

The effect of non-permanent netting on mandarin fruit

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In *Citrus* spp., non-permanent netting (NPN) is used during a particular stage in the season to protect trees and fruit from damage that could be caused by hail (Wachsmann et al., 2014). It is used in some cultivars during flowering, to exclude bees, preventing cross-pollination and seed development (Gambetta et al., 2013; Gravina et al., 2016; Otero and Rivas, 2017). However, it is unclear how the covering of trees with NPN before, during and after flowering impacts on the deposition of foliar sprays applied, insect pest prevalence and fruit production. The objectives of this study were to evaluate the effects of NPN on these aspects in the production of "Nadorcott" mandarin fruit.

Materials and methods

The study was conducted in a commercial orchard of six-year old "Nadorcott" mandarin trees, with "Carrizo" citrange rootstock at Citrusdal in the Western Cape province. Trees were planted at a spacing of 5.5 × 2.5 m.

The following NPN treatments were applied prior to flowering in August 2017: 1) trees covered with NPN from August 2017 to November 2017 (NPN August to November.), 2) trees covered from August 2017 to March 2018 (NPN August to March), and 3) trees covered from August 2017 until harvest in July 2018 (NPN August to July). Trees were covered to the ground with a white (18% shade) AHN-55 (55 g·m⁻²) mesh type NPN.

Data collection:

Foliar spray deposition

To evaluate the effects of NPN on foliar spray deposition in the tree canopy, control and NPN treatments were sprayed in January 2018 and in June 2018 at different water volumes, with a 2 000 L oscillating Nieuwoudt spray machine. The January sprays were applied at volumes of 3 500 and 15 000 L·ha⁻¹. The June sprays were applied at volumes of 3 500, 7000 and 15 000 L·ha⁻¹. Each foliar spray contained fluorescent pigment allowing for visualisation of the spray deposition on the leaf and fruit surfaces. Leaves and fruit were sampled from three uniform trees within the respective treatment replicates. For the January evaluation, only leaves were sampled; whereas fruit and leaves were sampled for the June evaluation. Samples were collected from different tree canopy positions: three vertical positions, viz. top, middle and bottom; and two horizontal positions, viz. inner canopy (leaves 30 to 50 cm inside the tree canopy) and outer canopy (leaves or fruit on the outside of the tree canopy). Deposition quantity was measured as the percentage of leaf or fruit area covered by pigment particles, i.e. the percentage fluorescent particle coverage (FPC%). Deposition uniformity between leaves or fruit was calculated as the uniformity in pigment deposition in a batch of 12 leaves or five fruit (standard deviation × 100/mean) and referred to as CV%.

Insect pest prevalence

False codling moth (FCM) was monitored using a yellow Delta trap containing a sticky floor and

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a pheromone lure to attract males. Mediterranean fruit fly was monitored using a Sensus trap containing a Capilure (trimedlure) capsule and a small dichlorvos-impregnated block, to attract and kill male fruit flies. Traps were placed in the tree canopy in one control, one NPN August to March, and one NPN August to July replicate. The farm was included in the commercial area-wide Xsit Sterile Insect Release programme. Both wild and sterile FCM males were therefore monitored by traps.

Leaf mineral nutrient concentration

Leaves were sampled according to the South African citrus industry standard (Du Plessis 1977; Du Plessis et al., 1992; Du Plessis and Koen, 1992). Mineral nutrient analyses in leaf samples were conducted by an accredited commercial analytical laboratory. The concentrations of the mineral nutrients in the leaf were expressed as $\text{mg}\cdot\text{g}^{-1}$ leaf dry weight (DW) for macronutrients, or $\text{mg}\cdot\text{kg}^{-1}$ leaf DW for micronutrients.

Fruit yield

Commercial fruit harvest commenced at the end of July 2018 and was completed by end August. To determine the total fruit yield of the respective treatments, fruit from two trees within each treatment replicate row were harvested and total fruit yield was determined for each replicate in kg fruit per tree. A sample of 150 fruit from each treatment was measured using an electronic calliper. This allowed determination of the average fruit weight and fruit size distribution from each treatment.

Fruit quality

Fruit quality attributes, i.e. fruit size (diameter), total soluble solids (Brix°), titratable acidity (TA), and fruit juice content (%), were determined from 36 fruit within each treatment.

