Global Theme on Agroecosystems

Report no. 24

Spreading the Word on Fertilizer in Zimbabwe

International Crops Research Institute for the Semi-Arid Tropics

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Abstract

Next to drought, poor soil fertility is the single biggest cause of hunger in Africa. Despite this, smallholder farmers use very little manure, and less so, the recommended inorganic fertilizers. This is largely due to the input being unaffordable to the majority of smallholders. In drier regions, farmers are also concerned about application risks.

In light of this, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is promoting the use of small fertilizer quantities (micro-dosing) that smallholders are more likely to afford and adopt. Although higher rates are known to give higher yields, the marginal returns from the small investment when using lower fertiliser rates are much better.

In the 2003-04 cropping season, with assistance from the Department for International Development (DFID) and the European Commission Humanitarian Aid Office (ECHO), a large-scale relief program distributed 25 kg of ammonium nitrate to each of 170,000 small-scale farmers through a consortium of non-governmental organizations (NGO). With technical assistance from ICRISAT and a simple fertilizer pamphlet, NGOs established 1,200 on-farm trials across the country to demonstrate the micro-dose approach. In each trial, the farmer selected the cereal crop, and compared results with and without fertilizer. Data were obtained from more than 900 of these demonstrations, and a national survey assessed impacts on the larger group of 170,000 farms.

Despite poorer than average rains, micro-dosing increased grain yields by 30 to 50%, and almost *every* farmer achieved significant gains. The 170,000 households increased their production levels by an estimated 40,000 tons. The program significantly improved household food security, and saved US$7 million in food imports. Many of these farmers are now becoming interested in investing their own resources in fertilizer, but access remains a constraint. The program has started working with fertilizer companies to test strategies for resolving this problem.

Key words: *fertiliser, hunger, poor soil fertility, Zimbabwe*

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Contents

Introduction

Throughout the 1980s and 1990s, the International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) primarily targeted the development and dissemination of earlier maturing varieties of sorghum (*Sorghum bicolor* [L.] Moench) and pearl millet (*Pennisetum glaucum* [L.] R. Br.) as a means to improve productivity and reduce the risks of drought in semi-arid agro-ecologies of southern Africa (Heinrich 2004). Farmers liked the new varieties for their early maturity and large grain size; and adoption rates were favorable. But limited gains were achieved in crop yields and productivity. This is because of the low inherent fertility of most soils in the region. Even so, farmers were reluctant to risk investments in fertilizer. Surveys in southern Zimbabwe, for example, indicated that less than 5% of farmers commonly used fertilizer (Ahmed et al. 1997 Rusike et al. 2003). Sixty percent of households owning cattle did not even use cattle manure as an amendment for crop production. Current and past use of inorganic fertilizer and manure, and average rates of application for Malawi and Zimbabwe are summarized in Table 1 (Twomlow and Ncube 2001). Similar data have been reported for other countries in sub-Saharan Africa (Hillhorst and Muchena 2000).

Table 1. Current and past use of inorganic fertilizer and manure, and average rates of application, Malawi and Zimbabwe (Twomlow and Ncube 2001).

Country	Practice	Proportion of farmers using technology (%)	Rate of application	Official recommendation
Malawi				
	Using inorganic fertilizer	4-31	17 kg/ha compound 23-21-0 + 4S	100-150 kg/ha Compound 23-21-0 + 4S soon after germination and 100-150 kg of CAN or urea two weeks after germination
	Ever used inorganic fertilizer	99		
	Using manure	30-40	1,5 t/ha	10 t/ha
Zimbabwe				
	Using inorganic fertilizer	5-75	50 kg/ha mostly Ammonium Nitrate (35.4 N)	150-200 kg/ha Compound D 8-14-7 + 6.5 S and 100-150 kg/ha Ammonium Nitrate
	Ever used inorganic fertilizer	21-50		
	Manure	6-60	4 t/ha	20-40 t/ha

During the late 1990s, ICRISAT worked with the Agricultural Production Systems Research Unit (APSRU) to initiate a crop systems modeling exercise that allows assessment of a range of options for the use of small quantities of nitrogen fertilizer (Rohrbach 1999). This started from the proposition that farmers may, at best, initiate investments in small quantities of fertilizer. The modeling examined whether this should be concentrated on a small area, or spread over a larger area while considering rainfall risks and multiple planting dates (Carberry et al. 2004). Alternatively, farmers could sell their fertilizer to earn cash.

