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Ref. No.

The effect of Prosol Agrigrow (water additive) on the growth of avocado trees in the nursery

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Aim: To determine the effect of Prosol Agrigrow on the growth of avocado trees in the nursery

Materials and Methods

The current study was carried out at the Schagen Nursery of the Fruit Farm Group approximately 20 km west of Nelspruit (Mbombela) in Mpumalanga. This nursery is situated in one of the major avocado cultivation areas in the country. The planting material used for this study was 'Hass' avocado trees grafted on clonal 'Bounty' rootstocks. The trees were planted in 7 liter black plastic bags in a composted pine bark growth medium. This medium was tested prior to planting to be free of diseases. The study consisted of two experiments.

The first experiment was carried out over a four-month period during 2019. This experiment was laid out in a randomized pseudo-block design, with two treatments, consisting of ten replicates per treatment and six data trees per replicate. The treatments were a Prosol Agrigrow water additive treatment and an untreated control. The treated trees were hand watered with Prosol Agrigrow two times a week. A dilution ratio of 1:10 000 (Prosol Agrigrow: water) was used. Untreated trees were watered with clean water.

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Both treatments also received standard nursery fertilizer applications. After five months of application, the following data was collected: tree height, stem diameter, internode length, leaf size and area, leaf, stem and root dry mass, tree nutrient levels and nutrient levels of the growth medium. For tree and growth medium nutrient levels, the leaf, stem and root material and the medium were first digested. Levels of all nutrients, except nitrogen, phosphorus and boron were determined using atomic absorption spectrometry. Levels of nitrogen, phosphorus and boron were determined colorimetrically.

The second experiment was also carried out over a four month period, but during early 2020. For this experiment, the Prosol Agrigrow solution was at a dilution ratio of 1:100 000 and therefore ten times more diluted than for the first experiment. As for the first experiment, treated trees were hand watered with the Prosol Agrigrow solution twice a week, while untreated trees were watered with clean water. The experimental design for the second experiment was a randomized block design with ten replicates per treatment and 20 trees per replicate. The same data was collected than for the first experiment with the exception of internode length. An additional measurement was carried out half-way through the second experiment where tree height was accessed.

All data was analyzed using GenStat (version 14, 2010) statistical software, with the two treatments being compared using analysis of variance. Treatments were regarded as statistically significantly different when $P < 0.05$.

Results and Discussion

Experiment 1

It was clearly evident that the Prosol Agrigrow significantly improved the vigour of nursery avocado trees (Figure 1). It can be seen in Figure 1 that the treated trees were substantially taller and had larger leaves. In this instance, the application of Prosol Agrigrow at a ratio of 1:10 000 resulted in a 40% increase in tree height (Figure 2 A). Trees were not only taller, but had thicker stems as well, in which case the Prosol Agrigrow

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resulted in a 26% increase in stem diameter (Figure 2 B). Although the treated trees were taller, internode length was not significantly affected by the treatment (Figure 2 C), but treated trees had significantly more nodes (P = 0.01) and therefore significantly more leaves than the untreated trees. The mean number of leaves for the treated trees were 14 leaves per tree, while being 10 leaves for the untreated trees. As a result of the more vigorous growth of the treated trees, stem dry matter content was increased by 71% when compared to the untreated trees (Figure 2 D).

Figure 1: Visual effect of Prosol Agrigrow on the growth of nursery avocado trees (treated trees left and untreated trees right)

