Mesh crop covers on potatoes to protect against psyllids: The additional challenge of aphids

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In New Zealand, USA and Mexico, potato (*Solanum tuberosum* L.) crops are attacked by *Bactericera cockerelli*, the tomato potato psyllid (TPP). Mesh crop covers which are used in Europe and Israel to protect crops from insect pests have been used experimentally in New Zealand for TPP control. While the mesh was highly effective for TPP management, the green peach aphid (GPA), *Myzus persicae*, was found in large numbers under the mesh. This study investigated the ability of the GPA to penetrate different mesh hole sizes. Experiments using four sizes (0.15×0.15, 0.15×0.35, 0.3×0.3 and 0.6×0.6 mm) were carried out under laboratory conditions to investigate: (i) which mesh hole size provided the most effective barrier to GPA; (ii) which morph of adult (apterous or alate) and/or its progeny could breach the mesh; (iii) would leaves touching the underside of mesh, as opposed to having a gap between leaf and mesh, increase the number of aphids breaching the mesh; and (iv) could adults feed on leaves touching the mesh by putting only their heads and/or stylets through the mesh?

No adult aphids, either alate or apterous, breached the mesh; only nymphs did this, with the majority being the progeny of alate adults. Nymphs of the smaller alate aphids breached the three coarsest mesh sizes; nymphs of the larger apterous aphids breached the two coarsest sizes. No nymphs breached the smallest mesh size. When the leaflets touched the mesh from below, the number of aphids breaching the mesh increased, but this effect was not statistically significant. Adults did not feed through the mesh, though it is believed they were able to sense the potato leaflet using visual and olfactory cues and producing nymphs as a result. As mesh is highly effective for managing TPP on field potatoes, alternative measures to manage aphid colonisation of this crop due to aphid nymphs breaching the mesh are required; one option is introducing aphid biocontrol agents under the mesh.

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Abstract

In New Zealand, USA and Mexico, potato (*Solanum tuberosum* L.) crops are attacked by *Bactericera cockerelli*, the tomato potato psyllid (TPP). Mesh crop covers which are used in Europe and Israel to protect crops from insect pests have been used experimentally in New Zealand for TPP control. While the mesh was highly effective for TPP management, the green peach aphid (GPA), *Myzus persicae*, was found in large numbers under the mesh. This study investigated the ability of the GPA to penetrate different mesh hole sizes. Experiments using four sizes (0.15×0.15, 0.15×0.35, 0.3×0.3 and 0.6×0.6 mm) were carried out under laboratory conditions to investigate: (i) which mesh hole size provided the most effective barrier to GPA; (ii) which morph of adult (apterous or alate) and/or its progeny could breach the mesh; (iii) would leaves touching the underside of mesh, as opposed to having a gap between leaf and mesh, increase the number of aphids breaching the mesh; and (iv) could adults feed on leaves touching the mesh by putting only their heads and/or stylets through the mesh?

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Keywords: aphids, tomato, potato, psyllid, mesh

Introduction

Potatoes are the highest grossing vegetable in New Zealand, with consumers purchasing approximately NZ $119 million worth of potatoes in 2013 (Horticulture New Zealand, 2014; New Zealand Grown Vegetables, 2017). They are also the second highest export earner of all

New Zealand-grown vegetables (Wassilieff, 2008). Although the global monetary value of potatoes is difficult to estimate, in 2005, the net import of fresh and processed potatoes by developing countries was valued at US$ 6 billion (FAO, 2008). However, potato production is threatened by *Bactericera cockerelli* (Ŝulc 1908) (Hemiptera, Triozidae), commonly known as the tomato potato psyllid (TPP). This phloem-feeding insect originated in central and North America but was first identified in New Zealand in the 2005-2006 growing season (Teulon et al., 2009) and has recently colonised crops in Western Australia (DPRID, 2018). TPP feeds on plants in the Solanaceae and Convolvulaceae families (Wallis, 1955). It transmits the bacterial pathogen *Candidatus* Liberibacter solanacearum (Liefting et. al., 2009) (CLso). CLso causes retarded plant growth, yellowing and cupping of leaves, reduction in yield and tuber quality, and produces stripes in the tubers known as zebra chip, which is more visible after cooking, rendering them unmarketable (Martin, 2016; Munyaneza, 2013). TPP can cause farmers to abandon an entire crop (Munyaneza, 2013; Munyaneza, 2014).

