Effect of Phosphonate Applications, for Phytophthora Brown Rot Control, on 'Nadorcott' Mandarin External Fruit Quality

Phosphonate foliar applications in the period prior to harvest are used in citrus production for the control of Phytophthora brown rot control. Several grower reports indicated that these applications caused phytotoxic damage on 'Nadorcott' mandarin fruit. Trials were conducted over two seasons (2016 and 2017) in two climatically different citrus production areas of South Africa. These trials consisted of ammonium and potassium phosphite foliar applications (at full dose or half dose) at green, colour break or full colour stages of fruit development. Results indicated that, regardless of the type of phosphonate or dosage applied, phytotoxic damage was observed at harvest if foliar applications were done at colour break or full colour stage of fruit development. The same results were observed in the different climatic areas. It is recommended that skirt pruning or foliar applications of registered contact fungicides be used to mitigate Phytophthora brown rot on 'Nadorcott' mandarin fruit.

Introduction

In South Africa, brown rot of fruit is primarily caused by *Phytophthora nicotianae* or *P. citrophthora* (Meitz-Hopkins et al., 2013). It is a disease that can severely reduce yield and/or fruit quality in the orchard or in the postharvest cold chain (Adaskaveg et al., 2015; Montenegro et al., 2008). The disease is especially severe in areas where rainfall occurs during the late stages of fruit development and maturation (Adaskaveg et al., 2015). Properly timed foliar applications with phosphonates have been shown to be an excellent preventative control measure for brown rot of citrus fruit as well as root rot caused by *Phytophthora* sp. (Graham, 2011).

However, an increasing number of reports were made by growers in cooler, winter rainfall, production areas of South Africa that they have experienced phytotoxic damage to mandarin fruit when they applied phosphonates at late fruit developmental stages when colour development was advanced. As these were the first reports of such damage on mandarin fruit, further investigation was warranted.

MATERIALS AND METHODS

Cultivar and trial sites

'Nadorcott' mandarin was used as all reports of phosphonate phytotoxic damage occurred on fruit of this cultivar. Different trial

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CONTINUED FROM PAGE 47 technology enabled citrus propagation material to be freed of viruses and other pathogens, thus opening the door to the use and importation of a wide range of highly productive disease-free cultivars and rootstocks.

The steps leading to Hannes's involvement in South Africa's soon-to-be named Citrus Improvement Programme were chronicled by Chet Roistacher when he came to South Africa to receive his Honorary Doctorate in 1999. He reminded those present that at the 6th International Conference of Citrus Virologists which South Africa hosted in 1972, our scientists were informed about the new STG technique being developed in California. Following a visit to California by Louis von Broembsen to view the technique in 1974, Hannes de Lange was appointed to take on the project of introducing it to South Africa.

He did this with resounding success and was awarded the Transvaal Agriculture Researcher of the Year prize in 1982 for his contribution. Hannes's remarkable achievement in painstakingly commercializing the delicate STG process has had a huge and lasting impact on the ongoing success of the SA citrus industry. In 1986 Hannes, being the true researcher he always was, moved on to the National Botanical Institute at Kirstenbosch where he established the tissue culture unit used for the preservation of endagered plant species.

Thereafter Hannes conducted an extensive study of threatened fynbos species and in 1992 was awarded a PhD by the University of Stellenbosch for his work on the embryology and ecology of these endangered species. This research has had worldwide recognition for, amongst others, unraveling the role of chemicals in veld fire smoke that aid seed germination.

Hannes initiated research into the production of Honeybush which led in 1999 to the establishment of the SA Honeybush Association. He was presented with four awards for his outstanding research contribution during this period.

Since his official retirement in 1999, Hannes has conducted contract research for different local and overseas entities to develop various selected South African plant species for pharmaceutical and other purposes. He is currently entering into a long-term project with the Rooibos industry for the genetic improvement of their propagation material.