Fruit surface damage

Fruit surface damage evaluations were done at the time of commercial harvest in July 2018, on the same fruit that was used for fruit quality evaluations. All the fruit was examined for sunburn damage, light or severe wind damage, and any evidence of pest damage or chemical burn.

Statistical analysis

All collected data were statistically analysed, using appropriate statistical methods.

Results

Foliar spray deposition

For the January foliar spray deposition analysis, greater FPC% was observed on control leaves compared with the NPN treatment (8.8 and 6.1 FPC%, respectively), regardless of foliar spray volume (Table 1). Similarly, foliar spray volume had no influence on CV%, although it was significantly better on leaves in control trees, compared to trees covered with NPN (64.9 and 75.2 CV%, respectively) (Table 1).

Table 1. Effects of non-permanent netting (NPN) on deposition quantity (FPC%) and deposition uniformity (CV%) of foliar sprays on leaves of "Nadorcott" mandarin trees in January 2018

Treatments	FPC%	CV%
Control	8.8a ²	64.9b
NPN	6.1b	75.2a
P value	0.0055	0.0062

² Different letters in the same column denote significant differences between values at the 95% confidence level

The NPN treatment effect results on leaves in June showed that, irrespective of the foliar spray volume, significantly more fluorescent pigment was deposited on leaves of control trees compared to leaves of NPN trees (4.8 and 3.1 FPC%, respectively) (Table 2). Comparison of the CV% in trees from the different NPN (covered vs. open) treatments showed that CV% on leaves of control trees was better compared to leaves of NPN trees (59.6 vs. 80.5 CV%), irrespective of foliar spray volume (Table 2).

Table 2. Effects of non-permanent netting (NPN) on deposition quantity (FPC%) and deposition uniformity (CV%) of foliar sprays on the leaves of "Nadorcott" mandarin in June 2018

Treatments	FPC%	CV%
Control	4.8a ²	59.6a
NPN	3.1b	80.5b
P value	0.0035	0.0014

² Different letters in the same column denote significant differences between values at the 95% confidence level

The results obtained from fruit collected in June indicated that the 15 000 L.ha⁻¹ foliar spray volume resulted in the best FPC% on fruit at both horizontal canopy positions (inside = 16.9 FPC% vs. outside = 17.9 FPC%), irrespective of NPN treatment (covered or open) (Table 3). The 7 500 L.ha⁻¹ foliar spray volume resulted in an FPC% of 15.26 on fruit on the outside of the tree canopy, which was similar to the FPC% on fruit for the 15 000 L.ha⁻¹ foliar spray volume. However, on fruit on the inside of the tree canopy, the 7 500 L.ha⁻¹ foliar spray volume resulted in significantly poorer FPC% (10.14). The poorest FPC% on fruit resulted from the 3 500 L.ha⁻¹ foliar spray volume (inside = 9.3 FPC% and outside = 6.9 FPC%) (Table 3). The FPC% in the 3 500 L.ha⁻¹ foliar spray volume was similar on fruit in the control (8.8 FPC%) and NPN treatments (7.4 FPC%) (Table 3). For the 7 500 L.ha⁻¹ foliar spray volume, the FPC% values on fruit differed significantly between the control and NPN treatments. On the fruit from control trees, the FPC% was 19.3 and 6.1 on fruit from NPN treatments (Table 3). At the 15 000 L.ha⁻¹ foliar spray volume the FPC% on fruit was similar for NPN and control trees (15.3 vs. 19.5 FPC%). Results from the spray volume and NPN treatment interaction showed that the 15 000 L.ha⁻¹ foliar spray volume resulted in similar CV% on fruit from NPN and control trees (43.1 and 44.3 CV%) (Table 3). On fruit from control trees, the 7 500 L.ha⁻¹ foliar spray volume resulted in similar CV % compared to that obtained for the 15 000 L.ha⁻¹ foliar spray volume. However, in the NPN treatment, the 7 500 L.ha⁻¹ foliar spray volume resulted in the poorest (70.3 CV%) (Table 3). The 3500 L.ha⁻¹ foliar spray volume performed similarly to the 15 000 L.ha⁻¹ foliar spray volume in terms of CV%, for both NPN and control treatments (47.8 and 40.9 CV%) (Table 3).

