Assessment of damage caused by the spider mite *Mononychellus planki* (McGregor) on soybean cultivars in South America

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Abstract

The aim of this study was to quantify the reduction in grain productivity caused by tetranychid mites in different soybean genotypes. For this purpose, two experiments were carried out in two different experimental sites, one with 20 and another with 25 soybean cultivars. The sites had distinct soil features and were chosen to verify the influence of local conditions in the manifestation of intrinsic soybean plant resistance to spider mites. The experimental design was of randomized blocks with subdivided plots and four replications. The effects of cultivars were assessed in plots 5 x 25 m and yield reduction was investigated in subplots regarding presence and absence of tetranychid mites. The presence of mites on each cultivar was checked weekly after the emergence of soybean plants, until the detection of its occurrence. To evaluate the mite population, 25 leaflets of the upper stratum and 25 of the lower stratum of plants were randomly collected from a 20 cm² area to quantify the density of mites. The results showed that predominant species was *Mononychellus planki* (McGregor) (>90%). The other species such as *Tetranychus urticae* (Koch), *Tetranychus ludeni* (Zacher), *Tetranychus gigas* (Pritchard) and *Tetranychus desertorum* (Banks) were also observed. The population of mites and grain yield loss differed significantly depending on the soybean cultivar. The average reduction in soybean productivity in both experiments was 483 kg of soybean/hectare, corresponding to an average reduction of 20% of the productive potential of the cultivars evaluated. The spider mites can cause a great damage to soybean cultivar. Therefore, growers must regularly scout for its presence in the field, applying control measures as soon as the level of spider mites significantly increases.

Keywords: *Glycine max*, tetranychid mites, economic damage, yield loss.

Abbreviations: AE_Acid equivalent; AI_active ingredient; ASL_above sea level.

Introduction

Soybean is one of the main agricultural crops in Brazil, with a production of 95.4 thousand tons in the 2015/16 crop in a cultivated area of 33.2 million ha (CONAB, 2017). Some limiting factors to soybean crop yield include pest insects and mites. The first occurrence of mites in Brazil has been recorded from soybeans in Rio Grande do Sul State (Flechtmann, 1972), severe attacks have been observed in different crops and different regions of Brazil (Guedes et al., 2007; Roggia, 2010), requiring the application of acaricide for their control.

Factors such as acreage increase, introduction of genetically modified varieties and increasing use of insecticides and fungicides (Roggia, 2010) have been indicated as possible causes for the increase in populations of phytophagous mites (Guedes et al., 2007). This highlights the need for the adoption of an integrated management of mites by identifying, quantifying and assessing their populations as well as analyses of damages, aiming at the definition for the time of control.

Temperature, air humidity, precipitation and other weather events are considered the main co-factors that modulate the population dynamics of phytophagous mites (Guedes et al., 2007; Roggia et al., 2008). However, Arnemann et al. (2015) indicated that plant factors are also important, as different soybean genotypes present different tolerance levels. These variations can be attributed to the production of secondary metabolites, the morphology of leaf surface and the presence of natural enemies (Boom et al., 2003). Another possibility is the variation caused by the production of defense compounds that act to repel organisms harmful to the plant, called induced defense (War et al., 2012).

