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Influence of Growth Regulators on the Growth and Flowering Characteristics of Goldenrod (*Solidago x Hybrida*)

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Abstract

Goldenrod is a popular filler for flower arrangements and bouquets. This study was conducted to determine the effects of foliar treatments of gibberellic acid (GA_3) and paclobutrazol (PBZ) on the growth and flowering characteristics of goldenrod (*Solidago x hybrida* cv. 'Tara') grown under open field conditions. Beginning from 30 days after planting, GA_3 at a concentration of 250 mg L^{-1} was sprayed on plants 0 times (control), once and twice at one-week intervals, and again 30 days after planting, PBZ at concentrations of 125, 250 and 500 mg L^{-1} was sprayed on plants once. The stem length was 68.51 cm in the control, while it was 78.61 cm and 83.33 cm in the plants treated once and twice with GA_3, respectively and 60.17 cm, 55.38 cm and 50.71 cm in the plants treated with 125, 250 and 500 mg L^{-1} of PBZ, respectively. The number of secondary inflorescences per stem was 29.70 and 31.43 in the plants treated once and twice with GA_3, respectively and 21.96 in the control, whereas it ranged from 20.07 to 20.67 in the PBZ treatments. The number of stems per plant was 0.94 in the control, 1.45 and 1.62 in the plants treated once and twice with GA_3, respectively and ranged from 0.83 to 0.91 in the PBZ treatments. With respect to almost all characteristics, the best results were recorded in plants treated once and twice with GA_3.

Keywords: Goldenrod, Gibberellic Acid, Paclobutrazol, Stem Length, Secondary Inflorescences

1. Introduction

Goldenrods are herbaceous perennial plants from *Asteraceae* family (Mabberly, 1997). These plants are usually wild, but are also grown commercially in greenhouse, tunnels, and even in open fields under net houses (Anonymous, 1998). About 100 species of the genus Solidago are mostly native to

North America (Athavle et al. 2006). Goldenrod blooms in the late summer or fall in nature (Gross and Werner, 1983), and its flowers are generally yellow (McGrew, 1997). It is a popular filler flower for floral arrangements and bouquets (Anonymous, 1998). Goldenrod is also used as a dried flower and an outdoor ornamental plant (McGrew, 1998). It is a facultative long-short day plant, and long days are required for bolting and short days are required for flowering induction (Anonymous, 1998).

Plant growth regulators are generally used in floriculture industry for height control, lateral branching and flowering. Gibberellins (GAs) regulate diverse activities in plants and play important roles in several processes including seed germination, shoot elongation, cell division and cell elongation (Rademacher, 1993; Hooley, 1994; Kende and Zeevaart, 1997). Gibberellic acid can stimulate growth by increasing cell elongation in some plant species and by increasing both cell elongation and cell division in others (Metraux, 1987; Jupe et al. 1988). Gibberellic acid treatments were reported to promote early flowering in different floriculture crops and increase yield and quality (Shlomo et al. 1985; Jana and Kabir, 1987; Eraki et al. 1993; Davies et al. 1996; Karagüzel, 1996, 2004; El-Naggar et al. 2009). Lee et al. (1999) reported that GA_3 increased stem length and number of flowers per plant in Lilium.

Growth retardants inhibit gibberellin biosynthesis and reduce cell division and cell elongation (Halevy, 1986; Rademacher, 1993; Boldt, 2008). Therefore, they are commonly used in floriculture industry for height control (Bailey and Whipker, 1998; Pasian, 1999; Hayashi et al. 2001; Karlovic et al. 2004). Growth retardants at the same time increase the number of lateral shoots, resulting in a larger number of inflorescences (Whealy et al. 1988; Keever and Foster, 1989). Most plant growth retardants, such as paclobutrazol, daminozide and chlormequat chloride, are successfully applied to control height, branching and flowering in many plant species (Larson, 1985; Bailey and Whipker, 1998; Rademacher, 2000; Hayashi et al. 2001; Karlovic et al. 2004).

