

The Development of Effective Microorganism (EM) Technology in New Zealand

Mike Daly
New Zealand Nature Farming Society

ABSTRACT

EM was imported into New Zealand for research purposes in 1994. Scientists from Government research institutes, AgResearch and HortResearch, conducted research from 1994 to 1996 on EM Technology, and the results were presented at conferences both internationally and within New Zealand.

Results from that research demonstrated that EM applied to crops of onions, sweetcorn and process peas gave significant increases in yield of up to 30% above an untreated control ($P < 0.05$). A pot trial investigating the effect of EM on *Aphanomyces* root disease of process peas did not show any significant effect on reduction of the disease. In a laboratory experiment, the application of EM to soil/litter mixtures, stimulated C mineralization significantly greater than a control and glucose control.

To facilitate the development and expansion of EM Technology in New Zealand, a charitable trust was established in 1997. This trust called the New Zealand Nature farming Society is administered and directed by farmers and aims to make, distribute and promote the use of EM technology and nature farming principles in New Zealand. In early 1998 an EMRO Technical Officer from Japan came to New Zealand and facilitated the setting up of a production plant to make EM. As a result the New Zealand Nature Farming Society are now making EM and distributing it within New Zealand.

The approach to spread the technology has been to identify and work with 'Key' farmers as identified and representing the various main types of agricultural production, such as sheep farming, crop production, vegetable production, dairy farming and fruit production. These key farmers are selected as the best available so that they are respected by their peers and recognised as good leaders. The key farmers are then taught how to use EM on their farms and encouraged to set-up on-farm experiments. Farmers are the best teachers to other farmers and this group of key farmers then become the platform for expansion and uptake of EM technology throughout the region and country.

Recent results from on-farm trials have shown increases in sheep production with EM applied to the drinking water and sprayed onto to the pasture prior to grazing. EM applied to potatoes and Bokashi applied to potatoes both improved yield compared to untreated controls. In fruit production, EM application to young apple trees over a five month period has resulted in increased tree growth compared to untreated controls. These results will be presented in detail and the progress made on the development of EM technology in New Zealand reported in this paper.

INTRODUCTION

New Zealand -The Country

New Zealand lies in the south-west Pacific Ocean and consists of two main (North and South Islands) and a number of smaller islands whose combined area of 270,500 square kilometres is similar to the size of Japan or the British Isles. The nearest largest land mass is Australia, some 1,600 kilometres to the West

The climate described as temperate, is largely influenced by New Zealand's shape and form. Being a long narrow mountainous country surrounded by a large expanse of ocean, means quite large extremes in climatic conditions, characterised by sudden changes in temperature and weather conditions. The main mountain chain in both Islands has a major effect on climatic conditions giving rise to generally wetter, milder conditions in the west and drier and often hotter conditions in the east. Overall, the climate is very suitable for many agricultural farming activities, particularly livestock production which allows outdoor grazing all year round.

New Zealand has a relatively small population (3.7 million), green countryside and an abundance of clean clear rivers and lakes giving it a reputation of a clean environment devoid of industrial and agricultural pollution which is common in many European countries.

New Zealand -The Agriculture

Traditional farming has centred on sheep and cattle to produce sheep meat, beef, wool, dairy products and hides, although in recent years new types of livestock have included deer for meat (venison) and antler (velvet) production, and goats for meat (chevron) and fibre (mohair) production. Cereal crops, predominantly wheat and barley are grown on a limited scale, mainly for the home market. In addition process crops such as peas carrots and beans and onions are grown increasingly. Land used for meat and wool farming is mainly hill country and rolling downs. The lowlands and coastal plains support dairy, arable and horticultural production.

New Zealand's agriculture, particularly its sheep, cattle and deer systems are characterised by relatively low inputs, particularly of pesticides and nitrogenous fertilisers. The pastures are clover-based and provide in most cases, all of the nitrogen requirement by N fixation. Superphosphate is the most common input used in these systems and animal health remedies for external and internal parasites. These inputs are not permitted under a registered organic system (NZBPPC). Because our conventional agriculture is low input and managed in a grassland out-door environment, the gap between conventional and organic farming is not considered great.