The robustness of the response to small quantities of fertilizer was surprising (Dimes et al. 2003). Simulation results for a 1960 to 1999 rainfall period in southern Zimbabwe suggested that farmers could increase their average yields by 50 to 100% by applying as little as 9 kg of N per ha directly to the base of the plant. These results indicated farmers were better off applying lower rates of nitrogen on more fields, than concentrating a limited supply of fertilizer on one field. On-farm experimentation was then initiated with farmers on micro-dosing alone or in combination with available animal manures. The on-farm trial results confirmed that farmers could increase their yields by 30 to 100% by applying approximately 10 kg of N per ha (Dimes et al. 2005; Rusike et al, personal communication). Larger average gains could be obtained by combining the nitrogen fertilizer with a basal application of low grade manure (Ncube et al. personal communication). The question remained whether this result could be replicated across much larger numbers of farmers.

The problem of scaling out was solved in 2003/04 by encouraging wider adoption of micro-dosing in the context of national drought relief programs. Donors were already distributing seed and fertilizer inputs to drought affected farmers. Support was obtained from the Department for International Development (DFID) and the European Commission Humanitarian Aid Office (ECHO) to encourage the application of the micro-dosing of ammonium nitrate (AN) fertilizer by 170,000 farmers. The results reported in this paper are for the first season of wide scale testing in 2003-2004.

Materials and Methods

On-Farm Protocol

In 2003, under a drought relief program funded by DFID and ECHO, 170,000 farmers across seven districts of southern Zimbabwe, Natural Farming Regions III, IV and V, were provided 25 kg of AN along with a 1 page pamphlet in the local language advising on how to apply this (Figure 1). Over 1,200 of these farmers (52% women) were taught how to establish demonstration plots of approximately one acre (0.2 ha) in close collaboration with partner non-governmental organizations (NGOs) and local extension staff from the department of Agricultural Research and Extension (AREX). Half of the plot (0.1 ha) would receive approximately 10 kg of AN fertilizer and the other half of the plot (0.1 ha) would receive no fertilizer. These farmers could apply the AN for any cereal grain. They were simply advised to apply 1 beer bottle capful of AN (5 g) for every 3 plants. This works out to a rate of about 8 to 10 kg of nitrogen per hectare (approximately 20% of recommended levels). It was suggested that this be applied when the plant was at the 5 to 6 leaf stage. All other crop management decisions (planting date and method, time of weeding, etc) were left to the farmer. The number of trials established and successfully harvested in each district is summarized in Table 2 along with the identity of the collaborating NGO.

Simple record books were provided to each collaborating farmer to record crop planted, date of planting, date and number of weedings, date of fertilizer application, yield information and any other observations they wished to make. We also collected data on basic household resource levels such as draft animal ownership. Field Assistants were recruited in each locality to assist the farmers with record keeping, the collection of rainfall records from simple daily catch gauges located in each village, harvesting of the plots and crop yields. Given the number of demonstrations undertaken, it was not possible to physically weigh the threshed yield from every plot. Where this was not possible, the yield from each sub plot was placed in 50 kg sacks, and the number to the nearest half sack was recorded. Spot checks were made throughout the seven districts to quantify the weight of threshed grain that a 50 kg sack contained, in order to convert the number of sacks recorded into grain yield per ha on a dry weight basis. Typically, a 50 kg bag of maize (*Zea mays* L.) cobs contained 21.58 kg of grain, a 50 kg bag of pearl millet heads contained 18.38 kg of grain, and sorghum was 20.71 kg of grain per 50 kg bag.

How to Use Small Quantities of Nitrogen Fertilizer

You received 25kg of Nitrogen fertilizer for use during this cropping season.

This pamphlet describes the best way to use this fertilizer.

Why apply nitrogen fertilizer?

- It makes crops grow and mature faster
- It reduces the effects of late planting
- It increases grain yields

Which crops should be fertilized?

- You can apply fertilizer to any crop. The best is to put it on your main cereal crop, ie maize, sorghum, or pearl millet.
- Fertilizer can be applied on any field, whether or not you have applied basal fertilizer, manure or anthill soil.

When to apply fertilizer?

