THE LEMON BORER MOTH = THE CITRUS FLOWER MOTH, *PRAYS CITRI:* Its biology and control on citrus

SEAN D. MOORE & WAYNE KIRKMAN *Citrus Research International, P.O. Box 20285, Humewood, 6013, South Africa*

ABSTRACT

It was confirmed that the citrus flower moth, *Prays citri,* is the pest which is primarily or even exclusively responsible for oviposition, superficial larval penetration, gumming and ultimately necrotic blotching on lemon fruit. It was also determined that the first generation of citrus flower moth in spring attacks lemon blossoms and it is the second generation that oviposits on fruit, leading to blemishing of fruit and possibly even crop reduction. Two species of parasitoids were recorded attacking citrus flower moth larvae. No clear relationship could be established between citrus flower moth trap catches, blossom infestation and fruit damage. Further research is therefore required in order to determine whether an intervention threshold can be established. Spray trials conducted during three different seasons confirmed that sprays should be directed against the first generation of larvae infesting blossoms, in order to prevent or reduce fruit damage by the ensuing generation. DiPel *(Bacillus thuringiensis)* worked adequately well to be regarded as a product of choice, particularly due to its IPM-compatibility.

OPSOMMING

Sitrusblommot, *Prays citri,* is bevestig as die plaag op suurlemoenvrugte wat hoofsaaklik of selfs uitsluitlik verantwoordelik is vir eierlegging, oppervlakkige larwale penetrasie, gomafskeiding en uiteindelik nekrotiese letsels. Dit is ook bepaal dat die eerste generasie sitrusblommot die suurlemoenblomme in die lente aanval en dat die tweede generasie hul eiers op die vrugte lê, wat tot beskadiging van die vrugte en selfs moontlike oesvermindering lei. Twee parasiet spesies wat sitrusblommot aanval is gevind. Geen duidelike verhouding kon tussen sitrusblommot lokvalvangstes, blombesmetting en vrugskade vasgestel word nie. Daar is dus 'n behoefte vir verdere navorsing om te bepaal of 'n intervensie-drempelwaarde ontwikkel kan word. Spuitproewe wat gedurende drie verskillende seisoene toegedien is, het bevestig dat bespuitings gemik moet word teen die eerste generasie larwes wat die blomme besmet, om vrugskade deur die daaropvolgende generasie te verhoed of verminder. DiPel (*Bacillus thuringiensis)* se werking was doeltreffend genoeg om as die voorkeur produk beskou te word, veral omdat dit "IPM"-verenigbaar is.

INTRODUCTION

The presence of the citrus flower moth, *Prays citri* (Millière) (Lepidoptera: Yponomeutidae) in South Africa has been recognised since 1915 (Van den Berg, 1998). It has been recorded as a pest of citrus for at least several decades (Annecke & Moran, 1982; Kamburov, 1986). However, it has always been considered as a sporadic or minor pest and consequently nothing has been registered to date for its control on citrus in South Africa (Van den Berg, 1998). It generally only attacks lemons and limes, but occasionally other citrus cultivars too (Moore, 2012). Traditionally, citrus flower moth damage is to the blossoms and young fruit in spring and mid-summer. The adult female moth will lay her eggs on blossoms and the larvae will eat into the flower organs (Fig. 1) and web them together before pupation (Fig. 2). Damaged flower buds and flowers quickly wilt and are shed. However, since 2000/2001 necrotic blotches have been observed on lemon fruit (Moore, 2003). These have been associated with larvae hatching out of moth eggs laid on the fruit when they are still very small and superficial penetration of the fruit by these neonate larvae, leading to gumming of the fruit (Fig. 3). These penetration marks are initially fairly small, but once the fruit matures, they appear as brown necrotic scars, which can lead to the fruit being downgraded (Fig. 4). Severe levels of infestation have even been reported to cause substantial fruit drop and a reduction in the crop (Moore, 2003). This damage was originally associated with *Cryptoblabes gnidiella* (Milliere) (Lepidoptera: Pyralidae) which was referred to as the lemon borer moth, as this species was recorded on lemons in the presence of the damage described (Moore, 2003). However, subsequent investigations have revealed that this association may have been erroneous, based on the incidental occurrence of *C. gnidiella* in lemon orchards, and that the citrus flower moth appears to be the main or even exclusive culprit.

