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Changes in Chlorophyll Content, External Quality Characters, Dry Weight and Vase Life of Strelitzia (*Strelitzia* spp.) Leaves Affected by Different Preservative Solutions

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Abstract
One of the most important cut foliage plants is strelitzia (*Strelitzia* spp.) which has several usages. This research program was focused on increasing the vase life of strelitzia cut foliage in the normal storage condition. The experiment was arranged as completely randomized design with three replications. Treatments included combinations of four different levels of gibberellic acid (GA3) and benzyl adenine (BA) each with 0, 50, 100 and 150 ppm concentrations and an extra control. In all treatments except the extra control, silver nitrate (AgNo3) with fixed concentration of 40 ppm and sucrose with fixed concentration of 3% was used. Average temperature, light intensity and relative humidity during the study were 20°C, 865 lux (12/12 day- night) and 70%, respectively. Measured traits were: vase life, chlorophyll content, dry weight and external quality of leaves. Results showed that GA3 and BA had positive effects on increasing the vase life of strelitzia cut foliage and improving the chlorophyll content and external quality characters. Although, the combination of 150 ppm GA3 and 100 ppm BA and also 100 ppm GA3 and 50 ppm BA prolonged the vase life of strelitzia leaves up to 112 days in the storage condition as compared to 59 days for the control treatment, but considering other traits such as chlorophyll content, dry weight and external quality characters plus economic factor, the use of the gibberellic acid alone (at 50 ppm concentration) or in combination with some concentration of benzyl adenine (i.e. 50 ppm) together with silver nitrate and sucrose is recommended to increase the vase life and other quality characters of strelitzia cut foliage.

Keywords: Benzyl adenine (BA); Cut foliage; Gibberellic acid (GA3); Strelitzia; Vase life

Introduction

Many kinds of ornamental plans are used as cut foliage. One of the most important cut foliage is strelitzia which is used for different flower arrangements in many ceremonies. One major problem in the marketing management of most cut flowers and leaves is the postharvest senescence and consequently the reduction of their vase life which is caused by two factors. The growing condition of the mother plants and unfavorable environmental conditions may reduce vase life of the cut foliage significantly (Bani Jamali and Edrisi 2009).

Da Silva (2003) studied the effect of different chemicals on increasing the vase life of cut flowers. The cut flowers kept their freshness longer when settled in preservative solutions. To increase the vase life of cut foliage, various treatments can be used, among which sucrose is one of the most common substance. Carbohydrates deterioration is a primary sign for the senescence of harvested plant tissues, and the availability of carbohydrates would strengthen the vase life of the cut organs (Ebrahimzade *et al*. 2003). The application of 0.25% sucrose to vase solutions significantly enhanced vase life in *Eucalyptus crenulata* and *Eucalyptus gunnii* (Jones *et al*. 1993). Sander Sonia flowers, which fed with sucrose, showed more firmness as compared with the control flowers (kept in water only) and also contained high levels of galactose (O'Donoghue *et al*. 2002). Nair *et al*. (2003) showed that AgNo3 (20ppm) with sucrose (4%) caused delay of stem curvature (10 days) and petals falling (7 days) in Gerberas' cut flowers as compared to the control flowers. AgNo3 (20 ppm) and sucrose (6%) delayed petal paleness for about 16.7 days while it was 8 days for the control treatment.

GA3 and BA have been recommended as the most useful and popular compounds to increase the vase life of young cut flowers and foliage and delaying their senescence. Gibberellic acid prevents chlorophyll degradation and thereby delays leaf senescence of leaves (Khoshkhui *et al*. 2000). Several authors showed the positive effect of BA on increasing the vase life of the cut leaves (Paul and Chantrachit 2000; Pinto *et al*. 2007; Danayi *et al*. 2009). Kafee *et al*. (1998) also proved the effect of BA on delaying the senescence of cut foliage due to its impact on the construction of nuclear acids and proteins. Cytokinins also increase the mobilization or movement of different substances toward the plant organs and thereby increase the life of cut foliage. Benzyl adenine increased the leaf chlorophyll content by reducing respiration rate and protein synthesis and maintaining the chloroplast structure. Cytokinins and gibberellic acid also prolong the vase life of plant leaves due to the maintenance of viable cells. This has been reported by Pinto *et al*. (2007) on the cut foliage of *Calathea louisae*. Their results showed that a combination of GA3 and BA (250 and 500 mg L^{-1}, respectively) significantly extended the longevity of cut foliage. This combination also maintained leaves' green coloration and brightness for a longer time as compared with the control. Paul and Chantrachit (2000) expressed that BA (100 ppm in the plunge and spray method) increased the vase life of two varieties of Anthurium, *Heliconi apsittacorum* var. "Andromeda", *H. chartacea* var. "SexyPink" and *Alpinia perpurata*, but it wasn't effective on the vase life of *Zingiber spectabilis*, *Strelitzia* and *Dicranopteris linearis*. Different *Anthurium* varieties showed different vase life from 20% decrease to more than twice increase, depending on the BA treatment. Pinto *et al*. (2007) reported that vase life of cut foliage of *Ctenathe setosa* significantly extended when they were treated with GA3 or BA (6 days longer as compared to the control). Moreover in that study, leaves' color and brightness significantly increased as well compared to the control treatment.

