Broad Mite on Primocane-fruiting Blackberry in Organic Production in Arkansas

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Additional index words. *Rubus*, high tunnels, pest susceptibility, *Polyphagotarsonemus latus*

Summary. The broad mite (*Polyphagotarsonemus latus*) was found in association with leaf-curling symptoms on primocane-fruiting blackberry (*Rubus rubus*) in Arkansas in 2007–2009. Broad mite had not been previously reported on blackberry. The plots sampled in this study were part of a study comparing harvesting in the fall versus harvest in spring and fall, high tunnels versus ambient conditions, and three genotypes, all under organic production. Leaves were sampled, broad mites per leaf counted, and leaf area and trichome density measured. Results indicated that broad mite is capable of overwintering in a moderate temperate climate and that it reduces leaf area of primocane-fruiting blackberry. The fall-only harvest system had fewer broad mites than fall and spring harvest. There were a range of genotype effects on broad mite populations, including one genotype, 'Prime-Jan®', on which broad mite populations remained low, and one genotype, APF-46, on which mite populations grew significantly. Observations indicate that the broad mite may be a pest of 'Prime-Ark® 45', another primocane-fruiting cultivar.

In Sept. 2007, malformed leaves were observed on APF-46, a University of Arkansas primocane-fruiting (PF) blackberry selection, at the Arkansas Agricultural Research and Extension Center, Fayetteville, AR (lat. 36°5′4″ N, long. 94°10′29″ W). Symptoms included stiff, curled leaves with margins turned downward and aborted flower buds (Fig. 1). Within 1 month, the condition had developed in most plots of a study of PF blackberries in ambient conditions and under high tunnels. These symptoms were observed in Sept. 2008 on 'Prime-Jim®', a PF cultivar, as well as on APF-46, although the symptoms on 'Prime-Jim®' were less pronounced. 'Prime-Jan®', a PF blackberry cultivar in the same plantings, did not display any symptoms. Broad mites were identified on leaf samples from affected plants by the distinctive pattern of white projections on their oblong eggs (Gerson, 1992) (Fig. 2). Although symptoms were only observed on two genotypes, the broad mite was identified on all three. Similar leaf symptoms and presence of broad mite were reported on 12 Oct. 2009 from PF blackberry in southwestern North Carolina. The record of this detection is catalogued in the North Carolina State University Plant Disease and Insect Clinic records (H.J. Burrack, personal communication).

The symptoms on these PF blackberry genotypes, downward leaf curling and bud abortion, were similar to those described on many crops fed on and affected by the broad mite (Gerson, 1992). Leaf area was reduced by the broad mite on both pepper [*Capsicum annuum* (Coss-Romero and Peña, 1998)] and cucumber [*Cucumis sativus* (Grinberg et al., 2005)] in association with leaf-curling symptoms.

A review by Gerson (1992) listed 55 dicotyledonous species on which broad mite has been found to cause damage, but no blackberry or raspberry species were named. This list included many fruit and vegetable crops in the Fabaceae, Cucurbitaceae, Myrtaceae, Solanaceae, Proteaceae, and Vitaceae families.

Waterhouse and Norris (1987) reported that broad mite occurred in tropical and subtropical climates of Australia, Asia, Africa, North America, South America, and the Pacific Islands. In temperate and subtropical areas, the broad mite was a pest of greenhouse plants. However, in 1979, broad mite was found damaging lemons in a commercial grove in California (Brown and Jones, 1983). This mite adversely affected citrus in the fall (Gerson, 1992). Karl (1965, as cited in Gerson, 1992) concluded that broad mite could not survive outside of a tropical, subtropical, or controlled greenhouse environment. In grapes (*Vitis vinifera*), the optimum temperature for broad mite reproduction was 25 °C (Ferreira et al., 2006). Outbreak populations of broad mite were observed only in late vegetative and early flowering stages of pepper (Coss-Romero and Peña, 1998), and seedlings infected at earlier stages had greater damage than those infected later (Jovicich et al., 2004). Matos et al. (2009) determined that pepper species with higher trichome densities generally had a lower rate of population growth of broad mite, although they concluded that their results could not be universalized because of the wide variety of morphologies and distribution patterns of trichomes.

