New Zealand Kiwifruit Journal

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Seaweed Application to Hayward Kiwifruit (Actinidia Deliciosa) Orchard Trial:

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Abstract:
We undertook this commercial orchard trial in order to investigate whether the use of seaweed soil & foliar treatments had any effect on leaf size or shape and does its use effect fruit weight, brix or dry matter to any measurable or economic amount. We found that leaf area was significantly increased by 6.4% (p=0.027) and that this was due to increase in leaf length but not the width, thus altering the leaf shape (p=<0.001). The change to leaf size and shape does not appear to be related to any increase in leaf nutrient content, but it appears to be hormonally activated. When the leaf analysis nutrient content data was subjected to compositional data analysis (CODA) with isometric log ratios, we found that the treated vines had enhanced photosynthetic efficiency. Treatment with seaweed did significantly increase fruit weight by 7.3% (p=0.010) giving a NZ$3,000 per hectare advantage through using seaweed treatments.

Key Words: Seaweed, Kiwifruit, Leaf size, Leaf Shape, Fruit Size, Compositional Data Analysis.

Trial partners:
1) **Stuart Steel Long-ridge Orchards**. Made his orchard available for trial, applied the seaweed products, harvested the treated and untreated areas separately and had the bulk fruit grading done separately.
2) **Agrisea Ltd.** Supplied Seaweed based products. Paid for lab leaf analysis. No other input.
3) **Bio Soil & Crop.** Planned and Coordinated trial, took leaf & fruit samples, made leaf and fruit measurements, processed the resulting data and prepared trial summary.

Hypothesis:
Do Seaweed treatments have any significant effect regarding:
1) Increase in Fruit size, Fruit dry matter or Fruit Brix?
2) Changes to leaf Size or leaf shape?
3) Change in leaf nutrient composition?

Introduction:
The use of seaweed in agriculture is a very old tradition of uncertain age, in the case of Ireland it is known to extend back many centuries, where seaweed was gathered from the beaches after storms and applied to shallow soils as a fertilizer for growing vegetables, with great success (see photo).
Despite the long history of the use of raw seaweed and seaweed extracts, agricultural scientists are not all in agreement and some have strong opinions e.g.

a) "Seaweed concentrates are known to cause many beneficial effects on plants as they contain growth promoting hormones (IAA and IBA, Cytokinins) trace elements (Fe,Cu, Zn, Co, Mo, Mn, and Ni), vitamins and amino acids. Liquid extracts obtained from seaweeds are successfully used as foliar sprays for several crops" Pise & Sabale 2010.

b) "A leading Waikato soil scientist has slammed a decision to give Paeroa company AgriSea a sustainability award, dubbing its soil additives "snake oil. .. These products do not contain sufficient concentrations of plant nutrients, organic matter or plant growth substances to elicit increases in plant growth when applied as recommended." Waikato times (2007)

Wet seaweed being taken to a croft for use as fertiliser: Aran Islands, Co. Galway, 1900-35. (T.H. Mason).

Stefan Kraan

With such conflicting information, it is important for agronomists and producers alike to obtain reliable information regarding the effectiveness of all farm or orchard inputs they are using or recommending. This is the reason why this trial of seaweed products for use with Hayward kiwifruit was set up and executed by Bio Soil & Crop Ltd NZ.

Expermental information:

The Trial was conducted in New Zealand during the 2007/2008 growing season.

The products; Agrisea Ltd provided the soil and leaf applied products, which were based on seaweed gathered at the East Cape NZ. The seaweed; Brown Kelp (***Ecklonia radiata)*** is partially dried on the beach and then cold fermented at the factory in Paeroa, Waikato, NZ. Because there is no heat processing we would expect the activity of the Cytokinnins to be undamaged and possibly better than that of other heat processed products.

The Trial Site ; Longridge Orchard Paengaroa is situated close to TePuke New Zealand, which is considered Globally as the optimum climatic location for kiwifruit production. Conventional cultural practices were used in this orchard with some organic type inputs being used. The soil type is classified as a coarse Vitrand (USDA) and was constant between the blocks, irrigation was available and used at the growers discretion with the proviso that both areas get the same treatment. Two adjacent equally sheltered and equally sunny blocks were selected for the trial both with the area of about one hectare. There were no shelter belts separating the blocks and there were no shading issues. One block was to be treated with seaweed products and the other without and the choice of which block was to be treated was decided on with the toss of a coin. Both blocks had a history of similar productivity and fruit size. Apart from the seaweed treatments both areas received all other inputs and management practices on an equal basis.