- Apply nitrogen fertilizer when the crop is at 5 or 6 leaf stage. At this stage plants will be about knee height to an adult.
- You can apply even slightly later, but it **must** be applied before flowering.

How to apply fertilizer?

- Take a beer bottle cap and fill it with fertilizer. This is a very small quantity, but it is still enough for 2 to 3 plants.
- Do not broadcast the fertilizer –apply it carefully near the base of each plant, as shown in the picture. In this way, all the fertilizer goes directly to the plant and nothing is wasted.

Should you apply fertilizer on dry soil?

- No — if you apply fertilizer to very dry soil, it will not work properly. Wait until there is some rain and the soil is wet.

Should you use manure?

- Manure and fertilizer, both are important.
- If you have already applied manure or anthill soil, and later you apply fertilizer as well, yield will be even higher.

What type of fertilizer to use?

- There are different types of nitrogen fertilizer, eg Ammonium nitrate (AN), Calcium ammonium nitrate (CAN), and Lime ammonium nitrate (LAN).
- All three are very similar, and should be applied in the same way. Only the quantities will be slightly different, as shown in the table below.
- Urea is another type of nitrogen fertilizer. After applying urea, you **must** add soil on top, to cover it. Covering is not required for AN, LAN, or CAN.

Application rate for different fertilizers

	AN	LAN / CAN	Urea ★
Nitrogen content	34%	28%	46%
Application rate	1/3 beer cap per plant	1/2 beer cap per plant	1/4 beer cap per plant

★ *Cover with soil after applying urea*

This pamphlet was developed by ICRISAT after testing the microdosing method extensively with farmers in several districts.

For more information, consult your local AREX officer

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DFID Department for International Development

Figure 1. English language version of the micro-dosing flyer distributed to more than 160,000 households in the 2003-2004 season. (The flyer is now in its 4th iteration for the 2005-2006 cropping season in Zimbabwe, and has been shared with programs in Kenya, Mozambique and RSA.).

Table 2. Distribution of Micro-dosing trials across seven districts of southern Zimbabwe and collaborating Non-Government Organization.

District	Non- Government Organization	Number of Paired plots targeted	Number paired plots successfully implemented by crop and gender					
			Maize		Pearl Millet		Sorghum	
			male	female	male	female	male	female
Bikita	CARE	80	17	23	0	0	0	0
Gokwe	CARE	80	45	21	0	0	0	0
Hwange	COSV	400	112	86	54	49	39	26
Matobo	World Vision	400	79	126	7	17	21	41
Mberengwa	CARE	80	47	40	0	2	1	2
Zaka	CARE	80	14	22	1	0	1	5
Zishavane	CARE	80	28	0	0	4	3	
Total Number Paired plots harvested		915*	316	326	62	68	66	77

* 444 male, 471 female

Statistical Analyses

Following the recommendations of Stern et al. (2004) for 'unbalanced' on-farm experimentation, grain yields for each of the three crops were analyzed using the residual maximum likelihood method (REML) variance components analysis in Genstat Version 6.1. The model used to analyze the data was:

Response variate: Yield

Fixed model: Constant + Fertilizer

Random model: District + Ward

Gender, draft animal power ownership, household labor, number of weedings, field type (homestead plot/main field) were tested as fixed variables, but found to be not significant in accounting for any of the unexplained variability. Further analyses are underway for various sub sets of the data.

A national post harvest survey was undertaken in 2004 to assess impacts on the larger group of 170,000 farmers. Full details of this survey are reported in Rohrbach et al. (2005).

Results and Impact

Table 2 summarizes the number of successful paired plots harvested by crop, and gender of host farmer across the seven districts. Despite the flyers (Figure 1), and the training provided to the 1200 host farmers, the timing of fertilizer application and weeding dates were highly variable (Table 3). Despite these differences in the management of the demonstration plots, virtually all of the farmers applying micro-dosing of AN during the 2003/04 cropping season achieved a significant ($P=0.001$) increase in grain yields (Figure 2). Average yield gains on the 915 harvested comparison demonstration plots ranged between 30% and 50% depending on rainfall received, the crop grown and the district (Figure 3 and 4). Highest yields from both control and micro-dosed plots were observed

Table 3. Timing of fertilizer application and weedings relative to planting dates for seven districts in southern Zimbabwe.