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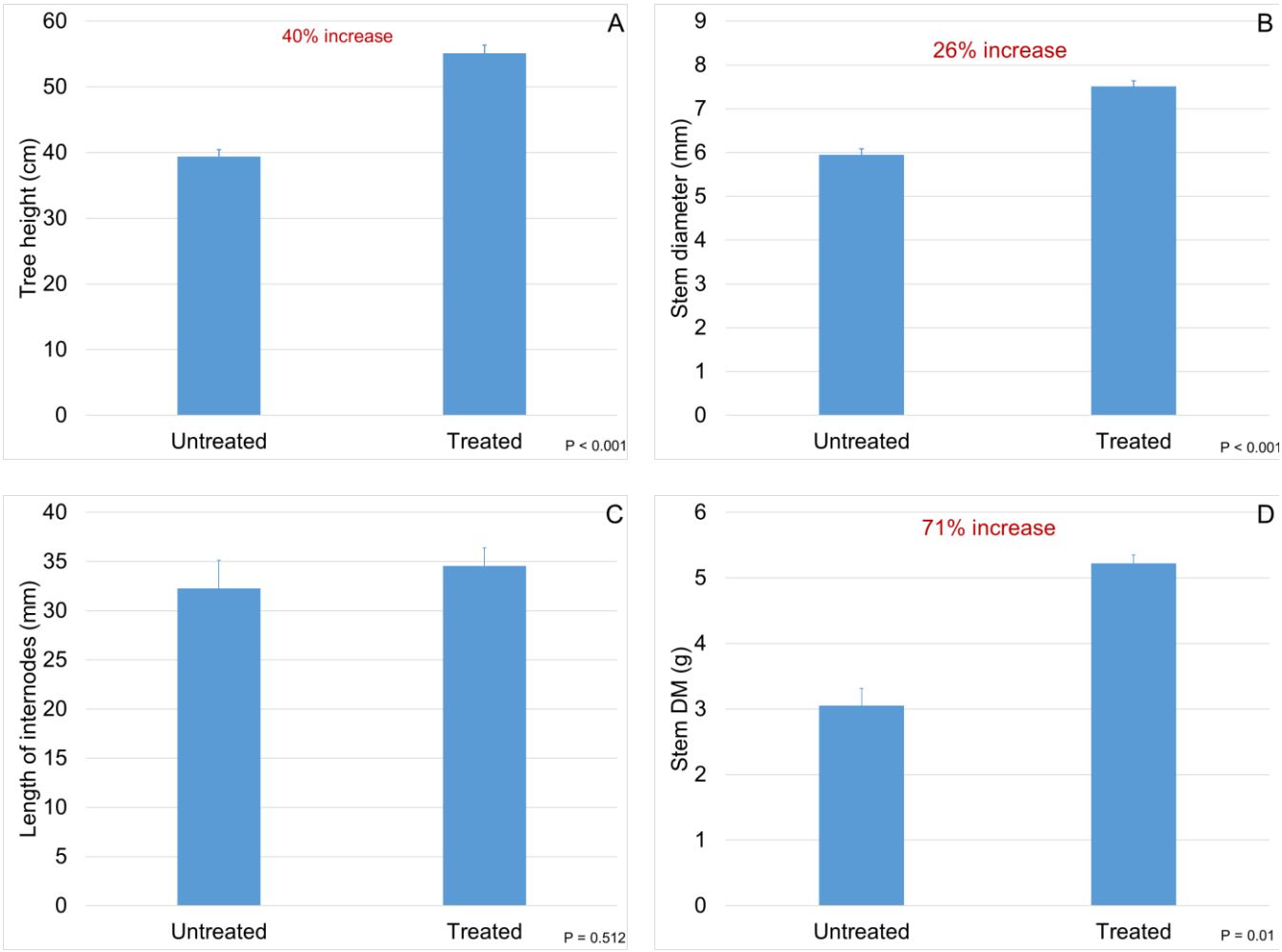

Figure 2: The effect of Prosol Agrigrow on the growth of avocado nursery trees, with A) tree height, B) stem diameter, C) internode length, and D) stem dry mass

As seen in Figure 1, the application of Prosol Agrigrow had a significant effect on leaf growth of avocado nursery trees. Both the length and the width of the leaves of the nursery trees were increased by 42 and 35% respectively (Figure 3 A and B). As a result of that leaf area was increased with 89% (Figure 3 C). The larger leaves resulted in a dry matter

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content increase of approximately 146% (Figure 3 D). Due to the larger leaf area and higher number of leaves per tree of the treated trees, it can be expected that the treated trees are more productive than the untreated trees. This is because of the higher photosynthetic area of the treated trees that may result in higher production of carbohydrates and energy for the treated trees. In addition, components in the Prosol Agrigrow (especially zinc and copper) is known to increase photosynthesis of the trees.

