Evaluation of the efficiency of Complete Blend 10® for improving plant nutrient status and yield in almonds

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Abstract

Macro and micro elements are an integral part to proper plant nutrition. Every plant needs these elements in order to function correctly and reproduce. Macro elements include Nitrogen (N), Phosphorus (P), Potassium (K), Sulphur (S), Calcium (Ca), and Magnesium (Mg). Micro elements include Iron (Fe), Manganese (Mn), Copper (Cu), Zinc (Zn), Boron (B), Chloride (Cl) and Molybdenum (Mo). Although these elements are categorized into macro and micro, all these elements are essential, just in different concentrations. Maintaining macro and micro nutrients also have a direct influence on achieving the best yields, especially in almond crops. With the macro and micro nutrients combined, the plant status is improved through increased photosynthesis, sugar translocation, biotic and abiotic stress resistance, increased flower to fruit development ratios and regulates processes within the plants such as the opening and closing of stomata (Kumar, Kumar and Mohapatra, 2021). This trial was conducted to analyse how a single application of a multi elemental fertiliser known as Complete Blend 10® effects the nutrient status and yield in almonds. It was found that trees treated with Complete Blend 10® had denser canopies, higher whole nut weight, hull weight, kernel weight and out-turns compared to the control. It was also measured that on average, Complete Blend 10® treated trees contained more nuts per tree compared to the control. Due to Complete Blend 10® containing multiple macro and micro elements, leaf and soil nutrition was also improved.

Keywords: Almond production, macro nutrients, micro nutrients, plant nutrition, yields, photosynthesis, sugar translocation, stress resistance, flower to fruit ratio, process regulations.

1. Introduction

In almond production, supplying a blanket fertiliser of a combination of macro and micro elements is essential, especially at post-harvest, spring root flush and shortly after fruit set to provide the trees with enough nutrients to promote good root growth, increased flower development, optimal fruit fill and kernel development as well as promoting the vegetative growth of the almond trees. Dual Chelate Fertilizer Pty LTD has developed a liquid, fertigated macro and micro nutrient fertilizer called Complete Blend 10®. Complete Blend 10® is carefully designed to provide an effective blanket of both macro and micro nutrients including: Nitrogen (N), Phosphorus (P), Potassium (K), Sulfur (S), Magnesium (Mg), Zinc (Zn), Copper (Cu), Iron (Fe), Boron (B) and Molybdenum (Mo). All these nutrients play key roles in achieving optimal yields and growth in agricultural production. Along with the core nutrients, Complete Blend 10® also contains Biologically Active Organic Molecules (BAOM) at a concentration of 1%. BAOM is a key patented chelation technology designed to enhance the translocation and availability of nutrients within the plant system.

In this study, the effect of fertigated Complete Blend 10® will be assessed in increasing almond yields and almond parameters such as hull weight and kernel weight. These parameters will be compared to control almond trees. Leaf nutrient analyses will also be done to assess tree growth along with comparative photos of treated and control rows and nut development. This trial will also analyse the differences in the total amount of nuts between Complete Blend 10® trees and the control trees with out-turn calculations determined from samples collected from each tree.

2. Objectives

The specific objectives of this trial were to:

- Assess the effectiveness of Complete Blend 10® in improving almond yield parameters via evaluation of whole nut and kernel weight.
- Analyse the physical growth and crop vigor of the trees and nuts through images.
- Compare leaf nutrient analyses to show differences in leaf nitrogen concentrations and other macro and micro nutrients.
- Determine out-turn differences between almond trees treated with complete blend 10 and control almond trees.
- Measure the quantity of nuts per tree between Complete Blend 10® and control trees.

3. Materials and Methods

Site selection and Trial Design

This trial was conducted in an Almond orchard within the Sunraysia region of Victoria. Two areas of the orchard were chosen for analysis with each area of the orchard having 2 sperate replicates in 2 neighbouring blocks. The trial layout is shown in figure 1. A commercial application of Complete Blend 10® was applied through fertigation in accordance to the orchard's fertigation program. Treated and control rows each had 7 trees each which were analysed and used to gather data such as leaves and nuts. Control trees were isolated using isolation taps which were fixed on the drip lines to create a temporary control area which separated the control trees from receiving an application of Complete Blend 10®.

Table 1 shows the application rates and dates for the Complete Bled 10® trial. Complete Blend 10® was applied to the treatment rows once during the start active growing season, shortly after fruit set. For the rest of the growing season, the orchards regular fertiliser program was applied.

Table 1: Application rates and application dates of Complete Blend 10®

Treatment	Rate (L/ha)	Application Date
Control	0 L/ha	N/A
Complete Blend 10®	30 L/ha	31/08/2020

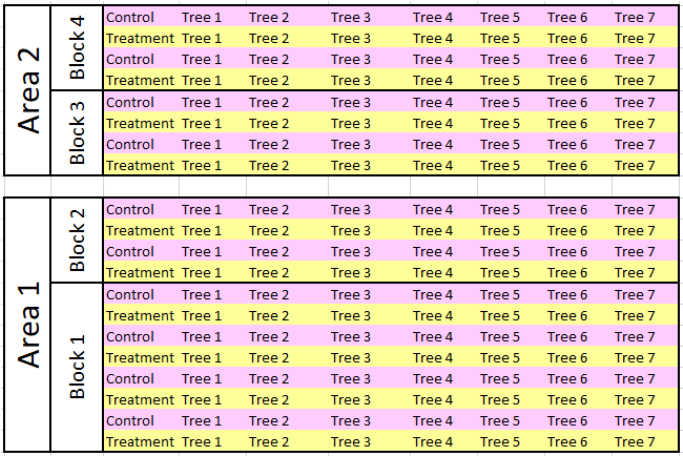

Figure 1: Trial design layout in 2 separate areas of the almond orchard. each area had 2 separate blocks where data was gathered. In total there were 4 replicates of this trial spread over 4 blocks in 2 different areas.

