EFFECT OF PACLOBUTRAZOL AND POTASSIUM NITRATE SPRAYS AT FLOWERING ON NEW SHOOT DEVELOPMENT, LEAF NUTRIENT ELEMENT CONCENTRATIONS, FRUIT DROP, SOLITARY FRUIT WEIGHT AND TREE YIELD IN MALUMA HASS AVOCADO

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ABSTRACT

Productive 'Maluma Hass' avocado trees were sprayed with pacolubtrazol or paclobutrazol/potassium nitrate during flowering with the aim of increasing tree yield and fruit size. Avocet was applied at 0.7% (v/v) and potassium nitrate at 2 or 3% (w/v). Paclobutrazol increased fruit drop, increased fruit roundness and gave rise to an increase in fruit solitary weight. Tree yield was reduced by 10%, however, the fruit weight (size) increase did not compensate for the fruit thinning effect of paclobutrazol. Paclobutrazol reduced new shoot length by 20% on average, the reductions resulting from reduced internode extension. Number of new shoots was not reduced (pacloburazol also does not affect new-shoot leaf number nor leaf expansion). Potassium nitrate was effective in increasing leaf N and K concentrations and, to an extent, countering the effects of paclubutrazol. Paclobutrazol reduced the fruit box count number (4 kg box) on average from Count 13 or 14, to Count 12. The results of the current study do not support the practice of spray application of paclobutrazol during flowering as a measure to increase tree productivity or significantly reduce new shoot length (canopy expansion).

INTRODUCTION

Paclobutrazol or uniconazole sprays made at flowering are generally applied by avocado growers worldwide to "supposedly" increase fruit retention, increase fruit size and markedly reduce the vigour of the spring flush, which emanates from the inflorescences or buds subtending the inflorescences. These products are gibberellic acid (GA) synthesis inhibitors (Rademacher, 2016).

GA is mainly associated with cell elongation and, consequently, shoot-internode elongation. Uniconazole or paclobutrazol are effective in shortening new shoots, but not reducing new shoot number, number of new shoot leaves or leaf expansion (Oosthuyse, 2019). Fruit retention is considered to be increased as a result of paclobutrazol or uniconazole reducing the vigour of the new shoots arising during and after flowering, and as such, reducing the demand for nutrients (assimilates) by competitive new shoots in the vicinity of the assimilate requiring fruits (Wolstenholme *et al.*, 1988). Fruit size is considered to be increased also due to reduced shoot competition for assimilates arising (Whiley *et al*., 1992).

Potassium nitrate (KNO_3) spraying during flowering reduces fruit drop and increases fruit size by facilitating and promoting phloem transfer (Cakmak *et al*., 1994; Vreugdenhil, 1985) of assimilates to the fruits from leaves and other internal sources, since potassium is a vital regulatory element concerning phloem function. Tree sprays containing KNO_3 are known to increase fruit size in a number of fruit types, e.g., peach, olive or orange (Dikmelik *et al.*, 1999; Boman, 2001; Sarfaraz, 2011). They may also reduce fruit drop after flowering in facilitating assimilate movement to competing, newly developing fruits. KNO_3 sprays on mango inflorescences have been found to increase fruit retention in numerous studies (Oosthuyse, 1997).

The aim of the current study was to assess the effect on new shoot development, fruit retention, fruit size and tree yield of sprays of paclobutrazol and/or potassium nitrate made during or shortly after flowering in 'Maluma Hass' avocado. The effect on initial fruit drop was also assessed.

Figure 1: Trees used for the experiment (farm of Nick Human in the vicinity of Tzaneen, South Africa).

MATERIALS AND METHODS

In late August, 2017, sixty bearing 'Maluma Hass' avocado trees were selected for uniformity of size and flowering intensity in two rows in a five-year old, ridged, orchard block on the farm of Nick Human in the vicinity of Tzaneen (Fig. 1). The trees were irrigated with micro-sprinklers and were fertilised and pruned professionally. They were mulched yearly, and pests and diseases were controlled following the guidelines of commercial practice for the growing region.

