Journal of Tekirdag Agricultural Faculty
Tekirdağ Ziraat Fakültesi Dergisi

Aralık/December 2024, 21(5)
Başvuru/Received: 06/03/23
Kabul/Accepted: 06/12/24
DOI: 10.33462/jotaf.1260695

http://dergipark.gov.tr/jotaf
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ARAŞTIRMA MAKALESİ **RESEARCH ARTICLE**

Usability of 'Pink Pearl' 'Aiolos' and 'Blue Jacket' Hyacinth (*Hyacinthus orientalis* L.) varieties with Pre- and Postharvest Boric Acid Application as Cut Flowers*

Hasat Öncesi ve Sonrası Borik Asit Uygulanmış 'Pink Pearl' 'Aiolos' ve 'Blue Jacket' Sümbül (*Hyacinthus orientalis* L.) Çeşitlerinin Kesme Çiçek Olarak Kullanılabilirliği

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Abstract

The study aimed to investigate the effect of boric acid (BA) treatments on availability of 'Pink Pearl' 'Aiolos' and 'Blue Jacket' hyacinth varieties as cut flower. For this purpose, 0, 50, 100 and 150 ppm boric acid doses were applied to hyacinths in pre- and post- harvest period. Boric acid (BA) was sprayed to leaves before harvest, while mixed into vase solution after harvest. The potted hyacinth plants were placed in a high plastic tunnel after stratification. The temperature in plastic tunnel kept at 18-20 ºC during the cultivation. Pre-harvest treatments were performed as spraying prepared BA solutions to the leaves when the leaves reached to full size. During the vegetation period, the qualitative and quantitative parameters such as total leaf number, spike stalk length, leaf color (L* and hue (h°)), leaf chlorophyll (SPAD) value, total floret number, leaf length, total plant length, and total blooming spike number were measured. After harvest, hyacinth plants were placed in vase solution and monitored for post-harvest strength under 12 hours light/12 hours dark photoperiod conditions. Water uptake, the spike stalk length, and the vase longevity of the spike were observed during the vase life period. The BA treatments did not show any significant effect on the vase life of the hyacinth spike. The 150-ppm BA, however, improved leaf quality by increasing leaf chlorophyll and hº values while decreasing L* values. In conclusion, it can be suggested that the 'Aiolos' cultivar has a potential as cut flower due to its longer plants and flower stems both in pre- and post-harvest period, as well as its longer vase life. Among the BA applications, it was concluded that the 100 ppm application is a viable option for increasing water uptake and reducing weight loss during the vase period.

Keywords: Hyacinth, Boric acid, Spike stalk length, Chlorophyll SPAD, Vase life

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Atıf: Olgaç, Y., Kasım, R., Kasım, M. U. (2024). Hasat öncesi ve sonrası borik asit uygulanmış 'Pink Pearl' 'Aiolos' ve 'Blue Jacket' sümbül (*Hyacinthus orientalis* L.) çeşitlerinin kesme çiçek olarak kullanılabilirliği. *Tekirdağ Ziraat Fakültesi Dergisi,* 21(5): 1323-1335.
Citation: Author 1, Author 2, Author 3. (2024). Usability of 'Pink Pearl' 'Aiolos' and 'Blue Jacket' hyacinth (*Hyacinthus orientalis* L.) varieties with pre- and postharvest boric acid application as cut flowers. *Journal of Tekirdag Agricultural Faculty,* 21(5): 1323-1335.

*This study was summarized from the Yağmur Olgaç's MSc thesis.

Öz

Çalışmada borik asit (BA) uygulamalarının 'Pink Pearl' 'Aiolos' ve 'Blue Jacket' sümbül çeşitlerinin kesme çiçek olarak kullanılabilirliği üzerine etkilerinin incelenmesi amaçlanmıştır. Bu amaçla sümbüllere hasat öncesi ve sonrası dönemde olmak üzere 0, 50, 100 ve 150 ppm dozlarında borik asit uygulanmıştır. Borik asit hasat öncesi yapraklara püskürtme şeklinde uygulanırken hasat sonrasında vazo çözeltisine karıştırılarak uygulanmıştır. Soğuk katlama uygulamasının ardından sümbül bitkileri plastik tünele alınmıştır. Yetiştirme sırasında plastik tünelin sıcaklığı 18-20 °C arasında tutulmuştur. Hasat öncesi borik asit uygulamaları yapraklar tam büyüklüğünü aldığında püskürtme şeklinde yapılmıştır. Vejetasyon süresi boyunca, toplam yaprak sayısı, başak sapı uzunluğu, yaprak rengi (L* ve hue (h°)), klorofil (SPAD değeri), toplam kandil sayısı, yaprak uzunluğu, toplam bitki uzunluğu ve toplam çiçeklenen başak sayıları gibi kalitatif ve kantitatif parametreler ölçülmüştür. Hasattan sonra sümbül bitkileri vazo çözeltisine yerleştirilmiş, 12 saat aydınlık/12 saat karanlık foto periyot şartlarında hasat sonrası dayanımı açısından izlenmiştir. Bu süreç boyunca ise su alımı, başak sapı uzunluğu ve vazo ömrü gözlem ve ölçümleri yapılmıştır. Çalışma sonucunda BA uygulamalarının sümbül başaklarının vazo ömrü üzerinde önemli bir etkisi olmadığı tespit edilmiştir. Bununla birlikte 150-ppm BA uygulamasının klorofil (SPAD) ve h° renk değerlerini arttırmak ve L* değerlerini azaltmak suretiyle yaprak kalitesini arttırdığı saptanmıştır. Çalışmanın sonuçlarına göre, 'Aiolos' hem hasat öncesi hem de hasat sonrası dönemde daha uzun bitki ve çiçek saplarına sahip olması ve daha uzun vazo ömrü nedeniyle potansiyel bir kesme çiçek çeşidi olarak önerilebilir. BA uygulamaları arasında ise 100 ppm'in vazo ömrü süresince su alımını arttırması ve ağırlık kayıplarını azaltması bakımından kullanılabilecek bir uygulama olduğu sonucuna varılmıştır.