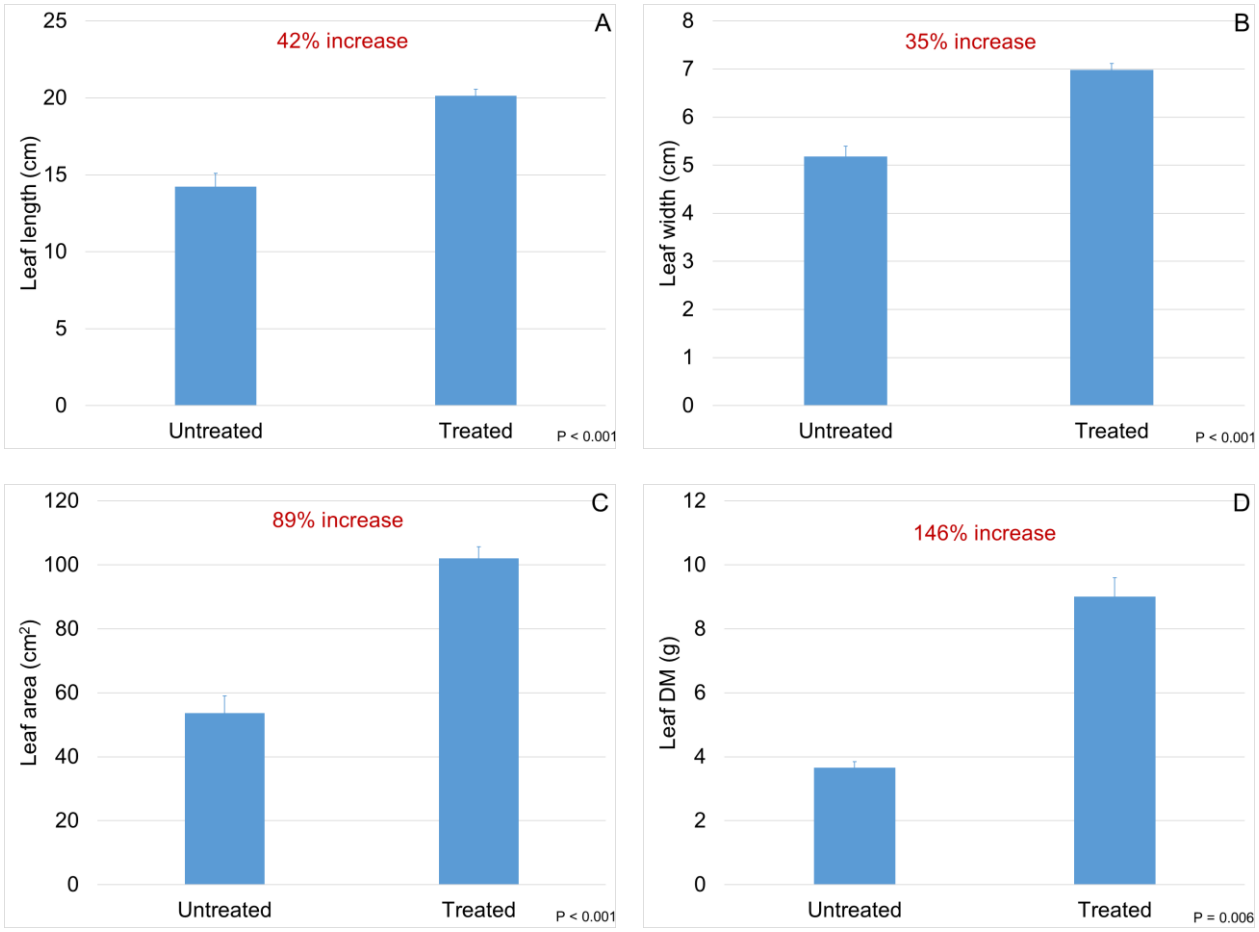

Figure 3: The effect of Prosol Agrigrow on leaf growth of nursery avocado trees, with A) leaf length, B) leaf width, C) leaf area, and D) leaf dry matter content

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The Prosol Agrigrow had a significant effect on root growth of avocado nursery trees. It can be seen that the root mass was increased significantly by the Prosol Agrigrow treatment. It could visually be seen that the root ball of the trees treated with Prosol Agrigrow already filled the volume of the bag (Figure 4 A), while it was not the case for the

untreated trees (Figure 4 C). Once the roots were removed from the trees and the growth medium, it could be seen that the root ball mass volume occurred much larger for the treated trees (Figure 4 B), compared to the untreated trees (Figure 4 D). Once all roots were dried and weighed, it was found that the increase in root dry mass was approximately 462% (Figure 5). It is therefore clear that Prosol Agrigrow caused much more vigorous growth of avocado trees in the nursery.

Figure 4: The visual effect of Prosol Agrigrow on root growth of nursery avocado trees (A and B: roots of treated trees, and C and D: roots of untreated trees

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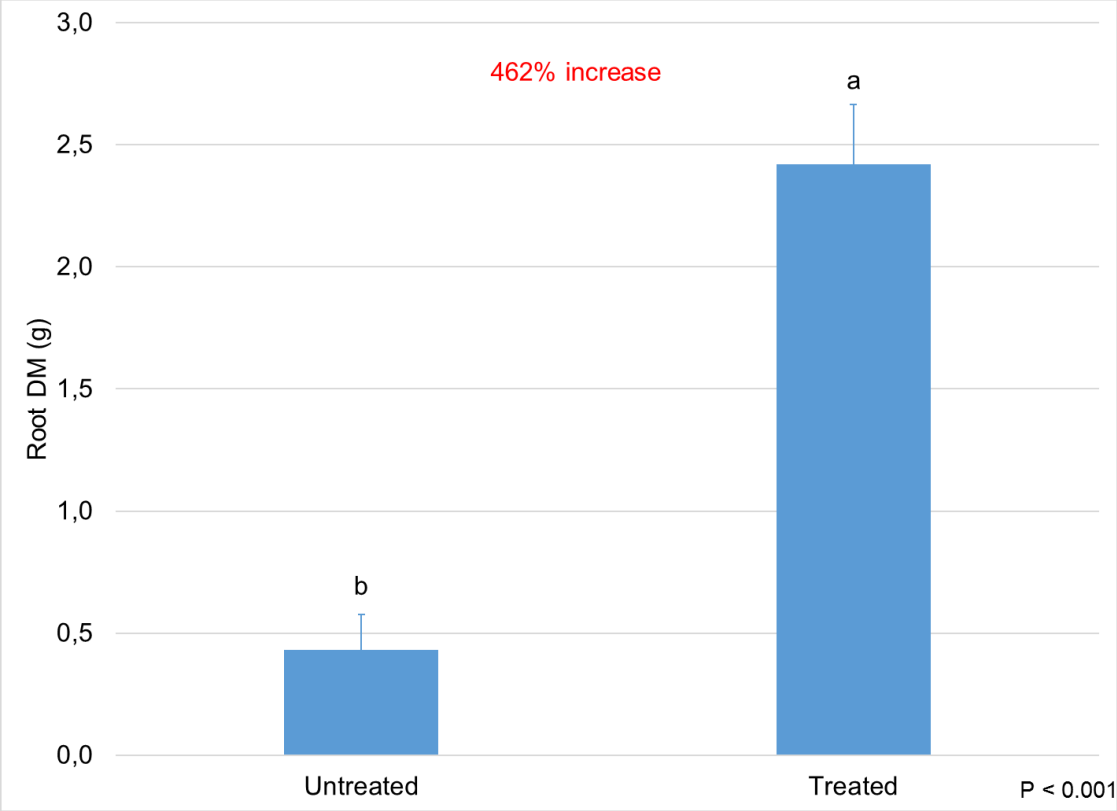