Here we report on the identification of the pest responsible for the damage to fruit, monitoring of the citrus flower moth and trials conducted to control the citrus flower moth on lemons in the Eastern Cape Province. Finally, we provide guidelines on how to best deal with the pest.

MATERIALS AND METHODS

Identification

During spring of the 2003/04 season, three Eureka lemon orchards in Sundays River Valley, Eastern Cape, with signs of lepidopteran presence were identified. These were on Fedwin (33°29'46"S 25°29'46"E), Woodridge (33°28'23"S 25°41'06"E) and Blaartjiebrug (33°37'42"S 25°42'21"E) farms. Lepidopteran presence was defined as the occurrence of larvae, pupae or eggs on fruit or blossoms. On 29 October 2003 one bucket (IPS) trap was

FIGURE 1. *A citrus flower moth larva eating into a lemon blossom.*

FIGURE 2. *Lemon blossoms damaged by citrus flower moth larvae – wilted and webbed together.*

hung in each of the three orchards. A *C. gnidiella* pheromone dispenser (Yogev, Israel) was inserted into the lid of each trap. Traps were erected in the third tree of the third row on the southern side of each orchard. As the prevailing wind direction was south-easterly or south-westerly, the pheromone could be carried by the wind into the orchard, and detected by any male moths in the orchard. Traps were checked weekly on the same day for a period of 6 weeks (i.e. from 29 October to 10 December 2003). Pheromone dispensers were replaced every three weeks. Simultaneously, inspections of fruit and blossoms were conducted for the presence of lepidopteran larvae and eggs. Samples of larvae and eggs were collected. These were reared to adulthood on artificial diet (Moore *et al.,* 2014) and identified. Samples of larvae causing similar damage in the Western Cape were also collected for identification.

Monitoring

During spring of the 2004/05 season, two Eureka lemon orchards on Carden Farm (33°28'13"S 25°41'23"E) in Sundays River Valley which had a history of citrus flower moth infestation were identified. On 1 October 2004 one bucket (IPS) trap was hung in each of the two orchards. A citrus flower moth pheromone dispenser (Insect Science, South Africa) was inserted into the lid of each trap. Traps were erected a few trees within the orchard on the southern (upwind) side. Dispensers were changed every 4-5 weeks. Traps were checked weekly on the same day for a period of 7 weeks (i.e. from 8 October to 17 November 2004). Simultaneously, inspections of blossoms and fruit were conducted for the presence of lepidopteran larvae and eggs.

Monitoring was repeated in 2008 in a similar fashion in three other Eureka lemon orchards in Sundays River Valley (Blaartjiebrug Farm; Lone Tree Farm (33°31'59"S 25°41'48"E); and Siyatemba Farm (33°30'15"S 25°39'59"E)). The only difference was that Delta traps rather than bucket traps were used with the citrus flower moth lure. Traps were hung on 8 October and were checked weekly for 14 weeks until 19 January 2009.

After checking traps and removing moths from the traps, blossoms were inspected for larval and pupal infestation. This was done on 10 blossom clusters on 10 data trees in each orchard. This was continued for 3-4 weeks until all blossoms had dropped off. Once all blossoms had dropped off, inspections were conducted on fruit instead. These inspections were for eggs and gumming – penetration marks of neonate larvae. This was done in order to determine whether there was a relationship between trap catches and infestation or damage.