EM in New Zealand

EM was imported into New Zealand for research purposes in 1994. Scientists from Government research institutes, AgResearch and HortResearch, conducted research from 1994 to 1996 on EM Technology, and the results were presented at conferences both internationally and within New Zealand. The research was based on using EM on our relatively large scale extensive agricultural systems which has typically lower labour inputs and higher mechanisation than many of the Asian countries that EM has been researched. Positive results using EM were obtained (Daly 1996, Chamberlain et al., 1997, Daly & Stewart 1998). This encouraged New Zealand researchers and growers to seek the further development of EM technology in this Country.

METHODS

Field trials 1996

These were sited within 25 km of Lincoln University, Canterbury, New Zealand (latitude 43° 39' south, longitude 172° 27' east, altitude 50 m asl), on commercial farms and run in partnership with the farmer who cultivated, planted and managed the crop, and assisted with taking measurements.. The crops all received irrigation when the farmer determined it was necessary.

The onion crop (*Alium cepa* cv. "Pukekohe Long Keeper") was grown on a "Wakanui" silt loam soil (Kear et al., 1967) which was prepared by rotary hoeing after a winter green feed crop in August. The field had previously been in ryegrass/white clover pasture for four years. The trial was direct seeded using a precision seeder in 1.5 m wide beds with four rows to the bed using a 300 mm between row spacing. Seed spacing within the row was 60 mm. The trial had four replicates and a plot size of 5 by 1.5 m. EM was applied at a rate of 10 L ha⁻¹ with 10 L ha⁻¹ of molasses mixed into water and applied at 10 000 L ha⁻¹ through a watering can onto the foliage of the crop, on November 11, December 22 and January 20. Crop vigour was assessed visually at bulbing (January 22). At harvest (March 7) the field dried onions were graded and weighed.

The process pea crop (*Pisum sativum* cv. "Princess") was grown on a Templeton silt loam soil (Kear et al., 1967) which was ploughed after an oat grain crop. The straw was incorporated by cultivation during the winter. The peas were sown on 7 October at 290 kg ha⁻¹ using a 15 cm between row spacing. In addition the field had a basal application of 250 kg ha⁻¹ of reactive phosphate rock applied to correct a low soil phosphate concentration. The trial had four replicates and a plot size of 5 by 10 m. EM was applied as the previously described rate twice during crop growth (at mid flower and at early pod development). The crop was irrigated on the 16 and 23 December, and harvested on the 31 December.

The sweetcorn (*Zea mays* var. *convor saccharata* cv. "Honey and Pearl") was grown on a Wakanui silt loam soil (Kear et al., 1967) which had been intensively managed using raised beds with a six year rotation of vegetable crops. The previous crops were peas and beans. An unreplicated split-plot design was used with three sowing dates (October 18, November 24, December 19) as main-plots, and two foliar applied treatments (EM and a control i.e. water only) as sub-plots. Sub-plot size was 4 by 1 m (3 rows of corn). The EM was applied as previously described. The control treatment received water at 10 000 L ha⁻¹. Applications were made after plant emergence at 10-15 day intervals throughout the growing season up until flowering, for each sowing date. This gave an average of seven foliar applications per sowing date. The sweetcorn plants from each sowing date were harvested when they reached fresh maturity. Ten plants per plot were randomly selected and components (whole plants, number of stems, number of cobs) measured.

Laboratory incubation 1996

The soil used for the incubation was from the A horizon of a Selwyn loamy sand (a moderately fertile recent soil [Kear et al., 1967]). The soil sample (0-5 cm) was taken after the vegetation and the surface litter was removed and was sieved through a 2 mm sieve. The soil water content was adjusted to 26% and was preincubated for four days at 30°C and sieved again (4 mm) prior to the incubation. The equivalent of 50 g oven dry soil, was weighed into gas-tight glass jars for the incubation and 1% w/w ground pasture litter was added to all jars. The pasture litter, mainly white clover (*Trifolium repens*) and ryegrass (*Lolium perenne*), was dried at 80°C and ground (500 µm).