Anahtar Kelimeler: Sümbül, Borik asit, Başak sapı uzunluğu, Klorofil SPAD, Vazo ömrü

1. Introduction

The hyacinth (*Hyacinthus orientalis* L.) is a bulbous biennial herbaceous plant, and originated Mediterranean Region (USDA, 2023). The hyacinth is a valuable flower that was highly adapted to the cut flower sector with its attractive flowers and pungent odor. The production area and production quantity of hyacinth are 37 da and 991000 pieces in Turkey, respectively (TÜİK, 2023). The hyacinth is used as an outdoor plant, and its availability as a cut flower is limited due to its short flower stalk and the fact that stalk starts to elongate after the flower buds are formed. Thus, elongating the flower stalk before opening the floret is crucial in using hyacinth as a cut flower.

Boron (B) is one of the critical micronutrients for the optimum development and quality in plants (Deliboran et al., 2020). B plays crucial role in cell division and elongation in young growing plant tissues (İkinci and Aldanmaz, 2022). Furthermore, boron participates in cell-wall synthesis and structural integrity in plants. B is taken from the soil in uncharged boric acid (BA) form (Shireen et al., 2018). Due to these important functions of boron in the plants, numerous studies have been performed recently to determine the effects of boron applications on plant growth, yield, and quality in the pre-harvest and post-harvest periods.

Preharvest spray treatment of BA on iris plant leaves improved floral properties and yield per plant (Khalifa et al., 2011). Similarly, BA has led to an increase in flower number, yield, and quality parameters of rose plants (Poornima et al., 2018). On the other hand, the BA treatment on cut carnation flowers retarded senescence as a result of slowing down in ethylene production. BA treatment also reduced weight loss, increased sugar concentration up to maximum level, increased water uptake, flower weight and flower diameter and prolonged vase life in cut carnation flowers (Serrano et al., 2001; Ahmadnia et al., 2013; Krishnamoorthy et al., 2017). Additionally, BA treatment in gladiolus was extended the vase life of cut spikes significantly, increased the spike diameter, and inhibited the proliferation of microorganisms in the vase solution, and was effective in maintaining spike quality (Jian-Bo et al., 2009). Similarly, the BA treatments extended the vase life (Liavali and Zarchini, 2012; Hashemabadi et al., 2014) and reduced bacterial count on the flower stalk tip on cut rose flowers (Hashemabadi et al., 2013).

To our knowledge no study has been conducted the effect of boric acid on plant development, cut flower quality and vase life of hyacinth. Therefore, the determination of the effect of BA treatments on plant development, elongation of spike stalk, vase life, and availability as a cut flower of three different hyacinth varieties were aimed in this research.

2. Materials and Methods

This research was conducted at a high plastic tunnel and postharvest physiology laboratory in Arslanbey Vocational School of Kocaeli University from September to March vegetation period of 2019-2020.

2.1. Plant material

Bulbs of hyacinth cultivars 'Pink Pearl', 'Aiolos', and 'Blue Jacket' were purchased from Asya Lale Construction Agriculture and Livestock Trade and Limited Company in Konya. The calibration of bulbs, in terms of width, was 14-15. The bulbs of hyacinths had a health certificate, and the conformity of bulbs has been confirmed in terms of ISO-9001 quality standards and TSE2547 flower bulb standards. The study focused on three hyacinth cultivars: 'Aiolos,' a white-flowered type growing up to 25 cm tall; 'Blue Jacket,' with purple flowers, reaching 15-20 cm in height; and 'Pink Pearl,' with pink flowers and grows in height up to 15-20 cm. All three varieties are planted in October, and they flower from March to May. They were chosen for their relatively short stature, vibrant colors and pleasant fragrance and their primary use in container and/or outdoor plantings. Total of 120 bulbs for each variety were used in the experiment. The bulbs were planted into production pots that were 17.5 cm wide and 25 cm tall as one bulb per pot. Pots were filled halfway with 2:1:1/4 peat (Klasmann Rec 1PN Potgrond P, 0-10 mm, pH: 6, fertilizer content: 1.5) garden soil: perlite mix, a bulb was then placed in each pot, and were topped off with the same mixture on October 24, 2019.

2.2. Cold scarification and production

Planted bulbs were placed in a cold storage room set at 9±1°C temperature and 90-95% relative humidity for cold scarification and kept for a period of seven weeks for 'Blue Jacket' and for a period of eight weeks for 'Pink Pearl' and 'Aiolos' varieties. After designated storage periods, the pots were placed in a high plastic tunnel at 18-20 ºC temperature.

2.3. BA treatments

Pre-harvest BA treatments were started fifteen weeks after planting when each plant has at least two well-developed leaves. BA was treated at doses of 50 ppm, 100 ppm, and 150 ppm per plant and a total of thirty plants were used in each treatment group, whereas the leaves of plants in the control group were sprayed with water. For postharvest treatments, BA was mixed into vase solution containing 2% sucrose. Five hyacinth spikes from each treatment group were placed in vases containing 50, 100, and 150 ppm BA separately. Spikes of control group were placed in vases containing water.

