OVERVIEW OF A VARIETY OF TRIALS ON AGRICULTURAL APPLICATIONS OF EFFECTIVE MICROORGANISMS (EM)

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ABSTRACT

Effective Microorganisms (EM) is a commercially available liquid containing a variety of lactic acid bacteria, yeasts and phototrophic bacteria. These organisms create conditions which favour mutual support and enable them to outcompete harmful pathogens, while producing useful substances such as vitamins, enzymes, hormones, amino acids and anti-oxidants that create a reducing environment. Various EM agricultural application trials were run, mostly in partnership with farmers. The diverse applications included the following: improving soil conditions for better plant growth, treating waste water, controlling pests and diseases, improving animal growth, enhancing compost production and extending the shelf life of harvested crops. Generally EM appears to give the best results in situations where the natural balance of microorganisms has been severely disrupted or where agricultural inputs are in short supply. In situations where natural microorganism populations are reasonably intact, or where a balanced supply of inputs is available, the addition of EM does not seem to make a significant difference.

INTRODUCTION

Beneficial microorganisms perform essential functions in agricultural systems, but as they are not visible to the naked eye, they are often overlooked. Many agricultural practices inadvertently harm beneficial microorganisms, by creating conditions that favour pathogenic microorganisms, enabling them to flourish instead. Indigenous microorganisms have traditionally been applied by some Namibian farmers, such as fermented millet to treat mange on the skin of goats.

Reliance on indigenous microorganisms may produce variable results, depending on the spores present on the materials to be fermented, or in the fermenting vessel, or in the air. Effective Microorganisms (EM) is a commercial product that ensures greater consistency of microbial species composition and enhanced effectiveness of agricultural applications. It is a liquid containing different types of naturally occurring microorganisms, principally a consortium of lactic acid bacteria, yeasts and phototrophic bacteria that create the right conditions for mutual support, enabling them to outcompete harmful pathogens, while producing useful substances such as vitamins, enzymes, hormones, amino acids and anti-oxidants that create a reducing environment (Higa, 1996).

There are many ways in which EM can be applied (Sangakkara, 2001), amongst these, improving soil conditions for better plant growth, treating waste water, controlling parasites, pests and diseases, improving animal growth, and enhancing compost production. The majority of microbial applications in agriculture reported in Xu, Parr, & Umemura (2000) were based upon EM.

To reduce the costs of EM applications, farmers can multiply their own EM, either by simply fermenting the mother culture, known as stock EM, with molasses and water in a container that is airtight, or by a multitude of advanced methods to achieve superior quality (Pinto, 2004). Since the different types of microbes in EM multiply at different rates, the stock EM should not be multiplied more than once. The multiplied EM is usually further diluted immediately before application. The suggested dilutions for different uses are as follows:

- Undiluted – for controlling rust or dosing animals against intestinal worms
- 10 x dilution – for controlling bad smells, applying to wounds or unblocking drains
- 100 x dilution – for making compost or silage or other fermented feed
- 1 000 x dilution – for irrigating soils, spraying onto plants or worm bins or drinking water for animals.
- 10 000 x dilution – for aquaculture or cleaning water in ponds or tanks

The diluted EM may be applied by spraying onto solid surfaces, or pouring into liquids or loose solids. It can also be applied in the form of various EM derivatives (APNAN, 1995; EMROSA, 2004; Rosenberg & Linders, 2004).

For pest control EM can be fermented with plants that have appropriate repellent properties or with distilled alcohol and grape vinegar. For supplementing animal feed EM can be fermented with low-cost, loose organic material, such as husks or bran. This product is known by its original Japanese name of bokashi. Bokashi can also be used to enrich the soil. Manure and/or other organic material can be composted with EM. For stronger fertilizer EM can be fermented with a low-cost source of protein, such as fishmeal or blood from slaughtered animals. When treating dirty water or conditioning soil, it may be possible to enhance the effectiveness of EM by adding charcoal, or a similar material with tiny perforations, in which the microbes can house themselves.

To remain viable, EM should ideally be stored within a temperature range of 10 °C to 20 °C. Under these conditions stock EM will remain viable for about six months after culturing (EMROSA, 2004). Multiplied EM has a lower viability which is linked to the dilution rate used in its multiplication. For example, 1 part stock EM to 1 part molasses to 18 parts water will produce multiplied EM with a viability of about 30 days, while 1 part stock EM to 5 parts molasses to 94 parts water will produce multiplied EM with a viability of only about 6 days (Pinto, 2004). Due to its perishability, special care needs to be taken when EM is transported and stored.

