Control Of Aphid Virus-Vectors in *Cucurbita pepo* L. in KwaZulu-Natal, South Africa

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ABSTRACT

Five methods were tested for their effectiveness in reducing both aphid numbers and stylet-borne virus diseases in *Cucurbita pepo* L. fields. The treatments used were a white reflective mulch, a straw mulch, an experimental garlic repellant, companion planting with fennel (*Foeniculum vulgare* L.) and the *C. pepo* cultivar 'Puma' which has virus resistance. The reflective mulch and straw mulch were consistently better than the other treatments in reducing aphid numbers. The reflective mulch performed best in reducing disease. In a second trial there was no significant difference between the treatments, although the reflective mulch still ranked first in disease reduction. Aphid numbers visiting plots were inversely correlated with the effectiveness of the treatments in reducing virus disease.

RESUMEN

Se estudió la efectividad de cinco métodos para reducir las poblaciones de áfidos y de enfermedades virales transmitidas por estos en plantaciones de *Cucurbita pepo* L. Los tratamientos usados fueron acolchado blanco reflejante, acolchado de paja, un repelente de ajo experimental, la siembra de hinojo (*Foeniculum vulgare* L.) como cultivo acompañante y el uso del cultivar 'Puma' de *C. pepo* el cual presenta resistencia a virus. Los acolchados reflejante y de paja fueron consistentemente mejores que los otros tratamientos para reducir las poblaciones de áfidos. El acolchado reflejante fue el tratamiento que redujo mejor la enfermedad. No existió diferencia significativa entre los tratamientos cuando se realizó un segundo experimento, aunque el acolchado reflejante fue clasificado como el primero en cuanto a la reducción de la enfermedad. Las poblaciones de áfidos que visitaron las parcelas se correlacionaron inversamente con la efectividad en reducir las enfermedades virales presentada por los tratamientos.

Key words: Cucumis pepo, aphid-borne viruses

Papaya ringspot virus - Type W (PRSV-W), *Watermelon mosaic virus* 2 (WMV2), *Watermelon mosaic virus* - Morocco (WMV-M), *Zucchini yellow mosaic virus* (ZYMV) and *Cucumber mosaic virus* (CMV) can severely limit the production of cucurbits (Lovisolo, 1980; von Wechmar et al., 1995). WMV2, WMV-M, ZYMV and CMV have been recorded previously in South Africa (van der Meer, 1985; van der Meer & Garnett, 1987; von Wechmar et al., 1995). These viruses are transmitted in the stylet-borne manner by aphids (Francki & Habili, 1990; Shukla et al., 1994). Non-colonizing aphids (i.e., aphids which probe, then reject a plant as a host) can be important in the ecology of two viruses infecting cucurbits: PRSV-W and WMV2 (Zitter, 1977). This is presumably true for the other potyviruses mentioned above. Aphids are an important factor in the spread of viruses both within a field and over long distances. In some cases, it has been noted that diseased plants seem to be more favorable to rapid vector development than healthy plants (Swenson, 1968).

A number of aphid species have been recorded as feeding on members of the Cucurbitaceae. The following list, covering sub-Saharan Africa, was compiled by Millar (1994): *Aphis gossypii* Glover, *A. craccivora* Koch, *A. fabae* Scopoli, *Myzus persicae* Sulzer and *Macrosiphum euphorbiae* Thomas. The most common aphid species or biotype is not necessarily the most important vector, because vector efficiency may be more important. On the other hand, the most efficient virus vectors may not be the most important vectors, as the development of large populations of inefficient vectors may be more important (Swenson, 1968; Thresh, 1976).

In the epidemiology of plant viruses, the date that the virus is first introduced to a field or area is extremely important, because the earlier (and therefore the longer) that the virus is present, the greater the damage to the crop (Thresh, 1974). There are farming practices which ultimately result in a better

Table 1. The effects of different aphid repellents and companion planting on aphid: Average number and rank of the treatments in Trial 1 and Trial 2.

Treatment	Trial 1		Trial 2	
	Number	Rank	Number	Rank
Control	179.50b[1]	4	271.25b	3
Garlic Repellent	159.50b	3	309.50b	5
Reflective Mulch	85.00a	2	142.50a	1
Fennel	185.00b	5	N/A	N/A
Puma	N/A[2]	N/A	279.50b	4
Straw Mulch	74.50a	1	238.00b	2
F-ratio	6.156**		4.894*	
P	0.0062**		0.0142*	
CV%	31.24%		23.43%	

[1]Treatments with no letters in common are significantly different.
[2]N/A = Not Applied, NS = Not Significant, * = Significant, ** = very significant, *** = highly significant.