To each of 10 trees the following spray treatments were carried out:

a) Control (untreated)
b) Avocet (250 g/L paclobutrazol formulation) at the recommended rate of 0.7% (v/v) at the flowering stage indicated in Figure 2
c) b) plus KNO_3 at 2% (w/v, 2 kg/100 L water)
d) b) plus KNO_3 at 3% (w/v, 3 kg/100 L water)
e) b) plus KNO_3 at 2% and KNO_3 sprayed again at 2%, 6 days after flowering at the stage indicated in Figure 3
f) b) plus KNO_3 at 3% and KNO_3 sprayed again at 3%, 6 days after flowering at the stage indicated in Figure 3.

There were 10 single tree replicates of six treatments (incl. control). The Complete Randomized Blocks experiment design was adopted.

Figure 2: Stage of flowering on Aug. 31, 2017, when the first spray applications were made.

Figure 3: Stage of flowering on Sep. 6, 2017, when potassium nitrate was late-applied six days after paclobutrazol (Avocet at 0.7%) application.

Figure 4: Degree of leaf wetting; light cover.

Figure 5: Light-cover spraying. The nozzles were set to fine. To ensure complete tree wetting, an "up-down-around" method of spraying was adopted.

Light cover sprays were made using 16 L knap sack sprayers (Fig. 4). The nozzles were set to deliver a fine spray (Fig. 5). LI 700 adjuvant at the rate of 32 ml per 16 L was mixed into the solutions made up (Fig. 6). Care was taken to spray all of the leaves on the trees. Spraying was carried out in the late afternoon when conditions were cool.

Ten bearing units per tree, each comprising a terminal inflorescence and its developing new shoots, were labelled shortly after spraying (Fig. 7). These were well distributed around the upper half of the tree canopy.

On Sep. 22, 2017, leaf samples were taken from each tree for nutrient-element analysis. Figure 8 shows the general stage of fruit development on the date of leaf sampling. Mature leaves from under each bearing unit of each tree were sampled (Fig. 9). A full analysis was conducted on the leaves taken from each tree by SGS Laboratory, Somerset West, South Africa. N, P, K, Ca, Mg, Na, Cu, Fe, Mn, Zn or B leaf concentrations were analyzed.

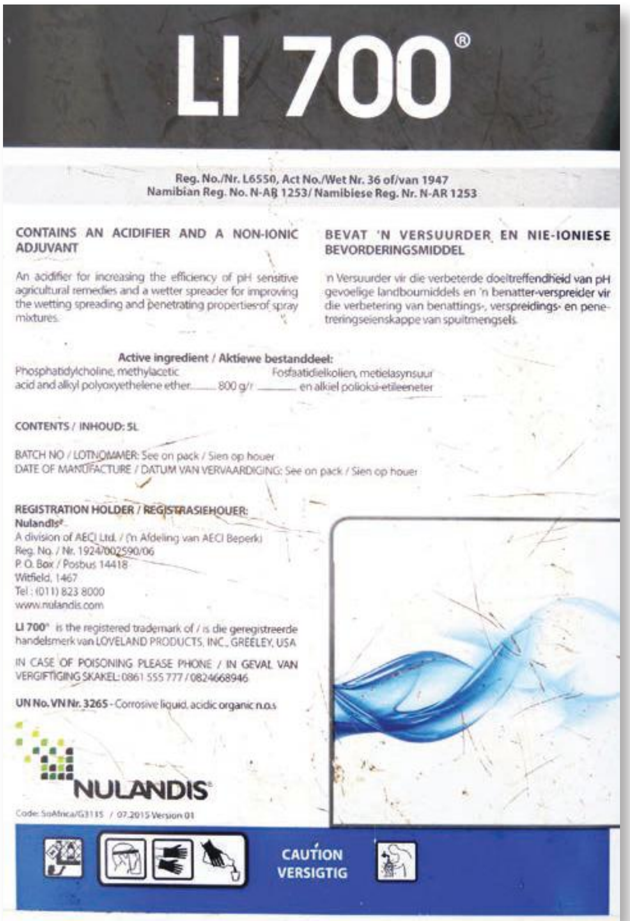

Figure 6: 32 ml of LI 700 wetter was added to each 16 L knap sack sprayer.

