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Effect of different plant densities and GA₃ concentrations on flower and yield parameters of golden rod (*Solidago canadensis* L.)

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Abstract

A field experiment entitled “Effect of different plant densities and GA₃ concentrations on flower and yield parameters golden rod (*Solidago canadensis* L.)” was conducted during the *kharif* season of 2023-24 at College of Horticulture, VNMKV, Parbhani, with a view to find out the effect of different plant densities and GA₃ concentrations and their interaction on flower and yield parameters of golden rod and economics of different treatments. The experimental field was fairly uniform, levelled and well drained. The experiment was laid out in Factorial Randomized Block Design with twelve treatments and two factors in three replications each. The first factor was Plant Density (S) which had levels S₁ – 30 × 20 cm, S₂ – 30 × 30 cm and S₃ – 30 × 40 cm. The second factor was GA₃ concentrations (G) which had levels G₁ – 0 ppm (control), G₂–100 ppm, G₃–150 ppm and G₄–200 ppm. Variety of golden rod used for experimental study was Local. On the basis of present studies it can be stated that days to initiation of panicle and days to opening of first flower were found least with the plant density of 30 × 40 cm and the GA₃ concentration in which the minimum days were taken with 200 ppm GA₃ concentration. The maximum number of primary branches per panicle and diameter of the main stalk of panicle were found in the plant density 30 × 40 cm and the GA₃ concentration of 200 ppm. Flower yield in respect of number of panicles per plant, number of panicles per plot and yield of panicles per hectare was maximum with plant density of 30 × 40 cm and spraying of 200 ppm GA₃ concentration.

Keywords: Golden rod, plant density, GA₃ concentration, flowering, yield

Introduction

Golden rod, scientifically known as *Solidago canadensis* L., belongs to the Asteraceae family and is native to North America. It is popular as a cut flower for vases and table arrangements and as an essential filler for bouquets. Golden rod serves as a potential source of natural herbicide, glycosides, essential oil, and natural fungicide. It possesses anti-inflammatory, anti-catarrrhal, and antiseptic properties and is particularly effective in treating chronic nasopharyngeal catarrh. *Solidago* is also used for pigment extraction for dyes (Biertumpfel *et al*, 2001) ^[1] and supports honey bees (*Apis mellifera*) and bumble bees (*Bombus* spp.) (Stefanic *et al*, 2003) ^[5]. The flowers are suitable for drying (Vethamoni and Nanthakumar, 2002) ^[7].

Adequate spacing is essential for each plant's development; overcrowding can lead to stunted growth and reduced yield. Proper spacing allows plants to reach their full potential both above and below ground, ensuring less competition for sunlight, water, and nutrients. Additionally, spacing helps prevent the spread of pests and diseases among plants. To enhance the growth, flowering, and yield of golden rod, it is essential to apply technological improvements. Gibberellic acid (GA₃) plays a critical role in promoting vegetative growth and high-quality flowers. Furthermore, optimal spacing, when used in conjunction with appropriate GA₃ concentrations, can improve vegetative growth, increase the number of suckers per hectare, and produce superior quality panicles. Therefore, it is anticipated that the effective combination of plant density and GA₃ at suitable levels will lead to better overall growth, flowering, and yield of golden rod. Considering the above fact, the experiment was undertaken to evaluate the effect of various plant densities and GA₃ concentrations on growth and yield parameters of golden rod.

