The Nutrient Value and Effect of Fish Meal as a Fertiliser for Hayward Kiwifruit Grown Under an Organic Regime.

Philip Barlow & Alan McCurran (Bio Soil & Crop Ltd New Zealand)

Abstract:
In this trial we tested the use of dried Fish Meal as a soil applied fertiliser for organically grown Kiwifruit (Actinidia Delisiosa var Hayward) . The treatments [3 X 6 replicates = 18 blocks] had a Nitrogen equivalent of T1 = 33.3Kg/Ha N and T2 = 66.6Kg/Ha N and for comparison we had zero fish meal control blocks.

The Chlorophyll meter showed a significant result commensurate to the amount of Fish meal fertiliser applied; the difference in the mean result comparing zero fish meal to the high input (T2) was significant at the $p <= 0.1$ level. Using a florescence chlorophyll meter we were able to demonstrate that with increased nitrogen levels there was also increased photosynthetic potential in the leaves [R^2 0.66 $p<0.01$].

The presentation of the leaf nutrient analysis data exposed a serious error that can occur when using leaf analysis data as a measure of success in a plant/fertiliser trial. We found that when leaf analysis data is expressed as percentage and ppm nutrient per unit dry weight basis; then a serious Type II error occurred for that method failed to compensate for the nutrient dilution effect that naturally comes from with leaf growth. To avoid this Type II error; the kiwifruit leaves were also measured and weighed so that the total uptake of nutrients as mg/leaf dry weight is reported.

The Fish meal fertiliser effect on nutrient uptake has proven to be very interesting, for 12/12 of the nutrients had the highest ranking for the lower fertiliser application rate (T1). And for the high fertiliser rate (T2) we found in 11/12 of the nutrient rankings, nutrient uptake was lower than for the Zero application control blocks. We found that fish meal is a good fertiliser for increasing nutrient uptake, also for organic horticulture we learned that we should take care not to merely aim to mimic the typical conventional nutrient inputs because this resulted in the use of excess fish fertiliser and it was detrimental to overall growth.

Further work is needed to determine the optimum fish meal spread rate for nutrient uptake and stimulation of soil micro-biological organisms.

Key words:
Fish meal fertiliser, Nutrients, Hayward Kiwifruit, Organic, Leaf Analysis, Chlorophyll Meter

Trial Partners:

Bio Soil & Crop Ltd:

Alan McCurran Field and lab operations.

Philip Barlow Technical input, data processing and reporting.

Kiwifruit Management Services Graham Cathie & Dean Gilbert:

Use of Home Orchard, Field work and management of the vines during the trial.

Zespri International Ltd (Richard Pentreath),

Trial Management, Technical input and funding for the trial expenses.

Hypothesis:

Fish meal applied to organically grown Hayward Kiwifruit has a significant effect regarding:

1) Changes in fruit yield, fruit size, fruit dry matter or fruit brix?
2) Changes to leaf size or leaf shape?
3) Change in leaf nutrient composition?
4) Change in flower to bud ratio the following spring?

Introduction:

When growing fruit crops including Hayward Kiwifruit under the certified "Organic" regime (also referred to as biological production) there are few nitrogen (N) rich fertilisers that are acceptable for use under the certified organic regime. It is well known that there are improved plant growth benefits through the addition of nitrogen containing animal manures, but it was not until the nineteenth century that the essentiality of nitrogen was scientifically proven (Marschner 1986, p3).

The amount of nitrogen inputs required to grow a crop of Hayward kiwifruit has been difficult to establish and there are differing opinions among agronomists.

For the non-organic kiwifruit sector, N inputs are frequently in the order of 100-150 kg/ha/year which is expected to be sufficient to maintain adequate leaf N levels, to promote replacement cane and to cover the annual crop removal of nitrogen; which is approximately 60 kg/ha (Boyde L. 2005).