This study was undertaken within an existing study comparing high tunnel versus ambient conditions in blackberry production. High tunnels have multiple uses in berry production, including uses in harvest season manipulation and pest and disease management. Because of the effects of high tunnels on temperatures, light levels, and relative humidity, it was thought that high tunnels could have an impact on pest biology.

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Units

To convert U.S. to SI, multiply by	U.S. unit	SI unit	To convert SI to U.S., multiply by
0.3048	ft	m	3.2808
25.4	inch(es)	mm	0.0394
6.4516	inch^2	cm^2	0.1550
(°F – 32) ÷ 1.8	°F	°C	(1.8 × °C) + 32

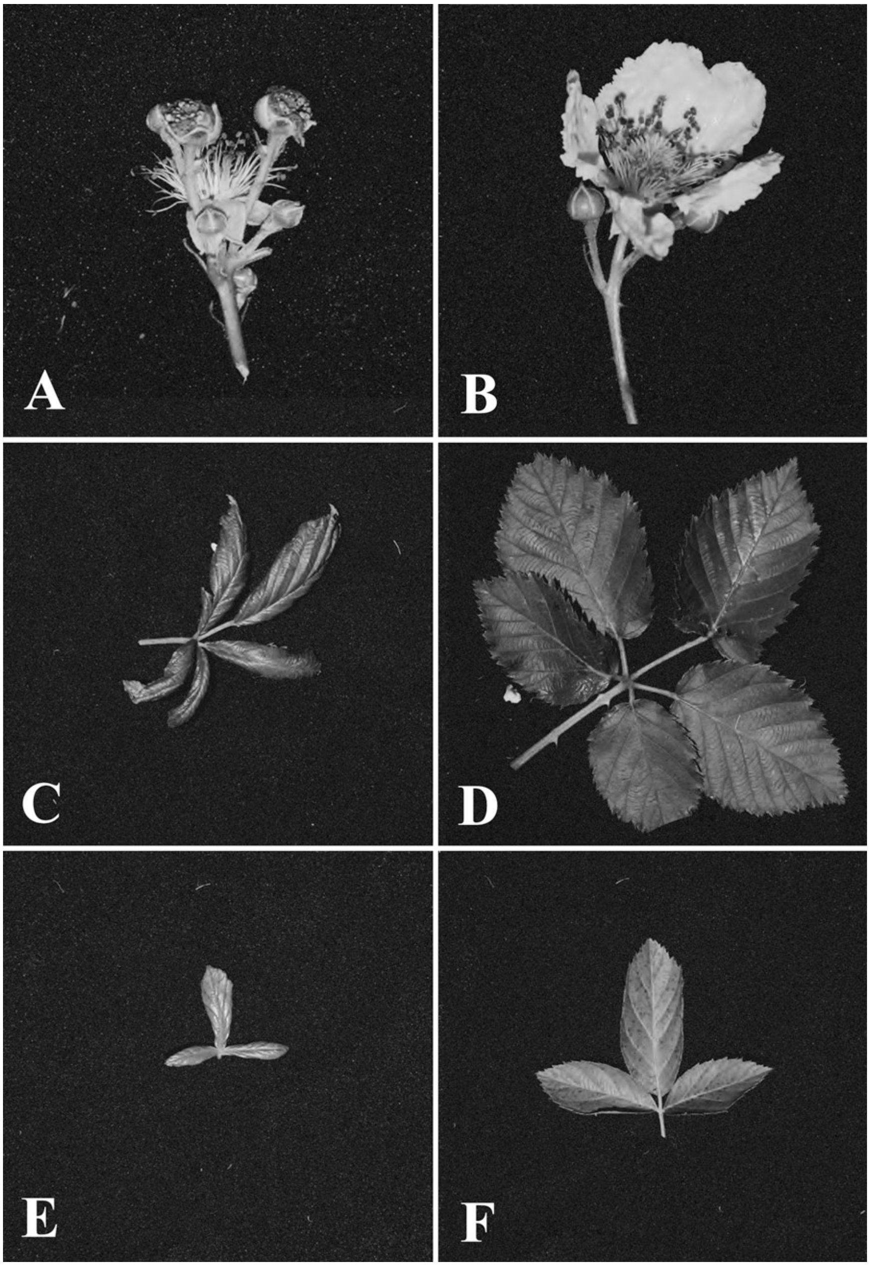

Fig. 1. Leaf curling found in association with broad mite on primocane-fruiting blackberry genotype APF-46 in Fall 2009 at Fayetteville, AR: (A) broad mite-infested floral buds, (B) uninfested floral buds, (C) infested pentafoliate leaf, (D) uninfested pentafoliate leaf, (E) infested trifoliate leaf, and (F) uninfested trifoliate leaf.

This study was conducted to determine: 1) the effects of harvest system, high tunnels, and genotypes on the populations of broad mite that develop on PF blackberries in late summer and early fall; 2) to document the damage caused by broad mite to the same genotypes; and 3) whether the damage is the same for each genotype.

Materials and methods

This study was performed within an already existing study of PF blackberry. In the study, practices were entirely organic, and no insecticides or acaricides of any kind were used, including organically approved insecticides. The study was arranged as two randomized complete block (RCB) designs with three replications of 4-m rows. In one RCB, primocanes were harvested and dormant floricanes were left in the plot and harvested in spring (spring and fall harvest system). In the other, the primocanes were harvested in the fall, and dormant floricanes were mown to the ground and removed from the planting (fall-only harvest system). Within each RCB, three genotypes were tested under high tunnels and ambient conditions. The genotypes in the study were 'Prime-Jim®', 'Prime-Jan®', and APF-46.

