Evaluation of the Efficiency of Transit Silicate to Improve Pest Resistance and Yield of Almonds

Dual Chelate Fertilizer Pty Ltd.
PO Box 963, 162 New Guinea Road Robinvale VIC 3549, Australia
Correspondence:
info@dualchelate.com

Silicon (Si), although a micro element, is one of agriculture's key plant nutrients due to its beneficial effects on plants with research specifically being conducted in the benefits of Silicon is managing and assisting in the tolerance of both biotic and abiotic stresses. Along with management in stress conditions, Si has also been proven to promote greater yields at a greater quality as a result of increased stress tolerance and increased beneficial plant physiology. Transit Silicate® was applied to selected trees and on average produced heavier almond whole nuts (weight from nuts collected off the ground and off trees), dried kernel weights and decreased the number of aborted nuts, gummed nuts and nuts effected by pests (Carob moth and Carpophilus beetle).

Key words: Silicon, almonds, abiotic and biotic tolerance, yields, Carob moth, Carpophilus beetle

Introduction

Silicon (Si) is the second most abundant element in the Earth's crust, however it is rare to see plants accumulate enough silicon for it to become beneficial in terms on biotic and abiotic pest tolerance. This is why Si fertilisation in agricultural crops has raised much attention and is now being explored as a suitable addition for integrated pest management. Plant available Si is limited in most soils as the silicon/silicate is most commonly found naturally in the solid phase contained in crystalline structures where chemical weathering is needed in order to break down the solid phase into an absorbable or liquid phase which produces monosilicic and polysilicic acids. These silicic acids are plant available and hence absorbable by plants roots. However, this chemical weathering process can be slow as the source of dissolved Si is produced through biochemical reactions by microbes in the soil. Therefore, it is important to apply supplemental sources of Si which are plant available through soil applied fertiliser.

Dual Chelate Fertilizer had developed a Silicon based fertigated fertiliser known as Transit Silicate®. Transit Silicate® contains 33% potassium silicate which is available for microbes to convert into silicic acid. This formulation also contains amino acids (7%) and Biologically Activate Organic Molecules (BAOM) (1.5%). These added amino acids and BAOM both assist in the translocation of the silicic acid through the plant to the cell walls where structure is increased resulting in a natural abiotic and biotic resistance. The amino acids also assist in the uptake of the silicon through the roots as the amino acids act as a chelating agent. This increases the effectiveness of Transit Silicate®. Apart from the silicon, Potassium (K) is also a key macro element which makes up Transit Silicate®. Potassium assists in plant growth by regulating the movement of water, nutrients and carbohydrates. These regulatory processes all play positive roles in assisting in increasing yields and overall tree growth. This study aims to evaluate the efficiency of soil applied Transit Silicate® at nut development stages and assess overall nut parameters such as whole weight, hull weight and kernel weight along with an average kernel damage from biotic and abiotic stresses.

Objectives

1. Evaluate the effect of fertigation with Transit Silicate® on improving nutrient status of almonds.
2. Evaluate the effect of fertigation with Transit Silicate® on the yield parameters of almonds: nut weight, hull weight and kernel weight.
3. Evaluate the effect of Transit Silicate® on improving nut quality by looking at damage caused through Carpophilus beetle, Carob moth and aborted nuts.

Materials and Methods

Site Selection and Trial design

This trial was conducted in an Almond orchard within the Sunraysia region of Victoria. The block selected in the orchard had severe pest pressure in the past making it a suitable area for this trial. The trial was conducted in 2 separate areas of the block with a total of 5 replicates of control and treated rows. Commercial Fertigation of Transit Silicate was applied across the block twice during plant development, once during the nut development stage and once during the nut maturing stage. Trees on the control rows had isolation taps on the drip line which prevented Transit Silicate from reaching 10 trees in each control row. Ten trees from each of the control rows were isolated from the drip tapes, and were considered the control trees. Ten trees from the adjacent rows were considered as the treatment trees.

Treatment and application rate

Table 1: Table 1: Treatment rates of Transit Silicate applied to almond trees and the trial design used.