4.Observations

Soil Nutrient Analysis

Soil samples (30cm deep) were taken in mid-January 2021 just prior to the beginning of almond harvesting as requested by the orchards technical agronomist following correct soil sampling techniques. Soil samples were then sent to the Australian Precision Ag Laboratory (APAL) for a full soil nutrient profile analysis. See figure 2 for images of soil sample collection. The results were then analysed using GraphPad Prism

software to determine any significant differences in soil nutrient concentration between the treatments.

Figure 2: Image of soil sampling for Complete Blend 10® trial. Soil samples were taken 30cm deep and sent to APAL for analysis.

Leaf Nutrient Analysis

Leaf samples were taken in mid-January 2021 just prior to the beginning of almond harvesting as requested by the orchards technical agronomist following correct leaf sampling techniques. 10 leaves from each tree per row were collected and the samples were then expressed posted to APAL for a full leaf nutrient analysis. See figure 3 for images of leaf collection. The results were then analysed using GraphPad Prism software to determine any significant differences in leaf nutrient concentrations between the treatments.

Figure 3: Images of leaf sampling. Leaves were taken from non-fruiting spurs at the 3rd leaf. Samples were sent to APAL for analysis.

Whole Nut weight, hull weight and hull nuts from nuts collected before harvest

Before commercial harvest, 10 nuts per tree (100 nuts per row) were collected from the trial blocks to get whole nut weights, hull weights and kernel weights. This was done to compare the out-turns calculated from nuts collected on the tree and also nuts collected at harvest from the ground. This data was also collected to compare weight between each component of the nut.

Nut collection at harvest for field weight (kg of nuts/tree)

Once the trees had been shaken and the nuts were on the ground, all the nuts from 16 trees (8 trees from the control and 8 trees from the Complete Blend 10® treatment) were raked into rows, sifted using a slatted shovel and then weighed. This provided data on the quantity (kg) of nuts per tree. Trees which have similar canopy densities were chosen to weight nuts from. Figure 5 shows the methods used to gather the field weight data. A small sample of approximately 500 grams of nuts were also collected from each tree to make final out-turn calculations.

Figure 4: Images of nuts collected from shaken trees. Nuts were sifted to remove leaves, sticks and dirt then weighed to provide kg of nuts/tree

Out-turn calculations

Out-turns are calculated to determine the percentage of kernel in a whole almond nut. The higher

the percentage, the heavier the kernels are. Out-turns are crucial to determine profits made on almond orchards. In this trial, out-turns were calculated from almond nuts collected prior to harvest and also during harvest. Out-turns are calculated using the following equation:

Out-Turn% = (Kernel Weight/Whole Nut Weight) x 100

Statistical analysis

Statistical analyses (t-test and multiple t-tests) were done using GraphPad Prism 9. Significant difference ($P<0.15$) between treatments was determined by comparing the replicate means. Error bars were also used on graphs.

5. Results

Figure 5: A photo taken of a control row before harvest which is adjacent to the Complete Blend 10® treated row.

Figure 6: A photo taken of almond trees treated with Complete Blend 10®.

Figure 7: Control almond tree in the Complete Blend 10® trial before harvest.

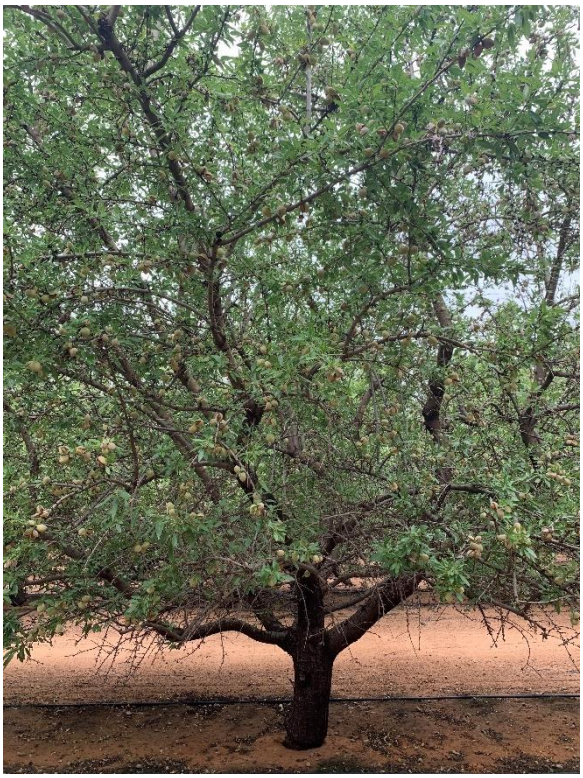

Figure 8: Almond tree treated with Complete Blend 10® before harvest.

