REPORT FOR HEALTHY SOIL, HEALTHY FOOD RESEARCH (by Fambidzanai Permaculture Centre)

A program dubbed Healthy soils healthy Foods is being implemented across the southern Africa region with participating organisations from Zimbabwe, Zambia, Malawi and South Africa . This research was thus commissioned for Zimbabwean partners on this program.

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Contextualizing biofertilizers as a panacea for healthy soils and healthy food

[Field report by FPC for SKI-Healthy soil Healthy Food Initiative done in Zimbabwe]

1 Introduction

1.1 Background

The six Seed and Knowledge Initiative (SKI) partners hosting an Healthy Soil Healthy Food (HSHF) center have been promoting biofertilizers since 2017 (see - https://www.seedandknowledge.org/biofertilisers-come-to-africa-4-how-to-biofertiliser-booklets/) , mostly through training of trainers, farmer leaders and extension officers but also through supporting the establishment of biofertilizer production centers. The concept of biofertilizer application and use is borrowed from South America, who have been using the concepts for decades in their soil health management, and was introduced into the SKI and AFSA network through trainings by renowned agronomist in soil health from South America, named Juanfran Lopez. In 2020, this work was included in the Healthy Soil Healthy Food Initiative (HSHF) that was jointly designed and is now jointly implemented with Alliance for Food Sovereignty in Africa (AFSA). The six SKI partners are participating in the HSHF initiative, each as a host of a HSHF center of excellence in the region, namely: Soil Food and Healthy Communities (SFHC) in Malawi, Kasisi Agriculture Training Centre (KATC) in Zambia, Biowatch in South Africa and Towards Sustainable Resources Organization (TSURO) , Participatory Organic Research Extension and Training (PORET) and Chinyika Development Association Trust CDAT (Chinyika) in Zimbabwe. There are 10 other HSHF centers of excellence hosted by AFSA members in East and West Africa.

The partners have all reported that they have observed a great uptake of the technology in the farming communities they work with, in link with the benefits that the biofertilizers bring in terms of soil health and crop yields (Sivamurugan, 2018; Yadav and Sarkar, 2019), accessibility and affordability. Reports from the different partners are indicative of the fact that there are varying production levels across the different areas and this is done from different forms of materials from place to place. It has also been noted that farmers have started increasingly generating interest due to evidence of effectiveness of biofertilizer use. However, as the demand is getting higher, there is a need to optimize and upscale the production and availability of biofertilizers in these communities and more so towards commercialization. In that regard, there is a need to properly document the effectiveness of the biofertilizers currently made and used by the farmers working with SKI partners, including analyzing the recipes; the composition of end products; impacts on soil for various crops and in different cropping conditions as well as adoption trends. This analysis will not only be useful for guiding the farmers in their preparation and use of biofertilizers for best results, but also for further promoting the technology to extension officers and other government officials, up to decision makers, as well as other Non-Governmental Organisations (NGOs) or Community Based Organizations (CBOs) working with farmers. In addition, this research will facilitate the development of farmer research networks by sharing information on how others are adapting prescribed recipes to suit available raw materials and thus provoking other communities to try out the same and share the results and, in the process, creating a network of farmers working on researches around biofertilizer preparation and application.