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Methodology

The experiment entitled “Effect of plant densities and GA₃ concentrations on the growth, yield and quality of golden rod (*Solidago canadensis* L.)” was carried out at the College of Horticulture, Vasantao Naik Marathwada Krishi Vidyapeeth, Parbhani (Maharashtra) during the year 2023-2024. The experiment was laid out in Factorial Randomized Block Design with twelve treatment combination and three replications. The first factor was Plant Density (S) which had levels S₁ –30 × 20 cm, S₂ –30 × 30 cm and S₃ –30 × 40 cm. The second factor was GA₃ concentrations (G) which had levels G₁ – 0 ppm (control), G₂-100 ppm, G₃-150 ppm and G₄-200 ppm. Variety of golden rod used for experimental study was Local. Total number of plots was 36 having plot size 1.5 m x 2.0 m = 3.0 m². Fertilizers were applied at rates of 150 kg/ ha of nitrogen (N), 100 kg/ ha of phosphorus (P₂O₅) and 100 kg/ ha of potassium (K₂O). The phosphorus and potassium fertilizers were applied uniformly as a basal dose across all plots. Nitrogen was applied in two split doses: half of the nitrogen was applied 10 days after planting, and the remaining half was applied 40 days after planting. Immediately following the fertilizer application, the crop received sufficient irrigation. Various flowering parameters like days to initiation of panicle, days to opening of first flower, number of primary branches per panicle and diameter of the main stalk of panicle were studied under the experiment. While yield parameters like number of panicles per plant, number of panicles per plot and yield of panicles per hectare were evaluated.

Results and Discussion

Days to initiation of panicle

From the tabulated data it is evident that the effect of different plant densities on the initiation of panicle was significant. The shortest time to panicle initiation was observed in the least dense planting arrangement, S₃-30 x 40 cm (38.88 days), followed by S₂-30 x 30 cm (39.84 days). The longest period for panicle initiation was recorded in the densest arrangement, S₁-30 x 20 cm, (40.68 days). The reduced number of days to panicle initiation in the least dense planting arrangement (S₃) can be attributed to sparse plant density, which provides more access to light, nutrients, and moisture, thereby promoting earlier panicle initiation. Similar results were found by Tingare *et al.* (2007) [6] in Golden rod.

The effect of different GA₃ concentrations was also significant. The shortest duration for panicle initiation was recorded at the highest concentration of GA₃, G₄-200 ppm (37.26 days), followed by G₃-150 ppm (38.79 days). The longest period for panicle initiation occurred in the control treatment G₁-0 ppm (42.81 days). The application of GA₃ promotes early vegetative growth, and as the concentration increases, the time to panicle initiation decreases. This may be due to the enhanced physiological processes driven by GA₃, such as improved cell division and elongation, which result in earlier panicle formation. These results were similar to the results found out by Rajput. P. D. (2011) [3].

The interaction effect of plant densities and GA₃ concentrations on the days to panicle initiation was found to be non-significant, as indicated by the data in the table. While both factors individually influenced the panicle initiation period, their combined effect did not show a statistically significant interaction.

Days to opening of first flower

From the tabulated data it is evident that the effect of different plant densities on the days to the opening of the first flower was significant. The least number of days to the first flower opening was recorded in the least dense planting arrangement, S₃-30 x 40 cm (74.99 days), followed by S₂-30 x 30 cm (77.49 days). The longest time to flower opening was recorded in the densest arrangement, S₁-30 x 20 cm (80.66 days). The reduction in the number of days to opening of the first flower in the least dense arrangement (S₃) can be attributed to better spacing, allowing for enhanced sunlight exposure and nutrient absorption, which promoted early flowering. The results are in close agreement with the finding of Sodha *et al.* (1998) [4] in golden rod.

The data indicated that the effect of different GA₃ concentrations was also significant. The fewest days to the first flower opening were recorded at the highest concentration of GA₃, G₄ -200 ppm (74.07 days), followed by G₃-150 ppm (76.87 days). The longest time to flower opening occurred in the control treatment G₁-0 ppm (80.70 days). The application of GA₃ enhances early growth, with higher concentrations resulting in earlier flowering. This may be due to GA₃'s role in promoting cell division and elongation, leading to an accelerated flowering process. The results are same as found by Gaikwad and Sharad (2006) [2]. The interaction effect of plant densities and GA₃ concentrations on the days to the opening of the first flower was found to be non-significant, as indicated by the data in the table. Although both factors independently influenced the timing of flower opening, their combined effect did not showed a statistically significant interaction.