For the organic sector to mimic the same N inputs as used in the non-organic sector then 8 to 10 T/Ha of high quality 50:50 Chicken manure/compost blend (2 to 3% N dry weight basis) would be about equal for N input. However for many Biological producers this simple mimic has missed the essence of organic philosophy e.g. Using the natural ecology within the orchard to optimise the nutrient recycling from the vine leaf & cane debris and the ground cover herbage and to maintain or increase soil humus and also to promote maximum soil life. When organic manure inputs are used, they are frequently referred to as soil amendments rather than fertilisers because not only do they contain the N,P,K elements as nutrients but they also have the dual nature supplying organic precursors to soil humus and bio-stimulants which accelerate the activity of various soil micro-organisms (Gobat JM, Aragno M, Matthay W, 2003 p337) .

There are several types of N rich organic manures frequently used in organic agriculture including; animal/poultry dung, composted vegetable matter including municipal green waste and processed fish waste. Fish based soil amendment products are nutrient rich (11% N dry weight see table 1) and the products are usually promoted as having the ability to promote soil microbial activity.

There are three main types of fish fertilizer:

1) Fish meal: The only dry solid fish fertilizer. It is most often made of bi-catch fish, which would otherwise be discarded at sea or on landfill sites. The fish are heated, pressed, and dried, and the fats and oil are removed and are sold for various other uses. In some processes, phosphorus is added to stabilize and deodorize the meal.
2) Hydrolysed fish: This is made from whole fresh fish or fish scraps, which are broken down with special enzymes. Phosphoric acid is used in this manufacturing process to stop enzymatic digestion. The result is a slurry-like fertilizer that is soluble in water. No heat is used in making hydrolysed fish, so it keeps more of the fish's original proteins, hormones, and vitamins in their natural state.
3) Fish emulsion: This is made with a heating process creating a water soluble emulsion that is sold as fertilizer product. Like the other fish fertilizers, phosphoric acid is often added to lower the pH level;

The claims of fish fertiliser manufactures for increased agricultural productivity are abundant on the internet and elsewhere, but finding scientific proof is hard. And to the contrary, the Victoria State Government Australia state that they found no benefit in a pasture trial even when the liquid fish product was applied at 8 to 10 times the prescribed rate . (Vic State Gov).

In view of the conflicting information there is a need for an investigation to evaluate whether fish fertiliser has any beneficial effects on Hayward kiwifruit as described in our hypothesis above.

Experimental information:

The orchard used for the trial is in the heart of New Zealand's Organic Kiwifruit district of Pyes -Pa near Tauranga, Bay of Plenty. The vines are fully matured and have being under the organic regime for decades. The trial design was a Latin square model which ensured that the six replicated blocks for each treatment were evenly distributed for proximity to the shelter belts and were equally sunny. The fish fertilizer product used was a dry fishmeal which was analyzed for nutrient content and the results are presented in Table 1.

There were three treatments as follows (see Table 1):

Zero application

T1 300Kg/Ha Fish meal which may be expressed as 780g/Vine

T2 600Kg/Ha Fish Meal which may be expressed as 1560g/Vine
(close to conventional orchard Nitrogen input)

The prescribed inputs were spread evenly over the root zone of each treated vine at the appropriate spread rate. Apart from these separate treatments all other inputs were equal as per usual orchard inputs but excluding any additional fish based products. Ordinary Green waste Compost was applied to the whole orchard as an light even dressing using a mechanical spreader therefore all treatments had the same input.