1.2 Conceptual Framework

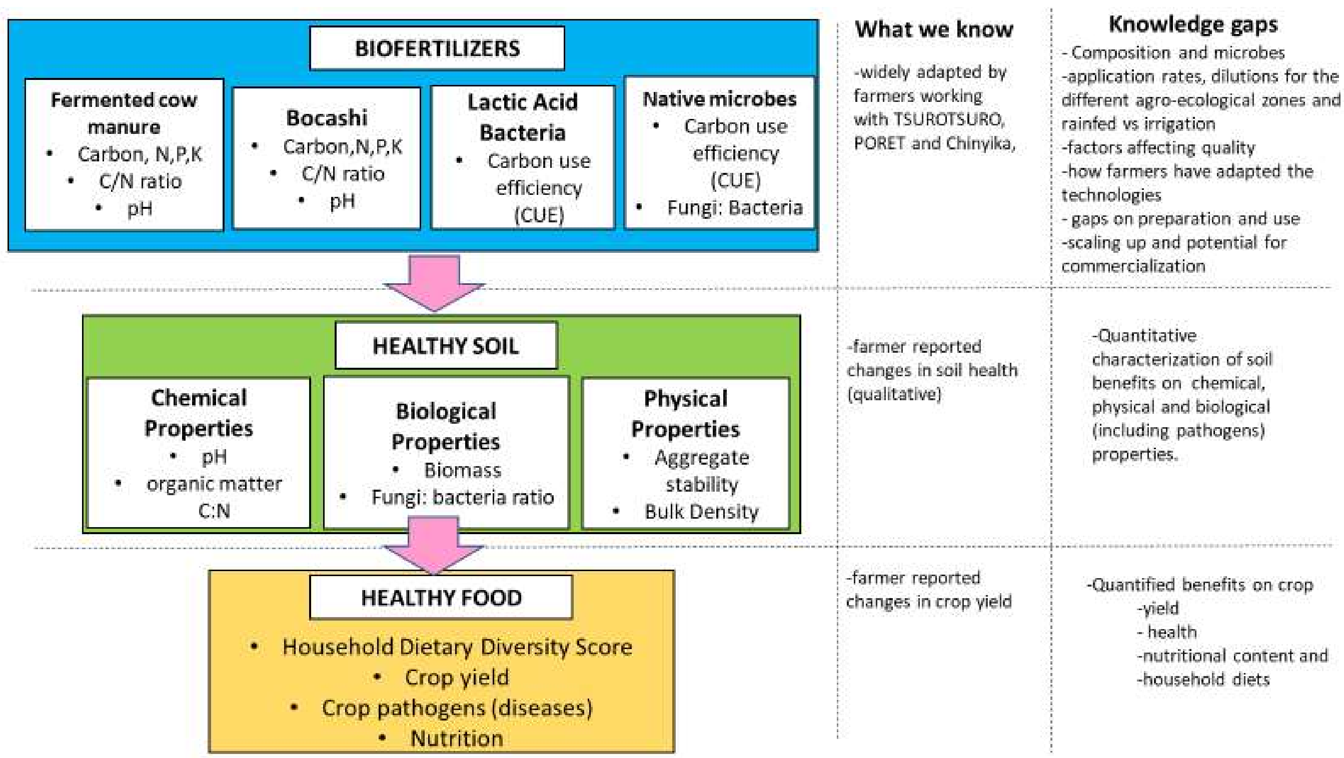

Figure 1*: A conceptual framework on the use of biofertilizers and effects on soil health properties and ultimately healthy food; highlighting what we know within the SKI HSHF initiative and the knowledge gaps that need to be investigated in order for out and up scaling.*

1.3 Objectives

The general objective of this initial phase is to put in context the biofertilizer technology use, adoption, optimization, and its potential as a steppingstone to healthy soils and ultimately healthy food in smallholder communities in Zimbabwe.

Specific objectives

i . To evaluate the current practices on the making and use of the biofertilizers technology only as trained by SKI

ii. To investigate how farmers have adapted and customized for use the initial technology brought to them from South America

iii. To characterize the quality parameters (e.g., nutrients: nitrogen, phosphorus, potassium (NPK); carbon, C:N ratio, microbes, and pH) of the biofertilizers currently being prepared and used by farmers working with partner organizations.

iv. To document qualitative/quantitative benefits on yield and soil as reported by farmers and quantify the benefits to soil properties following lab analysis.

v. To identify knowledge gaps on the preparation, use, optimization, scaling up and potential commercialization of the biofertilizers.

vi. Establish the potential of Farmer Research Networks (FRN) to lead through the research and development process on biofertilizer.

1.4 Approach

1.4.1 Activity 1: Focus group discussions (FDGs)

Focus group discussions were held in each of the 3-partner organization TSURO, PORET and Chinyika in their districts of operation namely Chimanimani for both TSURO & PORET and Gutu for Chinyika Community Development Trust. The field work on data collection was conducted in the period from August to December of 2022 (Table 1). Discussions were held in the local language with the guidance of the themes and questions on the FGD guide (Appendix i) and the sessions were recorded through the use of recording devices and an individual taking notes of the sessions. .

The participants of the focus groups discussions were purposefully selected based on the experience of use of the different biofertilizers. The people considered for the focus group discussions were supposed to have at least one season of field use of the biofertilizers so that they would be able to share practical information that relates to the specific areas of their origins and not theoretical. On average the farmers had experience from at least two farming seasons on the use and application if biofertilizers.

1.4.2 Activity 2: Key informant interviews (KIIs)

Key informant interviews were carried out with extension officers and project staff in each of the project areas and a total of 10 key informants were recorded. The key informant interviews were guided by the same themes as for the FDGs but also include a theme on the optimization, scaling up and potential commercialization of the biofertilizers (Appendix 2).

1.4.3 Activity 3: Soil and biofertilizer analysis

Soils were sampled from a 0-15 cm depth from randomly selected farmers from the 3 selected centers of excellence. Samples were collected from farmers using different types of biofertilizers and the sampling comprised of fields where the biofertilizer was used for an average of at least 2 farming seasons, and a comparatively same plot where nothing was applied. Soil analysis was run at the FPC lab and at Kutsaga Research Institute lab.

Collection of a liquid biofertilizer sample (right); and collection of a Bokashi biofertilizer sample (left) in Chimanimani. October 2023. Credit : Takwana Bishi and Mellissa (respectively)

Liquid biofertilizer quality was assessed by collecting a 500 ml sample of biofertilizers randomly selected from farmers in each of the study areas. Bokashi was collected from "ripe" heaps from randomly selected farmers from different points of the heap to ensure homogeneity of the sample. Appropriate sampling, storage and transportation techniques were done. The samples were analyzed for N,P,K and pH, total Carbon and microbes (fungal to bacteria ratio).

1.4.4 Activity 4: Technical support and progress monitoring

This was mainly a technical support visit to each partner to assist in the interpretation of the biofertilizer analysis results and how these can be translated to work on the ground. This was coupled with actions to strengthen the capacity of FRN networks and setting the groundwork that sets the tone for FRN led research. The sessions for soil analysis results and respective interpretation was conducted with selected lead farmers together with extension officer from both government and host organisations who are promoting biofertilizer application.

