Investigating The Potentials Of Growing Benches And Effective Microorganisms In Arid Environment: The Namib Desert

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Abstract

The potential uses of growing benches and effective microorganisms as possible gardening alternatives in water-scarce environments such as the arid Namib Desert were investigated over a period of 7 months (January-July 2006) at the Gobabeb Training and Research Centre. Recycled wastewater from Gobabeb Training and Researching Centre was used to water plants and Effective Microorganisms (EM) was used in trials to speed up the rate of organic matter decomposition and assign trial treatments. Growth heights of 144 Tomato plants, cultivar Flora Dade, were measured on every 7^{th} day.

Highest growth heights were recorded in the No EM growing bench after it was supplemented with goat manure, followed by EM growing bench. The only highly-significant difference was observed between the bed types (p-value < 0.001). Results of this study suggest that the success of the growing benches was due to greater moisture availability for the plants on the growing benches compared to the flat beds. There was no significant difference between EM and NO EM plots. This was likely due to a lack of nutrients (in the donkey manure used) and to resulting competition for nutrients between plants and the microbes, and due to a poor microbial activities.

Keywords: Gobabeb training and Research Centre, Namib Desert, water scarce, growing benches, Effective Microorganisms (EM), and growth height canopy.

1. Introduction

Deserts are the world's most arid ecosystems; hot and dry winds, infertile salty mobile soils, water scarcity and extreme heat that results in a high evaporation all limit crop production in deserts (Brookbank, 1997). Water is the most limiting natural resource affecting agricultural productivity (Hutchinson et al, 1985). This is a particular problem in the far lower Kuiseb valley of the Namib Desert. Water scarcity is a prominent problem in arid environments, including Namibia. Appropriate alternative measures to reduce water use and water loss need to be exercised, in order to increase agricultural production in an environmental sustainable way (Dausab et al, 1994). As water availability continues to worsen and food production practices increase pressure on the minimal available resources and the environment, adequate education and demonstrations are essential for communities. This is to ensure sustainability use of resources and the environment. This includes the sustainable use of resources, the need to adopt practical sustainable lifestyles, such as recycling wastewater for agricultural use, and the use of modern crop cultivation practices with minimal soil disturbances (Barrier, 1993:46).

In view of this, an investigation into the potentials of growing benches and the use of effective microorganisms was carried out to determine how these methods could be suitable for use in harsh environment for the Kuiseb Topnaar of the Namib Desert. Key issues considered were: the scarcity of high quality water for communities' agricultural use, the current production status of the communities, the climate of the desert ecosystem and the increasing cost of water for the Topnaar communities, especially in the far lower Kuiseb. The main objectives of the investigation were (a) to identify the potential benefits of gardening in benches and effective microorganisms use for agriculture in arid environments, especially the far lower Kuiseb and (b) compare the effects of EM and growing benches on crop growth.

2. Background

Despite a large number of constraints to plant production in the desert environment of the Kuiseb, residents still have interest in gardening. Topnaar communities do run small gardens, primarily for home consumption. They mainly grow cabbages, watermelons, carrots, beetroots, squashes and pumpkins for home consumption. However, most of them have stopped gardening due to water scarcity and high water fees (particular in downstream settlements). They have also never received any technical assistance from the Ministry of Agriculture, Water and Forestry on how to improve their gardening techniques such as better irrigation practices/water conservation (Werner, 2003). An interview conducted during the study period found that people indicate increased interest in gardening due to a planned tourism concession some community members want to make use of this upcoming potential market.

In Topnaar—and many other—communities, knowledge about the use of modern agriculture and use of equine manure such as that of horses and donkeys, Effective Microorganisms and the use of growing benches, is limited. This lack of knowledge and information sources is the main reason communities do not use this manure and modern agricultural practices. A gardener at Oswater said he has used donkey manure but stopped due to weed problems, long composting durations and lack of a kraal for his animals (S. Kooitjie, *pers. comm*., 2006).

Growing benches are raised beds constructed with bricks and lined to retain soil. This system of growing plants, usually vegetable crops, allows a gardener to grow very intensively in a limited area, by adding copious amounts of garden compost and other composted organic matter in a build bed [seems like you should have some citations for this information]. These areas also allow vegetable gardening to be successfully carried out, by creating small areas of very fertile soil, when the garden soil is very poor and water is scarce to support good production. Where soil is poor and water is limited, growing benches are potential gardening methods for such conditions. They confine soil, dead leaves and other debris within their borders. They are similar to raised beds except that they are used where water is scarce to increase soil moisture, and where soil does not suit gardening to retain improved soil. They are not holed to increase drainage as in the case of raised beds. In consideration of the desert climate, growing benches could be beneficial for home gardening as they would help enhance gardening due to better water use, could improve the outputs per area with limited inputs and retain improved soil. They also do not require the usual space between rows because farmers need not walk in the bed to cultivate or harvest. [any sources at all for this paragraph?]