2007. On 5 Nov. 2007, leaf samples were taken from 'Prime-Jim®', 'Prime-Jan®', and APF-46. Six plots were sampled, three under high tunnels and three under ambient conditions. Because the harvest season was already advanced, samples were only taken on one date. There was no indication based on visual inspection of differences between harvest systems; thus, these plots were randomized across the two RCB studies without regard to harvest system. To standardize leaf size and maturity, 10 canes in each row were randomly selected, and the leaf of the fifth node from the apex was removed. Blackberry primocane leaves have three to five leaflets. Ten leaflets were randomly selected from these selected leaves of each row. A stereomicroscope was used to scan each leaf and count the number of broad mites on each selected leaflet. The presence or absence of leaf curl was noted and the area of each leaflet was measured with a portable leaf area meter (LI-3000A; LI-COR Biosciences, Lincoln, NE).

2008. To compare genotype differences in leaf trichome density, 10 leaves were sampled randomly from each cultivar on 5 May 2008. A 3-mm line was placed randomly three times across the abaxial surface of the leaf according to the protocol used by Roda et al. (2001) on apple (*Malus* ×*domestica*) leaves. The trichomes intersecting the line were counted and the average of each leaf was taken. Samples were taken at this time because it was thought that broad mite population growth would be initiating during this period as optimal temperatures (25 °C) for growth beginning in April and May in Arkansas.

To quantify mites, leaf samples were taken on multiple dates from each cultivar in each plot of the PF blackberry high tunnel study. In 2008, all plots were sampled to include harvest system as a factor. Ten leaflets were selected per sample as noted for 2007. However, to further minimize variance, only apical leaflets of each leaf were taken. Mites were removed from leaves using a rotary brushing machine, and broad mites found on the receptor plate were counted after brushing all 10 leaflets. Samples were taken on 12 Sept., 23 Sept., and 8 Oct. Leaf areas of the same leaves were measured like in 2007. Both parameters were analyzed as means for each experimental unit.

Because the mean number of broad mites per leaf was less than the SD, the means were transformed using a logarithm [log (number of broad mites per leaf + 1)]. Mean leaf area and trichome density as well as transformed broad mite means were analyzed by date as repeated measures using the GLM procedure (SAS Version 9.1; SAS Institute, Cary, NC) with means separation using Fisher's protected least significant difference test. The GLM procedure was also used to test a linear correlation of broad mites per leaf or broad mites per square centimeter with average leaf area. Because methods used in each year were different, counts were not compared between years.