The treatments were a control, a glucose and an EM plus glucose treatment. All treatments received 1 mL of liquid prior to the incubation. The control received water, the glucose treatments received 1 g L⁻¹ glucose solution, and the EM treatment received 0.1% v/v EM and 1 g L⁻¹ glucose solutions. This is equivalent to an application rate of 10 000 L ha⁻¹ (based on the hypothetical surface area of a 5 cm deep column of soil of 50 g mass at a bulk density of 1.1 g cm⁻³ [i.e. the bulk density of the field soil]), the same rate applied to the field crops.

Glass jars containing CO² traps, plastic containers holding 20 mL of 1M NaOH mounted on a wire stand, were sealed and incubated at 30°C. There were four replicates of

each treatment. Each week the jars were taken out of the incubator, and the traps rapidly removed and sealed (to avoid CO² contamination). The jars were left with the lids off for approximately an hour to avoid anaerobia. Traps with fresh NaOH solution were placed into the jars and the jars resealed. Analysis of the traps was carried out using a method adopted from Anderson (1984) titrating with 1M HCl after the addition of BaCl₂ to the NaOH (to precipitate the carbonates) using phenolphthalein indicator.

Laboratory Bioassay 1997

A verified bioassay was used to measure the level of biological control on pea (*Pisum sativum*) seedlings offered by two concentrations of effective microorganisms EM1 (1:1:1000), and EM2 (2:2:1000), and a water + molasses control, against three inoculation levels (0, 5x10², 5x10³ spores/ml) of *Aphanomyces euteiches* zoospores (Merfield et al., 1997).

Field Trials 1997

These were sited within 25 km of Lincoln University, Canterbury, New Zealand (latitude 43° 39' south, longitude 172° 27' east, altitude 50 m asl), on commercial farms and run in partnership with the farmer who cultivated, planted and managed the crops, pasture and animals, and assisted with taking measurements. The crops and pasture all received irrigation when the farmer determined it was necessary.

Forty in-lamb, two tooth ewes were randomly selected and split into two groups, an EM treatment group and a control. The trial was started on 31 July 1996 just as the ewes began to give birth. EM at a rate of 10l with 10l of molasses in 200l of water ha⁻¹ was applied to the pasture using a tractor mounted crop sprayer, every two weeks. EM was applied in damp weather or to dew. A trough dispenser was used to add EM to the water supply of the EM group animals. The ewes were first weighed on the 31 of July, then six weeks later after lambing, and then approximately every two weeks. Lambs were first weighed on the 14 of September and then approximately every two weeks.

Field Trials 1998

The onion crop in 1998 *Alium cepa* cv. "Pukekohe Long Keeper") was grown on a "Wakanui" silt loam soil (Kear et al., 1967) which was prepared by rotary hoeing after a winter green feed crop in August. The field had previously been in ryegrass/white clover pasture for four years. The trial was direct seeded using a precision seeder in 1.5 m wide beds with four rows to the bed using a 300 mm between row spacing. Seed spacing within the row was 60 mm. The trial had five replicates and a plot size of 5 by 1.5 m. EM was applied at a rate of 10 L ha⁻¹ with 10 L ha⁻¹ of molasses mixed into water and applied either at 10 000 L ha⁻¹, through a watering can, or through a sprayer at 800 L ha⁻¹, or 200 L ha⁻¹ onto the foliage of the crop. EM and Foliarfeed (fish based foliar fertiliser) applications began 27 September 1997, were repeated 2-3 weekly and concluded on 6 February 1998 (total of 9 applications) At harvest (March 1) the field dried onions were graded and weighed.