Mites that infest soybean plants tend to focus on the abaxial surface of the leaflet, where they feed by puncturing the cells and sucking the exuded liquid. This removal of
The characteristic symptoms of mite attacks in soybeans are the presence of white or yellow spots on the leaf surface, which evolve tanning and necrosis, leading to premature drop of leaflets, accelerated maturation and higher percentage of small grains (Dehghan et al., 2009). The occurrence of pest intensifies after stages R4–R5 of the crop (Arнемann et al., 2015). In North America, Gray (2006) reported that control measures must be adopted considering the presence of 20–25% of the soybean leaves with symptoms of attack in the growing season (discoloration) and 10–15% in the reproductive period. To date, only one study (Suekane et al., 2012) suggested the economic injury level for mite control in soybeans, which was conducted in a greenhouse with the mite species Tetranynchus urticae (Koch) and only in one soybean cultivar. Among the alternative methods of control included in the Integrated Pest Management (IPM) approach, the use of genetic resistance has been emerged as a valuable tool in the control of mites, since several studies have reported significant differences in population density and plant susceptibility to mite attack among different soybean cultivars (Sedaratian et al., 2009; Dehghan et al., 2009; Razmjou et al., 2009). Genetic tolerance of plants to arthropods is also affected by abiotic factors; and thus, may vary according to the environmental conditions to, which the plant is subjected (Fancelli and Vendramim, 2008). Considering the increasing occurrence of mites in the soybean crop and the lack of information on the damage they cause, this study aimed to quantify, yield loss caused by tetranychid mites in different soybean cultivars under field conditions as well as classification of these cultivars according to their susceptibility to mite attack.

Results and Discussion

Mite species

The species of phytophagous mites identified in the experiments were Mononychellus planki (McGregor), Tetranynchus urticae (Koch), Tetranynchus ludeni (Zacher), Tetranychus giga (Pritchard) and Tetranychus desertorum (Banks). Guedes et al. (2007) and Roggia et al. (2008) identified these species as relevant in soybean culture infestations. The predominant species (>90%) in the samples was M. planki. The influence of mite predators in the mite population dynamics was not significant, since its occurrence was observed only in a few samples. Therefore, this variable was not subjected to statistical analysis. Low occurrence of mite predators is a common aspect of soybean crops, being attributed mainly to unfavorable management practices, such as the use of broad-spectrum pesticides (e.g. herbicides and fungicides, Roggia et al., 2008; Roggia, 2010).

Population density of mites

The results of the analysis of variance indicate significant difference ($p < 0.05$) on population density of mites between the cultivars evaluated in both locations (Table 1), showing that each cultivar was affected differently upon development and density of mite populations. These variations are directly associated to the biology of the mite species, the climatic conditions and the capacity of genetic resistance of plant (Dehghan et al., 2009), which depends on morphological aspects of the leaf surface (Elden, 1997), production of defense compounds (Ali, 1999) and nutritional value of the vegetal tissue (Brown et al., 1991).

The smallest populations of mites were observed in cultivar FUNDACEP 57 RR (average 0.75 mites/20 cm$^2$) in Experiment I and SYN 1059 RR in Experiment II (average 5.74 mites/20 cm$^2$). Cultivar BMX Energy RR presented the highest densities of mites in both experiments, with 11.69 mites/20 cm$^2$ in Experiment I and 25.31 mites/20 cm$^2$ in Experiment II. This is corroborating with the results obtained by Arнемann (2013), who classified this genotype as one of the most vulnerable to mite infestation. The Scott and Knott test was used to constitute seven classes of cultivars according to the occurrence of mites, highlighting the significant effect of cultivars on fluctuation of mite populations.

Phenological stage of the soybean crop was also interfered with the population dynamics of mites, since the development of the plant in short periods tends to favor the configuration of resistance (Arнемann, 2013). Sedaratian et al. (2009) investigated the occurrence of T. urticae in 14 soybean genotypes and found significant difference in population density of mites and resistance levels between the materials evaluated. Similar results were reported from Egypt (Sawires et al., 1990), EUA (Brown et al., 1991) and Iran (Razmjou et al., 2009).