Insect pest prevalence

Table 3. Mean deposition quantity (FPC%) and deposition uniformity (CV%) values for the significant foliar spray water volume × treatment interaction on the fruit from non-permanent netting (NPN), or control trees sprayed at either 15 000, 7 500 or 3 500 L.ha⁻¹ in June 2018

Foliar spray water volume (L.ha ⁻¹)	Treatments	FPC%	CV%
15 000	Control	19.5a ²	44.3b
	NPN	15.3a	43.1b
7 500	Control	19.3a	50.9b
	NPN	6.1b	70.3a
3 500	Control	8.8b	40.9b
	NPN	7.4b	47.8b
P value		0.0262	0.0484

² Different letters in the same column denote significant differences between values at the 95% confidence level.

The average number of weekly sterile FCM male catches in the control traps relative to the NPN treatments, was considerably high (Fig. 1A). A few sterile moths were caught in traps that were under the NPN (Fig. 1A). Trap catches of wild FCM were very low for the duration of the experiment. No wild FCM males were caught in the NPN treatments during the times when the netting was in place (Fig 1B). Wild FCM males were only caught in the control treatment and in one of the NPN treatments after the netting had been removed. Regarding fruit flies, the same pattern was repeated as for FCM with catches greatly reduced beneath the NPN (Fig. 1C).

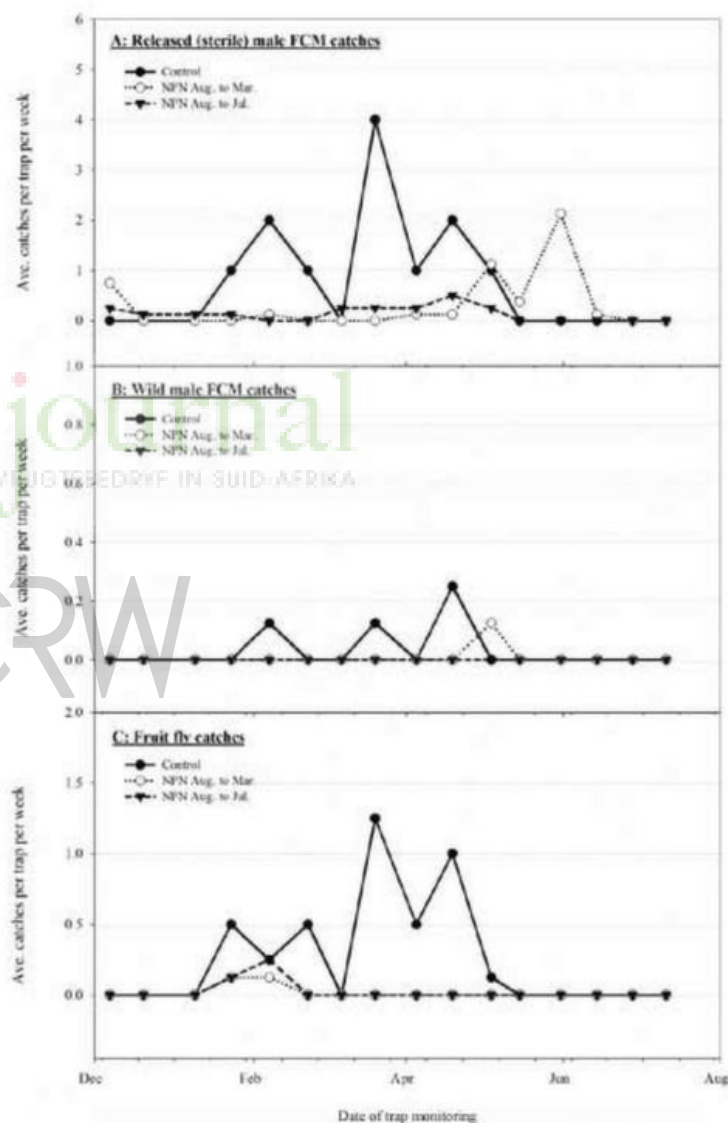


Fig. 1. The average number of a) released (sterile), male false codling moth (FCM) (*Thaumotobia leucotreta*), b) wild, male FCM, and c) fruit flies (*Ceratitidis capitata*) catches per trap per week for control and non-permanent netting (NPN) treatments from December 2017 to July 2018