Hannes has, throughout his career, shown himself to be a professional researcher in every sense. Dedicated, focused, yet disarmingly modest, he was always aware of the significance of the challenges we face and he has pursued his work with passion and intensity. His contribution to the citrus industry is immense and appreciated.

Foliar applications of phosphonates causes phytotoxicity on ‘Nadorcott’ mandarin fruit if done after colour break phase of fruit development.

Jan van Niekerk.

JAN VAN NIEKERK[1,2]*, CHARL KOTZE[1], JADE NORTH[1,3] AND PAUL CRONJE[1,3]

[1] Citrus Research International, PO Box 28, Nelspruit, 1200, South Africa

[2] Citrus Research International, Department of Plant Pathology, University of Stellenbosch, Private Bag X1, Matieland, 7602, South Africa

[3] Citrus Research International, Department of Horticultural Science, University of Stellenbosch, Private Bag X1, Matieland, 7602, South Africa

** Corresponding author e-mail address: janvn@cri.co.za*

sites were selected for this study to determine whether climatic conditions during fruit development played any role in the fruit’s susceptibility to phytotoxic damage or if it was related to this specific cultivar and product combination.

The first trial site (2016 and 2017) was located outside Nelspruit in the Mpumalanga province, which is characterized by little or no rain during the ‘Nadorcott’ harvest period in winter. In 2016, the second trial site was located at Riviersonderend in the Western Cape Province. This area is prone to rain, and therefore at a high risk for brown rot development, during the ‘Nadorcott’ harvest period. The second trial site in 2017 had similar climatic characteristics to Riviersonderend but was near Riebeek-Kasteel. The switch in trial site was necessitated due to a severe drought experienced at Riviersonderend in 2017.

Treatments

In the first season (2016), potassium phosphite {[555 g.L^{-1} a.i. (350 g.L^{-1} phosphorous acid equivalent)] and ammonium phosphite {[386 g.L^{-1} a.i. (300 g.L^{-1} phosphorous acid equivalent)] were applied according to label rates to treated trees. In the case of the potassium phosphite it was 570 mL/100 L water and for ammonium phosphite the rate was 666 mL/100 L water with trees sprayed from both sides to just before the point of run-off, approximately 10 L per tree. A motorized backpack mist blower was used for all applications in order to only spray single trees. The application times coincided with the immature green, colour break and full colour stages of fruit development. Treatments were the same at both sites while a single buffer tree was left between treatments.

In the second season (2017) the treatments at both sites were the same as applied in 2016. However, two additional treatments were added. Apart from the label dosages, both potassium phosphite and ammonium phosphite were also applied at half the recommended dosages, i.e. 285 mL/100 L water for potassium phosphite and 333 mL/100 L water for ammonium phosphite.

Evaluation of phytotoxicity

The incidence of the phytotoxic damage was documented as both percentage incidence as well as a phytotoxic index for each group of 40 fruit. This dual recording resulted in a better understanding of not only the incidence of damage per treatment, as expressed by mean percentage damaged fruit, but also the severity of the damage on the individual fruit as expressed as an index between 0 and 3, with 3 being the most severe damage.

RESULTS

Phytotoxic damage symptoms

At trial evaluation in both years similar symptoms of phytotoxic damage were observed on fruit sprayed with either potassium or ammonium phosphite. On fruit that was sprayed with these chemicals at colour break phase, the phytotoxic damage on the fruit rind manifested as dark brown lesions of variable sizes (Fig. 2 A-B). These lesions consisted of an area where the flavedo was damaged to such an extent that the white, underlying albedo was exposed. A green margin was furthermore observed to occur around the lesions (Fig. 2 A-B).

On fruit that was sprayed with the above-mentioned chemicals at the full colour developmental phase (Fig. 2 C-D), much more severe damage was observed of the fruit rind compared to fruit sprayed at the green stage (not shown). Again the lesions were of variable sizes but had the appearance of dark brown, sunken areas where the flavedo was damaged and the underlying albedo had a reddish brown colour (Fig. 2 C-D).