Control

Three chemical control trials were conducted. The first was targeted against eggs on fruit and the second and third were targeted against larvae on blossoms – all orchards were conspicuously infested at the time of application. All orchards were Eureka lemon, planted in 1998 and spaced at 6 m x 4 m (rows x trees) apart. All sprays were applied as diffuse medium cover sprays.

The first trial was conducted on Woodridge Farm (33°28'23"S 25°41'06"E) in the Sundays River Valley. Two replicates of each of 6 treatments were applied to randomly laid out blocks of five trees each. Treatments were Mevinphos 150 g/L EC (65 ml); Agrimec 18 g/L EC (abamectin, 10 ml) and BP medium oil (0.3%); Alsystin 480 g/L (triflumuron, 10 ml); BP medium oil (two concentrations: 0.3% and 0.8%) and DiPel DF 32000 IU/mg (*Bacillus thuringiensis,* 12.5 g) (all rates are per 100 L water). Untreated trees were retained as control blocks. Sprays were applied on 24 November 2003 with hand held spray guns at 7 L/tree. The efficacy of the treatments was evaluated on 10 December 2003. Ten fruit of similar size were

FIGURE 3. *Gumming from a lemon in response to penetration by a citrus flower moth larva.*

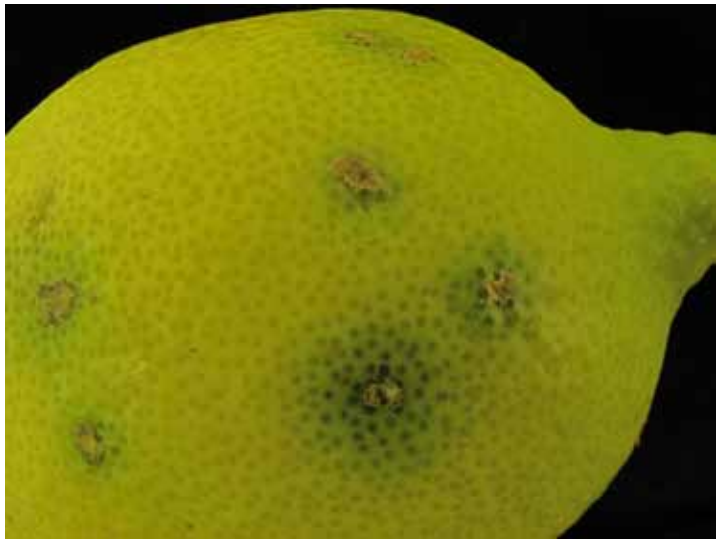

PHOTO BY PETER STEPHEN, CRI.

FIGURE 4. *Brown necrotic lesions on a lemon fruit each caused by penetration by a citrus flower moth larva when the fruit was young*

randomly picked from the three centre trees in each block. Fruit were taken back to the laboratory and microscopically inspected for eggs and blemishes (gumming spots).

The second trial was conducted on Carden Farm. In this trial, larger blocks of 112 trees (i.e. four rows of 28 trees) were used. Two treatments were applied: Phosdrin 500 g/L SL (mevinphos, 30 ml) plus Agral 90 (18 ml); and DiPel (12.5 g) also with the same dose of Agral 90 (all rates per 100 L water). Sprays were applied on 9 November 2004, more than two weeks earlier than treatments had been applied in the previous year. Sprays were applied at 8.9 L of spray mix per tree using an oscillating tower mist-blower. The efficacy of the treatments was evaluated on 17 November 2004 by scouting each of 10 trees in the middle of each treatment block for larvae and pupae. Each tree was scrutinised for exactly 3 minutes. Evaluation of fruit damage was conducted on 1 December 2004 by selectively picking 100 spring-set fruit from each treatment. Fruit were then carefully inspected with the aid of a magnifying head-loop and all eggs and penetration marks recorded.

