Efficacy of insecticides for control of non-persistently transmitted viruses

Important non-persistently transmitted viruses affecting vegetables

Non-persistently transmitted viruses are the most common type of viruses affecting vegetable crops. Non-persistently transmitted means the insect vectors can spread the virus immediately after feeding on an infected plant but only for a few minutes. The most common of these viruses affecting vegetable crops are spread by aphids.

Almost all these viruses are potyviruses. This includes potyviruses causing mosaic in zucchini (papaya ringspot virus, zucchini yellow mosaic virus and watermelon mosaic virus), lettuce mosaic virus, turnip mosaic virus potato virus Y and carrot virus Y.

Turnip mosaic virus in Chinese cabbage

Horticultural mineral oils

Horticultural mineral oils have consistently demonstrated efficacy for reducing non-persistent virus spread, though they appear ineffective against persistent viruses. Their use has been reviewed by Al-Mrabeh et al. (2010), Yang et al. (2019) and Rolot et al. (2021). Rolot et al. (2021) assessed multiple treatments for control of potato virus Y (PVY) in field trials and concluded that oils, in particular mineral oil, were the only effective treatments. Insecticides were only effective if mixed with mineral oil.

Oils reduce transmission in several ways, reviewed by Al-Mrabeh et al. (2010), Yang et al. (2019) and Rolot et al. (2021): as well as killing the insect vectors and reducing their probing activities, oils interfere with the binding of the virus particles within the stylets and mask the volatile emissions of plants, reducing the ability of insect vectors to locate them. They also induce plant defences such that infection is impeded even if a virus is transmitted.

Al-Mrabeh et al. (2010) specified characteristics of the most effective mineral oils, and methods of application. Mineral oils are more effective than other oil types. For example, in field trials in potato crops, rapeseed oil provided a lower level of protection against PVY than mineral oil (Rolot et al., 2021). Likewise, comparing three oil types applied in combination with imidacloprid (applied at planting), mineral oil was the most effective (Martin-Lopez et al., 2006). This treatment resulted in a 59% reduction in PVY infected plants compared with imidacloprid alone, whereas rapeseed oil resulted in a 41% reduction, and soya oil was ineffective. Recommendations regarding frequency of application of oils vary. In their review Yang et al. (2019) stated that they need to be reapplied frequently, but MacKenzie et al. (2014) and MacKenzie et al. (2017) found that early application was more important than increasing the number of sprays applied. Al-Mrabeh et al. (2010) stated that frequency should be sufficient to provide continuous coverage as plants grow but noted that this varied between studies.

The efficacy of oils can be increased by combining them with other crop protection methods. Boiteau et al. (2009) found combining oils with a crop border (oil applied either to the border, the crop or both) was almost twice as effective as either an oil application or border alone. Dupuis et al. (2017) found the combination of a mineral oil plus straw mulching was more effective than either treatment, reducing PVY incidence by 59%, compared to 43% for mineral oil and 27% for straw mulching. Likewise, Rolot et al. (2021) found straw mulching increased protection in crops treated with oil and may have reduced the number of oil sprays required. However, Kirchner et al. (2014) found that combining mineral oil and straw mulch did not reduce PVY incidence further than mulch alone.

Papaya ringspot virus in zucchini

Al-Mrabeh et al. (2010) listed several studies showing that control of virus transmission was enhanced when an oil was mixed with an insecticide (mainly pyrethroids). More recently, Lowery et al. (1990) found that combining an oil with cypermethrin allowed a lower concentration of oil to be used for control of turnip mosaic virus (TuMV) in field trials. MacKenzie et al. (2014), MacKenzie et al. (2016) and MacKenzie et al. (2017) analysed the effect of various management practices on PVY spread in potato crops. They found that although mineral oil alone was effective, efficacy was increased when combined with an insecticide, particularly lambda-cyhalothrin or flonicamid. The insecticide treatments alone were largely ineffective (MacKenzie et al., 2017). However, Rolot et al. (2021) found that applications of systemic insecticides plus mineral oil only improved control of PVY when winged aphid activity was high.