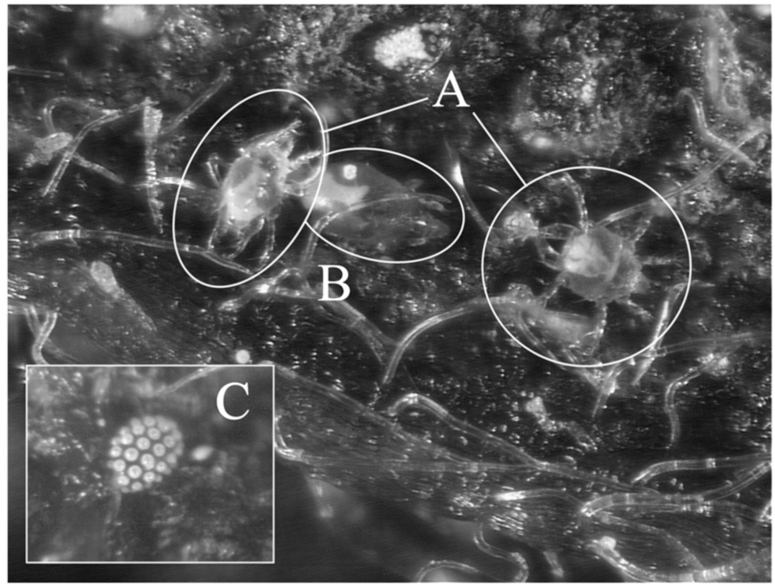

Fig. 2. Broad mite on leaves of 'Prime-Ark® 45' in 2009 at Fayetteville, AR: (A) adult males with characteristic long legs, (B) adult female, and (C) egg with characteristic raised protrusions.

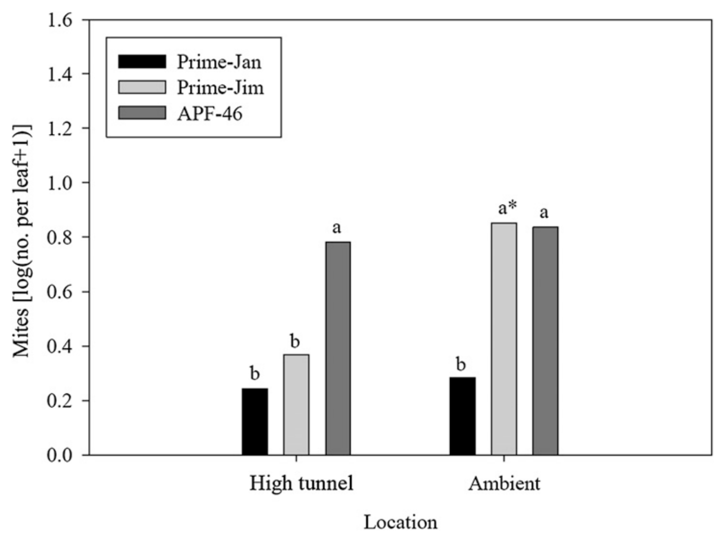

Fig. 3. Mean number of broad mites per leaf for the interaction of three primocane-fruiting blackberry genotypes ('Prime-Jan®', 'Prime-Jim®', APF-46) in two environments in Fall 2007 at Fayetteville, AR. *Mean bars labeled with different letters are significantly different according to *t* test at $P < 0.05$ using Fisher's protected least significant differences.

Results and discussion

2007. There was a genotype by location interaction for significant effects on broad mite count. APF-46 had significantly more broad mites than 'Prime-Jim®' and 'Prime-Jan®' under high tunnels, but differences between APF-46 and 'Prime-Jim®' were not significant in ambient plots (Fig. 3). APF-46 had significantly more broad mites than 'Prime-Jan®' in both locations. 'Prime-Jim®' had significantly higher broad mite numbers in ambient conditions than under high tunnels. APF-46 was the only genotype that showed symptoms of leaf curl, and differences were significant ($F = 33.51$, $P < 0.0001$) between the area of healthy, uncurled leaflets of APF-46 (16.21 cm^2) and that of curled, broad mite-infested leaflets (9.6 cm^2).

