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THE INFLUENCE OF BENZYLADENINE ON THE FLOWERING OF *LIATRIS SPICATA* L. 'ALBA' CULTIVATED FOR CUT FLOWERS IN AN UNHEATED PLASTIC TUNNEL AND IN THE FIELD

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S u m m a r y

The study focused on the influence of benzyladenine (BA) on the flowering of *Liatris spicata* L.'Alba' cultivated for two years in an unheated plastic tunnel and in the field. Benzyladenine at a concentration of 0, 100, 200, 400 mg×dm^{-3} was applied on the leaf twice during both years of the experiment. It was noted that cultivation of *Liatris spicata* L.'Alba' in an unheated plastic tunnel leads to the growth of longer inflorescence stems with a bigger fresh weight and a larger number of primary shoots. However, in comparison with control plants, it decreases the yield of inflorescence stems in the first and second year of the plants' flowering. It is beneficial to apply benzyladenine at a concentration of 400 mg×dm^{-3} on the leaves of *Liatris spicata* L. 'Alba' cultivated in an unheated plastic tunnel, because this treatment increases the number and fresh weight of inflorescence stems as well as the number of primary shoots in the first and second year of the plants' flowering. It is also justified to apply benzyladenine at a concentration of 400 mg×dm^{-3} on *Liatris spicata* L. 'Alba' cultivated in the field, as it leads to a greater number and fresh weight of inflorescence stems in the first and second year of flowering.

Key words: *Liatris spicata*, benzyladenine, unheated plastic tunnel, flowering

INTRODUCTION

Liatris spicata is a valuable ornamental plant. It grows long, straight and stiff inflorescence stems: 50 – 120 cm long. On the stems there are flowers gathered into baskets which form a dark pink, purple-red, violet, ivory or white spiky inflorescence. The baskets comprise of narrow ligulate flowers which make them look fluffy. *Liatris spicata* bears flowers in an untypical way – from the top down to the bottom. Flowering lasts from July until the end of summer.

Liatris spicata is a constantly underestimated plant, but it is certainly worth a greater interest and attention. It is used in flower beds, where it integrates well with other plants. It can also be cultivated for cut flowers. In bouquets it looks impressive in flower compositions as the main flower but also as the secondary decoration.

Traditionally, *Liatris spicata* is cultivated in the field. In order to obtain earlier flowering, flowers of better quality, and bigger yield, there have been numerous attempts to cultivate it under a covering, predominantly in unheated plastic tunnel (H e t m a n and P o g r o s z e w s k a , 1997).

In order to obtain greater yield and better quality of inflorescence stems, the unheated plastic tunnel is successfully used to cultivate several species of ornamental plants (H e t m a n and P o g r o s z e w s k a , 1995; 1995a; 1996; 1996a; P o g r o s z e w s k a , 1998; W r a g a , 1999; J a n o w s k a , 2000; S z c z e p a n i a k , 2000).

Ornamental plants' flowering and growth can also be influenced by means of growth regulators. Application of benzyladenine in some plants stimulates the development of side buds, which enhances their decorative value (Pogroszewska and F r ą c z e k , 2000; P o b u d k i e w i c z , 2005). Increasing the number of shoots, benzyladenine increases the size of plants such as for example *Hosta* (G a r n e r et al., 1997; K e e v e r and B r a s s , 1998; K o t a ń s k i et al. 2005). And it can be involved in the flower bud initiation process (G r z e s i k and R u d n i c k i , 1989; Ł u k a s z e w s k a , 1991; D a v i e s et al. 1996; S u h , 1997; P o b u d k i e w i c z , 2006). BA affects flowers' morphological features (K a w a - M i s z c z a k et al. 1992; S a n i e w s k i et al. 1997).

The aim of the experiment was to study the influence of benzyladenine (BA), applied in various concentrations, on flowering of *Liatris spicata* L. cultivated in an unheated plastic tunnel and in the field.

MATERIALS AND METHODS

The research was conducted in 2004 and 2005. *Liatris spicata* plants were planted on 8th October, 2003 in local soil in an unheated plastic tunnel and in the field, in 1.5 m wide patches and in three rows with a distance of 0.40 x 0.48 m. The research was conducted in the first and second year of the plants' flowering.

Benzladenine (BA) was used at a concentration of: 0, 100, 200 and 400 mg×dm^{-3}. Preparations were applied on the leaf twice and control plants were sprayed with distilled water. The first treatment was given once the plants reached the height of 16-22 cm (using 40 ml of solution/plant) and the second one when the plants were about 40 cm high (using 60 ml of solution/plant).

