Spread of Wheat Curl Mite and Wheat Streak Mosaic Virus is Influenced by Volunteer Wheat Control Methods

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Abstract
Wheat streak mosaic virus is the most damaging disease in winter wheat in the western Great Plains. The wheat curl mite is the vector of this virus and utilizes volunteer wheat as a "green bridge" to over-summer and re-infest fall planted winter wheat. This study demonstrates the effect of tillage and glyphosate control of volunteer wheat on mite movement and subsequent virus infection. Small mite populations (1 to 2 mites per tiller) caused high infection rates in winter wheat. Both tillage and glyphosate were effective at reducing mite populations on volunteer wheat, but tillage resulted in more rapid reduction of mite populations. If volunteer wheat is to be controlled close to planting time, tillage is the best choice for rapid control of mite populations when warm dry weather conditions exist.

Introduction
The wheat curl mite (WCM) (Fig. 1), Aceria tosichella Keifer, is the vector of wheat streak mosaic virus (WSMV), a serious disease of winter wheat (Triticum aestivum L.) in the western Great Plains (9). Average losses from WSMV have been shown to be about 2% annually (ca. $20 million) in Kansas (2). Volunteer wheat has a significant role in the survival and spread of WCM and the epidemiology of WSMV in winter wheat (10), by providing a "green bridge" host to sustain the WCM from wheat harvest until fall planted wheat emerges. Widespread outbreaks of WSMV are most often associated with volunteer wheat that emerges before harvest as a result of hail which shatters wheat seed from the heads (11). Wheat curl mite movement from pre-harvest volunteer wheat to the fall planted winter wheat crop is the most serious potential source of WSMV infection (10) (Fig. 2).

Fig. 1. Electron microscope image of wheat curl mite.

Fig. 2. Wheat streak mosaic virus plant symptoms.
Tillage has been the primary method of controlling volunteer wheat in many continuous winter wheat and winter wheat-fallow rotations; however, volunteer wheat control with tillage can be difficult at times because of wet or cool conditions (13). With increased use of conservation tillage practices in recent years, herbicide use for volunteer wheat control has increased. Glyphosate [N-(phosphonomethyl)glycine] has provided cost-effective, dependable control of volunteer wheat in reduced-tillage systems (3,7). Depending on conditions, glyphosate can take several weeks to completely kill the volunteer wheat. This lag time must be factored into control timing because the slowly dying wheat is still a source of WCM (12). The objective of this study was to look at the effects of volunteer control measures near planting time on WCM populations and their ability to prevent WSMV infections in newly planted wheat.

**Volunteer Wheat Control**

The study was conducted in the summer of 1998 and 1999 at the High Plains Ag Lab near Sidney, NE. Simulated volunteer wheat was grown in a summer fallow field by planting winter wheat ('Alliance') in plots consisting of three strips 2.4 m wide by 13 m in length using a double-disc drill (25-cm row spacing). A 2.4-m-wide strip was left between each of the three volunteer strips for two planting dates of the winter wheat crop. Tilled alleys 13.7 m wide were maintained between all plots and replicates to minimize WCM movement between plots. In order to establish significant mite populations, volunteer wheat was planted prior to the local wheat harvest on June 22, 1998 and July 2, 1999. A randomized complete block design with three main plot treatments (tillage, glyphosate, and no control) with four replications was used in both years. Tillage and glyphosate were applied to the volunteer wheat on August 19, 1998 and August 26, 1999. Tillage consisted of undercutting sweep blades, followed immediately on the same tillage unit by a rod weeder to insure a fast and effective kill of the volunteer wheat. Glyphosate was applied at the rate of 0.56 kg ai/ha.