Experimental sites

In general, the occurrence of mites in the cultivars in Experiment I was lower than observed in Experiment II. Later sowing date in Experiment II can be pointed as one aspect responsible for this difference, since other abiotic factors such as rainfall and humidity did not interfere significantly on the mite population development, and acted equally on the different cultivars. The weather condition in Experiment I was highly favorable to mite development, having long periods of low rainfall and low relative air humidity, as previously suggested by Guedes et al. (2007) and Roggia et al. (2008). However, no significant effect of such climatic conditions was observed on the population density of mites in the different genotypes (Supplementary Figure 1 and 2). In experiments conducted with different soybean cultivars in two crop seasons (2009/10 and 2010/11), Siqueira (2011) also observed significant variations in populations of M. planki between the two periods, but did not find any correlation with climatic factors, since weather conditions were similar in both seasons. Regarding the influence of phenological stages of the soybean plant in the population development of mites, Arнемann et al. (2015) reported that infestation tends to start at the phenological stage V5 for most cultivars, increasing in density until the plants reach stage R5. In
cotton, significant reductions in yield are also linked to early infestations, when associated with high rates of population increase and longer time of development (Wilson, 1993).

**Effects of spider mite attack on grain yield**

The results of the analysis of variance for grain yields show a significant effect (p<0.01) for the cultivars due to the treatment with acaricide in both locations (Table 2). It demonstrates that the grain yield of each cultivar was differed significantly between sprayed and unsprayed subplots, but not in relation to the other cultivars. Therefore, general averages of all the cultivars were used to quantify yield loss, defined as the percentage difference between yield averages of the area treated with acaricide versus the untreated area.

Yield loss of soybean due to mite attack was 435 kg ha⁻¹ (23%) and 531 kg ha⁻¹ (18%) for Experiments I and II, respectively, although the occurrence of mites was higher in Experiment II, with an average population of 17.67 mites per 20 cm². These results highlight the importance of mite control in soybean and the definition of a control level, avoiding significant losses due to the attack of mites.

The observed yield loss due to the lack of control ranged from 7.52% (cultivar A 6411 RG) to 44.45% (cultivar TMG 7161 RR) in Experiment I and from 5.68% (cultivar NS 6636 RR) to 29.83% (cultivar NA 4990 RG) in Experiment II. The comparison of data from Tables 1 and 2 indicates that the cultivars with the highest density of mite do not have the largest yield loss. The Pearson correlation coefficient calculated for these two variables (number of mites versus yield loss) was 0.23 in Experiment I and 0.27 in Experiment II, both classified as low according to Shimakura (2006). Therefore, it was not possible to establish a direct linear correlation between the two variables.

**Classification of cultivar susceptibility**

Although resistance of cultivars to attack by mite is difficult to quantify due to the complexity of factors involved (Arnemann, 2013), the relationship between population of mite and yield loss allows a classification of cultivars in terms of their susceptibility to mite damage. In this study, we present a classification of cultivar susceptibility considering the average population of mites and yield loss (Figure 1 and 2). The use of Tocher’s optimisation method allowed the clustering of the soybean genotypes in homogenous groups, constituting six classes of cultivars in Experiment I (São Sepé) and eight classes in Experiment II (Santa Maria). These classes were ranked according to their relative susceptibility to mite attack. Cultivars that presented high yield losses under low population of mites were classified as highly susceptible to damage by mites. Conversely, cultivars with low yield losses in conditions of high infestation were classified as having high tolerance to mite attack, withstanding high densities of mites without losing grain yield.

There was a significant variation in the results between the two experiments, and most cultivars showed higher susceptibility to damage by mites in Experiment I (Table 2). Weather conditions did not have a direct effect on the population dynamics of the pest, but may have affected the development of the plants, causing differences in the levels of natural resistance expressed by the different cultivars in the two experimental sites. The crops were rain-fed in both sites, and the periods of low rainfall recorded in Experiment I as well as low air humidity (Supplementary Figure 1) may cause the plants to undergo a state of hydric stress, increasing its vulnerability to mite attacks (Estebanez-Gonzalez and Rodriguez-Navarro, 1991).

The later sowing date of Experiment II favored the occurrence of higher population densities of tetranychid mites in this site, but also triggered the manifestation of resistance in these plants, since a shorter period of development increases the chances of resistance in soybean (Fenner, 1998) and cotton (Wilson, 1993). Additionally, brief periods of exposure to mite feeding can induce higher levels of resistance in some cultivars, as mite-resistance is linked to cumulative lipid peroxidation of the tissues and loss of carotenoids and chlorophyll in the plant (Hildebrand et al., 1986).