2. Findings

2.1 FDGs and KIIs

2.1.1 Location and composition of Focus group discussions

A total of 11 FGDs were done with the three partners organizations as shown in Table 1. Most groups showed a dominance of female farmers in terms of numbers.

Conducting Focus Group discussion in Chimanimani in Ward 16 (right) and Ward 5 left, October 2022. Credit: Shepherd Mudzingwa

Table 1: Location and composition of the Focus Group Discussions

Organization	District	Ward	Natural Farming Region[1]	Composition by gender	Time taken per focus group
TSURO	Chimanimani	16A	NR 1	7 females 2 males	1-hour 2 minutes
		16A B	NR1	12 females 2 males	1 hour 10 minutes
		7	NR1	7 females 3 males	1-hour 5 minutes
		5	NR 4	7 females 3 males	1-hour 20 minutes
PORET	Chimanimani	5	NR 3	10 females	1hr 13 minutes
		3,15	NR 4	1 male 9 females	1 hour 58 minutes
		20,6,7	NR 5	6 males 10 females	1hour 40 minutes
		2	NR 4	13 females 7 males	2hours
Chinyika	Gutu	18	NR 4	5 males 1 female	1hour 40 minutes
		18	NR 4	13 females 11 males	2 hours 10 minutes
		35	NR 4	5 females 4 males	2 hours

2.1.2 Current practices on the making and use of the biofertilizers

Findings show that most farmers followed the recipes outline in the booklets as trained by SKI expect for a few adaptations that will be outline in this report. Across all the sites, it was confirmed that the concept of the preparation and application of the different types of biofertilizers was introduced as new concepts through the work of the partners supported by SKI through their linkage with South America partners. It emerged from the research that farmers across all the three partners have concentrated on the preparation and use of three types of soil amendments namely: Bokashi, Fermented Cow Manure and Soil Native Microbes (SNM). Generally, no farmers produced or used lactic acid bacteria (LAB) mainly due preferential promotion by trainers favoring the former, as key informants cited lack of resources to train for all. Table 2 shows the types of biofertilizers used in each region, the current application rates and the crops where these are

[1] https://www.fao.org/3/a0395e/a0395e06.htm

applied. In general, we note that there seems to be an association with the natural farming region and the types of biofertilizers preferred. In the drier farming regions (3,4 and 5) there is less adoption of the liquid biofertilizers as the farmers alluded that these needed a higher moisture and humidity to avoid crop burn.

Making of Bokashi as prescribed in the recipe from SKI (right) and a "ripe" compost heap in Chimanimani by farmers under TSURO, October 2023. Credit: Takwana Bishi (Fambidzanai Permaculture Centre)

It emerged from the research that armers in natural region one and two are preparing and using the following gin the order of priority and use : Bokashi, Fermented Cow Manure and Soil Native Microbe. It is imperative to not that Soil native microbe was the least adopted practice among those being practiced and it was being practices by a minority of farmers among those who participated in the focus groups. Farmers in natural region three   are actively using Bokashi and Fermented Cow manure in that order of importance and increased use. Farmers in natural region four and five are mainly using Bokashi for their dryland production with only a few who are using fermented cow manure in their irrigated fields.

Table 2: The types Biofertilizers used in each region, the current application rates and the crops where these are applied

Organization	Region	Biofertilizer Type	Popularity of use[2]	Application rates and method	Crops
Tsuro	Chimanimani	Bokashi	Strongly adopted	• Banded in a continuous line for beans • 300 g per planting hole for maize • 600 g per planting hole for tomatoes • 5 kg per planting hole fruit trees	Beans, maize, tomatoes, coffee, mango, tomatoes, small grains
		Fermented cow dung manure	Strongly adopted	• Various dilution rates e.g., Dilution is 5l to 20 L water, 1L to 15L, 1L to 3 l L water as it depends on crop and weather conditions. When it is too hot, the fertilizer is made more dilute to avoid burn • Farmers try with one crop to make sure dilution is right and it won't burn the crop.	Maize, beans, tree crops, cow peas, tomatoes -Sprayed on leaves early morning or at night -Water regularly after spraying
		SNM	Medium rate of adoption	• Dilution is 1L to 15L	Maize, beans, tree crops, cow peas, tomatoes, wheat
PORET	Chimanimani	Bokashi	Strongly adoption	• Handful or tea cup the crop (an approximated rate of 250g/planting station according to the farmer) • For heavy feeders like tomatoes 3 handfuls (an approximated rate of 750g/planting station)	Maize, sorghum
		Fermented cow manure/SNM	Weakly adopted	• Ward 5 farmers do not apply liquid manure fertilizer as the area is very hot. • Ward 3,15 farmers apply it on mango tree	Fruit trees, maize
Chinyika	Gutu	Bokashi	Strongly adopted	• 2 handfuls/500 g /1 tea cup applied	Tomatoes, have not yet tried on maize, vegetables
		Fermented cow manure/SNM	Weakly adopted	• Most farmers had not started making because of lack of containers. • A few that do apply 1L : 15L water	Maize

[2] Strongly adopted refers to more than 75% of the focus group discussion participants confirming its application, Medium rate of adoption refers to at least 50% of the focus group discussion participants confirming its application, Weakly adopted refers to less than 50% of the focus group discussion participants confirming its application.