The way in which EM functions is not entirely understood. EMROSA (2004) states that "EM can suppress harmful microorganisms by competitive exclusion" and that "The majority of microbes are opportunistic – they are not harmful or beneficial by themselves but work with the dominant microorganisms. When microorganisms (beneficial ones, pathogenic ones, or opportunistic ones in the air, water and soil) try their best to survive, they create a 'society' for food and a living environment for each other. If there are too many pathogens present, they build a pathogenic 'society'. Beneficial organisms will build a preferable 'society' for living organisms if their numbers are superior." According to Wood & Abuchar (2002), lactic acid bacteria in EM do not only produce lactic acid which kills pathogenic microorganisms, but also significant amounts of growth inhibitors such as reuterin, a broad-spectrum antimicrobial agent, proven to inhibit the growth of bacteria, fungi and protozoa. Furthermore, the phototrophic bacteria in EM are able to separate out the hydrogen in ammonia, hydrogen sulphide and hydrocarbons. These bacteria from the family Chromatiaceae are also known as purple sulphur bacteria and are reputed to be rapid consumers of gasses such as ammonia and hydrogen sulphide (Pfenning & Trüper, 1992).

EMROSA (2004) ascribes the effectiveness of EM in fly control to the fact that it reduces ammonia gas, which normally attracts flies from up to 5 km away, and to the actinomycetes, found in some types of EM, which feed on the chitin produced by fly larvae when turning into pupae. On the other hand, Kapongo & Giliomee (2000) found no reduction in the number of flies emerging from poultry manure, but that EM increased the parasitoids on fly larvae and pupae. Higa (2001) claims that the antioxidant substances, formed by EM in the decomposition and fermentation of organic matter, induce microbes to secrete decomposing enzymes such as lignin peroxidase, and that such enzymes have the capacity to decompose residual agrochemicals. He attributes further benefits to the wave resonance of the microbes in EM. The Russian Science News Agency (undated) reported that researchers used the ability of purple phototrophic bacteria in EM to break down toxic peptides and other toxins formed by algae, thus cleaning water that supported an algal bloom. In the case of EM derivatives used for pest control, Wood, Miles & Tahora (1999) note that lactic acid bacteria produce esters from alcohol and vinegar which deter insects by creating a repellent barrier between insect and plant. These repellent barriers, in conjunction with the smells emanating from aromatic plants fermented with EM, result in much lower levels of insect attack.

The Department of Agriculture at the Polytechnic of Namibia ran various trials with EM. These took place mainly as a student training activity, during which students facilitated farmer experimentation as part of their studies (e.g. Zimmermann, 2005). This paper gives a broad overview of these trials, but does not provide details of individual trials.

MATERIALS AND METHODS

Preparation of materials

For most of the trials, stock EM was multiplied 20 times, at a ratio of 1:1:18 by volume of stock EM, molasses and water respectively. The use of borehole or rainwater was preferred, but if municipal water had to be used, it was exposed to the sun for a day to prevent chlorine from killing the microorganisms. The water was warmed to about body temperature and the molasses stirred in until dissolved. This warm molasses solution was then poured into the fermenting vessel, usually a plastic bottle with an airtight screw-on lid. To provide the microorganisms with extra minerals, small quantities of rock salt, granulated kelp and ground turmeric were generally added to the molasses solution in the fermenting vessel. After this, the stock EM was added and, where necessary, the vessel was topped up with warm water so that only a small air gap remained when the lid was tightly screwed on. The vessel was then kept in a warm, dark place for at least two weeks, during which time the lid was occasionally unscrewed to release the excess gas that built up inside. For a few of the trials the stock EM was multiplied 100 times, at the ratio of 1:5:94 of stock EM, molasses and water, as suggested by EMROSA (2004).

Many trials made use of fermented organic material, known as bokashi. The most conveniently available and affordable organic materials were used to make bokashi; these included millet husks, wheat bran, maize bran and malt dust from the brewing industry. Water was warmed and molasses stirred into it, followed by Multiplied EM (M-EM) at the ratio of 30:1:1 by volume. The resulting solution was poured into the organic material in small quantities, and thoroughly mixed in by hand until it was just moist throughout, so that no moisture could be squeezed out of it by hand. To achieve this optimum moisture content, the ratio of solution to organic material varied from about 1:2 for very dry and fine organic material, to about 1:5 for coarse organic material with a slightly higher moisture content. The moistened material was then pressed tightly into strong plastic bags, with as much air as possible being pressed out before tying the bags shut with string. The filled bags, normally containing about 30 kg of bokashi, were left in a warm, dark place to ferment for at least four weeks.

In a few trials, manure from different animals, or rumen content from slaughtered cattle, was composted by fermenting with EM. In other trials silage or haylage was made by fermenting chopped green plant material or dry plant material respectively. The procedures for making these EM derivatives were similar to those for making bokashi, described above. If there was insufficient time to ferment the manure, it was simply mixed with 1 % of M-EM and applied straight to the soil.