To measure mite movement out of the volunteer plots, split-plot treatments of winter wheat were planted on two planting dates by using a double-disc drill. Wheat seed was treated with imidacloprid (Gaucho 480, Gustafson Inc., Plano, TX) at a rate of 1.2 g/kg seed, and was planted at the rate of 68 kg/ha. Plots of wheat 2.4 m wide by 13 m in length were planted in the strips left open in the volunteer plots. In 1998, the two winter wheat planting dates were July 29 and August 12. In 1999, the two planting dates were August 10 and August 20. During both years, the first planting date was approximately at the 2-leaf stage at the time of herbicide and tillage treatments and the wheat of the second planting date was just emerging at the time of treatments.

**Volunteer Wheat Sampling**

Volunteer wheat was sampled both before and after treatment to determine WCM numbers by microscopic examination (Fig. 3). Pre-treatment counts were made on August 18, 1998 and August 26, 1999. Post-treatment sampling of volunteer wheat in 1998 and 1999 consisted of selecting ten plants at random per plot and counting mites on two predominate tillers per plant. Post-treatment samples were taken on August 26 in 1998, and September 2 and 9 in 1999. Temperature and precipitation data were obtained for the study periods both years (5,6).

Fig. 3. Wheat curl mites on wheat leaf (ca. 60X).
**Planting Date Sampling**

Wheat from both planting dates was sampled in September each year four weeks after treatments were applied and WCM counted to determine percent infestation and total number of WCM per tiller. An indirect protein-A sandwich enzyme-linked immunosorbent assay (ELISA) was used as described by Mahmood et al. (4) to test plant material for the presence of WSMV. ELISAs were done on samples from the two winter wheat planting dates. The 1998 study was sampled on May 26, 1999 to estimate the infection of WSMV, and the 1999 study was sampled on September 23, 1999. The time of sampling after infection with WSMV is not critical because the infection remains through the life of the plant. This is demonstrated by high infection levels from both spring sampling in 1998 and fall sampling in 1999 (Table 2).

Analyses of variance were done using PROC GLM (8). Mean separations were obtained using Fisher’s protected LSD.

**WCM in Volunteer Wheat**

Mite infestations in the volunteer wheat were much higher in 1999 than in 1998 (Table 1). In both years, pre-treatment sampling indicated that populations of WCM were not significantly different between treatments.

Table 1. Wheat curl mite numbers per tiller of volunteer wheat before and after treatments applied to control volunteer wheat.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Pre-treatment</th>
<th>7-day post-treatment</th>
<th>14-day post-treatment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Mites per tiller</td>
<td></td>
<td></td>
</tr>
<tr>
<td>1998</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Untreated</td>
<td>5.4</td>
<td>72.1</td>
<td>--</td>
</tr>
<tr>
<td>Glyphosate</td>
<td>16.0</td>
<td>15.5</td>
<td>--</td>
</tr>
<tr>
<td>Tillage</td>
<td>17.6</td>
<td>0.00</td>
<td>--</td>
</tr>
<tr>
<td>LSD .05</td>
<td>NS</td>
<td>45.6</td>
<td>--</td>
</tr>
<tr>
<td>1999</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Untreated</td>
<td>104.8</td>
<td>108.9</td>
<td>127</td>
</tr>
<tr>
<td>Glyphosate</td>
<td>110.8</td>
<td>8.1</td>
<td>0.79</td>
</tr>
<tr>
<td>Tillage</td>
<td>112.2</td>
<td>0.69</td>
<td>0.06</td>
</tr>
<tr>
<td>LSD .05</td>
<td>NS</td>
<td>48.1</td>
<td>26.4</td>
</tr>
</tbody>
</table>

x Treatment dates: August 19, 1998; August 26, 1999.

Volunteer wheat samples in 1998 that were taken 7 days after control treatments were applied had significant differences in WCM populations between treatments. Mite numbers increased dramatically for the untreated control, but the glyphosate treatment maintained similar mite populations compared to the pre-treatment populations. Mite populations for the tillage treatments dropped to zero. Dry environmental conditions during this time affected volunteer control. Because of the dry conditions, tillage worked well at killing the volunteer in the first seven days, and tilled plants inspected at this time were completely dead and no mites were found. However, the glyphosate-treated plants were showing symptoms of herbicide injury but remained alive at seven days after treatment. Mites remained active on the plants, but populations were much lower than in the untreated plots.