Percentage incidence and severity (PI) of phytotoxic damage

At both trial sites no damaged fruit was observed at harvest when potassium phosphite was sprayed at the green stage (Table 1; Fig. 1). Although not significantly higher compared to potassium

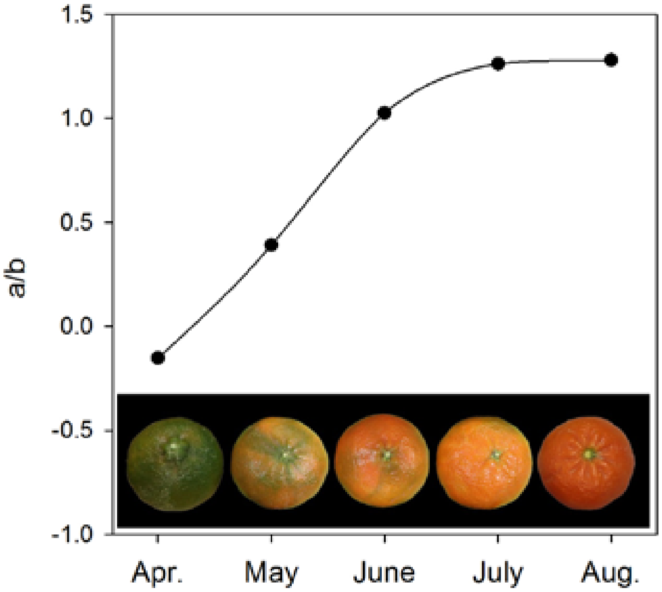

Fig. 1. *Graphic representations of the colour change in the 'Nadorcott' mandarin fruit at the various treatment application dates between April and August. Colour change is expressed as the Hunter a/b ratio.*

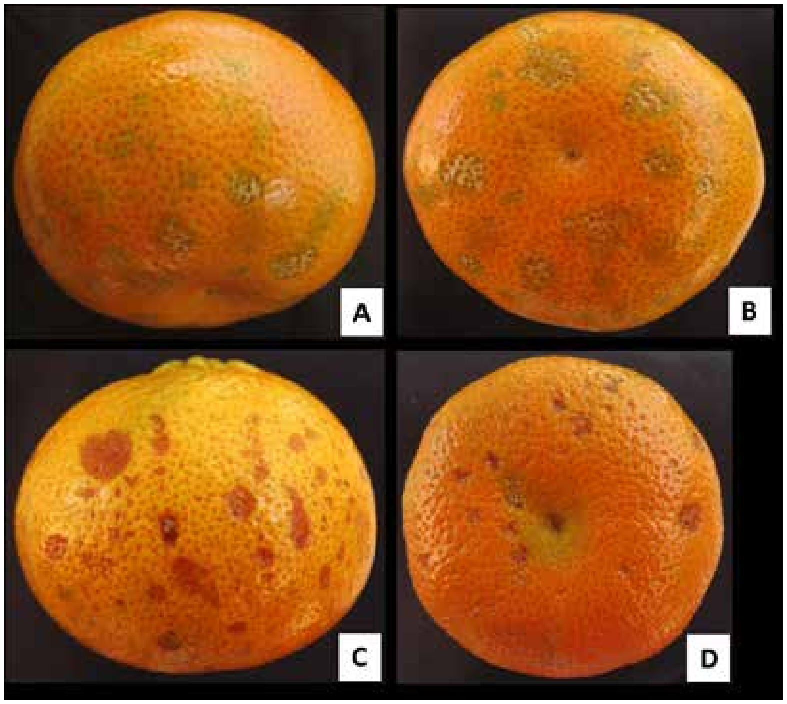

Fig. 2. *Phytotoxic damage caused on the rind of 'Nadorcott' mandarin fruit at harvest after potassium or ammonium phosphite applications (full or half dose) at colour break (A, B) or full colour (C, D) stage of fruit development.*

phosphite, 0.2% damaged fruit was observed at harvest, at both trial sites, on fruit sprayed with ammonium phosphite at the green stage. However, this was not significantly more than the unsprayed control (Table 1). For this application, the average PI on the 0.2% damaged fruit, was only 0.002 indicating that very slight damage had occurred (Table 1).