A liquid made from fermented spices and known as EM3-in-1 was used in some of the trials. Water was warmed and molasses stirred in at the ratio of 30:1 by volume. Equal masses of fresh garlic, ginger and chillies were chopped and poured into a plastic bottle followed by an equal mass of dried black pepper. The molasses solution was poured into the bottle, which was then topped up with the same volume of M-EM as the undiluted molasses. The mass of each spice used was about 20 g/L of liquid. The lid was tightly screwed onto the bottle, which was then kept in a warm, dark place for at least two weeks, during which time the lid was occasionally unscrewed to release the strongly aromatic gas that built up inside.

Some trials made use of a strong mixture of molasses, grape vinegar and distilled alcohol fermented with EM, and known as EM5. Water was warmed and molasses stirred in at the ratio of 6:1 by volume and poured into a plastic bottle. The bottle was then topped up with grape vinegar, gin and M-EM, each to the same volume as the undiluted molasses. With the lid screwed on, the bottle was stored in a warm, dark place for at least three weeks. The bottle was occasionally opened to release the pleasantly aromatic gas that had built up inside.

Fermented plant extracts, known as EM-FPE, were used in some trials. In most cases a plastic bucket with a lid which fitted tightly, was used as a fermentation bucket. Plants, often weeds, were selected according to desired characteristics, such as aromatic properties that repel certain pests and those rich in minerals that support healthy microorganism populations. The plants, or their leaves, were harvested and placed in the bucket until they loosely filled it, without being compacted. Water was warmed and molasses stirred in followed by M-EM at the ratio of 30:1:1 by volume. This solution was poured onto the plants until it covered them and reached almost to the rim of the bucket. The lid was firmly sealed to ensure that the bucket was airtight, after which it was kept in a warm, dark place for at least two weeks. During this time the lid was occasionally lifted at the side to release the gas that built up inside.

General procedures for conducting trials

The EM treatments were tried on a sample of plants or animals while, whenever possible, conventional treatments were applied to a similar sample and/or a similar sample was left untreated as the control. In cases where there was no control, measurements were taken before and after EM treatment. Again, where possible, treatments were replicated, so that statistical analyses could be performed on the results. The majority of trials were conducted by farmers as part of action research initiated during visits to communities in August, when the trials usually commenced, and follow-up visits in October. During their first visit students provided the M-EM or its derivatives and demonstrated how they should be applied and how measurements should be taken and recorded. During the second visit the trials were jointly evaluated and the results shared with other community members. Over and above the action research trials, other trials were conducted by students for their research projects, during In-service Training or for the Bachelor of Technology programme. Yet others were conducted as part of coursework or independently. The numbers of trials performed under each of the abovementioned levels are shown in Table 1.

Applications for soil health

The simplest EM application to the soil consisted of diluting M-EM in water about 500 times and using that to irrigate plants, either as a single application or as weekly applications. In some trials molasses equal in volume to the M-EM was also added, to feed the microbes. Bokashi or EM-fermented manure was incorporated into the soil in some trials, usually at the rate of about 1 kg/m^2, or up to 10 % if mixed into sand for pots or growing benches. Treated soil or growing medium was usually moistened and left for two weeks for the pH to rise back to normal, after which it was used as a medium for sowing or transplanting. Several trials raised *Eisenia fetida* earthworms, with dilute M-EM applied when moistening the bedding of the EM treated worms, usually once a week.

Applications for plants

Due to the low pH of EM, (at around 3.5), the EM derivatives had to be greatly diluted before spraying onto plants, mainly for pest control. The derivatives tried were EM3-in-1, EM5 and EM-FPE made from a diversity of plants. The dilution rate was either 500 times or 1 000 times and applications were usually applied weekly. If sprayed onto harvested crops to prolong shelf life, then lower dilution rates were used, varying between 10 and 100 times. For germination trials, seeds were soaked for a day in a 100 times dilution of M-EM before sowing in trays.

Applications for animals

Animals were either provided with bokashi as supplementary feed, preferably at 3 % of their intake, or sprayed with an EM derivative to control external parasites. Silage and haylage were made from locally available plant materials only during the first action research visit, being allowed to mature until the second visit when it was offered to animals to gauge its palatability. The derivatives tried for parasite control were EM5, EM3-in-1, and EM-FPE made from a diversity of plants. The dilution rates varied from undiluted to 10 times.

Applications for water

Water was treated in two trials with both M-EM and bokashi dumplings. The effective dilution rate for the M-EM was 500 times for treating semi-purified water but 10 000 times for treating a fish pond. For the semi-purified water the bokashi dumplings were made from a mixture of 40 % by volume of charcoal that had been soaked in M-EM, 40 % dry clay, 15 % M-EM and 5 % bokashi. For the fish pond the mixture consisted of 80 % by volume of dried sludge from the bottom of the pond, 10 % M-EM, 5 % dry clay and 5 % bokashi. The mixtures were squeezed into dumplings about the size of tennis balls and allowed to ferment for a week, before being put into the water at the rate of about four dumplings per m^3.