Number of primary branches panicle⁻¹

Plant density significantly influenced the number of primary branches per panicle. The maximum number of primary branches per panicle was recorded in the least dense planting arrangement S₃-30 x 40 cm (31.78). This was followed by S₂-30 x 30 cm (27.29), while the minimum number of primary branches was recorded in the densest planting S₁-30 x 20 cm, (26.67). The increase in the number of primary branches in the least dense planting S₃ may be due to better spacing, allowing more sunlight and better nutrient availability, promoting healthier growth and more branching. Similar results were found in the study done by Tingare *et al.* (2007) [6].

The data also indicated that GA₃ concentrations had a significant effect on the number of primary branches per panicle. The highest number of primary branches was observed in the treatment G₄-200 ppm (31.04), followed by G₃-150 ppm (28.98). The lowest number of branches was found in the control treatment G₁-0 ppm (26.39). The application of GA₃ likely stimulated vegetative growth, leading to increased branching. Higher concentrations of GA₃ are known to promote cell division and elongation, which could explain the increase in the number of branches with higher GA₃ concentrations. These results are similar with that found by Gaikwad and Sharad (2006) [2].

The interaction between plant densities and GA₃ concentrations on the number of primary branches per panicle was significant. The highest number of primary branches was observed in the S₃G₄ treatment (30 x 40 cm + 200 ppm GA₃), with 37.37 branches per panicle. On the other hand, the lowest number of branches was recorded in

the S₁G₁ treatment (30 x 20 cm + 0 ppm GA₃) with 25.92 branches per panicle. This significant interaction suggests that the combination of wider plant spacing and higher GA₃

concentrations led to an increased number of primary branches, likely due to the complementary effects of better resource availability and enhanced vegetative growth.

Table 1: Effect of plant densities and GA₃ concentrations on flower and yield parameters of Golden rod

Treatments	Days to initiation of panicle (days)	Days to opening of first flower (days)	Number of primary branches panicle ⁻¹	Diameter of main stalk of panicle (cm)	Number of panicles plant ⁻¹	Number of panicles plot ⁻¹	Yield of panicles hectare ⁻¹ (lakhs)
Factor A: Plant Densities (S)							
S ₁	40.68	80.66	26.67	0.62	4.09	187.38	6.25
S ₂	39.84	77.49	27.29	0.65	4.19	114.60	3.82
S ₃	38.88	74.99	31.78	0.71	4.73	107.27	3.58
SE ±	0.19	0.70	0.23	0.00	0.03	0.92	0.03
C.D. at 5 %	0.57	2.14	0.70	0.01	0.10	2.69	0.19
Factor B: GA₃ Concentration (G)							
G ₁	42.81	80.70	26.39	0.63	4.12	130.35	4.35
G ₂	40.35	79.21	27.91	0.65	4.24	133.67	4.46
G ₃	38.79	76.87	28.98	0.67	4.39	138.21	4.61
G ₄	37.26	74.07	31.04	0.69	4.59	143.43	4.78
SE ±	0.22	0.79	0.28	0.01	0.04	1.06	0.04
C.D. at 5 %	0.64	2.36	0.84	0.03	0.13	3.10	0.12
Interaction A x B: (SxG)							
S ₁ G ₁	44.13	84.31	25.92	0.60	4.01	183.50	6.12
S ₁ G ₂	41.22	82.14	26.31	0.60	4.05	185.67	6.19
S ₁ G ₃	39.15	79.78	26.94	0.63	4.12	189.00	6.30
S ₁ G ₄	38.23	76.44	27.53	0.64	4.17	191.33	6.38
S ₂ G ₁	42.52	80.47	26.4	0.63	4.09	111.80	3.73
S ₂ G ₂	40.53	78.55	26.65	0.65	4.19	114.60	3.82
S ₂ G ₃	39.11	76.60	27.89	0.66	4.23	115.80	3.86
S ₂ G ₄	37.22	74.33	28.21	0.67	4.24	116.20	3.87
S ₃ G ₁	41.77	77.32	26.86	0.67	4.27	95.75	3.19
S ₃ G ₂	39.31	76.95	30.78	0.70	4.47	100.75	3.36
S ₃ G ₃	38.11	74.23	32.11	0.72	4.83	109.83	3.66
S ₃ G ₄	36.34	71.45	37.37	0.76	5.35	122.75	4.09
SE ±	0.38	1.39	0.47	0.01	0.07	1.83	0.06
C.D. at 5 %	N/S	N/S	1.41	0.03	0.22	5.38	0.18