Due to the negative impacts of TPP on potatoes in New Zealand, organic farmers have encouraged researchers to investigate non-chemical management approaches. Biological options such as the mite *Anystis baccarum L* (Merfield et al., 2016), among others, were explored but with little success. In the laboratory, the coccinellid beetle *Cleobora mellyi* has very high consumption rates of TPP, but this remains to be confirmed in glasshouse and field crops (O'Connell et al., 2012; Pugh, O'Connell & Wratten, 2015). In comparison, a physical control technique using high-density polyethylene insect mesh covers was able reduce TPP populations on field potatoes to very low levels, even outperforming insecticides (Merfield, 2017; Merfield et al., 2015).

Mesh covers have been used in Europe for many years to protect potatoes and other crops from insects (Hill, 1987). In New Zealand, such covers have only recently been implemented experimentally. Mesh with a size up to 0.7 mm (commercial label indicated 0.6 mm) was able to efficiently manage the pest (Merfield et al., 2015). Additional benefits were that plants grown under the mesh had higher yields than the controls grown in the open, and were less affected by potato blight, though it was not determined if this was 'main' blight (*Phytophthora infestans*, Mont. de Bary) or 'early' blight (*Alternaria solani*, Sorauer) (Merfield et al., 2015).

Despite the promising results obtained with mesh, an unexpected result was that aphids, believed to be mostly the green peach aphid (GPA) (*Myzus persicae* (Sulzer)) appeared in large numbers under the mesh sheets, particularly in 2016-17 field trials where the edge of the mesh was dug into the soil, creating a complete seal (Merfield, 2017). Aphid populations were significantly higher under all mesh covers when compared to uncovered crops, probably due to the microclimate and the exclusion of the aphid's natural enemies by the mesh (Merfield, 2017).

Aphids can significantly affect plant growth and development, which causes reduced yields. They feed from the phloem (Dixon, 1973) causing damage to shoots and leaves (Capinera 2001), and excreting honeydew (Dixon, 1973), which results in the growth of sooty moulds (Chomnunti et al., 2014) that can cover the adaxial leaf surface, causing a reduction in respiration, transpiration and photosynthesis. These factors further reduce plant growth, development, and crop yield (Centre for Agriculture and Bioscience International 2017; Chomnunti et al., 2014), resulting in significant economic losses (Centre for Agriculture and Bioscience International, 2017). Such damage is more severe in young plants and when the aphid population is high (Capinera, 2001). In addition, GPA is a vector of many plant viruses that also cause significant yield losses (Capinera, 2001).

The GPA is the most common and widespread aphid on potatoes in New Zealand as it feeds on many host-plant species (Stufkens & Teulon, 2001). It is also the most economically important aphid on potatoes, both in New Zealand and worldwide, because it transmits both potato virus Y and leaflet curl virus, which are among the most damaging of the potato viruses (Saguez, Giodanengo & Vincent, 2013; Selvaraj & Ganeshamoorthi, 2012; Srinivasan, Cervantes & Alvarez, et al., 2013; Syller & Marczewski, 2001; Woodford, 1992). The main management tool for aphids in potatoes is insecticides. However, the GPA has developed resistance to a number of these (Centre for Agriculture and Bioscience International, 2017; Foster, Denholm & Devonshire, 2000) which poses challenges to potato farmers and researchers for future aphid management.

With mesh crop covers being highly effective for TPP management on potatoes, the major challenge is understanding how aphids are circumventing the mesh, and/or if adults can, from outside mesh, feed on leaflets touching the underside of it. If so, this means aphids outside the mesh could transmit viruses to potatoes under it. This could discourage seed-potato growers from using the mesh as a management option for TPP because of increased virus transmission to tubers intended for propagation.

With these gaps in knowledge, the present research was therefore designed to investigate (i) if aphids can enter covers of different mesh sizes; (ii) if there is a difference between alate or apterous adults and/or if their progeny have the ability to penetrate mesh; (iii) if having potato leaves touching the mesh from below increases the number of aphids penetrating it than when the leaves do not touch the mesh; and (iv) if adult aphids are capable of feeding on potato leaves through the mesh without entering it.