Apple trees cv Braeburn on 793 roostock planted on a Wakanui silt loam soil (Kear et al., 1967) A paired design of 16 trees was used, with 8 trees receiving EM paired with 8 trees as untreated controls. The trees were part of a larger block organically managed for experimental use and were in their second leaf since planting. EM was applied at a rate of 10 L ha⁻¹ with 10 L ha⁻¹ of molasses mixed into water and applied at 10 000 L ha⁻¹, at 2-3 weekly intervals from October to January (6 applications). The EM solution was applied around the root-zone of the trees. The trunk girths were measured at the start and end of the period.

A farmer applied EM and Bokashi to his Potato crop (planted October 1997) and measured the response in numbers of potatoes and weight. The Bokashi was applied 2 times at 2000kg ha⁻¹ and the EM solution at (1:1:1000) was applied 4 times at 10 000 L ha⁻¹ during the growing season. The roots were dug, counted and weighed at maturity (March 1998).

RESULTS

1996 Trials

TABLE 1 Influence of EM plus molasses on onion mid season vigour, yield and grade (Daly 1996)

Treatment	Vigour (1-5)	Score ¹	Total Yield (t ha ⁻¹)	First grade (t ha ⁻¹)	Process grade (t ha ⁻¹)	Small grade (t ha ⁻¹)
Control	2.6		42	25	11	6
EM + molasses	3.0		54	44	6	4
<i>LSD</i> _{P=0.05}	0.8		11	13	6	3

¹A high score indicates high vigour

EM plus molasses caused a significant yield increase over the untreated control and produced more first grade onions (Table 1).

TABLE 2 Influence of EM plus molasses on pea herbage chemical analysis² and yield (Daly 1996)

Treatment	N %	P %	K %	S %	Mg ppm	Ca ppm	Yield (t ha ⁻¹) at 105 TR ¹
Control	3.46	0.29	1.34	0.26	0.20	0.76	6.1
EM + molasses	3.46	0.32	1.46	0.24	0.21	0.74	8.0
<i>LSD</i> _{P=0.05}	-	-	-	-	-	-	1.4

¹TR = Tendorometer reading, ²Unreplicated composite samples

The yield of peas was increased by EM plus molasses (Table 2). There were no major differences in the herbage nutrient concentrations of peas between treatments (Table 2) and no nutrients were deficient (Clarke et al., 1986).

TABLE 3 Influence of EM plus molasses and sowing date on sweetcorn growth (Daly 1996)

Sowing Date	Treatment	Whole Plant Weight ¹ (kg)	Tiller No.	Cob No.	Cob Weight ¹ (g)
October	EM + molasses	1.06	2.6	1.5	440
	Control	1.04	2.2	1.7	370
November	EM + molasses	1.02	2.6	2.0	380
	Control	0.89	2.7	1.8	310
December	EM + molasses	1.12	2.4	1.9	400
	Control	0.93	1.7	1.2	300
Overall Mean	EM + molasses	1.07	2.5	1.8	400
	Control	0.95	2.2	1.6	330
<i>LSD</i> _{P=0.05}	-	0.21	1.0	1.1	45