Observations and measurement of the number and length of inflorescence stems, their fresh weight and the number of primary shoots were carried out during the whole experiment process.

The experiment was set up in the system of random block in 3 replicates, where a plot with 6 plants served as a replicate. The results were analyzed statistically by means of variance analysis for double classifications, evaluating the significance of differences by means of Turkey's confidence intervals at the level of significance of α= 0.05.

RESULTS

A significant difference in the number of inflorescence stems was noted in the first year of *Liatris spicata* flowering, depending on the cultivation place (Table 1). The plants cultivated in the unheated plastic tunnel grew 19.8% of inflorescence stems less than the plants in the field. The plants cultivated in the field and treated with benzyladenine at a concentration of 200 and 400 mg×dm^{-3} produced inflorescence yield that was 11.7% (BA – 200 mg×dm^{-3}) and 17.3% (BA – 400 mg×dm^{-3}) higher than the yield of the control plants (not treated with the substance). The plants cultivated in the plastic tunnel and treated with BA at a concentration of 400 mg×dm^{-3} produced inflorescence yield significantly higher than the control (by 19.4%)

The inflorescence stems of the plants cultivated in the unheated plastic tunnel in the 1st year of the study were 10.4% longer than the stems of the plants cultivated in the field (Tab. 1). The plants cultivated in the plastic tunnel and treated with benzyladenine at a concentration of 400 mg×dm^{-3} produced inflorescence stems 18.4% shorter than the control plants. It was observed that the plants cultivated in the tunnel had the tendency to produce shorter inflorescence stems, the bigger the concentration of benzyladenine was.

In the 1st year of flowering, the plants cultivated in an unheated plastic tunnel produced stems with greater fresh weight than that of the plants cultivated in the field (Tab. 1). The difference was 19.4%. In all the tested concentrations, the bioregulator significantly differentiated the fresh weight of *Liatris spicata* cultivated in the tunnel. Benzyladenine at a concentration of 400 mg×dm^{-3} proved to be most desirable, as it also had a positive effect on fresh weight of stems in the field, leading to value growth of the tested feature by 48% and 31.4% compared to the control plants.

The inflorescence stems of *Liatris spicata* cultivated in the plastic tunnel in the 1st year of flowering produced 1.5 times more primary shoots than the plants cultivated in the field (Tab. 1). Interaction of the studied factors was marked by the greatest number of primary shoots in the plants growing in the tunnel and treated with the substance at a concentration of 400 mg×dm^{3}. There were nearly 3 times more of them than in the control plants. In the field, however, BA did not affect branching of *Liatris spicata* stems.

The age of the plants clearly influenced the yield of *Liatris spicata* inflorescences. The yield in the unheated plastic tunnel in the 2nd year of flowering was 107.3% greater than in the 1st year. In the field, it was 94.6% greater than in the first year.

In the 2nd year of flowering, the *Liatris spicata* plants cultivated in the plastic tunnel produced inflorescence yield 14.6% smaller than the yield of the plants cultivated in the field (Tab. 1). The plants treated with BA at all the concentrations, both in the field and in the tunnel, produced more inflorescence stems than the control plants. The greatest yield of inflorescence stems was obtained by the application of benzyladenine at a concentration of 400 mg×dm^{-3}. The treatment in the unheated plastic tunnel increased yield by 112.3%, whereas in the field by 77.2% compared to the control plants.

It was observed in the 2nd year of *Liatris spicata* flowering that the plants cultivated in the unheated plastic tunnel produced inflorescence stems 14.4% longer than the plants cultivated in the field. A significant effect of benzyladenine on the length of inflorescence stems of *Liatris spicata* in the 2nd year of flowering was observed after the application of BA – 400 mg×dm^{-3} to the plants in the field. This treatment led to shortening of inflorescence stems length by 8.7% in comparison to the control plants.

The inflorescence stems of *Liatris spicata* cultivated in the unheated plastic tunnel in the second year of flowering differed significantly in the fresh weight from the stems of the plants cultivated in the field (Tab. 1). Those plants which grew in the plastic tunnel produced an inflorescence that had fresh weight 17% higher than the weight of an inflorescence of the plants cultivated in the field.

The plants cultivated in the unheated plastic tunnel and treated with BA at all the concentrations produced inflorescence stems with greater fresh weight than that of the control plants. Inflorescence stems with the greatest fresh weight were obtained from the plants

Table 1
The effect of benzyladenine on morphological features of inflorescence stems of *Liatris spicata* L. 'Alba'.