The third trial was conducted on Blaartjiebrug Farm. A large section of the orchard was split into 4 quarters, each consisting of 8 rows with 16 trees in each row. A different treatment was applied to three of the quarters using a mistblower, and the last quarter was used as an untreated control. Sprays were applied at 8 L per tree on 27 October 2008. The treatments were Mevinphos (100 ml); Ultracide 420 g/L EC (methidathion, 150 ml) plus Agral 90 (18 ml); and DiPel (12.5 g) plus Comodobuff (50 ml). Although Ultracide is known to be one of the least effective organophosphates against Lepidoptera, it was included in the trial, due to its common usage in the region against other pests (e.g. mealybug and citrus thrips) at that time of year. However, since 2008, this product is no longer commonly used as a result of more stringent residue restrictions. Efficacy of treatments was evaluated on 30 October and again on 6 November 2008. This was done by inspecting 10 blossom clusters on each of 10 trees positioned in the middle of each treatment block.

No statistical analyses were conducted on the data from the first two trials. Results from the third trial were compared using ANOVA and the Bonferroni multiple range test to compare mean values (Statistical Graphics Corporation, 2001).

RESULTS AND DISCUSSION

Identification

No moths were caught in any of the traps during the 6 week monitoring period (i.e. from 29 October to 10 December 2003) when using the *C. gnidiella* pheromone dispenser, despite the conspicuous presence of larvae and pupae on blossom and fruitlet clusters and eggs on fruit. The identification of the moths previously observed was therefore brought into question. Samples of larvae and pupae, collected from the orchards were reared to adulthood and all were identified as the citrus flower moth, *Prays citri* (by Martin Krüger of the Transvaal Museum).

Thirty percent of larvae collected from a Nadorcott orchard in the Western Cape were parasitised by *Apanteles* sp.. As the larvae were collected early in the season (i.e. 17 October 2003), this is considered to be a very impressive level of parasitism. No parasitism was found in the Eastern Cape during this particular survey. However, on a later occasion, a *Brachymeria* sp. was identified (by Janine Kelly of the Agricultural Research Council) parasitizing citrus flower moth larvae.

Monitoring

During October and November of 2004, high numbers of citrus flower moths were caught in the bucket traps in lemon orchards. Moths caught per trap per week ranged from 51 to 301 in one orchard and 11 to 119 in the other orchard, over an eight week period (8 October to 17 November). However, larvae were

only observed on blossoms for the first time on 29 October. During the following week, larval and pupal numbers had increased but remained relatively low. There therefore appears to be a notable lag-time between the first high catches of moths and conspicuous larval infestation of fruitlets. On 1 December only 1.9% of fruit had any citrus flower moth eggs on them and only 0.89% of fruit showed any gumming (from larval penetration).

In 2008, from 13 October to 6 November (four weeks), moths caught per delta trap per week peaked at 45 at Blaartjiebrug Farm, 111 at Lone Tree Farm and 22 at Siyatemba Farm. During this time, infestation of blossom clusters by citrus flower moth larvae and pupae, peaked at 27% at Blaartjiebrug, 2% at Lone Tree and 3% at Siyatemba. No signs of eggs or gumming (larval penetration) on fruit were recorded at Lone Tree and Siyatemba Farms on any of the weeks that inspections were conducted from 6 November 2008 to 19 January 2009. At Blaartjebrug Farm where infestation of blossoms was slightly higher, some eggs and gumming were noted (on 10 December and thereafter) on a small percentage of out of season (slightly larger) fruit on trees adjacent to a windbreak. However, this was not observed on small fruitlets within the orchard.

As trapping for citrus flower moth over the two seasons was conducted with different trap types in each season, it is not yet possible to say what level of catches would lead to unacceptable fruit damage. Additionally, both blossom infestation and fruit damage were extremely low during the two seasons, despite trap catches being considered as very high, particularly during 2004. Far more work (several seasons where varying pest and damage levels are recorded) is required in order to establish reliable relationships between trap catches, blossom infestation and fruit damage and thus determine thresholds for intervention (control measures).