The present research program was conducted to study the effects of different preservative solutions on the vase life, chlorophyll content, external quality characters and dry weight of strelitzia cut foliage.

Materials and Methods

The experiment was carried out in the Department of the Horticulture, Gorgan University of Agricultural Sciences and Natural Resources, Gorgan, Iran. Cut foliage of strelitzia (*Strelitzia Spp.*) was prepared from a greenhouse in the vicinity of Gorgan. After transferring the cut foliage to the laboratory, the leaves were put into pots which were covered by the plastic film to prevent direct evaporation of the vase solution. Light intensity, temperature and relative humidity were kept close to the room conditions and were recorded every day. Therefore, average temperature, light intensity and relative humidity during the study were 20°C, 865 lux (12/12 day-night) and 70%, respectively. Chlorophyll content, dry weight, external quality characters and vase life of cut foliage were measured during the experiment.

Chemical solutions were prepared before the production of cut foliage and then put in the pots in appropriate concentrations. Each pot contained 0.5 liter of solution. Sixteen different treatment combinations of GA and BA (from Merck and Sigma companies, respectively), each in four concentrations (0, 50, 100, 150 ppm) were used in the experiment. These treatments together with an extra control (only distilled water) were arranged in a completely randomized design with three replications. Silver nitrate (AgNo3) with fixed concentration of 40 ppm (from the Merck Company) and sucrose with fixed concentration of 3% were used in all treatments except the extra control.

Leaf chlorophyll was measured by a chlorophyll meter (model CCM 200 from ADC Company). The chlorophyll content was measured on all leaves of each pot and their average value was used for the data analysis. Chlorophyll content was measured 15 times from 11 November till 22 February during the study period.

Five characters including leaflet burning, getting tube like form, paleness, bent angle of main vein and dryness and fragility of leaves, were considered for measurement of the external quality of leaves. Each character was measured on each leaf separately. The measurement method was based on the observable external changes scored from 1 to 10 (Amerin *et al.* 1965). Each cut leaf was given the score of 10, when it had no external negative change. But when some external changes were seen during the storage period, lower scores were then given accordingly. The final score was obtained from the average of five quality characters already mentioned. When cut foliage was given a score of about 5 or less, it was considered as the ruined foliage or leaf. The scores were described as follows: 10= Excellent, 9= Very good, 8= Good, 7= Acceptable, 6= Average, 5= A little bad, 4= Relatively bad, 3= Bad, 2= Not acceptable, 1= Very bad.

To measure dry weight of cut foliage, a leaf from each pot was chosen and all were put in the oven at 70^{o}C. Then dry weight of the cut foliage in each experimental unit was measured after eight hours. Furthermore, during the storage time, the vase life for each treatment was recorded as an important character in this study.

Data were analyzed using SPSS software (Version 17). After analysis of variance, the means were compared by the LSD test at the 0.05 probability level.

Results

Analysis of variance showed the significant effects of gibberellic acid, benzyl adenine and their interaction on leaf chlorophyll content and external quality characters of streilitzia cut foliage (Table 1). The existence of interaction indicated that the differences among gibberellic acid concentrations were not similar at different levels of benzyl adenine for these characters (Figure 1). On the other hand, only gibberellic acid had a significant effect on the dry weight of streilitzia cut foliage and this character was not affected by benzyl adenine and its interaction with the gibberellic acid (Table 1).