Aesthetic display, flower number and size and vase life are the primary characteristics sought in filler flowers used for floral arrangements and bouquets such as goldenrod. In the Dutch auctions, goldenrods are graded by stem length, stem weight and ripeness (Anonymous, 2009). Although goldenrod has been known since the past, its use as a filler flower in ornamental plants sector has gained importance particularly recently. The studies conducted on goldenrod species have concentrated more on the medicinal properties of goldenrod species used as wild and medicinal plants (Kalemba, 1992; Güntner et al. 1999; Apati et al. 2003; Jiang et al. 2006). Many species of goldenrod are used as medicinal plants. Very few papers were published on cultivated goldenrod and the species used as filler flowers in the floriculture industry. In this study, it was aimed to determine the effects of growth regulators gibberellic acid (GA_3) and paclobutrazol on the growth and flowering characteristics of cultivated goldenrod.

2. Materials and Methods

The study was conducted under open field conditions at the Agricultural Research and Application Center of Agricultural Faculty at Suleyman Demirel University (latitude 37^o 83' N, longitude 30^o 53' E, altitude 1,020 m) between May and September 2006 in Isparta, Turkey. *Solidago x hybrida* cv. 'Tara', commonly grown in Turkey and used as a filler flower in the ornamental plants sector, was used as a plant material in the experiment. Rooted cuttings of goldenrod were planted on 15 May 2006 in plots (4 m long and 1.0 m wide) with a plant density of 20 plants m^{-2} (with four rows). Beginning from 30 days after planting, GA_3 at a concentration of 250 mg L^{-1} was sprayed on the plants once and twice at one-week intervals and paclobutrazol at concentrations of 125, 250 and 500 mg L^{-1} was sprayed on the plants once. However, only water was sprayed on the control (0) plants. The experiment was laid out in randomized plots design with 3 replications, and each replication contained 40 plants. Water and nutrients were supplied through a drip irrigation system. Plants were fertilized at every irrigation application with 120 ppm N, 30 ppm P_2O_5 and 140 ppm K_2O during the experiment (Anonymous, 1998). Days to flower, stem length, stem diameter, stem fresh weight, number of secondary

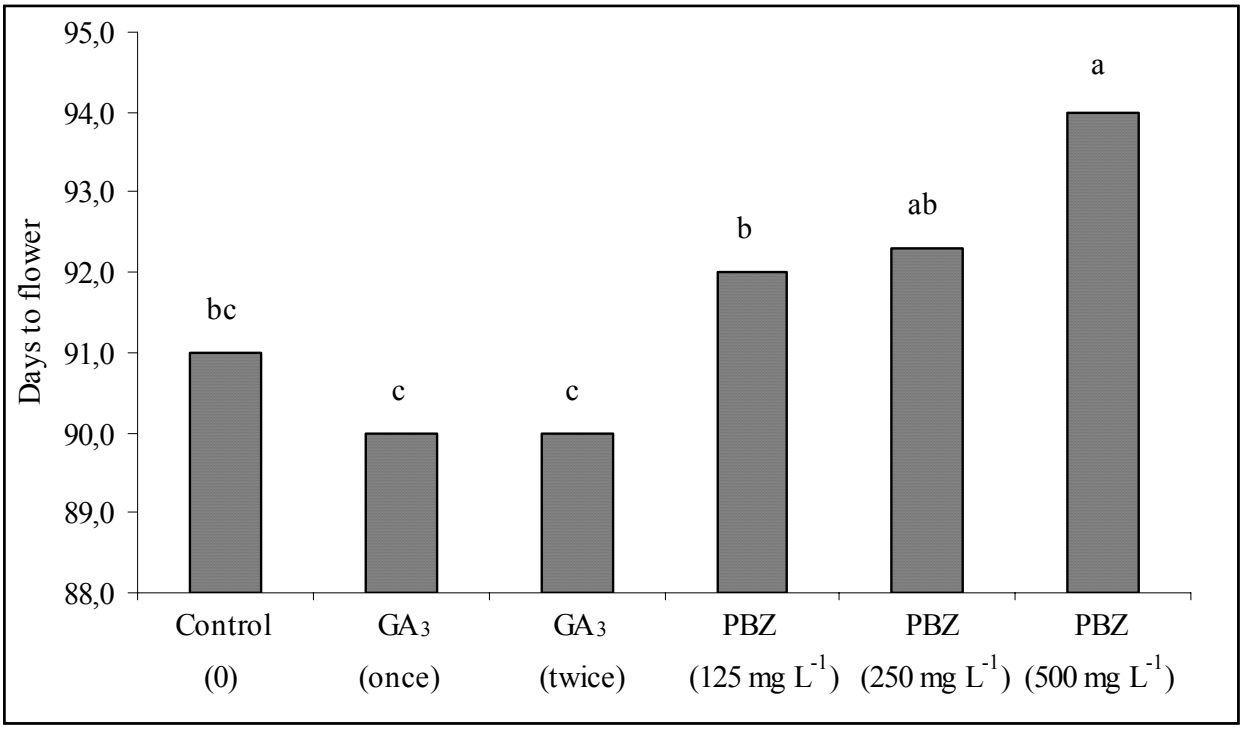
inflorescences, dry matter content and number of stems per plant were recorded in the study. Data were subjected to analysis of variance (ANOVA), and the mean values were compared using Duncan's multiple range test at P=0.05 level.