Figure 5: The effect of Prosol Agrigrow on root dry mass avocado nursery trees

Nitrogen and boron levels were found to be significantly higher in the stems of treated trees compared to stems of untreated trees (Table 1). Levels of other nutrients in the stem were not significantly affected by the Prosol Agrigrow treatment (Table 1). Boron and manganese content in the leaves were significantly affected by Prosol Agrigrow treatment. In this instance the boron and manganese levels in the leaves for the treated trees were significantly lower than the untreated trees (Table 2). The boron levels in the roots were affected by the Prosol Agrigrow treatment. In this instance, the boron levels in the roots of treated trees were significantly higher than in the roots of untreated trees (Table 3). The results clearly indicate that the Prosol Agrigrow treatment altered the translocation of boron in the plant, but this would need further investigation and clarification. It is also important to note that the levels of nutrients are well within the norms for avocado trees and that there is therefore no evidence of metal toxicity in the plants.

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Table 1: The effect of Prosol Agrigrow on the nutrient status of the stems of nursery avocado trees

Nutrient	Untreated	Treated	P - value
Nitrogen (%)	1.41 ± 0.01	1.60 ± 0.03	0.037**
Phosphorus (%)	0.21 ± 0.01	0.22 ± 0.02	0.31
Potassium (%)	1.88 ± 0.11	1.73 ± 0.11	0.56
Calcium (%)	0.51 ± 0.04	0.44 ± 0.03	0.46
Magnesium (%)	0.40 ± 0.01	0.36 ± 0.01	0.13
Zinc (mg/kg)	37.3 ± 2.4	40.0 ± 3.2	0.59
Cu (mg/kg)	9.3 ± 1.2	5.0 ± 0.6	0.039**
Manganese (mg/kg)	260.7 ± 30.8	286.3 ± 24.1	0.58
Iron (mg/kg)	68.3 ± 11.4	48.7 ± 0.7	0.24
Boron (mg/kg)	44.9 ± 1.8	106.3 ± 5.8	0.015**

*** Indicate significant difference at the 95% confidence level*

Table 2: The effect of Prosol Agrigrow on the nutrient status of the leaves of nursery avocado trees

Nutrient	Untreated	Treated	P - value
Nitrogen (%)	2.95 ± 0.11	2.83 ± 0.09	0.16
Phosphorus (%)	0.26 ± 0.02	0.28 ± 0.02	0.09
Potassium (%)	1.41 ± 0.06	1.51 ± 0.04	0.21
Calcium (%)	0.91 ± 0.06	0.73 ± 0.05	0.05
Magnesium (%)	0.61 ± 0.04	0.50 ± 0.03	0.07
Zinc (mg/kg)	37.8 ± 2.1	35.6 ± 1.4	0.11
Cu (mg/kg)	19.8 ± 3.2	13.4 ± 1.3	0.06
Manganese (mg/kg)	957.0 ± 24.6	862.6 ± 15.2	0.006**
Iron (mg/kg)	109.5 ± 10.8	91.2 ± 8.2	0.08
Boron (mg/kg)	123.8 ± 6.2	116.0 ± 4.5	0.039**

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Table 3: The effect of Prosol Agrigrow on the nutrient status of the roots of nursery avocado trees

Nutrient	Untreated	Treated	P - value
Nitrogen (%)	3.54 ± 0.52	3.03 ± 0.29	0.64
Phosphorus (%)	0.27 ± 0.03	0.18 ± 0.02	0.30
Potassium (%)	3.38 ± 0.18	2.97 ± 0.26	0.52
Calcium (%)	0.19 ± 0.01	0.20 ± 0.01	0.50
Magnesium (%)	0.51 ± 0.21	0.28 ± 0.01	0.46
Zinc (mg/kg)	72.5 ± 7.5	64.5 ± 0.5	0.46
Cu (mg/kg)	8.0 ± 1.0	7.0 ± 0.001	0.50
Manganese (mg/kg)	645.0 ± 9.0	853.5 ± 96.5	0.30
Iron (mg/kg)	354.5 ± 61.5	383.5 ± 24.5	0.58
Boron (mg/kg)	47.0 ± 15.7	122.0 ± 2.9	0.015**