District	Days after Planting Fertilization (minimum –maximum)	First Weeding (minimum – maximum)	Second Weeding (minimum – maximum)
Bikita	58(18-101)	27(4-68)	57(28-103)
Gokwe	42(6-72)	22(6-49)	38(18-87)
Hwange	42(0-74)	27(3-105)	39(21-97)
Matobo	52(3-120)	33(4-96)	50(16-136)
Mberengwa	61(25-111)	25(1-80)	50(16-96)
Zaka	54(22-84)	21(2-54)	25(24-86)
Zishavane	39(27-52)	25(19-36)	75(38-105)

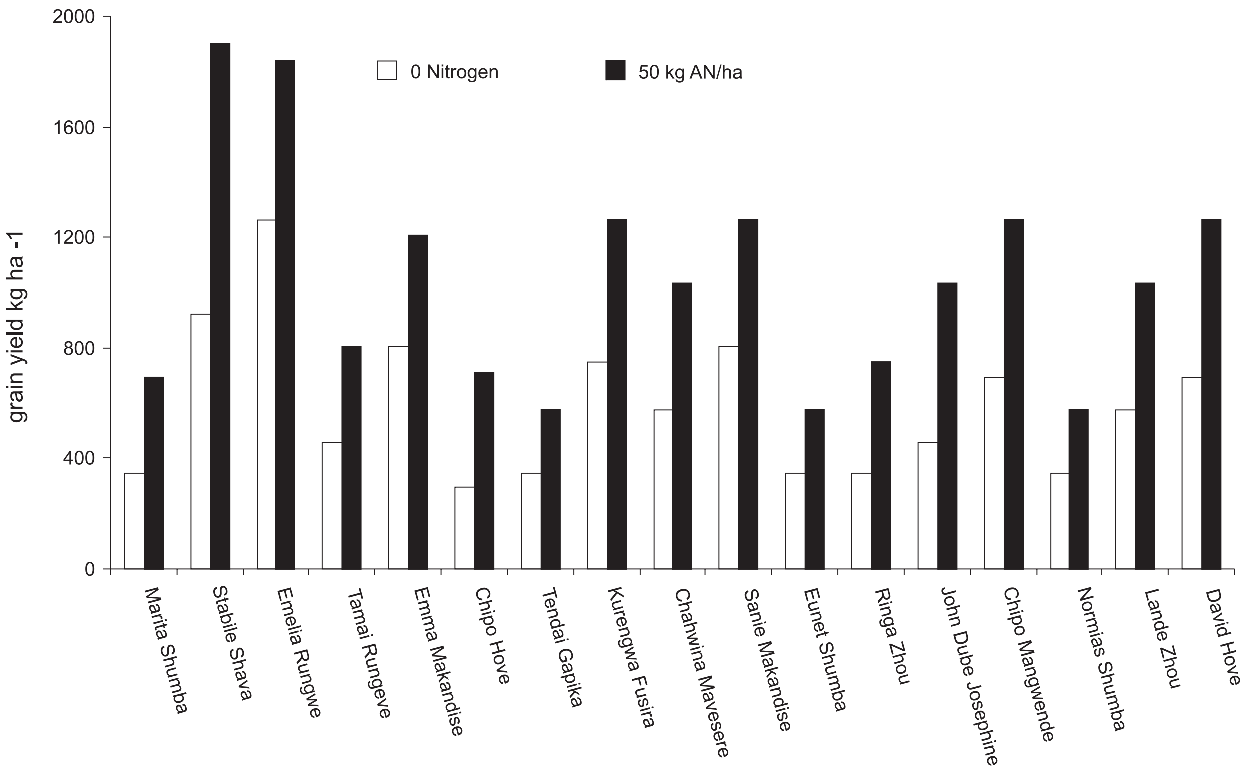

Figure 2. Virtually all farmers gained from micro-dosing with Ammonium Nitrate in the 2003-2004 season. Results from 17 collaborating farmers in Mberengwa District.

for Gokwe District, where the majority of farmers grow a commercial cotton crop using inorganic fertilizers, followed by a maize crop with no fertility amendments. A typical farmer comment from Gokwe was 'I did not know maize would respond to a top dressing of Ammonium Nitrate. I thought only cotton responded to fertilizer'.

