Observations on the Use of Effective Microorganisms (Kyusei EM^{TM}) on Selected Vegetable Crops Using Nutrient Enriched Water from a Water Recirculated Intensive Fish Production System

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Abstract : *Integrated aquaculture-agriculture production systems were developed primarily for sustainable food production in rural areas of South Africa. The problem of environmental pollution was addressed by utilizing the nutrients in the agricultural waste products to fertilize the fish ponds, thus stimulating pond productivity and releasing nutrients such as nitrogen and phosphorus into irrigation water for vegetable crop production. Due to problems encountered with soil quality as a result of the build-up of nutrients due to chemical fertilizers and the excessive use of pesticides, it was decided to implement EM technology to restore the organic and micro-biological balances of the cultivated lands. Three vegetable crops, namely cabbage, spinach and lettuce, were cultivated under different irrigation systems, using EM, organic compost and inorganic chemical fertilizing programmes. After the first application of EM Bokashi, significant improvements in vegetable yields were recorded. EM treated plots proved to be superior in the yields of cabbage and lettuce clearly exceeding the agricultural average for South Africa. In the case of spinach, EM treated plots under drip irrigation proved to be the most productive. Application of irrigation water as well as soil quality, appeared to be two factors that must be considered when acertaining the amount of EM to be applied to further improve yields following organic farming. Recommendations are made to evaluate the health status of EM treated soils.*

Introduction

Although the agricultural output of South Africa can potentially increase to meet the short to medium term demand for food, the ultimate constraint in the long term remains the availability of water and the optimal use thereof. With an average annual precipitation of approximately 500 mm for the country (well below the World average), continuous efforts are being made in the construction of dams to optimise retention of the surface run-off waters in order to provide for the increasing demand for this scarce commodity for domestic, industrial and agricultural purposes. At this stage, it has already become necessary to recycle water for industrial use in particular, but also for domestic purposes. Due to the development and exploitation of innovative technologies, there still remains considerable scope to extend the food production potential of water in agriculture as such. One way to achieve this objective, it to integrate aquaculture with traditional agricultural practices where the same volume of water can be used to grow fish before the nutrient-enriched water is used to irrigate crops instead of discharging effluent waters from fish ponds into river systems.

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The increasing costs of various components in formulated fish feeds, coupled with the world wide shortage of fish meal as protein, have forced the major freshwater fish producing countries to find alternative means of supplementing expensive fish feed with less expensive substitutes without sacrificing too much of the growth performance of the pond fish. One way is to promote the natural fish pond productivity by using inorganic fertilizers in the ponds. However, it was demonstrated that pond fish production can also be enhanced by the application of organic susbstances such as animal manures. This approach has been investigated by Chinese farmers centuries ago (Lin, 1954; Tang, 1970). The fish production potential of ponds can be further exploited. Fish with different feeding habits can be used in combinations that optimise the utilization of the various trophic levels in fish pond ecosystems (Woynarowich, 1956; Bardach et al., 1972; Buck et al., 1979; Moav et al., 1977; Hepher and Pruginin, 1981; Hepher, 1988). In South Africa, notable contributions were made during the past 20 years to the use of pig, cattle, poultry and sheep manures in fish mono-and polyculture systems to promote fish pond productivity and consequent fish yields with and without the addition of high protein formulated fish feeds (Prinsloo and Schoonbee, 1984 a-c; 1985; 1986; 1987 a). Integrated aquaculture-agriculture systems were next investigated by Prinsloo and Schoonbee (1987 b) during which nutrient-enriched wastewater from duck-cum-fish ponds was employed in vegetable production. This idea was further developed by Prinsloo et al. (1999 a, b) in the Northern Province of South Africa. Fish produced in these integrated systems as well as in intensive water recirculating systems (Prinsloo et al., 1999 c, d) was used to combat and alleviate malnutrition successfully amongst pre-school children in rural areas (Steyn et al., 1994; Steyn et al., 1995; Tichelaar et al., 1999).