3. Results

3.1. Days to Flower

Plant growth regulators significantly ($p<0.01$) affected the days to flower. The plants treated once and twice with GA_3 flowered in 90 days, while the plants untreated with any plant regulators (control) flowered in 91 days. The plants treated with 125, 250 and 500 mg L^{-1} of paclobutrazol flowered in 92, 92.33 and 94 days, respectively (Figure 1).

Figure 1: Effect of GA_3 and PBZ on days to flower (GA_3; Gibberellic acid, PBZ; paclobutrazol)



3.2. Stem Length

The applications of plant growth regulators significantly ($p<0.01$) affected the stem length. The longest stems were obtained from once and twice applications of GA_3 (83.33 cm and 78.61 cm, respectively), followed by the control (68.51 cm). The stem length decreased with increasing concentration of paclobutrazol. The stem lengths under 125, 250 and 500 mg L^{-1} of paclobutrazol treatments were 60.17, 55.38 and 50.71 cm, respectively (Figure 2).

3.3. Stem Diameter

The GA_3 treatments increased the stem diameter. The highest stem diameters were measured in the plants treated once and twice with GA_3 (7.40 mm and 7.32 mm, respectively). However, control (6.76 mm), 500 mg L^{-1} (6.88 mm) of paclobutrazol treatment and once and twice applications of GA_3 were included in the same group in terms of stem diameter. Thinner stem diameters were recorded in 125 mg L^{-1} (6.46 mm) and 250 mg L^{-1} (6.54 mm) of paclobutrazol treatments as compared to the GA_3 treatments (Figure 3).

3.4. Stem Fresh Weight

Stem fresh weight was significantly ($p<0.01$) affected by plant growth regulators. The highest stem fresh weight was recorded in the plants treated twice with GA_3 (41.29 g), followed by the plants treated once with GA_3 (33.14 g) and the control (28.22 g). Stem fresh weights close to those of the control plants were determined in 125 mg L^{-1} (23.41 g) of paclobutrazol treatment, whereas the stem fresh weights decreased in 250 mg L^{-1} (20.1 g) and 500 mg L^{-1} (20.44 g) of paclobutrazol treatments as compared to other treatments (Figure 4).

