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Effect of chemical and bio-fertilizers on growth and flowering of golden rod (*Solidago canadensis* L.) CV. "Local"

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Abstract
A field experiment was conducted to study the effect of chemical and bio-fertilizers on growth and flowering of golden rod (*Solidago canadensis* L.) CV. "Local". The experiment was laid out in Randomized Block Design (RBD) with factorial concept having eight treatment combinations, comprising of two levels of recommended dose of fertilizers (75 % and 100 % RDF) and four levels of bio-fertilizers (No bio-fertilizers, *Azotobacter*, *Azotobacter* + PSB and *Azotobacter* + PSB + KMB). The treatments were replicated thrice. Among two levels of RDF, application of 100 % RDF (150:100:100 NPK kg/ha) significantly increased all growth and flowering parameters and microbial population (53.48 2 10^{-6} CFU/ml) in soil also. In case of bio-fertilizers, application of *Azotobacter* + PSB + KMB to golden rod significantly increasded growth with better quality flowers as well as maximum microbial population in soil with highest nitrogen and phosphorus content. In case of interaction, the application of RDF @ 100 % along with *Azotobacter* + PSB + KMB was found superior with respect to vegetative growth, flowering and yield parameter of golden rod.

Keywords: Golden rod, RDF, *Azotobacter*, PSB, KMB

1. Introduction
Golden rod (*Solidago canadensis* L.) belongs to family Asteraceae and native to North America. It is hardy perennial flower crop cultivated for its flower stalk which is mainly used as filler material in flower arrangement. The genus *Solidago* comprises about 130 species and few them like *Solidago canadensis, S. virgaurea, and S. memoralis* are grown in beds, borders or rock garden. It is grown in various agro climatic conditions but prefer sunny location for better growth and development. Golden rod is a heavy feeder and has a large requirement of nutrients. At present, due to lack of scientific knowledge related to nutritional aspects, growers are not able to boost the productivity of golden rod. Chemical fertilizers are main suppliers of major plant nutrient (N, P and K). For maximization of yield and quality of any flower crop, fertilization especially with proportion is to be properly followed. Continuous use of inorganic fertilizers has resulted in ecological imbalance with consequent ill effect on soil and environment. To maintain long term soil health and productivity there is a need for integrated nutrient management through manures and bio-fertilizers apart from costly chemical fertilizers for better yield of the crop (Mondal *et al.* 2003) [7]. Soil fertility cannot be maintained with the application of inorganic fertilizer alone. Therefore, the rational and practical means to maintain soil fertility and to supply plant nutrients in balanced proportion is to practice integrated plant nutrient supply through the combined use of organic and biological sources. Now a days, use of bio-fertilizers reduced the harmful effect of chemical fertilizers, increased soil fertility, growth of plant and yield. It has a crucial role in augmenting nutrient supply to crops by increasing the nutrient availability through exploitation of natural processes like biological N fixation, solubilization of insoluble P, decomposition and recycling of organic wastes, *etc.* In view of this fact, the investigation was undertaken to study their effect on growth, yield and quality of golden rod cv. Local.

2. Materials and Methods
The investigation was conducted at Floriculture Research Farm, ASPEE College of Horticulture & Forestry, Navsari Agricultural University, Navsari during 2015-2016. The

experiment was laid out in Randomized Block Design (RBD) with factorial concept comprising of two levels of RDF @ 150:100:100 NPK kg/ha (75 % and 100 % RDF) and four levels of bio-fertilizers (without bio-fertilizers, *Azotobacter*, *Azotobacter* + PSB and *Azotobacter* + PSB + KMB and eight combinations of chemical and bio-fertilizers. The treatments were replicated thrice. FYM @ 15 t/ha was applied during field preparation time. The healthy suckers of golden rod were obtained from the Floriculture Research Farm. Solution of *Azotobacter*, PSB and KMB @ 1 lit of each was prepared with 5 lit water according to the treatments and suckers were dipped in the solution for 30 minutes. Phosphorous and Potash were applied as basal dose after 10 days of planting and nitrogen was applied in four equal split *viz*. first split was applied with basal dose after 10 days of planting while remaining three doses were applied at 3, 6 and 9 months after planting. For soil application, *Azotobacter*, PSB and KMB @ 2 lit each was mixed in well decomposed, fine FYM @ 50 kg per acre kept overnight and after that it was applied in soil after 15 days of first and second dose of chemical fertilizer application. Observations on vegetative, flowering and yield were recorded and the data was analyzed as suggested by Panse and Sukhatme (1967) [9].