Materials and methods

GPA was sourced from a colony cultured on *Brassica rapa* subsp. *chinensis* (L.) pak choi (cultivar: Mei Qing Choi F1) kept at Lincoln University in a controlled-temperature room. The room was kept at 16 h day length, temperature of 23°C with a 4°C range and 60% relative humidity. Potato plants (cv. Ilam Hardy) were grown in a glasshouse at the Lincoln University plant nursery.

For the laboratory work, two 9 cm diameter Petri dishes were used to create two compartments separated by mesh; the top dish contained the aphids and the bottom one a single potato leaflet, except in the 'control' treatments in which three aphids were placed in the bottom dish (Figure and Table Legends

Fig. 1). A piece of moist tissue paper was placed in the bottom dish to maintain humidity. Leaflets were then collected from potato plants and cotton wool was placed over the petiole of the leaflet, which was inserted into an Eppendorf tube filled with water to maintain leaflet turgidity. The tube with leaflet inserted was placed in the lower dish with the adaxial surface facing up. The mesh was carefully glued around the full circumference of the opening between the two dishes, because, in previous experiments, aphid nymphs could locate and penetrate minimal gaps between the mesh and hard surfaces (C. Merfield, pers. comm., 2018). The two Petri dishes were then held together with plastic food wrap. For the mesh treatments, three adult aphids were inserted through a hole (150 mm diameter) in the top of the upper dish, after which the hole was sealed with mesh 0.15×0.15 mm held in place by adhesive tape.

There was a total of 24 treatments in a 4×2×3 factorial design: Four mesh sizes × two aphid morphs (apterous or alate) × (three leaflet/aphid positions). Design was a randomised complete block, with five blocks. For each mesh size and aphid morph, there was a control in which aphids were placed directly on the leaflet under the mesh (so eight 'controls'). There were 16 (=4×2×2) treatments each with a mesh barrier between aphids and leaflets. Commercially-stated mesh sizes were 0.15×0.15 mm, 0.15×0.35 mm, 0.3×0.3 mm and 0.6×0.6 mm. Aphid morphs were apterous or alate, while leaflet positions were touching or not touching the mesh barrier. The experiment ran for 72 h, at which point the number of aphids, both adults and nymphs, on the leaflets were counted. The experiment was conducted in a controlled temperature room with 16 h day length, temperature of 23°C ± with 4°C range and relative humidity of 60%.

To investigate whether adult aphids could feed through the mesh, all adults (n=240=16×5×3) used for the study of breaching the insect mesh were lightly touched with a fine artist's brush (size 00) at 12, 24, 36 and 48 hours through the opening of the top Petri dish. Therefore, 240 individuals were touched four times each, giving a total of 960 tests of feeding. Those that remained in the same position following probing were taken as having their stylets inserted into the leaflet and therefore to be feeding (Auclair, 1963; Giordanengo et al., 2010). Those that moved following probing were considered to not have been feeding.

Mesh sizes 0.15×0.15 mm and 0.15×0.35 mm were supplied by AB Ludvig Svensson (www.ludvigsvensson.com) as ECONET 1515 and ECONET 1535. Those measuring 0.3×0.3 mm and 0.6×0.6 mm were supplied by Crop Solutions Ltd. (www.cropsolutions.co.uk) and were custom-made for an earlier field trial (Merfield, 2017). To test the accuracy of the measurement for each mesh size used in this experiment, ten random samples of each mesh type were selected and 10 holes of each sample were measured under a Nikon SMZ25 microscope (magnification range 0.63–15.75×). The mean, minimum and maximum mesh measurements are presented in Table 1.

All data were analysed in a randomised block analysis of variance (ANOVA) (with a factorial treatment structure) using GenStat® 18th edition. The response variable, number of aphids on potato leaflets, was subjected to a square root transformation to normalise the data before analysis. Also, the analysis was split into two ANOVAs to achieve homogeneity of variance: (1) the eight mesh-size × aphid-morph controls, which were relatively high in variability, were analysed separately as a 4 × 2 factorial with 5 blocks; (2) for the 16 non-control treatments, 5 treatments were all zeroes and hence had zero variability, so were omitted from the analysis, leaving 10 treatments which were analysed as a (2 × 2 + 1) × 2 factorial with 5 blocks.

