Inter-row Soil Cover to Reduce Incidence of Aphid-borne Viruses in Pumpkin

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ABSTRACT. Inter-row soil cover used in conjunction with vegetable crop production has the potential to reduce aphid-borne plant virus incidence while also reducing the need for pesticide applications and preserving inter-row soil structure. In this study, inter-row soil covers were compared with a conventional, bare soil treatment for their ability to reduce aphid-borne virus incidence and associated yield loss in pumpkin (*Cucurbita pepo* L. var. *pepo*). In 2006, inter-row soil cover crops included Sericea lespedeza [*Lespedeza cuneata* (Dumont de Courset)] G. Don], and sunn hemp (*Crotalaria juncea* L.). Sericea lespedeza was used in the 2007 trial, but naturally occurring weed species were used instead of sunn hemp. *Watermelon mosaic virus* (WMV) was detected in the 2006 trial and *Papaya ringspot virus* (PRSV) and WMV were detected in the 2007 trial. In

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2006, no differences were observed for WMV incidence among treatments, although significantly more aphids were identified on pumpkin plants in the Sericea lespedeza treatment. Enzyme-linked immunosorbent assay absorbance values for WMV accumulation in pumpkin plants for whole treatment, and for samples shown to be infected, were significantly lower in the Sericea lespedeza treatment, indicating less virus accumulation in these samples. No differences were observed among treatments for marketable pumpkin fruit number or yield. In the 2007 trial, WMV incidence was significantly less in pumpkin plants in the weed treatment compared with Sericea lespedeza early in the season, but incidence did not differ among treatments later in the season. PRSV incidence did not differ among treatments early in the season but was significantly lower in pumpkin plants in the Sericea lespedeza treatment than the bare soil treatment later in the season. Significantly more aphids occurred on pumpkin plants in the weed treatment than in the Sericea lespedeza and bare soil treatments. Significantly more aphids occurred on pumpkin plants in the Sericea lespedeza treatment than the bare soil treatment. Marketable pumpkin fruit numbers and yield were significantly greater for the Sericea lespedeza treatment than the bare soil and weed treatments. These data indicate that pumpkin plants grown with an inter-row soil cover may have less aphid-borne virus despite greater numbers of aphids.

KEYWORDS. *Potyvirus*, *Papaya ringspot virus*, *Watermelon mosaic virus*, Sericea lespedeza, sunn hemp

INTRODUCTION

Plant virus diseases are a common occurrence in cucurbit crops worldwide. A survey conducted in Alabama identified four viruses, *Cucumber mosaic virus* (CMV), *Papaya ringspot virus* (PRSV), *Watermelon mosaic virus* (WMV), and *Zucchini yellow mosaic virus* (ZYMV), with PRSV and WMV detected most frequently (Murphy et al., 2000). These viruses each cause varying types and severity of symptoms in cucurbit crops (Zitter et al., 1996).

The non-persistent manner of virus transmission by aphid vectors, as is the case for CMV and viruses in the genus *Potyvirus* (e.g., PRSV, WMV, and ZYMV), is a particularly difficult system for development of management schemes. When transmitted in this manner, the virus can be acquired by an aphid during brief probes (seconds to minutes) of infected cells and transmitted to a healthy cell of that host plant or another plant in a similar manner. Transmission occurs too quickly for effective control of the virus by use of insecticides to control the aphid (Pirone, 1991; Raccah, 1986). Furthermore, research has shown that application of insecticides may cause an increase in aphid activity, thereby increasing plant-to-plant movement of the aphid and spread of the virus (Raccah, 1986).

One effective approach to manage aphid-transmitted viruses involves use of reflective mulches (Conway et al., 1989; Momol et al., 2004; Summers et al., 1995; Wyman et al., 1979). Since most plant viruses are transmitted by flying insects, it is reasonable to predict that deterrence of entrance of the insect vector into the field may allow plants to achieve a state of maturity resulting in reduced impact of the infection. This phenomenon is referred to as age-related plant resistance (Agrios et al., 1985; Avilla et al., 1997; Bosque-Perez et al., 1998; Garcia-Ruiz and Murphy, 2001; Rosenkranz and Scott, 1978; Soler et al., 1998). The effectiveness of the reflective properties of such mulches, however, may be reduced as plants increase in size, thereby covering the mulch.