Treatment	Rate L/ha	Application timing
Control	0	
Transit Silicate	30 L/ha	Nut developing stage (14th October) Nut maturing stage (18th November)

Observations
Leaf nutrient analysis

After the final application of Transit Silicate in mid November, twenty leaves per plant were collected from each tree in both the control and treatment rows. These leaves were washed and analysed at Analytical Laboratories and Technical Services Australia (ALTSA), Victoria for the presence of the listed elements: Nitrogen (N), Posphorus (P), Potassium (K), Sulfur (S), Calcium (Ca), Magnesium (Mg), Sodium (Na), Alminium (Al), Boron (B), Copper (Cu), Iron (Fe), Magnanese (Mn), Zinc (Zn), Silicon (Si) and Molybdenum (Mo).

Kernel Weight, Hull weight and Nut Weight.

Before commercial harvest, 20 nuts per tree were collected to get whole nut weights, hull weights and kernel weights. These kernels and hulls were sent to ALTSA for a nutrient analysis.

During harvest when the trial trees had been shaken, a 1 metre transect of whole nuts was collected from the ground between the 5th and 6th trees in each row. Whole nut weights and average out-turn percentages were recorded.

Statistical Analysis

A statistical analysis (T-test) was done using Prism 7 (Graph Pad Software). Significant difference ($P<0.15$) between the treatments was determined by comparing the replicate means. Graphs with error bars were also created using Prism 7.

Results

Figure 1: A photo taken of almond trees treated with Transit Silicate (treatment) before shaking.

Figure 2: A photo taken of control almond trees before shaking.

Figure 3: Almond branch from a tree treated with Transit Silicate.

Figure 4: Control almond tree branch in the Transit Silicate trial.

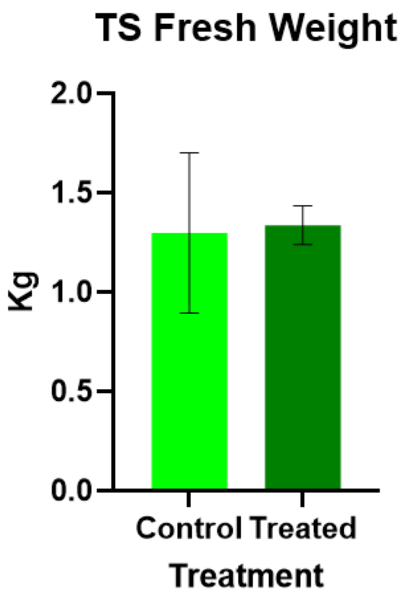

Figure 5: The average fresh weight of almonds collected from almond trees in the Transit Silicate trial (P<0.15).

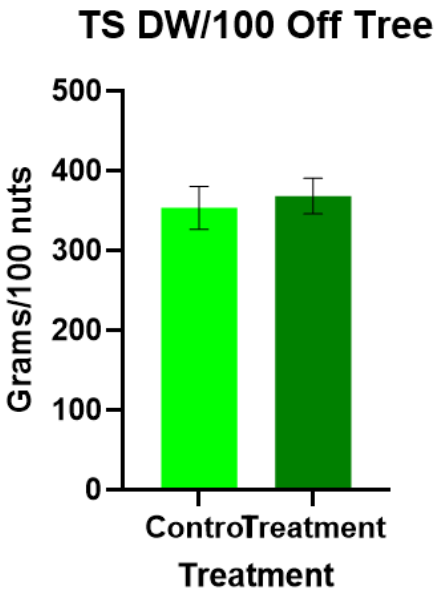

Figure 6: The average dry whole weight of 100 nuts collected from almond trees in the Transit Silicate trial. (P<0.15)

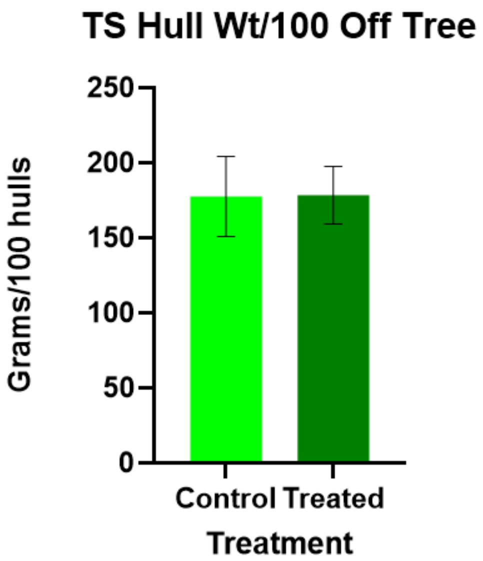

Figure 7: The average hull weight of 100 nuts collected from almond trees in the Transit Silicate trial. (P<0.15)