Figure 2: Effect of GA_3 and PBZ on stem length (GA_3; Gibberellic acid, PBZ; paclobutrazol, Bars denote standart deviation)

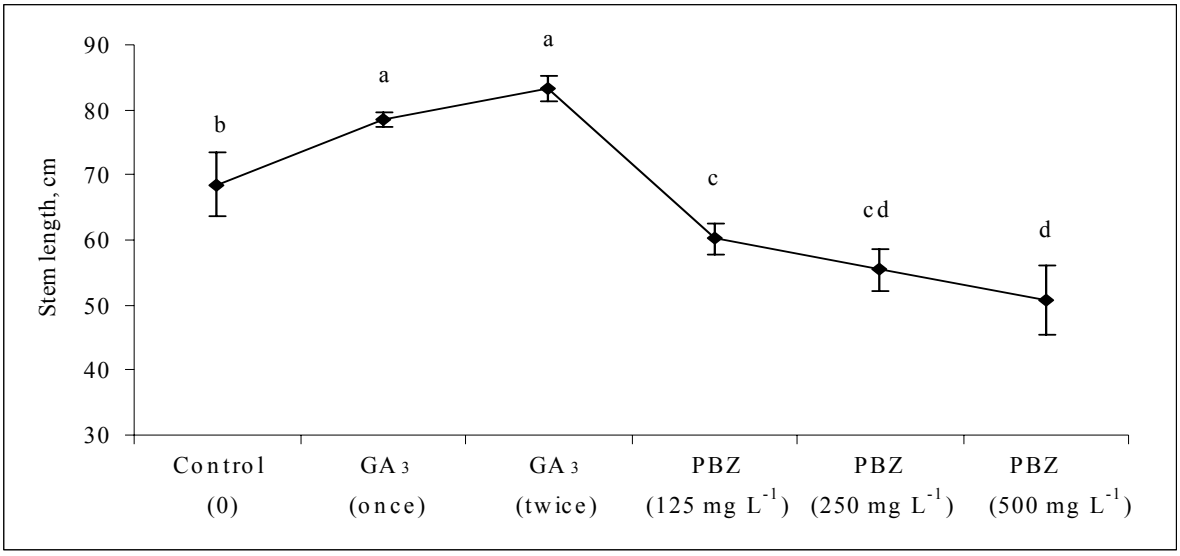


Figure 3: Effect of GA_3 and PBZ on stem diameter (GA_3; Gibberellic acid, PBZ; paclobutrazol, Bars denote standart deviation)