Due to the short life of streilitzia cut foliage in flower stores and other places with no environmental control, it can be said that controlled conditions (light, temperature and humidity) are effective on increasing the cut foliage's vase life, because in our experiment the vase life of strelitzia leaves was prolonged up to 59 days in the storage condition as compared with 12 days in the uncontrolled condition. Sucrose, silver nitrate, gibberellin and benzyl adenine are suitable treatments to preserve streilitzia cut foliage. The best treatment combination was 150 ppm of GA3 with 100 ppm of BA, which prolonged the vase life of strelitzia leaves up to 112 days in the storage condition as compared to 59 days for the control treatment.

The lowest reduction in chlorophyll content was observed in the vase containing 50 and 150 ppm of GA3 with 0, 50 and 100 ppm of BA. In contrast, the lowest amounts of chlorophyll content were seen in the control treatments with 0 ppm GA3 and BA (Figure1). Longevity of green color in leaves is a sign of increasing the vase life of cut leaves treated with gibberellic acid and benzyl adenine.

As the time past in the storage condition, external quality of cut foliage was changed which included five measured indices of leaflet burning, getting tube form, paleness, bent angle of mid-rib and dryness and fragility of leaves. Among them first change which appeared on the strelitzia preserved cut leaves was getting tube form by curving leaflets toward midrib. Therefore, leaves were more sensitive in terms of getting tube form. Next appeared symptom on cut leaves was bent angle of mid-rib. Cut leaves started to bend soon after getting tube form. Bending was appeared in the middle of the foliage to the right or left direction but there was no relation between bending and treatments. By passing the time, paleness increased and leaves lost their green color. Next change was leaflet burning and the last one was dryness and fragility which happened less than other measured characters. As Figure 2 shows, all treatment combinations were useful to improve the external quality character of cut leaves in comparison to the control (only water). The best result was obtained from the concentration of 100 ppm GA3 plus 50 ppm BA and also the combination of 150 ppm GA3 plus 100 ppm BA. However, these treatment

Table1. A portion of analysis of variance for dry weight, chlorophyll content and external quality characters of strelitzia's cut foliage affected by gibberellic acid and cytokinin (benzyl adenine)

Source of variation	df	Dry weight	Chlorophyll	External quality character
G	3	0.028[+]	0.020	0.010
C	3	> 0.05	0.000	0.000
G × C	9	> 0.05	0.010	0.000

[+]P-value; G= Gibberellic acid, C= Cytokinin (benzyl adenine)

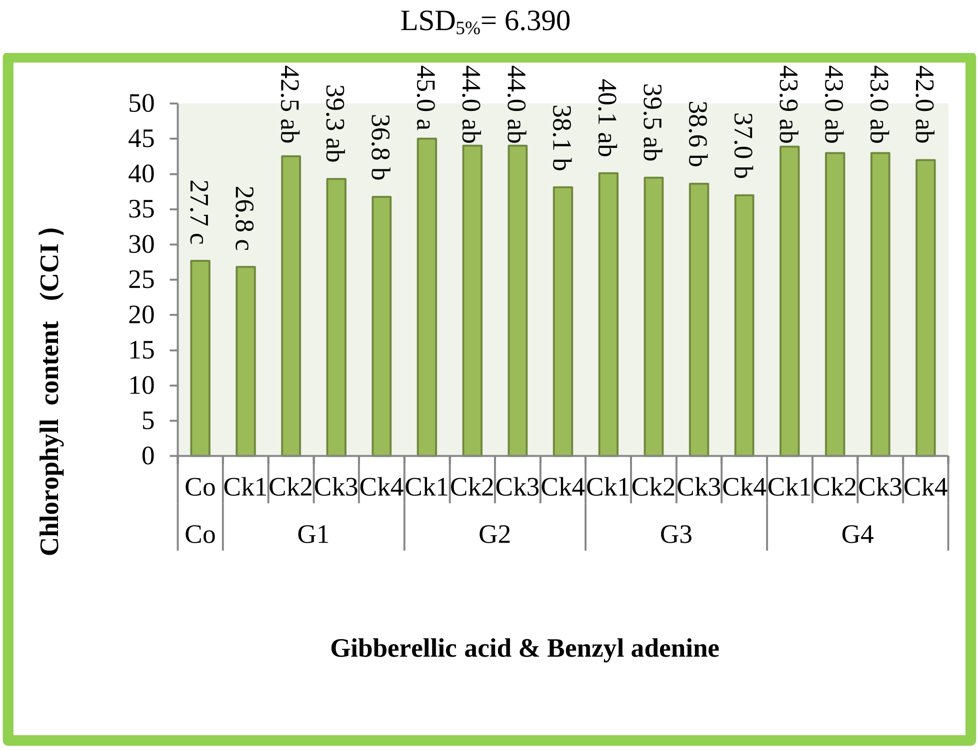

Figure 1. Combined effect of gibberellic acid and benzyl adenine on chlorophyll content of strelitzia's cut foliage. Ck= Cytokinin (benzyl adenine), G= Gibberellic acid, C0= Control, Ck1 & G1= 0 ppm, CK2 & G2= 50 ppm, CK3 & G3=100 ppm, CK4 & G4= 150 ppm