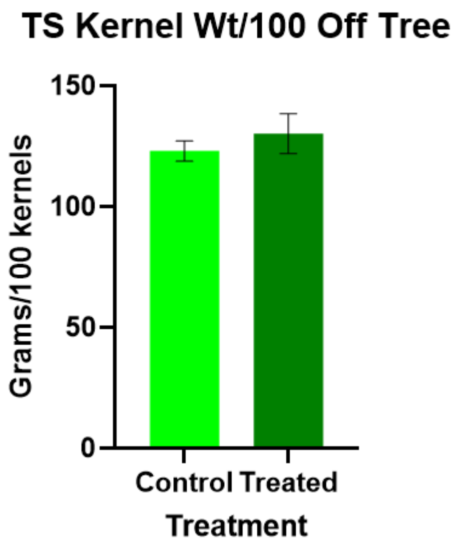

Figure 8: The average kernel weight of 100 nuts collected from almond trees in the Transit Silicate trial. (P<0.15)

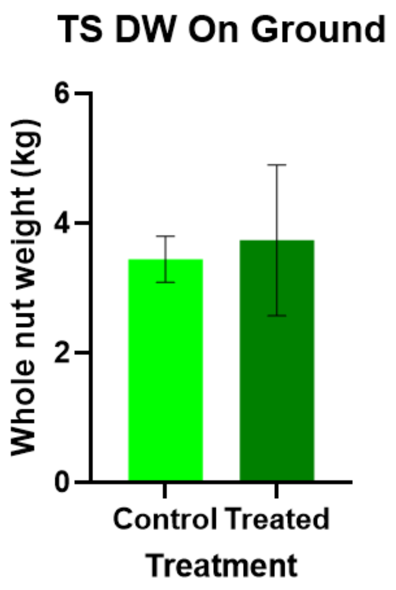

Figure 9: The average whole nut weight of nuts collected off the ground in a 1 meter transect. Nuts collected from almond trees in the Transit Silicate trial after shaking. (P<0.15)

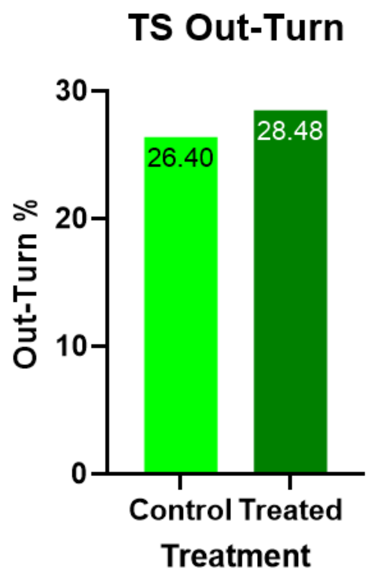

Figure 10: The out-turn percentage of the control and treated almonds collected from the ground after shaking in the Transit Silicate trial.