Further analyses is being undertaken to quantify the impacts of weed management and AN application date on yield responses, and will be reported elsewhere. What is striking is the consistency of the grain yield increases observed across households, irrespective of gender, household labour or access to draft animals. This contributed directly to improvements in food access of many of the poorest and most food insecure households in the country. (Figure 5).

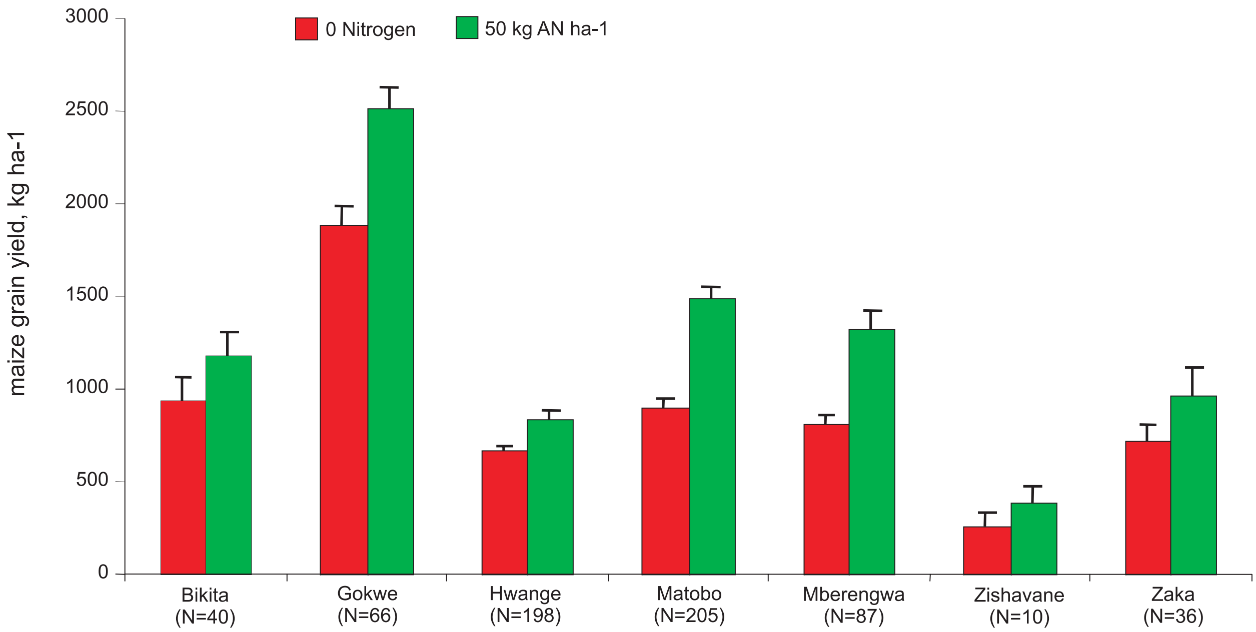

Figure 3. Yield response of maize to micro-dosing with 50 kg Ammonium Nitrate per ha, for across seven districts in southern Zimbabwe, 2003-2004.