combinations were not significantly different from those of 50 ppm GA3 plus 0, 50 and 100 ppm BA. Similar to the chlorophyll content, the lowest value for the external quality character was seen in the control treatment with 0 ppm GA3 and BA and leaf demolition was faster than other treatments which consequently resulted in the shorter vase life. This means that the imposed treatments involving GA3 and BA improved the external quality characters of cut foliage in strelitzia.

Figure 3 shows the effect of GA3 on the dry weight of strelitzia leaves. The concentration of 50 ppm GA3 showed highest dry weight as compared to other GA3 concentrations. It seems that treating the cut foliage of strelitzia with GA3 improves the dry weight of strelitzia specially, at the 50 ppm concentration.

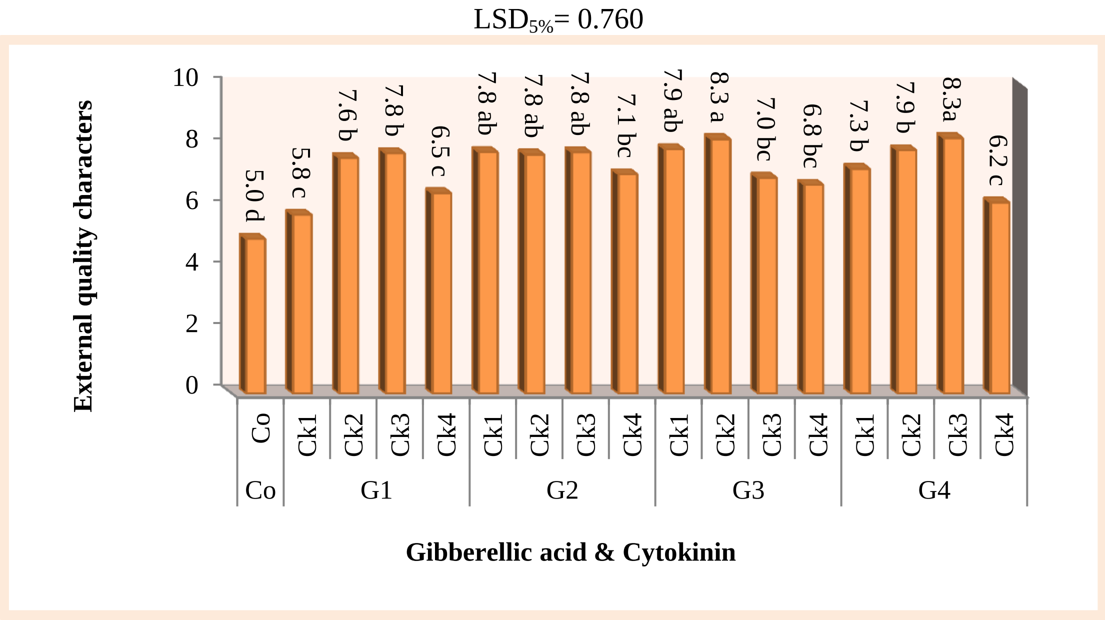

Figure 2. Combined effect of cytokinin (benzyl adenine) and gibberellic acid on the external quality characters of strelitzia's cut foliage.
CK= Cytokinin, G= Gibberellic acid, C0= Control, Ck1 & G1= 0 ppm, Ck2 & G2= 50 ppm, Ck3 & G3=100 ppm, Ck4 & G4=150 ppm