In 1999, sampling of the volunteer wheat at both 7 days and 14 days after treatment showed lower mite populations in the two volunteer control treatments than the untreated plots. Mite density in the untreated control increased slightly over this time, but densities dropped sharply in the two volunteer control treatments. Neither control treatment dropped to zero even by 14 days after treatment indicating that a low level of mite activity was maintained on plants that were just barely alive. Environmental conditions were
wetter in 1999 and allowed a few tilled plants to survive longer, and plants in the glyphosate-treated plots showed greater herbicide injury in 1999 as a result of being under less drought stress at the time of herbicide application than in the previous year.

**Movement of WCM into Winter Wheat**

The main effects of the volunteer control treatment were significant for the percentage of infested tillers and the number of WCM per tiller in the winter wheat. In addition, the split-plot (winter wheat planting date) effects were significant for all these variables. However, several of the volunteer control treatment by planting time interactions were also significant. As a result, treatment by planting date means for these variables are presented in Table 2.

Table 2. Percent of tillers infested with WCM, number of WCM per tiller, and percent WSMV infection in two planting dates of winter wheat.

<table>
<thead>
<tr>
<th>Treatment</th>
<th>Planting date</th>
<th></th>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>1998x</td>
<td>1999y</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>% inf. tillers</td>
<td>% inf. tillers</td>
<td>No. WCM per tiller</td>
<td>No. WCM per tiller</td>
<td>% WSMV</td>
</tr>
<tr>
<td>Untreated</td>
<td></td>
<td>78</td>
<td>93</td>
<td>75</td>
<td>95</td>
<td>8.7</td>
</tr>
<tr>
<td>Glyphosate</td>
<td></td>
<td>43</td>
<td>80</td>
<td>13</td>
<td>23</td>
<td>1.5</td>
</tr>
<tr>
<td>Tillage</td>
<td></td>
<td>8</td>
<td>53</td>
<td>3</td>
<td>10</td>
<td>0.2</td>
</tr>
<tr>
<td>LSD .05</td>
<td></td>
<td>37</td>
<td>31</td>
<td>26</td>
<td>18</td>
<td>0.2</td>
</tr>
<tr>
<td>Mean</td>
<td></td>
<td>42.5</td>
<td>75.0</td>
<td>30.0</td>
<td>42.6</td>
<td>3.45</td>
</tr>
<tr>
<td>LSD .05z</td>
<td></td>
<td>9.0</td>
<td>13.2</td>
<td>1.46</td>
<td>4.85</td>
<td>11.3</td>
</tr>
</tbody>
</table>


Y 1999: planting date 1 = August 10; planting date 2 = August 20; sampled Sept 23.

z Least significant differences for the planting date means.

Mite densities in the winter wheat were higher in 1999 than in 1998, just as was seen for the volunteer wheat plants. The percentage of infested tillers differed across the treatments for both planting dates each year (Table 2). For both planting dates in both years, the tillage treatment had lower mite infestation levels than the untreated, but the glyphosate treatment had lower infestations than the untreated only for the second planting date. The treatment by planting date interaction for percentage infested tillers was significant for both years indicating response differences across treatment and planting dates.

For 1998, the tillage control treatments reduced the percentage of infested tillers and the number of WCM per tiller for both planting dates compared to the untreated. The glyphosate treatment reduced mite numbers but not mite infestation levels. For these variables, no differences were seen between the glyphosate and tillage control treatments; however, the mite infestation and
density values for the tillage treatment were always numerically lower than for the glyphosate treatment. WCM numbers during both years of the study and for both planting dates had similar results. For each planting date each year there were no differences between the glyphosate and tillage treatments; however, both of these treatments had lower WCM densities than the untreated plots. In both years, sampling of the glyphosate and tillage treatments indicated that only low populations of mites infested the second planting date.