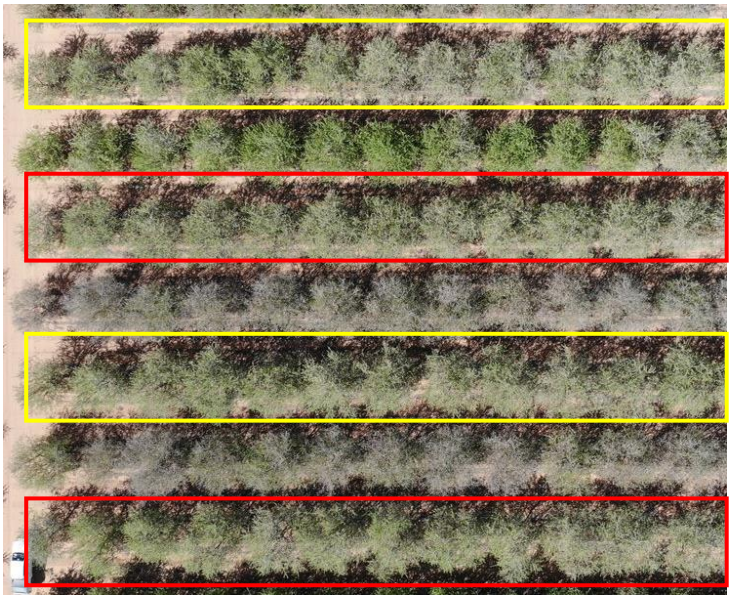

Figure 9: Drone image of one block treated with Complete Blend 10®. Rows with red rectangles were treated with Complete Blend 10® and rows with yellow rectangles were control rows.

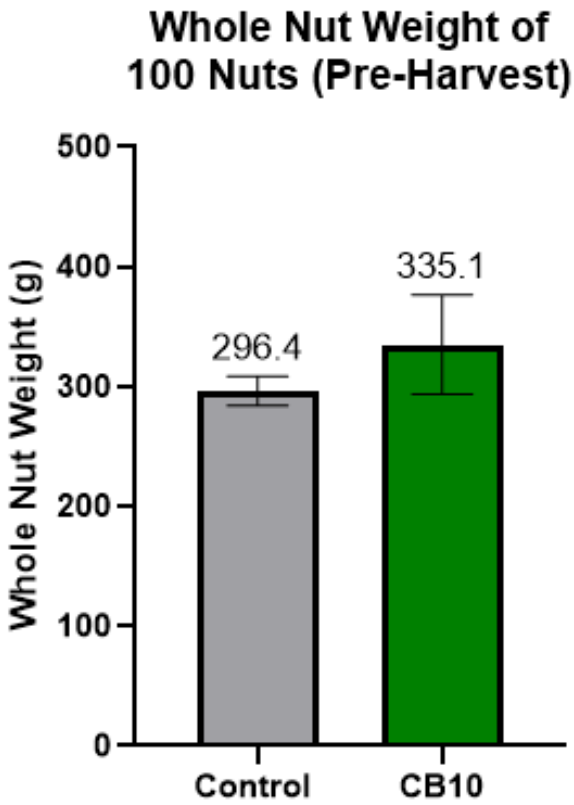

Figure 10: The average whole nut weight of 100 nuts collected from almond trees in the Complete Blend 10® trial. Nuts were picked randomly from trees. Significant difference (P<0.15).

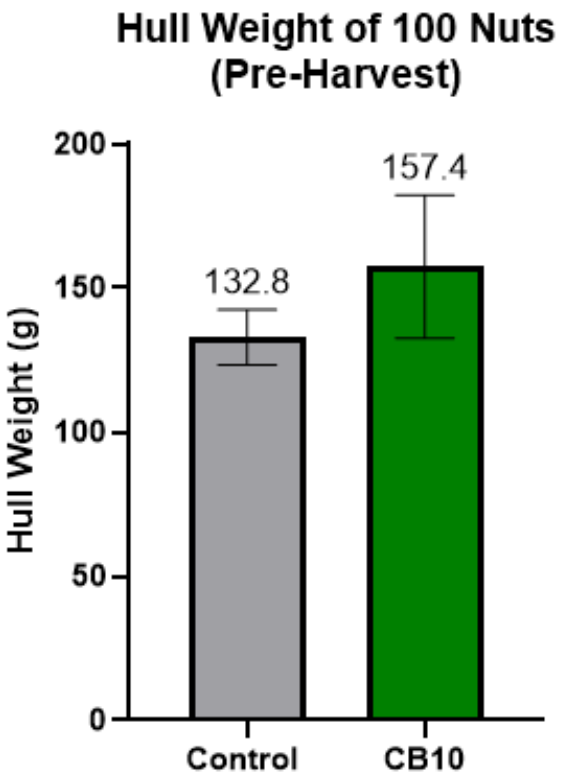

Figure 11: The average hull weight of 100 nuts collected from almond trees in the Complete Blend 10® trial. Nuts were picked randomly from the trees. Significant difference (P<0.15).