2.4. Pre-harvest observation and measurement

Total leaf number: Leaves were counted at three growth stages, when the first leaves are formed, at 50% flowering, and before spike harvest. *Spike stalk length* was measured from the soil surface to the base of the spike. *The leaf length:* The length of the longest leaf on the plant was measured. *Plant length was* determined as the distance between stem base and the tip of the spikes. *Leaf color* was measured using a colorimeter (Minolta, CR-400, Osaka, Japan), as L*, a* and b*. From the L*, a* and b* values hue angle color values were calculated using Equation (1) below:

$$h^{\circ} = 90 + tan^{-1}\, {a*}/{b*} \quad (when\ a < 0\ and\ b > 0) \qquad \text{(Eq. 1)}$$

The light source of the colorimeter is a D65 lamp and has an 8 mm head. The calibration of the apparatus was done before measurement using a white calibration plate (L*=97.52; a*=-5.06; b*=3.57) (Mcguire, 1992; Radzevičius et al.; 2014, Kasım and Kasım, 2016). *Chlorophyll (SPAD value)* content of hyacinth was measured with SPAD 502 Plus (Konica Minotla, Inc., Osaka, Japan) in two leaves of per plant. *Total blooming floret number in spike* was determined by counting floret in spikes daily. *The blooming duration* was measured as the number of days from the opening of the first florets to the last florets in spikes.

2.5. Post-harvest measurement, observation, and analysis

In this section of the experiment, the 'Pink Pearl' variety was not evaluated because of the short spike stalk. *Vase life:* The day of the wilting of all the florets in spikes was accepted as completion of vase life. Hyacinths were weighed immediately after cutting and also during vase period at every other day.

The weight loss of hyacinth spikes (WL) was calculated by the following Equation (2):

$$WL\ (\%) = (initial\ weight - last\ weight)\ x\ 100/initial\ weight \qquad \text{(Eq. 2)}$$

Where; 'initial weight' denotes the weight measured right after harvest, and 'last weight' refers to the weight recorded during each analysis period.

Water uptake: During each analysis period, the vase solution was transferred to a measuring cylinder, and measured. Water uptake was calculated by subtracting the solution left in the cylinder from the initial volume.

Spike stalk length: Hyacinth plants were uprooted with their bulbs to prevent stem length shortening. After the hyacinths were transported to the laboratory, the bulb leaves at the base of the stem were removed. Spike stalk length was measured in centimeters using a ruler.

Chlorophyll (SPAD) content was measured from two points of each leaf per hyacinth plant during vase life, using SPAD 502 Plus (Soil-Plant Analysis Development, Konica Minolta, Inc. Osaka, Japan) which can measure the relative value of plant chlorophyll content.

2.6 Experimental design

The experiment was planned according to a Completely Randomized Experimental Design with a factorial arrangement of varieties and BA dosages with three replicates (ten plants per replication for pre-harvest and five plants per replication for post-harvest). The data were analyzed using statistic software SPSS 22.0 followed by Duncan's Multiple Range tests at $p<0.05$

3. Results and Discussion

3.1. Preharvest studies

Analysis showed that neither the main effects of BA dosages nor the interaction effects were significant regarding total leaf number, leaf length, spike stalk length, and plant length whereas the cultivar main effect was significant. Furthermore, it has been observed that in all dosages tested the BA treatments did not perform superior to the control treatments in the enhancement of plant growth (*Table 1*). 'Aiolos' (6.10) had the lowest leaf number whereas the leaf number of 'Pink Pearl' was the highest (7.42). The longest leaves were obtained from 'Aiolos' (20.66) followed by 'Blue Jacket (18.05 cm) and 'Pink Pearl' (14.47 cm). Similarly, the spike stalk length was the highest (23.92 cm) in 'Aiolos' compared to the other two cultivars. The highest plant length and spike stalk length was recorded in 'Aiolos' (27.85 and 21.39 cm, respectively).

No literature was found associated with the effect of BA treatments on the development of hyacinth. However, in respect to plant growth results apparently indicate that the dosages of boric acid used in this study do not necessarily have depressing effect on plant growth in hyacinth. Earlier works show that plant response to boron varies depending on species and genotypes (Vera-Maldonado et al., 2024). Poornima et al. (2018) found that BA applications increase the number of leaves in 'Mirabilis' cut rose, and Qureshi et al. (2015) reported similar results in carnation. However, researchers used different microelements such as iron and magnesium along with BA. In these studies, the combination of boric acid with micronutrients such as iron and magnesium increased plant height due to the synergistic effects of micronutrients. For example, iron is the main component of enzymes such as dehydrogenase, proteinase, and peptidase and thus stimulates the growth hormones and affects growth. It can be speculated that no fertilization other than boric acid was applied in the current study may be a reason why boric acid did not affect studied plant growth parameters.