Table 2. The AUPPC values and rank of the treatments in Trial 1 and Trial 2.

Treatment	Trial 1		Trial 2	
	AUPPC	Rank	AUPPC	Rank
Control	628.25b[1]	4	1485.75b	3
Garlic Repellent	558.25b	3	1649.38b	5
Reflective Mulch	297.50a	2	780.50a	1
Fennel	647.50b	5	N/A	N/A
Puma	N/A[2]	N/A	1540.88b	4
Straw Mulch	260.75a	1	1249.50ab	2
F-ratio	6.156**		4.511*	
P	0.0062**		0.0187*	
CV%	31.24%		24.28%	

[1]Treatments with no letters in common are significantly different.
[2]N/A = Not Applied, NS = Not Significant, * = Significant, ** = very significant, *** = highly significant.

crop as well as reduce the impact of virus diseases by affecting the efficiency of virus vectors (Zitter & Simons, 1980). Various aspects of virus disease management have been examined by a range of authors: Daiber and Donaldson (1976) (reflective mulches), Eulitz (1977) (reflective mulches), Zitter (1977) (reflective mulches), Zitter and Simons (1980) (chemical control, reflective mulches, cultural and non-chemical approaches), Maelzer (1986) (chemical control), Nentwig (1988) (biological control), Yang and Tang (1988) (cultural or non-chemical approaches), Gonsalves and Garnsey (1989) (mild strain protection), Wiles et al. (1989) (cultural or non-chemical approaches), Brown and Stephenson (1990) (biological control), de Oliveira et al. (1990) (straw mulch), Jones (1991) (reflective mulches), Grossman (1993) (cultural or non-chemical approaches), Altieri (1994) (biological control), Pinese et al. (1994) (reflective mulches, cultural or non-chemical approaches), Clough and Hamm (1995) (chemical control), Rummel et al. (1995) (straw mulch), Briggs et al. (1996) (cultural or non-chemical approaches), Hori (1996) (garlic oils), Jervis and Kidd (1996) (biological control), Desbiez and Lecoq (1997) (chemical control, reflective mulches, mild strain protection). Insecticide treatments have previously been shown to have no benefit where stylet-borne viruses are involved in the virus pathosystem because the use of these chemicals can increase the rate of virus spread within a field (Budnik et al., 1995: Desbiez & Lecoq, 1997; Gibson & Rice, 1989; Maelzer, 1986; Pinese et al., 1994; Swenson, 1968: Yuan & Ullman, 1996; Zitter & Simons, 1980) and eliminate beneficial insects (Brown & Stephenson, 1990).

This study was undertaken to investigate the effectiveness of some of these strategies in reducing aphid numbers, and thus virus disease severity on the crop *Cucurbita pepo* L. (courgette), under the environmental conditions experienced in KwaZulu-Natal, South Africa.

MATERIALS AND METHODS

Two trials were conducted at Bayne's Drift (Gilmorehill Farm, 25 km north of Pietermaritzburg) in the KwaZulu-Natal Midlands. During summer (November-March) mid-day temperatures often exceed 35ºC. Winters (May-July) have severe frosts which not only prevent the cultivation of cucurbits, but probably destroys most aphid populations in the area. Thus each year, aphid populations are replaced by individuals which migrate or are blown inland from the coastal regions. As a result, virus disease is only a serious problem in the mid to late growing season (December-April). The *C. pepo* cultivar 'Elite' was used except where otherwise indicated. Each plot measured 2.5 m X 8 m, and contained two rows of 15 plants.

Fluctuations of aphid numbers can be monitored by using colored sticky traps (Heathcote, 1974). "Bug Trap" yellow color traps (Agribiol, Vlaeberg, South Africa) coated with a long lasting glue were used in this study. At each trial site, one trap was placed in each replication plot (four per treatment). The traps were collected and replaced every seven days. After collection the number of aphids on the trap was determined. The following treatments were used:

1) Companion planting - Fennel (*Foeniculum vulgare* L.) seedlings were planted after every two *C. pepo* plants. This resulted in each *C. pepo* plant having a fennel plant adjacent to it. The motivation for this was to improve the structural diversity of the plots, which has been shown to be beneficial in crop production (1).
2) Garlic repellant - This substance was an experimental garlic (*Allium sativum* L.) extract (Kombat Chemicals, Greytown, South Africa) which was diluted 1:10 in water and sprayed to the point of runoff onto the *C. pepo* plants at seven-day intervals for 5 weeks. The odor is reportedly unattractive to many insects, and would thus discourage them from landing on the treated plants (Hori, 1996).
3) Straw (*Eragrostis* sp.) - The mulch was spread to a depth of approximately 12 cm deep and extended approximately 0.5 m on either sides of the plants. The reflectance of the straw and the presence of more predators was expected to influence the number of pests visiting the plants.
4) Reflective mulch - White Knittex Shade Net® (Knittex,

plants. The reflectance of this material was expected to repel pest insects as well as change the visual appearance of the plants by creating a green against white matrix as opposed to a green against brown matrix as is normal in crop fields.

Pinetown, South Africa) giving 60% shade was used as the reflective mulch. Strips of this material (8 m x 0.5 m) were laid down on both sides of each row of *C. pepo*

5) Resistant cultivars - In the second trial the fennel treatment was replaced by the use of the virus-resistant cultivar 'Puma'.

6) A control where no treatment was applied was included in the trials.

To judge the effectiveness of the different treatments in reducing disease severity, a rating scale was developed which gave each plant a score depending on the severity of the symptoms: zero (no symptoms) through nine (plant severely stunted, fruit with distinct symptoms or no fruit produced, severe leaf mosaic, severe leaf distortion).

The effect of the treatments on aphids was assessed using the area under the pest progress curve (AUPPC), while disease control was assessed using the area under the disease progress curve (AUDPC). A two-way analysis of variance (ANOVA) was applied to the data obtained in the trials, using "Statsgraphics".

RESULTS

The results of aphid captures on the sticky traps are shown in Table 1 and 2. Table 1 compares the number of aphids caught in the different treatment plots, while Table 2 compares the AUPPC values. The reflective and straw mulches achieved the greatest reductions in aphid numbers in both trials. The effect of treatments on virus disease in the plots is shown in Table 3 and Fig. 1 and 2. Table 3 compares the AUDPC values obtained. Fig. 1 and 2 show the disease progress in the treatments in the two trials. Fig. 3 and 4 compare the effect of the treatments on aphids with the effect of the treatments of virus disease severity. Trial 1 was terminated prematurely after three weeks due to a severe hailstorm which destroyed all the plants in the field.

DISCUSSION

In both trials the straw and white reflective mulches were the best treatments, having the lowest aphid counts. This was particularly noticeable in Trial 1 where aphid numbers reached their season peak, and pest (vector) pressure was high. In both trials the reflective mulch was significantly better than all other treatments, except the straw mulch, in repelling aphids. The performance of the reflective mulch is believed to be due to two factors. The first of these is that the white surface reflects short-wave radiation which is unattractive to flying aphids. This effect has been reported on by Wyman et al. (1979), Zitter and Simons (1980), Prokopy and Owens (1983), Gibson and Rice (1989) and Jones (1991). The second reason is that the presence of the mulch alters the appearance of the crop by changing the crop background from brown to white. This does not match the search pattern of immigrating aphids, and therefore fewer insects enter the plots (Prokopy & Owens, 1983). The action of the straw mulch is probably similar to that of the reflective mulch but at a lower intensity.

The garlic repellent appeared to offer some level of control in the first trial (Fig. 3), although this control was not significant when compared with the control (Table 1 and 2). In the second trial no level of control was provided (Table 1 and 2). The true efficacy of the repellent may not be apparent when aphid numbers are monitored with sticky traps. The repellent is probably active when the insects are in close proximity to the plants. Thus the insects are still present in the plots and will be attracted to the traps, even though they may not be actually landing and/or feeding on the crop plants. This possibility was demonstrated in Trial 2 (Table 3) where this treatment ranked second in effectiveness in reducing disease severity.

In Trial 1, when aphid numbers were high, the fennel treatment performed worse than the control. During this trial the temperature was high, and the fennel plants suffered from heat stress. Fennel grows more slowly than *C. pepo* and did not reach the flowering stage before the fruiting stage of the crop. As the motivation for using fennel was the attractiveness of its flowers to beneficial insects (parasitoid wasps, syrphid flies, etc.) (Salto et al., 1991) its slow development makes it unsuitable as a companion plant in this crop. Some benefit may