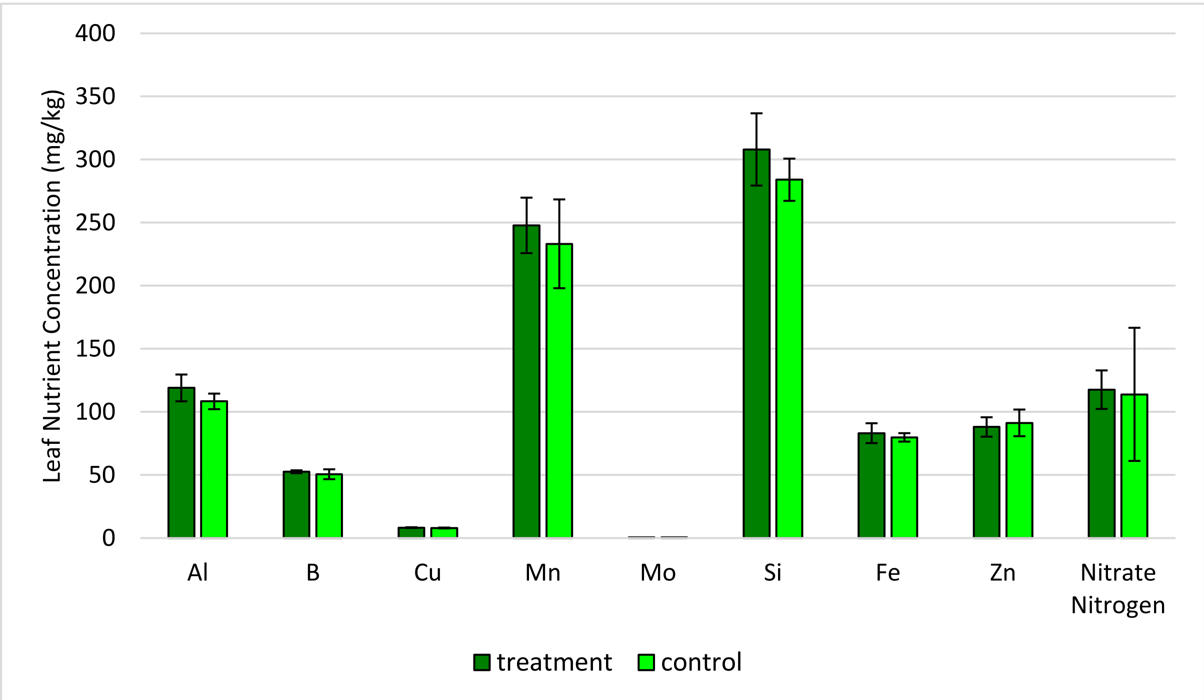

Figure 11: Leaf nutrient concentrations of almond leaves in the Transit Silicate trial. Measurements are taken in mg/kg. A t-test was performed to determine the significant difference between the control vs treated, different superscripts show significant difference (P<0.15). The t-test was performed with Prism 7 (Graph Pad Software).