The treatments consisted of:

1) One soil applied treatment October 2007
2) Three foliar sprays 5L/Ha in 1,000L water (seven day intervals) applied straight after petal fall 2007.
    a. The non-treated area was sprayed with water only.

Results:

Leaf Size & Shape (see table 1):

Leaf Size & Shape Results

Table 1			Result							
		Untreated			Treated					
Factor	Unit	N (reps)	$\bar{x}$	Sdev	N (reps)	$\bar{x}$	Sdev	Difference (%)	t test	P-value
Leaf Length (L)	cm	60	11,917	1,161	60	12,658	1,323	6,2 Longer	3,264	0,001 S*
Leaf Width (W)	cm	60	14,908	1,159	60	14,95	1,104	0,3 Wider	0,202	0,841
Leaf shape (L/W)	Ratio	60	0,801	0,068	60	0,849	0,089	6,0 Longer	3,327	0,001 S*
Leaf size (L x W)	cm	60	178,4	27,1	60	189,8	28,86	6,4 Larger	2,235	0,027 S
$\bar{x}$ = mean average: NS = Not significant; N (Reps) = number of leaves measured										
S = Significant: p=<0.05		S* = Highly Significant p=<0.01								

Leaf size was ascertained by harvesting and measuring 60 leaves from each treatment block measuring leaf length (L) and width (W), not including the petiole.

L x W = Leaf area and $\frac{L}{W}$ = Leaf Shape Ratio

The leaves from the treated blocks were 11cm^2 (6%) larger and this was mainly due to the promotion of longer rather than wider leaves thus altering the overall shape of the leaves.

The leaf form of A delicious var Hayward is significantly polymorphic and leaf shape is under the control of naturally produced plant hormones (Ferguson A.R 1990):

1. Juvenile form (Ovate, acute tip, strongly dentate edges & pubescent) these are also found on mature vines but are restricted strong vigorous shoots often referred to as “Water shoots”.
2. Mature form Terminated shoots (Obovate, Retuse tips, Obtuse base, Mildly crenate edges with hairs.
3. Mature form Non-terminated shoots (Obovate, Cuspidate tips, Cordate base, Mildly crenate with edge hairs.

Leaf Nutrient Composition (see table 2):