Diameter of main stalk of panicle (cm)

The data revealed that different plant densities significantly affected the diameter of the main stalk. The maximum stalk diameter was observed in the least dense planting arrangement S₃- 30 x 40 cm (0.71 cm). This was followed by S₂-30 x 30 cm, (0.65 cm) and the minimum diameter was noted in the densest planting S₁-30 x 20 cm (0.62 cm). The larger stalk diameter in the least dense planting could be attributed to the reduced competition for resources such as light, nutrients, and space, which allowed the plants to grow stronger and develop thicker stalks. Similar results were found in the study done by Tingare *et al.* (2007)^[6].

The data also indicated a significant effect of different GA₃ concentrations on the diameter of the main stalk. The maximum stalk diameter was recorded in the G₄-200 ppm (0.69 cm), followed by G₃-150 ppm (0.67 cm). The minimum diameter was observed in the control treatment G₁-0 ppm (0.63 cm). GA₃ application, especially at higher concentrations likely promoted the elongation and strengthening of the plant structure resulting in a wider main stalk. The increase in stalk diameter with higher GA₃ concentrations suggests enhanced cell expansion and overall vigor of the plant. These results are similar with that found by Gaikwad and Sharad (2006)^[2].

The interaction between plant densities and GA₃ concentrations had a significant impact on the diameter of the main stalk. The highest stalk diameter was recorded in the S₃G₄ treatment (30 x 40 cm + 200 ppm GA₃) measuring 0.76 cm. The smallest diameter was observed in the S₁G₁

treatment (30 x 20 cm + 0 ppm GA₃) with a value of 0.60 cm. This significant interaction suggests that a combination of wider plant spacing and higher GA₃ concentrations contributed to an increased diameter of the main stalk. The plants in these conditions likely benefited from both improved spacing and the growth-enhancing effects of GA₃, leading to stronger and thicker stalks.

Number of panicles plant⁻¹

Plant density had a significant impact on the number of panicles per plant. The highest number of panicles was observed in the widest spacing S₃-30 x 40 cm (4.73), followed by S₂-30 x 30 cm (4.19). The lowest number of panicles was recorded in the densest spacing S₁-30 x 20 cm (4.09). This increase in panicle number in the wider spacing is attributed to reduced competition for nutrients and light, resulting in a better overall plant structure and more panicle initiation. The results are same as found by Sodha *et al.* (1998)^[4] and Tingare *et al.* (2007)^[6] in golden rod.

The concentration of GA₃ significantly influenced the number of panicles per plant. The maximum number of panicles was observed with the highest concentration of GA₃, G₄-200 ppm (4.59), followed by G₃-150 ppm (4.39). The lowest number of panicles was noted in G₁ -0 ppm (4.12). The application of GA₃ promotes cell division and elongation, which leads to better tillering and an increased number of panicles per plant. Similar results were found in the study done by Gaikwad and Sharad (2006)^[2] in golden rod.

The interaction between plant densities and GA₃ concentrations showed a significant effect on the number of panicles per plant. The highest number of panicles was observed in the S₃G₄ treatment (30 x 40 cm + 200 ppm GA₃), which recorded 5.35 panicles per plant, whereas the lowest number of panicles was recorded in the S₁G₁ treatment (30 x 20 cm + 0 ppm GA₃) with 4.01 panicles per plant. This indicates that wider spacing along with higher GA₃ concentrations creates favorable conditions for producing a higher number of panicles per plant, due to the improved physiological growth and development of the plants.