Table 4. Effects of non-permanent netting (NPN) on leaf mineral nutrient concentration in March 2018

Treatments (n=8)	Leaf macronutrients concentration (mg·g ⁻¹ leaf DW)					
	N	P	K	Ca	Mg	
Control	31.1	2.0	12.3	37.1	3.1	
NPN	32.9	1.9	12.9	38.1	3.3	
P value	0.0516	0.7873	0.6653	0.7413	0.6545	
	Leaf micronutrients concentration (mg·kg ⁻¹ leaf DW)					
	Na	Mn	Zn	Fe	Cu	B
Control	387	132	40a ^z	277a	3.5	60
NPN	401	107	22b	156b	3.5	73
P value	0.7884	0.3623	0.0317	0.0041	1.0000	0.2109

^z Different letters in the same column denote significant differences between values at the 95% confidence level

Leaf mineral nutrient concentrations

There were no differences between the concentrations of any of the macronutrients N, phosphorous (P), potassium (K), calcium (Ca) and magnesium (Mg) in leaves of the control and the NPN treatment in March (Table 4). For micronutrients, the concentrations of zinc (Zn) and iron (Fe) were significantly greater (by 81 and 78%, respectively) in leaves of the control treatment compared with leaves of the NPN treatment (Table 4).

Fruit yield

In the NPN August to November and NPN August to March treatments, fruit yield (kg fruit per tree) and number of fruit per tree were significantly lower compared to the control and the NPN August to July treatments (Table 5). The NPN August to March treatment resulted in the lowest fruit yield (69 kg and 765 fruit per tree), but it did not differ significantly from fruit yield of the NPN August to November treatment (72 kg and 782 fruit per tree) (Table 5). The NPN August to July treatment resulted in the greatest fruit yield (102 kg and 1157 fruit per tree), but it did not differ significantly from fruit yield of the control (95 kg and 1112 fruit per tree) (Table 5). Fruit of the NPN treatments consisted of a greater amount of larger sized fruit (SC1 to SC1XX), whereas fruit in the control consisted of more smaller sized fruit (SC4 to SC 5) (Fig. 2).

Fruit quality

The NPN treatments had no significant effect on fruit rind colour, juice content and juice Brix°, compared to the control.

Table 5. Effects of different non-permanent netting (NPN) treatments on fruit yield of "Nadorcott" mandarin

Treatments (n=8)	Fruit yield	
	kg per tree	No per tree
Control	95a ^z	1112a
NPN August to November	72b	782b
PN August to March	69b	765b
NPN August to July	102a	1157a
P value	0.0008	0.0002

^z Different letters in the same column denote significant differences between values at the 95% confidence level

Fruit surface damage

Across all treatments, light wind damage was most common (42%), followed by undamaged or clean fruit (36%), and fruit showing severe wind damage (19%) (Fig. 3). When comparing the wind damage on fruit from inside the canopy, the percentage of light wind damage was greater for fruit from the control treatment compared to NPN treatments (Fig. 3). Inner canopy fruit in the NPN August to November treatment had the highest percentage of clean fruit and the lowest percentage of light wind damage, but also had the greatest percentage of severe wind damaged fruit (Fig. 3A). For the outer canopy fruit, the amount of fruit suffering wind damage, particularly in the severe wind damage category, was significantly greater than that of the inner canopy. The NPN August to July treatment showed an equal percentage of clean fruit to the NPN Aug. to Mar. treatment, but the percentage of severe wind damage was lower (Fig. 3B). The NPN August to November (22%) and the NPN August to March (21%) treatments resulted in similar fruit sunburn damage, compared to the control (27%) (Fig. 4). The longer NPN treatment (NPN August to July) resulted in significantly lower percentage of sunburned fruit compared to the control (9 vs. 27), but a similar percentage of sunburned fruit compared to the NPN Aug. to Mar. treatment (Fig. 4).