Leaf Nutrient Composition

Table 2				Result						
			Untreated			Treated				
Factor	Unit	N (reps)	$\bar{x}$	Sdev	N (reps)	$\bar{x}$	Sdev	Difference (%)	t test	Prob
Nitrogen	%	3	2,300	0,100	3	2,267	0,058	1,4 Lower	0,500	0,649
Phosphorus	%	3	0,173	0,006	3	0,180	0,010	4,0 Higher	1,000	0,387
Potassium	%	3	2,133	0,153	3	2,133	0,115	0,00 Same	0,000	1,000
Sulphur	%	3	0,387	0,042	3	0,297	0,023	23,3 Lower	3,274	,044 S
Calcium	%	3	2,827	0,202	3	2,220	0,160	21,5 Lower	4,077	0,015 S
Magnesium	%	3	0,363	0,032	3	0,283	0,015	22,0 Lower	3,893	0,033 S
Iron	ppm	3	51,67	1,528	3	44,00	5,000	14,8 Lower	2,54	0,064
Manganese	ppm	3	68,33	5,033	3	54,00	5,568	21,0 Lower	3,308	0,030 S
Zinc	ppm	3	17,33	1,528	3	14,33	0,577	17,3 Lower	3,182	0,062
Copper	ppm	3	8,00	1,000	3	9,67	1,528	20,8 Higher	1,581	0,200
Boron	ppm	3	35,00	1,00	3	30,667	2,887	12,4 Lower	2,457	0,109
Chloride	%	3	0,700	0,155	3	0,600	0,078	14,3 Lower	0,997	0,393
ilr 1 Major/ Minor Nutrients	Ratio	3	8,129	0,093	3	8,110	0,138	0,2 Lower	0,196	0,855
ilr 2 Major Nutrients / Boron	Ratio	3	5,094	0,048	3	5,103	0,094	0,2 Higher	0,158	0,884
ilr 3 Anions / Cations	Ratio	3	-1,162	0,069	3	-1,067	0,027	8,2 Higher	2,215	0,127
ilr 4 (N+S+Cl) / P	Ratio	3	1,375	0,088	3	1,222	0,094	11,1 Lower	2,052	0,110
ilr 5 (N +S) / Cl	Ratio	3	0,255	0,135	3	0,259	0,099	1,6 Higher	0,034	0,974
ilr 6 N / S	Ratio	3	1,263	0,059	3	1,439	0,067	13,9 Higher	3,400	0,028 S
ilr 7 (K +Na) / (Ca + Mg)	Ratio	3	1,912	0,047	3	2,038	0,06	6,6 Higher	2,885	0,048 S
ilr 8 Ca / Mg	Ratio	3	1,451	0,066	3	1,456	0,04	0,3 Higher	0,089	0,934
ilr 9 (Cu+Zn+Mn) / Fe	Ratio	3	-0,776	0,057	3	-0,702	0,081	9,5 Higher	1,282	0,276
ilr 10 (Cu+Zn) / Mn	Ratio	3	-1,437	0,06	3	-1,244	0,01	13,4 Higher	5,489	0,028 S
ilr 11 Cu / Zn	Ratio	3	-0,5549	0,138	3	-0,464	0,409	16,4 Higher	0,338	0,762
ilr 12 Nutrients / Filling	Ratio	3	-6,978	0,055	3	-7,092	0,039	1,6 Lower	2,916	0,049 S
$\bar{x}$ = mean average: NS = Not significant; N (Reps) = number of Leaf Analyses										
S = Significant: p=<0.05		S* = Highly Significant p=<0.01								

Three 20 leaf samples for each treatment were sent to Hills laboratory Hamilton for standard nutrient analysis giving a total of six separate sets of nutrient results. This is the bare minimum sets of nutrient results needed for a statistical analysis yet despite this we did find some significant results.

Sulphur, Calcium, Magnesium and Manganese were all found at a significantly lower level in the seaweed treated vines; there were no significant increases.

A common error that confounds many plant trials when using leaf nutrient analyses, is that the data is expressed as percentage dry weight and no account is made of changes in growth rate or leaf size. In this trial we have measured leaf area and certainly the increase does account for much of the decrease in leaf nutrient content due to the dilution effect. We did not measure the leaf mass and if the seaweed increased leaf thickness to the same degree as leaf length, then perhaps the remainder of the reduced leaf nutrient content could be accounted for.

Recognizing the inherent weakness of using the standard percent and ppm dry weight method of reporting leaf analysis, a recent development has been Compositional Data Analysis (CODA) Parent L.E et al (2013), where the nutrient data is converted to meaningful Isometric-Log-Ratios (ilr). This method removes the restraints of data that sums to a greater whole of 100 as in percent or one million as is ppm and therefore allows use of the full range of statistical analysis without fear of creating spurious results.

After our leaf nutrient data was subjected to CODA we found that the resulting nutrient balance ratios ilr 6, ilr 7, ilr 10 were all significantly increased apparently as a direct result of the decreases of the specific nutrients previously discussed.

The ratio Ilr 12 is different to the other ratios in that it is comparing the sum of the nutrients in the analysis divided by the filling value.

Filling value = $100 - (\sum measured\ nutrients)$

When the total leaf analysis measured nutrients (expressed as percent dry weight) are summed, the result is usually ≈ 9 or 10% the unmeasured remainder amounts to about 90%, which closes the sum to 100%. The filling value is composed mainly of the carbon based products resulting from photosynthesis, including cellulose & sugars etc. The nutrients are the tools needed to produce the products of photosynthesis. Therefore this reduction in the ratio ilr 12 for treated vines indicates leaves with greater photosynthetic efficiency.