Figure 7: Labelled bearing unit on a tree on Nov. 14, 2017.

The number of fruits on each bearing unit was counted on Nov. 14, 2017, Dec. 18, 2017, and April 3, 2018 (tree harvest date). The stages of fruit development on Nov. 14, and on Dec. 18, 2017, are shown in Figures 10 and 11.

Figure 8: General stage of fruit development when the leaf samples were taken (Sep. 22, 2017).

Figure 9: Mature leaves under each bearing unit were sampled for nutrient-element concentration determination (dry leaf concentrations).

Figure 10: General stage of fruit development on Nov. 14, 2017.

Figure 11: General stage of fruit development on Dec. 18, 2017.

On April 3, 2018, the fruits on each tree were harvested, weighed and counted. Solitary weight was ascertained from these determinations. The longitudinal and equatorial circumferences of the fruits on the bearing units were measured to ascertain size and determine an index indicating shape. In addition, the length of the longest and shortest new shoot on each of the bearing units was measured, and the number of new shoots comprising each bearing unit was counted.

The final data, being tree totals or averages, were subjected to analysis of variance. "95% LSD Interval for Factor Means Plots" are presented to clearly show differences relating to the treatments.

RESULTS AND DISCUSSION

Figure 12 shows the effect of the treatments on fruit drop percentage during the period from Nov. 14, to Dec. 18, 2017.

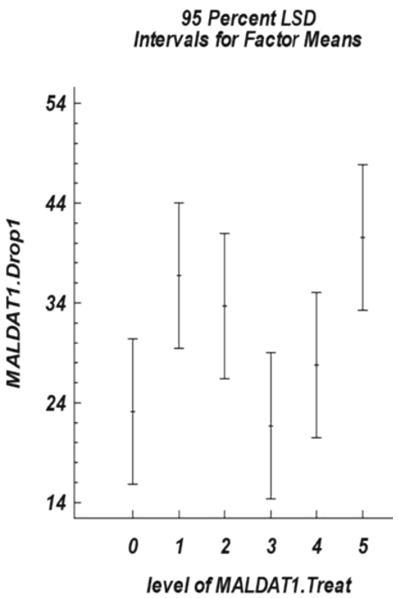

Figure 12: Percentage fruit drop during the period from Nov. 14, to Dec. 18, 2017. Treatment is indicated on the X-axis and % drop on the Y-axis. *Treatments: "0" - control; "1" - PBZ; "2" - PBZ+2%KNO_3; "3" - PBZ+3%KNO_3; "4" - PBZ+2%KNO_3+2%KNO_3; "5" - PBZ+3%KNO_3+3%KNO_3.*

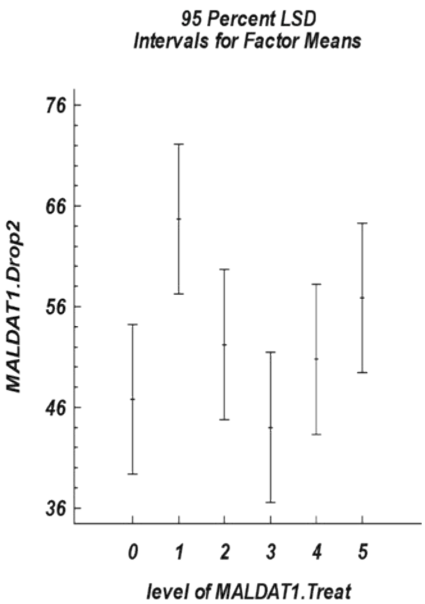

Figure 13: Percentage fruit drop during the period from Nov. 14, 2017, to Apr. 3, 2018. Treatment is indicated on the X-axis and % drop on the Y-axis. *Treatments: "0" - control; "1" - PBZ; "2" - PBZ+2%KNO_3; "3" - PBZ+3%KNO_3; "4" - PBZ+2%KNO_3+2%KNO_3; "5" - PBZ+3%KNO_3+3%KNO_3.*

Percentage fruit drop during this period was apparently increased by a number of the treatments. KNO_3 application may have acted to counter fruit drop to an extent in certain instances.