Donkey manure was chosen for the trials. The manure was used with the aim to increase the water holding capacity of the soil. The choice of the organic matter was also based on the ability to aerate the soil and to feed the microbes. Organic matter with a low C: N ratio is highly preferred in the use of EM as it provides the microbes with readily available carbons to feed on (Sangakara, undated). Donkey manure does not fulfill this requirement and the selection was based on attending the water problem.

3. Materials and Methods

Upon the conduction of the trial, the following materials and methods were used.

3.1 Materials

- A total of 82 clay bricks measuring 14 cm by 24 cm and 11cm.
- A builder's plastic measuring 9m by 2m.
- 16 wheelbarrows of donkey manure collected along the Kuiseb River and piled up in the sun for 3 weeks to compost.
- 24 wheelbarrows of river sand
- Tomatoes seeds (*L. esculentum,* cultivar Flora Dade).
- Effective microorganisms and molasses.
- Shovel, wheelbarrow, wastewater from trickle filter and watering cans.

A growing bench measuring 8.5m x 1mx 0.24m was constructed, housing 8 plots measuring 1m x 1m. Clay bricks were used to support the bench, which was lined with a plastic. The other eight plots were constructed on the ground and are referred to as flat beds in this paper. Four treatments were run on the trials: No EM flat bed (NOEMFB), EM flat bed (EMFB), EM growing bench (EMGB) and No EM growing bench (NOEMGB). The above four treatments were replicated four times each, resulting in a total number of 16 plots of equal size arranged in a Latin square design. River sand was collected and used in trials, as the site soil was very hard, rocky and shallow for the growing crops. Donkey manure was collected along the river, as there are no reliable concentrated sources in the Kuiseb (since Topnaar donkeys are not kept in kraals). Manure was mixed in plots with river sand at a ratio of 1:1½ wheelbarrows per $1m^2$.

Figure 1 shows a growing bench with ready mixed soil.

Tomatoes seedlings were sown in plastic pots on the 7th of March and were transplanted on the 16th of April, at the age of one month. Donkey manure was used as the growth medium. Some pots were sown with the goat manure as a backup in case the donkey-sown pots did not germinate. Germination records were kept for the number of days that it took for the seedlings to emerge. No record of germination rate was made because the trials were primarily aimed at investigating the potential of growing benches, not at determining the best growth medium.

Seedlings were transplanted at a spacing of 30cm x 40cm, resulting in 9 plants per plot, 36 plants per treatment and an overall of 144 plants in the trial. Treatments were started on the first day of transplanting by applying EM directly in water for EM-treated plots at a ratio of 1:1000 ml. Watering was done twice a week, with 5 Litres per plot. For Tomato plants, the recommended amount of water is 30ml per week, but as this was inadequate in relation to the climate of the area, the quantity was increased. Growth height of the plants were measured from the 22nd of April and continued after every 7th day after the last measurements were taken, by measuring from the base of the plant to the tallest leaf of each individual plant. Data were recorded after every measurement was taken into a computer, using SPSS programme and Excel. Two-way ANOVA was used to compare height results of treatments at a 5% significance level.

EM Plots were treated with EM-3-in-1 by spraying any time they showed any insect infestation at a ratio of 1:100 (dilution varied with infestation rate). EM-3-in-1 is an insect repellent made from the mixture of fermented plant extracts such as chilli, ginger and garlic and is applied to plants by spraying. Non-EM plots were sprayed only with a mixture of garlic-ginger solution, crushed and soaked in water. The solution was then extracted and sprayed directly on plants. Plants were supplemented with goat manure solution after they showed a deficiency of Nitrogen and Phosphorus, by supplementing half of each replicate. The manure was soaked overnight in a Hessian bag tied and put in a bin. The solution was applied by diluting it in water at a ratio of 60:40 (water: manure solution). All plants were eventually treated with goat manure supplement after those not supplemented at first did not show any improvement after a period of one month.