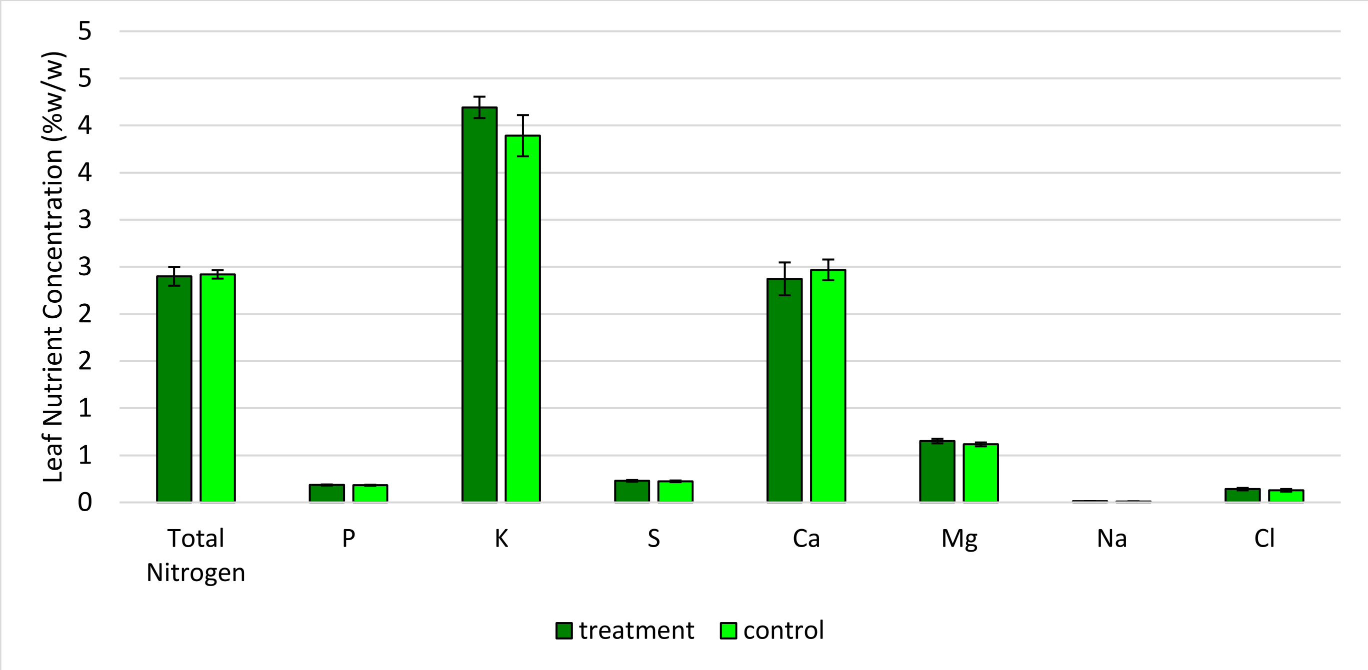

Figure 12: Leaf nutrient concentrations of almond leaves in the Transit Silicate trial. Measurements are taken in %w/w. A t-test was performed to determine the significant difference between the control vs treated, different superscripts show significant difference (P<0.15). The t-test was performed with Prism 7 (Graph Pad Software).

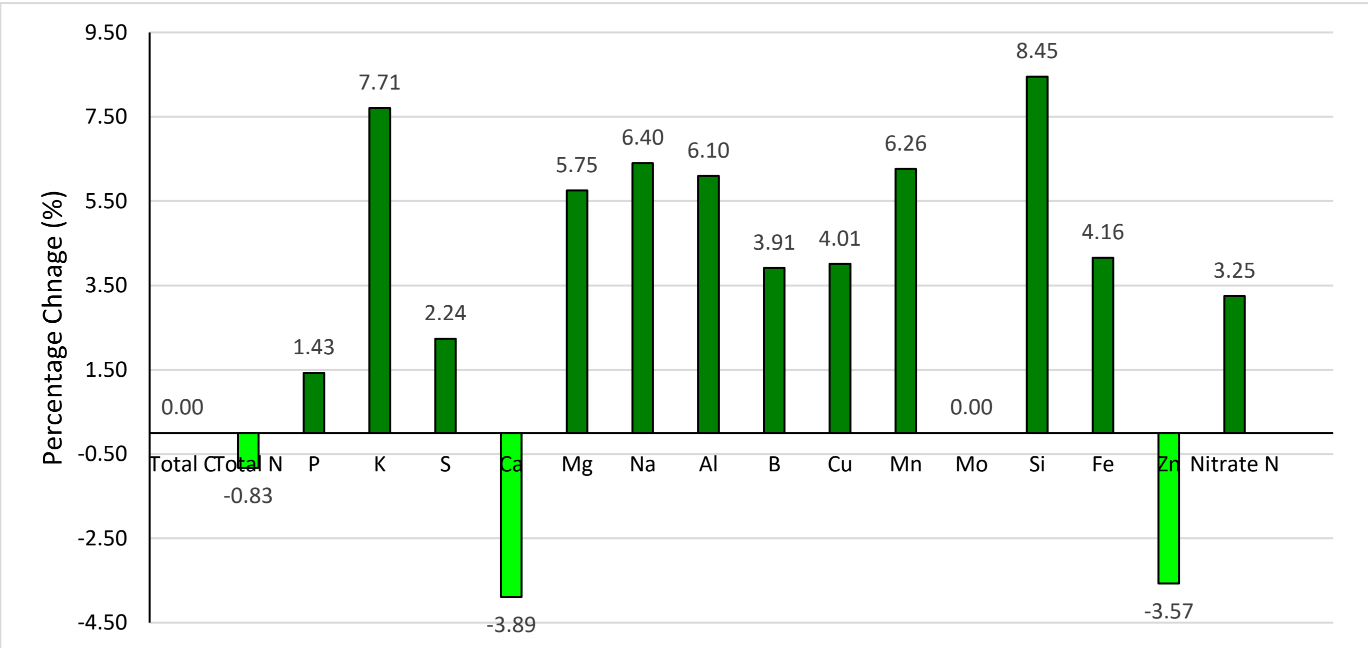

Figure 13: The percentage change of nutrient concentrations measured in the leaves collected from treated and control rows in the Transit Silicate trial. Values with a positive percentage change indicate that nutrient levels were higher in Transit Silicate treated plants. Values with a negative percentage change indicate that nutrient levels were higher in control plants.