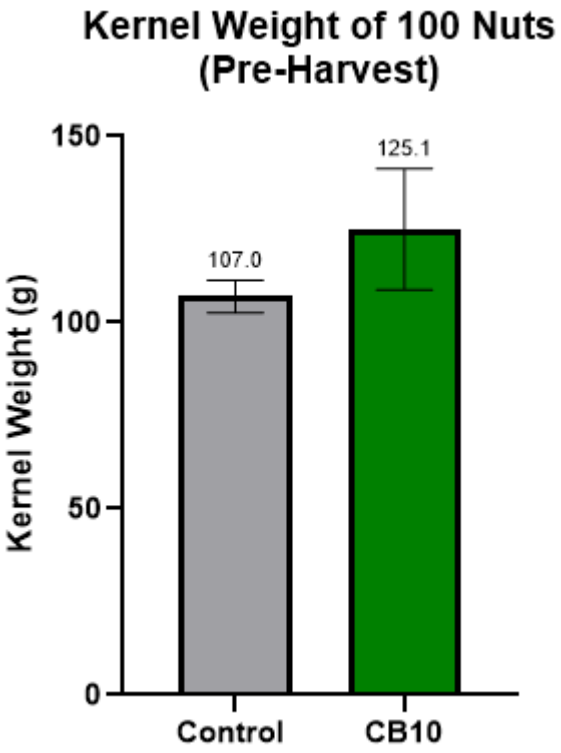

Figure 12: The average kernel weight of 100 nuts collected from almond trees in the Complete Blend 10® trial. Nuts were picked randomly from trees. Significant difference (P<0.15).

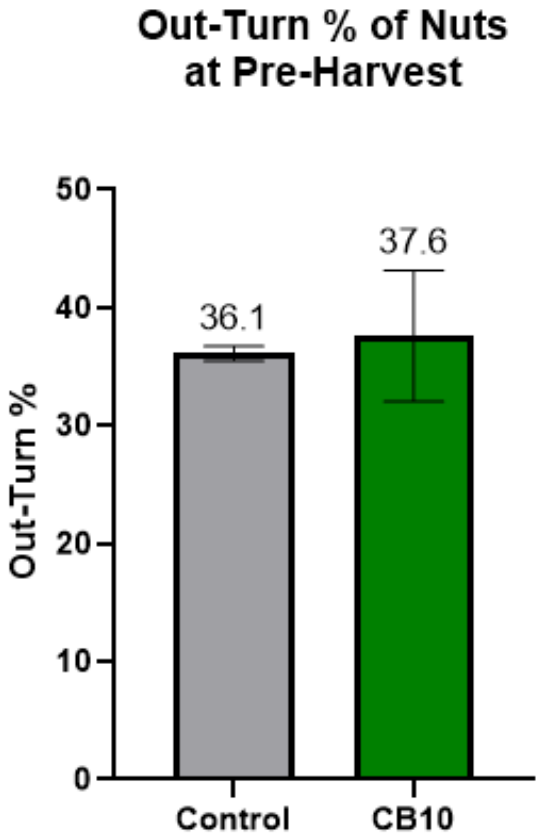

Figure 13: Out-turn % of nuts collected on the trees before harvest begins.

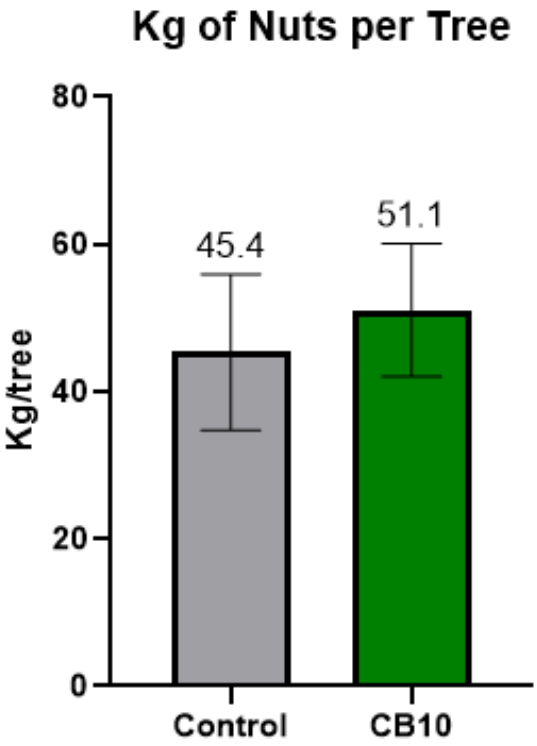

Figure 15: The average quantity of nuts per tree between Complete Blend 10® and control trees.

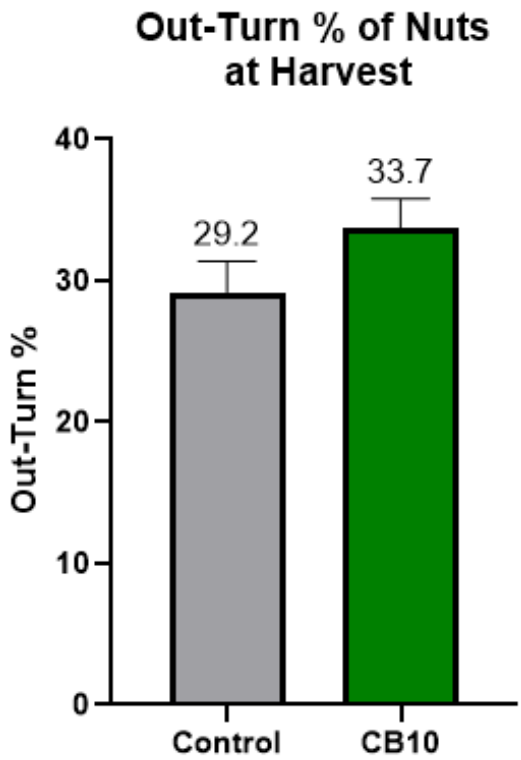

Figure 14: Out-turn % of almonds at harvest.
Significant difference (P<0.15).