Control

In the first trial, all treatments resulted in some reduction in numbers of eggs per fruit (Fig. 5). Not surprisingly, Alsystin was the most effective treatment in reducing egg numbers (by 59%), as it was the only specific ovicide used. All treatments also reduced damage to the fruit (by up to 63%) (Fig. 5). Surprisingly, less damage was recorded on fruit sprayed with 0.3% oil than with 0.8% oil. As it was determined that it was the second generation of moths that caused damage to fruitlets, sprays were applied a lot earlier in the second trial, being targeted against larvae on blossoms (i.e. the first generation). Larval and pupal infestation of fruitlets was markedly lower on both Phosdrin (95.6%) and Dipel (78.3%) treated trees than on untreated trees (Fig. 6), although, infestation was not particularly high.

Surprisingly, reduction in eggs and penetration marks per fruit was not dramatic (Fig. 6). During the previous year's trial, Mevinphos and Dipel sprays reduced egg numbers by 39% and 22%, respectively. Numbers of penetration marks were reduced by 38% and 40%, respectively. During this trial in 2004, Mevinphos and Dipel reduced egg numbers by 36% and 35%, respectively. Numbers of penetration marks were reduced by 36% and 48%, respectively. Therefore, even though sprays were applied earlier than during the previous trial (i.e. targeted against larvae of the first generation rather than eggs of the second generation) and treatments were applied to larger blocks than during the previous trial, results were not better.

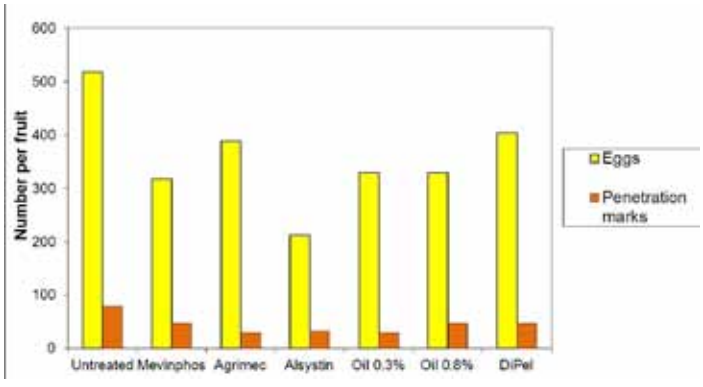

FIGURE 5. *Citrus flower moth eggs and damage on lemon fruit (on 10 December 2003) at Woodridge Farm after various treatments (applied 29 October 2003).*

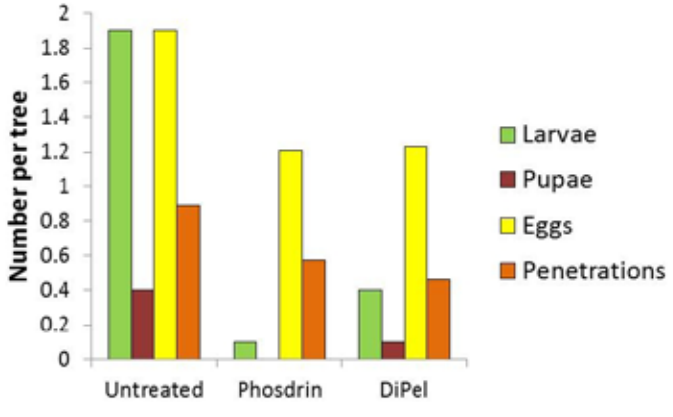

FIGURE 6. *Citrus flower moth larvae and pupae per tree eight days after spraying two treatments (on 9 November 2004) at Carden Farm and eggs and damage on lemon fruit 22 days after spraying.*