Table 1. Variety and BA dosages main effects and their interactions for the total leaf number, leaf length, spike stalk length, and total plant length

	BA dosages	***Hyacinth varieties***			***BA dosages***
		Pink Pearl	***Aiolos***	***Blue Jacket***	***main effect***
Total leaf number	Control	7.25	6.02	6.30	**6.52**
	50 ppm	7.53	6.07	6.48	**6.69**
	100 ppm	7.61	6.13	6.49	**6.74**
	150 ppm	7.31	6.17	6.34	**6.60**
	Cultivar main effect	**7.42 A**	**6.10 C**	**6.40 B**	
Leaf length (cm)	Control	14.41	20.27	18.51	**17.73**
	50 ppm	14.64	20.34	17.72	**17.57**
	100 ppm	14.32	21.16	18.13	**17.87**
	150 ppm	14.53	20.88	17.73	**17.75**
	Cultivar main effect	**14.47 C**	**20.66 A**	**18.05 B**	
Spike stalk length (cm)	Control	10.89	20.46	19.03	**16.43**
	50 ppm	11.37	21.71	18.5	**16.90**
	100 ppm	11.03	21.97	18.36	**16.74**
	150 ppm	11.27	21.42	18.03	**16.56**
	Cultivar main effect	**11.14 C**	**21.39 A**	**18.48 B**	
Plant length (cm)	Control	16.41	26.78	24.83	**22.28**
	50 ppm	17.3	28.24	24.23	**22.88**
	100 ppm	16.61	28.15	24.23	**22.60**
	150 ppm	17.11	28.25	24.42	**22.88**
	Cultivar main effect	**16.86C**	**27.85 A**	**24.43 B**	
Significance[z]	*Cultivar main effect ***, BA dosage main effect[ns], Cultivar x BA dosage[ns]*				

[z]Two way ANOVA; ns: not significant; *, **, ***: significant at $p<0.05$, 0.01 and 0.001, respectively. Values within the rows followed by the same letter are not significantly different; the numbers are averages of all replicates.

It was detected that the plant and spike stalk length and leaf length of the Aiolos variety is longer than those of the 'Blue Jacket' and 'Pink Pearl. Pasztor et al. (2020) investigated the effects of three different planting times, November 10, November 24, and December 1, on the flower height of different hyacinth varieties. They found that the stem heights of the varieties varied between 8 cm and 13.66 cm, as the 'Blue Jacket' variety being with longest flower height. In the present study, bulb planting was conducted on October 24, and the spike stalk lengths were measured as 21.39 cm and 18.48 cm for ‘Aiolos’ and ‘Blue Jacket’, respectively. The quality of hyacinth plants depends on a range of factors such as genotype, cultivation period, and growing conditions (temperature, light spectrum and intensity, etc.) (Śmigielska et al., 2014). In the conditions of experimental area of this study, the stem lengths of both varieties from bulbs planted in October were longer than those measured by Pasztor et al. (2020). Similarly, Nicu and Manda (2024) measured the stem height of the 'Blue Jacket' hyacinth variety planted in October as 24.16 cm. It is therefore likely that the planting time had an important effect on the characteristics presented here.

The highest L* value was measured in the 'Aiolos' variety as 45.31, followed by 'Blue Jacket' and 'Pink Pearl' as 44.52 and 42.65, respectively. Furthermore, BA treatments increased L values, 50 ppm was more effective compared to 150 ppm and control, 50 ppm, and 100 ppm were placed statistically in the same group (*Table 2*). The CIE L* a* b* color system defines colors using three axes: The L* value for lightness and a* and b* for chromaticity coordinates. On a color space diagram, L* is displayed vertically, ranging from 0 (black) to 100 (white) (Ly et al., 2020). A higher L value indicates increased brightness, while a lower value corresponds to dullness (Yao et al., 2023). In this study, hyacinth leaves treated with 50 ppm BA were brighter than those with 150 ppm BA which resulted in darker leaves. This finding was also supported by h° and chlorophyll SPAD measurements. Tantan et al. (2022) found that 300 ppm BA treatment led to the lightening of the leaf color. In contrast to this finding, the lowest BA level resulted in the lightening of the leaf color of the hyacinth, in the present study.

The main effect of the BA dosage on h° value was statistically significant. The h° values of leaves were increased with increasing BA levels (*Table 2*). Control treatment resulted in lower h° values (125.15) in comparison to BA treatments, and the highest values was from 150 ppm BA treatment (125.52). In the CIE L* a* b* color coordinate system, h represents the hue or color name. It is defined by the hue angle (h°) in degrees on a* b* plane, starting from the positive a* axis and progressing counterclockwise. Red corresponds to 0 (or 360°), yellow to 90°, green to 180°, and blue to 270° (Scalisi et al., 2022). An increase in h° value toward 180° indicates a shift toward green, while a decrease suggests a movement toward yellow. Thus, in this study, the increase in h° values with higher BA doses signifies that the leaf color is becoming greener or retained green color.

Table 2. Leaf L*and h° values, and chlorophyll (SPAD) content of hyacinth cultivars treated with different doses of BA.

	Treatments	*Hyacinth varieties*			*BA dosages*
		Pink Pearl	*Aiolos*	*Blue Jacket*	*main effect*
L*	Control	42.76	45.31	44.6	**44.22 ab**
	50 ppm	42.52	45.80	44.73	**44.35 a**
	100 ppm	43.07	45.15	44.47	**44.23 ab**
	150 ppm	42.25	44.98	44.27	**43.83 b**
	Cultivar main effect	**42.65 C**	**45.31 A**	**44.52 B**	
h°	Control	126.79	123.76	124.88	**125.15 b**
	50 ppm	126.92	123.74	125.05	**125.24 ab**
	100 ppm	126.64	124.36	124.88	**125.29 ab**
	150 ppm	127.46	124.02	125.09	**125.52 a**
	Cultivar main effect	**126.95 A**	**123.97 B**	**124.98 B**	
Chlorophyll (SPAD)	Control	59.91	58.56	60.41	**59.63 b**
	50 ppm	60.78	58.13	60.06	**59.66 b**
	100 ppm	60.61	58.58	60.09	**59.76 ab**
	150 ppm	61.24	58.91	60.61	**60.23 a**
	Cultivar main effect	**60.64 A**	**58.54 B**	**60.29 A**	
Significance[z]	*Cultivar main effect***, BA dosage main effect***, Cultivar x BA dosage[ns]*				

[z]Two way ANOVA; ns: not significant; *, **, ***: significant at $p<0.05$, 0.01 and 0.001, respectively. Values within the rows and columns followed by the same letter are not significantly different; the numbers are averages of all replicates.