Cultural practices generally recommend removal of weeds that border, or grow within, the crop. This process produces a barrier between the crop and the potential source of viral inoculum and insect pests. It is well established, however, that migrating alate aphids are visually stimulated by, or attracted to, the contrast of plant and soil (A'Brook 1968; Smith, 1969). As a result, aphids tend to accumulate more along field edges where the greatest visual contrast occurs. Not surprisingly, the incidence of virus infection tends to be greatest along field edges (Broadbent et al., 1951; Hampton, 1967; Jones, 1993; Swenson, 1968). These observations have been incorporated into management strategies involving border rows of trap crops and intercrops. Border rows of various types were used to reduce virus incidence in pepper (*Capiscum annuum* L.; Fereres, 2000; Simons, 1957), potato (*Solanum tuberosum* L.; DiFonzo et al., 1994), and soybean (*Glycine max* L. Merrill; Bottenberg and Irwin, 1992) but were less effective with pumpkin (*Cucurbita pepo* L. var. *pepo*; Damicome et al., 2007). Intercrops of wheat (*Triticum aestivum* L.; Toba et al., 1977) and sorghum (*Sorghum bicolor* L. Moench.; Damicone et al., 2007) were successful at reducing virus incidence in cantaloupe (*Cucumis melo* L.) and pumpkin, respectively.

Pumpkin crops appear particularly vulnerable to aphid-borne viruses, due in part to the later planting date typically used to allow fruit production to coincide with an autumn harvest. This later planting date allows aphid vector populations to build throughout the growing season but prior to pumpkin planting, with the result being extensive movement of virus into the crop. This project was undertaken to determine the efficacy of inter-row soil covers as a strategy to reduce aphid-borne virus incidence in pumpkin.

MATERIALS AND METHODS

Experimental Design and Treatment Description

Seeds of pumpkin, cv. Trickster, were hand-sown 45 cm apart into holes punched into the white plastic mulch by a waterwheel transplanter. Plots were 7.6 m wide by 9.1 m long. Each plot had two rows and each row was 6 m long by 84 cm wide. In each plot, the space consisting of cover crop; i.e., between and outside the rows of pumpkin, was 127 cm wide. Plots were separated from each other by 20 m along rows and 15 m to the side of each plot.

White plastic mulched rows consisted of raised beds (20 cm high by 84 cm wide) treated prior to bed preparation with P_2O_5 fertilizer broadcast applied at 0.8 kg per 10 m of row. A drip irrigation tube was placed under the white plastic mulch during mulch application. The irrigation line was used to deliver water and fertilizer as recommended for pumpkin production. All beds were fumigated with methyl bromide (335 $kg \cdot ha^{-1}$ of 67% methyl bromide+33% chloropicrin) before being covered with white plastic mulch.

The conventional treatment between beds was bare soil. In both years there were two alternative treatments. In both years the first treatment was Sericea lespedeza [*Lespedeza cuneata* (Dumont de Courset) G. Don], line AU L18, a low-growing perennial, sown (drilled) at 23 $kg \cdot ha^{-1}$ into a prepared seedbed in the spring of 2003. The second treatment in 2006 was sunn hemp (*Crotalaria juncea* L.), a plant with a more upright habit, sown (drilled) at a rate of 67 kg ha^{-1} the week preceding when pumpkin seed were sown. In place of sunn hemp was a mix of naturally occurring weeds used in 2007. The weed species were for the most part *Digitaria sanguinalis* (L.) Scop. (crabgrass), *Eleusine indica* (L.) Gaertn. (goosegrass), *Amaranthus retroflexus* L. (pigweed), *Jacquemontia tamnifolia* (L.) Griseb. (smallflower morning glory), *Solanum nigram* L. (nightshade), *Mollugo verticillata* L. (carpetweed), and *Cyperus esculentus* L. (yellow nutsedge), most of which had upright growth habits.

Virus Disease, Aphid Densities, and Yield

Plants were tested for virus infection using commercially developed double antibody sandwich enzyme–linked immunosorbent assay (ELISA) kits (Agdia, Inc., Elkhart, Ind.). All plants in each treatment were tested by ELISA for presence of CMV, PRSV, WMV, and ZYMV. Each ELISA procedure was performed according to the manufacturer’s instructions.