Figure 13 shows the effect of the treatments on fruit drop percentage during the period from Nov. 14, 2017 to Apr. 3, 2018.

Percentage fruit drop was greatest where paclobutrazol was only applied. KNO_3 application in addition to paclobutrazol application appeared to counter the fruit drop associated with paclobutrazol application. Differences relating to rate of KNO_3 application or number of KNO_3 applications were not clearly apparent.

Figure 14 shows the effect of the treatments on fruit drop percentage during the period from Dec. 18, 2017 to Apr. 3, 2018 (drop after natural Nov. drop).

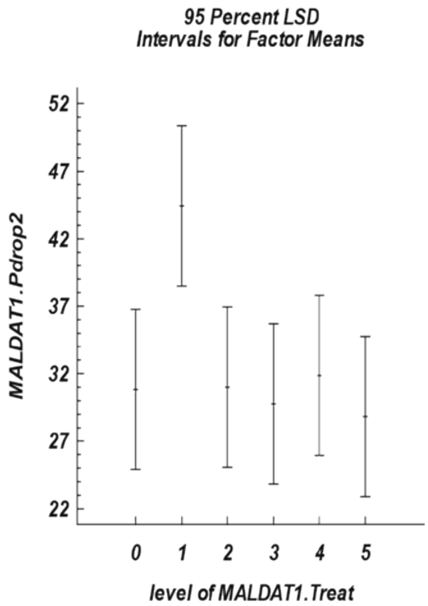

Figure 14: Percentage fruit drop during the period from Dec. 18, 2017, to Apr. 3, 2018. Treatment is indicated on the X-axis and % drop on the Y-axis. *Treatments: "0" - control; "1" - PBZ; "2" - PBZ+2%KNO_3; "3" - PBZ+3%KNO_3; "4" - PBZ+2%KNO3+2%KNO_3; "5" - PBZ+3%KNO_3+3%KNO_3.*

Percentage fruit drop during this period was clearly greatest where paclobutrazol was singly applied. KNO3 application appeared to counter the fruit drop effect associated with paclobutrazol application. Differences relating to rate of KNO_3 application or number of KNO_3 applications were not apparent.

Figure 15 shows the effect of the treatments on fruit shape.

Pacalobutrazol altered fruit development in rendering rounder fruit. This indicates translocation of paclobutrazol into the fruits. Potassium nitrate addition did not appear to influence fruit shape.

Figure 16 shows the effect of the treatments on tree yield.

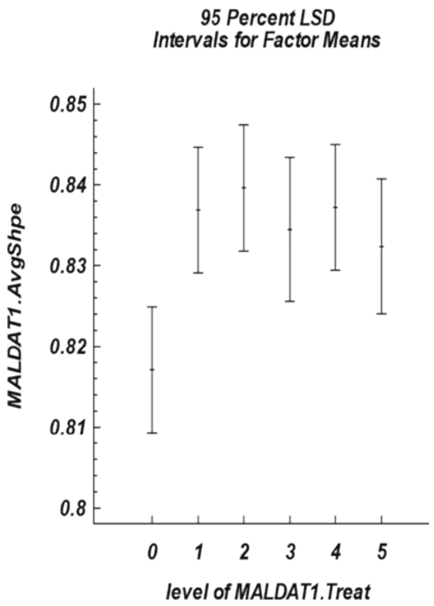

Figure 15: Fruit shape index (y-axis) in relation to treatment (fruit shape index = equatorial circumference divided by longitudinal circumference; the index increases to a maximum of 1 as fruits become rounder). Treatment is indicated on the X-axis. *Treatments (x-axis): "0" - control; "1" - PBZ; "2" - PBZ+2%KNO_3; "3" - PBZ+3%KNO_3; "4" - PBZ+2%KNO_3+2%KNO_3; "5" - PBZ+3%KNO_3+3%KNO_3.*