Conclusion

In general, the use of NPN in the production of "Nadorcott" mandarin reduced foliar spray deposition on leaves and fruit, resulting in lower concentrations of certain micronutrients in leaves. In trees where NPN was removed before July, yield was

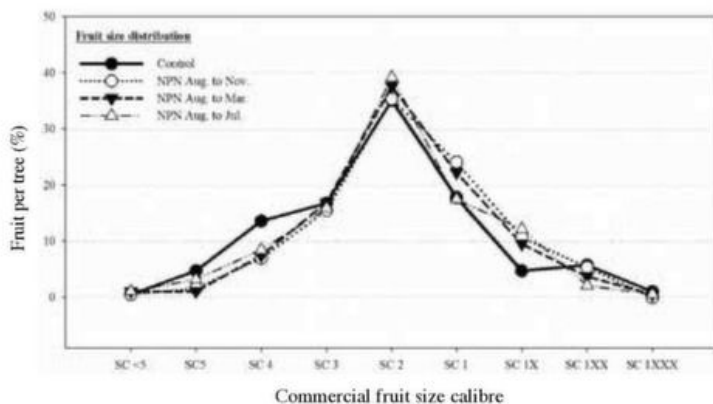


Fig. 2. Effects of different non-permanent netting (NPN) treatments on the distribution of different commercial fruit size calibres (SC) in the yield of "Nadorcott" mandarin

reduced by up to 37%, but a longer NPN treatment resulted in similar fruit yield compared to the control. The lower fruit yield in short NPN treatments was probably caused by fruit drop exacerbated by the physical removal of NPN. The use of NPN had no effect on commercial fruit quality attributes and where the NPN treatment was applied until fruit harvest, sunburn damage of fruit was reduced by 17%; outer canopy fruit suffered increased wind damage or scarring. Citrus growers in very windy areas should, therefore bear this in mind if considering making use of NPN. 🌸

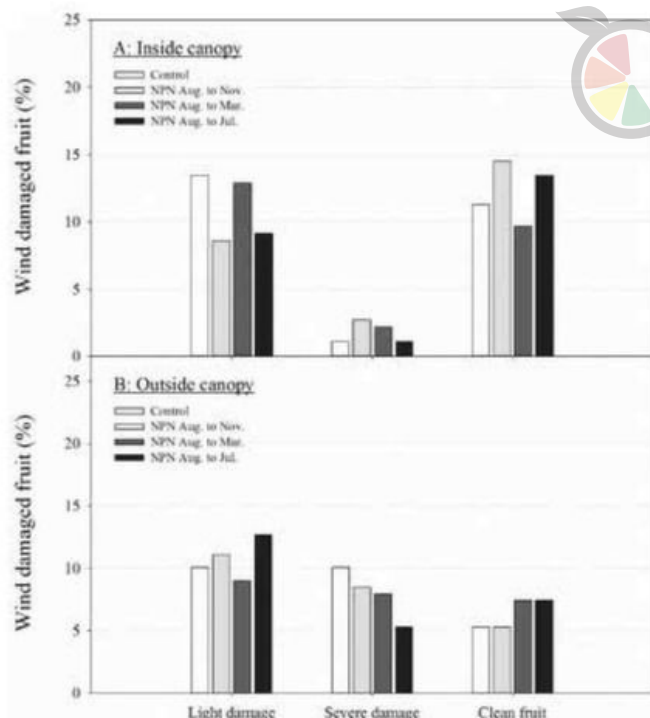


Fig. 3. Wind damage of fruit from all treatments a) inside and a) outside tree canopies of control and non-permanent netting (NPN) treatments at time of commercial harvest in July 2018

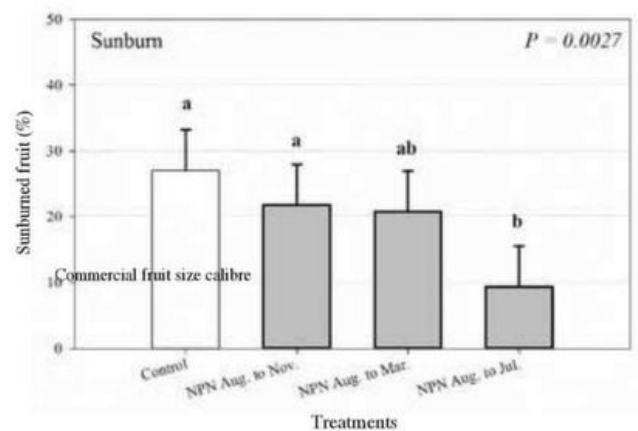


Fig. 4. Effects of different non-permanent netting (NPN) treatments on sunburn of "Nadorcott" mandarin fruit

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