Figures 2 - 3 above shows symptoms of Nitrogen and Phosphorus deficiency, and artificial drought: affected by high salt concentrations (top), the granite rock, which lies underneath the flat beds (bottom)

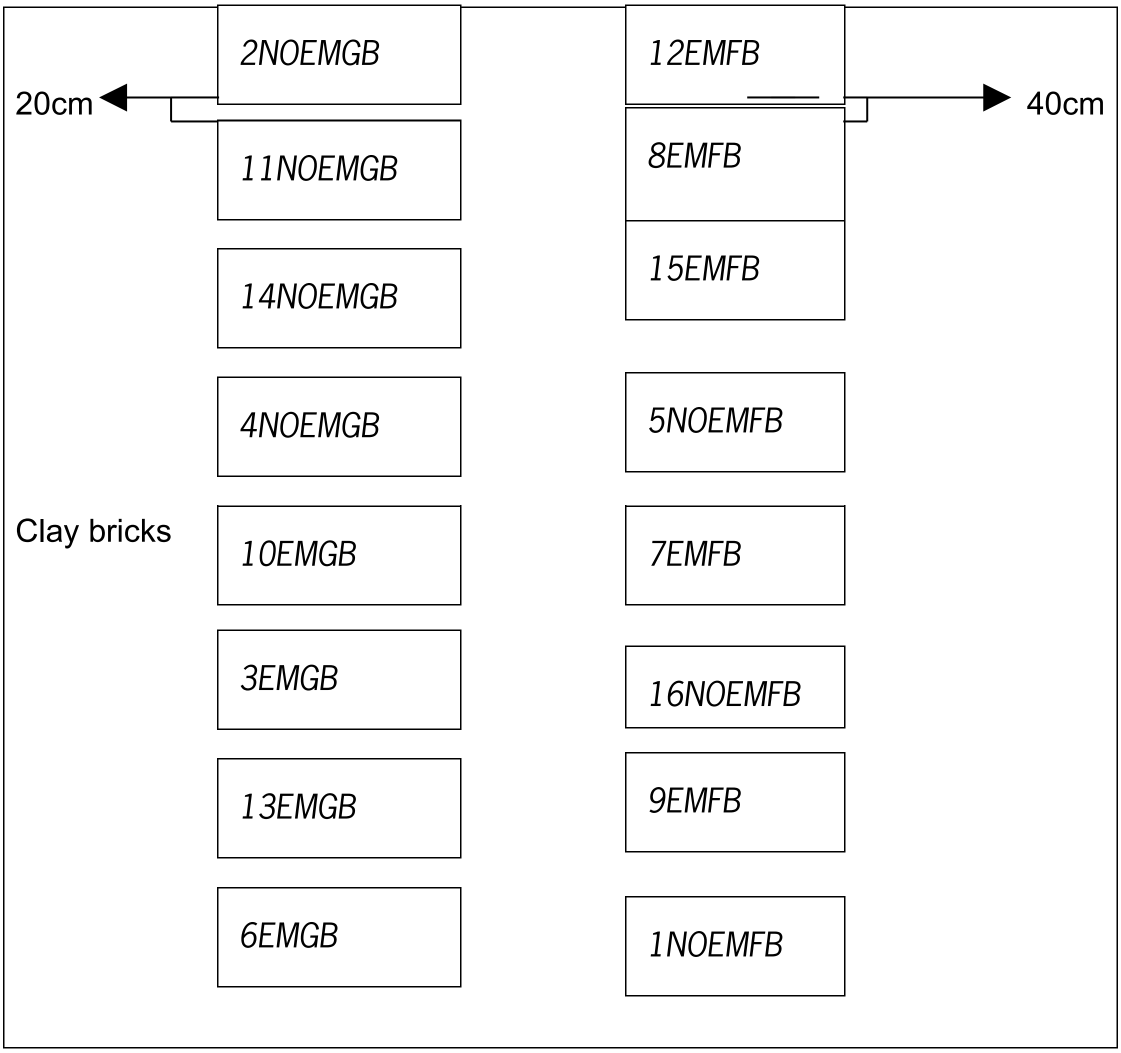


Diagram 1: Randomized plot layout. Key: EMGB = EM growing bench; NOEMGB = No EM growing bench: EMFB = EM flat beds and NOEMFB = No EM flat bed.