The correlation coefficient between the two sites was 0.47 for the variable number of mites (moderate correlation) and 0.06 for the variable yield loss (very weak correlation), indicating that the manifestation of intrinsic plant resistance is highly dependent to the local conditions. Therefore, the presented classification of cultivars according to their susceptibility to mite attack (Table 3) is valid for the local regions where the experiment was conducted.

Potential resistance of soybean to tetranychid mites was addressed by Sedaratian et al. (2011), who analyzed life table parameters of two-spotted spider mite *Tetranychus urticae* (Koch) on 14 soybean genotypes, evaluating susceptibility through the rates of population increase. However, the study was conducted under experimental conditions and with cultivars adapted to the Iranian environment, and since local aspects are key factors in the expression of genetic resistance (Fancelli and Vendramim, 2008). Classification of genotypes and environment must be taken into the account for particular environmental condition of the region, to which the study or cultivation is aimed, as well as using genotypes with local commercial importance. Furthermore, few studies have proposed control levels based on the capacity of the mites to cause damage under field conditions, according to their population in each soybean cultivar.

**Yield loss and economic injury level**

In the 2005/06 crop, in areas with and without chemical control of spider mites such as in São Sepé, Rio Grande do Sul State, the tetranychid attacks caused losses of 270 kg ha⁻¹ on average in soybean production (Arnemann et al., 2006). Studies in the south half of the Rio Grande do Sul State during the 2004/05 crop showed that in outbreaks of mite incidence in crops, the plant wilt and yield losses of up to 50% may occur (Silva and Gassen, 2005). Carlson (1969) conducted an experiment that evaluated the chemical control of mites in soybean by applying different acaricides in California and reported yield losses of up to 90% in untreated areas, compared with areas where the chemical control was used. For Klubertanz (1994), this loss may reach 60% of grain yield.
Table 1. Average number of spider mites in 20 cm² per leaflet, in soybean cultivars in the municipalities of São Sepé e Santa Maria, RS, Brazil, during the 2011/2012 season

<table>
<thead>
<tr>
<th>Soybean cultivar</th>
<th>Experiment I</th>
<th>Experiment II</th>
</tr>
</thead>
<tbody>
<tr>
<td>A 6412 RG</td>
<td>7.725</td>
<td>16.55c</td>
</tr>
<tr>
<td>A 7321 RG</td>
<td>2.44f</td>
<td>13.14c</td>
</tr>
<tr>
<td>BMX Ativa RR</td>
<td>2.67f</td>
<td>25.27a</td>
</tr>
<tr>
<td>BMX Energia RR</td>
<td>11.69f</td>
<td>25.31a</td>
</tr>
<tr>
<td>BMX Potência RR</td>
<td>2.87f</td>
<td>22.98a</td>
</tr>
<tr>
<td>BMX Turbo RR</td>
<td>5.03f</td>
<td>20.34b</td>
</tr>
<tr>
<td>Don Mario S&amp;R (Apolo RR)</td>
<td>2.52f</td>
<td>14.34c</td>
</tr>
<tr>
<td>FPS Urano RR</td>
<td>4.52d</td>
<td>24.43a</td>
</tr>
<tr>
<td>FUNDAÇEP 57 RR</td>
<td>0.75g</td>
<td>7.80d</td>
</tr>
<tr>
<td>NA 4990 RG</td>
<td>4.03e</td>
<td>18.53b</td>
</tr>
<tr>
<td>NA 5909 RG</td>
<td>1.12f</td>
<td>21.56b</td>
</tr>
<tr>
<td>NK 7059 RR (V-max RR)</td>
<td>0.78g</td>
<td>11.93c</td>
</tr>
<tr>
<td>NS 4823 RR</td>
<td>4.85d</td>
<td>10.82d</td>
</tr>
<tr>
<td>NS 5859 RR</td>
<td>6.25c</td>
<td>20.87b</td>
</tr>
<tr>
<td>NS 6636 RR</td>
<td>3.47e</td>
<td>16.36c</td>
</tr>
<tr>
<td>ROOS Caminho RR</td>
<td>11.01a</td>
<td>24.42a</td>
</tr>
<tr>
<td>SYN 1059 RR (V-top RR)</td>
<td>1.86f</td>
<td>5.74d</td>
</tr>
<tr>
<td>SYN 1161 RR</td>
<td>3.09e</td>
<td>14.74c</td>
</tr>
<tr>
<td>SYN 1163 RR</td>
<td>3.46e</td>
<td>24.41a</td>
</tr>
<tr>
<td>TMG 7161 RR</td>
<td>8.62d</td>
<td>18.90b</td>
</tr>
<tr>
<td>FUNDAÇEQ 59 RR</td>
<td>-</td>
<td>8.93d</td>
</tr>
<tr>
<td>NS 7300 RR</td>
<td>-</td>
<td>13.91c</td>
</tr>
<tr>
<td>SYN 1157 RR</td>
<td>-</td>
<td>18.53b</td>
</tr>
<tr>
<td>SYN 1158 RR</td>
<td>-</td>
<td>17.42d</td>
</tr>
<tr>
<td>08ca905023</td>
<td>-</td>
<td>23.82a</td>
</tr>
<tr>
<td>General average</td>
<td>4.44</td>
<td>17.67</td>
</tr>
<tr>
<td>CV (%)</td>
<td>42.5</td>
<td>-</td>
</tr>
</tbody>
</table>

