J. Crop Prot. 2016, 5 (1): 49-57
doi: 10.18869/modares.jcp.5.1.49

Research Article

Effects of drought stress and super absorbent polymer on susceptibility of pepper to damage caused by *Aphis gossypii* Glover (Hem.: Aphididae)

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Abstract: Pepper plant *Capsicum annuum* L. has great nutritional value and many pharmaceutical properties but its sensitivity to pests such as *Aphis gossypii* Glover, especially in drought stress conditions, has limited its production. To evaluate the effect of drought stress on the population and damage rate of this pest in greenhouse condition, four moisture treatments including; full irrigation, 15, 30 and 45 percent of water deficit, and four treatments with different amounts of super absorbent polymer (SAP) containing 2, 4, 6 and 8 g per pot were separately performed in completely randomized design. Four weeks after applying drought stress, the pots were moved near the aphid sources. Density of aphids was examined after one month of infestation, and the plant growth characteristics after two months. It was found that the increase in severe drought stress (45% DI_{45}) significantly raised the population of this pest and remarkably decreased plant growth rate and yield. However, the low stress of drought (15% DI_{15}) not only caused relative reduction of insect's population, but also saved water consumption and increased crop yield. However, the insect population was elevated as a result of increase in the amount of irrigation. Although the excessive use of SAP (8 g) increased the aphid population, the current experiment showed the use of 4 and 6 g of super absorbents could minimize the irrigation stress, decrease the pest population and improve yield of the plants by retaining the moisture in drought conditions.

Keywords: drought, *Aphis gossypii*, pepper, super absorbent, water stress

Introduction

Pepper *Capsicum annuum* L. is a perennial plant that grows in tropical and subtropical climate. It is mostly used in food and pharmaceutical industries. In recent years, its cultivation is increasing (FAO, 2012) and today the importance of pepper in diet and for its therapeutic properties has been well realized.

Various pests can damage pepper, among them cotton aphid, *Aphis gossypii* Glover, sometimes causes severe damages. The adults and nymphs of this pest suck the plant sap of leaves and the growing tips of shoots. The feeding may cause foliage chlorosis and

Handling Editor: Saeid Moharramipour

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Received: 11 June 2014, Accepted: 13 November 2015
Published online: 09 December 2015

premature death. There is often a great deal of leaf curling and distortion which hinders efficient photosynthesis. Excretion of honeydew by this aphid allows sooty moulds to grow, resulting in decreased yield and quality (Khanjani, 2013). Feeding can also dwarf plants; reduce leaf surface area, shoot biomass and photosynthesis (Bagwell *et al*., 1991; Johnson, 1991).

Various factors such as water stress, soil moisture (Showler, 2012; Popov *et al*., 2006) and host plant can affect population of arthropods (Smith, 2005). When available water is insufficient for plant growth, photosynthesis and transpiration; plants encounter water deficit stress, a serious problem that reduces world crop production (Fan *et al*., 2006; Vincent *et al*., 2005). Drought stress has adverse effects on plant growth and indirectly might increase population and damage of pests through changes in nutritional value of plant. Moderate stress is known to improve the nutritional value of some plant tissues and sap, in some instances to reduce concentrations of plant defense compounds that help reduce pest populations to economically tolerable levels, each of them can lead to greater pest damages (Smitley and Peterson, 1996; Popov *et al*., 2006; Showler, 2012).

When water stress is more severe, host plant suitability for arthropod declines (Showler, 2012) because of insufficient availability of water for the pest and senescence and drying of plant's tissues. Although severe water deficit stress causes host plant useless for herbivores, chronic mild water deficit stress can enhance the nutritional value of plants for arthropods, resulting in greater host plant preference, increased pest population, intensified injury to crops, and even outbreaks that affect production on large scale areas. For example populations of Russian wheat aphid, *Diuraphis noxia* (Morvilko), increased in non-irrigated wheat, *Triticum aestivum* L., fields as compared with fields that received irrigation (Archer *et al*., 1995). The cabbage aphid, *Brevicoryne brassicae* L., infested water deficient stressed rape, *Brassica napus* L., more heavily than non-stressed plants (Burgess *et al*., 1994; Popov *et al*., 2006).