A chlorophyll meter, such as the SPAD-520 (Soil-Plant Analysis Development 502) is a common tool for assessment of total chlorophyll content. It measures the SPAD value, or greenness, which provides a rapid, convenient, and non-destructive evaluation of plant chlorophyll content and overall health. Higher SPAD values indicate better plant health and chlorophyll concentration, with measurements typically ranging from 24.0 to 70.6, depending on the plant type (Zhang et al., 2022). The main BA and the main cultivar effect were significant with regard to chlorophyll (SPAD) value (*Table 2*). For the BA dosages main effect, the chlorophyll (SPAD) value ranged from 59.63 to 60.23, consistent with the findings of Zhang et al. (2022). While control and 50 ppm BA treatments resulted in lowest chlorophyll (SPAD) content, 59.63 and 59.66, respectively, the highest chlorophyll (SPAD) content, 60.23, was obtained form 150 ppm BA treatment. This was also supported by the h°-value results. Although h° values showed no significant differences among BA applications, the notable increase with 150 ppm BA compared to the control, underscores its positive effect in maintaining both green color and chlorophyll content in the leaves. The significant reducing effect of 150 ppm BA on L values of leaves further confirmed these results.

It appears that the cultivars also had significant effect on chlorophyll (SPAD) content. For the cultivar main effect, the highest level of chlorophyll (SPAD) content, 60.64 and 60.29, were found in 'Pink Pearl' and 'Blue Jacket', respectively, while 'Aiolos' resulted in the lowest levels in all BA treatments. In fact, 150 ppm BA presented the highest chlorophyll (SPAD) content in all cultivars, although interaction effect was not significant.

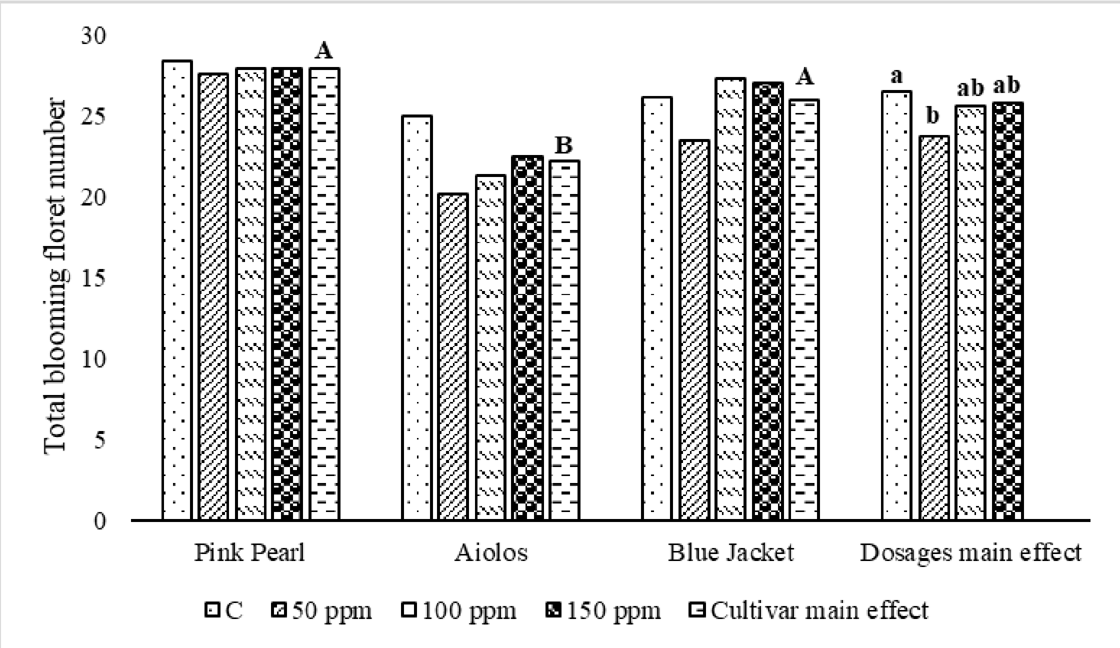

Figure 1. Total blooming floret number of spikes treated with different dosages of BA

Different lower case letters above bars indicate significant differences among the BA dosages and different capital letters indicate significant differences among cultivars (p<0.05).C: control

Main effects of dosages and cultivars were statistically significant for blooming floret numbers compared to the control. The 'Pink Pearl' (27.95 florets) and 'Blue Jacket' (25.99 florets) cultivars had more blooming florets than the 'Aiolos' cultivar (22.24 florets). In reference to the dosages main effect, all BA applications reduced the total number of blooming florets, the lowest number was found in 50 ppm BA treatment, the dosages ranking second consisted of, in descending order, 150 and 100 ppm BA (*Figure 1*). The 'Pink Pearl' cultivar produced higher total floret number due to its twin spike formation, but its shorter stem length (11.14 cm, *Table 1*) limited its suitability as a cut flower. Previous studies reported that BA applications increased flower numbers in iris (Khalifa et al., 2011) and rose (Poornima et al., 2018) plants. Qureshi et al. (2015) found that 5, 10, 15, and 20 ppm BA applications significantly increased flower numbers in carnations compared to controls. In contrast with these postulations, our results indicate that BA treatment led to a decrease in the number of florets in studied hyacinths varieties. It may be postulated that the efficiency of BA in promotion of number of florets, may depend on the plant species and dosages. However, for cut flower production, the fewer florets per spike can be beneficial as increased floret numbers can lead to heavier spikes that bend in vases, a common issue in the cut flower industry.