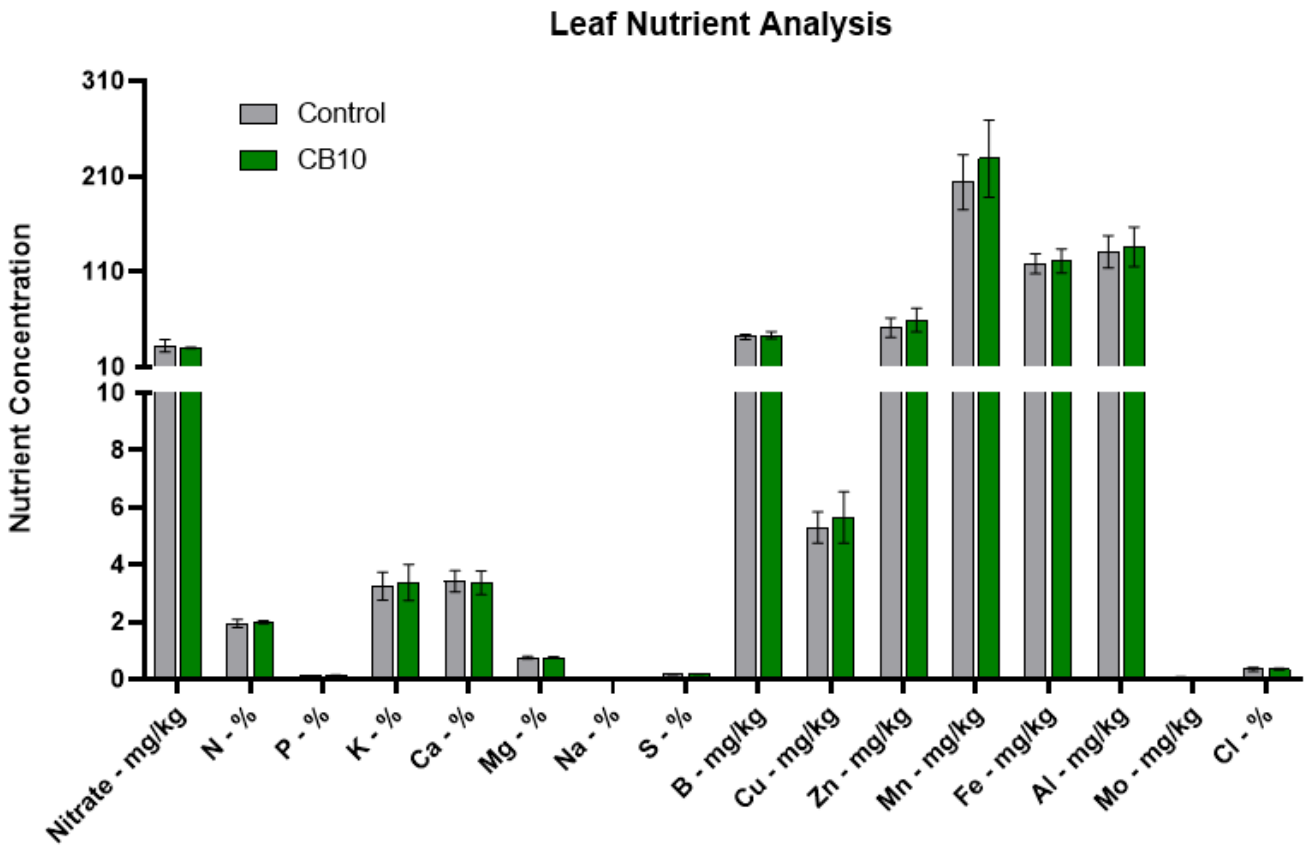

Figure 16: Leaf nutrient analysis of control almond trees and Complete Blend 10® treated almond trees. Leaf samples were taken in mid-January 2021 in accordance with correct leaf sampling times. Samples were analysed by APAL.