In dry areas, water scarcity is the main limiting factor for crop production. Thus, the use of super absorbent polymer (SAP) may effectively increase plant growth by improving nutrient use efficiency and water retention into the soil. These polymers are soil conditioners, developed to aid plant establishment and growth in drought condition. Also SAP is one of the effective water saving strategies in times of water shortage, prevents plant stress and may play an important role in saving water and reducing the plant infestation (AL-Harbi *et al*., 1999).

Although several studies have been investigated on effects of drought stress on pest population, the effect of drought stress on *A. gossypii* damage to pepper has not been reported so far. Hence, the purpose of the current study was to examine the effect of drought stress and SAP on aphid population in an attempt to reduce aphid damage to pepper.

Materials and Methods

The experiment was conducted in a greenhouse located at the experimental site of Bu-Ali Sina University, Hamedan, Iran. During the experiment, the mean temperature minima and maxima ranged from 16.6 ± 3.5 ºC to 32.4 ± 4.1 ºC, the relative air humidity was 70.6 ± 15.5% and a photoperiod of 16: 8 h (L: D).

Aphid and plant source

Pepper, *C. annuum*, seeds were obtained from National Gene Bank, Karaj, Iran and were planted in 2.5 *kg* pots containing sand and sheep manure. The cotton aphid, *A. gossypii*, were collected from infested cucumber plants and reared on pepper. The aphid clones were separately maintained on potted pepper plants in a greenhouse at 25 ± 1 °C, 70 ± 10% RH and 16: 8 h (L: D).

Drought stress assay

The experiment was performed in completely randomized design. This included four moisture treatments: full irrigation (FI), 15% water deficit

(DI_{15}), 30% water deficit (DI_{30}), and 45% water deficit (DI_{45}) per pot. Furthermore, four other treatments were separately used with different amounts of 2, 4, 6 and 8 g of super absorbent polymer (Sodium polyacrylate) per pot. In addition, full irrigation was used for 2nd set of treatments. Each treatment had ten replicates and each plant represented one replicate. The plants were exposed to similar sunlight and irrigated three times per week (at 8:30 pm). Potted plants were treated with one of the above eight treatments. Four weeks after applying irrigation treatments, pepper plants at ten-leaf stage were placed in an environment with high population of *A. gossypii* (*i.e.*, nearby of aphid source) to evaluate the rate of preference, population density and plant yield. To determine the aphid population density, all infested leaves were selected as index. Adults and nymphs of the aphid were counted using a stereomicroscope by 25X magnification. Also, plant height from ground level to the terminal bud was assessed and the number of flowers was taken as indication of the plant yield.

Data analysis

The collected data were analyzed with ANOVA, PROC GLM (SAS Institute, 2003). If significant differences were detected, multiple comparisons were made using Tukey's post-hoc test ($p < 0.05$). Pearson correlation coefficient was determined to assess the relationship between plant features and water deficit as well as amounts of using SPSS version 13.0 (SPSS, 2004). The graphs were produced by Sigma Plot version 11.0 (Systat Software 2008).

Results

The analysis of variance indicated a significant difference in the aphid population density (nymph and adult) among water deficit treatments and different amounts of super absorbent (Fig. 1 and 2). Among the moisture treatments, the highest aphid population density was observed in plants treated with 45% water deficit (DI_{45}), and the lowest in plants irrigated at 15% water deficit (DI_{15}). In addition, the pest population increased on the plants receiving full irrigation treatment ($F_{3, 36} = 247.09$, $P < 0.0001$) (Fig. 1).