*** Indicate significant difference at the 95% confidence level*

Considering nutrient build-up in the growth medium, it is evident from Table 4 that higher levels of nitrogen occurred in the growth medium. For the treated growth mediums, nitrogen content was 23.36 mg/L, while 7.29 mg/L for the untreated growth mediums. Zinc, copper and iron also tended to be higher, but the differences were not statistically significant (Table 4). All other elements, conductivity and the pH of the growth medium were not affected by the application of Prosol Agrigrow (Table 4). There is therefore a low risk of heavy metal accumulation and heavy metal toxicity when applying Prosol Agrigrow in the nursery.

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Table 4: The effect of Prosol Agrigrow on the accumulation of heavy metals in the nursery growth medium

Element	Untreated	Treated	P - value
pH	4.39 ± 0.06	4.50 ± 0.08	0.58
Conductivity (mS/m)	54.40 ± 6.90	53.40 ± 2.60	0.93
Nitrogen (mg/L)	7.29 ± 1.78	23.36 ± 5.31	0.026**
Phosphorus (mg/L)	13.14 ± 1.74	9.12 ± 1.30	0.07
Potassium (mg/L)	58.20 ± 6.14	52.83 ± 5.78	0.041**
Calcium (mg/L)	14.03 ± 1.21	9.39 ± 1.80	0.37
Magnesium (mg/L)	6.89 ± 0.23	5.57 ± 1.10	0.37
Zinc (mg/L)	0.03 ± 0.00	0.07 ± 0.01	0.09
Copper (mg/L)	0.01 ± 0.00*	0.02 ± 0.00	
Iron (mg/L)	1.10 ± 0.44	6.37 ± 2.68	0.34
Manganese (mg/L)	0.62 ± 0.03	0.56 ± 0.18	0.76
Boron (mg/L)	0.37 ± 0.22	0.28 ± 0.09	0.62
Sodium (mg/L)	9.48 ± 3.53	8.18 ± 0.66	0.76
Chlorine (mg/L)	8.29 ± 3.72	9.70 ± 0.50	0.80

*** Indicate significant difference at the 95% confidence level*

Experiment 2

During this experiment, the Prosol Agrigrow was used at a concentration of 1:100 000 which was 10 times more diluted compared to the concentration used for the first experiment. It may therefore be expected that at this more diluted concentration the effect of the Prosol Agrigrow would be less remarkable. Nevertheless, even at the lower concentration of 1:100 000, trees still grew more vigorously when compared to the untreated trees. In this instance, tree height was increased with 19% (Figure 6 A). It is evident that the Prosol Agrigrow increased cellular enlargement as the lengths of the internodes was increased significantly with 49%, compared to the untreated trees (Figure 6 C). However, stem diameter was not significantly affected (Figure 6 B). The Prosol

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Agrigrow at the lower concentration of 1:100 000 also had no significant effect on dry matter accumulation when compared to the untreated trees.

