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DEVELOPMENT OF INFLORESCENCE AS INFLUENCED BY PLANTING GEOMETRY AND NITROGEN LEVELS IN GOLDEN ROD (*SOLIDAGO CANADENSIS* L.)

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Abstract

An investigation was carried out during 2014-15, on effect of planting geometry and nitrogen levels on panicle development and yield of golden rod to understand its developmental phases and time vested with the producers and consumers to handle the material before it is put to ultimate use. It has shown significant differences among the nitrogen doses and planting geometry levels. The study revealed that lower dose of nitrogen (0 kg ha^{-1}) with closer spacing (30 cm × 15 cm) took minimum number of days to initiation of first panicle, 50% flowering, complete flowering, first floret opening, completion of all floret opening followed by 100 kg ha^{-1} of nitrogen and 45 cm × 15 cm spacing respectively, whereas, higher dose of nitrogen (300 kg ha^{-1}) with wider spacing (45 cm × 30 cm) delayed withering of apical florets. However, maximum numbers of marketable panicles plot^{-1} were recorded with 300 kg ha^{-1} nitrogen with 30 cm × 30 cm spacing.

Key words : Golden rod, panicle, planting geometry.

Introduction

Golden rod is a herbaceous perennial botanically known as *Solidago canadensis* L. It belongs to the family Asteraceae and is a perennial flower crop cultivated for attractive flower stalk. The genus *Solidago* is native to North America (Biswas and Parya, 2008). The bloom is a pyramid-shaped cluster of many tiny flowers, which are yellow in colour. The inflorescence of golden rod is very complex in nature. Each small head consist several disc florets. Heads are auxillary, solitary on main axis as well as on branches and on small branchlets forming a whole compound flower stalk with golden yellow inflorescence. The blooms are very attractive as cut flowers and are used in bouquets as filler material and for floral arrangements. Golden rod is also used as a dry flower and outdoor ornamental plant. Golden rod is one such crop that attracts anincreasing attention, because of its extensive use as filler material and interior decorations. Considering the importance and increasing popularity of the golden rod. It is felt important to study the performance of the crop under different planting geometry levels and nitrogen doses in order to find out the optimum values.

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Materials and Methods

The present investigation was carried out at Horticultural College and Research Institute, Venkataramannagudem (Andhra Pradesh), India in 2014-15 to study the effect of nitrogen levels and planting geometry on growth and yield of golden rod. Sixteen treatment combinations with four levels of nitrogen (0, 100, 200 and 300 kg ha^{-1}) and four levels of planting geometry (45 cm × 30 cm, 30 cm × 30 cm, 45 cm × 15 cm and 30 cm × 15 cm) were tried in factorial randomized block design with three replications. Half dose of nitrogen was applied as per the treatment before planting and the remaining half dose of nitrogen was applied after 45 days of planting. However, potash and phosphorus were applied as a basal dose before planting. The data recorded on all parameters were analyzed by the ANOVA technique as described by Panse and Sukhatme (1967). The treatment means were compared using the critical difference values calculated at 5 per cent level of significance.

Results and Discussion

Number of days taken for first panicle initiation

Different levels of nitrogen and planting geometry levels had shown significant influence on number of days taken for first panicle emergence (table 1). Among nitrogen levels, the first panicle emergence was earlier (52.96 days) in N_1 followed by N_2 (55.65 days). The minimum number of days taken for first panicle emergence (54.10 days) in closer spacing (S_4) followed by S_3 (56.34 days) among planting geometry levels. Number of days taken for first panicle initiation were maximum (60.41 days) with highest dose of nitrogen whereas plants with wider spacing (S_1) recorded maximum value (58.90 days). The interaction of N_1S_4 recorded earliest panicle emergence (49.41 days) in terms of first panicle initiation and N_1S_4 was on par with N_2S_4 (52.16 days) and N_1S_3 (52.17 days) whereas, maximum delay in panicle emergence was observed in N_4S_1 (61.60 days), it was on par with N_4S_2 (61.17 days) and N_3S_1 (60.47 days).

Number of days taken for 50% flowering (50% plants showing panicle initiation)

Significant differences were noticed with respect to number of days taken for 50% flowering among the different levels of nitrogen and planting geometry (table 1). N_1 level took the least number of days for 50% flowering (74.90 days) and was on par with N_2 (76.28 days) whereas, maximum days (82.64 days) was recorded by N_4. Among planting geometry levels S_4 level was the earliest (75.01 days) was on par with S_3 (77.03 days) and S_1 registered maximum days (82.25 days) in respect of 50% flowering. Among the interactions, the treatment combination of N_1S_4 (70.86 days) was the earliest for 50% flowering, was on par with N_2S_4 (73.28 days), N_2S_3 (74.56 days) and N_1S_3 (74.83 days). On the other side, maximum delay in 50% flowering was recorded by N_4S_1 (86.35 days) among the interactions.