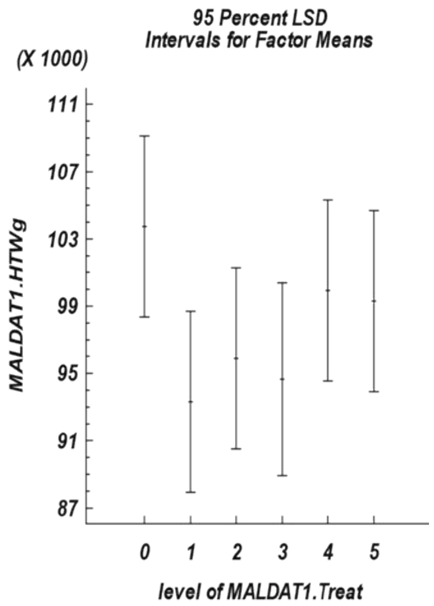

Figure 16: Tree yield (kg) (y-axis) in relation to treatment. *Treatments (x-axis): "0" - control; "1" - PBZ; "2" - PBZ+2%KNO_3; "3" - PBZ+3%KNO_3; "4" - PBZ+2%KNO_3+2%KNO_3; "5" - PBZ+3%KNO_3+3%KNO_3.*

Paclobutrazol when applied singly reduced tree yield. Potassium nitrate may have countered the reduction to an extent where two applications were made (Treatment 4 or 5).

Figure 17 shows the effect of the treatments on number of fruits per tree at harvest.

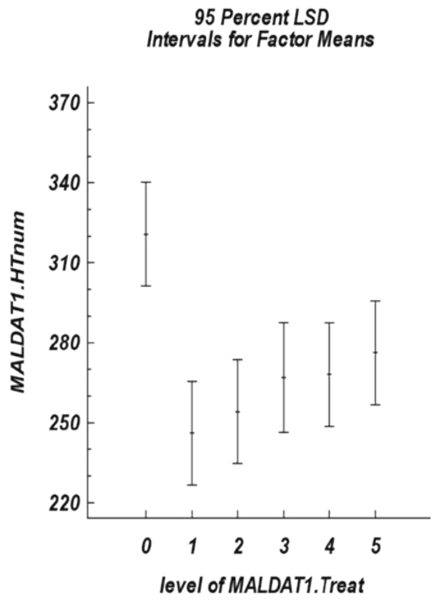

Figure 17: Number of fruits per tree (y-axis) in relation to treatment. *Treatments (x-axis): "0" - control; "1" - PBZ; "2" - PBZ+2%KNO_3; "3" - PBZ+3%KNO_3; "4" - PBZ+2%KNO_3+2%KNO_3; "5" - PBZ+3%KNO_3+3%KNO_3.*

Fruit number was reduced as a result of paclobutrazol treatment irrespective of whether accompanied by KNO_3 or not. The KNO_3 additions may have acted to reduce the reduction to a relatively small extent.

Figure 18 shows the effect of the treatments on solitary fruit weight.