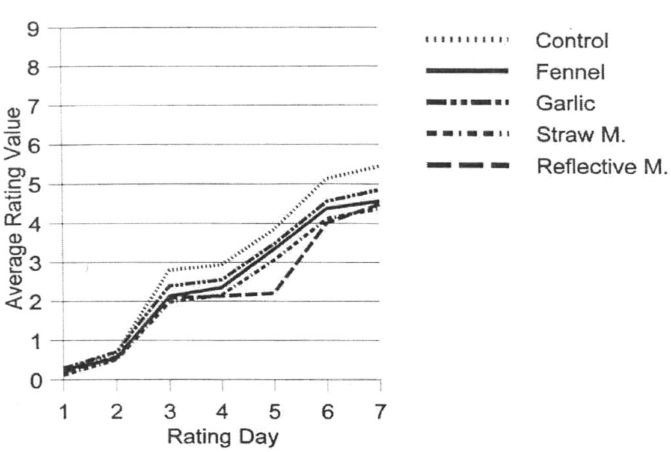

Fig. 1. The comparison of virus-disease progress in five different treatments in a *Cucurbita pepo* field (Trial 1).

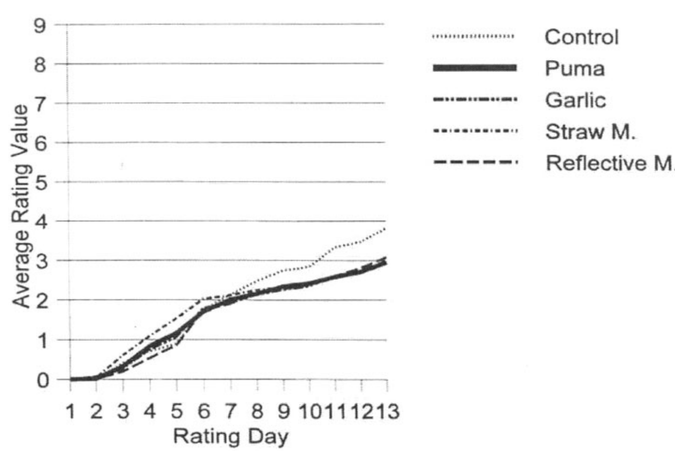

Fig. 2. The comparison of virus-disease progress in five different treatments in a *Cucurbita pepo* field (Trial 2).

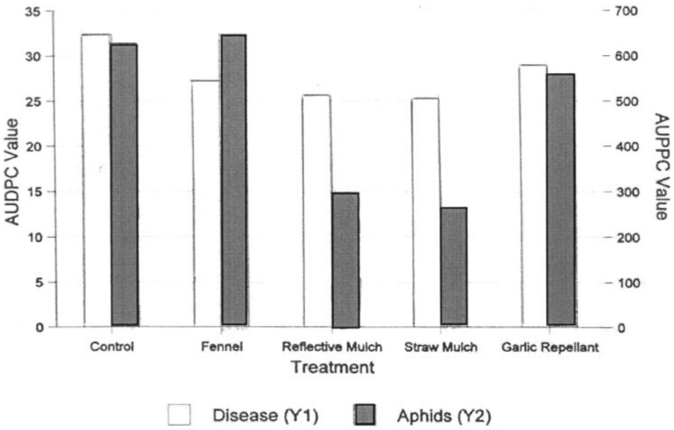

Fig. 3. Comparison between virus disease level (AUDPC) and aphid incidence (AUPPC) in Trial 1.

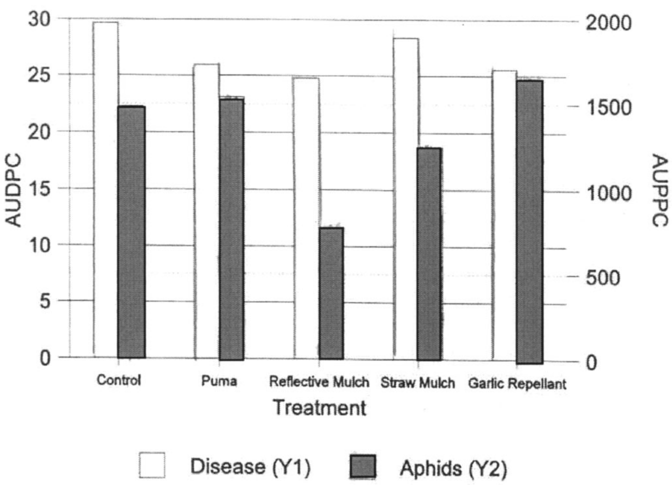

Fig. 4. Comparison between virus disease level (AUDPC) and aphid incidence (AUPPC) in Trial 2.

be derived from planting stands of fennel between or near fields (eg. on contour banks) a few weeks earlier than the crop to be protected. This would allow the fennel to reach the flowering stage at a time when the presence of beneficial insects could increase the productivity of the crop (i.e. from planting until the start of fruiting). In both trials where it was used, a high number of aphids was recorded in the fennel plots. This was probably due to fennel having aphid species which use it, but not *C. pepo*, as a host. Therefore a greater number of individuals would be attracted to the plots. Due to its poor performance in the first trial, this treatment was replaced in the second trial by the use of the virus-resistant zucchini cultivar 'Puma'. The use of the cultivar 'Puma' did not reduce aphid numbers (Tables 1 and 2) relative to the control.