Fruit Size, Dry Matter & Brix (see table 3):

Fruit Wieght, Dry Matter & Brix Results

Table 3		Result								
		Untreated			Treated					
Factor	Unit	N (reps)	$\bar{x}$	Sdev	N (reps)	$\bar{x}$	Sdev	Difference (%)	T Test	Prob
Average fruit size (whole block)	grams	Total area	97,35	#N/A	Total area	101,67	#N/A	4,4 Increase	This is the bulk result whole treatment areas.	
Rejected Fruit	%		16,5			16,06		0,44 Decrease		
Fruit Dry Matter	%	61	16,44	0,877	60	16,83	2,21	0.39 More	1,273	0,207
Fruit Brix	index	61	4,98	0,21	60	5,04	0,21	1,2 Higher	1,595	0,113
Fruit Weight (individual)	grams	61	85,45	13,11	60	91,7	13,01	7,3 Heavier	2,633	0,010 S*

$\bar{x}$ = mean average: NS = Not significant; N (Reps) = number of fruit measured

S = Significant: p=<0.05 S* = Highly Significant p=<0.01

At full maturity each area was picked separately in to bulk bins and kept separate until after the fruit had been passed over a mechanized fruit grader. The average fruit size (whole block) result and the rejected fruit results are the overall averages calculated by the grader's computerized operating system and are therefore specific to the treated & untreated areas respectively as whole blocks. Because the results from the grader provide one value per whole treatment area, we are limited on what statistics are available for analyzing the data, but none the less the area receiving seaweed treatments did have heavier fruit (4.4% increase) and a slightly lower reject rate i.e. 0.44% lower. The lower reject weight is probably due to having less fruit rejected due to being too small to meet the criteria for grade one fruit.

One month prior to the main harvest, 60 fruit samples were collected from each treatment area by the fruit maturity testing services of Ag-first Ltd following standard non-biased protocols. Then they measured fruit weight, dry matter and brix following industry norms, which have been designed to give the most representative result for each maturity area. The full data set from the two 60 fruit samples was subjected to comprehensive data analysis. We did not find significant results for either fruit dry matter or brix, perhaps because of the fruit immaturity. We did find a highly significant result for the weight of the seaweed treated fruit, having an average weight of 91.7 grams which was 7.3 % heavier than the untreated area.

Discussion:
The seaweed treatment effect on the leaves was significant as shown by the increase in just the length of the leaves and was not a general all-round enlargement (see table 1). This extra growth does not appear to be caused by increasing nutrient content (see table 2) but is more likely to be due to a hormonal effect, mimicking the natural kiwifruit hormones that are already known to have an effect on leaf morphology. At the time of the trial we did not have the means of measuring leaf density or chlorophyll activity, which are factors that we now appreciate are very important in this kind of investigation. None the less using the ratio ilr 12 we have been able to demonstrate that with the seaweed treatments the leaves did have greater photosynthetic efficiency.
When considering the bulk harvest from the respective treatments we found that the seaweed treatment had the advantage of both increased fruit weight and reduced reject rate.
The data from 60 fruit samples was subjected to robust statistical analysis and we can conclude by stating that the use of Seaweed treatments did increase fruit weight to a highly significant degree ($p=<0.01$). (see table 3)
With the above data, the respective Orchard Gate Return per hectare was calculated using 2007/8 values:
Seaweed Treated = NZ$34,300 per hectare
Untreated = NZ$31,281.
The advantage in using seaweed products was more than NZ$3,000 per hectare.

Cautionary notes:
Because this trial was conducted in a commercial orchard and there were financial constraints; the trial was not laid out with the preferred scientific replicated Latin square design, therefore we preempt any critics by stating that we are aware of this weakness in the trial design and invite investors to allow a fully replicated trial.
In this trial we have identified that there are distinct economic advantages in using seaweed products with Hayward kiwifruit, however because we believe that the active ingredients of seaweed are hormonal in their mode of operation, we must not assume that there will be a similar response for all other plant species; each of these will need to be assessed on a species by species basis.

Acknowledgments:
Amelia Barlow. Who did the field work on behalf of Bio Soil & Crop.
Keith Atwood. Thanks to Keith Seaweed products were supplied free of charge and he helped in planning the trial.
Steve Saunders. Provided the analysis or orchard gate return.
Stuart Steel, Long Ridge orchards. His input into this trial was invaluable and he has done the kiwifruit growing industry a great favor.

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