A single leaf sample, positioned near the apical portion of the vine, was collected from each plant. The leaf was wrapped in a dampened paper towel, placed in a plastic zipped storage bag and transported on ice to Auburn University for testing. Leaf samples were ground between two steel rolling pins on a motorized leaf squeezing apparatus (Piedmont Machine and Tool, Six Mile, S.C.). Each leaf was ground on a weighted basis in general extraction buffer (Agdia, Inc.) at a ratio of 1 g tissue to 2.5 mL buffer. Each microtiter plate contained a known positive control sample for the respective antibody system and at least three negative control samples. Upon adding substrate, reactions were allowed to develop at room temperature for 60 to 90 min and were then recorded using a Sunrise microtiter plate reader (Phenix Research Products, Hayward, Calif.). A sample was considered positive for presence of virus if the ELISA absorbance value was greater than the average plus three standard deviations of the negative control samples. Three sets of ELISA-based data are presented: virus incidence, ELISA(total), and ELISA(positive). Incidence, for purposes of this study, represents the percentage of infected plants (i.e., number of plants considered infected, based on ELISA, divided by the number of plants tested within the respective treatment). ELISA(total) represents the mean ELISA absorbance value for all samples within the respective treatment, including samples considered positive and negative for virus infection. ELISA(positive) represents mean ELISA absorbance values for only those samples considered positive for virus infection.

In the 2006 trial, virus-like symptoms developed on pumpkin plants after one month. Leaf samples for virus tests were collected at a single date just prior to fruit harvest, 59 days after pumpkin seed was sown. In the 2007 trial, virus-like symptoms were observed on a small percentage of plants in the first month of growth. Leaf samples for virus tests were collected two times in 2007, the first at 30 days and the second just prior to harvest at 64 days after sowing (das).

Populations of all aphids were monitored on three dates in 2006 (15 and 24 Aug. and 7 Sept.) and on a weekly basis in 2007 beginning at 5 July by visually searching the leaves and stems of five randomly selected pumpkin plants in each row within each replicated unit. Numbers of all aphids per plant were recorded. Pumpkin fruit were harvested at fruit maturity and graded for uniform size, shape, and color according to USDA standards.

Statistical Analysis

A randomized complete block design was used with three inter-row soil cover treatments each replicated four times. The data were subjected to analysis of variance (SAS, Cary, N.C.). The use of different treatments in 2006 (sunn hemp) and 2007 (weeds) did not allow analyses to be pooled. Years were treated separately.

RESULTS

2006

Visual assessments for virus-like symptoms indicated no presence of disease during the first ca. 30 days after sowing pumpkin seed. At times thereafter, typical virus-like symptoms such as mosaic patterns on young leaves became increasingly more apparent. WMV was the only virus detected by ELISA in tested leaf samples.

WMV incidence, based on detection of virus by ELISA, did not differ significantly among treatments (Table 1). Since leaf samples were processed for ELISA on a weighted basis, it was valid to make relative comparisons for the amount of virus accumulation based on ELISA absorbance values. In this case, the treatment average for WMV accumulation in pumpkin leaf samples was significantly less in the Sericea lespedeza treatment than in the sunn hemp and bare soil treatments (Table 1, ELISA(total)). In addition, WMV accumulation was less in pumpkin leaf samples from the sunn hemp treatment than for those in the bare soil treatment. The ELISA values used to examine WMV accumulation in leaf samples represented treatment means and included values considered positive and negative for the presence of virus. When ELISA absorbance values for leaf samples shown to be positive for WMV infection were compared, WMV accumulation was significantly less in pumpkin plants in the Sericea lespedeza treatment with no difference between pumpkin plants in the bare soil and sunn hemp treatments (Table 1, ELISA (positive)).

Aphid numbers were relatively consistent among monitoring dates in 2006 (data not shown). There were significant treatment effects for total aphid numbers (alate and apterous) on pumpkin plants (Table 2). Significantly more aphids occurred on pumpkin plants in the Sericea lespedeza treatment than on pumpkin plants in either the bare soil or sunn hemp treatments. In addition, there were significantly more aphids on pumpkin plants in the sunn hemp treatment than in the bare soil treatment. There were no significant differences among treatments for marketable pumpkin fruit numbers or yield (Table 3) because there was extensive variability within the sunn hemp treatment.