Fig 1. Relationship between mite population and yield loss in soybean cultivars grouped by Tocher’s optimization method, in the municipality of São Sepé, during the 2011/2012 season.

Table 2. Grain yield (kg ha⁻¹) of soybean cultivars in relation to mite control, in the municipalities of São Sepé and Santa Maria, RS, Brazil, during the 2011/2012 season.

<table>
<thead>
<tr>
<th>Soybean cultivar</th>
<th>With control</th>
<th>Experiment I</th>
<th>Experiment II</th>
</tr>
</thead>
<tbody>
<tr>
<td>A 6412 RG</td>
<td>1.537</td>
<td>1205.50b</td>
<td>2058.66b</td>
</tr>
<tr>
<td>A 7321 RG</td>
<td>2.437</td>
<td>1760.19b</td>
<td>2631.66b</td>
</tr>
<tr>
<td>BMX Ativa RR</td>
<td>1.677</td>
<td>1062.49b</td>
<td>1749.58b</td>
</tr>
<tr>
<td>BMX Energia RR</td>
<td>2.225</td>
<td>1606.50b</td>
<td>2168.33b</td>
</tr>
<tr>
<td>BMX Potência RR</td>
<td>2.372</td>
<td>1896.46b</td>
<td>2807.08b</td>
</tr>
<tr>
<td>BMX Turbo RR</td>
<td>2.048</td>
<td>1308.19b</td>
<td>2863.33b</td>
</tr>
<tr>
<td>Don Mario Apolo RR</td>
<td>2.221</td>
<td>1825.03b</td>
<td>2777.91b</td>
</tr>
<tr>
<td>FPS Urano RR</td>
<td>1.936</td>
<td>1492.11b</td>
<td>2148.33a</td>
</tr>
<tr>
<td>FUNDAÇEP 57 RR</td>
<td>1.993</td>
<td>1626.25b</td>
<td>2205.83b</td>
</tr>
<tr>
<td>NA 4990 RG</td>
<td>1.789</td>
<td>1295.18b</td>
<td>1345.00b</td>
</tr>
<tr>
<td>NA 5909 RG</td>
<td>2.023</td>
<td>1820.00b</td>
<td>2382.50b</td>
</tr>
<tr>
<td>NK 7059 RR</td>
<td>1.900</td>
<td>1324.24b</td>
<td>2732.50b</td>
</tr>
<tr>
<td>NS 4823 RR</td>
<td>1.552</td>
<td>1292.06b</td>
<td>2635.83b</td>
</tr>
<tr>
<td>NS 5858 RR</td>
<td>1.490</td>
<td>1263.57b</td>
<td>2513.33b</td>
</tr>
<tr>
<td>NS 6636 RR</td>
<td>1.108</td>
<td>869.80b</td>
<td>3040.00b</td>
</tr>
<tr>
<td>ROOS Caminho RR</td>
<td>1.840</td>
<td>1303.23b</td>
<td>2598.33b</td>
</tr>
<tr>
<td>SYN 1059 RR</td>
<td>1.741</td>
<td>1341.36b</td>
<td>2840.83b</td>
</tr>
<tr>
<td>SYN 1161 RR</td>
<td>1.901</td>
<td>1737.24b</td>
<td>2477.91b</td>
</tr>
<tr>
<td>SYN 1163 RR</td>
<td>1.806</td>
<td>1387.24b</td>
<td>2868.75b</td>
</tr>
<tr>
<td>TMG 7161 RR</td>
<td>1.654</td>
<td>919.27b</td>
<td>3267.50a</td>
</tr>
<tr>
<td>FUNDAÇEP 59 RR</td>
<td>-</td>
<td>-</td>
<td>2524.16b</td>
</tr>
<tr>
<td>NS 7300 RR</td>
<td>-</td>
<td>-</td>
<td>2621.66b</td>
</tr>
<tr>
<td>SYN 1157 RR</td>
<td>-</td>
<td>-</td>
<td>3063.33b</td>
</tr>
<tr>
<td>SYN 1158 RR</td>
<td>-</td>
<td>-</td>
<td>3347.50a</td>
</tr>
<tr>
<td>08ca905023</td>
<td>-</td>
<td>-</td>
<td>2675.00b</td>
</tr>
<tr>
<td>General average</td>
<td>1.851</td>
<td>1416.04b</td>
<td>2439.06a</td>
</tr>
<tr>
<td>CV (%)</td>
<td>24.05</td>
<td>6.97</td>
<td>12.73</td>
</tr>
</tbody>
</table>