Results

For the eight 'control' treatments, with aphids below the mesh, there were no significant differences in nymph numbers produced by the two aphid morphs, nor any significant linear or quadratic components of mesh size (assuming these were in the ratio 1 : 2 : 3 : 6), nor any significant interaction components (Table 2).

In the 16 treatments (see above) with adults placed above the mesh, only nymphs, not adult aphids, were able to pass through the mesh. Nymphs of the smaller alate adults breached the 0.15×0.35, 0.3×0.3 and 0.6×0.6 meshes but not the 0.15×0.15 mesh (Table 2). Nymphs of the larger apterous nymphs breached the 0.3×0.3 and 0.6×0.6 meshes but did not breach the 0.15×0.15 and 0.15×0.35 ones. For the alate aphids, the number of nymphs breaching the mesh increased with mesh size (P=0.098 for the linear component of the main effect of mesh size, assuming a ratio of mesh sizes of 2 : 3 : 6; Table 2).

When averaged over the larger 0.3×0.3 and 0.6×0.6 mesh sizes and over leaflet-touching or not-touching treatments, more nymphs of alate adults than nymphs of apterous adults got through the mesh, but the difference was not statistically significant (P=0.192). On the transformed scale, main effect means were 0.788 for nymphs of alate adults and 0.491 for those of apterous adults, which back transformed to 0.62 and 0.24 nymphs, respectively.

When leaflets touched the mesh, there were higher numbers of nymphs breaching the mesh than when the leaflets did not touch it, but the difference was not statistically significant (P=0.612). On a transformed scale, main effect means were 0.638 when the leaflet and mesh were touching, and 0.536 for not touching, which back transformed to 0.41 and 0.29 nymphs, respectively.

The interaction between aphid morph (alate and apterous) and the leaflet touching mesh or not was ‘nearly significant’ (P=0.066). For nymphs from alate adults that circumvented mesh, the mean square root-transformed number of nymphs was 1.021 for leaflet touching the mesh and 0.556 for not touching, while for nymphs of apterous adults, these means were 0.300 and 0.683, respectively; hence the interaction was (1.021 – 0.556) – (0.300 – 0.683) = 0.848, which was ‘nearly’ significantly different from zero (P=0.066). That is, the difference between leaflet touching and not touching, differed between alate and apterous (at P=0.066).

No aphids were found, at any time, to be feeding through the mesh, as all aphids moved following probing with the artist’s brush.

Discussion

Aphid host feeding and host recognition

Alate GPA and other aphids disperse wind currents (Dixon, 1971; Kennedy, 1950) and their first step in finding a host plant is by detecting it by olfactory and/or visual cues pre-alighting (Döring, 2014). However, the white colour of the mesh used in field trials (Farias-Larios & Orozco-Santos, 1997; Merfield, 2017) and the absence of the visual cue of green-yellow plants would be expected to reduce aphid alighting on the mesh (Ben-Yakir et al., 2012). However, the presence of aphids in all mesh plots in the field trial by Merfield (2017) indicates that adults must be alighting on the mesh. After alighting, aphids examine the plant to determine if it is a suitable host by probing the subepidermal tissues of the plant. Subsequently, they do more deeper probing, and if the plant is suitable, they will evaluate the pholem (Vargas et al., 2005). When an alate adult determines that a plant is a suitable host they feed and reproduce, they may then disperse to another host (Dixon, 1971; Kennedy, 1950). Adults will start reproducing after feeding for at least 30 minutes (Powell, Tosh & Hardie, 2006). However, the results in this study found that the aphids did not feed, yet they still reproduced. This appears to contradict previous research that contact with the plant and active feeding is required for reproduction. This indicates that the aphid may be able to detect the host plant without feeding on it, i.e., by olfactory and possibly visual clues through the mesh, resulting in its making a decision to reproduce. The results with the leaflet not touching the mesh could be evidence that aphids are detecting the plants by non-physical means. However, to confirm this, a second control treatment in the experiment would have been required: that of putting the aphids on mesh without a potato leaflet to determine the number of nymphs produced and the numbers of the latter penetrating mesh in the total absence of vegetation. In addition to the issue of host detection through mesh, as the adult aphids are not feeding on the plant, they cannot gain nutrients and energy so would have to reproduce using stored embryo energy and nutrients, which would be expected to limit the number of nymphs produced. A further limitation of this study is that the number of nymphs that did not penetrate the mesh were not counted. Therefore, it is not possible to determine what proportion of nymphs penetrated the mesh and whether or not they were able to detect the leaf through the mesh and then actively penetrate it in search of food.