4. Results and Discussion

4.1 Results

4.1.1 Germination

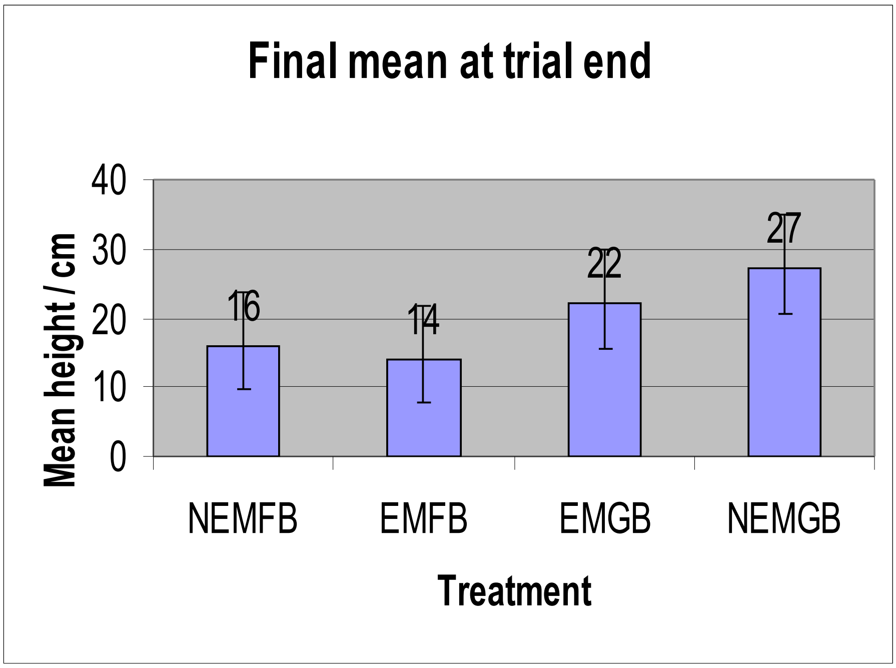
Germination for the donkey mixture was observed five days after sowing while germination in the goat manure was observed after ten days. A possible explanation for the differences in germination duration can be that donkey manure has more organic matter that helped to cool and mulch the soil when high temperatures and dry winds were common around March. Organic matter helped to retain moisture and when cold winds are present, the organic matter traps air that warm up and in turn raise soil temperature. For the goat manure pots, high temperatures and wind presence increased evaporation resulting in a hard coating developing on the surface and delaying seeds from breaking through. This was due to poor surface mulch.

4.1.2 Growth results

In reference to the final means of the treatments at the trial ends (see graph 1 and table 1), there was no significant difference observed between plants grown on the growing bench and flat beds under the two treatments, but plants without EM (NOEMGB) grew better than any other treatment, having the highest mean of 27 with all replicates considered together, followed by those grown on the bench with EM with a mean of 22 after being supplemented with goat manure. Flat beds of both EM and NO EM showed means of 14 and 16 respectively, indicating no significant differences. The highest mean differences were observed between the NO EM treatments on growing bench and flat bed, showing mean values of 27 and 16. There was a significant difference in means between the EM groups on the growing bench and the flat beds as mean values of 14 and 22 were observed. NOEM plants on the growing bench grew better than any other treatment, and this was observed from the month of June (Graph 2). On overall NEMGB grew better than any replication through the trial periods (graph 3).

From the results of treatments (graph 2) there were no significant differences in plants growth before plants were supplemented, as monthly mean values of 4 and 5 were observed for NEMFB, EMFB and NEMGB and EMGB (April-May). This indicates that donkey manure does not help plants grow due to poor nutrients in the manure.

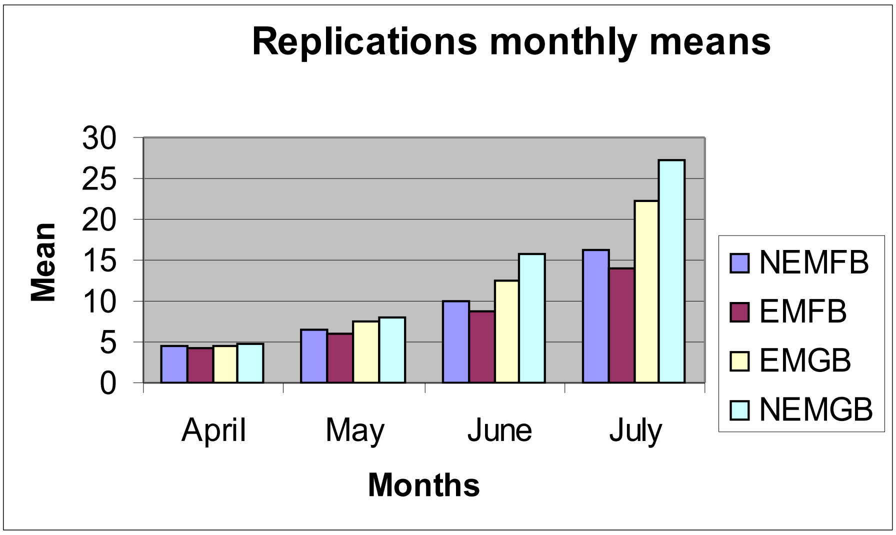
NOEM treatment grew better compared to any other treatment and this was observed from the month of June (monthly mean value 16) compared to EMGB=12, EMFB=9 and NEMFB=10 after plants were supplemented with goat manure.