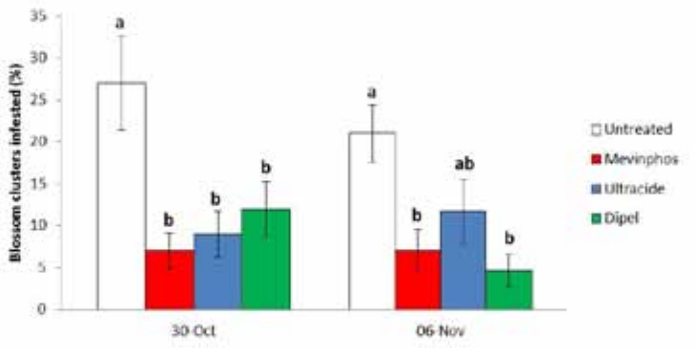

FIGURE 7. *Citrus flower moth infestation of lemon blossom clusters after various treatments, applied on 27 October 2008 on Blaartjiebrug Farm.*

It is therefore possible that sprays should have been applied even earlier than was the case in this trial (even though larvae were not yet evident). This would imply that pheromone traps might be of use in the earlier timing of sprays against peaks in moth catches. It is also possible that sprays should have been applied to even bigger blocks (i.e. wider than four rows) in order to experience the full potential impact of the spray.

Larvae could also acquire some protection from flowers and foliage, particularly when webbing them together. As both mevinphos and DiPel are short residual products, this phenomenon would be exacerbated. Results might therefore be better with longer residual products, such as chlorpyrifos, which is known to be an effective lepidoptericide. It can also be concluded that good penetration of sprays is important in countering the protection which larvae experience within the webbed-together blossom clusters.

In the third trial, within three days after spraying, all three treatments had significantly reduced infestation (Fig. 7). There was no significant difference in efficacy between the treatments. A week later, infestation in the Ultracide treated block was no longer significantly different from the untreated control. At this stage, infestation in the DiPel treatment was the lowest (72.2% reduction). Being the most IPM-compatible of the products tested, this was encouraging. From the first to the second evaluation (7 days) there had been no decline in infestation for the two chemical treatments. However, infestation in the untreated control and where DiPel had been applied had declined markedly.

The ultimate test of the efficacy of these treatments would have been the measurement of impact on the ensuing generation i.e. reduction in egg laying and larval penetration of fruit. However, no second generation activity was observed, even in the untreated control.

CONCLUSION *(including recommendations)*

Despite earlier conclusive reports that *Cryptoblabes gnidiella* (amongst other lepidopteran species) infested lemon orchards where blossom and fruit damage was recorded (Moore, 2003), it appears that the primary or even sole culprit responsible for this damage is the citrus flower moth, *Prays citri.*

It appears that if the first generation of citrus flower moth, which develops on the blossoms and pupates among webbed clusters, survives and remains in the orchard, the second generation of moths will lay their eggs on the young fruitlets once there are no more blossoms on the lemon trees. Larvae will always hatch through the lower surface of the egg that is attached to the fruit, leading to immediate penetration into the fruit. Penetration is never successful i.e. the larva always dies in the process. However, the damage to the fruit remains and as the fruit develops to maturity, these penetration marks appear as necrotic blotches on the fruit.

It is not clear why this second generation would attack the fruit in a manner which has rarely if ever before been observed in lemon orchards in South Africa and why this behaviour now seems to have become the norm, particularly in the Eastern Cape and to a lesser extent in the Western Cape. It may be related to size of the first generation attacking the blossoms, the pesticide programme used (or not used) or a demise in parasitism levels. Similar damage has been reported to occasionally be associated with citrus flower moth on non-lemon citrus varieties in Reunion (Serge Quilici, pers. comm.).

It is therefore important for farmers to monitor the presence of larvae on their lemon blossoms and if infestation levels are unacceptably high, to apply a spray. Pheromone-baited traps can be used to assist with this monitoring but unfortunately no intervention thresholds have been established yet, so the definition of "unacceptably high" is still unclear. There is also no threshold for infestation on blossoms to indicate that damage to fruit by the ensuing generation would occur. Such a study must still be conducted.