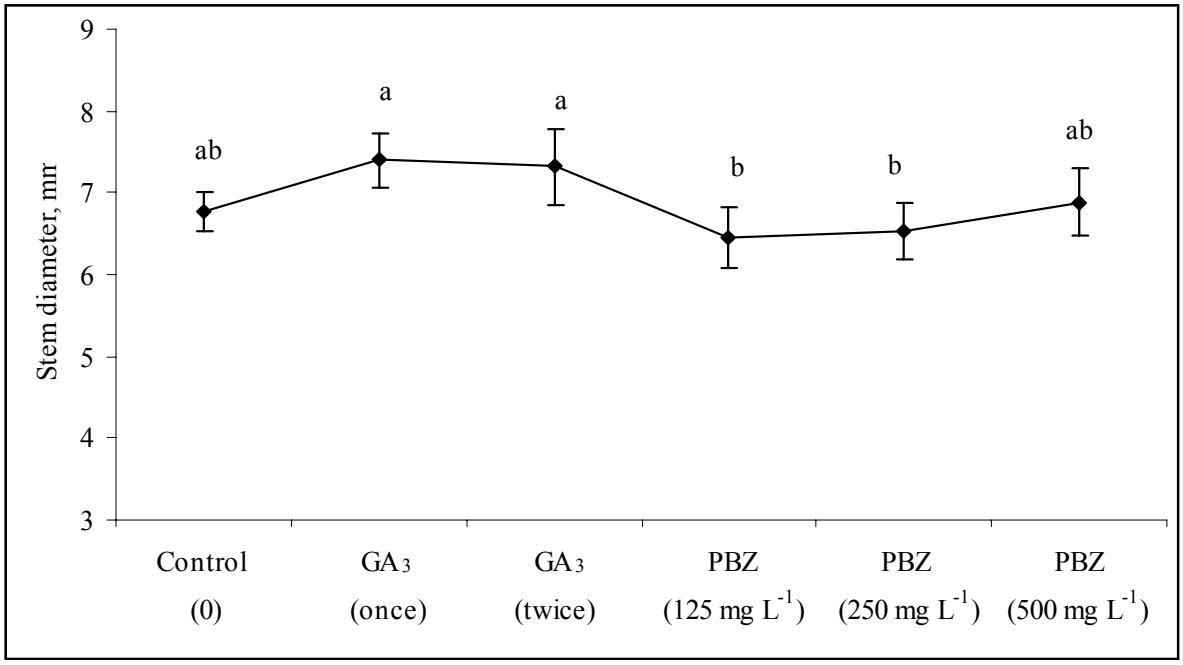
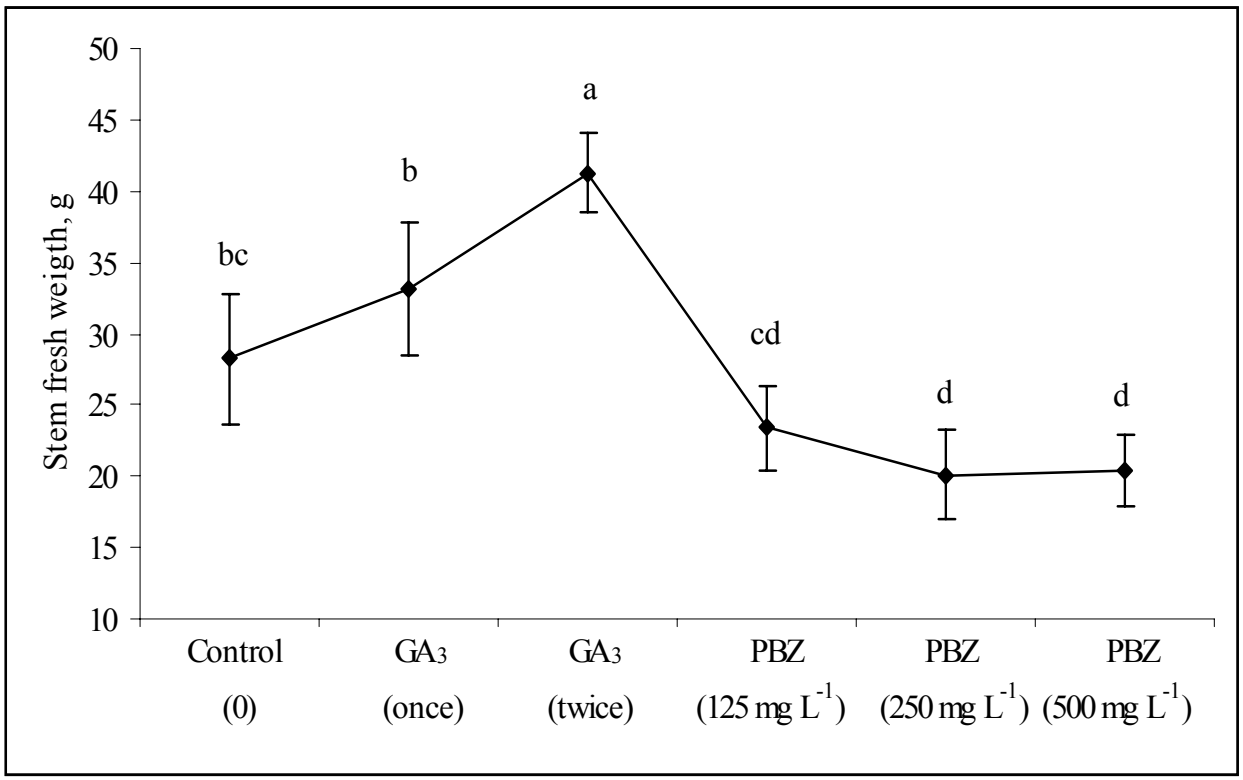


Figure 4: Effect of GA_3 and PBZ on stem fresh weigth (GA_3; Gibberellic acid, PBZ; paclobutrazol, Bars denote standart deviation)



3.5. Secondary Inflorescences

With respect to the number of secondary inflorescences, the treatments were included in two different groups. The first group consisted of the twice and once applications of GA_3, from which the highest numbers of secondary inflorescences were obtained (31.43 and 29.70, respectively), while the second group consisted of the control and paclobutrazol treatments. The numbers of secondary inflorescences were recorded as 21.96, 20.67, 20.07 and 20.10 in the control and in 125, 250 and 500 mg L^{-1} of paclobutrazol treatments, respectively (Figure 5).