Number of days taken for complete flowering

There were significant differences among the nitrogen levels and planting geometry levels with regard to complete flowering (table 1).

Among nitrogen levels N_1 recorded minimum days (80.75 days) for complete flowering followed by N_2 level (83.59 days). Among planting geometry levels S_4 recorded minimum days for complete flowering (82.34 days) followed by S_3 (83.91 days). With respect to interactions, best value (78.67 days) was recorded by N_1S_4 level and was on par with N_1S_3 (79.89 days) and N_2S_4 (81.02 days). The maximum delay (89.83 days) was registered by N_4S_1 level and was on par with N_4S_2 (88.32 days) and N_3S_1 (88.04 days) among interactions whereas, N_4 (87.72 days) and S_1 (86.62 days) were late in complete flowering. In golden rod, the inflorescence is capitulum, but it appears like a small floret and stalked. Numerous capitula arise on the branched plageotropic portion of the main stem which gives an appearance of panicle with a few leaves arising in between. In the present study, the earliest flowering was observed by the application of no nitrogen or lower dose of nitrogen. There was significant delay in the higher doses *i.e.* N_3 and N_4, however the difference between them was not significant with respect to days taken for first panicle initiation. The widest spacing of 45 cm x 30 cm (S_1) took maximum number of days for first panicle initiation, 50% flowering and complete flowering. The plants at 30 cm × 30 cm spacing also took similar amount of time, which was statisticalon par with 45 cm × 30 cm in respect of these values.

This might be due to increased vigour and enhanced vegetative growth of plants receiving 200 and 300 kg ha^{-1} of nitrogen and those spaced at 45 cm × 30 cm as well as 30 cm × 30 cm. These plants as a result of maximum uptake of nutrients by individual plant might have diverted maximum proportion of photosynthates into vegetative parts in the initial life significantly postponing their transition into reproductive phase. Further late occurrence in the developmental phases *viz*., 50% flowering, complete flowering, first harvesting and second panicle initiation might be prospective to the time taken for first initiation of panicles by the highly nurtured and widely spaced plants. However, an early panicle initiation and flowering in plants with least supply of nitrogen and closer planting geometry might be due to early physiological maturity of plants as a result of their minimum vegetative growth of plant compared to wider spacing. These results are in concurrence with the findings of those reported by Jadhav *et al*. (2014) in calendula, Naidu *et al*. (2014) in marigold, Sharma *et al*. (2010) in marigold, Venugopal and Patil (2010) in helichrysum and Mane *et al*. (2006) in tuberose.

Number of days taken for first floret opening in a panicle

The data presented for the number of days taken for first floret opening was significantly influenced by different levels of nitrogen and planting geometry (table 2). The minimum number of days taken for first floret opening (7.58 days) was recorded by N_1 level was on par with N_2 (7.96 days) whereas, N_4 recorded maximum number of days (8.62 days) for first floret opening. Among planting geometry levels, S_4 recorded the minimum number of days for first floret opening (7.03 days) and was on par with S_3 (7.32 days) on the other hand, S_1 recorded maximum number of days (9.42 days). With respect to interactions, N_1S_4 recorded minimum number of days (6.42 days) and it was on par with N_2S_4 (6.76

days) and N_1S_3 (6.78 days). The delay in first floret opening was observed in N_4S_1 (9.86 days) and it was on par with N_4S_2 (9.18 days) and N_3S_1 (9.68 days).

Number of days taken for completion of all florets opening in a panicle

Significant differences were noticed with respect to number of days taken for completion of floret opening among the different levels of nitrogen and planting geometry (table 2). N_1 level was earlier for completion of floret opening (14.27 days) and was on par with N_2 (14.98 days) whereas, among planting geometry levels S_4 level was the earlier (13.15 days) was on par with S_3 (13.69 days). Among the interactions, the treatment combination of N_1S_4 (12.01 days) was the earliest for completion of floret opening compare to all the combinations and was on par with N_2S_4 (12.67 days) and N_1S_3 (12.70 days).

The maximum delay in all floret opening was recorded with N_4S_1 (18.43 days) and was on par with N_4S_2 (17.62 days) and N_3S_1 (18.09 days) among interactions. Among nitrogen levels, N_4 was late for completion of all florets opening whereas, in respect of planting geometry levels, wider spacing (S_1) registered maximum days (17.62 days).