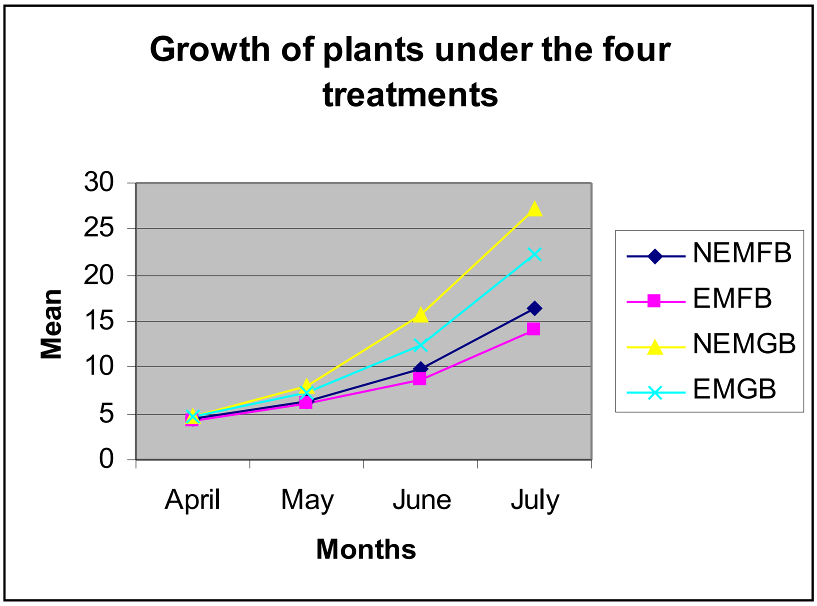
Graph 1: Mean height values with all replicates considered together over the trial period. The values inside the bars are final height mean values. Error bars indicate 95% confidence interval.

Table 1 shows the monthly and final (July) mean height values with all replicates considered together.

Treatment	April	May	June	July
NEMFB	4	6	10	16
EMFB	4	6	9	14
EMGB	5	7	12	22
NEMGB	5	8	16	27



Graph 2: Shows mean height values with all replicates considered together. NEMGB grew better than any other treatment and this was observed from the period of June and July.



Graph 3 shows the growth of plants under the different treatments. NEMGB grew faster than any other treatment.

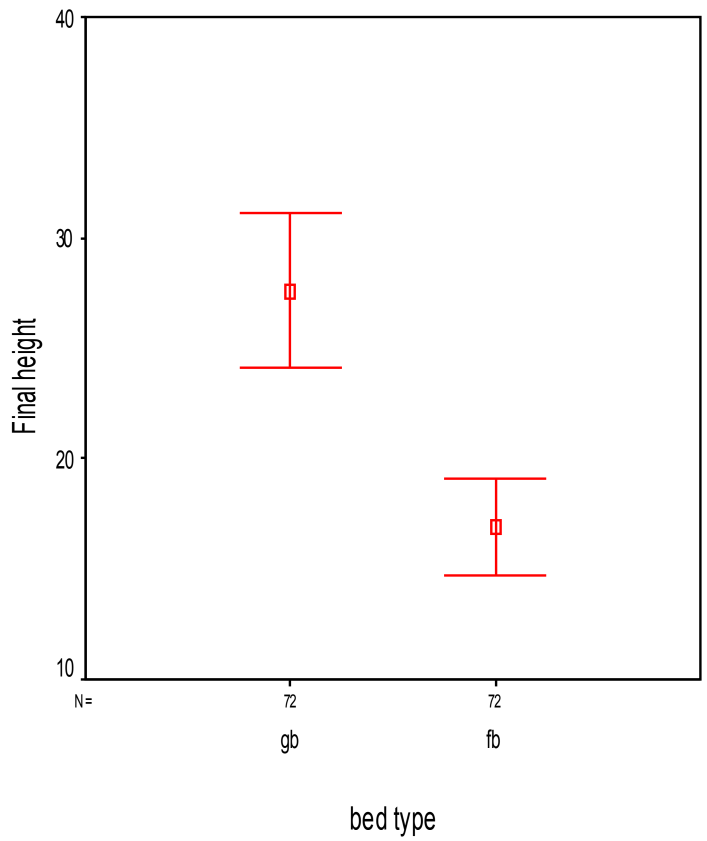
Two-way ANOVA analysis of plant heights on the final day of the trial (Table 2) shows that there was only a significant difference between the bed types: growing benches and flat beds ($p < 0.001$). There was no significant difference between treatments EM and NO EM ($p = 0.157$). Furthermore, there was no a significant difference between the interaction of two factors: treatment and bed type as ($p = 0.348$).