2.1.3 Constraints

The farmers reported the following constraint with regards to making of biofertilizer:

- Lack of manure because of little livestock ownership in most of the households. They sometimes halve the recipe to suit manure available or may buy the manure from other farmers making it very expensive.
- Farmers are not sure of the best application rates and dilution levels of the biofertilizers. The information shared during the training is generalized and not customized to their local conditions hence they feel more need to be done to establish the application rates.
- Lack of equipment such as containers to make and store liquid fertilizers.
- Limited by proper infrastructure for the preparation and safe storage conditions for the biofertilizers. Farmer groups intending to expand their production indicated that processing shades are one of the major limitation since the preparation has to be done under the shade and also stored on places with limited moisture.
- Limited information and knowledge on the alternative substitutes for use and the potential benefits of using biomass accumulators in the preparation compared to ordinary planting material.

2.1.4 Adaptations and customizations made to the initial technology brought to them from South America

Most farmers and informants reported sticking to the recipe as is laid out in the handbooks and literature provided during the training. However in some instances the following adaptations were reported:

"We have not changed the recipe but trying to see how Bokashi with different litter e.g mupesepese[3] *(Vernonia polyanthes) compares with other forest litter" Ward 16 A farmer, Chimanimani.* The farmers had not yet concluded as to how the litter performs compared to other litter.

[3] An invasive plant fast colonizing the eastern part of the country including large swaths of Chimanimani district

Substitutes for molasses

- Farmers reported to have adapted the use of sugarcane instead of the prescribed molasses according to the recipes learnt. Those using sugar cane reportedly cut the sugar cane into small pieces and soak the small pieces in water for 2 or three days when signs of fermentation are showing up and they would also taste the solution for sweetness. This alternative replacement of molasses was commended with those using this method as equally effective but however there was a recommendation for further research to evaluate the effectiveness and differences in quality parameters as a result of this alternatives. But from their qualitative use from the groups with more than 2 seasons of use there is no significant difference between the use of molasses and the sugarcane syrup.

- There is also the use of fruit juices more especially mangoes in place of molasses. The mangoes are said to be left to ripe naturally until they get overripe, they are squeezed and soaked in water for overnight. The solution is then sieved and the distillate is used for preparation of biofertilizers in place of molasses.

- Majority of farmers acknowledged they were taught during the trainings to substitute molasses sugar cane and the respective quantities. Majority of all the farmers confirmed the replacement of molasses with sugar and it was agreed not to be their own adapted means but part of the shared recipes since it was shared during trainings. It emerged from the focus group discussion that from their qualitative evaluations the farmers have not seen any significant differences on the use of the two and they rated them to be equally effective.
- Some farmers in the highland areas confirmed the use of banana peels from ripe bananas as a substitute to molasses. Famers using this method highlighted that they gather banana peels from ripe bananas and pound them into a paste. They mix the paste with water and soak it over night before use. However, this is not a very common substitution.
- Other farmers highlighted that they have resorted to the use of mulberry juice in place of molasses. They indicated that they gather sizable amounts of sweet mulberries and pound them in a pestle and mortar then soak the pulp in water overnight for use of the solution thereof.

Substitutes for yeast.

- Some farmers in the high veld of natural region one where there is average annual rainfall above 1000mm reportedly used wheat flour in place of yeast. Farmers using this method are taking raw wheat flour used for their homemade bread and apply the same quantity as that of yeast and the fermentation process is efficient in the same way as application of yeast. In the discussion with the different groups, indications were that, increasing the quantity of the wheat flour will result in hastening of the fermentation process. It also emerged from the discussion both with farmers and key informants that there is need to analyze the difference in chemical and biological qualities of the adapted methods in comparison against the provided recipes.
- Farmers in some areas also reported using mahewu "traditional brew" in place of yeast and have noted that the Bokashi with mahewu smells sweeter. Mahewu is an African fermented tradition brew prepared from fermented meal from grains such as maize, sorghum and millets) So, instead of adding 20 L warm water in the preparation process of either fermented cow manure or bokashi, farmers reportedly add 20 L mahewu and remove yeast from the recipe.
- It emerged from one of the groups in Chimanimani that there is use of water from fermented maize seeds in place of yeast. The farmers reported that they would soak maize seed of reasonable quantity based on availability for one week and sieve to separate the water and the fermented grain.
- Farmers in Gutu (Chinyika) reckon locally brewed beer can be used instead of yeast but they have not tried it yet.

2.1.5 Qualitative/quantitative benefits on yield, soil and household economy as reported by farmers.

The farmers reported various benefits to the soil, yields and to their household income that can be attribute to the use of bio fertilizers.

Benefits to the soil

- Farmers reported that Bokashi had residual fertility and they noted that where they applied the biofertilizer they noticed "whitish stuff" the following season. This could be an indicator of microbial activity mainly fungal action. Some farmers with experience of the use of the biofertilizers cited the effects of residual fertility to stretch up to even two years. Other farmers also indicated that they would experience the full benefits of Bokashi application not in the season where they would have applied but in the following season.