Number of days taken for withering of apical florets in a panicle

Significant differences were noticed with respect to number of days taken for withering of apical florets among the different levels of nitrogen, planting geometry and their interactions (table 2). Among nitrogen levels, N_4 level took the maximum number of days for withering of apical florets (19.55 days) and was on par with N_3 (18.84 days) whereas, among planting geometry levels, S_1 level was the best (21.27 days) in terms of days to withering of apical florets, was on par with S_2 (19.95 days). Among the interactions, the treatment combination of N_4S_1 (22.32 days) was the best and was on par with N_3S_1 (21.91 days) and N_4S_2 (21.08 days). The early (17.11 days) withering of apical floret were recorded by lower level of nitrogen (N_1) whereas, among spacing S_4 registered least value (15.84 days). The interaction of N_1S_4 was earlier (14.46 days) for withering of apical florets and was on par with N_2S_4 (15.27 days) and N_1S_3 (15.26 days).

It has shown significant differences among the nitrogen doses and planting geometry levels. Application of nitrogen at 300 kg ha^{-1} was on par with 200 kg ha^{-1} with respect to days taken for first floret opening, completion of floret opening and withering of apical florets. Though, they are on par with each other differ significantly with lower doses since they haddelayed occurrence of floret developmental stages. Thus, the high levels of nitrogen at N_3 and N_4 doses gave maximum time for handling the spikes since they took different stages of bloom and consequent withering in a much delayed manner when compared to N_2. This might be due to more vegetative growth triggered by higher nitrogen application and the shoots stand at low C: N ratio thereby leading to delay in onset of flowering and occurrence of maturation stages of the bloom. Similar results were also obtained by Verma *et al*. (2012) in gladiolus and Monish *et al*. (2008) in china aster.

Similarly at wider spacing the plants took maximum time to show first floret opening, completion of all florets opening and withering apical florets indicating that the golden rods harvested from the spacing of 45 cm × 30 cm and 30 cm × 30 cm would show the phases of bloom in a delayed fashion giving more time for their utility. Wide spaced plants giving good spikes or flowers was also reported by Jadhav *et al.* (2014) in calendula, Naidu *et al*. (2014) in marigold, Sharma *et al.* (2010) in marigold, Venugopal and Patil (2010) in helichrysum and Mane *et al*. (2006) in tuberose.

Number of panicles per plot

The graded levels of nitrogen, planting geometry and their interactions showed significant influence on the number of panicles per plot (table 3). The nitrogen level N_4 recorded the highest number of panicles per plot (71.88). Among planting geometry levels, S_4 was the best with 109.32 panicles per plot followed by S_3 (74.56) and S_2 (56.66). Among the interactions, the treatment combination of N_4S_4 recorded the highest number of panicles per plot (111.08) was on par with N_3S_4 (109.23). The minimum number of panicles per plot (67.76) was recorded by N_1 among nitrogen levels. Among planting geometry levels, S_1 registered the minimum number of panicles per plot (38.00). With respect to the interactions, N_1S_1 registered the least number of panicles per plot (36.09).

Number of marketable panicles per plot

The data on number of marketable panicles per plot as influenced by various levels of nitrogen, planting geometry and their interactions were presented in table 3. Among nitrogen levels the highest number of marketable panicles per plot (42.53) were recorded with N_4 and it was on par with N_3 (40.47). Among planting geometry levels, S_2 recorded highest number of marketable panicles per plot (38.80) was on with S_1 (31.00) and S_3 (29.35). The interaction of N_4S_2 was best with

Table 1 : Effect of nitrogen levels, planting geometry and their interaction on different phases of panicle development in golden rod.

Planting geometry \ Nitrogen level	Days to first panicle initiation					50% flowering					Complete flowering				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
S_1	55.63	57.90	60.47	61.60	**58.90**	78.45	80.74	83.45	86.35	**82.25**	82.78	85.83	88.04	89.83	**86.62**
S_2	54.63	57.34	58.33	61.17	**57.87**	75.44	76.55	79.56	83.44	**78.75**	81.66	84.62	86.38	88.32	**85.25**
S_3	52.17	55.20	58.10	59.87	**56.34**	74.83	74.56	77.42	81.32	**77.03**	79.89	82.90	85.44	87.40	**83.91**
S_4	49.41	52.16	55.81	59.01	**54.10**	70.86	73.28	76.44	79.46	**75.01**	78.67	81.02	84.33	85.34	**82.34**
Mean	**52.96**	**55.65**	**58.18**	**60.41**	**56.80**	**74.90**	**76.28**	**79.22**	**82.64**	**78.26**	**80.75**	**83.59**	**86.05**	**87.72**	**84.53**

	S.Em.±	CD at 5%	S.Em.±	CD at 5%	S.Em.±	CD at 5%
N	0.71	2.15	0.76	2.30	0.51	1.53
S	0.70	2.10	0.77	2.31	0.46	1.38
N × S	1.16	3.51	1.38	4.17	1.06	3.20

Table 2 : Effect of nitrogen levels, planting geometry and their interaction on development phases of inflorescence in golden rod.