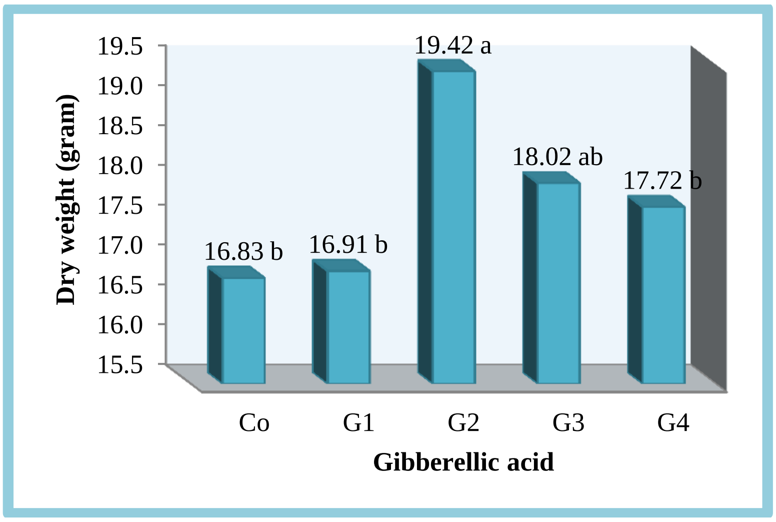

Figure 3. The effect of gibberellic acid on dry weight of strelitzia's cut foliage.
G= Gibberellic acid, C0= Control, G1= 0 ppm, G2= 50 ppm, G3=100 ppm, G4=150 ppm

Discussion

Our results show that the environmental condition similar to the current study with average humidity of 70%, temperature of 20°C and light intensity of 865 Lux is relatively a proper environment for preserving strelitzia cut leaves in the storage condition. It is important to mention that natural postharvest life of cut leaves of strelitzia in flower shops with no control of atmosphere (light, temperature and humidity) is relatively short. We showed that the vase life of the controlled condition in the current study was about 59 days as compared with 12 days in the open environment condition with no control of atmospheric parameters. Although, the application of AgNo3 and sucrose resulted in the significant improvement of the external quality characters and non-significant increase of dry weight and consequently the vase life of cut foliage in trelitzia, but the improvement was not profound when compared with the treatment combinations of GA and BA. Ketsa *et al*. (1995) and Hadas *et al*. (2010) also reported similar results.

Based on results obtained in this experiment, GA3 and BA were suitable to preserve the cut leaves of strelitzia. The best treatments for longer durability of the strelitzia cut leaves were the combinations of 150 ppm GA3 plus 100 ppm BA and also 100 ppm GA3 plus 50 ppm BA, together with 40 ppm AgNo3 and 3% sucrose. Therefore, we can suggest that gibberellic acid and benzyl adenine extended the longevity of the leaves because of preventing chlorophyll loss, increasing photosynthesis and so delaying leaf senescence. Considering GA3 alone, although all concentrations were effective but the concentration of 50 ppm GA was better than others when all measured characters were involved. This concentration preserved the chlorophyll content of the cut leaves, strengthened their delicateness and succulence, improved the external quality characters of the cut foliage and increased their dry weight. Other researchers also showed that GA3 had significant positive effect on vase life and leaf quality of strelitzia (Skutnik *et al*. 2001; Mutui *et al*. 2006; Pinto *et al*. 2007; Danayi *et al*. 2009). Gibberellic acid also prevents chlorophyll degradation and thereby delays leaf senescence (Khoshkhooy *et al.* 2000). Therefore, the use of GA3 (specially, at 50 ppm concentration) is recommended for preserving the strelitzia cut leaves (Kjonboon and Kanlayanarat 2005).

Results of this experiment shows that some concentrations of BA, either in combination with GA3 or alone (at 50 and 100 ppm) could increase the vase life of strelitzia cut leaves because it postponed leaf demolition, reduced chlorophyll loss and improved external quality characters of this plant. Paul and Chantrachit (2000), Pinto *et al*. (2007) and Danayi *et al*. (2009) also reported that BA had positive effect and increased the vase life of the cut leaves. Furthermore, Kafee *et al*. (1998) stated that BA delayed the senescence of cut foliage and its effect could be related to the impact of the synthesis of nucleic acids and proteins. Cytokinin also increases mobilization of nutrients toward plant organs and increases cut foliage life.

In conclusion, although the treatment combinations of 150 ppm GA3 plus 100 ppm BA and also 100 ppm GA3 plus 50 ppm BA prolonged strelitzia vase life up to 112 days, however, when other traits such as chlorophyll content, dry weight and external quality characters plus economic considerations were involved, the use of the gibberellic acid alone (at 50 ppm concentration) or in combination with some concentration of benzyl adenine (i.e. 50 ppm) together with silver nitrate and sucrose is recommended to increase the vase life and other quality characters of strelitzia cut foliage.

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