- It was highlighted that the application of biofertilizers specifically bokashi resulted in moderate soil temperature which the farmers would actually feel the difference on touching the soil compared to the areas where or soil amendments have been added.
- The farmers indicated that soils where bokashi was applied was more aggregated compared to where they applied mineral fertilizer.
- It emerged from the focus group discussion that farmers have not witnessed any physical changes and benefit in the soil on the use and application of SNM and Fermented Cow Manure. This could probably be due to the limited timeframe of application which has been below 5 years with the average ranging within 2 years or seasons of application and use of biofertilizers and also that these fertilizers are not applied directly to the soil so benefits would be noted indirectly due to increased biomass production.

Benefits to the crop

- They observed good crop stand with large cobs and large grains for cereal crops .
- They noted no after taste when Bokashi is used on leafy vegetables and the vegetables are of better quality (greener).
- The biofertilizers help reduce plant pests and diseases incidences. Some farmers mainly from Natural region 3,4 and 5 reported having termite challenges on areas where they have used other forms of organic matter such as manure and ordinary compost while plots on where bokashi was used there was no recorded termite challenges or incidences.
- Farmers confirmed that the growth and development of crops grown using bokashi at basal dressing had good crop establishment characteristics "My maize crop was looking good and attractive but showed its own natural green color which is not too deep like that of a crop applied synthetic fertilizers. The crop looked healthier and the yield was comparatively high" (Mrs. Majokwiro, a farmer in Chimanimani under TSURO, September 2022) However, the farmers cited challenges of increased water requirement as a result of the use of biofertilizer specifically liquid fertilizers as to avoid burn and hence majority of farmers in natural region

3, 4 & 5 prefer have resorted to use of bokashi only in irrigated fields on horticultural crops mainly tomatoes, leafy vegetables, onions, garlic, potatoes and butternuts.

Benefits to the household economy

- Bokashi saves household income as it is less expensive to buy per unit measure compared to other available synthetic alternatives. There is however need for basic costing of the materials and the total labor cost to have a conclusive position regarding this assertion.

- Biofertilizers also present an opportunity to use and recycle waste material such as litter.

2.1.6 Knowledge & Research and training needs

✓ In field soil analysis- this is to establish the different soil chemical and biological parameters that relate to the quality of soil amendments used in the respective management of soil health. Documentation of the analyses outcomes over time will assist giving a clear picture of the trend and the changes overtime rather than focusing evaluation on analyses results from a single season.

✓ There is constant need to establish the nutrient content of the biofertilizers so as to pave way for effective use and sustainable adoption, commercialization and development of community-based production center. One farmer, Mr Hasha from Chimanimani said, *"If we know the nutrient content, then we can confidently sell the biofertilizer product"*

✓ Cropping systems that suit and match well with emerging soil health aspects still remain a critical knowledge gap. There is little knowledge on the best ways of managing the cropping systems with respect to each biofertilizer application e.g. if bokashi is applied this season at a specific application rate would this not affect the preceding crop in a rotation or another crop in an intercropping setting.

✓ Most farmers believe through seeing and hence the need for demonstration plots to show the difference in performance of the biofertilizers. These demonstrations should be maintained and monitors over time to evaluate the short, medium- and long-term benefits of application of biofertilizers together with economic evaluations of the same over time.

- ✓ It emerged from the farmers that there is need to explore the option of utilization of different types of manure/organic materials i.e using goat manure, chicken manure and legume residues used in preparations of biofertilizers and evaluate on the effectiveness based on the availability of the animals in each locality.
- ✓ There is need to evaluate the quality parameters both chemical and biological of the different adapted recipes applicable in the farmers context to ascertain how these are affected by the adaptations made and this will be more towards customization of the recipes to suit local context.
- ✓ There is need to further explore the issues of residual fertility coupled together with activated biological processes of soil fertility enhancement and how this can be linked to following seasons and different cropping systems.
- ✓ Farmers highlighted the need for research to focus on the relationship of use of these biofertilizers to management of pest and diseases. There is a general consensus and feeling that there is potential in use of these biofertilizers in reduction or management of pest and disease incidences.
- ✓ There is need for standardization of application rates basing on predetermined containers with known weights. This will enable easiness of adaption since application will be standardized instead of using palm size which varies from person to person and hence subject to over or under application.
- ✓ There is generally a knowledge gap on the storage of the biofertilizers and changes in efficacy during the storage. There is need to establish concretely the efficacy of these biofertilizers with respect to niche specific conditions and how these potentially affect potency of the biofertilizer

2.1.7 Scaling up and potential commercialization

Most of the groups have not considered selling yet as they are still experimenting on the products and are not yet sure of nutritional compositions which they say is important to convince their clients to buy their products. Some farmers also noted that they do not have enough inputs i.e., manure, molasses and bran for them to consider making enough to sale. In addition, it also emerged that one of the limitations towards expansion of production of biofertilizer is infrastructure such as shades for use during preparation and conducive storage space for finished products. Farmers interested in producing the biofertilizers at scale cited capital investment as a limiting factor since they would require infrastructure to support the production processes hence their operations will be limited to the capacity of their available infrastructure. In areas where there is little livestock the farmers cited high costs of production since they have outsourced manure which is a key ingredient in the preparation processes and is required in significantly huge volumes.

However, a few groups reported the following;

- Farmers in Chimanimani have started selling the biofertilizer for $ 15 USD per 50 kg bag of Bokashi and $1 for 1 Liter of liquid manures. They indicated that there is potential for selling more as there have been more inquiries from potential buyers but the limitation to expansion of the production is related capital costs.
- Some farmers are starting to charge other farmers for Bokashi practical training sessions for a nominal fee or paid in a few bags of the bokashi that is produced.
- Other groups of farmers in Chimanimani are looking at the potential market and are interested to sell.