Table 2: 300 treated Transit Silicate nuts and 300 control nuts were randomly selected to analyse for defects including aborted nuts, kernel gumming and Carpophilus beetle and Carob moth.

	Aborted Kernels	**Kernel Gumming**	**Pest Damage** (Carob Moth, Carpophilus Beetle)
Control			
Treated			

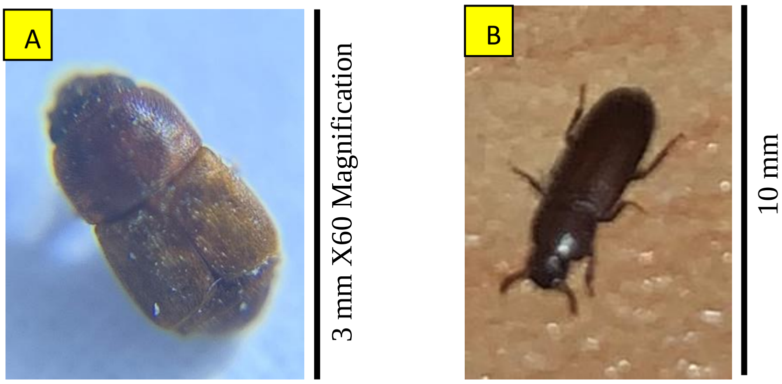

Figure 14: Images captured on pests found in the control almond kernels. Carpophilus beetle (A) and Red Flour beetle (B). Images captured by Alice Kirk, Dual Chelate Fertilizer.

Figure 15: Visual comparison of randomly selected almond kernels from the Transit Silicate trial.

Discussion

The physical appearance and nut development of the control and treated trees is compared in figures 1-4. When looking at the overall tree growth and development in figure 1 and 2, the Transit Silicate treated trees (figure 1) had a slightly more foliage in the lower portion of the canopy in comparison to the control trees (figure 2). However, all of the Nonpareil trees in this block all had low amounts of vegetative growth on the lower portions of the tree canopy.

Figures 3 and 4 also showed the nut development on the lower branches of the treated (figure 3) and control (figure 4) trees. When comparing these images, there were more nuts located on the lower portions of the trees treated with Transit Silicate in contrast to the control trees. Again, majority of the Nonpareil trees in this block non not have a large number of nuts on the lower portions of the trees. However, it should be noted that when collecting nuts and leaves for analysis, it was more difficult collecting nuts from the control trees in comparison to the treated trees. The slight increase in vegetative growth and nut development observed in the Transit Silicate treated trees can be explained through the addition of Amino Acids and Biologically Active Organic Molecules (BAOM) which make up 7% and 1.5% of the formulation of Transit Silicate respectively. Amino Acids and BAOM assist in the uptake, transportation and translocation of nutrients in the soil and in the plants through biologically chelating elements. Figure 13 shows that in almond trees treated with Transit Silicate, there were higher concentrations of P, K S, Mg, Na, Al, B, Cu, Mn, Si, Fe, Nitrate N and Cl in the leaves. Again, these increases in nutrient concentrations is a result of the biological chelation through Amino Acids and BAOM.

Figures 5-10 show the different almond parameters researched. Although there are no significant differences in the fresh weight, dry weight and hull weight, there was a statistically significant difference between the treated and control kernel weights represented in figure 8. Almond trees treated with Transit Silicate had a percentage increase of 6% in kernel weight in comparison to the control trees. This increase in kernel weight is also correlated to the increase in the whole nut dry weights shown in figure 6. Almond trees treated with Transit Silicate had a 4% increase in the dry weight of almonds harvested off the trees before harvest in comparison to the control. Although this is not statistically different, it is still an important difference to note.

During harvest, once the nuts were shaken and swept on the ground, a 1 meter transect of nuts was collected between the 5th and 6th tree out of the 10 trees observed for each treatment and replicate. The results are shown in figure 9 where there was an 8% increase in the weight of whole nuts from trees treated with Transit Silicate.