For controlling aphid numbers in *C. pepo* fields, the use of either a white reflective mulch or a straw mulch is recommended. The synthetic reflective mulch could be better used by large-scale producers, while the straw mulch could be used by small-scale or resource-poor farmers. The recommendation of use of the materials by different spheres of farming is largely due to the initial cost of the material, and the subsequent labor involved in applying it. The reflective mulch is expensive, but gives good aphid control and can be laid down with the aid of mechanical implements. The straw mulch is cheaper and offers a comparable level of aphid control, but is labor intensive to apply.

In Trial 1 all treatments performed better than the control, although only the fennel, white reflective mulch and the straw mulch were significantly different from the control (Table 3, Fig. 2). As the fennel did not perform in the manner expected (i.e., attracting beneficial arthropods), the improved performance of the zucchini plants could have been due to a commensal relationship between the two plant species. Despite this effect, the use of fennel as a companion plant in *C. pepo* crops cannot be recommended due to its slow rate of development compared to that of *C. pepo*, and its intolerance of field conditions during the growing season. Ideally, a companion plant should have a similar rate of development to that of the main crop. This would make farm management easier. A further potential negative aspect is that the presence of fennel in a field may serve as a source of one of the potyviruses. Recently a strain of *Potato virus Y* (PVY-O) was found in fennel plants growing as weeds (Espino de Paz et al., 1997).

The failure of the garlic repellant to reduce disease incidence was probably due to the use of sprinkler irrigation rather than drip irrigation. The crop had to be irrigated regularly due to the high temperatures (>35ºC) experienced at that time of year. There was also a great deal of convectional rainfall at that time. A combination of the rainfall and irrigation would have washed the repellant from the leaves of the crop, reducing or eliminating its beneficial effect. The use of an adjuvant which increases adhesion of the repellant to the leaves may correct this problem. An advantage of using the garlic repellant is that it appears to have little or no effect on beneficial insects. Indeed, ground beetles (Coleoptera: Carabidae) seemed to be attracted to it. Although bees (*Apis melifera* L.) left the flowers during spraying, no repellant effect was noticed at other times.

Although the straw mulch ranked higher than the white reflective mulch, the two treatments were very similar in their performance in reducing disease (Table 3, Fig. 1). This action was due to the reduced number of aphids in these plots. By reducing the number of aphids in an area, the chance of infection of the crop with one or more of the viruses investigated was reduced. The reduced weed growth and water loss from these plots reduced both competition and water stress, resulting in healthier plants. If possible, measures to control *Cyperus esculentus* should be taken in order to reduce disruption of the white reflective mulch. These two treatments could be successfully implemented to reduce virus disease. An advantage of the Knittex Shadenet® as a reflective mulch is that it is durable and can be used for more than one crop, unlike many of the conventional plastic reflective mulches. The net structure, as opposed to the solid plastic, allows some evaporation of water which could reduce potential waterlogging, although the net structure allows for the growth of weeds. The use of a greater shade factor should reduce this problem. A potential negative aspect of the straw mulch is that it can encourage infection by *Rhizoctonia* (H.A.J. Hoitink, 1998, Opportunities for control of plant diseases with composts, presentation at International Congress of Plant Pathology, Edinburgh).

In the second trial there was no significant difference between the treatments, although all treatments performed better than the control (Table 3, Fig. 2). The failure of the straw mulch to produce quality plants was probably due to the high degree of water retention in these plots which stressed the plants. It may also have led to root diseases which would have reduced the vigor of the plants. The performance of the cultivar 'Puma' is encouraging as this virus-resistant cultivar is available to farmers and appears to offer some benefit in virus disease control but not aphid control. The potential of a treatment to reduce virus disease can be indicated by monitoring aphid numbers. If aphid numbers are reduced relative to a control treatment, the severity of virus disease within the crop can be expected to be reduced (Figs. 3 and 4).

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