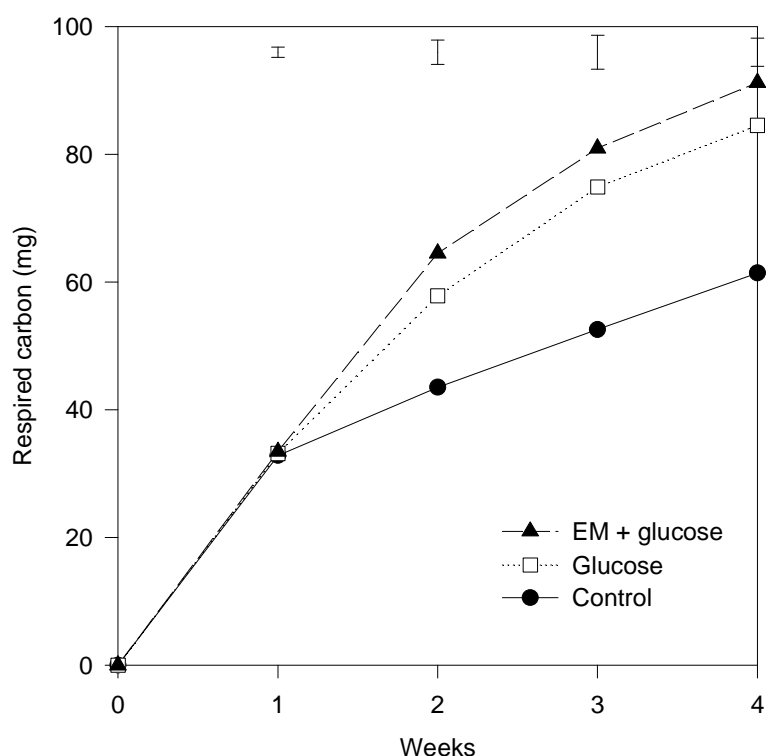
¹Fresh Weight

The weight of sweetcorn cobs was significantly increased by EM plus molasses ($P < 0.05$, Table 3). There was variability in the sweetcorn plant weight data, however, a consistent trend of increased plant weight following applications of EM plus molasses was evident across all sowing dates (Table 3). The numbers of tillers and cobs were not significantly influenced by EM plus molasses applications (Table 3).

Laboratory incubation

During the first week of the incubation C was rapidly respired at a similar rate for all treatments, after which the rate of C mineralization decreased (Fig. 1). The cumulative amount of C mineralized was significantly greater than the control by 38 and 49% respectively for glucose and EM plus glucose treatments (Fig. 1). There was a significant increase in the cumulative amount of C mineralized by approximately 8% resulting from applying EM (i.e. over the glucose treatment). This 8% net increase from applying EM was substantially greater than the amount of C added in EM (i.e. 6.7 and 0.01 mg C respectively).

FIGURE 1 Influence of EM on the cumulative amount of carbon respired (bars are LSDs $P=0.05$), (Daly & Stewart 1998).



Laboratory Bioassay 1997

There was no significant difference ($P>0.05$) between the EM1, EM2, H₂O Control, or Molasses Control treatments. There was a highly significant difference ($P<0.001$) between the three disease (Ae) treatments, indicating a difference between control and disease levels 1 & 2 (Table 4).

TABLE 4 Effect of treatments on die-off rate of peas (analysis of variance) (Merfield et al., 1997)

	Ae0 Control	Ae1 Disease level 1	Ae2 Disease level 2	Total	S.E for Total
EM1 (1:1:1000)	0.00	2.52	1.32	1.28	0.354
EM2 (2:2:1000)	0.00	3.46	2.08	1.85	0.403
H ₂ O Control	0.00	3.62	1.48	1.70	0.442
Molasses Control	0.00	2.99	1.17	1.39	0.411
Total	0.00	3.15	1.51	1.55	
S.E. For Total	0.000	0.291	0.152		

There was no evidence of disease suppression by the EM treatments.. The high level of significance between the three Ae levels ($P<0.001$) indicates the technique was correct. Retrospective advice by EMRO and APNAN staff indicated that alternative preparations of EM e.g. EM5 (EM fermented with vinegar and alcohol) or EM Fermented Plant Extracts (EM fermented with fresh weeds) would have been more appropriate in this situation.

Field Trials 1997

The growth rates of sheep and lambs grazing on EM treated pasture and drinking water were compared.