The role of leaves touching the mesh

The interaction of aphid morph and leaf touching or not touching the mesh was nearly significant (P=0.066), but the direct comparison of leaf touching vs. not touching was not significant. This indicates that aphid nymphs do not require potato leaves to touch the mesh in order to penetrate it. Had aphid penetration of the mesh been reduced when leaves were not touching it, it could have provided an opportunity for commercial growers to develop a system to keep the mesh from touching the plants. This could have been particularly useful for potato seed breeders for reducing GPA numbers when the crop area is comparatively small (tens of square meters to hectares) and of very high value (Bisognin et al., 2006). So, based on these results, raising the mesh off the crop would not reduce aphid ingress and would therefore be of no value. However, this study was effectively a no-choice test, with the adults and nymphs confined in close proximity to the mesh and potato leaflet. In the field, alate aphids that alight on the mesh have the option of flying off in search of other hosts if they do not detect potatoes beneath the mesh. In this situation, lifting the mesh off the crop foliage could produce a different result to these laboratory findings. In addition, the gap between the leaf and mesh was only a few millimetres and future research could investigate various distances between the leaflet and the mesh to determine if there is specific distance over which the adults cannot detect the potatoes under the mesh and that also results in nymphs no longer breaching the mesh. Further studies under field conditions would therefore be of more practical value to potato growers and also potentially shed new light on the mechanisms of host finding by aphids (Döring, 2014).

Supplementing the mesh approach

Results obtained in this study showed that GPA can colonise potato crops cultivated beneath insect mesh and, with the rapid clonal reproduction of GPA, populations would reach levels that could destroy crops. However, results from Merfield (2017) for the control of TPP are considered too promising to abandon the use of mesh crop covers due to aphid infestation. Therefore, the mesh should be used to manage TPP, with a second management approach used to manage GPA under the mesh, ideally using a non-chemical approach.

A wide range of commercially available biological control agents (BCAs) have been used to successfully manage GPA, particularly in protected envrionments such as glasshouses. For example, these include *Aphidius matricariae* Haliday (Hymenoptera: Braconidae), *Aphidius colemani* Viereck (Hymenoptera: Braconidae) (Zamani et al., 2007) *Micromus tasmaniae* Walker (Neuroptera: Hemerobiidae) (Harcourt, 1996; Jonsson et al., 2008) *Adalia bipunctata L.* (Coleoptera, Coccinellidae) (Jalali et al., 2010). However, the use of BCAs has a higher success rate in protected agriculture than in the open field (Van Emden & Harrington, 2007). Mesh crop covers are a form of protected cropping, and as the mesh not only keeps pests and naturally occurring BCAs out of the crop, the covers can also ensure that BCAs introduced under the mesh cannot escape, unlike in open fields. It is therefore believed that the best option for control of aphids that do penetrate the mesh is to use commercially available BCAs as used in other forms of protected cropping. Finding the optimum species of BCA to put under the mesh, the numbers and frequency of introductions, and the value of floral resources and banker plants under the mesh is, however, considered to require a substantial amount of research.

Commercial relevance of this work

From a commercial potato production perspective, especially for seed potatoes, the fact that the adults do not feed through the mesh could be an important finding as it indicates potato viruses will not be transmitted through mesh. However, this result is not direct evidence for lack of transmission, as it only demonstrated a lack of feeding but not a lack probing. GPA can transmit viruses only by probing (Radcliffe & Ragsdale, 2002). Direct testing of virus transmission is required, using virus-infected aphids to test the rates of transmission when mesh is present or not.