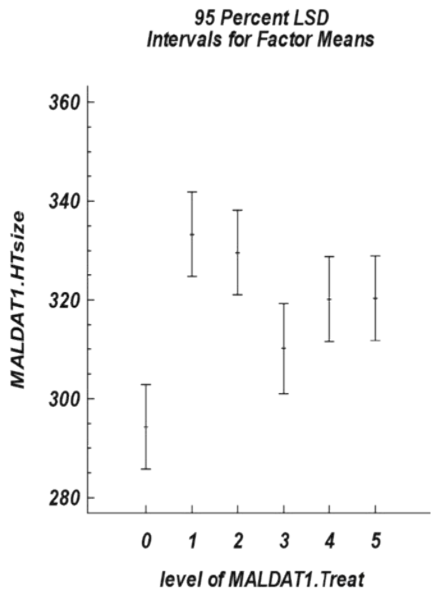

Figure 18: Solitary fruit weight (g) (y-axis) in relation to treatment. *Treatments (x-axis): "0" - control; "1" - PBZ; "2" - PBZ+2%KNO_3; "3" - PBZ+3%KNO_3; "4" - PBZ+2%KNO_3+2%KNO_3; "5" - PBZ+3%KNO_3+3%KNO_3.*

Fruit solitary weight (size) was increased as a result of paclobutrazol treatment. There was is no clear evidence for KNO_3 aiding in increasing solitary weight.

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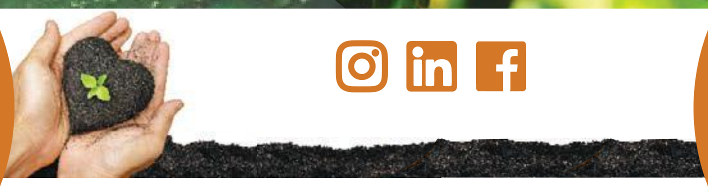

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Reductions in solitary weight where KNO_3 was added may have occurred due to lesser drop caused by KNO_3. The increases in solitary fruit weight were not such that the reductions in tree yield were countered. The average solitary weight of the fruits on the trees treated only with paclobutrazol was 333 g (Count 12). The fruits on the untreated trees weighed 294 g on average (Count 13 or 14).

Figure 19 shows the effect of the treatment on the number of new shoots developing from each bearing unit.

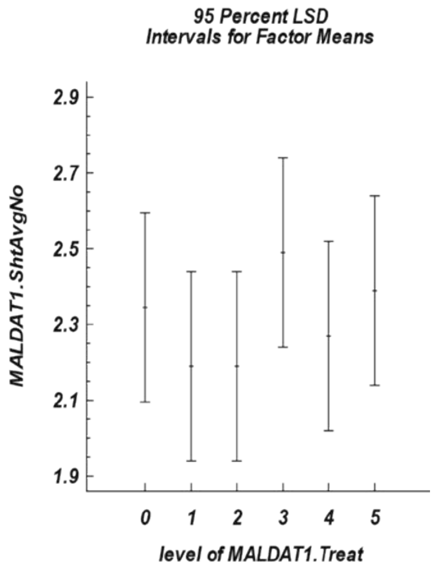

Figure 19: Number of new shoots per bearing unit (y-axis) in relation to treatment. *Treatments (x-axis): "0" - control; "1" - PBZ; "2" - PBZ+2%KNO_3; "3" - PBZ+3%KNO_3; "4" - PBZ+2%KNO_3+2%KNO_3; "5" - PBZ+3%KNO_3+3%KNO_3.*

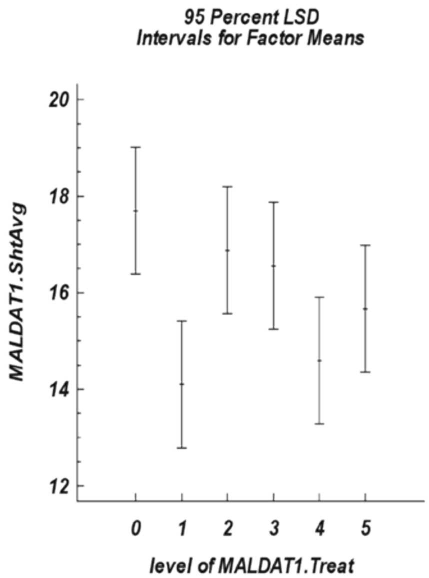

Figure 20: Average length (cm) of the new shoots per bearing unit (y-axis) in relation to treatment. *Treatments (x-axis): "0" - control; "1" - PBZ; "2" - PBZ+2%KNO_3; "3" - PBZ+3%KNO_3; "4" - PBZ+2%KNO_3+2%KNO_3; "5" - PBZ+3%KNO_3+3%KNO_3.*

The spray treatments did not appear to affect the number of new shoots developing on the bearing units.