TABLE 1. Virus incidence and accumulation in pumpkin plants grown in different intercrop treatments

WMV	Incidence[Z]		ELISA(total)[Y]		ELISA(positive)[X]	
2006 Trial						
Bare soil	68.6 a[W]		0.756 a		1.023 a	
Sericea lespedeza	25.0 a		0.325 c		0.825 b	
Sunn hemp	48.7 a		0.580 b		1.052 a	
	Incidence		ELISA(total)		ELISA(positive)	
	30 das[V]	64 das[V]	30 das	64 das	30 das	64 das
2007 Trial						
WMV						
Bare soil	27.5 ab	65.7 a	0.432 a	0.366 b	0.690 b	0.444 ab
Sericea lespedeza	30.0 a	77.5 a	0.414 a	0.433 a	0.590 b	0.498 a
Weed	7.0 b	60.5 a	0.336 b	0.312 b	1.116 a	0.393 b
PRSV						
Bare soil	5.5 a	91.0 a	—[U]	0.417 a	0.209 ab	0.450 b
Sericea lespedeza	29.2 a	59.0 b	—	0.349 b	0.216 a	0.526 a
Weed	9.2 a	88.2 ab	—	0.470 a	0.205 b	0.521 a

[Z]Incidence represents the percentage of plants in a respective treatment infected with *Watermelon mosaic virus* (WMV) or *Papaya ringspot virus* (PRSV).
[Y]ELISA(total) represents the average ELISA absorbance value for all plants in the respective treatment.
[X]ELISA(positive) represents the average ELISA absorbance value for those samples considered positive for infection by virus in the respective treatment. A sample was considered positive for presence of virus if the ELISA absorbance value was greater than the average plus three standard deviations of the negative control samples.
[W]Values in columns followed by different letters are significantly different ($P < 0.05$).
[V]das = days after sowing. In the 2006 trial, WMV incidence, ELISA(total) and ELISA(positive) were determined at 59 das.
[U]ELISA values are not presented because the average absorbance value is below the threshold for a positive reaction for virus infection.

2007

Pumpkin plants expressing virus-like symptoms were observed within the first month from the date seed was sown. Each pumpkin plant was sampled two times during the 2007 trial with each sample tested for CMV, PRSV, WMV, and ZYMV. Leaf samples tested positive for PRSV and WMV with no detection of CMV or ZYMV.

TABLE 2. Average total number of aphids counted on five randomly selected pumpkin plants in each row in 2006 and 2007

Treatment	Aphid numbers[Z]
2006 Trial	
Bare soil	0.9 c[Y]
Sericea lespedeza	10.2 a
Sunn hemp	2.7 b
2007 Trial	
Bare soil	551.9 c
Sericea lespedeza	710.8 b
Weed	999.0 a

[Z]Aphid numbers include apterous and alate aphids.
[Y]Values in columns followed by different letters are significantly different ($P < 0.05$).

TABLE 3. Marketable number and yield of pumpkin fruit in 2006 and 2007

Treatment	Marketable no.[Z]	Marketable yield (kg)[Z]
2006 Trial		
Bare soil	143.5 a[Y]	160.7 a
Sericea lespedeza	179.7 a	206.9 a
Sunn hemp	154.0 a	185.4 a
2007 Trial		
Bare soil	23.0 b	20.7 b
Sericea lespedeza	36.0 a	36.1 a
Weed	22.5 b	21.0 b

[Z]Pumpkin fruit were harvested at fruit maturity and graded for uniform size, shape, and color according to USDA standards. Marketable fruit number and yield are presented as average values per plot for the respective treatment.
[Y]Values in columns followed by different letters are significantly different ($P < 0.05$), according to Fisher's least significant difference test.

WMV incidence for the first test period at 30 das, based on detection of virus by ELISA, was significantly less in pumpkin plants in the weed treatment than in the Sericea lespedeza treatment with neither treatment differing from the bare soil treatment (Table 1, Incidence, 30 das). Not surprisingly, perhaps, the lower incidence of WMV in pumpkin plants in the weed treatment resulted in a lower amount of virus detected, on average, relative to plants in the bare soil and Sericea lespedeza treatments (Table 1, ELISA(total), 30 das). Interestingly, examination of ELISA absorbance values for pumpkin plants shown to be infected with WMV revealed significantly lower amounts of virus in the bare soil and Sericea lespedeza treatments relative to the weed treatment (Table 1, ELISA (positive), 30 das).

WMV incidence increased dramatically for the second test period at 64 das but with no differences among treatments (Table 1, Incidence, 64 das). Significantly lower whole treatment ELISA values occurred for pumpkin plants in the bare soil and weed treatments compared with plants in the Sericea lespedeza treatment (Table 1, ELISA(total), 64 das). Average ELISA values for pumpkin leaf samples from plants shown to be infected with WMV were significantly lower in the weed treatment compared with the Sericea lespedeza treatment, with neither differing from the bare soil treatment (Table 1, ELISA(positive), 64 das).