Analysis for the presence of WSMV for both winter wheat planting dates was done each year, and the results are shown in Table 2. In 1998, the tillage treatment was able to reduce virus incidence significantly for each planting date, and for the second planting date the virus incidence had been reduced to zero. However, the glyphosate treatment did not reduce the virus incidence for either planting date. No treatment by planting date interaction was seen for this year. However, in 1999, the virus incidence data resulted in a significant interaction between treatment and planting date. This resulted because neither of the volunteer control treatments reduced the virus incidence in the first planting date. However, both glyphosate and tillage reduced virus incidence for the second planting date and the virus incidence in the untreated remained high.

Volunteer Control and Timing

These studies demonstrate the role that pre-harvest volunteer wheat has in the spread of WCM and infection by WSMV and the need to control volunteer wheat well in advance of planting the new crop of winter wheat. Various forms of tillage such as blading, disking or rod-weeding are common mechanical forms of volunteer wheat and weed control after wheat harvest in the summer. Glyphosate is the most common form of chemical control of volunteer wheat and weeds in stubble fields after harvest. Glyphosate may take several weeks to completely kill the volunteer wheat if environmental conditions are favorable (3). The effectiveness and kill time of either of these treatments can vary considerably depending on environmental conditions. Hot dry conditions will greatly enhance the effectiveness of tillage in completely killing volunteer wheat in several days. This was demonstrated by more rapid effectiveness of reducing mite number and virus infections in this study. In contrast, glyphosate effectiveness will be limited in hot dry conditions if the plants aren’t actively transpiring (1). This was likely a contributing factor in the reduced effectiveness of glyphosate at controlling virus infection in 1998.

Weather conditions in August 1998 were conducive for effective tillage because of dry conditions. The total rainfall for August was 4.1 cm, and 3.6 cm of that rain fell before August 12. Treatments on August 19 occurred in relatively dry conditions with average daily temperatures of 28°C. Sample results from seven days after treatment showed no WCM in the volunteer from the tillage plots and WCM populations remaining consistent in the glyphosate plots. The dry warm conditions that aided volunteer control by tillage reduced the effectiveness of glyphosate in killing the volunteer wheat host, as indicated by the WCM counts remaining nearly the same. Thomas et al. (12) indicated that mites on wheat treated with glyphosate maintained high populations until the plants had completely died back to the crown.

Weather conditions during the study period in 1999 were wetter, with 9.7 cm of rain falling in August and a 4.1 cm rain falling four days before the August 26 treatment date. August average daytime highs were 28°C and nighttime lows averaged 13°C. Under these conditions, performance of glyphosate was enhanced and control by tillage was reduced, and the relative effectiveness of mite and virus reduction were equal for the tillage and glyphosate treatments.

An interesting point from the data is the low number of mites per plant required to cause a high incidence of WSMV. The data show that mite infestations in winter wheat of only 1.5 mites per tiller resulted in a 95% infection rate of the winter wheat crop. This relationship indicates that virus spread can be prevented only by excellent control of mite populations.

Planting date of the wheat crop in relation to surviving volunteer wheat in the surrounding area is important. Under best farming practices of treating and
killing volunteer wheat several weeks before planting, no mites from volunteer wheat would survive to infest the new wheat crop. This study demonstrates the level of infestation that is possible if volunteer wheat is not treated in a timely fashion or if the treatment is not effective in killing the volunteer. The time to reach effective control is more of a factor with glyphosate treatments than tillage. If volunteer wheat is controlled close to winter wheat planting time, tillage would be the best choice to provide rapid control of mite populations, as long as conditions are conducive to rapid kill from tillage (i.e., warm and dry).

Controlling volunteer wheat and eliminating WCM movement from the volunteer wheat is the key to effective suppression of the spread of WSMV. Choosing a control method that will effectively kill the volunteer wheat before emergence of the winter wheat crop is important in managing WCM and WSMV.

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Literature Cited