For instance, gerbera flowers experience this problem due to their large capitulum, prompting ongoing research to mitigate stem bending (Gerabeygi et al., 2021; Liu et al., 2021; Mohammadi et al., 2024).

The average flowering duration of the 'Pink Pearl' variety was significantly longer than those of the 'Aiolos' and 'Blue Jacket' varieties (*Figure 2*). This is due to its twin spike formation, with the second bloom extending the flowering period. In contrast, the 'Aiolos' and 'Blue Jacket' varieties fell, statistically, in same group in flowering time. BA applications did not affect the flowering duration of varieties. Similarly, Tantan et al. (2020) reported that flowering duration of gladiolus was not influenced by BA applications.

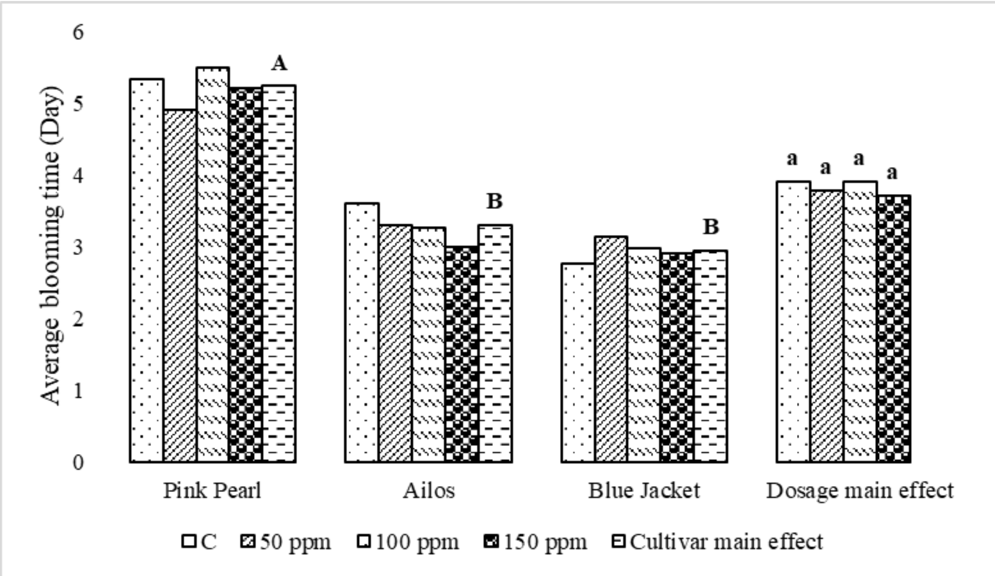

Figure 2. Average blooming duration of hyacinth cultivars treated with different dosages of BA

Different capital letters indicate a significant difference among cultivars (p<0.05).C: control

3.2. Postharvest studies

As stated in the Materials and Methods section, hyacinth plants were harvested along with their bulbs to ensure the flower stems remained long, and the bulb leaves at the base of the stem were removed. This allowed stems to prolong their longevity, enhance their quality as cut flowers. However, in terms of plant length, spike stalk length and leaf length, 'Aiolos' variety performed superior to the 'Blue Jacket' variety, emphasizing its suitability as cut flower. Stem length is a key factor for selecting flower species as cut flowers because cut flowers are graded and marketed by stem length, and is crucial for facilitating harvesting and extending vase life since re-cutting/trimming the lower ends of stems when necessary about 2 cm helps to prolong their vase life. Stem lengths vary by flower type and market; for instance, exported roses have a minimum length of 40 cm, while those for the domestic market require 25 cm. Distributors set a minimum length of 46 cm across all types, whereas growers suggest a range of 30-41 cm for marketable flowers (Yiğiter and Coşkun, 2024), and in the wholesale flower markets, hyacinths are sold in wraps of 25 stems and are sold in stem lengths of between 25 and 35cm tall (George et al., 2023).

Table 3 presents hyacinth flowers' water uptake rates, highlighting a significant interaction between variety and BA doses. Interestingly, however, cultivar responses to same BA dosages differed. While 100 ppm BA in 'Aiolos' variety resulted in the lowest water uptake, 'Blue Jacket' variety's water absorption was the highest in same BA dosage. Similarly, 150 ppm BA in 'Aiolos' variety resulted in highest water uptake, while 'Blue Jacket' variety's water absorption was the lowest in same BA dosage. However, 100 ppm BA for 'Aiolos' variety and 150 ppm BA for 'Blue Jacket' variety performed inferior to the control treatment. Boric acid delays the onset of ethylene production in carnation flowers, slowing down the aging of the flowers and thus increasing water uptake (Serrano et al., 2001). It has been reported that applying 200 ppm BA increases the water uptake of carnation flowers (Al-Attrakchii and Al-Mahdawe, 2015; Sarhan et al., 2023). Farooq et al. (2021) noted that the application of 150 µM BA postpones the aging of *Digitalis purpurea* L. cut flowers by increasing water uptake. Our results confirmed the earlier reports on the effect of different BA dosages on different species in terms of water uptake, and it seems that this effect translated into significant differences in hyacinth cultivars studied here.