During the survey, it was determined that the excessive use of SAP (*i.e.*, 8 g) increased the density of nymphs and adults causing the population density to reach its peak (402.20 ± 1.20 aphids per plant). The lowest population density was found on the plants which received a lower amount of SAP (*i.e.,* 4 g) ($F_{3, 36} = 895.66$, $P < 0.0001$) (Fig. 2).

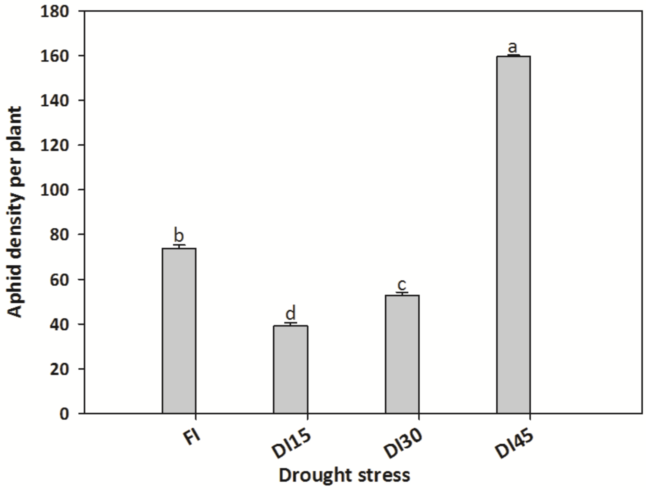

Figure 1 Mean number (± SE) of nymphs and adults of *Aphis gossypii* individuals counted on the exposed leaves treated by different water deficit. Bars with same letters do not differ significantly (Tukey's test, $P < 0.05$). FI, DI_{15}, DI_{30} and DI_{45} indicate full irrigation, 15, 30 and 45% water deficit respectively.

[DOR: 20.1001.1.22519041.2016.5.1.8.7]

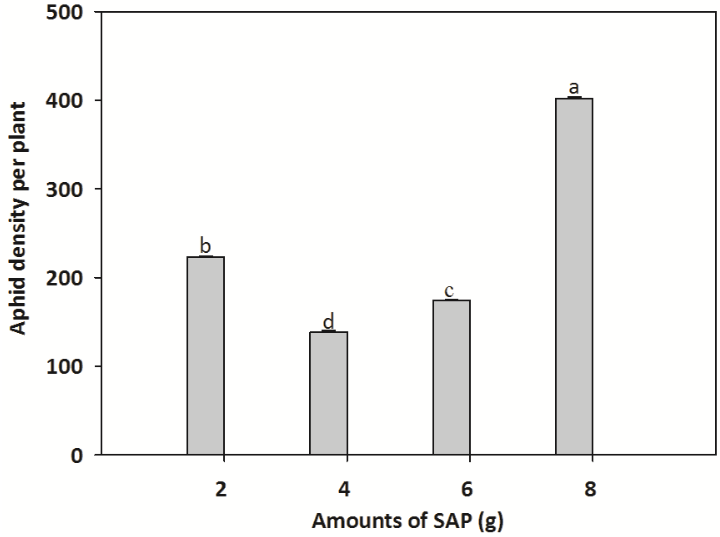

Figure 2 Mean number (± SE) of nymphs and adults of *Aphis gossypii* individuals counted on the exposed leaves of plants growing in pots the soil of which was treated with different amounts of super absorbent polymer (SAP). Bars with same letters do not differ significantly (Tukey's test, $P < 0.05$).

As drought stress (DI_{45}) increased, the number of pest-infested leaves went up. However, with the decrease in the stress (DI_{15}), the amount of infected leaves reached to its minimum ($F_{3,\ 36} = 14.17$, $P < 0.0001$) (Table 1). The effect of different water deficit treatments on certain plant characters such as plant height showed a significant reduction in 45 percent less irrigation (DI_{45}) ($F_{3,\ 36} = 12.73$, $P < 0.0001$). Plants treated with 45% water deficit (DI_{45}) showed the highest reduction in total number of flowers compared to what was observed in full irrigation (FI) and 15% water deficit (DI_{15}) ($F_{3,36} = 13.27$, $P < 0.0001$) (Table 1).