It is fortunate that a soft product like DiPel *(Bacillus thuringiensis)* is adequately effective in controlling larvae infesting blossoms. This product (or products with this active ingredient) should be registered against citrus flower moth. Other products, which might be applied at around that time for control of citrus thrips or mealybug (such as organophosphates or pyrethroids) will also control or suppress any citrus flower moth larvae present. Growers must ensure that sprays are applied against this generation and not only once egg laying on fruit is observed. Sprays should also be applied in a manner that allows good penetration and coverage, to counter the protection that larvae can enjoy from the webbed-together blossoms.

Celebrating and developing citrus expertise at CRI

T G GROUT

During the latter part of 2013, certain staff members at Citrus Research International passed some significant milestones of service to the citrus industry. The Extension Manager, Dr Hennie le Roux reached 30 years' service and the bookkeeper Bella Thulare achieved 25 years' service. Dr Fanie van Vuuren, who was employed by CRI on a contract basis after he was supposed to have retired, has now continued his citrus virology research for another 10 years! Dr Paul Cronje, who has recently made some breakthroughs in rind condition research passed his 10 year milestone and Wayne Kirkman who is investigating techniques to detect insect larvae in citrus fruit, has also served the citrus industry for 10 years. MC Pretorius recently took up a third regional Extension coordinator position and the position he vacated in soilborne disease management was filled by Dr Jan van Niekerk from Westfalia in January 2014. The busy CRI Diagnostic Centre at Nelspruit was also strengthened with the appointment of Bheki Cele from SASRI in a Technician position.

Dr Hennie le Roux has now been serving the citrus industry for more than 30 years.

REFERENCES

Annecke, D.P. & Moran, V.C. 1982. *Insects and mites of cultivated plants in South Africa.* Butterworth & Co., Durban. 383 pp.

Kamburov, S.S. 1986. New pests and beneficial insects on citrus in South Africa Part I. *Citrus and Subtropical Fruit Journal,* 625: 6-7, 9-11.

Moore, S.D. 2012. Citrus flower moth (Chapter 3.9.3). In: *Integrated Production Guidelines, Vol III: Integrated pest and disease management.* Ed. T.G. Grout. Citrus Research International, South Africa.

Moore, S.D., Richards, G.I., Chambers. C. & Hendry, D. 2014. An improved larval diet for commercial mass rearing of the false codling moth, *Thaumatotibia leucotreta* (Meyrick) (Lepidoptera: Tortricidae). *African Entomology* 22(1): In press.

Moore, SD. 2003. The lemon borer moth: a new citrus pest in South Africa. *SA Fruit Journal* 2(5): 37-41.

Statistical Graphics Corporation, 2001. *Statgraphics Plus for Windows Version 5.1.* STSC Inc., Rockville, MD.

Van den Berg, M.A. 1998. Citrus flower moth *Prays citri* (Millière). pp. 189-190. In: *Citrus pests in the Republic of South Africa.* Second edition. Eds. E.C.G. Bedford, M.A. van den Berg and E.A. de Villiers. Agricultural Research Council, South Africa.

Linda Grobler Vereer

'n Groot eer het Linda Grobler van Boshoek te beurt geval toe sy aangewys is as naaswenner van die Departement van Landbou se *"Female Entrepreneur Awards 2013 for Harnessing Women's Talent for Sustainable Food Security ~ A Vision Beyond 2030"* vir die Noordwesprovinsie. Sy is deur 'n groep afgevaardigdes van verskeie sektore geëvalueer vir haar insette in Witkrans Sitrus Boerdery en Witkrans Sitrus Kwekery. Sy het die toekenning ontvang op grond van haar boerderyvaardigheid, kundigheid en prestasie. Die toekenning is op 16 Augustus 2013 in Mafikeng deur die Minister van Landbou vir Noordwes, Gugile Nkwinti, Premier Thandi Modise en die LUR Desbo Mohono oorhandig. Die Sitrus kwekerybedryf van Suider-Afrika wil hiermee vir Linda baie gelukwens.