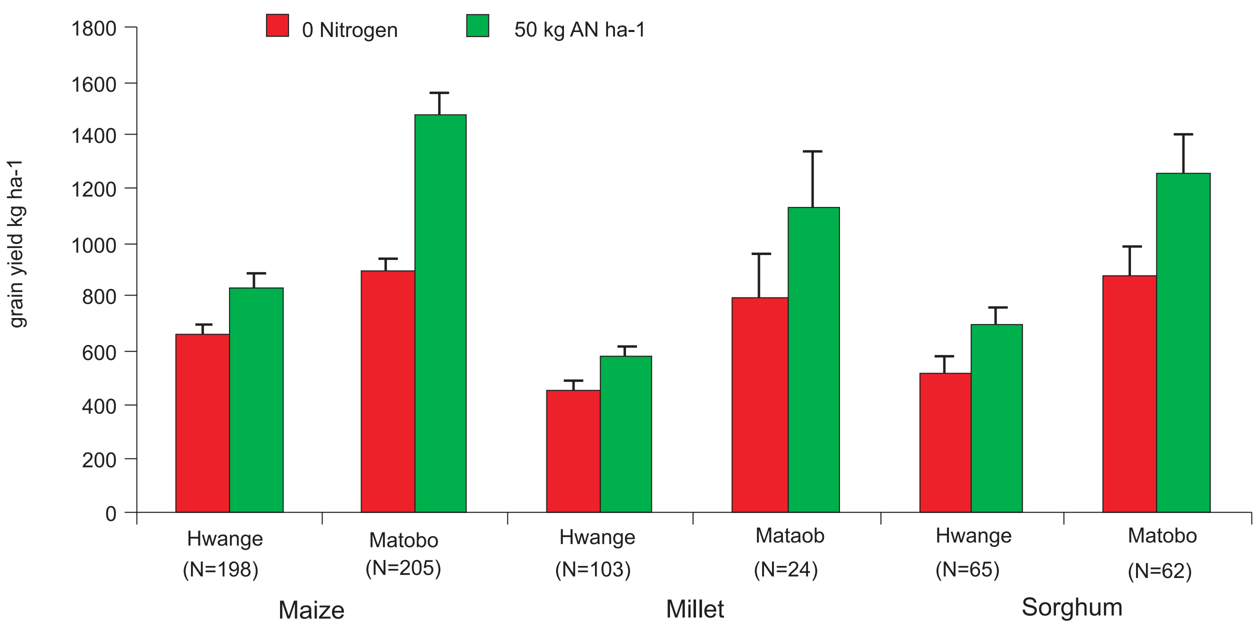

Figure 4. Yield responses of maize, pearl millet and sorghum to micro-dosing with 50 kg Ammonium Nitrate per ha, Hwange and Matobo districts, 2003-2004.

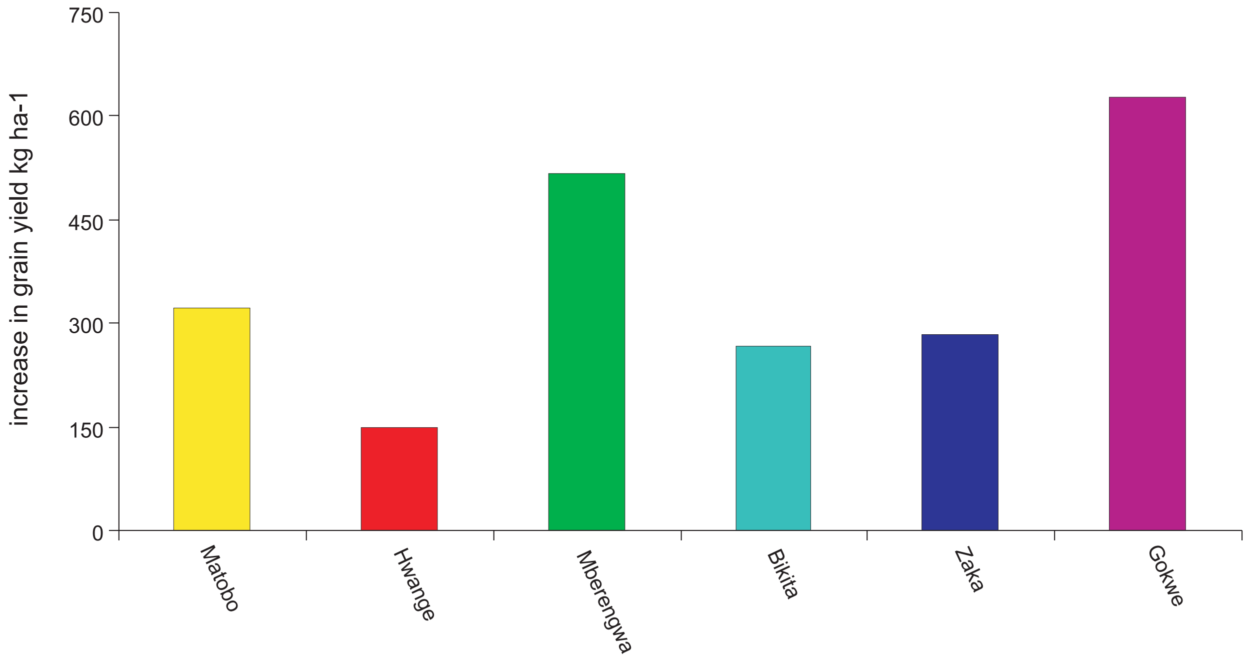

Figure 5. Additional maize grain produced per ha, from micro-dosing with Ammonium Nitrate in the 2003-2004 season for six districts in southern Zimbabwe.