Indicators of effectiveness

Criteria for determining the effectiveness of the EM applications varied. For soil applications, the mean height of plants was commonly used, since most trials ended before harvest. Otherwise yield was measured. There were some attempts to determine plant quality, from squeezing a drop of sap onto the prism of a refractometer and reading the total dissolved solids as % brix. In a number of bioassay trials the resulting overall fertilities of soils were compared through radish bioassays, by growing radishes in differently treated soils and weighing them after harvest. Vermiculture applications used the number of earthworms produced as an indicator of success. Germination trials determined the % germination. Pest control properties of EM were evaluated by counting pests, whether on plants or on animals, while some of the latter also used animal liveweight to determine the influence on animal performance. Other indicators of animal performance were the number of eggs or chicks produced by chickens. In very few cases samples were analysed in laboratories for chemical or physical properties. Where quantitative data was not collected, qualitative assessments were made, by noting whether animals appeared to be healthy, how eagerly they ate an EM derivative or the smell of the EM derivative.

RESULTS AND DISCUSSION

Overview

Of 62 trials conducted, 43 produced quantitative data. However, statistical analyses could only be performed on results from 30 trials, with 19 showing significant benefits of EM treatment at $P < 0{,}05$. Many of the qualitative results were impressive and farmers considered the EM treatments to be effective in 45 of the trials (Table 1). The shortage of quantitative data from action research was largely a result of some farmers not having collected the data as requested; however, in some cases it was because students failed to arrange for farmers to do so. The Bachelor of Technology projects provided the most statistically significant results, presumably due to their larger sample sizes.

Results from soil applications

In order to evaluate soils from various sites in a vegetable garden and crop field, Hangula (2004) performed a radish bioassay. M-EM was diluted 500 times and used for daily irrigation of half of the radishes; the radish fresh mass only increased in the better soils with higher organic content. This was as expected, since the microbes need organic matter to feed on. In an independent trial a section of lawn treated weekly with M-EM and molasses, both diluted 500 times, showed great improvement in vigour after only a few weeks. However, a single application of a similar solution did not significantly increase the yield of lucerne grown in good quality soil that had been well manured and regularly irrigated (Zimmermann, 2008).

Soil applications of bokashi also produced varied results. Data gathered by Ngalangombe (2006) showed young rape plants grown in pots with 10 % bokashi in the growing medium to have a slightly greater mean height than those grown in a medium to which a commercial soil amendment with micorrhizal fungi had been added; however, the difference was not significant at $P < 0{,}05$. Plants growing in pots with 10 % charcoal seemed to be inhibited slightly, but not where the charcoal had been soaked in a 50 times dilution of M-EM and molasses before it was added to the sand (Figure 1).

In another trial performed as coursework, no significant differences were found among sweet corn plants raised in growing benches containing river sand with 10 % feedlot manure, some fermented with M-EM, and some with 20 % charcoal and/or 10 % bokashi. However, Kibangu (2006) found that lettuce grown in a medium containing 3 kg/m^2 of bokashi made from rumen content yielded more than lettuce that received a 3 kg/m^2 feedlot manure treatment.

EM-fermented manure seemed to perform better than manure into which M-EM had simply been mixed. Kambuli (2006) grew tomatoes in soil treated with donkey manure with and without M-EM mixed in, but found no difference in height of plants. On the other hand, Zakaapi (2006) found

Table 1. Numbers of trials conducted with Effective Microorganisms (EM) in different categories

Level at which trial was facilitated	Total trials	EM tested on			Type of results produced		EM perceived as effective		Statistically significant
		Soil	Plants	Animals	Quantitative	Qualitative	Yes	No	
Community Action Research	29	7	9	13	12	17	20	9	5
In-service Training	15	5	6	4	14	1	11	4	6
Bachelor of Technology	10	4	1	5	10	0	9	1	7
Other	8	3	4	1	7	1	5	3	2
Total	62	19	20	23	43	19	45	17	19

that tomatoes grown in beds treated with EM-fermented goat manure grew significantly taller than those grown in beds with fresh goat manure, some irrigated with dilute M-EM, and some without M-EM, and others grown in soil treated with old goat manure without EM (Figure 2).

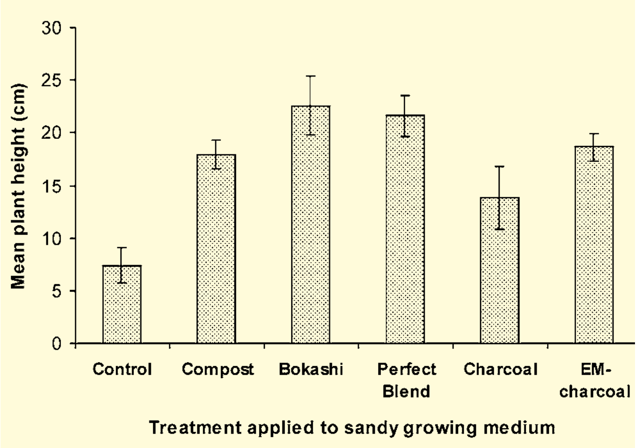

Figure 1. Mean height ± 95 % confidence limits of young rape plants growing in sand with a variety of amendments, based on data from Ngalangombe (2006).