TABLE 5 Influence of EM on the growth of lambs on EM treated pasture and EM treated drinking water over 1997 (Chamberlain, et al., 1997)

Period of measurement	Untreated control	EM treated Lambs
Late Sept	281	312
Early Oct	231	259
Late Oct	377	416
Early Nov	322	234
Late Nov	205	333
Overall Mean	286	319

There was no significant difference between the ewe liveweights. Internal parasite faecal egg numbers were lower in the EM treated lambs (Chamberlain, et al., 1997). The Lambs receiving EM had higher growth rates measured in grams per day compared with the control group for the first three weighings and the last, but a lower growth rate for the early November weighing. The average daily weight gain for EM lambs was 319 grams per day and 286 grams per day for the control group, a difference of 33 grams a day or a 12 % gain with the use of EM. Table 5.

Field Trials 1998

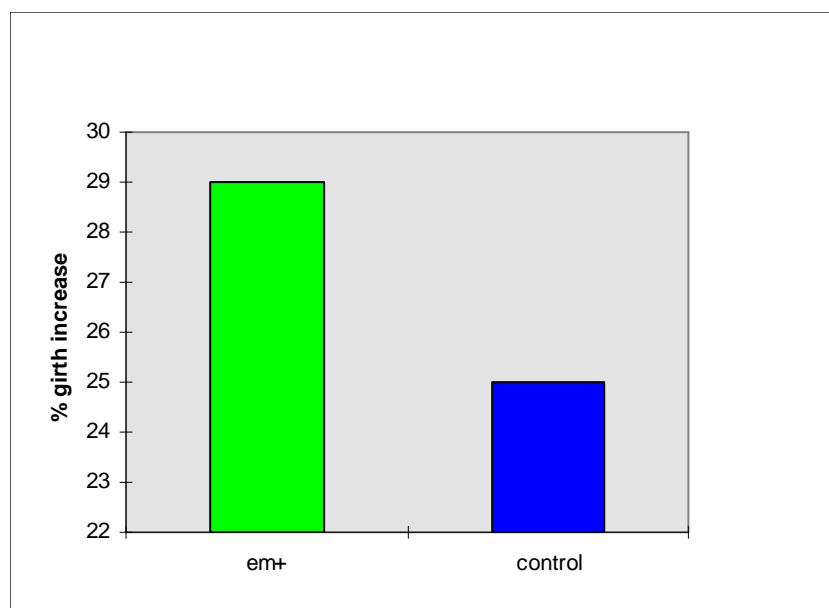
Significant differences ($P < 0.05$) were measured between EM + molasses and both control, and control + molasses. EM + molasses was also significantly higher than NPKS fertiliser. By adding EM+ molasses to the 'Foliafeed' an improvement was recorded in yield, however this was not statistically significant, although the difference was approaching significance.

TABLE 6 Influence of EM plus molasses on onion mid season vigour, yield and grade 1998

Treatment	Total Yield (t ha ⁻¹)	First grade (t ha ⁻¹)	Small grade (t ha ⁻¹)	Reject grade (t ha ⁻¹)
Control	65	32	2	15
Control + molasses	66	42	1	13
EM + molasses	74	50	2	2
Foliafeed (fish based foliar)	62	45	2	2
Foliafeed + EM + molasses	69	44	2	6
Fertiliser (NPKS)	64	45	1	3
<i>LSD</i> _{<i>P</i>=0.05}	8	11	2	9

EM + molasses also improved the quality with a higher proportion of first grade onions ($P < 0.05$) and less reject onions than the control ($P < 0.05$).

FIGURE 2 Effect of EM application on % girth increase of Apple Trees over a 4 month period (P<0.05).



The application of EM to young apple trees (2nd leaf) over the growing season gave an increase in growth as measured by girth circumference, over an untreated control (Fig.2, P<0.05).

A farmer growing a crop of potatoes conducted a simple comparative on-farm trial under the guidance of a Technical Officer from NZNFS. The results indicated a large advantage to both EM and Bokashi, compared to untreated controls (Table 7). The purpose of this trial was not to generate scientific data, but to train the farmer in the use of EM and allow him to compare different techniques and to measure these differences.

TABLE 7 Influence of EM plus molasses on Potato Growth-a farmers own trial 1998.