The present study showed using different amounts of SAP had a significant effect on the amount of pepper infestation to *A. gossypii* (Table 2). The pest-infested leaves significantly increased with the increase in amount of super absorbents. The most infected leaves were observed in the treatments in which the most SAP was used. It was also observed that the use of SAP in quantities of less than 8 g (2, 4 and 6 g) reduced the infestation ($F_{3,\ 36} = 18.11$, $P < 0.0001$) (Table 2).

Increase of SAP from 2 g to 8 g, significantly increased plant height ($F_{3,\ 36} = 50.27$, $P < 0.0001$). Plants exposed to the lowest amount of SAP (2 g per pot) showed the highest reduction in plant height compared to control (Table 2). A light increase was detected in the number of flowers after using different amount of super absorbent, especially when it used in quantity of 8 g per pot ($F_{3,\ 36} = 2.23$, $P < 0.0001$) (Table 2).

The results of Pearson correlation indicated that aphid density (number of nymphs + adults) was positively related to the water deficit and the amounts of super absorbent ($r = 0.61$ and 0.62; both $p < 0.01$). Strong negative relationships were found between plant height and the number of flowers with water deficit ($r = 0.67$, 0.64 both $P < 0.01$). No significant correlation was found between the number of flower and the amounts of super absorbent ($r = 0.19$, P □ 0.05). Also it was shown that the infested leaves percentage and plant height were positively correlated with amounts of super absorbent ($r = 0.37$, $P < 0.05$ and 0.59, $p < 0.01$ respectively) (Table 3).

Table 1 Differences in mean (± SE) size of selected vegetative growth features and leaves with infestation induced by *Aphis gossypii* in the water deficit assays.

Treatment	Number of flowers	Plant height (cm)	Infested leaves (%)
Full irrigation	35.0 ± 2.92a	29.4 ± 1.05a	17.00 ± 3.57b
15% water deficit	29.0 ± 4.03ab	20.7 ± 1.05b	5.80 ± 1.54c
30% water deficit	24.0 ± 1.30b	17.6 ± 0.56b	20.60 ± 0.38b
45% water deficit	7.4 ± 0.56c	16.1 ± 2.93b	28.70 ± 3.19a

Means followed by the same letters in a column do not differ significantly (Tukey's test, $P < 0.05$).

Table 2 Differences in mean (± SE) size of selected vegetative growth features and leaves with infestation induced by *Aphis gossypii* in plants treated with different amounts of super absorbent.

Super absorbent content (g)	Number of flowers	Plant height (cm)	Infested leaves (%)
2	18.8 ± 1.67ab	20.1 ± 1.06e	20.6 ± 2.81abc
4	18.2 ± 1.98ab	29.3 ± 0.38c	19.6 ± 4.32bc
6	21.2 ± 2.04a	35.0 ± 0.97b	13.2 ± 1.35c
8	21.6 ± 2.74a	38.3 ± 1.37a	29.2 ± 3.20a
Control	14.1 ± 0.83b	23.5 ± 1.28d	28.4 ± 2.36ab

Means followed by the same letters in a column do not differ significantly (Tukey's test, $P < 0.05$).

Table 3 Correlation coefficient (Pearson's coefficient) between plant features and assayed treatments.

Variables	Water deficit	SAP
Population density	0.61^{**}	0.62^{**}
Infested leaves (%)	0.50^{**}	0.37^{*}
Plant height	-0.67^{**}	0.89^{**}
Number of flower	-0.64^{**}	0.19^{ns}

SAP: Super absorbent polymer.
** $P < 0.01$; * $P < 0.05$; ns, $P \geq 0.05$.

