding microdosing technique places the same amount of fertilizer 5 cm away from the sorghum plantlet when soil moisture is sufficient. Placement of farmyard manure in seeding holes enhances efficiency in chemical fertilizer use due to improved soil structure and better soil water retention around the planting hole. As good as it has proved to be, microdosing can only perform successfully if it is accompanied with good agronomic management practices, which include good land preparation, use of improved seed, timely sowing, recommended plant spacing, proper maintenance of soil moisture, timely and effective weeding and effective control of insects and diseases.

In order to maximize returns from microdosing, it is important to explore the sources of manure and availability of labor as determinants for the appropriate and manageable area to put under crops. The higher the productivity per unit area the smaller will be the land under crops. Participatory engagement of all primary stakeholders is necessary at all stages of microdosing, starting from planning to implementation and adoption. It is the best way to create awareness and enhance farmers’ capacity to adopt microdosing and benefit from the technique.

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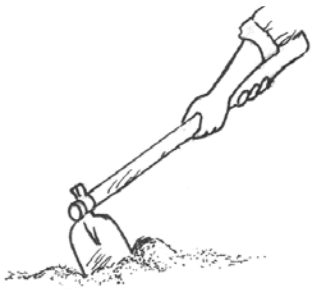
Annex 1



Checking soil moisture because the soil has to be moist enough.

Digging sowing holes.

After making the sowing holes, a handful of manure is dropped into each hole.

Fertilizer in one bottle cap dropped into the sowing hole.

A three-finger pinch of fertilizer is dropped into sowing hole.

Seed is dropped into a hole with a handful of manure and a three-finger pinch or bottle cap full of fertilizer.

Covering the sowing hole after dropping manure, fertilizer and seed.

Fertilizer applied through top dressing 5 cm away from plant.