Ruthes et al. (2007) reported a reduction of 23.33% of soybean productive potential in a condition when mites were not controlled in soybean. This reduction was similar to the average observed in the present study in the São Sepé experiment, where the unsprayed subplots presented a reduction of 23.29% of the productivity potential of the cultivars under an average population of 4.44 mites per 20 cm². For two-spotted spider mites (T. urticae), Suekane et al. (2012) proposed an economic injury level of 15.8% of chlorosis symptoms in leaflets, based on the value of US$11.00/60 kg of soybean and control cost of US$16.00/ha.

Considering that plant resistance has been recognized as a fundamental tool for integrated pest management programs (Zehnder et al., 2007), the quantification of yield damage under field conditions and evaluation of resistance levels on different genotypes provide valuable information for the management of spider mites in soybean. Accordingly, further attention should be devoted to the influence of abiotic factors in the population dynamics of mites, since local conditions affect significantly the expression of plant resistance and may cause variations in the cultivar performance between different sites.

Materials and Methods

**Plant materials and experimental design**

Two experiments were conducted in the 2011/12 crop, one in the municipality of São Sepé (Experiment I) and another in the municipality of Santa Maria (Experiment II), both in the state of Rio Grande do Sul, Brazil. The experiment design was randomized, with subdivided plots and four replicates. Each installment of 5 x 25 m was seeded with a different soybean cultivar (Supplementary Table 1), where half of the plot received acaricide applications and the other half remained without application. Experiment I was conducted from December 2011 to May 2012, in an area located 30°18’41"S and 53°31’42"W, at 175 m a.s.l. The soil had a predominant sandy texture with medium to low chemical fertility, according to the soil analysis conducted. Twenty soybean cultivars (Supplementary Table 1) were sown on December 6, 2011, using the no-till system, directly onto the straw with a density of 30 seeds m⁻². Experiment II was conducted from January to March 2012, in the experimental site of the Federal University of Santa Maria – UFSM, in the municipality of Santa Maria (29°45’52"S and 53°14’42"W, at 95 m a.s.l.), Rio Grande do Sul State, Brazil. The physical soil features was characterized as a medium clay soil with higher chemical fertility compared to Experiment I. Twenty-five soybean cultivars (Supplementary Table 1) were sown on January 16, 2012, using a density of 30 seeds m⁻².