PRSV incidence for the first sample period at 30 das did not differ among treatments (Table 1, Incidence, 30 das). The average ELISA absorbance values for treatments at 30 das were not above the threshold to be considered positive for PRSV infection (Table 1, ELISA(total), 30 das). This may have resulted from the generally low incidence of PRSV among treatments for this sample period. Although examination of average ELISA absorbance values for samples from PRSV-infected plants (i.e., ELISA positive samples) indicated relatively low values overall with those from the weed treatment being significantly less than in the Sericea lespedeza treatment (Table 1, ELISA(positive), 30 das).

As observed for WMV incidence, PRSV incidence increased for the second sample period (Table 1, Incidence, 64 das). PRSV incidence was significantly lower for pumpkin plants in the Sericea lespedeza treatment than in the bare soil treatment, neither of which differed from the weed treatment. In agreement with incidence data, average whole treatment ELISA values were significantly lower for pumpkin plants in the Sericea lespedeza treatment than for those in the bare soil and weed treatments (Table 1, ELISA(total), 64 das). However, PRSV-infected leaf samples contained on average significantly less virus for pumpkin plants in the bare soil treatment than for pumpkin plants in the Sericea lespedeza and weed treatments (Table 1, ELISA(positive), 64 das).

Aphid numbers on pumpkin plants appeared to be much higher in 2007 than observed in 2006 (Table 2). In 2007, significantly more aphids (apterous and alate) occurred on pumpkin plants in the weed treatment than in Sericea lespedeza and bare soil treatments (Table 2). In addition, there were significantly more aphids on pumpkin plants in the Sericea lespedeza treatment than in the bare soil treatment.

Pumpkin plants in the Sericea lespedeza treatment were larger and had more lush growth than those in bare soil and weed treatments (J. F. Murphy, personal observation). The observed better growth of pumpkin plants in the Sericea lespedeza treatment may have benefited yield. Total marketable fruit numbers and yield were significantly greater for pumpkin plants in the Sericea lespedeza treatment than for plants in the bare soil or weed treatments (Table 3).

DISCUSSION

We hypothesized that an inter-row soil cover would reduce virus incidence among pumpkin plants. This reduction in virus incidence would result from fewer aphids occurring in plots containing inter-row soil covers, and the inter-row soil cover would serve as a depository for virus if viruliferous aphids entered the plot. The first hypothesis was based on reports indicating that when aphids are in flight, they are attracted to or stimulated by contrasts in reflectance (A'Brook, 1968; Smith, 1969). Conventional cultivation practices consisting of crop plant with surrounding bare soil would therefore provide extensive contrast as opposed to a living, green soil cover surrounding the main crop plants. For the second case, it was hypothesized that aphids that entered bare soil plots would land directly on pumpkin plants. In contrast, aphids that entered plots containing an inter-row soil cover would be less likely to land directly on pumpkin plants and, instead, would land on inter-row soil cover plants. If aphid host identification behavior is taken into account, that is, the aphid makes multiple test probes of epidermal cells of one or more plants before choosing to feed, then the virus would be inoculated to inter-row soil cover plants with the aphid being virus free upon feeding on pumpkin plants.

The second hypothesis, but not the first, appears to provide a better explanation for some of the observed results. In 2006, aphid densities on pumpkin plants in the Sericea lespedeza treatment were significantly higher than aphid densities on pumpkin plants in the other treatments. Although WMV incidence did not differ among treatments, it was not greater in the Sericea lespedeza treatment despite the greater number of aphids. In the 2007 trial, WMV incidence was significantly less in the weed treatment than the Sericea lespedeza treatment early in the season (30 das), and overall there were significantly more aphids on pumpkin plants in the weed treatment. PRSV incidence was significantly less in the Sericea lespedeza treatment than in the bare soil treatment later in the 2007 season (64 das) and there were significantly more aphids on pumpkin plants in the Sericea lespedeza treatment than in the bare soil treatment. These data indicate that pumpkin plants sustained less infection when grown with an inter-row soil cover despite the occurrence of greater numbers of aphids in these treatments. Moreover, the data also indicate that the use of inter-row soil covers (at least those used in this study) did not deter aphids from entering the plots, as predicted for the first hypothesis.