Table 3. Spike stalk length, water uptake, vase life and chlorophyll SPAD content of hyacinth cultivars treated with different doses of BA.

	Treatments	***Hyacinth varieties***		***BA dosages main effect***
		Aiolos	***Blue Jacket***	
Spike Stalk length (cm)	Control	28.56	23.46	**26.01**
	50 ppm	28.79	24.33	**26.56**
	100 ppm	28.44	23.5	**25.97**
	150 ppm	27.42	23.91	**25.66**
	Cultivar main effect	**28.30 A**	**23.80 B**	
Significance[z]	*cultivar main effect***, BA dosage main effect[ns], cultivar x BA dosage[ns]*			
Water uptake (ml)	Control	28.00 **ab**	28.80 **ab**	**28.3**
	50 ppm	37.00 **a**	31.80 **ab**	**34.4**
	100 ppm	24.20 **b**	36.20 **a**	**30.2**
	150 ppm	37.40 **a**	26.00 **b**	**31.7**
	Cultivar main effect	**31.65**	**30.65**	
Significance[z]	*cultivar main effect***, BA dosage main effect[ns], cultivar x BA dosage[ns]*			
Vase life (days)	Control	11.00	9.40	**10.20**
	50 ppm	10.60	10.60	**10.60**
	100 ppm	11.00	10.60	**10.80**
	150 ppm	11.00	10.20	**10.60**
	Cultivar main effect	**10.90 A**	**10.20 B**	
Significance[z]	*cultivar main effect**, BA dosage main effect[ns], cultivar x BA dosage[ns]*			
Chlorophyl (SPAD) value	Control	60.36 **a**	58.62 **a**	**59.49**
	50 ppm	60.26 **a**	58.72 **a**	**59.49**
	100 ppm	56.54 **b**	60.96 **a**	**58.75**
	150 ppm	59.82 **a**	58.44 **a**	**59.13**
	Cultivar main effect	59.25	59.19	
Significance[z]	*cultivar main effect[ns], BA dosage main effect[ns], cultivar x BA dosage**			

[z]Two way ANOVA; ns: not significant; *, **, ***: significant at p<0.05, 0.01 and 0.001, respectively. Different capital case letters within the rows indicate significant differences among cultivars and different lower case letters within the columns indicate significant differences among the Cultivar x BA dosages interaction; the numbers are averages of all replicates.

The vase life of the 'Aiolos' variety (10.90 days) was significantly longer than that of the 'Blue Jacket' variety (10.20 days). The vase life of *Hyacinthus orientalis* as a cut flower is influenced by care and environmental conditions. On average, cut hyacinth flowers last 5-7 days in a vase, but with optimal care, they can last longer. Harvesting hyacinths with a small portion of the bulb (about 1 cm) can also extend their vase life (Răus et al., 2023). In the present study, the vase life of both hyacinth cultivars was higher than that reported by Raus et al. (2023). BA treatments are effective in increasing the vase life of different species. Reports demonstrated that BA treatments at different doses increased the vase life of carnation (Serrano et al., 2001; Ahmadnia et al., 2013; Krishnamoorthy et al., 2017), gladiolus (Jian-Bo et al., 2009) and rose flowers (Kshirsagar et al., 2021). However, in the present study, BA was not effective in extending the vase life of hyacinth cultivars. This may be due to the fact that the effect of BA on the promotion of the vase life is dependent on species and that hyacinth is less sensitive to BA application in the vase solution than other flower species.

The interaction between cultivars and BA dosages were statistically significant for chlorophyll (SPAD) content. The application of 100 ppm BA in vase solution significantly reduced the chlorophyll (SPAD) levels of the 'Aiolos' variety compared to other treatments, although differences between other dosages and control plots were non-significant. On the other hand, while there were not significant differences between BA treated and untreated plants in 'Blue Jacket' variety, 100 ppm BA resulted in the highest chlorophyll (SPAD) levels. Pre-harvest measurements yielded similar results. Chlorophyll pigment plays a crucial role in the photosynthesis process of plants by capturing sunlight and converting light energy into chemical energy. A higher amount of chlorophyll allows the plant to absorb more light and thus perform more photosynthesis, resulting in the production of more carbohydrates. This makes it an important factor in the growth and development of the plant (Pallavolu et al., 2023). In addition, a high chlorophyll content leads to a higher carbohydrate level in plants, which in turn increases the amount of flowering. Indeed, the total number of flowers blooming in the 'Blue Jacket' variety was found to be higher than that of the 'Aiolos' variety (*Figure 1*).