Treatment	Number of Potatoes (number/2 plants)	Weight of Potatoes (kg/2 plants)
White potatoes		
Untreated control	40	2.0
EM + molasses rep1	41	6.8
EM + molasses rep2	58	3.2
Bokashi	54	4.4
Red potatoes		
Untreated control	46	4.4
EM + molasses	91	6.0
Bokashi	45	5.8

EM expansion in New Zealand

To facilitate the development and expansion of EM Technology in New Zealand, a charitable trust was established in 1997. This trust called the New Zealand Nature Farming Society is administered and directed by farmers and aims to make, distribute and promote the use of EM Technology and Nature farming principles in New Zealand. In early 1998 an EMRO Technical Officer from Japan came to New Zealand and facilitated the setting up of a

production plant to make EM. As a result the New Zealand Nature Farming Society are now making EM and distributing it within New Zealand.

The approach to spread the technology has been to, identify and work with 'Key' farmers as representing the various main types of agricultural production, such as sheep farming, crop production, vegetable production, dairy farming and fruit production. These key farmers are selected on their skills and success in farming, so that they are respected by their peers and recognised as good leaders. The key farmers are then taught how to use EM on their farms and encouraged to set-up on-farm experiments. Farmers are the best teachers to other farmers and this group of key farmers then become the platform for expansion and uptake of EM technology throughout the region and country.

DISCUSSION

The positive results obtained from research conducted in replicated scientific experiments encouraged the author to set up a trust organisation with interested farmers to begin the process of developing EM making facilities in New Zealand. This organisation established in 1997 called, New Zealand Nature Farming Society (NZNFS) developed a plant to make EM under the guidance of an EMRO Technical Officer from Japan. The NZNFS is now making EM and distributing it for experimental use, pending certification and registration requirements.

The NZNFS is self funding and operating with a small budget and is expanding at a steady rate. The main method of expansion, through a key farmer network is working well and is likely to increase exponentially as the numbers of key farmers increase.

For the future the NZNFS would like to continue the expansion of EM technology in New Zealand, by working with key farmers in the production of food in a safe, sustainable and healthy manner. Beyond this, NZNFS would diversify into industrial applications and begin working with commercial partners to include EM in product manufacture and development.

REFERENCES

- Anderson, J.P. 1982. Soil Respiration. In: A.L. Page, R.H. Miller & D.R. Keeny, (eds) "Methods of Soil Analysis Part 2-Chemical and Microbiological Properties", 2nd Ed., American Society of Agronomy; U.S.A. 831-845.
- NZBPC. New Zealand Biological Producers and Consumers Council (NZBPCC) PO Box 36 170, Auckland.
- Chamberlain, T.P. Daly, M.J. & Merfield, C.N 1997. Utilisation of Effective Microorganisms in Commercial Organic Agriculture - A Case Study from New Zealand Proceedings of the 2nd International Nature Farming Conference, Bangkok, Thailand (inpress).
- Clarke, C.J. Smith, G.S. Prasad, M. & Cornforth, I.S. 1986. Fertilizer recommendations for horticultural crops. Ministry of Agriculture and Fisheries; Wellington.
- Daly, M.J. 1996: Effective micro-organisms (EM) in broadacre organic vegetable production on New Zealand farms. 11th IFOAM Conference Copenhagen, Denmark.
- Daly, M.J. Stewart, D.P.C. Influence of "effective microorganisms" (EM) on vegetable production and carbon mineralization - A preliminary investigation . Journal of Sustainable Agriculture (in press)
- Kear, B.S. Gibbs, H.S. Miller, R.B. 1967. Soils of the Downs and Plains Canterbury and North Otago New Zealand, Soil Bureau Bulletin 14. DSIR; Wellington.
- Merfield, C.N. Walter, M. Daly, M.J. 1997. The Biological Control of Pea Root Rot and Damping off on Lettuce by Effective Microorganisms. Presented at the Sixth Conference on Effective Microorganisms at Sara Buri Thailand (in-press).