Table 2: Results of the two-way ANOVA on height data of final day. The only significant difference observed was between bed types (p-value 0.00) as indicated in the table.

Source	Type III Sum of Squares	df	Mean Square	Frequency	P
Corrected Model	4575.296	3	1525.099	10.018	**.000**
Intercept	71315.703	1	71315.703	468.436	**.000**
Treatment	308.002	1	308.002	2.023	**.157**
Growing Bench OR Flat Bed	4132.347	1	4132.347	27.143	**.000**
Treatment * Growing Bench or Flat Bed	134.947	1	134.947	.886	**.348**
Error	21313.901	140	152.242		
Total	97204.900	144			
Corrected Total	25889.198	143			

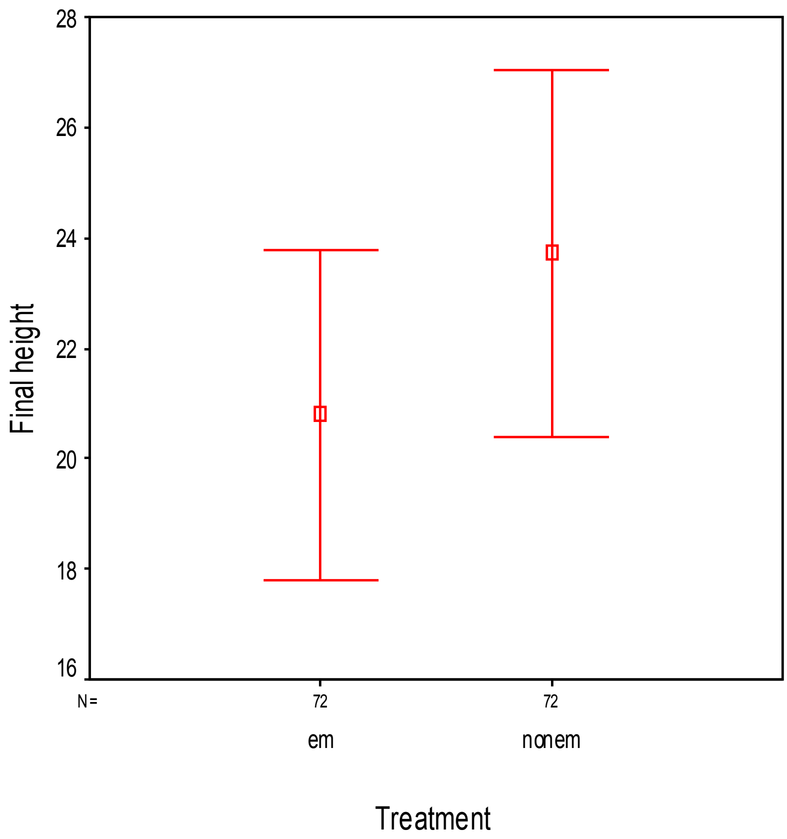
a R Squared = .177 (Adjusted R Squared = .159)

Since only ANOVA gives conclusive results, a detailed analysis of the final data collected on the treatments supports the above results. Figure 3 below shows mean values between the bed types. The means of the two bed types (growing bench and flat beds) are represented by the filled squares and the ‘whiskers’ are error bars that extend to cover the 95% confidence interval for the means. Growing Bench has a mean of 27 and Flat Bed has a mean of 16. There are no overlaps between the ‘whiskers’ suggesting that the groups are likely to be highly significantly different.



Graph 3: 95% confidence intervals shows plant means from the two bed types. The filled squares show the means of each treatment.

Figure 4 below shows mean height values for the final day of measurement between the treatments. Overall, EM treatments have means of 21 and No EM has a mean of 24. There are probably no high significant differences between the two treatments, as the 'whiskers' overlap.



Graph 4: 95% confidence intervals showing plant means from the two treatment types. The filled squares show the means of each treatment.

Data collection of the trials on possible yields is still continuing and this may be included in a further report. A large number of plants were still in the flowering and fruit stetting stage when the study ended.

4.1.3 Field Observations

All plants showed deficiency symptoms of nitrogen and phosphorus in the first two months after transplanting (April-May). A pale green colour on plant leaves indicates Nitrogen deficiency resulting in low chlorophyll. This is accompanied by a stunted growth due to reduce photosynthesis. Phosphorus deficiency is noticed by the presence of purple veins running through plant leaves and stems (figure 10). A poor stunted growth is also noticeable, and plants leave usually shows leaf tips die back and the plant die off within a short period. Plants will not respond to supplementation if not done early (Kamukuenjandje, 2005. This was from a poor nutrient source from the manure used at first (donkey manure). Supplementing the plants with goat manure rectified the problem. The manure was soaked in water overnight in a Hessian bag, and the mixture was applied at a ratio of 60% water to 40% manure once a week.