The 170,000 households participating in the program are estimated to have increased their production levels by 40,000 t valued at more than US$7 million in cereal grain imports no longer required (Rohrbach et al. 2005). The national survey results indicated that the distribution of small doses of fertilizer yielded a 2.5 times larger return on investment than the distribution of relief seed.

Despite this evidence, some agronomists remain uncertain about the value of micro-dosing. They claim this technology is not sustainable. The application of nitrogen without phosphorous and other micro-nutrients, is said to worsen the soil. Correspondingly, these observers assume that even at these small rates of application, plant access to other nutrients will quickly become binding. But there is no evidence for this proposition. Subsequent simulation runs using the Agricultural Production Systems Simulator (APSIM), recently validated for maize growing conditions in Zimbabwe (Dimes et al. 2003; Carberry et al., 2004), for a sandy soil under four management scenarios in Masvingo District for a 40 year period, suggest that the micro-dosing approach will continue to outperform existing practices (Nhamo and Dimes 2005). The recommended N fertilizer treatment (50 kg N ha^{-1}) gave cumulative grain production 160% higher than the current farmer practice of not applying N fertilizer (Figure 6). By comparison, applying 10 kg N ha^{-1} exceeded current farmer practice by 50%. The simulated average annual grain yield for the 0 N, 10 N and 50 N treatments were 745 kg ha^{-1}, 1040 kg ha^{-1} and 1900 kg ha^{-1}, respectively.

Some observers suggest that an alternative first step toward improving soil fertility should be the application of crop residues in order to build soil organic matter (SOM). ICRISAT's simulation results suggest that if 100% of maize crop residues are left in the field, farmers can achieve grain yields very similar to those observed for micro-dosing, 1100 kg ha^{-1} compared to 1040 kg ha^{-1} averaged over the 40 year simulation period (Figure 6). The lower performance of the residue retention treatment is because of the initial 12 years of depressed yield (relative to 0 N), as the carbon additions caused a new SOM equilibrium to develop, and in the process diminish N availability to the maize crop.