The ELISA(total) values were calculated from all samples within a treatment, including samples negative and positive for the presence of virus. These values tended to reflect virus incidence; that is, a lower virus incidence meant more samples considered negative for virus infection and therefore more samples with a low ELISA value. This effect was most pronounced for the ELISA total data at 30 das in Table 1 where, despite an average range of 5.5% to 29.2% infection among treatments, the total average ELISA value was below the threshold for being considered a positive reaction. The dilution effect of averaging negative and positive ELISA values was overcome by determination of the average value for only those samples considered positive within a treatment (Table 1, ELISA (positive)).

The level of accumulation of virus within a plant may reflect timing of infection relative to the developmental stage of that plant, and can vary with the virus and host. In 2007 the average ELISA(positive) values for WMV at 30 das were generally higher than those observed at 64 das. This may have resulted from rapid systemic infection and high levels of accumulation that occur in susceptible plants when infected early in their development. In contrast, infection at a later stage of development may result in systemic infection but with milder symptoms and lower levels of virus accumulation. For some virus–host interactions, infection at later stages in the plant's development may result in limited, if any, systemic infection due to mature plant resistance (Garcia-Ruiz and Murphy, 2001). PRSV accumulation followed the opposite path, however, with lower levels of accumulation at 30 das compared with 64 das. We do not know whether the differences in virus accumulation observed were due to timing of infection, peculiarities of the virus–host interaction or combinations thereof. More extensive monitoring of virus accumulation through time would likely provide greater knowledge of the spatial and temporal dynamics of virus infection within and among treatments.

The choice of inter-row cover crop may influence the level of protection afforded crop plants. Sericea lespedeza was chosen as a low-maintenance perennial that could be mowed to manage plant height and provide dense groundcover. Sunn hemp was intended to serve more as a physical barrier to aphids because of its rapid growth habit leading to a dense stand of tall stalked plants. The rapid upright growth habit, however, overly shaded the pumpkin plants and upon being cut back to pumpkin canopy height resulted in leafless stalks no longer providing a green soil cover. Although the sunn hemp treatment was, in some cases, better than the bare soil treatment, it did not perform as well as the Sericea lespedeza treatment and was discontinued in the 2007 trial. The incorporation of a weed treatment to replace sunn hemp was chosen primarily in response to results from the Sericea lespedeza treatment in 2006, which had the highest aphid densities on pumpkin plants in this treatment but not a correspondingly high incidence of virus. The basic premise for the weed treatment was that a groundcover consisting of diverse species may have high aphid densities but also greater insect diversity (including aphid predators) and subsequently lower virus incidence in pumpkin.

Cover crops intended to serve as a physical barrier have been successful at reducing virus incidence (Fereres, 2000; Simons, 1957), although not always better than other border and inter-row soil covers (Damicone et al., 2007; DiFonzo et al., 1994). Toba et al. (1977) indicated that wheat served as an effective inter-row soil cover to reduce aphid-borne virus disease for cantaloupe. They recommended that an effective cover crop should have a growth habit that does not compete with the main crop; it should not attract undesirable insects or be a host for viruses that threaten the main crop. Use of sorghum, as a border or inter-row soil cover, resulted in reduced virus disease in pepper, pumpkin, and soybean (Bottenberg and Irwin, 1992; Damicone et al., 2007; Fereres, 2000). Damicone et al. (2007) suggested that sorghum may have been a preferred host for the primary aphid vector in their study, thereby possibly serving as a virus depository and reducing aphid movement from sorghum to pumpkin.

In our study, at the time of the second evaluation date (64 das) in 2007, pumpkin plants in the Sericea lespedeza treatment were larger and appeared to be healthier, that is, lush, green vines and leaves, than pumpkin plants in bare soil or weed treatments, which had shorter vines and foliar chlorosis (data not shown). This may have translated to higher yields despite the relatively high virus incidence, in fact, pumpkin plants consistently produced higher yield when grown intercropped with Sericea lespedeza. Fruit number and yield, however, were lower in 2007 than in 2006. A plausible explanation for this is the sustained record-breaking temperatures and drought that occurred during the 2007 trial. The inter-row soil covers were not watered, which led to diminished plant growth in the weed treatment; however, the Sericea lespedeza plants remained green with dense growth. Furthermore, the occurrence of PRSV and WMV in the 2007 trial versus just WMV in the 2006 trial may have negatively impacted fruit number and yield. Further study is needed to understand the impact an inter-row soil cover may have on vegetable production, such as effects on soil nutrition and water retention within and in the vicinity of the cover crop.

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