Synthetic pyrethroids

Synthetic pyrethroids (insecticide group 3A) have been most successful when mixed with oils, with less evidence of efficacy when applied alone. Their use for management of non-persistent viruses has been comprehensively reviewed by Perring et al. (1999) and Al-Mrabeh et al. (2010). Laboratory studies reported reduced probing and inhibition of virus transmission, due in part to rapid knockdown, causing the vector to lose the virus before it could be transmitted, as well as repellent effects. These authors also reviewed field studies, with some reporting reduced transmission, but others increased virus spread due to increased vector activity caused by the repellent effect of pyrethroids. More recently, in laboratory trials Fenton et al. (2015) found that lambda-cyhalothrin applied to PVY infected plants significantly inhibited susceptible aphids from transmitting the virus to untreated, uninfected plants, by disorienting them for long enough to lose transmissibility. Boquel et al. (2015) found that lambda-cyhalothrin reduced the number of aphids that remained on the leaf and probed, and significantly decreased acquisition of PVY in *Rhopalosiphum padi*, but not in *Macrosiphum euphorbiae* or *Aphis fabae*. However, Samara et al. (2021) found that although lambda-cyhalothrin decreased probing, it had no significant effect on transmission of TuMV. Likewise, Lowery et al. (1990) found that cypermethrin reduced infection with TuMV by only 30% compared with untreated plants in laboratory trials. In field trials, Dupuis et al. (2014) found that although lambda-cyhalothrin effectively controlled aphids and had a statistically significant effect on spread of PVY, the 10% reduction was too low to be useful. Likewise, Lowery et al. (1990) found lambda-cyhalothrin resulted in only a moderate reduction in incidence of TuMV, and cypermethrin was not effective. Other studies have found no evidence of reduced transmission of PVY in field trials with pyrethroids alone (van Toor et al., 2009, MacKenzie et al., 2017, Rolot et al., 2021).

Neonicotinoids

Neonicotinoids (insecticide group 4A) have been considered for virus management due to their efficacy against virus vectors, but there is little evidence that they reduce transmission of non-persistent viruses. Samara et al. (2021) found that although acetamiprid affected aphid feeding behaviour, it did not reduce probing significantly during the first five minutes and did not significantly reduce transmission of TuMV. Likewise, Collar et al. (1997) and Boquel et al. (2015) found little to no effect of imidacloprid on aphid probing behaviour and no effect on PVY transmission. Boiteau and Singh (1999) and Davis and Radcliffe (2007) demonstrated good control of aphids with imidacloprid or thiamethoxam, respectively, but treatments had no effect on PVY. Alyokhin et al. (2002) found a significant decrease in viral transmission in plots treated with foliar-applied imidacloprid, but infection was still unacceptably high; in-furrow applications had no effect. Nolte et al. (2009) reported that preliminary research found that imidacloprid and clothianidin reduced PVY transmission, but no follow-up trials could be found in this literature search. van Toor et al. (2009) found that seed treatment with imidacloprid did not decrease PVY infection, either alone or in combination with foliar applied methamidophos or lambda-cyhalothrin, despite good control of aphids.

Pymetrozine

Pymetrozine (insecticide group 9B) is an anti-feedant with specific activity against phloem-feeding insects. Marketed as Chess® by Syngenta Australia, the manufacturer claims that 'First symptoms are visible within 15 minutes, feeding stops within 1 hour…' (Syngenta Australia Pty Ltd, n.d.).

Harrewijn and Piron (1994) found that although pymetrozine did not inhibit acquisition of PVY it reduced subsequent transmission. It also reduced mobility of winged aphids, which the authors speculated would therefore reduce virus spread. Margaritopoulos et al. (2010) found that both acquisition of PVY and inoculation were significantly reduced for up to seven days, and that efficacy was comparable with mineral oil. However, Boquel et al. (2015) found that pymetrozine had only a slight effect on aphid feeding behaviour and did not affect acquisition of PVY. Samara et al. (2021) found that although pymetrozine delayed the onset of probing slightly, it did not significantly reduce the duration of probing during the critical first five minutes and had only a small and non-significant effect on transmission of TuMV. Results from field trials have been generally unfavourable. Davis and Radcliffe (2007) and van Toor et al. (2009) found pymetrozine to be effective for reducing aphids, but it had no effect on PVY. Similarly, Rolot et al. (2021) found pymetrozine had no effect on PVY incidence, nor did it improve efficacy of a mineral oil. Nolte et al. (2009) stated that insecticides including pymetrozine were found to provide 'good to excellent' aphid control, and to reduce PVY transmission in preliminary trials, but no follow-up trials were found.