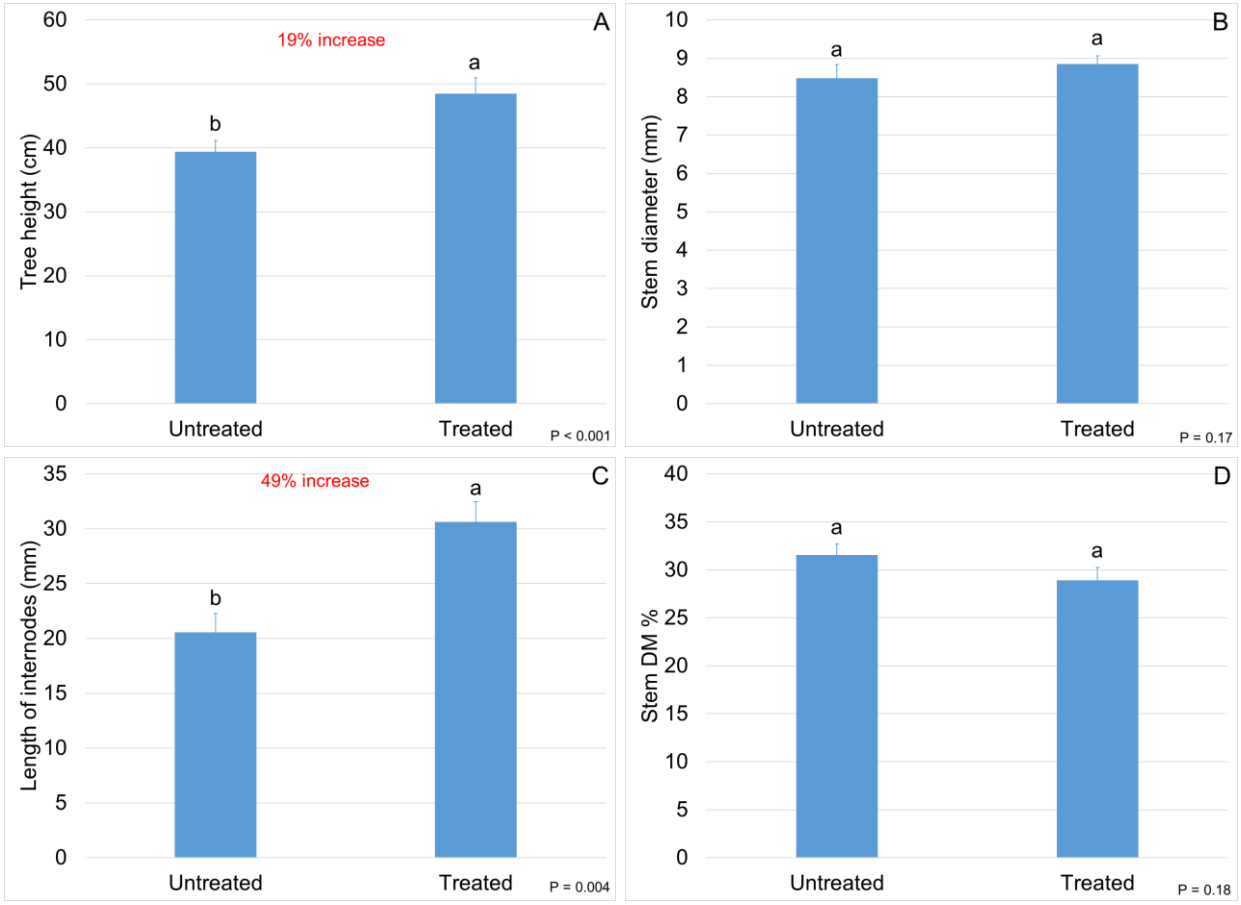

Figure 6: The effect of Prosol Agrigrow on the growth of avocado nursery trees, with A) tree height, B) stem diameter, C) internode length, and D) stem dry mass accumulation

The Prosol Agrigrow at the concentration used for this experiment, did not have a substantial effect on leaf growth. The length of the leaves was not significantly affected (Figure 7 A), but the width was increased with approximately 16% (Figure 7 B). The increase in leaf width resulted in a significant increase in leaf area with approximately 18% (Figure 7 C). With only an increase in the leaf width, leaves of the treated trees were more

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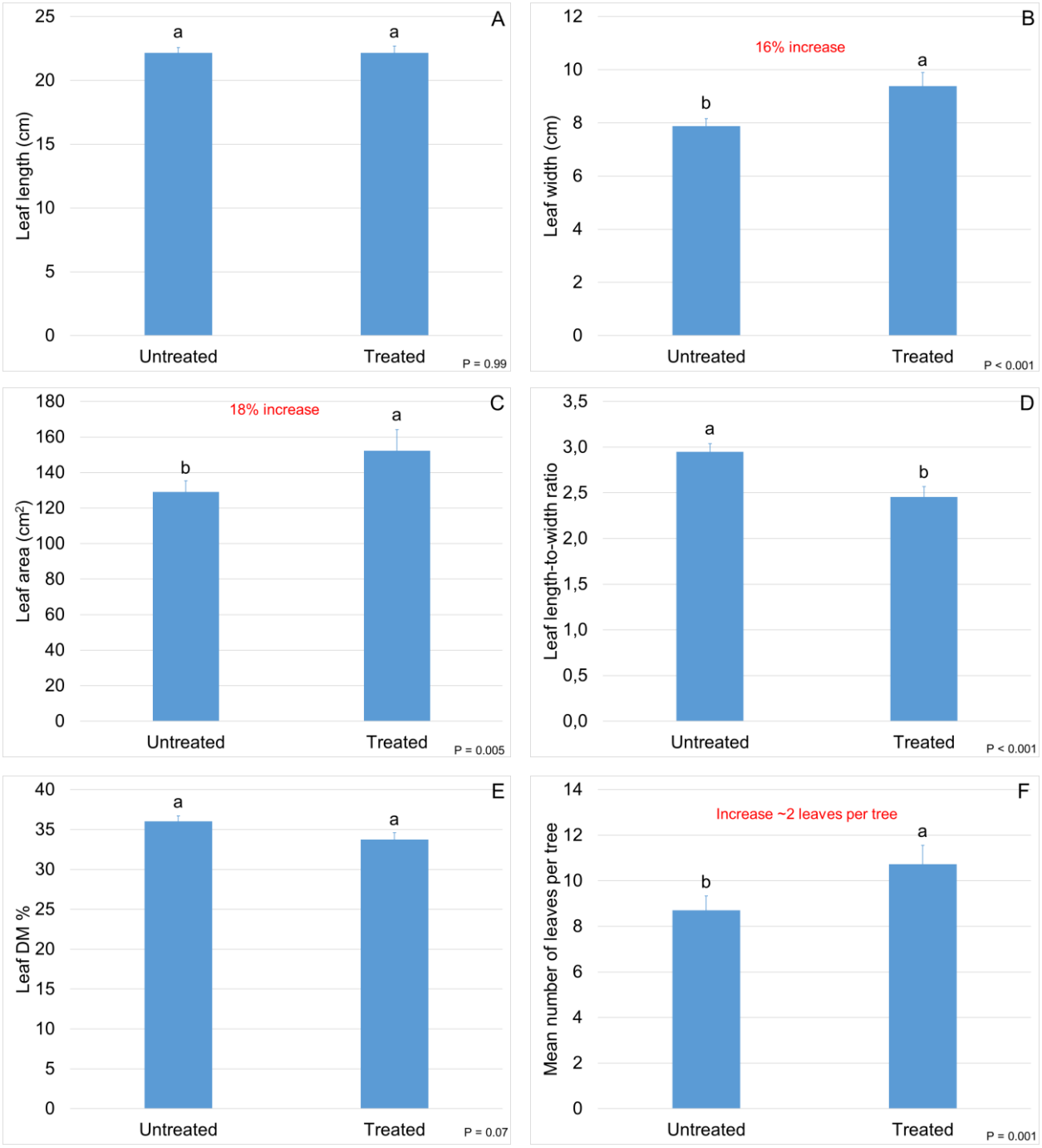