However, for fruit sprayed at the colour break stage, significant differences compared to the control were observed between the trial sites, irrespective of the chemical applied (Table 1). At the Riviersonderend trial site, no fruit were damaged by either of the chemicals when applied at the colour break stage. Compared to this, at the Nelspruit trial site, a mean percentage of 44.2% was damaged by potassium phosphite applications at colour break stage. The average PI of this fruit was 1.23 (Table 1). A mean percentage of 40% was damaged by ammonium phosphite applications at the same stage resulting in an average PI of 1.12 (Table 1).

The results obtained with applications at full colour again indicated significant differences between the areas and the two chemicals tested. At the Riviersonderend trial site 100.0% of fruit sprayed with potassium phosphite at this stage showed damage with a high PI of 2.36 (Table 1). This application in Nelspruit caused significantly less damage at 85.0% although the PI of 2.33 did not differ much from that observed at Riviersonderend (Table 1). The ammonium phosphite applications at the two sites resulted in statistically similar incidences of 93.3% in Riviersonderend and 95.0% in Nelspruit. Furthermore the PI of this application at the different sites were similar at 2.69 and 2.58 respectively and not in all cases notably more than the unsprayed control (Table 1).

Analysis of the 2017 data indicated that in terms of the incidence of damage observed, ammonium phosphite applications at half dose during the green phase, caused 1.7% fruit to show phytotoxic damage at harvest. However, the PI of this fruit was only 0.03 (Table 2) and the percentage damaged fruit was not significantly higher than the other chemical treatments or the unsprayed control where no damage was observed (Table 2).

At the colour break phase the potassium phosphite and ammonium phosphite applications, at full and half dosages, caused phytotoxic damage that was significantly more than the unsprayed control (Table 2). The full dose potassium phosphite application caused a mean percentage of damaged fruit of 59.2% that was, although not significant, more than potassium phosphite applied at half dose (40.0%) and ammonium phosphite (39.2%). The application with half dose ammonium phosphite caused a mean percentage of damaged fruit of 21. 7% that was statistically similar to the other treatments, except the full dose potassium phosphite application (Table 2). In terms of the severity, the most severe damage (PI 1.07) was also caused by the full dose potassium phosphite application. This was similar to the half dose potassium phosphite application (PI 0.70) and full dose ammonium phosphite application (PI 0.70). The latter two treatments did, however, not cause notably more severe damage than the half dose ammonium phosphite application [PI 0.33; (Table 2)].

Table 1. *Mean percentage (%) damaged fruit observed at harvest after potassium and ammonium phosphite treatments applied at the green, colour break and full colour stages of 'Nadorcott' mandarin fruit development in 2016 at the Riviersonderend and Nelspruit, South Africa, trial sites. Average Phytotoxic Index (PI) values are presented in parenthesis.*

Treatment	Riviersonderend			Nelspruit		
Color phase	Green	Colour break	Full colour	Green	Colour break	Full colour
	Mean percentage damaged fruit (Average PI)					
potassium phosphite	0.0 e[z] (0.000)[y]	0.0 e (0.000)	100a (2.358)	0.0 e (0.000)	44.2 d (1.229)	85 c (2.325)
ammonium phosphite	0.2e (0.002)	0.0 e (0.000)	93.3 b (2.692)	0.2 e (0.002)	40 d (1.121)	95 ab (2.575)
Unsprayed	0.0 e (0.000)	0.0 e (0.000)	0.0 e (0.000)	0.0 e (0.000)	0.0 e (0.000)	0.0 e (0.000)
LSD value	5.207					

[z]*Means with a different letter within a column differ significantly at the 5% level (Fisher's least significant difference)*