Figure 4 shows a flowering plant on the growing bench after being supplemented.

Figure 5 shows stunted plants on a flat bed even after being supplemented.

A large number of plants on flat beds failed to flower even though they were supplemented with goat manure. A possible explanation is that they were affected by the salty granite rock underneath the plots (figure 11). High soil salt contents can lead to loss of water from plant cells to soil through osmosis, resulting in stunted growth and eventually plants die off.

Flower setting were first observed in plants of NOEM and EM growing bench after supplementation and has the highest number of plants that flowered, but there was a delay in fruit setting.

Leaf miner diseases also negatively affected plants growth. Leaf miner is a viral disease that feeds on the plants leave and usually mines out the chlorophyll, resulting in slow growth due to reduced photosynthesis. No control of the disease was found during the study period. The main pest observed was white fly, which is very damaging to tomatoes as it sucks sugar from their fruits. The pest was controlled using EM-3-in-1 for the EM plots, and garlic-ginger mixture crushed in water for the non-EM plots. This repelled the pest for only a few days and no lasting control was found. Frequent spraying and increasing the concentration of the solution to make it stronger is therefore recommended.

Figure 6: Leaf damaged by the leaf miner.

5. Discussion

Since NOEMGB grew better than all replications after supplemented, I will examine the possible relative causes of this result.

NOEM plants on the growing bench grew faster than any other treatment, as observed from the month of June (Graph 2). Plants grown on the bench without EM probably grew better compared to any other treatment after having been supplemented due to a lack of competition from the microbes for the nutrients available. It has been well documented that the application of poor nutrient organic matter resulting from the animals' diets together with EM will result in competition for the little available nutrients from the soil, resulting in poor growth of the plants. Furthermore, the manure used was not of good quality as it was collected along the river since there is no reliable source: donkeys are not kept in kraals in the Kuiseb communities

Donkey manure and other organic matter such as saw dust and coir that have to decompose first before nutrients are available for plants usually result in poor growths of plants during the first few weeks. This is because the microbes in EM usually feed upon the organic matter nutrients while decomposing them, and will only release the nutrients after they die and decompose. This period or stage is called nitrogen negative period and usually results in little nutrients being available for the plants. As there was no EM applied in the NOEMGB treatment, this can be the cause of these results.

For the EM treatments, it has been well documented that the application of EM alone does not produce significant results as these cultures consist of different types of microbes, some of which are aerobic and some of which are anaerobic. The microbial populations and activities are not highly enhanced through the application of EM alone as under anaerobic conditions to break down the organic matter in the soil. Fermenting organic matter under anaerobic conditions increases the microbial populations and activities (Sangakara, undated). Oxygen availability is essential for the microbes' survivals and a poor availability would result in poor performance. The growing benches were lined with plastic; this might have reduced the oxygen regulation within the soil. Plastic is also a poor heat conductor and might have had a low temperature that lowered the microbial activities. EM favours temperature of 25ºC -30ºC .As in all techniques, EM must also be used diligently and with care, as per guidelines. Failure to do so would produce negative results (Sangakara, undated).

Growing benches help plants grow better due to moisture and nutrients retention that are constantly available to plants. For the plants on the growing bench under the treatments of No EM and EM, it can be that they performed better due to the soil temperature as the growing bench does not have much contact with the ground, meaning that it does not warm up as fast in high temperatures as plastic is a poor heat conductor. This in the end may have helped the plants grow well in the Kuiseb conditions by preventing or minimizing heat stress.

6. Conclusion

From my experiment, growing benches appear to work better than flat beds while EM appears to provide little benefit when applied on its own. Further trials need to be conducted to confirm whether EM bokashi would work better in growing benches as it has been documented that EM work best when applied with fermented organic matter. It has been noted in the use of EM that it should be applied with fermented organic matter for outstanding results. As results indicate that plants grew better on the growing bench after being supplemented with goat manure, growing benches should be used with quality organic matter like goat and cattle manure that is rich in plant nutrients such as nitrogen. EM and growing benches should be used with quality organic matter such as bokashi, and adequate moisture. Increasing the organic matter would help in temperature raise that can suit the microbes and retain moisture. Possible salt accumulations in the bench from the use of recycled wastewater cannot be concluded at this time, although is highly possible. Further studies in this issue need to be done.