Potato virus Y and potato leafroll virus are not maternally transmitted to nymphs of GPA (Radcliffe & Ragsdale, 2002). If adults are unable to feed through the mesh and therefore do not transmit viruses through this route and new-born nymphs that penetrate the mesh are also virus free, it appears that mesh could prevent virus infection of crops. However, uninfected nymphs and adults become infected by feeding on infected plants (Radcliffe & Ragsdale, 2002). Therefore, should any of the plants underneath the mesh already have a virus, e.g., transmitted via the planted tuber, aphids below the mesh can spread the virus(es) from infected to uninfected plants. As the mesh is believed to act as a barrier for aphid natural enemies (Merfield, 2017), and aphid populations can rapidly increase to very high levels (Merfield, 2017; Winder et al., 2014), existing viruses could be spread rapidly to all plants under the same mesh sheet.

In the present study, nymphs produced by alate adults breached the 0.15×0.35 mesh, while those produced by apterous adults did not. This supports the findings of Dixon & Wratten (1971) who found that alate aphids were smaller and produce fewer and smaller nymphs than did apterous aphids so this indicates that only the smallest size mesh (0.15×0.15 mm holes) would be an effective barrier. For larger mesh sizes, nymphs of both progenitors can enter the mesh, so both alate and apterous adults are potential threats to the crop. However, apterous aphids, lacking wings, could arrive only on the outside of mesh from other plants bordering the mesh. In field trials conducted by Merfield (2017), the periphery of mesh was kept free of vegetation with residual herbicides such that apterous aphids walking onto the mesh should have been eliminated, yet all mesh plots were infested by aphids. It is therefore believed that it was alate adults that were producing the nymphs that infested the mesh treatments in that trial.

In New Zealand and many tropical and subtropical regions around the world, GPA is anholocyclic (females are viviparous parthenogenetic in the absence of males) (Blackman, 2009). This means that one nymph is enough to start a colony, but, the more nymphs that are able to penetrate a mesh sheet, the faster the population will grow. This study found the 0.15×0.15 mesh was the only size that was entirely impervious to aphids. The next mesh size up, the 0.15×0.35 mesh, prevented colonisation by the larger nymphs of apterous aphids, but not the smaller progenies of alates. This means the mesh sizes capable of protecting potatoes from TPP are insufficient to protect potato crops from aphids. The 0.15×0.15 mesh (ECONET 1515, from Ludvig Svensson) is intended for glasshouse use, not field use, unlike the Crop Solution's mesh crop covers. The finest mesh currently designed for field use is 0.3×0.3 mm (Ian Campbell, Crop Solutions Ltd, pers. comm., 2017). Therefore, there are no commercially available field mesh crop covers that would also block GPA from potato crops.

Conclusions

Because of availability and cost, it is recommended that the 0.6×0.6 or 0.3×0.3 mesh be used to manage TPP, even though GPA nymphs can breach it. More research is needed on BCAs for managing GPA that penetrate the mesh. The potential for mesh to be an effective barrier to virus spread, both by adults and nymphs, needs to be confirmed. If mesh combined with BCAs for under-sheet aphid control is an effective means of controlling potato viruses, the benefits to the potato seed industry are believed to be considerable.

Acknowledgements

The authors would like to thank Brent Richards and Leona Meachen from Lincoln University glasshouse for assisting in growing the plants; Jenny Brookes for the supply of aphids; Brian Kwan for technical advice; Janine Johnson for editorial assistance; Crop Solutions Ltd and AB Ludvig Svensson for donating mesh crop cover samples.

Funders

Ministry of Foreign Affairs and Trade, New Zealand, and the Bio-Protection Research Centre, Lincoln University, New Zealand.

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Figure and Table Legends

Fig. 1. Experimental set up: (1) top Petri dish, (2) bottom Petri dish, (3) hole for aphid introduction, (4) mesh between dishes, (5) Eppendorf tube and leaflet. For the 8 'control' treatments, aphids were placed below the mesh, while for the other 16 treatments, aphids were placed above the mesh.

Table 1. Measurements of each mesh type.