Nutrient Inputs Fishmeal Trial

Table 1				Treatment 1		Treatment 2	
Product Nutrient Content (fresh weight)				300Kg/Ha 780g/Vine		600Kg/Ha 1560g/Vine	
	Result	Unit	Kg/Tonne	g/Ha	g/Vine	g/Ha	g/Vine
Nitrogen	11,1	Percent	111	33300	86,58	66600	173
Phosphorus	3,216	Percent	32,16	9648	25,08	19296	50
Potassium	0,627	Percent	6,27	1881	4,89	3762	10
Calcium	6,709	Percent	67,09	20127	52,33	40254	105
Magnesium	0,391	Percent	3,91	1173	3,05	2346	6,1
Sodium	1,65	Percent	16,5	4950	12,87	9900	26
Carbon	37,79	Percent	377,9	113370	294,76	226740	590
Boron	9,19	ppm	0,009	2,8	0,72	5,514	1,4
Iron	210	ppm	0,210	63	16,38	126	33
Manganese	8,21	ppm	0,008	2,5	0,64	4,926	1,3
Copper	2,13	ppm	0,002	`	0,17	`	0,33
Zinc	86,45	ppm	0,086	26	6,74	51,87	13
	Total		615,1				
Unmeasured items incl Moisture			384,9				

In early February 2013 using specific leaf sampling protocols, 25 leaves were collected from each block (six blocks per treatment & 3 treatments). Equalling 18 separate samples.

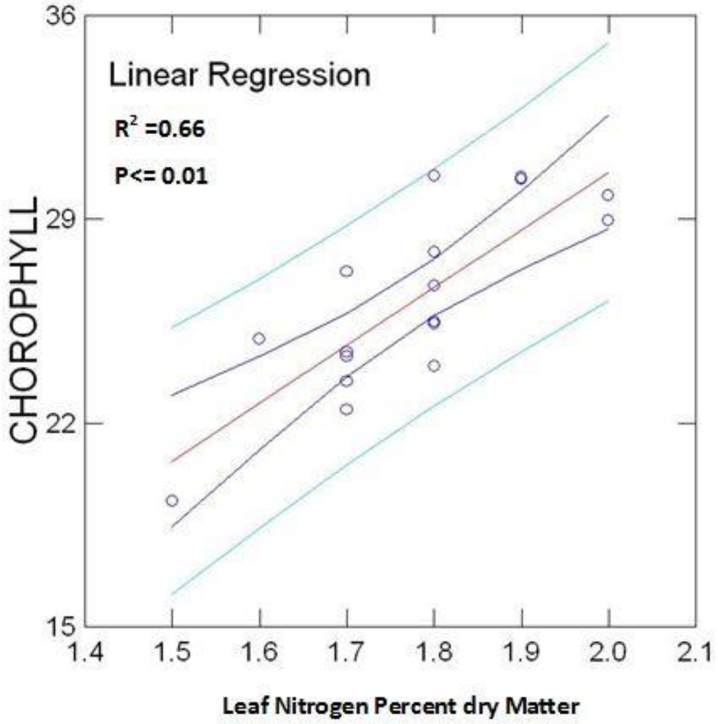
Before sending the samples to Hills laboratory Hamilton NZ standard nutrient analysis; the leaves were the measured for the following factors:

1) Photosynthetic potential using the Opti sciences CCM-200 florescence chlorophyll meter.
2) Leaf size was ascertained by measuring each leaf length (L) and width (W), not including the petiole. The same data was used to consider the overall shape of the leaves. L x W = Leaf area and $\frac{L}{W}$ = Leaf Shape Ratio
3) 50mm diameter discs were cut from the leaves, which were then weighed dried and then weighed again, from this data we could calculate the leaf moisture content and the specific leaf weight as mg/cm2.

It was in the trial schedule that, during Autumn 2013 the fruit was to be harvested separately for each treatment and passed over a commercial fruit grader where fruit size and yield was measured. However for reasons beyond our control this was not done and much valuable data was lost

November Spring 2013 (season after fish meal application) the Flower numbers were measured and compared to the winter bud numbers. This was to ascertain whether there were any long term benefits gained from improved cane quality.

Figure 1



Results & Discussion:

Leaf physical measurements:

The Chlorophyll meter showed a significant result commensurate to the amount of Fish meal applied (see Table 2).

The difference in the mean Chlorophyll meter result comparing zero fish meal to the high input (T2) was significant at the $p <= 0.1$ level.

The key nutrient affecting the chlorophyll meter readings was nitrogen (see Figure 1).