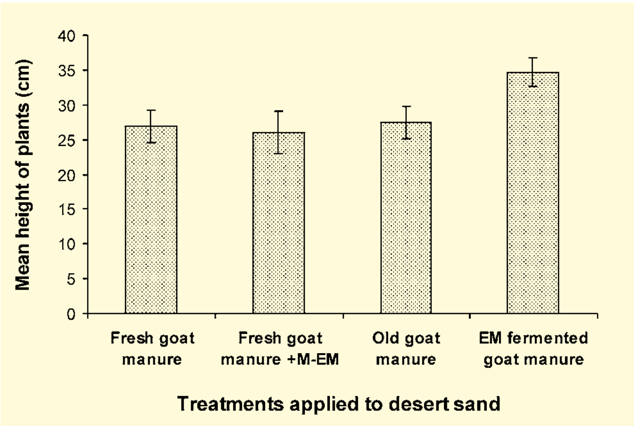

Figure 2. Mean height ± 95 % confidence limits of tomato plants grown in desert soil with a variety of amendments, based on data from Zakaapi (2006).

Shehaama (2007) grew taller cabbages with cattle manure and M-EM than with conventional NPK 2:3:2 fertilizer. Newaya (2004) found that maize plants were taller and radishes heavier when grown in soil to which either chicken or goat manure, each mixed with M-EM, had been applied, compared to plants grown in soil enriched with either bokashi or cattle manure mixed with M-EM. However, Nanyeni (2004) did not find a significant difference in height or leaf brix of maize grown with and without bokashi two months after applying the bokashi as top dressing where young maize plants were already established. An attempt by Poniso (2004) to produce compost from EM-fermented leaves of a variety of indigenous trees resulted in a product more like silage, so instead of applying it to the soil it was offered to cattle, and they gladly ate it.

A greater density of worms was found by Hailwa (2005) in bins containing garden refuse moistened with M-EM diluted 500 times, than in the control moistened with water. Hangula (2005) found a similar trend when growing earthworms in a mixture of sorghum hay and dairy cattle manure, though it was not significant at $P < 0{,}05$. Kandjimi (2006) raised earthworms in rumen content from slaughtered beef cattle. Since the pH of the rumen content was very high, usually above 8,0 about 1 % of M-EM was mixed into the rumen content intended for the EM-treated worm bins. However, this did not significantly lower its pH, nor was there a higher density of worms produced in these bins. It is likely that the microflora in the rumen fluid created optimal conditions by providing sufficient feed and performing sufficient services to keep the worms happy and that the addition of EM-microbes therefore made no difference.

Results from plant applications

Soaking seeds in M-EM diluted 100 times speeded up germination and increased the proportion of seeds which germinated in most of the species tested, in comparison to the control seeds soaked in water. However, this increase was usually marginal, and in a few species germination actually decreased. Rosenburg & Linders (2004) warn that legume seeds should not receive EM treatment. This is borne out by Mutumbulwa (2006), who found that only 15 % of *Albizia anthelmintica* seeds soaked in 1 % M-EM germinated, compared with 55 % soaked in water. She also found that EM soaking resulted in faster germination for *Kigelia africana*, with all the EM-soaked seeds germinating after 13 days, while all those soaked in water germinated after 25 days. Diergaardt (2006) found that EM soaking slightly speeded up the germination of parsley and chives, but slightly lowered the germination and subsequent growth rate of celery. An independent trial with seed of devil's claw, *Harpagophytum procumbens*, showed that EM soaking increased germination from 5,5 % to 12,5 % (Figure 3).

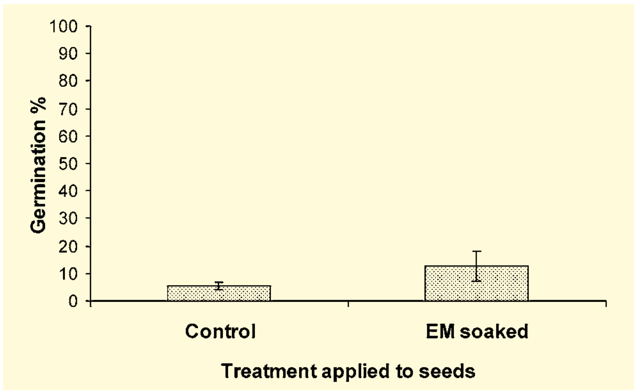

Figure 3. Mean germination rate ± 95 % confidence limits for seed of *Harpagophytum procumbens* soaked in water or in dilute M-EM for 24 hours before sowing.

Most trials on the use of EM derivatives for pest control proved successful, but to varying degrees. Kalingodi (2004) achieved notable success through the weekly spraying of newly transplanted tomato seedlings with garlic EM-FPE (Figure 4).