Transit Silicate contains 33% potassium silicate in its formulation. Silicon (Si) plays a role in maintaining plant health when exposed to biotic and abiotic stresses. Therefore, 300 randomly selected nuts from the control and treated almond trees where carefully examined for pest damage and other defects such as aborted kernels. The results are highlighted in table 2 and clearly show that out of 300 nuts, almond trees treated with Transit Silicate had less defects in comparison to the control, especially in terms of the number of aborted nuts. Treated trees had 3 aborted kernels where as control trees had 8 which is a significant increase. In terms of kernel gumming, 3 nuts were found with the defect in the control trees and 2 in the treated trees. When examining for pest damage caused by Carob moth and Carpophilus beetle, 6 kernels were damaged in the control trees were as 5 were damaged in the treated trees. Further investigation was taken to see what pest caused the damage. Out of the 6 pest effected kernels in the control treatment, 4 nuts were affected by Carob moth and 2 nuts were affected by Carpophilus beetle. In the treated kernels, 2 nuts were affected by Carob Moth and 3 kernels were affected by Carpophilus beetle. Figure 14 shows images of a Carpophilus beetle (A) and a Red Flour beetle (B) found in the control kernels.

Out of the 3 defects analysed (kernel abortion, kernel gumming and pest damage), the almond trees treated with Transit Silicate resulted in less defects overall in comparison to the control nuts. This can be explained by the beneficial role silicon plays in plant health. In abiotic stress (salinity, drought, thermal and heavy metal stresses), reactive oxygen species (ROS) are produced as a reaction to the stress. These ROS can heavily impact normal cell function and cause the death of cells. Through supplementation of Si, increased antioxidant defences are increased which prevents cell death. This is done through upregulation of silicon transporters and expression of proteins linked to photosynthesis, ribosomes, oxido-reduction, hormone signalling, metal ion binding, and defence responses. Silicon has also been found to play key factors in stomatal development which has key roles is photosynthesis and transpiration regulation which also assists in easing abiotic stresses such as drought or heat stress.

When analysing the benefits silicon has on biotic stresses such as pests and diseases, silicon has been found to accumulate in cell walls which can prevent damage by pests and diseases. Silicon has also been found to affect the host-pathogen interaction which prevents further damage to plants by stopping effectors and signalling molecules produced by the pest.

Conclusion

In conclusion, this trial was conducted to assess the efficiency of Transit Silicate to improve pest resistance and yield in almonds. The results gathered from this trial demonstrated that through applications of Transit Silicate at key kernel and nut development stages can increase the weight of kernels as well as increasing the out-turn whilst also reducing biotic and abiotic stress defects.

When studying the figures presented, it can be found that almond trees treated with Transit Silicate showed the following improvements:

- More vegetative growth in the lower portions of the canopy along with more nuts available for picking on the lower portions of the Transit Silicate treated trees.
- Out-turn of almond production had a percentage increase of 8% in almond trees treated with Transit Silicate in comparison to the control trees.
- Less biotic and abiotic stress defects. Noticeably lower number of aborted kernels in trees treated with Transit Silicate in comparison to the control trees.
- Less defects caused by kernel gumming and pest damage in trees treated with transit silicate.
- Approximately 70% of the elements tested for in the leaf nutrient concentration analysis

showed high levels in trees treated with Transit Silicate, especially in the elements: potassium and silicon.

- Significant difference in the kernel weights between the treated and control trees. Treated trees had a percentage increase of 6% in kernel weight in comparison to the control.