2008. The mean numbers of trichomes intersecting a 3-mm line on the abaxial surface of primocane leaves were significantly different among all genotypes: 'Prime-Jan®' (24.9), 'Prime-Jim®' (15.7), and APF-46 (7.5) ($F = 49.60$, $P < 0.0001$). These differences also occurred among plant locations, where plants grown in high tunnels that had fewer broad mites also had a lower trichome density (14.3) than plants in ambient conditions (17.7) ($F = 5.67$, $P < 0.022$).

In 2008, genotype had a significant effect on mean number of broad mites per leaf over time ($F = 5.73$; $P = 0.0103$). Although broad mite counts increased on 'Prime-Jim®' and APF-46 over the 1-month span, they decreased in 'Prime-Jan®' (Fig. 4). APF-46 had higher broad mite counts earlier than 'Prime-Jim®'. These trends were similar across both harvest systems, although there were significant differences between broad mite count means in different harvest production systems for the same genotype (Fig. 4).

The overall genotypic differences in the mean number of broad mites in 2008 were similar to 2007 with higher counts in 'Prime-Jim®' than 'Prime-Jan®' and the highest counts in APF-46. Mean broad mite numbers

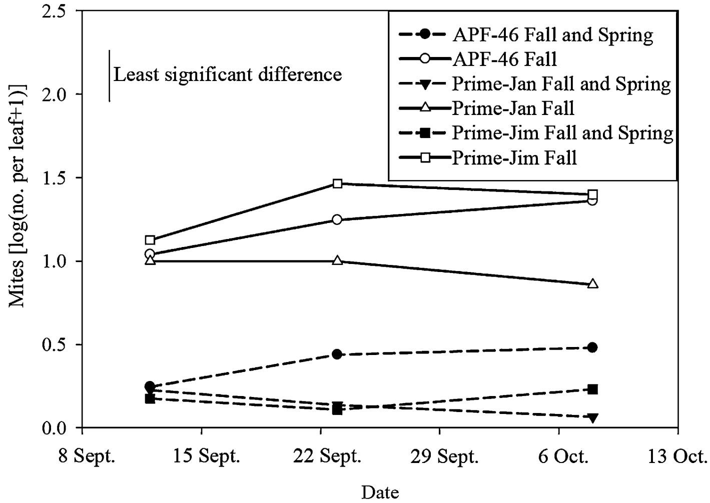

Fig. 4. Mean number of broad mites per leaf on three primocane-fruiting blackberry genotypes each after fall-only or both spring and fall harvest production systems across three dates in Fall 2008 at Fayetteville, AR. Bar represents least significant difference (LSD) at $P = 0.05$ and notes significant differences by date using paired t test with Fisher's protected LSD.

Table 1. Analysis of variance of between-subject effects of repeated measures analysis of mean broad mite number per leaf on primocane-fruiting blackberries in 2008 at Fayetteville, AR.

Source of variation	df	Mean square error	F	*P*
Harvest system[z]	1	22.13	297.83	<0.0001
Location[y]	1	0.63	8.53	0.0044
Genotype[x]	2	0.66	8.9	0.0003
Harvest system × location	1	5.16	69.38	<0.0001
Location × genotype	2	0.34	4.61	0.0123
Harvest system × genotype	2	0.22	2.99	0.055
Harvest system x location x genotype	2	0.19	2.59	0.0805
Replication	1	0	0.04	0.8437
Error	92	0.07	—	

[z]Harvest systems were spring and fall harvest or fall-only harvest, in which overwinter primocanes were removed.
[y]Locations were ambient conditions or under high tunnels.
[x]Genotypes were 'Prime-Jim®', 'Prime-Jan®', and APF-46.