Figure 4. The control tomato plants in the photo on the left were dying as a result of an attack by red spider mite while plants of the same age in the right-hand photo had been sprayed weekly with garlic EM-FPE diluted 100 times.

Using the same garlic EM-FPE, Helondo (2004) noted a reduction in thrips on onions and Amaambo (2004) noted less grasshopper damage on swiss chard. Kanutus (2006) also found a reduction in grasshoppers on rape sprayed with EM-FPE and top dressed with a thin layer of bokashi. After weekly spraying with EM-FPE made from a variety of weedy plants, Hasheela (2005) noted a reduction in an unidentified beetle on beetroot and Zakaapi (2005) noted a reduction in aphids on cabbages. Tjilumbu (2005a) harvested more tomatoes from plants sprayed with EM3-in-1, after many of the control tomatoes suffered from blossom-end rot. By examining the top three leaves of old tomato plants, Von Krosigk (pers. comm.) found that whiteflies reduced from about 40 to fewer than 10 after rotating the weekly spraying with EM3-in-1, EM5 and EM-FPE, while on young tomato plants there was a reduction in all but two of the 16 weeks of observation. Josua (2006) found that weekly spraying with EM3-in-1 reduced grasshoppers, stinkbugs and bagrada bugs on cabbages almost as well as the conventional chemical insecticide did. On the other hand, Amwandi (2007) found that EM3-in-1 controlled aphids on cabbages better than the conventional chemical insecticide.

Harvested crops treated with M-EM also showed variable results. Iitula (2004) found fungal growth roughly a week after harvest, on both untreated pawpaws and those that had been sprayed with M-EM diluted 10 times, although the subsequent damage caused by the fungus was less in the treated fruits. Hekandjo (2005) found that similarly treated tomatoes rotted after two months, but that treated onions produced much firmer bulbs that dried well, while the untreated bulbs were soft and oozed a smelly liquid when squeezed. Kibangu (2005) found no difference in quality of *Cenchrus ciliaris* hay sprayed with M-EM diluted 10, 33 and 100 times, with and without a similar dilution of molasses. However, it is unlikely that anaerobic fermentation had taken place because each large round bale had simply been covered with loose pieces of plastic instead of being wrapped in a single, large and airtight plastic sheet. Fillemon (2007) found no difference in the appearance of Swiss chard leaves sprayed with M-EM diluted 1 000 times and those sprayed with water before being stored in plastic bags in a room. However; those treated with EM lost a mean weight of only 3,7 g per packet, significantly less than in the control, where the loss was 5,5 g per packet over 8 days. We do not understand why these results differed. The recommended M-EM dilution rate of 10 times was not applied in this trial.

Results from animal applications

Attempts to make silage and haylage brought about mixed results. Shetukana (2006) found that cattle were not keen to feed on silage he had made from green leaves, nor on haylage made from dry tree leaves, both mainly from trees in Caprivi, but they did eat haylage made from dry grass collected near Windhoek, despite the sweet acidic smell that emanated from all three materials. Perhaps the cattle were discouraged by the chemical deterrents in the leaves from Caprivi, such as condensed tannins that are a common feature of broad-leafed trees growing on infertile sandy soil (Owen-Smith & Danckwerts, 1997). The silage made by Gawaseb (2004) from a mixture of chopped elephant grass (*Pennisetum purpureum*) and the indigenous *Cenchrus ciliaris* smelled more like rumen contents than like silage, nevertheless, cattle happily fed on it.

Supplementing animal diets with bokashi brought about positive results in animal performance. Shigwedha (2004) found that chicken feed supplemented with bokashi made from millet husks, increased the rate of laying by about four times, so that the chickens had more eggs than they could incubate. This may have been because the farmer fed the hens equal volumes of millet grain and bokashi to supplement their semi-free ranging in a large run, instead of feeding the bokashi at the recommended rate of 3 % of the diet. Josua (2005) found that chickens supplemented with a small amount of bokashi laid a mean of 7,5 eggs per hen over a month, compared with 3 eggs per hen for the control group. Mufeti (pers. comm.) reported that when supplementary bokashi was given, chickens raised a mean of 3,7 chicks per hen, compared with only 0,8 chicks per control hen.

Namushinga (2005) found that each of four piglets grew by 5,8 kg over eight weeks when given a daily supplement of about 80 g of bokashi, compared with the control piglets that gained only 1,5 kg. Aitana (2006) found that the supplementary feeding of five goats with 150 g bokashi per animal per day, resulted in a mean individual weight gain of 0,9 kg over seven weeks of the dry season, while the control goats lost 0,3 kg, and that five sheep gained 0,6 kg when given the supplement while the control sheep lost 0,2 kg over the same period. Kazapua (2005) found that when ten goats received a daily supplement of about 100 g bokashi per goat, they lost a mean of 1,8 kg each over 6 weeks of the dry season, while another ten goats lost 4,3 kg after receiving the same quantity of crushed pods of *Acacia erioloba*. Heita (2006) found that a goat kid that had been fed a handful of bokashi daily, gained 27 kg over two months, in comparison with an average weight gain of 12 kg for the three untreated kids at the start of the growing season (Figure 5).