The genotypes used in both experiments were chosen due to their importance in the current scenario of the soybean culture in southern Brazil, which was evaluated according to the frequency of use of these cultivars by the growers. Sowing was carried out under a normal pest free condition, with the subsequent infestation by mites occurring naturally. The plants were grown under rain-fed condition in both sites. The weather conditions (rainfall, temperature and air
Plant phenology

Soybean phenology was assessed according to the scale proposed by Ritchie et al. (1982) and adapted by Yorinori (1996), which breaks the plant cycle into two phases: (1) vegetative phase consisting of stages (VC) from emergence to the opening of cotyledons; (V1) first node, unifoliate open leaves; (V2) second node, first open trefoil; (Vn) until the last node with open trefoil, before flowering; and (2) the reproductive phase, composed of stages (R1) beginning of flowering up to 50% of plants with one flower; (R2) full flowering, most racemes with open flowers; (R3) end of flowering, pods up to 1.5 cm long; (R4) most pods in the top third measuring 2-4 cm; (R5.1) grains visible to the touch with 10% of filling; (R5.2) most pods with 11-25% of grain filling; (R5.3) most pods with 26-50% of grain filling; (R5.4) most pods with 51-75% of grain filling; (R5.5) most pods with 76-100% of grain filling; (R6) pods with 100% of grain filling and green leaves; (R7.1) beginning until 50% of yellowing of the leaves and beans; (R7.2) yellowing of 51-75% of the leaves and beans; (R7.3) more than 75% of the leaves and yellow beans; (R8.1) beginning until 50% of defoliation; (R8.2) more than 50% of defoliation; and (R9) maturation point of the crop.

Conduction of study

In both experiments, 300 kg/ha of NPK fertilizer (nitrogen, phosphorus and potassium) were applied in the sowing with a 10-20-20 formulation. The management of weeds in post-emergence stage V3 of all cultivars was carried out with the application of 1,040 g of acid equivalent (a.e.) ha⁻¹ of glyphosate (Crucial, Nufarm, Maracanaú, CE, Brazil). For the management of pests and diseases at early stage, the seeds were treated with 25 g of active ingredient (a.i.) ha⁻¹ of fipronil (Belure, Basf, São Paulo, SP, Brazil) and 1.25 + 0.5 g a.i. ha⁻¹ of fludioxonil + metalaxyl-M (Maxim XL, Syngenta Crop Protection, São Paulo, SP, Brazil). For the control of defoliating caterpillars, 10 g a.i. ha⁻¹ of chlorantraniliprole (Premio, DuPont, São Paulo, SP, Brazil) were used at two stages: when most cultivars were at the phenological stage V4 (first application) and at stage V7 (second application). The insecticide imidacloprid (105 g a.i. ha⁻¹) (Nuprid, Nufarm, Maracanaú, CE, Brazil) was applied at stages R4 and R5.3 of the cultivars for the management of stinkbugs and thrips. In addition, during the reproductive stage of the cultivars, three applications of fungicide were made for disease control. The applications were made when most cultivars were at R1, R4 and R5.4 stages. The fungicides used were composed of azoxystrobin (60 g a.i. ha⁻¹) + cyproconazole (24 g a.i. ha⁻¹) (Priori + Alto 100, Alamos, Porto Alegre, RS, Brazil).