Figure 7: The effect of Prosol Agrigrow on leaf growth of nursery avocado trees, with A) leaf length, B) leaf width, C) leaf area, D) leaf length-to-width ratio, E) leaf dry mass accumulation, and F) number of leaves per tree

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round than leaves from the untreated trees and had a lower leaf length-to-width ratio (Figure 7 D). Even though leaf area was significantly increased for the treated trees, the Prosol Agrigrow had no significant effect on leaf dry matter accumulation (Figure 7 E). The treated trees also had more leaves per tree than the untreated trees (Figure 7 F). Again, as for the first experiment, it may be expected that a larger leaf area could lead to increased tree performance and therefore the improved recorded growth. At the lower dose of 1:100 000, the root dry mass was not significantly affected as for the first experiment where the concentration of 1:10 000 was used (Figure 8).

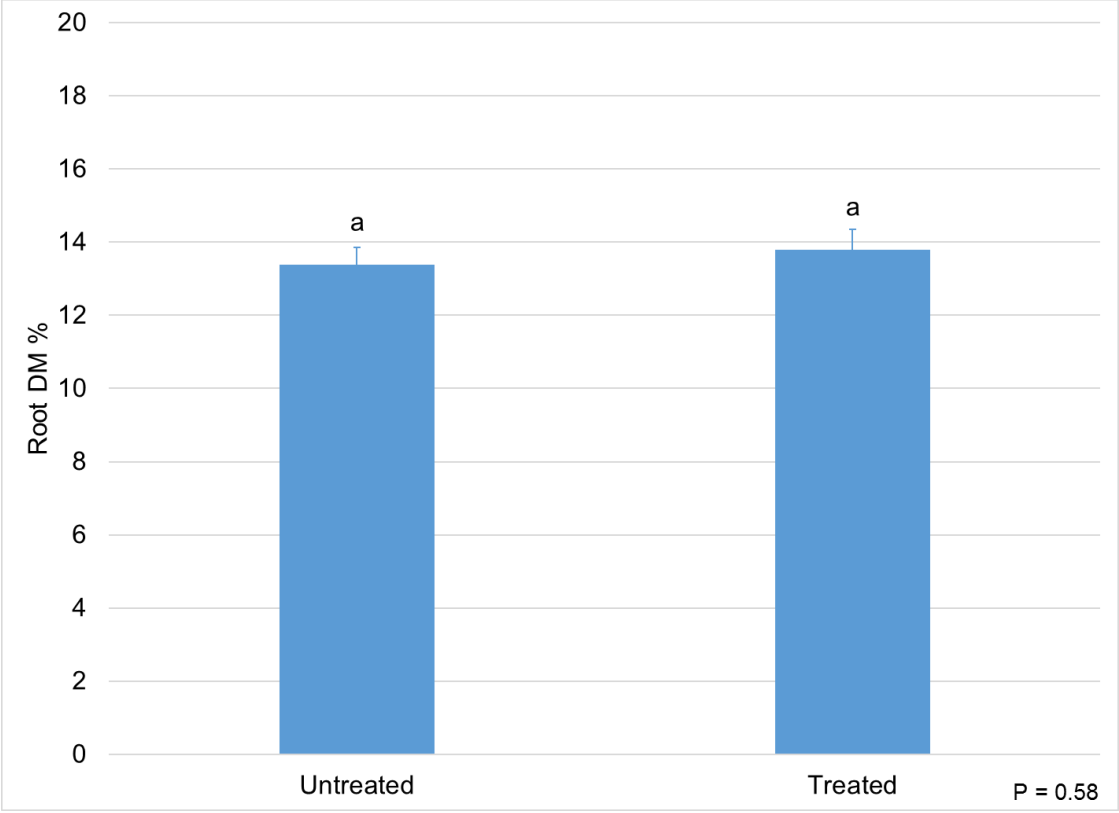

Figure 8: The effect of Prosol Agrigrow on root dry mass content of nursery avocado trees for the second experiment