Planting geometry \ Nitrogen level	Days to first floret opening					Completion of all floret opening					Withering of apical florets				
	N_1	N_2	N_3	N_4	mean	N_1	N_2	N_3	N_4	mean	N_1	N_2	N_3	N_4	Mean
S_1	8.90	9.26	9.68	9.86	**9.42**	16.64	17.32	18.09	18.43	**17.62**	19.88	20.98	21.91	22.32	**21.27**
S_2	8.19	8.60	8.75	9.18	**8.68**	15.73	16.51	16.80	17.62	**16.67**	18.83	19.76	20.10	21.08	**19.95**
S_3	6.78	7.18	7.55	7.78	**7.32**	12.70	13.41	14.12	14.55	**13.69**	15.26	16.16	17.01	17.53	**16.49**
S_4	6.42	6.76	7.26	7.67	**7.03**	12.01	12.67	13.56	14.34	**13.15**	14.46	15.27	16.34	17.27	**15.84**
Mean	**7.58**	**7.96**	**8.31**	**8.62**	**8.12**	**14.27**	**14.98**	**15.64**	**16.23**	**15.28**	**17.11**	**18.04**	**18.84**	**19.55**	**18.39**

	S.Em.±	CD at 5%	S.Em.±	CD at 5%	SE m±	CD at 5%
N	0.25	0.76	0.36	1.08	0.56	1.67
S	0.26	0.78	0.29	0.88	0.49	1.46
N × S	0.36	1.10	0.79	2.38	1.30	3.92

Table 3 : Effect of nitrogen levels, planting geometry and their interaction on yield of golden rod.

Planting geometry \ Nitrogen level	Number of panicle per plot					Number of marketable panicle per plot				
	N_1	N_2	N_3	N_4	Mean	N_1	N_2	N_3	N_4	Mean
S_1	36.09	37.45	38.12	40.32	**38.00**	20.18	25.38	38.12	40.32	**31.00**
S_2	54.66	55.93	57.06	58.99	**56.66**	19.76	25.11	54.35	55.99	**38.80**
S_3	72.19	73.56	75.34	77.14	**74.56**	18.34	23.42	37.24	38.38	**29.35**
S_4	108.10	108.88	109.23	111.08	**109.32**	18.00	23.26	32.16	35.43	**27.21**
Mean	**67.76**	**68.96**	**69.94**	**71.88**	**69.63**	**19.07**	**24.29**	**40.47**	**42.53**	**31.59**

	SEm	CD at 5%	SEm	CD at 5%
N	0.35	1.05	2.92	8.79
S	2.53	7.63	3.37	10.15
N × S	4.54	13.67	6.02	18.14

highest number of marketable panicles (55.99) and it was on par with N_3S_2 (54.35), N_4S_1 (40.32), N_3S_1 (38.12). Among nitrogen levels, minimum number of marketable panicles were recorded with N_1 (19.07) whereas, the least value (27.21) was recorded with S_4 in terms of marketable panicles per plot. The interaction of N_1S_4 registered minimum number of marketable panicles (18.00) and it was on par with N_1S_3 (18.34), N_2S_4 (23.26) and N_2S_3 (23.42). It is interesting to note that the number of marketable panicles per plot did not follow the trend as exhibited by the number of total panicles per plot or per m^2 particularly when the planting geometry levels were taken into account. The widest geometry of planting at 45 cm × 30 cm and next immediate level *i.e.* 30 cm × 30 cm were on par with respect to number of marketable panicles per plot and both were significantly higher compared to other closer geometry levels that recorded a higher number of total panicles per plot. This clearly indicated that even though the total number of golden rods produced per unit area was higher with the closest orientation of plants or closest planting geometry level, such panicles were of least quality and hence were inferior in marketability. Therefore, the wider spacings only could yield significantly higher number of marketable panicles per plot even though the total number of panicles produced by them was less. On the contrary, the nitrogen levels exerted the similar influence as observed in case of total panicles per plot. The highest number of marketable panicles per plot was registered by the application of nitrogen at 300 kg ha^{-1}, which was on par with that at 200 kg ha^{-1}. Similar opinions were expressed by Sodha and Dhaduk (2002) in golden rod and Kishore *et al.* (2010) in marigold.

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