In view of the general scarcity of our portable water resources available to rural communities, the optimal use of water in integrated systems, employing different kinds of irrigation methods, were recently implemented (Prinsloo et el., 2000 – in press). With the research and development invested into aquaculture in general, but particularly into integrated aquaculture-agriculture food production systems which are presently being established on a rural community basis, as well as on a commercial scale, the stage has been set to incorporate another concept developed in Asia, namely the inclusion of effective micro-organisms (EM Technology) into the various components of integrated aquaculature-agriculture food production systems under local conditions (Higa, 1996; Higa, 1998).

EM Technology is based on the philosophy of Mockichia Okada, a Japanese naturalist and philosopher, who founded Sekai Kyusei Kyo in 1935, which, in Japanese, literally means “saving the world through natural or nature farming methods” (Higa, 1998). Behind this philosophical approach, lies the basis of extremely fundamental and scientific truths which are primarily aimed at restoring the natural ecological balance in soils to a condition where nature, through its interaction between the unadulterated micro fauna and flora, can again play its role in the restoration of the health status of our agricultural soils. Negative aspects which are now ameliorated by the application of EM technology in Nature Farming, include the elimination of less beneficial organisms harmful to crops, as well as rectifying the detrimental effects of long term unwise applications of pesticides and inorganic fertilizers to agricultural soils.

According to this concept, Kyusei Nature Farming must fulfil the following five major requirements. It must in the first instance, produce **high quality food** to enhance human health. It must be **economically and spiritually beneficial** to both the farmers and consumers. Above all, it must be **sustainable** and easily practised. One of the basic principals also includes the fact that it must conform to nature and in this way **protect the environment**. Also, it must be able to produce **sufficient food** for an expanding world population. In other words, it must be economically viable.

Effective micro-organisms (EM Technology) based on the principals layed down by Okada, has become an important cornerstone of Kyusei Nature Farming Technology by improving different aspects of soil quality and productivity, by increasing the predominance and activity of beneficial soil micro-organisms and in this way, enhancing the growth, health, yields and quality of crops by protecting the environment from degradation and pollution (Higa, 1998).

The present investigation examined the production of selected vegetable crops by comparing the effect of EM on yields with those of organic composts and inorganic chemical fertilizers as employed in integrated aquaculture-agriculture food production systems in semi-arid rural areas of South Africa. The economical use of nutrient-enriched water employing different irrigation methods, was also incorporated in this investigation conducted on the premises of the University of the North, Northern Province, South Africa during the autumn-winter period of 1999.

Materials and Methods

Irrigation Water Used

Two types of nutrient-enriched irrigation water were used for drip, drum-drip and micro-irrigation systems and for flood irrigation, respectively. In the first case nutrient-enriched wastewater was obtained from a recirculating intensive fish production unit stocked with tilapia *Oreochromis mossambicus* (Peters) and the Sharptooth catfish *Clarias gariepinus* (Burchell) at various stocking densities.

This same water was also pumped into integrated fish-poultry ponds where chicken sheds were suspended over the fish ponds which then received further enrichment of the water as a result of the nutrients emanating from chicken droppings and waste chicken food (Prinsloo et al., 1999 b). This water was used in a flood irrigation programme.

Physical and Chemical Conditions of Wastewater

Routine physical and chemical analyses were undertaken on the wastewater used for irrigation purposes during both the autumn and early winter crop production periods. Analyses were performed according to standard international procedures (Standard Methods, 1995). Water temperature (c) was measured using a Thies hydro-thermograph. Dissolved oxygen concentrations (mg/) of the wastewater were determined using an Oxy 92 meter. pH values were determined with a portable Hanna 8244 pH meter. The electrical conductivity (S/cm) was recorded with a Hanna H1 8633 conductivity meter. Ammonia (NH_3-mg/), nitrite (NO_2-mg/), nitrate (NO_3-mg/), orthophosphate (PO_4-mg/), as well as turbidity (NTU) were all determined with a Hach spectrophotometer. Mean values, as well as ranges for the experimental data for each parameter, were calculated.

Irrigation Systems Employed in Vegetable Production

The following irrigation systems were employed during the present investigation: Flood irrigated water, which was the least economic in terms of water usage (Prinsloo et al., 2000 in press), employing a 50 mm diameter plastic pipe fitted with a valve, was siphoned from the chicken-fish pond system and discharged into the different vegetable plots.