3.6. Dry Matter Content

The effect of plant growth regulators on dry matter content was insignificant. The dry matter content was 26.62%, 27.76% and 27.58% in control and in once and twice applications of GA_3, respectively, whereas it was 27.53%, 26.99% and 26.05% in 125, 250 and 500 mg L^{-1} of paclobutrazol treatments, respectively.

3.7. Number of Stems Per Plant

The numbers of stems per plant in the plants treated with GA_3 were quite higher than those of the control and paclobutrazol treatments. The highest numbers of stems per plant were recorded in the plants treated once and twice with GA_3 (1.62 and 1.45, respectively); however, the difference between both treatments was insignificant. The difference in the number of stems per plant between control and paclobutrazol treatments was insignificant, and the numbers of stems per plant among these treatments ranged from 0.83 to 0.94 (Figure 6).

Figure 5: Effect of GA_3 and PBZ on stem fresh weigth (GA_3; Gibberellic acid, PBZ; paclobutrazol, Bars denote standart deviation)

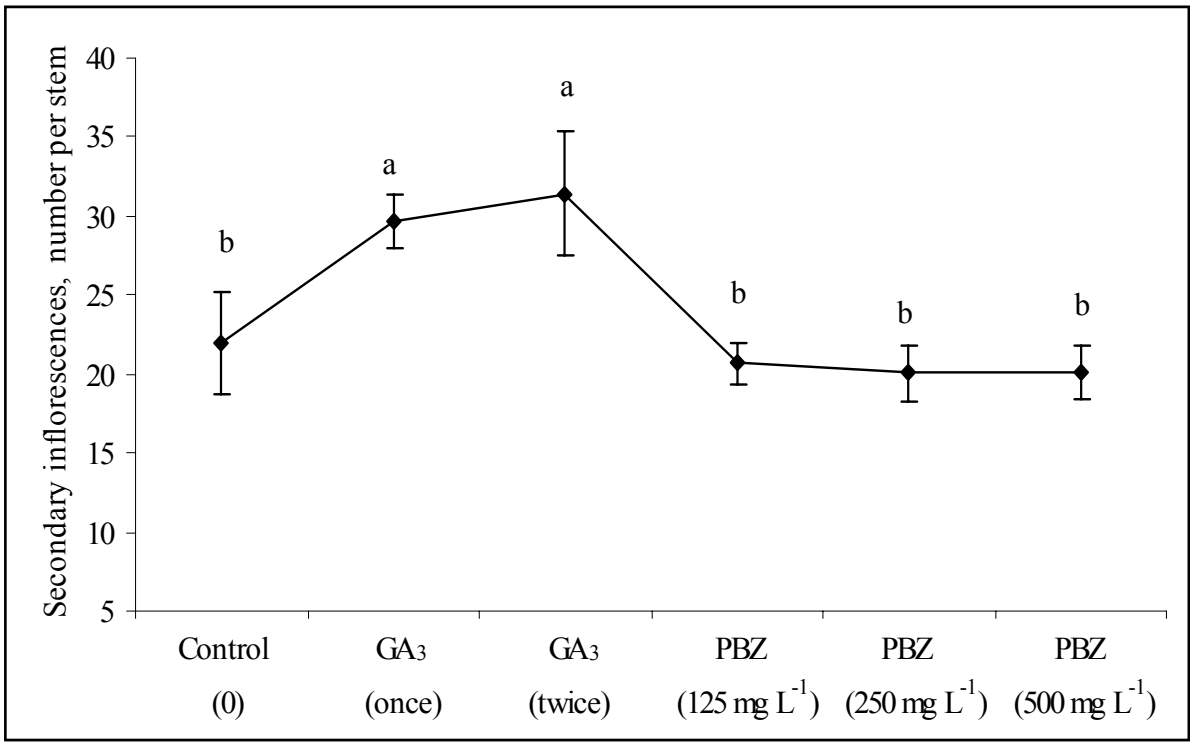
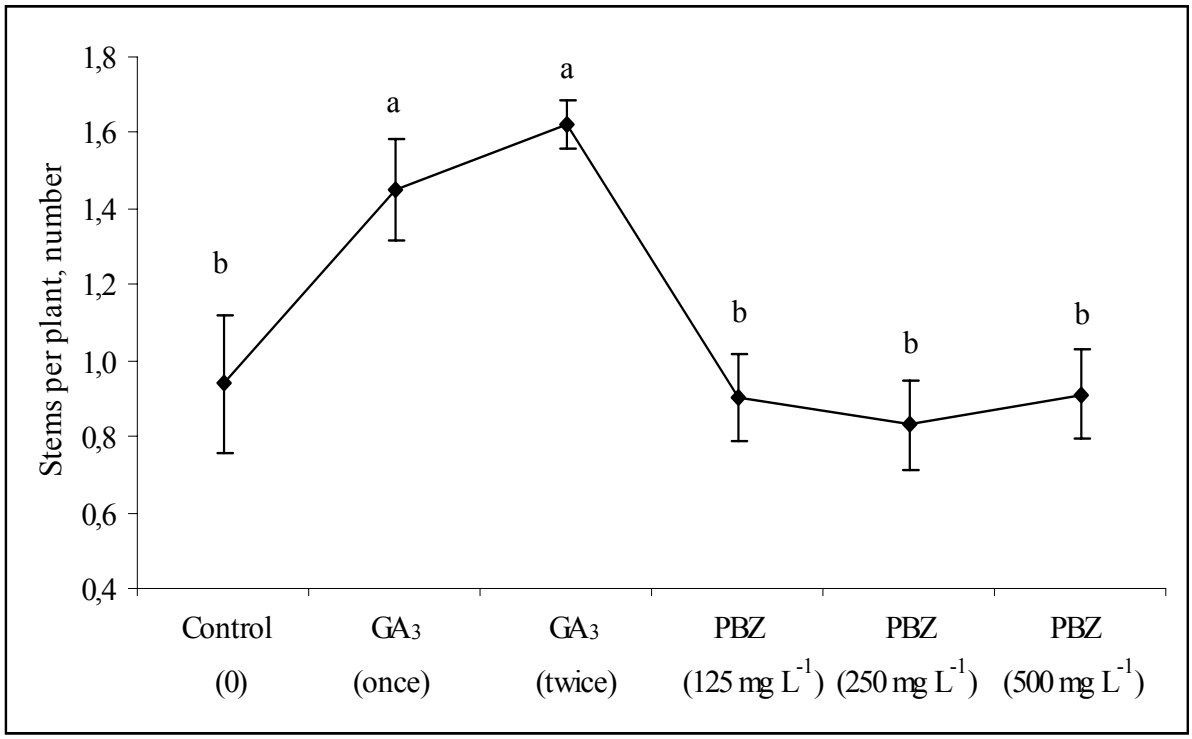


Figure 6: Effect of GA_3 and PBZ on stems per plant (GA_3; Gibberellic acid, PBZ; paclobutrazol, Bars denote standart deviation)



4. Discussion

Once and twice applications of GA_3 shortened the days to flower by 1 day as compared to the control and by 2 to 4 days as compared to different concentrations of paclobutrazol treatments. Similar results were reported by Patil et al. (1996), who reported that days to flower in goldenrod was shortened by the GA_3 treatment but extended by the paclobutrazol treatment. At the same time, Karagüzel (2004) reported that days to flower were significantly shortened with increasing number of GA_3 treatments on long days in *Gypsophila paniculata*. On the other hand, the paclobutrazol treatment retarded the days to flower. Previous studies revealed that the days to flower responses of plant species and cultivars to paclobutrazol treatments were quite different. It was reported that paclobutrazol did not affect days to flower in *Episcia* (Stamps and Henny, 1986), that days to flower were extended with increasing paclobutrazol concentration in *Matthiola* (Ecker et al. 1992) but that it shortened days to flower in *Zinnia* (Chen et al. 1993).