Storeroom with SNM and Fermented Cow dung liquid fertilizers to be used for future use in Ward 7 Chimanimani. October 2023. Credit Mellissa

2.2 Characterization of soil and biofertilizers

2.2.1 Soil analysis

Results showed that the soils were, on overall terms slightly acidic to neutral. However, with the limited samples collected, we noted only a slight difference in soil pH between the Bokashi treated soils and the control (soils which had no biofertilizer application (see Figure 2). The implication is that there is need to follow up on more seasons of application to see the benefits to soil properties especially on those soil indicators that are not readily sensitive to management changes.

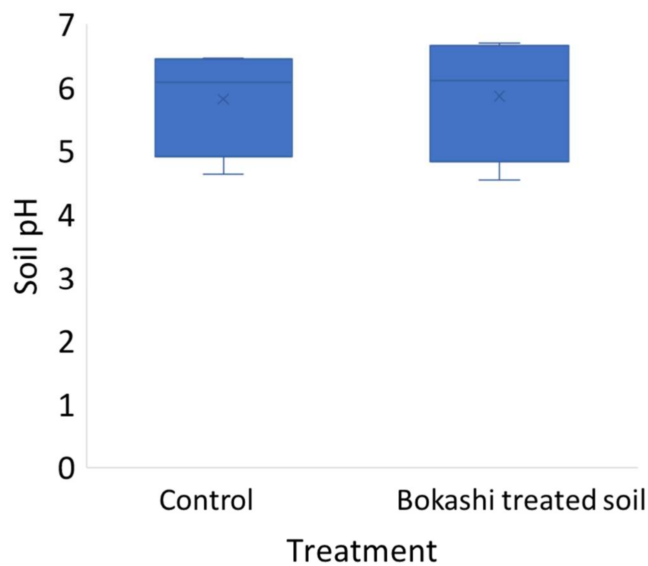

Figure 2: Soil pH for Bokashi treated soil and that without bokashi application

When it comes to soil nutrients however, there is evidence that the Bokashi application leads to improved nutrient availability in the short term and effects are expected to increase in the long term (Figure 3). Important to note is that both available phosphorus (phosphate) and mineral nitrogen are within the very low range (see Okalebo et al., 2002) and there is need to explore further options for increasing these nutrients since they significantly impact on farmers yields.

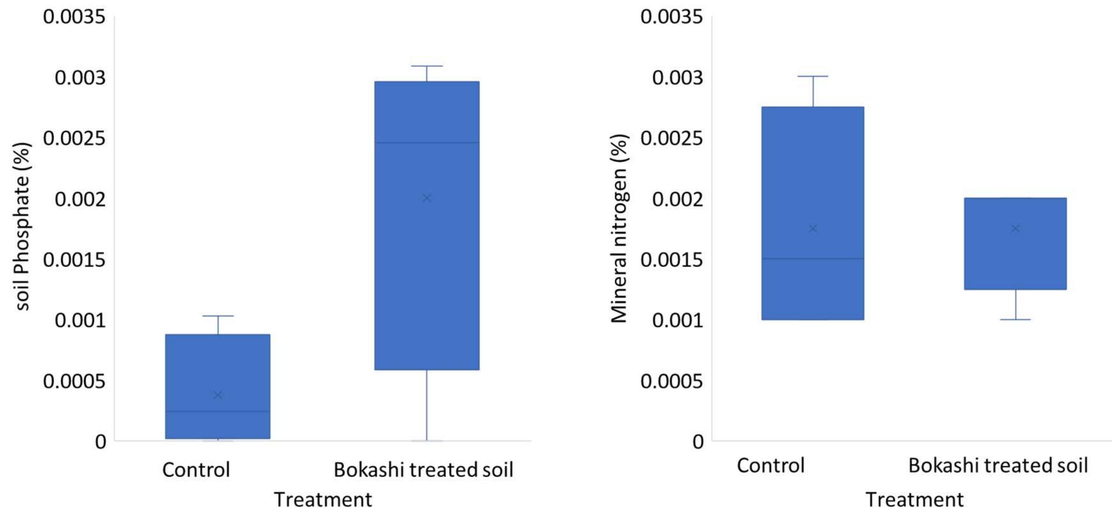

Figure 3:Available soil nutrients (phosphorus and nitrogen) in the analyzed soils

2.2.2 Biofertilizer analysis

Findings show that the bokashi manure in itself has very good potential to improve soil health over time as evidenced by the C/N ratio of 19.55 average (see table below). The C/N ratio gives us an indication of quality of manure and material less that C/N ratio 20 is considered good quality manure as it can be decomposed more easily and incorporated into soil pools that have the potential to increase soil carbon as well as soil microbial communities. The mineral content of the biofertilizer is on average very low (0.6:0.2:1.3-N,P,K) compared to the commercially produced basal fertilizer which has N,P,K content of 7:14:7. There is need to explore included materials that have a higher nutrient content such as legume residues in the recipe. However, given that farmers are reporting higher yields from Bokashi application despite the seemingly low nutrient content, there is need for further investigation on how the manure is enabling nutrient acquisition in these soils. The low C content and N content also suggests there is a lot of inorganic material (i.e soil) in the recipe that is taking up the overall mass of the manure.