A Rondo medium-range micro-sprinkler was employed as alternative low-dosage water irrigation system. Sprinklers were evenly spaced at distances of 1.5 m along the water distribution lines.

A commercially designed 1.5 bar Hydrodrip II integral lateral drip system fitted with in-line, 375 mm Super Amiad filters for the removal of solids from the waste water, which prevented blocking of the drippers, was used.

A self-constructed drum-drip system, consisting of a series of 200 drums each fitted with a valve and three lines of 30 mm tubing, 20 m in length and punctured at 300 mm intervals with 0.3 mm sized perforations, was employed.

Size of Plots and Crops Cultivated

The flood irrigation system consisted of three equal sized units of 15 rows each. Each row was 10 m long. The total surface area irrigated in this way, was 450 m^2. The micro-sprinkler irrigation system was made up of 6 units of 5 rows each of 20 m in length. This amounted to a total surface area irrigated of 600 m^2. The drip irrigation system consisted of a 700 m^2 unit made up of 15 x 50 m rows. A complete drum-drip system comprised three units, each with 3 rows of 20 m in length, covering a total irrigation surface area of 180 m^2. Three different crops were cultivated under one or more of the four different irrigation systems. These included cabbage, spinach and lettuce.

Soil Conditions of Irrigation Plots

Investigations showed the soils to be a sandy-loam nature and with a clay and sand content of 11 percent and 68 percent respectively (Rozanov et al., 1999 – unpublished report). Its hydrolic conductivity was classified as very rapid. The phosphorus contents of the irrigated plots varied but remained considerably higher than those of surrounding dry and virgin land.

Organic and Inorganic Fertilizing Programme

Organic Material Used in Preparation of Compost

Wheat straw compost was used as organic waste material on all irrigation plots particularly so as a result of the sandy nature of the soils. Compost constituents (volume/volume basis) comprised 90 percent wheat straw, 9 percent chicken manure and 1 percent bone meal. Following thorough mixing, a 1:1:500 EM Kyan et al. (1999): molasses:water mixture was sprayed onto the compost to achieve an approximate 30 –40 percent moisture content. The mixed material was layered, compacted and covered, first with hessian and then with a sealant ultra violet-resistant black plastic sheeting. During the first seven days, EM-compost was evenly mixed on a daily basis to prevent over-heating of the material during the initial fermentation phase and covered as described. Usually, the fermenting compost mixture may mature within this period but should preferably not be used within the first 30 days following preparation as described, as was the case during the present investigation. This EM-compost mixture was then evenly applied to the soils of all irrigation plots at an approximate density of 1 kg/m^2, and was mixed into the top 20 cm of the soil. In order to retain moisture of the EM treated soils, regular irrigation of the soil was maintained for two months using the various irrigation systems employed.

Fermentation of EM Bokashi

Two weeks before the planting of vegetable seedlings (middle, March 1999), EM Bokashi (APNAN, 1995) was prepared for application. The basic constituents (on a mass basis) included 70 percent wheat bran, 15 percent maize bran, 5 percent each of soya bean meal, fish meal and bone meal. Due to volumes required, a concrete mixer was employed to facilitate the homogenation of the mixture. A 1:1:500 (volume) EM:molasses:water mixture was added to obtain an approximate moisture content of 35 percent. This mix was transferred to woven hessian bags and anaerobically sealed in black ultra-violet, resistant plastic bags. A full seven day period was allowed to obtain the necessary state of fermentation of the material.

Subdivision of Irrigation Plots

As mentioned, flood, micro-sprinkler, drip and drum-drip irrigation systems, were employed to water the soils of the different fertilizer treatments which included compost only, EM Bokashi and an inorganic chemical fertilizer programme.

For **flood irrigation**, one block of 15 x 10 m rows, covering a surface area of 150 m^2 of the prepared land, received an additional 1 kg/ m^2 of the original EM treated wheat compost, 7 days before planting. This material was similarly worked into the soil as described.

A second block of the same size received 200 g/ m^2 of the fermented EM Bokashi. A third block (same size) received inorganic chemical fertilizer (2.3.4 (30) Zn) at a concentration of 4 g/ m^2. No further organic fertilizer was applied to this block.