Therefore we have deduced that Fish meal feriliser does increase leaf nitrogen levels and also increases the photosynthetic potential of the leaves (Taskos D.G 2015).

Although there was a tendency for leaf area to be larger with the use of fish meal, the result was not statistically significant.

Table 2			Leaf Dimentions and Chlorophyll Meter Results					
Greatest	Mid value	Lowest	Leaf size cm2	Sp Wt g/cm2	Ave Leaf Dry Wt grams	Leaf Moisture % Fresh wt	Leaf Shape Ratio L/W	Chorophyll Meter Index
Treatment	**No of observations**		450	42	42	42	450	168
Zero	Mean Ave		189,7	0,062	11,78	65,18	0,78	25,3
	Std Deviation		36,7	0,005	0,951	0,880	0,025	5,95
		Rank	3	2	2	2		3
Treat 1 T1	Mean Ave		190,3	0,067	12,65	63,71	0,78	26,10
	Std Deviation		42,0	0,008	1,130	1,784	0,022	5,11
		Rank	2	1	1	3		2
Treat 2 T2	Mean Ave		193,0	0,060	11,51	65,99	0,78	27,00
	Std Deviation		40,5	0,007	1,385	1,882	0,023	7,20
		Rank	1	3	3	1		1
Significance (p-value) T Test between Treatments			No sig result	No sig result	No sig result	T1 Vs T2 p = 0.057	No sig result	Zero Vs T2 p = 0.019

The overall leaf weight appeared to be greatest with the T1 treatment and that was mainly due to a higher Specific leaf weight (perhaps the leaves are thicker or denser). However once again the data did not give a statistically significant result.

The leaf shape ratio was identical on all three treatments.

We had a statistical "near miss" with leaf moisture content comparing T1 & T2 treatments p = 0.057, perhaps the increased photosynthisis increased the draw on soil moisture.

Nutrient levels:

The data from the laboratory analysis of the leaf nutrient content has been expressed in two ways side by side: (See Table 3 & 4)

1) The standard percentage & ppm dry weight.
2) Using the same Laboratory data we have factored in leaf size and specific leaf weight to express the data as milligrams of each nutrient per leaf

Table 3 Leaf Analysis - Major Nutrients Percent dry weight and Miligrams per Leaf Basis.

Greatest | Mid value | Lowest

Treatment		Nitrogen % dry wt	Nitrogen mg/leaf	Phosphorus % dry wt	Phosphorus mg/leaf	Potassium % dry wt	Potassium mg/leaf	Sulphur % dry wt	Sulphur mg/leaf	Calcium % dry wt	Calcium mg/leaf	Magnesium % dry wt	Magnesium mg/leaf	Sodium % dry wt	Sodium mg/leaf	Chloride % dry wt	Chloride mg/leaf
	No of observations	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6	6
Zero	Mean Ave	1,77	208,5	0,143	16,93	2,27	267	0,29	34,7	3,11	367	0,31	36,3	0,004	0,448	0,45	53,5
	Std Deviation	0,082	24,33	0,012	2,45	0,137	28,0	0,076	10,46	0,165	42,0	0,048	4,41	0,002	0,173	0,067	9,91
	Rank	3	2	2	2	1	2	2	2	1	2	1	2			3	3
Treat 1 T1	Mean Ave	1,78	225,8	0,140	17,67	2,18	277	0,30	37,6	2,95	376	0,30	37,3	0,003	0,358	0,47	58,7
	Std Deviation	0,133	27,61	0,015	2,11	0,117	31,8	0,060	9,41	0,507	81,4	0,050	6,86	0,000	0,059	0,104	12,99
	Rank	1	1	1	1	2	1	1	1	2	1	2	1			2	1
Treat 2 T2	Mean Ave	1,77	204,6	0,137	15,77	2,13	247	0,28	32,3	2,80	323	0,29	33,8	0,003	0,345	0,49	56,1
	Std Deviation	0,175	38,75	0,012	2,54	0,361	54,9	0,046	8,37	0,378	60,9	0,048	8,33	0,000	0,042	0,063	10,27
	Rank	2	3	3	3	3	3	3	3	3	3	3	3			1	2

Table 4 Leaf Analysis - Micro Nutrients ppm dry weight and Miligrams per Leaf Basis.