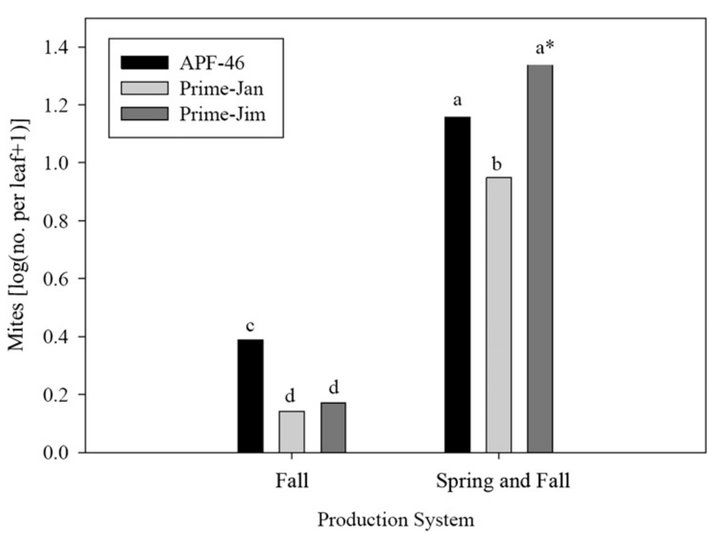

Fig. 5. Mean number of broad mites per leaf for the interaction of three primocane-fruiting blackberry genotypes ('Prime-Jim®', 'Prime-Jan®', APF-46) and two harvest production systems in Fall 2008 at Fayetteville, AR. *Mean bars labeled with different letters are significantly different at $P < 0.05$ using paired t test with Fisher's protected least significant differences.

were significantly different among all genotypes (Table 1). However, the greatest differences were found in the effects of harvest production system on broad mite counts (Table 1; Fig. 5), the interactions of harvest production system with genotype, and of harvest production system with planting location (Fig. 6). Because of these interactions, it was difficult to draw conclusions about the effects of high tunnels. In the fall and spring harvest system, the broad mite counts were greater under high tunnels than in ambient conditions, whereas in the fall-only harvest system, the plots under ambient conditions had more broad mites than those under high tunnels. 'Prime-Jim®' and 'Prime-Jan®' had similar counts of broad mite in the fall-only harvested system, whereas in the spring and fall harvested system, 'Prime-Jim®' and APF-46 had similar broad mite counts.

Linear correlation between the transformed number of broad mites [log (number per leaf + 1)] and the average leaf area was significant ($P < 0.0001$, F = 31.36, $r^2 = 0.41$) (Fig. 7) with no significant differences detected among locations, harvest production systems, or genotypes. No differences for slope or intercept were found for any treatment combination.

Conclusion

Although genotype had a strong effect on broad mite number per leaf, this effect varied between years and between harvest production systems. Harvesting production systems showed the largest mean difference. The cause of this difference may be that in the fall-only harvesting system, the floricanes are removed before bud break the next spring. This practice could be coincidentally removing overwintering sites of broad mite. Thus, broad mite numbers would start the growing season from very low levels. Less habitat would be removed in the fall- and spring-harvested system, resulting in a larger number of broad mites earlier in the growing season. If this is the case, the fall-harvested canes represent an earlier stage of population growth, which would indicate that although both 'Prime-Jim®' and APF-46 are susceptible to this pest, population growth of broad mite on APF-46 is greater than on 'Prime-Jim®'. This is supported by the apparent peak in