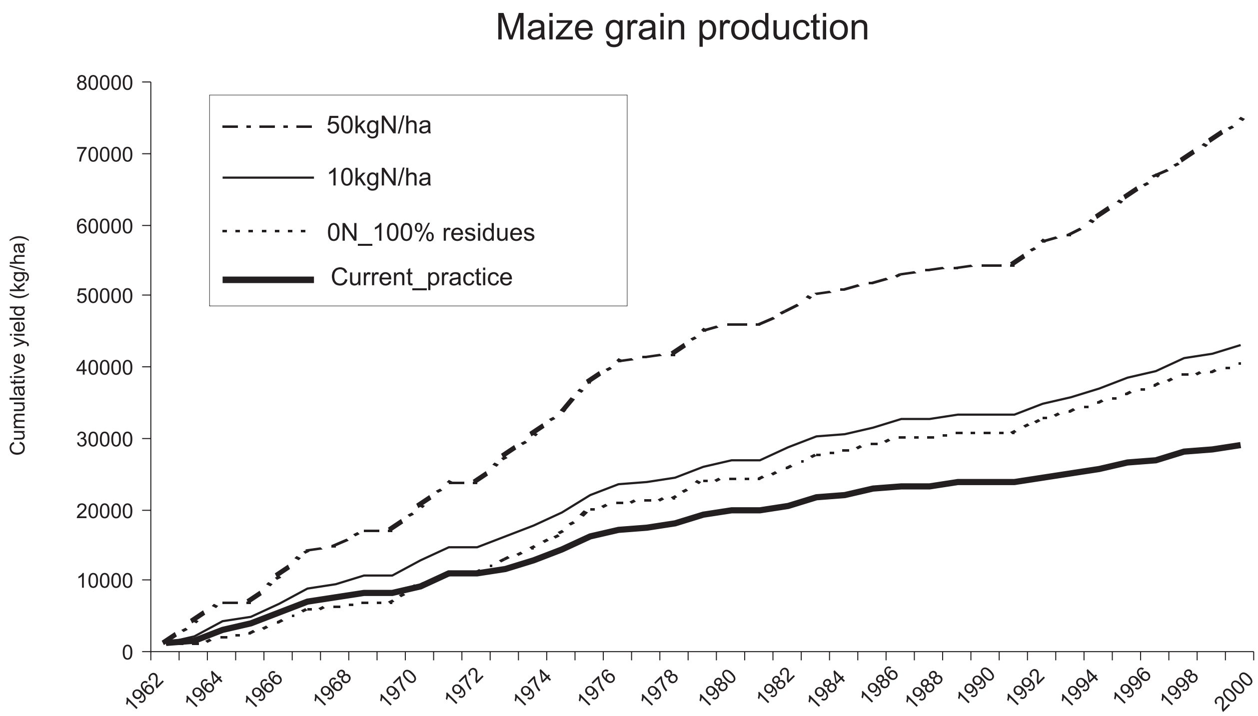

Figure 6. Simulated cumulative maize grain production for fertilizer (0, 10 and 50 kgN/ha) and residue management (0 and 100% retention) options at Masvingo, Zimbabwe.

However, this scenario is not particularly practical. Residues deteriorate quickly in this agro-ecology and most of these residues are fed to animals. The returns to feeding maize stover to draft animals is undoubtedly higher than the gains achieved from leaving these in the field.

Some agronomists argue that farmers are being misled into believing that they are better off using smaller doses rather than larger doses of nitrogen. These scientists, or extension workers, claim that farmers should only be advised on how to maximize their yields or productivity. To promote less than this is said to undermine national food security. Yet the consistent non-use of fertilizer undermines food security even more (Figure 6).

Ultimately, however, the consistency of these results is beginning to convince key investors. Fertilizer companies in Zimbabwe have expressed interest in promoting sales of smaller packages linked with appropriate extension advice. A similar program has been initiated in South Africa with strong support from both fertilizer companies and grain buyers. And related experimentation has been initiated with national research and extension staff in both Mozambique and Malawi.

Lessons learned

Micro-dosing with nitrogen has a high payoff in large areas of Africa where this nutrient is most limiting. This appears to be a particularly promising entry point to encourage fertilizer use among farmers who have not historically used such inputs – including farmers in drought prone, semi-arid agro-ecologies. This response appears consistent among farmers with widely varying resource levels and management capabilities.

The level and consistency of this response seems counter-intuitive to many agronomists. The first reaction of many has been to reject the result, claiming this is unsustainable. Many argue that farmers should instead be provided with advice on how to optimize their resource allocation or production levels by applying higher, recommended rates of fertilizer. Yet the response of most farmers to such recommendations has been to ignore them.

It appears that several seasons of results will be necessary to convince skeptics that the response to micro-dosing is consistent. On-going monitoring will also assess whether the adoption of micro-dosing leads to an evolving, and growing investment in improved soil and water management technologies – in a stepwise fashion.

Farmer interest in micro-dosing also highlights the value of considering alternative investment strategies among small-scale farmers. A few may start by accepting the larger investments advised by most extension agents. But most prefer to make smaller, incremental changes in their crop management practices. Correspondingly, extension recommendations should promote broader experimentation with a wider array of practices, rather than simply targeting an ideal solution.

Fertilizer companies have expressed interest in these results, although some remain uncertain of the value of first promoting smaller sales of nutrients. Further experimentation is planned with commercial sales of small packs of fertilizer.

Finally, relief programs offer a good opportunity to promote widespread adoption of well-tested technologies. Also, better targeting of these programs and monitoring of their impacts will improve the benefits of input relief.

The success of this program has stimulated a growing interest in this technology. The distribution of 25 kg packs of AN was encouraged again during the 2004/05 planting season. Posters and extension advices were again provided to encourage farmers to experiment with micro-dosing. Fertilizer shortages and an early end to the rains limited the numbers of participating farmers to approximately 130,000. However, this program will again be pursued in 2005/06.

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About ICRISAT

The International Crops Research Institute for the Semi-Arid Tropics (ICRISAT) is a nonprofit, non-political organization that does innovative agricultural research and capacity building for sustainable development with a wide array of partners across the globe. ICRISAT's mission is to help empower 600 million poor people to overcome hunger, poverty and a degraded environment in the dry tropics through better agriculture. ICRISAT belongs to the Alliance of Future Harvest Centers of the Consultative Group on International Agricultural Research (CGIAR).

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