The **micro-sprinkler** irrigated plots were divided into two equal main sections (block A and B). Each of these was sub divided into 3 smaller blocks of which each consisted of 5 x 20 m irrigation rows. One row of each set of adjacent 5 rows of both blocks A and B was then treated with the original EM-wheat compost (1 kg/ m^2). The remaining 4 rows of each of the sets of 5 rows of block A, received 200 g/ m^2 EM Bokashi. The corresponding remaining rows of block B were then treated with inorganic chemical fertilizer (2.3.4(30) Zn at a concentration of 4 g/ m^2.

The **drip irrigation** block was divided into two sub-blocks (A and B). Each of these blocks consisted of 5 x 50 m rows. Row five of each sub-block was treated with the original EM wheat straw compost at a rate of 1kg/ m^2. EM Bokashi was applied to rows 1-3 of each sub-block at a rate of 200 g/ m^2. Inorganic chemical fertilizer (2.3.4(3) Zn) was applied to rows 4 of each sub-block at a rate of 4 g/ m^2.

The **drum-drip** irrigated block was sub-divided into 3 equal sized sub-blocks (A B and C). Block A received the original EM treated wheat straw compost (1 kg/ m^2), block B was treated with 200 g/ m^2. EM Bokashi whilst block C received 4 g/ m^2 inorganic fertilizer (2.3.4 (30) Zn).

All fertilizers were immediately worked into the soils after application, to a depth of approximately 10 cm. A soil moisture content of approximately 50 percent was maintained.

Cultivation of Crops

Compost treated plots did not receive any further fertilizer application following planting. In the case of vegetables cultivated with EM Bokashi, the soil surface of the plots was covered with a thin layer of wheat straw for moisture retention. All the EM plots were sprayed once per week, for the first month, with 1:5000 EM:water solution. Thereafter they were sprayed once every fortnight until cropping. Chemically fertilized plots received additional concentrations of inorganic fertilizers. All additional inorganic chemical fertilizer applications commenced two weeks after planting. In the case of lettuce and spinach, two applications of potassium-ammonium-nitrate (KAN) were made at a concentration of 20 g/m^2, 3 and 6 weeks following planting. For cabbage, a different fertilizing programme was followed. Three applications of 1:0:1 (47) were applied during weeks 5,8 and 11 after planting at a concentration of 15 g/ m^2. KAN was applied during weeks 6,9 and 12 at a concentration of 15 g/m^2. No pesticides were applied to any of the crops.

Irrigation of the crops with nutrient-enriched fish pond water took place twice per week (flood irrigation) and once per day (micro-sprinkler, drip-and drum- drip irrigation).

Cropping of lettuce commenced 2 months after planting, whilst spinach was harvested over a period of 1 ½ months following 2 ½ months from planting. Cropping of cabbage occurred 3 ½ to 4 months after planting. Excess or non-utilizable leaves of all three vegetable types were excluded during the cropping and weighing programme. Results were expressed in kg/1 000 m^2 cultivated land.

Results

Water Chemistry of Fish Pond Water

Water chemistry results of the water used in the various irrigation systems for the period March to June 1999 in the vegetable crop production, are summarized in Table 1. Mean water temperatures ranged between 12.8 C (winter) and 20.0 C (autumn). There was a gradual build-up of dissolved oxygen in the water between March (6.1 mg/$^{-1}$) and June (9.2 mg/$^{-1}$), suggesting a nutrient build-up and consequent increase in algal activity of pond water, which is also reflected by data on pH for the consecutive months specially so in June when pH values recorded, ranged between 7:81 and 10:32. Fluctuations in conductivity can largely be ascribed to the regular addition of quantities of water from different fish holding tanks. This also effected the concentrations of ammonia in the water for the different months which ranged between a mean of 3.17 mg/$^{-1}$ (April) and 0.48 mg/$^{-1}$ (June). A similar pattern was observed for nitrite and nitrate. Soluble reactive phosphorus varied between a maximum of 8.715 mg/$^{-1}$ (March) and 5.973 mg/$^{-1}$ (June). Turbidity of the water declined towards June.