[y]*Average phytotoxic rating calculated per experimental unit of 40 fruit.*

Table 2. *Mean percentage (%) damaged fruit observed at harvest caused by full and half dose potassium and ammonium phosphite treatments applied at the green, colour break and full colour stages of 'Nadorcott' mandarin fruit development in 2017 at the Riebeek-Kasteel and Nelspruit, South Africa, trial sites. Average Phytotoxic Index (PI) values are presented in parentheses.*

Treatment	Colour phase		
	Green	Colour break	Full colour
	Mean percentage damaged fruit (Average PI)		
potassium phosphite (full dose)	0.00 fz (0.000)[y]	59.17 ab (1.067)	63.33 a (1.108)
potassium phosphite (half dose)	0.00 f (0.000)	40.00 bcd (0.696)	20.83 de (0.367)
ammonium phosphite (full dose)	0.00 f (0.000)	39.17 bcd (0.704)	52.50 ab (0.917)
ammonium phosphite (half dose)	1.67 ef (0.033)	21.67 cde (0.333)	41.67 bc (0.850)
Unsprayed	0.00 f (0.000)	0.00 f (0.000)	0.00 f (0.000)
LSD value	20.41		

[z]*Means with a different letter within a column differ significantly at the 5% level (Fisher's least significant difference)*

[y]*Average phytotoxic rating calculated per experimental unit of 40 fruit.*

Significant increased incidence of damage occurred in fruit in all treatments when applied at the full colour stage (Table 2). The highest incidence of damage was seen with the full dose of potassium phosphite applications, i.e. 63.3% and PI of 1.11. This percentage damage was statistically similar to the full dose ammonium phosphite applications (52.5%) with a PI of 1.11, which was markedly higher than the half dose treatments or untreated control treatment (Table 2). The half dose ammonium phosphite application had an incidence of 41.7% damaged fruit with a PI of 0.85. The half dose potassium phosphite application at colour break caused the least amount of damage with an incidence of 20.8% and PI of 0.37, both values significantly the lowest (Table 2).

Conclusions

Results from the current study, done over 2 years in climatically diverse production areas, clearly indicated that irrespective of application dosage (full or half), phytotoxic damage of 'Nadorcott' mandarin fruit occurred when potassium or ammonium phosphite foliar applications were done at either the colour break or full colour fruit developmental stage. Phosphonate applications therefore cannot be used as a means of brown rot control on late mandarin fruit from colour break stage of fruit development until harvest. Other measures such as skirting of trees or the foliar application of contact fungicides registered for *Phytophthora* brown rot control, should be employed to manage this disease in these cultivars. It is, however, still possible to use phosphonate foliar or trunk applications as part of a preventative management programme for root rot caused by *Phytophthora* sp. as these applications occur just after fruit set and during the immature green stage of fruit development (Le Roux, 2000).

Literature cited

Adaskaveg, J.E., W. Hao, and H. Förster. 2015. Postharvest strategies for managing *phytophthora* brown rot of citrus using potassium phosphite in combination with heat treatments. Plant Dis. 99:1477–1482.

Graham, J.H. 2011. Phosphite for control of *Phytophthora* diseases in citrus: Model for management of *Phytophthora* species on forest trees? N.Z. J. For. Sci. 41S:S49–S56.

Le Roux, H.F. 2000. Physiological interactions of phosphorous acid and control of root pathogens. Proc. Intl. Citricult. IX Congr., II: 926–928.

Meitz-Hopkins, J.C., M.C. Pretorius, C.F.J. Spies, L. Huisman, W.J. Botha, S.D. Langenhoven and A. McLeod. 2013. *Phytophthora* species distribution in South African citrus production regions. European J. Plant Pathol. DOI 10.1007/s10658-013-0346-9

Montenegro, D., O. Aguín, C. Pintos, M.J. Sainz and J.P. Mansilla. 2008. A selective PCR-based method for the identification of *Phytophthora hibernalis Carne*. Spanish J. Agr. Res. 6:78–84.