For the control of mites in treated subplots, three applications of acaricide abamectin (9 g a.i. ha⁻¹) were carried out. The first application was made when the first cultivar was at reproductive stage (R1). The second and third applications were performed at stages R4 and R5.4, respectively, considering the cultivar at the most advanced cycle at the time of evaluation of the phenological stage. After the pre-spray check, weekly samplings were carried out after the first application of acaricide in the treated subplots to verify the effectiveness of the acaricide treatment and eventually determining the need for new applications.

Traits measured

In both sprayed and unsprayed subplots, mites were sampled weekly, from stage V5 until the end of the cycle of the cultivars (Supplementary Tables 2, 3). The population density of mites was determined in each subplot with random collection of 25 leaflets completely expanded from the middle stratum and 25 leaflets of the higher stratum of the plants. The leaflets were packed in paper bags, identified, stored in a cooler with ice and transported to the Laboratory for the Integrated Pest Management of UFSM (LabMIP), where they were kept under refrigeration (approximately 8°C) until the total count of mites. Following the methodology proposed by Storck et al. (2012), the number of mites (eggs, immatures and adults) of each leaflet was counted in an area of 20 cm² (4 cm base by 5 cm toward the leaflet apex) with the aid of stereoscopic microscope (40x magnifying). For the identification of mite species, microscope slides were mounted in Hoyer medium with different morphological types found in the samples and analyzed under optical microscope with phase contrast at the Brazilian Agricultural Research Corporation – Soybean (Embrapa-Soja).

The average number of mites was calculated considering the evaluations, in which at least one of the cultivars showed an average population greater than five mites per 20 cm² in the subplot that was not treated with acaricide. In Santa Maria, data from five evaluations were used, which carried out on Mar 9, Mar 16, Mar 24, Apr 3 and Apr 11, 2012, while in São Sepé, data from three evaluations conducted on Feb 29, Mar 7 and Mar 14, 2012 were used. In both experiments the grain yield (kilograms of soybean grain per hectare) was determined by harvesting of a central area of 10 m² in each subplot with humidity correction to 13%. Yield loss for each cultivar caused by mite attack was calculated by the percentage difference between the average yields in subplots sprayed with acaricide versus average yields in subplots unsprayed.

Statistical analysis

The analysis of variance for figures of grain yield and average number of mites in leaflets of soybean plants of both experiments was made. The means were compared by Scott and Knott (p≤0.05) with the use of logarithmic transformation of data. The Pearson correlation coefficient was also calculated for the same variables. Tocher’s optimization method using distance matrix (Rao, 1952) was applied to cluster the cultivars in homogenous groups and rank them according to their susceptibility to mite attack. The software “Genes” (Cruz, 2013) was used for the statistical analyses. The weekly samples carried out in weeks 1-11 for Experiment 1 (São Sepé) and 1-10 for Experiment II (Santa Maria) composed the subplots.

Since the analysis of variance requires data (in this case, number of mites per plot) normally distributed with homogeneous variation, we applied the Taylor Power Law (Taylor, 1961) to identify the appropriate transformation of
the dependent variable \( y \). As the slopes \( b \) found were 1.56 and 1.66 for São Sepé and Santa Maria, respectively, it was concluded that the logarithmic transformation would be more appropriate for this case. Given the presence of null values, the transformation in \((y + 1)\) was applied.

**Conclusion**

In this experiment, the average loss in soybean productive potential was 20% due to mite attacks, with minimum losses of 5.68 % and a maximum of 44.45 %. This corresponded to an average reduction in grain yield of 483 kg of soybean/ha. The population of tetranychid mites varied significantly (1) between soybean cultivars, showing different resistance levels of plants to infestation, and (2) between the sites evaluated, showing the influence of local factors on population dynamics of this pest. It is possible to classify soybean cultivars according to their susceptibility to attacks of tetranychid mites, indicating that growers need to choose the soybean cultivars that are genetically less vulnerable to losses.

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**References**