Figure 20 shows the effect of the treatments on the length of the new shoots developing on the bearing units.

New shoot length was reduced by paclobutrazol (from 17.7 to 14 cm on average). The reduction was in the order of 20.3%. The KNO_3 applications appeared to counter the effect of paclobutrazol in reducing shoot length (inter-node extension).

Figure 21 shows the effect of the treatments on leaf N concentration.

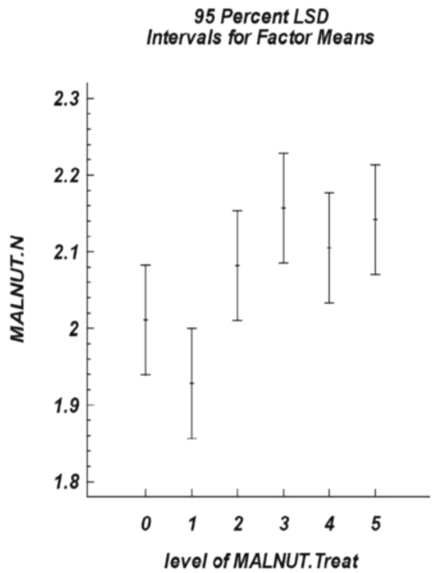

Figure 21: Leaf N concentration (%) in relation to treatment. *Treatments (x-axis): "0" - control; "1" - PBZ; "2" - PBZ+2%KNO_3; "3" - PBZ+3%KNO_3; "4" - PBZ+2%KNO_3+2%KNO_3; "5" - PBZ+3%KNO_3+3%KNO_3.*

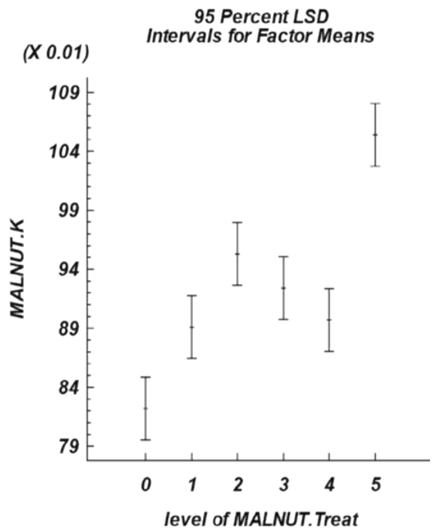

Figure 22: Leaf K concentration (%) in relation to treatment. *Treatments (x-axis): "0" - control; "1" - PBZ; "2" - PBZ+2%KNO_3; "3" - PBZ+3%KNO_3; "4" - PBZ+2%KNO_3+2%KNO_3; "5" - PBZ+3%KNO_3+3%KNO_3.*

Table 1: Leaf concentrations (least square means) of P, Ca, Mg, Na, Cu, Fe, Mn, Zn or B in relation to treatment. Means associated with different letters differ "statistically" at the 5% level of significance

Treat-ment	%P	%Ca	%Mg	Na (ppm)	Cu (ppm)	Fe (ppm)	Mn (ppm)	Zn (ppm)	B (ppm)
0	0.107^{a}	1.78^{a}	0.72^{a}	146^{ab}	9.5^{a}	72^{a}	572^{a}	23.6^{a}	20.4^{a}
1	0.117^{b}	1.80^{a}	0.74^{a}	157^{c}	11.2^{b}	76^{ab}	627^{ab}	26.3^{b}	22.2^{c}
2	0.123^{c}	1.81^{a}	0.72^{a}	154^{bc}	10.7^{ab}	78^{abc}	620^{ab}	26.5^{b}	22^{bc}
3	0.117^{b}	1.73^{a}	0.72^{a}	150^{bc}	10.4^{ab}	83^{bc}	667^{b}	25.4^{ab}	21.7^{bc}
4	0.121^{bc}	1.83^{a}	0.76^{a}	145^{ab}	11.6^{b}	84^{bc}	613^{ab}	24.6^{b}	22.1^{bc}
5	0.124^{c}	1.78^{a}	0.72^{a}	140^{a}	11.5^{b}	85^{c}	574^{a}	25.9^{b}	21.3^{c}