Shiningeni (2005) found that sheep receiving a daily supplement of 60 g bokashi per animal, after an initial dosing with 40 ml of M-EM, gained a mean of 1,3 kg each over seven weeks of the dry season, compared with 0,7 kg for sheep that had been injected with the conventional chemical nematicide, 0,3 kg for the control sheep and a loss of 0,1 kg for sheep that had each been dosed with 40 ml of M-EM but received no supplementation. Over those seven weeks there was a reduction in parasite loads of the nematode genera *Strongilus* and *Strongiloides* with all treatments, but Coccidia increased in all groups of sheep including the control (Figure 6). It is unclear whether the EM had anything to do with the increase in Coccidia or whether this was a coincidental factor over this coldest time of the year. The importance of alternative management interventions to chemical nematicides lies in the harmful effects of these poisons on dung beetles that perform essential services such as maintaining soil health and reducing breeding sites for flies and parasites (Kryger, Deschodt & Scholz, 2005).

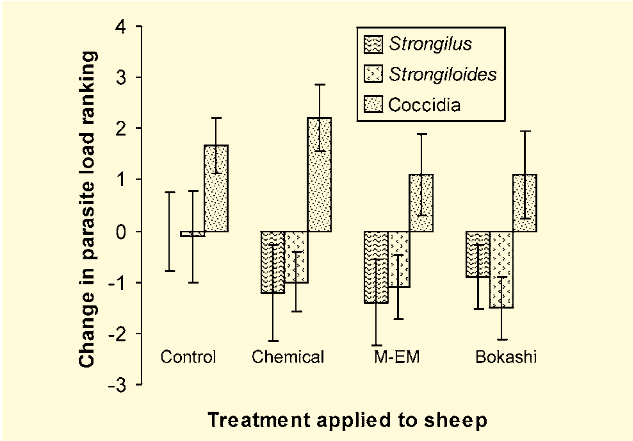

Figure 6. Mean change in parasite load ranking ± 95 % confidence limits over seven weeks from dung of sheep that received different treatments.

Other veterinary applications of EM were for treating diarrhoea and ticks. Tjizera (2005) noted that diarrhoea cleared up more quickly in goat kids that had been dosed with 10 ml of M-EM diluted in 200 ml water, compared with the control kids. Nanyeni (2005) noted that cattle were tick-free, four weeks after being sprayed weekly with EM5 diluted 10 times, while there was a low mean tick load of 3,5 ticks per control cow; also that flies were reduced from a mean of 39,5 flies per control cow to 12,5 flies per sprayed cow. Haikali (2006) found a gradual reduction in tick loads on cattle sprayed weekly with EM5 diluted with an equal amount of water, from a mean of 20 ticks to 8 ticks per cow at the end of seven weeks, while the mean tick load on the control cows rose from 20 to 22 ticks per cow over the same period. Tjilumbu (2005b) found a mean of 2,5 ticks under the tail per cow two months after spraying with EM5 diluted 10 times, while those treated under the tail with old engine oil had a mean of 4,4 ticks. After three months of weekly spraying with EM5, initially diluted but later undiluted, Kapalanga (2006) found a mean of 11 ticks per goat, compared with 37 ticks per control goat and 21 ticks per goat treated weekly with old engine oil.

Figure 5. Two months after receiving a supplementary handful of bokashi per day, the goat on the left had gained 27 kg compared with a mean gain of 12 kg for untreated goats, like the one on the right.

In three trials that compared the application of EM with conventional chemical acaricides, EM was found to be slightly less effective in reducing tick loads, although more beneficial on animal performance in the single trial in which the animals were also weighed. Mutonga (2006) found, after four weeks of weekly spraying with EM5 equally diluted with water, that the mean tick load on cattle was 19 ticks per cow, compared with 50 ticks per control cow and 12 ticks per cow sprayed weekly with the conventional chemical acaricide. Amaambo (2006) found that weekly spraying of goats with a combination of EM5 and EM3-in-1 not only reduced ticks as effectively as the conventional chemical pour-on treatment, but that the liveweight gain over the five weeks of the trial was significantly higher in the EM-treated group than in either the chemically treated goats or the control group (Figures 7 & 8).