Table 1. The Quality Conditions of the Irrigation Water from Water Recirculating Intensive Fish Production Units Used During the Autumn-Winter Vegetable Production Cycle (March – June 1999)

Analysis		Consecutive Months (March – June 1999)			
		March N=2	**April N=4**	**May N=4**	**June N=4**
Temperature (°C)	$\bar{x}$	20.0	19.1	15.7	12.8
	Range	(19.6-20.3)	(18.2-20.1)	(10.6-19.8)	(11.2-14.3)
Dissolved oxygen	x	6.1	7.3	7.8	9.2
(mg/l $^{-1}$)	Range	(4.8-7.4)	(6.1-9.4)	(7.1-9.4)	(8.2-10.3)
pH	Range	6.81-7.34	7.12-9.2	7.42-9.45	7.81-10.32
Conductivity (μ Scm^{-1})	x	137.5	155.5	141.2	126.4
	Range	(131.2-143.8)	(155.0-156.0)	(132.1-147.3)	(121.4=132.3)
Ammonia (NH_3 mg/l $^{-1}$)	x	2.93	3.17	1.52	0.48
	Range	(2.17-3.68)	1.59-3.77)	(0.98-1.79)	(0.13-0.72)
Nitrite (NO_2mg/l $^{-1}$)	x	0.447	0.822	0.394	0.246
	Range	(0.315-0.579)	(0.425-1.135)	(0.185-0.423)	().024-0.278)
Nitrate(NO_3 mg/l $^{-1}$)	x	9.4	12.3	5.2	5.4
	Range	(6.8-12.0)	(7.7-13.8)	(4.6-6.4)	(3.8-5.9)
Orthophosphate	x	8.715	6.377	6.435	5.973
(PO_4 mg/l $^{-1}$)	Range	(6.771-10.659)	(5.211-8.490)	(4.254-7.950)	(5.020-6.135)
Turbidity (NTU)	x	45.2	58.6	27.4	18.6
	Range	(33.0-57.4)	(41.6-63.7	(15.1-34.2)	9.0-22.5)

Vegetable Production

Cabbage Production

Results of the cabbage production for the different fertilizer programmes, expressed in kg/1 000 m^2 cultivated land (Table 2) can be summarized as follows. The EM Bokashi fertilizer programmes for the flood irrigation yielded the highest mean production of 8733 kg/1 000 m^2, which was slightly better than the previous winter production of 1997 where inorganic chemical fertilizer only was applied. The 1997 production however was clearly superior to the present production using chemical fertilizers (6963 kg) and organic compost only (6347 kg). Yields obtained for cabbage for all three fertilized treatments under flood irrigation exceeded the 1996 agricultural average for South Africa.

A similar situation existed at the micro-sprinkler irrigation plots where superior yields were again obtained with the EM Bokashi treatment (9157 kg) followed by that of chemical fertilizer with the poorest yields of 6188 kg/1 000 m^2 for compost only. In all three treatments, yields exceeded the cabbage winter production of 1997 as well as the South African agricultural average for 1996.

Of interest was the production of cabbage for the drum drip irrigated plots where a total production of 12548 kg/1 000 m^2 was obtained with chemical fertilizer. Second best was EM Bokashi (10314 kg) followed by that for compost. Yields for all three treatments exceeded the winter production for 1997 as well as the South African average for 1996.

Table 2. **Cabbage Production (Kg/1 000m^2) under Drum-drip-, Micro-sprinkler- and Flood Irrigation Conditions Applying Different Fertilizing Programmes During Autumn-Winter 1999**

Irrigation System	Parameter	Vegetable Production in kg/1 000m^2				
		Fertilizing Programme				
		EM Bokashi	Chemical Fertilizer	Compost	Mean Winter Production 1997 (Prinsloo et.al,2000)	Average Production in South Africa (Coertze, 1996)
Flood	Number of plots	4	4	4		
	Plants/1 000m^2	2 750	2750	2750		
	Mean individual mass(g)	3 175.7	2531.9	2307.9		
	Total production	8 733	6963	6347	8517	5000
	Range	(7475-11460)	(4659-12116)	(5519-7003)		
Micro-sprinkler	Number of plots	3	3	1		
	Plants/1 000m^2	3000	3000	3000		
	Mean individual mass(g)	3052.3	3004.7	2888.3		
	Total production	9157	9014	8665	5586	5000
	Range	(8290-9919)	(6934-10556)	-		
Drum-drip	Number of plots	2	2	2		
	Plants/1 000m^2	3000	3000	3000		
	Mean individual mass(g)	3438.0	4182.6	2888.3		
	Total production	10314	12548	8665	7267	5000