Table 2. Mean (√) number of aphid nymphs of apterous and alate parents breaching different mesh sizes when leaflets were touching the mesh or not. In A., controls were statistically analysed. In B., treatments with means in brackets indicate those that were omitted because they had zero mean and zero variability. m.e. = main effect.

Table 1(on next page)

Measurements of each mesh type.

Table 1. Measurements of each mesh type.

	Mesh size (mm)							
	0.15×0.15		0.15×0.35		0.3×0.3		0.6×0.6	
Mean	0.14	0.13	0.15	0.32	0.37	0.23	0.52	0.52
Max.	0.16	0.15	0.18	0.37	0.53	0.31	0.57	0.55
Min.	0.12	0.10	0.12	0.30	0.27	0.17	0.45	0.47

Table 2 (on next page)

Mean (√) number of aphid nymphs of apterous and alate parents breaching different mesh sizes when leaflets were touching the mesh or not.

Mean (√) number of aphid nymphs of apterous and alate parents breaching different mesh sizes when leaflets were touching the mesh or not. In (A) controls were statistically analysed . In (B) treatments with means in brackets indicate those that were omitted because they had zero mean and zero variability. m.e. = main effect.

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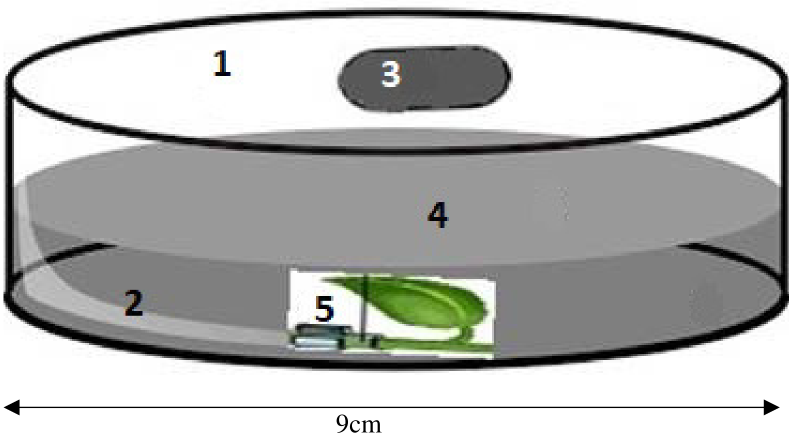
	Aphid morph	Mesh size (mm)	Mean of square root of # of nymphs below mesh	Back transformed means
A.				
Control	Apterous	0.15×0.15	2.460	6.05
		0.15×0.35	2.202	4.85
		0.3×0.3	1.940	3.76
		0.6×0.6	2.448	5.99
	Alate	0.15×0.15	1.823	3.32
		0.15×0.35	1.673	2.80
		0.3×0.3	2.455	6.03
		0.6×0.6	1.756	3.08
LSD 5%			**1.235**	
Significance of m.e., apterous vs alate			not sig.	
B.				
Leaflet not touching mesh	Apterous	0.15×0.15	(0.000)	0.00
		0.15×0.35	(0.000)	0.00
		0.3×0.3	0.483	0.23
		0.6×0.6	0.883	0.78
	Alate	0.15×0.15	(0.000)	0.00
		0.15×0.35	0.200	0.04
		0.3×0.3	0.283	0.08
		0.6×0.6	0.829	0.69
Leaflet touching mesh	Apterous	0.15×0.15	(0.000)	0.00
		0.15×0.35	(0.000)	0.00
		0.3×0.3	0.200	0.04
		0.6×0.6	0.400	0.16
	Alate	0.15×0.15	(0.000)	0.00
		0.15×0.35	0.546	0.30
		0.3×0.3	1.012	1.02
		0.6×0.6	1.029	1.06
LSD 5%			**0.905**	

Figure 1(on next page)

Experimental set up .

Experimental set up: (1) top Petri dish, (2) bottom Petri dish, (3) hole for aphid introduction, (4) mesh between dishes, (5) Eppendorf tube and leaflet. For the 8 ‘control’ treatments, aphids were placed below the mesh, while for the other 16 treatments, aphids were placed above the mesh.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