**"0"- control; "1"- PBZ; "2"- PBZ+2%KNO_3; "3"- PBZ+3%KNO_3; "4"- PBZ+2%KNO_3+2%KNO_3; "5"- PBZ+3%KNO_3+3%KNO_3*

Application of KNO_3 gave rise to increases in leaf N concentration. Differences regarding KNO_3 rate or number of KNO_3 applications were not apparent.

Figure 22 shows the effect of the treatments on leaf K concentration.

Application of KNO_3 and paclobutrazol gave rise to increases in leaf K concentration. Differences regarding KNO_3 rate or number of KNO_3 applications were not clear, although application of KNO_3 at 3% twice gave rise to a marked increase.

Table 1 shows the leaf concentrations of P, Ca, Mg, Na, Cu, Fe, Mn, Zn or B in relation to treatment.

In consideration of Ca or Mg, leaf concentration was not affected by the spray treatments. In considering P, Na, Mn, Fe, Cu, Zn or B, general increases occurred as a result of treatment. These increases probably relate to quantity changes in leaf organic molecules resulting from paclobutrazol and KNO_3 application.

CONCLUSION

The results of the current study do not support the practice of paclubutrazol spray application made during flowering. Paclobutrazol would appear to act as a fruit thinning agent, promoting fruit drop and possibly reducing initial set. The fruit size increases observed may relate wholly or partially to the reductions in fruit number caused. The influence of fruit size relating to tree fruit number has been shown (Oosthuyse and Donkin, 2001). An effected reduction in number of fruits results in greater availability of assimilates to the fruit remaining. The increases in size were still such that tree yield was reduced. The average reduction in tree yield was 10%. Size was increased, by one "4 kg box count", that being from Count 13 or 14 to Count 12. New shoot length was reduced by 20%. In the study by Oosthuyse (2015) it was shown that new shoot leaf number and size are not affected by paclobutrazol. Hence the reduction in new shoot demand for assimilates caused by paclobutrazol may not be of material significance.

Acknowledgement

Thanks are due to Nick and Nelius Human for their willingness to provide trees and help with data collection and tree supervision.

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Blok 52	Avo Orchard	63 of 63	100%	2.600 ha	100%	3.8 km/h	42%	21/10/2020
Blok 60A	Avo Orchard	53 of 52	100%	1.941 ha	100%	3.9 km/h	40%	21/10/2020
Blok 60B	Avo Orchard	62 of 61	100%	1.900 ha	100%	3.5 km/h	42%	21/10/2020
Blok 61	Avo Orchard	55 of 54	100%	1.846 ha	100%	3.5 km/h	36%	21/10/2020
Blok 62	Avo Orchard	17 of 17	100%	0.695 ha	100%	3.9 km/h	39%	21/10/2020
Blok 78	Avo Orchard	75 of 72	100%	2.144 ha	100%	3.4 km/h	41%	21/10/2020
Blok 64	Avo Orchard	40 of 41	98%	2.336 ha	100%	4.2 km/h	31%	21/10/2020
Blok 36	Avo Orchard	39 of 41	95%	1.575 ha	94%	3.2 km/h	34%	21/10/2020
Blok 70A	Avo Orchard	42 of 44	95%	2.545 ha	100%	4.4 km/h	37%	21/10/2020
Blok 66	Avo Orchard	29 of 31	94%	1.383 ha	99%	3.5 km/h	49%	21/10/2020
Blok 19	Avo Orchard	10 of 103	10%	0.398 ha	11%	4.0 km/h	48%	21/10/2020

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