Spinach Production

The production results of spinach (Table 3) under micro-sprinkler irrigation clearly suggested that chemical fertilizers were superior to the EM Bokashi and compost treatments in both the present and for the winter production period of 1997. Yields for the EM Bokashi treatments came second best for the drip and drum-drip irrigation systems. Compost was least productive in all cases. However, all three treatments clearly exceeded the 1996 average spinach production for South Africa.

Table 3. **Spinach Production (Kg/1 000m^2) under Drip-, Drum-drip-, and Micro-sprinkler Irrigation Conditions Applying Different Fertilizing Programmes During Autumn-Winter 1999**

Irrigation System	Parameter	Vegetable Production in kg/1 000m^2				
		Fertilizing Programme				
		EM Bokashi	Chemical Fertilizer	Compost	Mean Winter Production 1997 (Prinsloo et.al,1999)	Average Production in South Africa (Coertze, 1996)
Micro-sprinkler	Number of plots	4	4	2		
	Plants/1 000m^2	6000	6000	6000		
	Total production	1542	3118	2387	5947	1200
	Range	(1364-1718)	(2394-3640)	(1671-3094)		
Drip	Number of plots	3	1	1		
	Plants/1 000m^2	4200	4200	4200		
	Total production	3433	3071	3064	3751	1200
	Range	(3350-3515)				
Drum-drip	Number of plots	2	2	2		
	Plants/1 000m^2	4000	4000	4000		
	Total production	2253	2255	1721	1732	1200

Lettuce Production

All three treatments for lettuce production (Table 4) exceeded the 1997 as well as the 1996 agricultural average for South Africa, with EM being superior for the flood – and drum-drip irrigated plots and chemical fertilizer providing the highest yields in the case of drip and micro-sprinkler irrigation systems.

Table 4. Lettuce Production (Kg/1 000m^2) under Drip-, Drum-drip-, Micro-sprinkler and Flood Irrigation Conditions Applying Different Fertilizing Programmes During Autumn-Winter 1999

Irrigation System	Parameter	Vegetable Production in kg/1 000m^2				
		Fertilizing Programme				
		EM Bokashi	**Chemical Fertilizer**	**Compost**	**Mean Winter Production 1997 (Prinsloo et.al,2000)**	**Average Production in South Africa (Coertze, 1996)**
Flood	Number of plots	5	5	5		
	Plants/1 000m^2	6700	6700	6700		
	Mean individual mass(g)	1303.4	1094.3	1047.8		
	Total production	8733	7332	7020	4294	1500
	Range	(7717-9425)	(7092-7553)	(6326-7609)		
Micro-sprinkler	Number of plots	4	4	2		
	Plants/1 000m^2	7400	7400	7400		
	Mean individual mass(g)	1378.6	1569.7	1466.7		
	Total production	10202	11616	10854		
	Range	(9437-11375)	(11385-11792)	(9512-12198)		
Drip	Number of plots	3	1	1		
	Plants/1 000m^2	6000	6000	6000		
	Mean individual mass(g)	1509.9	1714.9	1296.6		
	Total production	9059	10289	7780	2260	1500
	Range	(8999-9119)				
Drum-drip	Number of plots	2	2	2		
	Plants/1 000m^2	7000	7000	7000		
	Mean individual mass(g)	1536.2	1506.7	1272.8	2500	1500
	Total production	10.753	10547	8910		

Discussion

After more than 20 years during which aquaculture has been researched in South Africa, not only for its application in commercial ventures, but also as a viable alternative for sustainable food production in rural areas where malnutrition can be alleviated, the following objectives have been achieved:

- Artificial propagation for candidate fish species have been successfully applied (Prinsloo and Schoonbee, 1983; Schoonbee and Prinsloo, 1984; 1986; Prinsloo et al., 1987; Prinsloo et al., 1993; Schoonbee et al., 1980; Schoonbee and Brand, 1982; Necht et al., 1982).