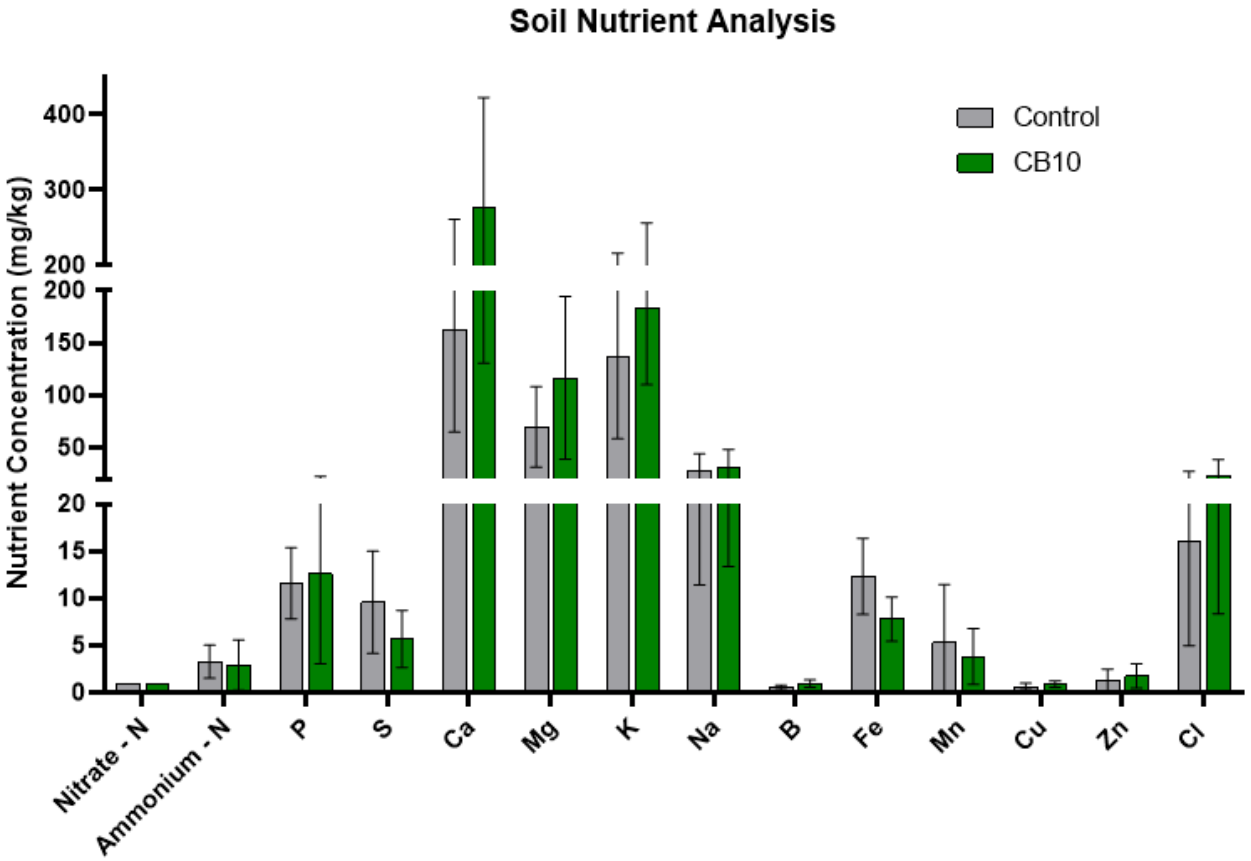

Figure 17: Soil nutrient analysis from control almond trees and Complete Blend 10® treated almond trees. Samples were analysed by APAL.

6. Discussion

Image Comparisons

Figure 5 to 9 show images taken between Complete Blend 10® treated trees and control trees. When comparing images of rows shown in figure 5 and 6, it can be seen that rows treated with Complete Blend 10® have increased vegetative growth in the lower portions of the canopy compared to the control trees. Overall, Complete Bend 10® trees have a more filled out appearance compared to the control trees and therefore these trees have a higher photosynthetic capacity due to more vegetative growth. This difference in vegetative growth can also be seen in figure 8 which shows more growth on the lower potions of the treated trees.

This increase in leaf production is a result of the macro and micro nutrients supplied to these trees through Complete Blend 10®. When analysing the leaf nutrient concentrations in figure 16, it can be seen that there was high concentrations of nitrogen, phosphorus, iron, magnesium and zinc. These elements all play crucial roles in leaf production and chlorophyll production (Silva and Uchida, 2000). With enhanced chlorophyll production, photosynthesis is increased and more sugars and carbohydrates are produced. This provides the trees with more energy to increase yields through more kernel filling (Sanchez-Bragado, Molero, Reynolds and Araus, 2016). There are also higher levels of copper, zinc, manganese, boron and potassium in the leaves of trees treated with Complete Blend 10® which all play roles in stress management. Since there are higher nutrient concentrations in Complete Blend 10® treated trees, there may have been a lesser degree of stress on the trees from nut development which can prevent loss of leaves displaying a fuller tree.

Pre-Harvest Analysis of Nuts

Figures 10 to 13 show multiple different analyses done on almonds collected from the trees before harvest. Whole nut weight, hull weight, kernel weight and out-turn % (pre-harvest) measurements and calculations were made to see if there were any differences in weight from nuts collected on the tree prior to harvest and nuts collected at harvest. These nuts were collected off the tree shortly before harvest to minimise any moisture differences.

100 nuts from each row were collected and measured and it was found that almond trees treated with Complete Blend 10® produced nuts which were 13.1% heavier than the control nuts (figure 10). This difference was statistically significant compared to the control and provides a high degree of confidence that a single application of Complete Blend 10® produces heavier almond nuts. Due to the 13.1% significant increase in whole nut weight, this trend was also followed through when analysing the hull, kernel and out-turn %. Figure 11 shows the hull weight comparison between the treated and control almonds. It was calculated that trees treated with Complete Blend 10® had a significant increase in hull weight of 18.5% compared to the control. Figure 12 shows the kernel weight comparison between the treated and control almonds. It was calculated that trees treated with Complete Blend 10® had a significant increase in kernel weight of 16.9% compared to the control. Figure 13 shows the out-turn % of nuts at pre-harvest between the two treatments and it was calculated that trees treated with Complete Blend 10® had a percentage increase of 4.2% in the out-turn percentage compared to the control. Since the kernel weights were higher in the treated trees compared to the control, the out-turn % was also higher. Having a higher out-turn % is extremely important as it relates directly back to return on investments.