BA concentration ($mg \times dm^{-3}$)	Number of inflorescence stems			
	1st year of flowering		2nd year of flowering	
	field	tunnel	field	tunnel
0	17.9 b*	14.4 cd	25.5 d	20.3 e
100	16.2 bc	13.0 d	33.6 c	25.5 d
200	20.0 a	15.7 bc	41.6 b	35.6 c
400	21.0 a	17.2 b	45.2 a	43.1 ab
Mean	18.7 A	15.0 B	36.4 A	31.1 B
BA concentration ($mg \times dm^{-3}$)	Length of inflorescence stems (cm)			
	1st year of flowering		2nd year of flowering	
	field	tunnel	field	tunnel
0	62.0 bc	69.4 a	62.1 bc	70.0 a
100	58.5 c	67.0 ab	60.0 cd	69.0 a
200	58.6 c	66.7 ab	59.8 cd	68.2 a
400	59.5 c	58.6 c	56.7 d	65.7 ab
Mean	59.6 B	65.8 A	59.5 B	68.1 A
BA concentration ($mg \times dm^{-3}$)	Fresh weight of inflorescence stems (g)			
	1st year of flowering		2nd year of flowering	
	field	tunnel	field	tunnel
0	36.6 c	38.3 c	35.1 c	37.3 c
100	39.5 c	56.0 a	37.6 c	45.6 ab
200	41.1 bc	49.5 a	39.4 bc	51.9 a
400	48.1 ab	56.7 a	46.0 ab	52.5 a
Mean	41.2 B	49.2 A	39.4 B	46.1 A
BA concentration ($mg \times dm^{-3}$)	Number of primary shoots			
	1st year of flowering		2nd year of flowering	
	field	tunnel	field	tunnel
0	1.2 b	2.2 b	1.0 b	1.8 b
100	2.2 b	4.2 ab	1.8 b	2.0 ab
200	3.5 ab	2.6 ab	1.8 b	3.8 ab
400	2.4 b	6.4 a	3.2 ab	5.9 a
Mean	2.6 B	4.1 A	2.2 B	3.6 A

* Means followed by the same letters are not significantly different at α=0.05 level of probability. Means of each year were compared separately.

sprayed with benzyladenine at a concentration of 400 mg×dm^{-3}. Those stems had 40.7% greater fresh weight than the weight of stems produced by the control plants. The plants cultivated in the field and treated with benzyladenine at a concentration of 400 mg×dm^{-3} produced inflorescence stems with fresh weight 31.0% greater than the weight of the control plants' stems.

In the 2nd year of cultivation, the *Liatris spicata* plants cultivated in the plastic tunnel produced 63.6% more primary shoots than the plants in the field (Tab. 1). Interaction of the studied factors was marked with the greatest number of primary shoots in the *Liatris spicata* plants growing in the unheated plastic tunnel and treated with BA – 400 mg×dm^{-3}. There were over 3 times more of them than in the control plants.

DISCUSSION

This experiment shows that plants cultivated in an unheated plastic tunnel produce a smaller yield than plants cultivated in the open field, which confirms the results obtained by Hetman and Pogroszewska (1996) who claimed that cultivation in a plastic tunnel decreases the yield of *Liatris spicata*. Similar effects were observed by Pogroszewska and Sadkowska (2006) in a research on *Astilbe x arendsii* Arends. Depending on the species, plants can react differently to cultivation in an unheated plastic tunnel. Pogroszewska's research (1998) on *Iris sibirica* and Hetman and Pogroszewska's research (1996) on flowering of *Helleborus x hybridus* hort. prove that cultivation in an unheated plastic tunnel increases plants' yield. Similar results were obtained by Janowska (2000) and Janowska and Schroeter (2001). The authors claimed that the inflorescence yield of *Dianthus barbatus* cultivated in a tunnel was greater than the yield of plants cultivated in the field. These observations are also confirmed by Puczel and Waźbińska (2003) in the research on *Craspedia globosa*, and by Wraga (1999) in the research on *Molucella laevis* L.