As for the first experiment, Prosol Agrigrow had little effect on tree nutrient status with most macro and micronutrient levels in the leaves not being affected significantly for the

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second experiment (Table 5). Leaf nutrient levels were further within the recommended norms for avocado trees, for both treated and untreated trees and there were therefore no nutrient deficiencies or imbalances. It was only copper and boron levels that were significantly higher for the treated trees, compared to the untreated trees. Higher copper levels could be an effect of the Prosol Agrigrow as copper is a major ingredient (6% copper nitrate in the product concentrate) in the Prosol Agrigrow. As for the first experiment, boron levels were affected, but in this instance, the boron levels were increased in the leaves, whereas it was decreased during the first experiment.

Table 5: The effect of Prosol Agrigrow on the nutrient status of the leaves of nursery avocado trees for the second experiment

Nutrient	Untreated	Treated	P - value
Nitrogen (%)	2.75 ± 0.14	2.55 ± 0.23	0.49
Phosphorus (%)	0.19 ± 0.01	0.20 ± 0.02	0.42
Potassium (%)	1.40 ± 0.10	1.31 ± 0.02	0.44
Calcium (%)	0.94 ± 0.15	0.93 ± 0.08	0.98
Magnesium (%)	0.52 ± 0.03	0.52 ± 0.02	0.91
Zinc (mg/kg)	39.0 ± 4.3	43.0 ± 5.3	0.57
Cu (mg/kg)	4.4 ± 0.2	5.4 ± 0.2	0.02**
Manganese (mg/kg)	1 074 ± 150	997 ± 78	0.66
Iron (mg/kg)	62.2 ± 4.2	62.4 ± 1.1	0.96
Boron (mg/kg)	15.1 ± 1.1	24.0 ± 2.3	0.02**

*** Indicate significant difference at the 95% confidence level*

Root nutrient levels, for the exception of iron, were not significantly affected for the second experiment (Table 6). Iron levels in the roots were increased with 88% for the treated trees. As this increase was not observed during the first experiment, this effect was most likely not related to the Prosol Agrigrow.

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Table 6: The effect of Prosol Agrigrow on the nutrient status of the roots of nursery avocado trees for the second experiment

Nutrient	Untreated	Treated	P - value
Nitrogen (%)	2.18 ± 0.36	1.50 ± 0.15	0.11
Phosphorus (%)	0.17 ± 0.03	0.15 ± 0.01	0.38
Potassium (%)	2.23 ± 0.13	1.93 ± 0.11	0.13
Calcium (%)	0.30 ± 0.06	0.35 ± 0.06	0.66
Magnesium (%)	0.31 ± 0.03	0.29 ± 0.02	0.61
Zinc (mg/kg)	49.7 ± 4.8	71.5 ± 6.3	0.04**
Cu (mg/kg)	10.0 ± 1.0	23.5 ± 5.5	0.10
Manganese (mg/kg)	346.0 ± 58.1	305.8 ± 33.8	0.55
Iron (mg/kg)	413.7 ± 80.4	778.0 ± 48.3	0.009**
Boron (mg/kg)	20.3 ± 6.6	16.8 ± 2.8	0.60

*** Indicate significant difference at the 95% confidence level*

Conclusion

Application of Prosol Agrigrow significantly improved the growth of avocado nursery trees, resulting in a reduction in the turnover time of nursery trees. This is highly desirable from a nursery point of view as it decreases the period the tree spend in the nursery and therefore costs. Trees are further produced quicker, which will eventually increase annual revenue for the nursery. Growth was increased with both concentrations used in the two experiments, namely 1:10 000 and 1:100 000 Prosol Agrigrow to water. However, growth was less significantly with the lower concentration of 1:100 000. Currently, it is uncertain how growth will be affected when using concentrations between the two concentrations used for these experiments and if a linear dose response will be obtained. Though a concentration of 1:10 000 gave highly satisfactory growth, it might be too expensive to be implemented by the nursery. On the other hand, a concentration of 1:100 000 may be economic, but the growth may not be as desirable as when the higher concentration is used. It is therefore important to investigate other concentrations between the two concentrations used to find an optimal concentration in terms of growth and to be

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economic to the nursery. From results of the two experiments, it is evident that Prosol Agrigrow alters boron translocation, and the basis of this should be investigated further. No accumulation of Prosol Agrigrow in the nursery growth medium and no phytotoxicity occurred when using Prosol Agrigrow. Prosol Agrigrow can therefore be safely recommended to be used as a water additive to improve the growth of avocado nursery trees.