The higher whole nut weight, hull weight and kernel weight seen in trees treated with Complete Blend 10® can be explained through the extra nutrients which Complete Blend 10® provides. Not only does Complete Blend 10® provide a boost in nutrition, it also contains the organic chelating agent BAOM. BAOM not only improves the uptake and translocation of nutrients within Complete Blend 10®, it can improve the uptake of other nutrients which are already present in the soil. The soil type that these almond trees were grown on was categorised as sand by APAL and therefore it is important to ensure that nutrients that are applied to

the soil are absorbed as quickly as possible to prevent the possibility of nutrients being leached past the rooting zone due to frequent irrigation. BAOM can improve this and reduce the leaching of nutrients making fertiliser applications more efficient.

Harvest Analysis of Nuts

Figures 14 and 15 both show the data collected from the almond trees at harvest time. Once the trees had been shaken, all the nuts from 18 trees were swept using a hand rake and each trees total kg's of nuts were weighed. Each tree had a small sample collected at harvest and out-turn % calculations were then done.

Figure 14 shows the out-turn percentages of the treated and control trees at harvest and it was calculated that control trees had an out-turn percentage of 29.2% and treated trees had an out-turn % of 33.7% which is a percentage increase on 15.4%. This increase in out-turn is statistically significant and suggests that trees treated with Complete Blend 10® produced kernels which made up a higher ratio of the whole nut weight compared to control trees.

Figure 15 shows the differences between the quantity of nuts per tree between the control and Complete Blend 10® treated trees. Complete Blend 10® trees on average had 12.6% more nuts per tree compared to the control trees.

The most required nutrients involved in improving almond nut yields are nitrogen, phosphorous, potassium, calcium, boron and zinc. These nutrients play roles in improving bud formation, energy transport, nut-fill, improving development of good quality nuts and maintaining new tissue development (Meriño-Gergichevich et al., 2021). Complete Blend 10® contains majority of these nutrients which are then utilised by the plant to promote these key plant processes.

Leaf and Soil Nutrient Analysis

Figures 16 and 17 show graphs of leaf and soil concentrations respectively. In the leaf nutrient analysis shown in figure 16, it was found that trees treated with Complete Blend 10® had higher levels of nitrogen, phosphorus, potassium, magnesium, sulphur, boron, copper, zinc, manganese and iron compared to the control.

In the soil nutrient analysis shown in figure 17, it was found that soil that was treated with Complete Blend 10® had higher concentrations of phosphorus, calcium, magnesium, potassium, boron (significantly higher), copper and zinc compared to the control.

These higher levels of nutrients in the leaf tissue and soil are a result of the extra nutrient provided by Complete Blend 10® and also the BAOM which acts as a natural chelating agent and improves the absorption and transportation of nutrients within the plant. This increase in nutrition observed in the trees treated with Complete Blend 10® correlates directly to the yield and out-turn increases highlighting the importance of providing essential nutrients to improve almond yields.

7. Conclusion

In conclusion this trial was conducted to evaluate how a single 30L/ha application of Complete Blend 10® shortly after flowering, effects plant nutrition and yields at harvest. Many parameters were considered and measured when coming to this conclusion including visual tree analyses, nut analyses before and after harvesting and also analysing out-turns between treated and control trees which relate directly to the orchards return on investment.

When studying the figures presented, it can be found that almond trees treated with Complete Blend 10® had the following results:

- Trees treated with Complete Blend 10® had a denser canopy and more leaves than then control trees.
- At pre-harvest, trees treated with Complete Blend 10® had higher whole nut weights, hull weights, kernel weights and out-turn % (pre-harvest) compared to the control which have percentage increases of 13.1% (significant), 18.5% (significant), 16.9% (significant) and 4.2% respectively.
- At harvest, trees treated with Complete Blend 10® produced higher out-turns compared to control

trees with a percentage increase of 15.4% (29.2% vs 33.7%).

- On average, trees treated with Complete Blend 10® had 12.6% more nuts per tree compared to the control.
- Leaves collected prior to harvest showed higher levels of nitrogen, phosphorus, potassium, magnesium, sulphur, boron, copper, zinc, manganese and iron in Complete Blend 10® treated trees compared to the control trees.
- Treated soil collected prior to harvest showed higher concentrations of phosphorus, calcium, magnesium, potassium, boron (significantly higher), copper and zinc compared to the control soil.

8. References

Kumar, S., Kumar, S. and Mohapatra, T., 2021. Interaction Between Macro- and Micro-Nutrients in Plants. *Frontiers in Plant Science*, 12.

Meriño-Gergichevich, C., Luengo-Escobar, A., Alarcón, D., Reyes-Díaz, M., Ondrasek, G., Morina, F. and Ogass, K., 2021. Combined Spraying of Boron and Zinc During Fruit Set and Premature Stage Improves Yield and Fruit Quality of European Hazelnut cv. Tonda di Giffoni. *Frontiers in Plant Science*, 12.

Sanchez-Bragado, R., Molero, G., Reynolds, M. and Araus, J., 2016. Photosynthetic contribution of the ear to grain filling in wheat: a comparison of different methodologies for evaluation. *Journal of Experimental Botany*, 67(9), pp.2787-2798.