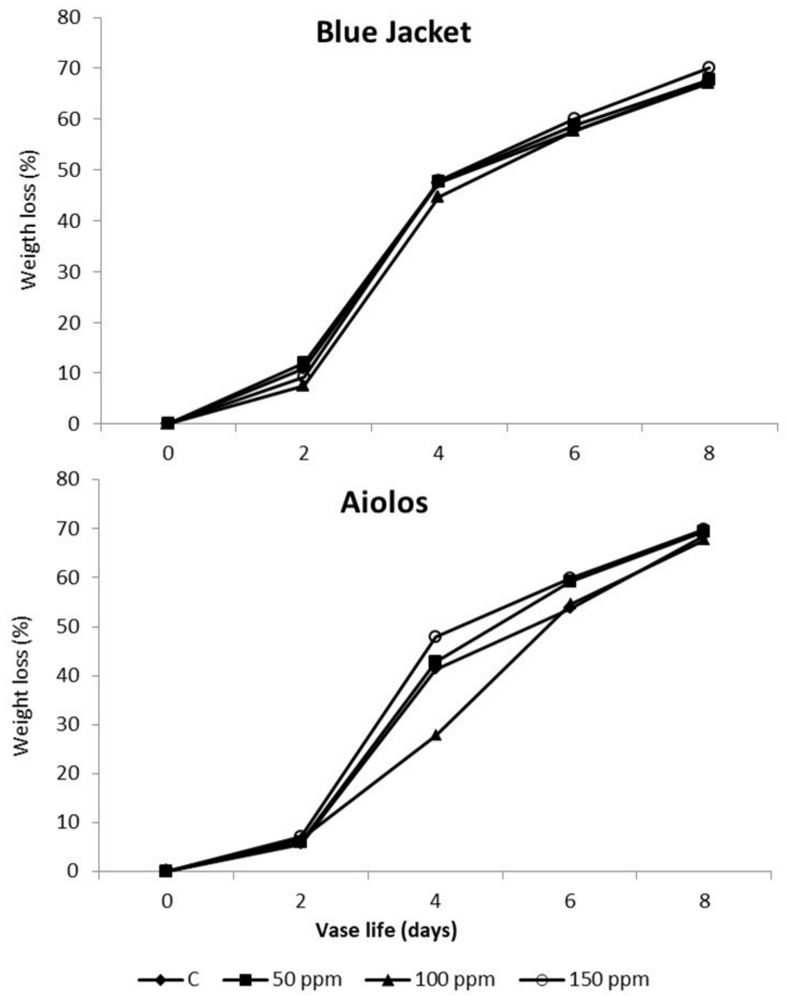

Figure 3. Weight loss of hyacinth cultivars treated with different dosages of BA

Weight losses increased in both varieties as vase life extended (*Figure 3*). Interaction between cultivar and dosages was significant for weight loss on the 4th day of the vase life, and the 100 ppm BA application significantly reduced weight loss, however, this dosage was more effective in reducing weight loss in the 'Aiolos' cultivar compared to the 'Blue Jacket' cultivar. On the 10th day of vase life, the interaction between cultivar and dose was not found to be significant, but the weight loss of the 'Aiolos' cultivar was lower than that of the 'Blue Jacket' cultivar.

4. Conclusions

The effect of Pre-harvest BA applications on vegetative characteristics of hyacinth varieties, such as total leaf count, leaf length, flower stem length, and plant height were not significant. However, cultivar main effect on these criteria varied significantly, with the highest total leaf count found in the 'Pink Pearl' cultivar, while the longest leaves, flower stems, and plant height were observed in the 'Aiolos' cultivar. The 150 ppm BA application significantly reduced the L value of the leaves, while significantly increased the h° and chlorophyll SPAD levels. L value of the 'Aiolos' cultivar was significantly higher than the other two varieties, while the h° value and the chlorophyll SPAD levels were significantly lower than those of other varieties.

All BA applications reduced the total number of blooming florets compared to control, the lowest number was found in 50 ppm BA treatment. Among the varieties, the total number of blooming spikes in ‘Aiolos’ was lower than that in ‘Pink Pearl’ and ‘Blue Jacket’. The average flowering time was not affected by BA applications, however, it was found that the flowering time of ‘Pink Pearl’ was longer than that of the other two varieties.

BA applications did not significantly affect flower stem length, vase life, water uptake, and chlorophyll SPAD levels after harvest. However, the effect of BA dosages x cultivar interaction on water uptake and chlorophyll SPAD levels were significant. 100 ppm BA application significantly increased water uptake in the ‘Blue Jacket’ cultivar, while reducing chlorophyll SPAD levels in the ‘Aiolos’ cultivar. After harvest, the flower stem length and vase life of the ‘Aiolos’ cultivar were longer than those of the ‘Blue Jacket’ cultivar. Interaction between cultivar and BA dosages was significant for weight loss on the 4th day of the vase life. The 100 ppm BA application significantly reduced weight loss, and the weight loss of the ‘Aiolos’ cultivar was lower than that of the ‘Blue Jacket’ cultivar.

In conclusion, both pre- and postharvest period, the ‘Aiolos’ cultivar had longer plant and flower stem lengths compared to the other varieties. The vase life of the ‘Aiolos’ cultivar was also longer than that of the ‘Blue Jacket’ cultivar. But the total number of blooming spikes in the ‘Aiolos’ cultivar was lower than other varieties. According to BA dosages main effect, 50 ppm BA reduced the number of blooming spikes but increased water uptake. On the other hand, 100 ppm BA was effective in reducing weight loss. Therefore, it has been observed that the ‘Aiolos’ cultivar has potential as a cut flower. Among the BA applications, the 100 ppm BA was found to be particularly effective in reducing weight losses, but its promoting effect on water uptake was dependent on variety.

Acknowledgment

This study was not funded by any institution.

Ethical Statement

There is no need to obtain permission from the ethics committee for this study.

Conflicts of Interest

We declare that there is no conflict of interest between us as the article authors.

Authorship Contribution Statement

Concept: Kasım, R.; Design: Kasım, R., Kasım M.U.; Data Collection or Processing: Olgaç, Y.; Statistical Analyses: Kasım, R., Kasım, M.U.; Literature Search: Olgaç, Y.; Writing, Review and Editing: Olgaç, Y., Kasım, R.

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