Table 1: Carbon and nutrient content of Bokashi biofertilizer made by SKI partners in Zimbabwe (2022)

Bokashi sample	C/N	N (%)	P (%)	K (%)	Microbial Biomass (CFU/g)
1	23.25	0.4	0.1	1.38	1720
2	16.92	0.38	0.05	1	1360
3	13.04	0.6	0.1	1.09	1440
4	10.11	1.26	0.82	1.48	260
5	35.3	0.4	0.24	1.61	5630
6	18.61	0.54	0.01	1.05	4230
7	19.68	0.6	0.01	1.2	5320
Average	**19.55**	**0.59**	**0.19**	**1.23**	**2851.429**

On microbial biomass, results showed that the three biofertilizers have good mobilization of microbes especially bacteria. Although we could not ascertain and characterize the types of microbial species, the total count for Fermented cow manure and Bokashi were very high (up to 5500 CFU/g) compared to mineral liquid fertilizers which typically have microbial biomass of 0. However the low microbial biomass in liquid biofertilizers can be attributed to the poor storage conditions of these liquid biofertilizers after preparation resulting in running out of feed for the microbial forms and the demise during the storage phase. SNM liquid fertilizer mobilized fewer microbes (see table below) and this could be attributed to the limited experience of preparation and also the number of farmers practicing. The three biofertilizers favored mobilization of bacterial compared to fungi species but it its important to note that there is need to establish ways of balancing bacteria ad fungus to improve on carbon use efficiency.

Table 2: Microbial Biomass count for the liquid biofertilizers made by SKI partners in Zimbabwe (2022)

Liquid manure type	Organization	Microbial biomass count (CFU/g) Bacteria	Fungi
SNM	Tsuro	0	
SNM	Tsuro	70	
Fermented Cow Manure	Tsuro	230	1630 (Fusarium)
Fermented Cow Manure	Tsuro	1720	
Fermented Cow Manure	Chinyika	5880	
Fermented Cow Manure	Chinyika	4960	30 (White Rhizopus)
Fermented Cow Manure	PORET	3840	
Fermented Cow Manure	PORET	1640	

2.3 Technical support and progress monitoring

It emerged from this research that there is a lot of potential for development and institutionalization of farmer research networks due to generally similarities in areas of interest among farmers from different regions and places. The desire and quest for knowledge among the famers on the application of biofertilizer concepts is generally the same across all the centers and hence makes it workable to synchronize research and share findings for replication and tests across all the regions.

Key informant and farmers indicated during discussions that significant effort has been put in facilitating exchange learning and these have been good platforms that indirectly set the tone for the farmer -led research.

During the feedback sessions where farmers were assisted in interpretation of the soil analysis results, it emerged that farmers from across the different areas are working on some more or less similar evaluation in their quest to improve performance of the biofertilizers. The following areas where the most common areas which farmers are working on differently and can have information from the findings from different areas shared for the benefits of all.

1. The use of litter and organic material from known biomass accumulator plants and leguminous plants
2. The substitution of yeast with other different materials
3. The substitution of molasses with several other alternatives

The above listed areas can be the basis of information and knowledge exchange and thus creating a network of farmers working on this research elements from across the region and beyond. From the findings of this research there is great potential for the establishment of wider and well-structured farmer research network on soil health with special focus of biofertilizer preparation and application specifically on their optimization.

3. Conclusion and recommendations

3.1. Conclusion

In conclusion, we note that most farmers in the studied area have generally not changed the current practices on the making and use of the biofertilizers technology as trained by SKI. However, the few farmers that have adapted the recipes have done so for store-bought, expensive and out of each inputs such as yeast and molasses replacing them with locally grown/available inputs such locally brewed traditional brew or fruit juice, respectively. Farmers noted various benefits to the soils such as increased residual fertility and to crops i.e. improved crop health as well as benefits to the household economy in terms of saving on fertilizer costs. However, there are a number of knowledge gaps that were drawn out by the farmers but of note is the knowledge on the nutrient content of the biofertilizers which they said would help with more efficient use and potential commercialization. Farmers are also keen on getting the appropriate dilution and application rates for the crops which would maximize yield. The benefits to soil health in particular soil pH were not as apparent and this can be attributed to the brief time from application of the biofertilizers to soil analysis however, the presence of more available nutrients in the biofertilizer (bokashi) treated soil compared to where no addition was done is encouraging. The presence of microbial biomass is also a good indicator that the biofertilizers will encourage soil health by encouraging colonization of soils with microbes. Lastly, there is good scope for the establishment of farmer research networks as generally similarities in areas of interest among farmers from different regions and places can be leveraged to form meaningful and lasting collaborations.

We concluded from the research findings that there is opportunity to promote different innovations that bulk manure production and at the same time increase the rate of adoption and use of the biofertilzers , e.g. Matanga matatu/ 3 pens concept, the use of pelleting machines to package the biofertilizer in a conventional approach which the market is used to. There are also opportunities to link farmers with plastic container sellers in different areas for access to requisite materials and also liking with grain millers who can a be a potential source of bran.