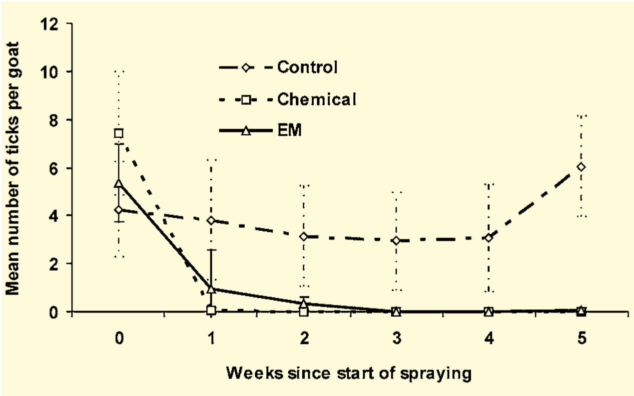

Figure 7. Mean weekly tick loads ± 95 % confidence limits for groups of goats that received different spraying treatments, based on data from Amaambo (2006).

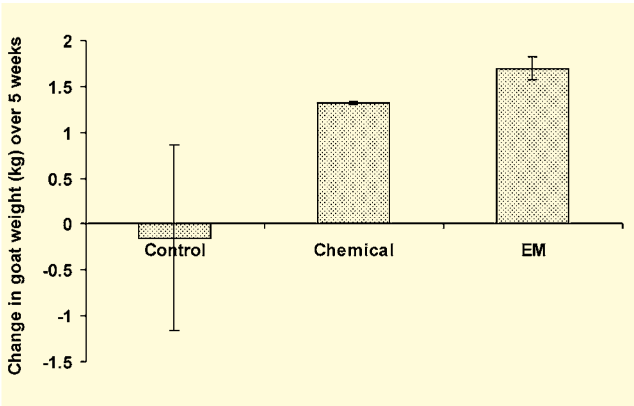

Figure 8. Mean liveweight change over five weeks ± 95 % confidence limits for groups of goats that received different spraying treatments for tick control, based on data from Amaambo (2006).

Liyemo (2007) found, after four weeks of weekly spraying with EM-FPE made from the local aromatic bush, *Laggera decurrens*, diluted with three parts of water, that the tick load on cattle was at a mean of 3 ticks per cow on one side of the body, compared with 24 ticks per control cow and 1 tick per cow sprayed weekly with the conventional chemical acaricide. The significance of using EM-FPE for tick control is that it is a lot cheaper to produce than EM5. Unfortunately industrial ethanol appears to be unavailable in Namibia and pharmaceutical ethanol is more expensive than gin. Some locally distilled brews which are cheaper are being tried in EM5 in order to establish their quality. The importance of alternative management interventions to chemical acaricides lies in the harmful effect the latter can have on tick predators (Ostfeld, Price, Hornbostel, Benjamin & Keesing, 2005) and, especially in the case of pour-ons, on dung beetles that perform important ecological services (Kryger, Deschodt, Davis & Scholtz, 2007).

Results from water applications

An attempt to reduce the pathogenic bacterial load of semi-purified water to make it suitable for irrigation of edible crops backfired. A treatment of two litres of M-EM and four bokashi dumplings in a tank of 1 m^3 greatly increased the total coliforms in the water. It is likely that the bokashi in the dumplings provided food which enabled the coliforms to reproduce rapidly. Bokashi dumplings should actually be used only in situations where the sludge has settled out at the bottom of a tank or water body.

After undiluted M-EM was poured into an old swimming pool converted into a fish pond, to provide an eventual dilution of about 10 000 times, Kanhinda (2004) found that the floating algae reduced to about 20 % of the surface compared with more than 50 % before. The bokashi dumplings that were thrown in later reduced the algae even further.

CONCLUSION

The results of EM applications were highly variable. The application of EM was shown to be significantly effective in 19 of the 62 trials, and perceived to be effective in a further 26 trials, while perceived as making no difference in 16 trials and worsening conditions in one trial. These differences in the effectiveness of EM may have resulted from differences in circumstances under which the EM was applied, or in differences in the storage and handling of the EM.

Generally EM appears to achieve the best results in situations where the natural balance of microorganisms has been severely disrupted or where agricultural inputs are in short supply. In situations where natural microorganism populations are still reasonably intact, or where a balanced supply of inputs is available, the addition of EM seems to make less of a difference.

The success of EM applications also depends on EM being stored and transported under ideal conditions. Care should be taken with this live product to ensure its viability. EM should be stored in airtight containers with minimal air spaces, away from direct sunlight, and not exposed to extreme fluctuations in temperature.

Since most applications of EM are greatly diluted with water, the costs are fairly low. Although EM can play a useful role in controlling some pests and diseases, the very fact that pests or diseases have broken out usually indicates that an underlying imbalance exists (Chaboussou, 2004). The use of EM in such cases should hopefully be a temporary measure, until the underlying causes of the outbreaks have been adequately addressed.

ACKNOWLEGEMENTS

We thank the many farmers and students who conducted these trials, and the Polytechnic of Namibia for funding most of them. Some follow-up trials are being funded by the German Ministry of Education and Research (BMBF) through the Biodiversity Transect Analysis in Africa (BIOTA Southern Africa) programme (01 LC 0624A2).

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