6.1 Recommendations and areas of improvements

Since the application of EM on its own does not produce a significant benefit, EM should be applied by adding it to soils where EM fermented organic matter such as saw dust, rice bran or wheat bran anaerobically (bokashi) has been added for more beneficial results. Anaerobic fermentation increases the microbial population and speed up their activities .These also acts as porous carriers to increase the microbial population and oxygen. These organic matters should be mixed with nitrogen-rich material such as rice, corn or wheat bran, fishmeal or oil cakes.

Growing benches should only be used with organic rich sources such as compost, coir and saw dust. The best viable option for the Topnaar is goat manure, as the others cannot be locally obtained. The ability of the organic matter to increase the soil moisture holding capacity is stressed in attending the problem of water scarcity. Equine manure should only be used when the animal has been well fed to produce quality compost and should always be used with other nutrients rich sources such as goat manure to support plants during the nitrogen negative periods (Milner, 1996).It is therefore beneficial to compost manure and work it in the soil three months prior to planting, (Milner, 1996: 28; A. Rothauge, pers. comm.). The quality of the output is heavily depended on the intake quality; therefore the animals' diet is important. In the case of the Topnaar communities, it should only be applied as a mulch to reduce water loss from the soil through evaporation as the animals have a poor diet.

The following are potentially interesting techniques that can be tested on the growing benches:

Irrigation through sprinkling would suit use for growing benches, since it produces little pressure on the soil and prevents compaction. Water application in the form of mist is the best method of irrigating for growing benches, and selecting irrigation equipments with the finest openings is preferred.

Seedlings to be planted under harsh environments should always be hardened off to increase their chances of outdoor survival and stress shock and should be transplanted at old age at 10-15 cm tall (Kamukuenjandje, 2005). This can be done through exposing seedlings to direct sunlight for a short period and reducing the amount of water and watering frequency. Care should be taken that the seedlings are not exposed for long hours to sunlight, because this will make them sturdy and has an effect on their growth. Failure to harden off seedlings may result in transplanting shock. Seedlings used in the trials were not hardened off and at transplanting were struggling to establish well.

Growing benches should be used in arid environments with high wind activities such as the Namib Desert and other climate-related areas with intercropping. This is because during windy days tall plants such as tomatoes can easily be blown away as has been observed during the study period. Intercropping with short crops such as root crops will help in wind breaking and reduce the surface area exposed to direct sunlight that will reduce evaporation. Root crops also have the ability to uptake excess salts that may built up in the bench. This includes beetroots, radishes: moderate salt tolerate crops and asparagus high salt tolerate crop. Constructing materials of bricks and cement are more advisable for the desert environment since plastic would not last long before being worn away by the heat. This would be expensive for the communities since the majority earns as little as N$ 500.00 per month (Munsu, 2006). A cost-benefit will be done when yield data is obtained.

6.2 Water as a constraint to gardening in the Kuiseb

According to Joel Kooitjie, the Kuiseb area agricultural extension officer, problems with water supply are the main reason communities in the lower Kuiseb are closing their gardens: they cannot afford to pay for the water fees.

Although water scarcity is the most limiting factor of gardening in the lower Kuiseb, communities up river with adequate water are not using water in a sustainable way. From my field observations, communities do not have control over the water flow in gardens, as there are no taps. The pipes watering the beds are connected directly to the water tanks which are far from the gardens (75 m to 200 m).

Unsustainable practices include the irrigation practices of flooding, which usually leads to leaching and diminishing the plants natural sugars. This usually leads to infestation of plants by insects such as aphids, and force the gardeners to consider the use of pesticides, as has been observed in one of the community garden. Apart from inappropriate water use through this kind of irrigation methods, the main problems are high evaporations, soil leaching and compaction, and pest outbreaks. Surface water flows encourages high evaporation from the sun and wind, resulting in fast drying out of the soil and more water applications. This form of irrigation should be discouraged and other potential irrigation methods should be researched.

Figure 7 above shows the common irrigation method applied in Kuiseb community gardens.

6.3 The future of gardening in the Kuiseb and income sources

As water consumption is increasing upriver due to an increase of gardens and livestock, coupled with inappropriate irrigation methods gardening activities and livestock farming down the river will drastically decrease. Water prices also influence the gardening activities down river (as the current situation indicates). The rising number of unattended donkeys in the park will have a strong link to the productivity of the !Nara melon, which is the main income source of the Topnaar communities. Efficient irrigation methods need to be adopted especially upriver such as at Oswater and Homeb to ensure sustainable agriculture. Alternatives such as fog harvesting could be helpful. Conservation measures such as irrigation methods, shorter irrigation periods, early morning or late afternoon irrigation times and mulching in gardens need to be practiced.

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