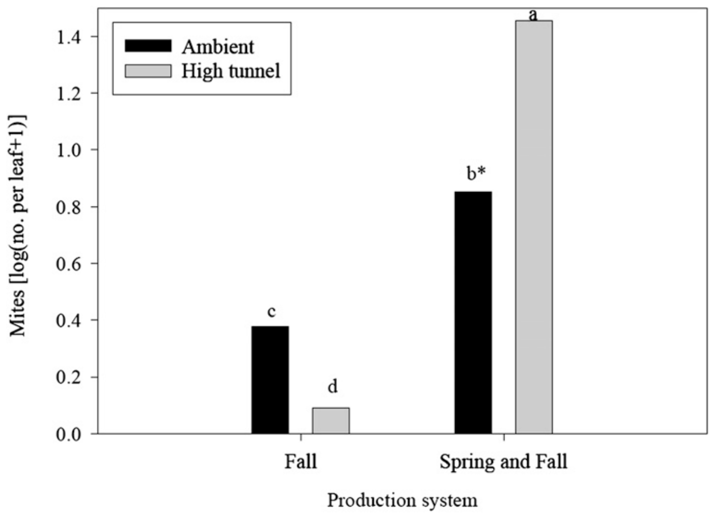

Fig. 6. Mean number of broad mites per leaf on primocane-fruiting blackberry plants for the interaction of two environments (ambient and high tunnel) and two harvest production systems in Fall 2008 at Fayetteville, AR. *Mean bars labeled with different letters are significantly different at $P < 0.05$ using paired t test with Fisher's protected least significant different.

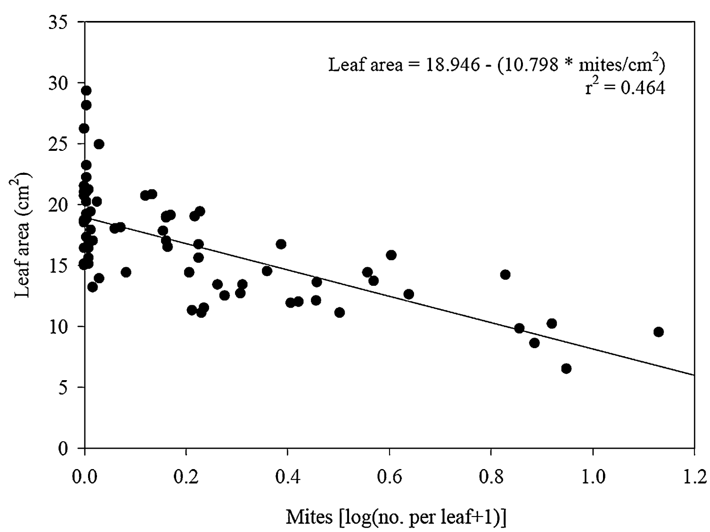

Fig. 7. Linear regression of the transformed number of broad mites per leaf [log (no. per leaf + 1)] versus leaflet area across three primocane-fruiting blackberry genotypes ('Prime-Jim®', 'Prime-Jan®', APF-46) in Fall 2008 at Fayetteville, AR; 1 cm² = 0.1550 inch².

counts of broad mite on APF-46 harvested in both the spring and fall, whereas the count increase on 'Prime-Jim®' was slower. Genotypic differences in trichome density were related to broad mite population densities as had been reported in pepper (Matos et al., 2009).

Leaf area data from both 2007 and 2008 demonstrate that broad mite had a negative impact on plant growth by diminishing leaf area. Diminished leaf area has been shown to diminish net photosynthesis in fruit crops (Hall and Ferree, 1976). Results from 2008 show this negative correlation is an inverse logarithmic correlation (negative linear correlation with the logarithm).

In Fall 2008–2009, leaf curl symptoms were observed on APF-45, which was recently released as 'Prime-Ark® 45'. Additionally, in 2009, broad mite was found on 'Prime-Ark® 45' in North Carolina (H.J. Burrack, personal communication). In both locations, broad mite adults and eggs were observed, although they were not quantified. These observations call into reconsideration the hypothesis that this broad mite could only be a pest in subtropical climates or controlled environments. Although Karl [1965 (as cited in Gerson, 1992)] reported that broad mite could not survive winter in temperate climates, the fact that infestation continued over a 3-year period indicates that broad mite may, in fact, be able to survive winter in the northern parts of Arkansas and in other moderate temperate climates. Also, broad mite may now be a pest of the newly released PF cultivar Prime-Ark® 45.

Further study is required to determine whether raspberries or floricane-fruiting blackberries are also susceptible to this pest as well as to understand differences in susceptibility between PF genotypes and the effects of conventional and organic production systems on this species.

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