Discussion

It seems that 15% water deficit is considered the most suitable condition for irrigation of pepper because it caused decrease in relative density of the pest while the plant had acceptable yield and growth at this irrigation level. Low levels of drought stress not only cause decline of aphid population but also save water. According to the results of the present study, it is necessary to avoid severe water stress (45%) of plants because it causes extreme infestation by aphid. Water deficit stress alters plant metabolism and biochemistry (Beck *et al.*, 2007), consequent changing plant physiological processes consequently effecting herbivorous arthropods host plant preferences, growth, and development (Showler, 2012). In water deficit stressed plants often osmotic potential is diminished (Bussis and Heineke, 1998), oxidative stress is increased (Knight and Knight, 2001), osmolytes such as antioxidants, amino acids, carbohydrates and inorganic ions are accumulated thereby altering the attractiveness and nutritional value of the plant to insects (Showler and Castro, 2010). Reduction of leaf water content due to water deficit stressed plants in combination with increase of nutritional metabolites (Garg *et al.*, 2001) may contribute to increase of nutritional value of plants per unit of surface area. It is possible that arthropods can perceive cues from host plant suitability through emission of plant volatile compounds or semiochemicals. Aphid impact on the assayed plants proved to be strongly correlated with severe water deficiency: aphids appeared to thrive better on plants suffering severe drought stress, and infestation was lower on plants which had low water stress.

[DOR: 20.1001.1.22519041.2016.5.1.8.7]

Correlations were reported between elevated free amino acid concentrations in phloem sap of water deficit stressed wheat, *T. aestivum*, and barley, *Hordeum vulgare* L., and population increases of the bird oat-cherry aphid, *Rhopalosiphum padi* (L.) (Weibull, 1987) and the cabbage aphid, *Brevicoryne brassicae* (L.), on *Brassica* spp. (Cole, 1997).

Overall, drought stress is considered as a limiting factor for plant yield and it causes an incidence of pest. Based on our observation, the increase in irrigation, stress reduction and increase in the use of super absorbent can improve the crop yield. The growth increase and the rate of nitrogen absorption in meristematic regions can severely lead to infestation (Nevo and Coll, 2001) and it possibly causes flooding of pests and damage to plant. Full irrigation and excessive use of super absorbent (8 g) with the increase in the nitrogen absorption might provide more vegetative growth. Metcalf and Metcalf (1994) found that increasing the amount of plant sap and level of soluble nitrogen in leaf is suitable for nourishment and growth of aphids. Also, they reported that the more cell swelling pressure in non-stressed plants caused the aphid infestation.

When herbivorous arthropods are unable to have access to sufficient amounts of water, their populations might decline. For example, aphid populations are reduced under continued and severe host plant water deficit condition (Showler, 2012). Black bean aphid, *Aphis fabae* Scopali, survivorship was diminished on continuously drought stressed sugar beet, *Beta vulgaris* L., leaves (Kennedy and Booth, 1959).The most likely cause of the host plants unsuitability for aphids under such conditions is low turgor which reduces the ability of aphids feeding (Wearing and Van Emden, 1967). The turgor facilitates aphid ingestion by forcing fluids out of the plant and through the aphid stylet lumens (Douglas and Van Emden, 2007); in addition, the turgor loss reduces or curtails feeding by aphids despite their cybarial pump. Similar results have been reported for black bean aphid on different host plants (Kennedy *et al*., 1958), cotton aphid, *A. gossypii* on cotton, *Gossypium hirsutum* L. (Komazaki, 1982). Some researchers consider drought stress as one of the factors reducing absorption of micronutrients (Rafiee *et al*. 2004; Mirlohi *et al*., 2004). Thus, the reduced absorption of these elements in plant is a result of the drought stress that leads to growth of insect population and yield reduction.