In the experiment, the inflorescence of *Liatris spicata* cultivated in a plastic tunnel had better quality, as estimated by the length and fresh weight of inflorescence stems than stems from field cultivation. This confirms the results of research on *Liatris spicata* by Hetman and Pogroszewska (1997). A similar reaction to cultivation in an unheated plastic tunnel is observed in case of: *Iris sibirica* (Pogroszewska, 1998), *Molucella laevis* L. (Wraga, 1999) and *Astilbe x arendsii* Arends (Pogroszewska and Sadkowska, 2006). However, based on the research on *Erigeron hybridus* Bergm.'Dunkelste', Szczepaniak (2000) informs that despite rich flowering, the plants in a plastic tunnel produced inflorescence stems of poor quality.

In our own research, the application of benzyladenine increased the number of inflorescence stems produced by *Liatris spicata.* A similar positive effect of benzyladenine on plants' flowering was noted by Boyle (1995) in the research on *Easter cactus* 'Crimson Giant' and by Lee et al. (1999) in experiments on *Oncidium*.

The plants of *Liatris spicata* treated with benzyladenine at a concentration of 400 mg·dm^{-3} produced inflorescence stems with a greater number of primary shoots than the control plants. A similar reaction of plants to benzyladenine was noted by Bessler (1997), who obtained a greater number of side branching due to benzyladenine in *Tillandsia*, and by Pobudkiewicz (2005), who showed that the application of BA on the leaf improves growth of *Dianthus caryophyllus* L. of Colorado Majestic Mountain group. Results obtained in our own research are not consistent with the results of research by Wang and Boogher (1987) on *Syngonium podophyllum* Schott. 'White Butterfly', in which even the concentration of 2000 mg×dm^{-3} did not have a positive effect on this feature.

In all the studies conducted, the plants treated with benzyladenine at a concentration of 400 mg×dm^{3} produced shorter inflorescence stems than the control plants. Similarly, Kim and Okubo (1996) inform about the shortening of *Lablab purpureus* stems, in comparison to the control, under the influence of benzyladenine. Analogical results were obtained by Kim et al. (2000) in the research on *Doritaenopsis* 'Happy Valentine' and by Pobudkiewicz (2005) in the research on pot carnation.

CONCLUSIONS

1. Cultivation of *Liatris spicata* L.'Alba' in an unheated plastic tunnel leads to the growth of longer inflorescence stems with a bigger fresh weight and a larger number of primary shoots. However, in comparison with control plants, it decreases the yield of inflorescence stems in the first and second year of plant flowering.
2. It is beneficial to apply benzyladenine at a concentration of 400 mg×dm^{-3} on leaves of *Liatris spicata* cultivated in an unheated plastic tunnel, because this treatment increases the number and fresh weight of inflorescence stems as well as the number of primary shoots in the first and second year of plant flowering.
3. It is also justified to apply benzyladenine at a concentration of 400 mg×dm^{-3} on *Liatris spicata* cultivated in the field, as it leads to a greater number and fresh weight of inflorescence stems in the first and second year of flowering.

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Wpływ benzyloadeniny na kwitnienie liatry kłosowej (*Liatris spicata* L.) 'Alba' uprawianej na kwiat cięty w nieogrzewanym tunelu foliowym i w polu

S t r e s z c z e n i e

Zbadano wpływ benzyloadeniny (BA) na kwitnienie liatry kłosowej (*Liatris spicata* L.) 'Alba' uprawianej przez dwa lata w nieogrzewanym tunelu foliowym i w gruncie. Benzyloadeninę w stężeniach: 0, 100, 200, 400 mg$\times$dm^{-3} zastosowano dolistnie, dwukrotnie w obu latach trwania doświadczenia. Stwierdzono, że uprawa liatry kłosowej w nieogrzewanym tunelu foliowym sprzyja wytwarzaniu dłuższych pędów kwiatostanowych, o większej świeżej masie i większej liczbie rozgałęzień I-rzędu, ale zmniejsza plon pędów kwiatostanowych w pierwszym i w drugim roku kwitnienia roślin, w porównaniu do roślin kontrolnych. Korzystne jest dolistne stosowanie benzyloadeniny w stężeniu 400 mg$\times$dm^{-3} na rośliny liatry kłosowej uprawianej w nieogrzewanym tunelu foliowym, gdyż zabieg ten zwiększa liczbę i świeżą masę pędów kwiatostanowych oraz liczbę rozgałęzień I-rzędu w pierwszym i w drugim roku kwitnienia roślin. Celowe jest stosowanie benzyloadeniny w stężeniu 400 mg$\times$dm^{-3} na rośliny liatry kłosowej uprawianej w polu, ze względu na większą liczbę i świeżą masę pędów kwiatostanowych w pierwszym i drugim roku kwitnienia.