The GA_3 treatments significantly increased the stem lengths. The stem length showed an increase with increasing number of GA_3 treatments; however, this increase was statistically insignificant. The once application of GA_3 at a concentration of 250 mg L^{-1} increased the stem length by about 10 cm as compared to the control, while the twice application of GA_3 increased it by about 15 cm. On the other hand, under the paclobutrazol treatments, the stem lengths were shortened by 8 to 18 cm as compared to the control, whereas they were shortened by about 20 to 30 cm as compared to the GA_3 treatments (Figure 2). Our results are similar to Patil et al. (1996) (in goldenrod), Gianfagna and Merritt (1998) (in *Aquilegia*), Pobudkiewicz and Novak (1992) (in g*erbera*) and Karagüzel (2004) (in *gypsophila*), who reported that the GA_3 treatments increased plant height in different plant species, and to Patil et al. (1996) (in goldenrod), Karlovic et al. (2004) (in *chrysanthemum*), Vrsek et al. (2002) (in *aster*) and Mansuroglu et al. (2009) (in *consolida*), who reported that growth retardants reduced plant height.

The GA_3 treatments increased the stem diameter. Similar results were reported in *Consolida orientalis* by Karagüzel and Mansuroğlu (2003). Nevertheless, the stem diameter was observed to decrease with increasing number of GA_3 treatments; however, this difference was found insignificant. The stem diameter showed an increase with increasing paclobutrazol concentration; however, this difference was also statistically insignificant. The obtained results are in agreement with the findings of Mansuroglu et al. (2009). The stem fresh weight also showed an increase with increasing number of GA_3 treatments in the study. Similar results were reported in *Gypsophila* by Karagüzel (2004).

The highest stem fresh weights were obtained from the GA_3 treatments, followed by control and paclobutrazol treatments, respectively. The difference in stem fresh weight among paclobutrazol concentrations was insignificant. The GA_3 and paclobutrazol treatments significantly affected the number of secondary inflorescences. The GA_3 treatments increased the number of secondary inflorescences as compared to the control, while the paclobutrazol treatments reduced it. Karagüzel and Mansuroğlu (2003) reported that the GA_3 treatments increased the flower number in *Consolida orientalis*, although this increase was insignificant, whereas the paclobutrazol treatments reduced the number of secondary inflorescences. Furthermore, Mansuroglu et al. (2009) reported that 125, 250 and 500 mg L^{-1} of paclobutrazol treatments reduced the number of secondary inflorescences in *Consolida orientalis*.

The GA_3 and paclobutrazol treatments did not affect the dry matter content. The number of stems per plant showed a significant increase in the plants treated once and twice with GA_3 as compared to the control, whereas the paclobutrazol treatments reduced yield. A 54.26% increase in the number of stems per plant was observed in the plants treated once with GA_3 as compared to the control, while a 72.34% increase was observed in the plants treated twice with GA_3. However, no difference in the number of stems per plant was found between the plants treated once and twice with GA_3. The GA_3 treatments increased the number of stems per plant by approximately 74.0% as compared to the paclobutrazol treatments. Wakchaure et al. (2008) reported that 30 and 45 days after planting, 125 mg L^{-1} of GA_3 treatment improved the yield and flower quality parameters in goldenrod, while Karagüzel (2004) reported that once and twice applications of 250 mg L^{-1} of GA_3 in gypsophila

increased the number of flowering shoots per plant. Even though the paclobutrazol treatments slightly reduced the number of stems per plant as compared to the control, this difference was statistically insignificant.

5. Conclusion

The effects of foliar applications of GA_3 and paclobutrazol on yield and quality parameters in goldenrod were investigated in the study. The study revealed that once and twice foliar applications of 250 mg L^{-1} of GA_3 shortened the days to flower and increased stem length, stem diameter, stem fresh weight, number of secondary inflorescences and number of stems per plant. In addition, the paclobutrazol treatments slightly retarded the days to flower and significantly reduced stem length and stem weight.

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