3.2 Recommendations

We recommend that a well-structured and wider project be carried out so as to maximize the use and adoption and potentially scaling up of biofertilizer use in Zimbabwe as a country, in Southern Africa and the entire African regions. There is also need for a long term and extensive research that will monitor the soil health parameters such as changes in microbial biomass over time and its link to production since these cannot be concluded from one set of results. In addition, it is recommended from the research that evaluation of biofertilizers and their characterization be focused not no nutritional composition but rather the microbial composition since there is evidence of improved yield despite the low nutritional composition relative to synthetic fertilizer options.

From the analysis of the findings from this research, it is recommended that baseline data be documented for comparison and tracking of the changes in soil physical and chemical properties. In addition to baseline data, is also recommended that programming of work on biofertilizers across the region have standard soil health indicators which are tracked and monitored for easiness of conclusion on these indicators.

It is recommended that more investment be considered in scientific work and equipment that assist in the monitoring of soil health parameters and this includes the access to mobile soil labs and other testing facilities. This a has potential for leveraging the adoption and scaling on the use and application of the biofertilizers. In addition more human capital for interpretation of soil health data is a critical factor in the success equation of the adoption of the biofertilizers. It is recommended that extension officers be capacitated not only to interpret soil analysis results only on soil chemical properties but both chemical and biological properties.

From the findings of this research, it is recommended that organisations and institutions working on soil health be organized and work towards development of a regional Farmer Research Network on soil health to keep track of soil physical, chemical and biological changes as a result of the use of these biofertilizers.

As farmers are currently exploring alternatives and means of improving production towards development of their commercial lines, it is recommended that more efforts be exerted in influencing the regulatory framework for commercial production of biofertilizer and other natural soil health management products. This is to cultivate a fertile policy environment ahead of the commercialization and development of the biofertilizer industry and at time work to motivate and promote its growth and development.

4. References

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Appendix 1: Focus Group Discussion Instrument

FOCUS GROUP DISCUSSION TOOL_FPC/SKI_HEALTHYSOILHEALTHYFOOD_ 2022

Community name____ Date________________

District____

Facilitator____Notetaker____________________________

Group description/name____

No. male participants________________ No. female participants_______

Age range of farmers in group_________________________

Average time taken:__________hrs. _____________mins

Opening Remarks (2 Minutes)

Good morning/afternoon. Thanks for coming today. My name is -------------and I work for ____________The goal of today's meeting is to understand how biofertilizers have been used and adapted in your communities and what effect they have on soils and crops. There are only a few things that will help our discussion. Firstly, everyone is expected to be an active participant. There are no "right" or "wrong" answers. Please speak freely but please do not to interrupt others while they are talking. We have note takers for reporting purposes only, no names are not attached to the notes. All feedback today will remain anonymous. Participation is free and there is no obligation to respond. Are you all willing to participate in this discussion?------------

Questions

A. *Background/ice breaker*

1. When did you start making biofertilizers?
2. Who came with this technology in the community?
3. a. What is your understanding of what biofertilizers are?
   b. Do they have advantages over commercial fertilizers?

B. Making, use and effects

4. Explain how people commonly make biofertilizers in this community?
5. Is this different from what you were trained. If so how have you adapted the recipes?

6. a. Which crops do you apply the biofert on?

   b. Is it on the whole farm or some portions?

   c. How big are the plots where biofert are applied?
7. What are the dilutions that work best with these fertilizers?
8. What are the conditions that affect the quality of biofertilizers produced?
9. How have the biofertilizers affected crops and soils since you started applying them?
10. What is the biggest challenge you face when making biofertilizers?

C. Potential for scaling out and commercialization

11. Do you know of other farmers who were not trained by the organization but have started using the fertilizers?
12. Have you or someone you know made biofertilizers to sell to other armers?
13. Is there potential in scaling up and out of the technology?

D. Research needs

14. Which areas do you need more knowledge in the making and use of the biofertilizers?
15. What questions do you think research can help answer with regards to the making and use of biofertilizers?

Thank you very much for your participation. The feedback and steps forward will be given to you through the officers you have been working with.

____***end***______________________________________

Appendix 2: KEY INFORMANT INTERVIEWS TOOL_FPC/SKI_HEALTHYSOILHEALTHYFOOD_ 2022

Name of Key informant______________________________________Date_______________

District____

Organization:_________________________

1=Lead farmer 2=Agronomist 3=Extension worker 4=Community leader 5=NGO leader

Interviewer____

Good morning/afternoon. My name is -------------and I work for _____________The goal of today's interview is to understand how biofertilizers have been used and adapted in your community and what effect they have on soils and crops. You have been selected as a key informant based on your knowledge of the farmers activities in this community. Participation is free and there is no obligation to respond. Are you all willing to participate in this interview?------------

Questions

1. Explain how people commonly make biofertilizers in this community?
2. How have they adapted the recipes?
3. How have the biofertilizers affected crops production in this community?
4. Has there been spontaneous uptake of biofertilizer use?
5. Is there scope in scaling up and commercialization of the biofertilizers?
6. Have you or someone you know made biofertilizers to sell to other farmers?
7. What questions do you think research can help answer with regards to the making and use of biofertilizers?

Thank you very much for your participation. The feedback and steps forward will be given to you through the officers you have been working with.

______________________________________end_______________________________________