Greatest | Mid value | Lowest

Treatment		Iron ppm dry wt	Iron mg/leaf	Manganese ppm dry wt	Manganese mg/leaf	Zinc ppm dry wt	Zinc mg/leaf	Copper ppm dry wt	Copper mg/leaf	Boron ppm dry wt	Boron mg/leaf	TotalNutrient mg/leaf
	No of observations	6	6	6	6	6	6	6	6	6	6	6
Zero	Mean Ave	39,50	0,47	58,17	0,69	13,67	0,161	14,333	0,169	52,83	0,62	987
	Std Deviation	3,728	0,066	7,250	0,132	1,211	0,020	4,082	0,052	6,145	0,070	102
	Rank	1	2	2	2	2	2	2	2	1	2	2
Treat 1 T1	Mean Ave	39,33	0,50	61,00	0,78	15,17	0,19	14,333	0,182	50,17	0,63	1032
	Std Deviation	6,831	0,091	9,960	0,165	1,835	0,032	1,033	0,022	4,021	0,067	150
	Rank	2	1	1	1	1	1	2	1	2	1	1
Treat 2 T2	Mean Ave	38,50	0,45	57,50	0,67	13,67	0,158	14,50	0,168	49,00	0,56	915
	Std Deviation	4,037	0,093	11,345	0,186	1,366	0,025	3,834	0,048	9,252	0,118	149
	Rank	3	3	3	3	2	3	1	3	3	3	3

With sodium excluded (Kiwifruit appear to have little use for sodium) we have 12 nutrients presented and in 8 out of the twelve nutrients the ranking between treatments was altered when comparing the two different ways of expressing the data. This is because the standard percent & ppm dry weight method of presenting nutrient trial results fails to take leaf growth into account. Therefore we consider it more accurate to present the trial results as milligrams of nutrient per leaf.

In every case [12/12] we found that Treatment T1 had the greatest nutrient uptake.
T2 had the lowest nutrient uptake [11/12] for all nutrients except chloride.

The rate of fish meal application was set at a level which was to mimic the typical nitrogen inputs for conventional kiwifruit orchards (Boyde L 2005) however, as this experiment shows it is a mistake to crudely apply those input rates to set fish meal input rates for organic orchards.

The data shows that the T1 treatment had in every case better nutrient uptake than both Zero and T2 treatments therefore it is quite possible that even the T1 rate of application was higher than ideal. The T2 treatment consistently had lower nutrient uptake than the zero control treatment and the only nutrient that was an exception was chloride. We are not sure of the exact reason for lower nutrient uptake; it may be due to direct competition between the nutrients (N versus S or K versus Mg for example) and the imbalance may result in an overall lower rate of nutrient uptake for all nutrients.

When taking compost N into account the nitrogen inputs for the T2 blocks was the approximate equivalent of that used for conventional orchards. However this study showed that it is inappropriate to mimic nutrient inputs typical of conventional orchards and apply those N rates as fish meal to organic orchards, evidently there are other factors involved probably of a biological nature.

Flower & Winter bud counts:

The data we gathered showed no significant difference in bud break or in Flower to bud ratio between the treatments.

Conclusions:

1. The use of fish meal fertiliser can increase nitrogen uptake in organic kiwifruit and as a result the photosynthesis rate was increased.
2. If excess rates of fish-meal are used then the end result might be worse than if none were used.
3. The chlorophyll meter was a useful predictor of leaf nitrogen levels on organic kiwifruit.
4. The method of using fish meal at rates that are set to mimic typical nitrogen inputs used on conventional orchards does not appear to be beneficial for organic orchards.
5. When using leaf analysis for evaluation of nutrients trials researchers need to be aware of the intrinsic danger of not taking in to account leaf growth and the resulting dilution effect account.

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