Flonicamid

Flonicamid (insecticide group 29) is a selective homopteran anti-feedant, with a similar mode of action to pymetrozine. Marketed as MainMan® by UPL, it is claimed to produce 'cessation of feeding within 15-60 minutes of exposure…' (UPL Australia Pty Ltd, n.d.).

In laboratory trials Boquel et al. (2015) found that flonicamid reduced aphid probing but did not affect acquisition of PVY. Samara et al. (2021) also found a small but significant reduction in time to first probing, but no delay in initiation of feeding and no significant effect on transmission of TuMV. MacKenzie et al. (2014), MacKenzie et al. (2016) and MacKenzie et al. (2017) found some indication of flonicamid efficacy for management of PVY in field trials, but only when used in combination with oil sprays.

Green peach aphid - SOURCE: Tsuchida, T (2016) Molecular basis and ecological relevance of aphid body colours. Current Opinion in Insect Science 17, 74-80

Other insecticides

Other insecticides evaluated for efficacy against virus vectors include carbamates and organophosphates (reviewed by Perring et al. (1999) and Al-Mrabeh et al. (2010)), however these have generally been ineffective against non-persistently transmitted viruses and are not compatible with IPM. Samara et al. (2021) assessed a variety of insecticides for effects of feeding and transmission of TuMV, in addition to those already described: tolfenpyrad (group 21), flupyradifurone (group 4D), sulfoxaflor (group 4C), cyantraniliprole (group 28) and spirotetramat (group 23). All delayed onset of probing to a greater (sulfoxaflor, spirotetramat) or lesser (tolfenpyrad) extent, but none had a significant effect on time to initiation of phloem feeding, and none had a significant effect on TuMV transmission. Jacobson and Kennedy (2014) also assessed cyantraniliprole in EPG studies and found it significantly reduced the time spent probing and feeding, but not until ten days post treatment. These authors noted that this would not be expected to reduce transmission of non-persistent viruses. Nolte et al. (2009) stated that insecticides including spirotetramat were found to reduce PVY transmission in preliminary trials, but no follow-up trials were found.

Two further insecticides claimed by the manufacturers to have antifeedant effects are afidopyropen (group 9D, marketed by BASF as Versys®) and the product Sero-X (Clitoria ternatea extract, produced by Innovate Ag). According to the manufacturer, Versys is claimed to 'stop feeding in as little as 15 minutes…' and to reduce virus transmission (BASF Australia Limited, 2018). Sero-X is claimed to have an anti-feedant and repellent effect (InnovateAg Pty Limited, n.d.).

Non-insecticidal treatments

Non-insecticidal treatments have also been assessed. Lowery et al. (1990) found that whitewash consistently reduced transmission of TuMV in laboratory and field trials. Marco (1986) and Marco (1993) also found whitewash sprays to be effective for control of PVY in potato and capsicum, and cucumber mosaic virus (CMV) in capsicum, although they also noted a detrimental effect on plants. Raworth et al. (2007) demonstrated that kaolin clay significantly reduced the number of winged aphids in blueberry compared to an untreated control, however virus infection (Blueberry scorch virus, B1ScV) was too low to determine whether there was any effect on transmission.

Bion® (acibenzolar-S-methyl), an organic compound which induces systemic acquired resistance in plants and is used as a fungicide, significantly reduced PVY spread compared to a control (Dupuis et al., 2014). However, the level of reduction (14%) was insufficient for management of the virus. Rolot et al. (2021) trialled various plant slurries (nettle, comfrey and horsetail) and Siliforce® (a silicon-based product which claims to improve plants' resistance to biotic and abiotic stresses and deter insects). None of these treatments were effective for control of PVY.

Conclusion

Reviews of laboratory and field trials have found that insecticides are generally ineffective for control of non-persistently transmitted viruses (Perring et al., 1999, Rolot et al., 2021). However, there is substantial evidence that mineral oils are effective for reducing transmission of non-persistent viruses, and that efficacy is enhanced when combined with other methods including some insecticides, crop borders and mulching. Although insecticides such as synthetic pyrethroids (in particular lambda-cyhalothrin) and pymetrozine reduced transmission in laboratory trials, they were generally ineffective in field trials. However, combinations of synthetic pyrethroids and mineral oils have proven more effective than either treatment alone. Treatments which form a physical barrier, such as whitewash sprays, have also been effective for management of non-persistent viruses.

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