The application of super absorbent can retain water and prevent moisture stress. This approach not only increases the yield and optimizes the use of water but also can reduce the damage of plant pests. According to the results of the current study, water stress increases *A. gossypii* population density and decreases crop yield. Heavy irrigation as a result of increasing turgor pressure leads to the increased infestation. In addition, the use of super absorbent in appropriate amounts can reduce drought stress, aphid infestation and increase plant performance. Therefore, using proper irrigation regime and super absorbent, in integrated pest management programs, can reduce *A. gossypii* infestation in pepper fields and improve the pepper yield.

Acknowledgment

The authors are highly appreciative to Prof. Allan T. Showler (USDA-ARS KBUSLIRL, Kerrville, Texas) for his critical and professional comments and Mr. Mojtaba Farahani (MA in TEFL, Bu-Ali Sina University, Hamedan, Iran) for his linguistic assistance.

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بررسی اثر تنش خشکی و پلیمر سوپرجاذب بر حساسیت فلفل به خسارت شته جالیز *Aphis gossypii* Glover (Hem.: Aphididae)

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چکیده: گیاه فلفل *Capsicum annuum* L.، با داشتن خواص غذایی و داروئی بسیار زیاد از اهمیت ویژه‌ای برخودار است، اما حساسیت این گیاه به برخی آفات از جمله شته جالیز *Aphis gossypii* Glover (Hem.: Aphididae) به‌ویژه در شرایط تنش خشکی منجر به محدودیت تولید آن گردیده است. به‌منظور بررسی اثر تنش خشکی بر جمعیت و میزان خسارت این آفت در شرایط گلخانه‌ای با چهار تیمار تنش خشکی شامل آبیاری کامل، ۱۵، ۳۰ و ۴۵ درصد کم آبیاری؛ و چهار تیمار با مقادیر مختلف پلیمر سوپرجاذب شامل ۲، ۴، ۶ و ۸ گرم روی فلفل سبز بررسی شد. لازم به‌ذکر است که اثر تیمار خشکی و مقادیر مختلف سوپرجاذب به‌صورت جداگانه در غالب طرح کاملاً تصادفی ارزیابی شد. به این‌منظور پس از گذشت ۴ هفته از شروع آزمایش گلدان‌ها به مجاورت منبع آلودگی که قبلاً تهیه شده بود انتقال داده شدند و فراوانی شته پس گذشت یک ماه و خصوصیات رشدی گیاه پس از گذشت دو ماه از آلودگی مورد بررسی قرار گرفتند. نتایج نشان داد که با افزایش تنش آبیاری و کم‌آبی جمعیت این آفت به‌طور قابل ملاحظه‌ای افزایش پیدا کرد و هم‌چنین میزان رشد و عملکرد گیاه به‌طور معنی‌داری دچار کاهش شد. تنش خشکی شدید (۴۵ درصد خشکی) موجب افزایش جمعیت شته جالیز و کاهش عملکرد محصول شد. با این حال تنش اندک خشکی (۱۵ درصد خشکی) علاوه بر این‌که کاهش نسبی جمعیت حشره را به‌همراه داشت، در مصرف آب نیز صرفه‌جویی شد. لازم به‌ذکر است با افزایش میزان آبیاری (آبیاری کامل)، نیز جمعیت این آفت افزایش پیدا کرد. اگرچه افزایش استفاده از پلیمر سوپرجاذب (۸ گرم) باعث افزایش آلودگی فلفل به شته جالیز شد اما این مطالعه نشان داد با استفاده از مقادیر مناسب سوپرجاذب‌ها می‌توان تنش آبی را به حداقل رساند، فراوانی جمعیت آفت را کاهش داده و عملکرد گیاه را با حفظ رطوبت در شرایط کم آبی، افزایش داد.

واژگان کلیدی: خشکی، *Aphis gossypii* ، فلفل سبز، سوپرجاذب، تنش خشکی

[DOR: 20.1001.1.22519041.2016.5.1.8.7]