Silva, J. and Uchida, R., 2000. *Plant nutrient management in Hawaii's soils*. Honolulu, Hawaii: College of Tropical Agriculture & Human Resources, University of Hawaii at Manoa, Chapter 3.

Appendix 1. Statistical Analysis of Results

Table 1: Analysis of yield parameters with reference to control and treated (Complete Blend 10®) almond trees. Values are given mean ± standard deviation. P value <0.15 was considered to be statistically significant

Parameter	Treatment		*P*-Value	Significance	% Change
	Control	Treated (Complete Blend 10®)			
Whole Nut Weight (g) (100 nuts) Pre-Harvest **Figure 10**	296.41 ± 12.35	335.13 ± 41.56	0.0536	Yes	13.1
Hull Weight (g) (100 Nuts) Pre-Harvest **Figure 11**	132.84 ± 9.63	157.39± 24.86	0.0477	Yes	18.5
Kernel Weight (g) (100 Nuts) Pre-Harvest **Figure 12**	107.03 ± 4.43	125.12 ± 16.29	0.0253	Yes	16.9
Out-turn % of Nuts Pre-Harvest **Figure 13**	36.12 ± 0.63	37.63 ± 5.57	0.524	No	4.2
Out-turn % of Nuts Harvest **Figure 14**	29.20± 2.19	33.72± 2.10	0.0105	Yes	15.4
Kg of Nuts per Tree (kg) Harvest **Figure 15**	45.36 ± 10.59	51.09± 9.04	0.263	No	12.6

Table 2: Analysis of different nutrient levels in the leaves with reference to Control and Treated (Complete Blend 10®). P value <0.15 was considered to be statistically significant.

Nutrient	Treatment (Mean)		*P* Value	Significance	% Change (Control to Treated)
	Control	Treated (Complete Blend 10®)			
Nitrate N (mg/kg)	32.38	30.25	0.388597	No	-6.56
Nitrogen (%)	1.944	1.989	0.408635	No	2.32
Phosphorus (%)	0.1238	0.1263	0.448270	No	2.02
Potassium (%)	3.251	3.380	0.653606	No	3.96
Calcium (%)	3.419	3.363	0.779797	No	-1.65
Magnesium (%)	0.7488	0.7538	0.807371	No	0.67
Sodium (%)	0.01000	0.008750	0.334282	No	-0.73
Sulphur (%)	0.1663	0.1738	0.204088	No	4.51
Boron (mg/kg)	42.00	43.50	0.365430	No	3.57
Copper (mg/kg)	5.300	5.650	0.361840	No	6.60
Zinc (mg/kg)	51.38	59.50	0.174657	No	15.82
Manganese (mg/kg)	203.8	228.8	0.176525	No	12.27
Iron (mg/kg)	118.5	121.3	0.640026	No	2.32
Aluminium (mg/kg)	131.0	136.3	0.587378	No	4.01
Molybdenum (mg/kg)	0.05875	0.05375	0.464448	No	-9.55
Chloride (%)	0.3450	0.3413	0.892893	No	-1.09

Table 3: Analysis of different soil nutrient levels and properties in the Complete Blend 10® trial. P value <0.15 was considered to be statistically significant.

Nutrient	Treatment (Mean)		*P* Value	Significance	% Change (Control to Treated)
	Control	Treated (Complete Blend 10®)			
pH 1:5 Water	5.954	6.768	0.010289	Yes	13.67
pH CaCl2	4.758	5.708	0.015505	Yes	19.97
Organic C (%)	0.2060	0.2480	0.431419	No	20.39
Nitrate – N (mg/kg)	1.000	1.000	N/A	N/A	0.00
Ammonium – N (mg/kg)	3.280	2.900	0.797429	No	-11.59
Colwell P (mg/kg)	11.60	12.60	0.833190	No	8.62
Sulphur (mg/kg)	9.560	5.680	0.200029	No	-40.59
Calcium (mg/kg)	163.0	276.6	0.187044	No	69.69
Magnesium (mg/kg)	69.80	116.6	0.262504	No	67.05
Potassium (mg/kg)	137.2	183.2	0.367371	No	33.53
Sodium (mg/kg)	27.74	30.82	0.780552	No	11.10
Boron (mg/kg)	0.5320	0.9500	0.092388	Yes	78.57
Iron (mg/kg)	12.32	7.780	0.060999	Yes	-36.85
Manganese (mg/kg)	5.300	3.820	0.641567	No	-27.92
Copper (mg/kg)	0.6420	0.8620	0.339710	No	34.27
Zinc (mg/kg)	1.282	1.746	0.571703	No	36.19
Ca:Mg ratio	1.560	1.560	>0.999999	No	0.00
K:Mg Ratio	0.7260	0.5540	0.421688	No	-23.69
ECEC (cmol/kg)	2.110	2.942	0.329582	No	39.43
Chloride (mg/kg)	16.00	23.40	0.400824	No	46.25
Salinity EC 1:5 (dS/m)	0.04600	0.05400	0.534592	N/A	12.08
(Ece dS/m)	1.114	1.230	0.693425	No	10.41
Clay %	3.920	3.380	0.803685	No	-13.78
Sand (+20 micron) %	92.80	94.80	0.464497	No	2.16
Silt (2-20 micron) %	3.340	2.120	0.057509	Yes	-36.53