- Alternative diets to replace expensive formulated fish feed were developed, evaluated and applied (Prinsloo et al., 1989; Hoffman et al., 1997).

- Mono and polyculture fish production under regional environmental and water quality conditions were researched and practically implemented (Prinsloo and Schoonbee, 1986; 1992; Schoonbee and Prinsloo, 1988; 1989; Prinsloo et al., 1999d).

- With the scarcity of available water for agriculture, particularly so in rural areas, integrated aquaculture-agriculture food production systems (poultry, fish vegetables and other crops) aimed at the multipurpose low cost utilization of available water resources, was developed (Prinsloo and Schoonbee, 1987 a; Prinsloo et al., 1999 a,b).

EM Technology was introduced in 1997 from Japan into South Africa by Mr. Yoshida (EMROSA, South Africa). During October 1998, small scale application of EM on vegetable crops commenced at the Aquaculture Research Unit, University of the North, as part of an integrated aquaculture-agriculture project which included poultry-cum-fish-cum-vegetable crop production. Although the major thrust was aimed at food production on a family and community base in rural areas of South Africa, its commercial potential was also investigated. In such integrated systems, there are a number of aspects where EM Technology can not only replace or improve the existing approach but may also contribute significantly to fish pond water quality conditions and health status of fish and soils where vegetable crops are produced (Hanekon et al., 2000 – submitted).

In this particular investigation, which must be considered of an exploratory nature, into the beneficial use of EM in vegetable crop production using nutrient-enriched waste water from fish ponds, the application of EM Boksahi, organic compost and inorganic chemical fertilizers, were evaluated and compared. The present results already confirm in more than one way the advantages of EM Bokashi in the superior production of leaved vegetables compared to the application of compost only or where inorganic chemical fertilizers were used as a standard practice. Even after a relatively short period following the incorporation of EM as soil nutrient releasing agent (2 months) yields for cabbage, spinach and lettuce increased significantly in comparison with the recorded South African agricultural average for these crops. At this stage, it was not surprising to find that inorganic fertilizer still produces yields which were satisfactory in terms of its crop growth potential. However, based on the present results already obtained, EM will most likely be the nutrient growth factor of choice in this component of integrated aquaculture-agriculture food production schemes. Even where EM performed second best (lettuce – drip irrigation – Table 4) or third (micro-sprinkler irrigation) in the present series of crop production, factors such as methods of water application, soil quality and chemical conditions, together with the build-up of EM treated organic material, may rectify the situation in the medium to long-term.

It must be borne in mind, that the soils of the land at the ARU are of a sandy loam nature with a clay and sand content of 11 percent and 68 percent, respectively. Its hydraulic conductivity is classified as very rapid (Tazanov et al., 1999 – unpublished report). Despite the fact that the fish pond irrigation water used, remained predominantly alkaline, fluctuating between 6.8 – 10.3, the water did not appear to have any significant effects on the soil –pH which fluctuated between 5.5 – 7.0. The fact that elevated pH levels in the sandy soils already exceeded limits for optimal crop production in both the flood – and micro-sprinkler plots suggested that the long term continuous use of nutrient-enriched water on these soils needs to be monitored. The introduction of EM treated organic material may rectify this problem.

From the literature it is clear that soil-pH can be manipulated through the application of EM Bokashi through the offset of degradative processes in the soils (Parr et al., 1992; Hornick and Parr, 1987). One important factor which must also be considered with the application of EM Technology, is the natural fertility of soils and as mentioned, the quality of the irrigation water which both tend to decline with the use of chemical fertilizers and the introduction of pesticides in crop pest control. Both factors exert a marked effect largely on the natural fauna and flora of soils (Wicherek and Bossien, 1998).

A measure of the soil microbial activity can be taken to assess the health status of agricultural land. Such a health control index system should be developed in South Africa with the introduction of EM (Jenkinson and Ladd, 1981; Maire, 1987; Tabatabai, 1982).

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