Key findings

Key Findings	Description
Increased lower canopy vegetation growth in treated trees.	Trees treated with Transit Silicate had more vegetative growth in the lower portions of the canopy in comparison to the control trees (figure 1 and 2).
Treated trees displayed more clusters of nuts in comparison to the control trees.	Trees treated with Transit Silicate had more bunches of nuts on the lower portion of the canopy compared to the control trees which had more sporadic nuts (figure 3 and 4).
8% percentage increase in **dry weight** of whole nuts collected at harvest.	When colleting nuts from the ground at harvest, trees treated with Transit Silicate produced more nuts in a 1 meter transect than control trees (figure 9).
6% percentage increase in **kernel weight** of nuts collected from treated trees.	When measuring kernel weight, there was a 6% increase in the weight of kernels collected from trees treated with Transit Silicate compared to the control trees (figure 8).
Transit Silicate treated trees had an out-turn of **28.48%** and **control** trees had an out-turn of **26.40%.**	When comparing the out-turn differences between the treated and control trees in the Transit Silicate trial, the treated trees resulted in a higher out-turn. This is because there was an increase in kernel weight displayed in trees treated with Transit Silicate.
Treated trees had **significantly** higher levels of **Silicon** and **Potassium** in their leaves	Trees treated with Transit Silicate had significantly higher concentration levels of Silicon and Potassium in their leaves which directly relates to the Potassium Silicate used in Transit Silicate (figures 11 and 12).
All elements besides Total Nitrogen, Calcium and Zinc where higher in leaves treated with Transit Silicate.	Trees treated with Transit Silicate produced leaves which had higher levels of all macro and micro elements except Total Nitrogen, Calcium and Zinc (figure 13).
Treated trees had **significantly less aborted kernels** than control trees.	Overall, trees treated with Transit Silicate had significantly less kernel abortion, less kernel gumming and reduced damage from pests. Pest damage seen in treated kernels was not as severe as the control (table 2).
Treated trees had **less damage** from **kernel gumming** and **pests** (Carpophilus beetle and Carob moth).	
Trees treated with Transit Silicate produced **larger kernels with more bulk density**.	Treated trees produced kernels which were larger and heavier than control kernels. Control kernels were shorter and rounder (figure 15).

Appendix 1. Statistical Analysis of Results

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

Parameter	Treatment		*P*-Value	Significance	% increase
	Control	Transit Silicate			
Fresh Whole Nut Weight (kg) **Figure 5**	1.298 ± 0.40	1.336 ± 0.098	0.843	No	2.93
Dry Whole Nut Weight (g) (100 Nuts) **Figure 6**	353.4 ± 26.74	368.2 ± 22.37	0.370	No	4.19
Hull Weight (g) (100 Nuts) **Figure 7**	177.6 ± 26.62	178.4 ± 19.22	0.958	No	0.45
Kernel Weight (g) (100 nuts) **Figure 8**	123.0 ± 4.24	130.2 ± 8.29	0.122	Yes	5.85
Whole Nut weight - 1m transect (kg) **Figure 9**	3.444 ± 0.35	3.736 ± 1.16	0.606	No	8.48

Table 2: Analysis of different nutrient levels in the leaves with reference to Control and Transit Silicate. P value <0.15 was considered to be statistically significant.

Nutrient	**Treatment (Mean)**		***P* Value**	**Significance**	**% increase**
	Control	**Transit Silicate**			
Total Carbon (%w/w)	41.8	41.8	N/A	N/A	0.00
Total Nitrogen (%w/w)	2.42	2.40	0.694	No	-0.83
Phosphorus (%w/w)	0.182	0.185	0.494	No	1.43
Potassium (%w/w)	3.89	4.19	0.0262	Yes	7.71
Sulphur (%w/w)	0.224	0.229	0.411	No	2.24
Calcium (%w/w)	2.47	2.37	0.327	No	-3.89
Magnesium (%w/w)	0.616	0.651	0.0381	Yes	5.75
Sodium (%w/w)	0.0100	0.0106	0.141	Yes	6.40
Aluminium (PPM)	105	111	0.277	No	6.10
Boron (PPM)	50.6	52.6	0.307	No	3.91
Copper (PPM)	7.98	8.30	0.159	No	4.01
Manganese (PPM)	233	248	0.454	No	6.26
Molybdenum (PPM)	0.500	0.500	N/A	N/A	0.00
Silicon (PPM)	284	308	0.144	Yes	8.45
Iron (PPM)	79.8	83.1	0.411	No	4.16
Zinc (PPM)	91.3	88.0	0.593	No	-3.57
Nitrate N (PPM)	114	118	0.884	No	3.25
Chloride (%w/w)	0.128	0.141	0.174	No	10.00