Number of panicles plot⁻¹

Plant density significantly affected the number of panicles per plot. The densest spacing S₁-30 x 20 cm recorded the highest number of panicles (187.38 per plot), while the medium spacing S₂ (30 x 30 cm) had 114.6 panicles and the widest spacing S₃ (30 x 40 cm) had the lowest panicles per plot with 107.27. The greater number of panicles in the denser planting may be due to the higher population of plants per unit area, which results in a higher total number of panicles, even if the number of panicles per plant is lower.

GA₃ application also had a significant impact on the number of panicles per plot. The highest number of panicles 143.43 per plot was observed with the highest GA₃ concentration G₄ (200 ppm), followed by G₃ (150 ppm) with 138.21 panicles. The lowest was recorded in the control treatment G₁ (0 ppm), with 130.35 panicles per plot. The increase in the number of panicles with higher GA₃ concentrations can be attributed to improved plant vigor and enhanced tillering resulting in more panicle production.

The interaction between plant densities and GA₃ concentrations showed a significant effect on the number of panicles per plot. The maximum number of panicles 191.33 per plot was observed in the S₁G₄ treatment (30 x 20 cm spacing + 200 ppm GA₃), while the lowest (95.75 panicles per plot) was recorded in the S₃G₁ treatment (30 x 40 cm spacing + 0 ppm GA₃). This indicates that dense planting combined with higher GA₃ concentrations leads to the highest number of panicles per plot, likely due to the cumulative effect of increased plant population and the positive physiological response of plants to GA₃.

Yield of panicles hectare⁻¹ (lakhs)

The plant density exhibited a significant effect on the yield of panicles per hectare. The closest spacing S₁ (30 x 20 cm) recorded the highest yield of 6.25 lakh panicles per hectare. This was followed by S₂ (30 x 30 cm) with a yield of 3.82 lakh panicles per hectare. The lowest yield, 3.58 lakh panicles per hectare was observed with the widest spacing S₃ (30 x 40 cm). The higher yield in denser plantings could be attributed to the greater number of plants per unit area, contributing to a higher total yield despite the fewer panicles per plant. The results are same as found out by Sodha *et al.* (1998) [4] and Tingare *et al.* (2007) [6].

GA₃ concentration also had a marked influence on the yield of panicles per hectare. The highest yield of 4.78 lakh panicles per hectare was recorded with the highest GA₃ concentration G₄ (200 ppm). This was followed by G₃ (150 ppm) with 4.61 lakh panicles per hectare. The control treatment G₁ (0 ppm) yielded the lowest number of panicles with 4.35 lakh panicles per hectare. This trend suggests that

increasing the GA₃ concentration positively impacts panicle yield, likely due to the growth-promoting effects of GA₃, which enhances plant vigor and tiller production. Similar results were found in the study done by Gaikwad and Sharad (2006) [2] & Rajput. P. D. (2011) [3].

The interaction between plant densities and GA₃ concentrations showed a significant effect on the yield of panicles per hectare. The highest yield (6.38 lakh panicles per hectare) was recorded in the S₁G₄ treatment (30 x 20 cm + 200 ppm GA₃), while the lowest yield (3.19 lakh panicles per hectare) was found in the S₃G₁ treatment (30 x 40 cm + 0 ppm GA₃). This indicates that closer planting combined with higher GA₃ concentrations results in the highest yield of panicles per hectare, emphasizing the combined benefits of increased plant density and the growth-enhancing effects of GA₃ application.

Conclusion

In view of the findings and results presented above, it may be concluded that days to initiation of panicle and days to opening of first flower were found least with the plant density of 30 x 40 cm and the GA₃ concentration in which the minimum days were taken with 200 ppm GA₃ concentration. The maximum number of primary branches per panicle and diameter of the main stalk of panicle were found with the plant density 30 x 40 cm and the GA₃ concentration of 200 ppm. Flower yield in respect to number of panicles per plant, number of panicles per plot and yield of panicles per hectare was found maximum with plant density of 30 x 40 cm and spraying of 200 ppm GA₃ concentration. The conclusions are based on the experiment done for only one season.

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