3. Result and Discussion

It is apparent from the data presented in Table 1, 2 and 3 that all the vegetative parameters, flowering and yield attributes and soil properties were significantly affected by different treatments.

3.1 Effect of Rdf

Results indicated that application of 100 % RDF (F_2) recorded maximum plant height (94.26 cm), leaf area (20.02 cm^2), number of sucker per plant (6.66) fresh weight of plant (159.07 g) and dry weight of plant (70.92 g) (Table 1). It might be attributed to the availability of three major nutrients that may led to enhanced growth as a result of increased cell division, cell enlargement and maximum conserved of photosynthesis to plant growth (Sajid and Amin, 2014) [12]. Phosphorous is an essential constituent of cell component such as phosphoproteiod and phospholipids, which are indispensable constituents of the various cell membranes and are also important to maintain the cell structure, while potassium control the movement of stomata and maintains electro-neutrality of plant cell and split application of nitrogen at different stages which is attributed to increased meristamatic activity and uptake of nitrogen at relevant time by the plant required to intensify the vegetative growth. More or less the above findings are in agreement with Savaliya and Vala (2015) [13] in golden rod. It is evident from the data presented in Table 2 that application of 100 % RDF (F_2) recorded minimum number of days taken for panicle initiation (112.92 days) and highest length of panicle (73.90 cm) and vase life of panicle (6.72 days). It might be due to improved vegetative growth of plant under the highest level of nitrogen, which resulted in more storage and subsequent utilization of carbohydrates and thus improved various flowering characters (Savaliya and Vala, 2015) [13]. These findings are in close conformity with the findings of Mahmoodinezhadedezfully *et al.* (2012) [6] in tuberose and Sajid and Amin (2014) [12] in chrysanthemum. The results revealed that 100% RDF gave best result as compare to 75 % RDF. Significantly maximum number of panicle per plant (3.98), number of panicle per plot (321.98) and number of panicle per hectare (662.50) were recorded from the plants receiving 100 % RDF (F_1). This might be due to vigorous growth and development of panicle with increase nitrogen level (Savaliya and Vala, 2015) [13]. Synthesis of amino acid, chlorophyll formation and better carbohydrates transformation give more number of flowers which increase yield. Similar trend have also been reported by Mahmoodinezhadedezfully *et al.* (2012) [6]. in tuberose. Significantly maximum Organic carbon (0.700 %) and microbial population (53.48 2 10^{-6} CFU/ml) were noted with 100 % RDF (F_2) application whereas, nitrogen, phosphorous, potassium, pH and EC were not affected significantly by chemical fertilizers.

3.2 Effect of bio-fertilizers

Application of bio-fertilizers was significantly influenced the growth and yield of golden rod. With respect to growth parameters of golden rod, maximum plant height with panicle (101.32 cm), leaf area (22.45 cm^2), number of suckers per plant (7.43), fresh weight (185.81 g) and dry weight of plant (82.50 g) were recorded with the plant received combined application of *Azotobacter* + PSB + KMB (B_3). *Azotobacter* fixes the atmospheric nitrogen and PSB mobilize phosphorous making these elements available for plant growth and development. *Azotobacter* secretes certain growth promoting substances like auxin, gibberellins, vitamins and organic acids which improve the growth. Whereas, PSB has ability to fix higher dose of phosphorous which stimulate root growth and enhances the absorption of nutrients thus resulting vigorous growth. The results are in agreement with the findings of Rathi, *et al*. (2005) [11]. Kumar *et al*. (2006) [17] and Dami Vandana *et al*. (2013) in marigold.

Flowering parameters and yield of golden rod were significantly affected by application of bio-fertilizers. Early initiation of flower panicle (108.14 days), maximum length of panicle (79.89 cm) and vase life (7.10 days) were resulted in the plant received *Azotobacter* + PSB + KMB (B_3). It might be due to inoculation of *Azotobacter*, PSB and KMB which increased availability of macro and micro nutrients and improved hormonal activities in plant ultimately affect flowering characters (Syamal *et al*. 2006) [17]. They produce growth promoting substances which are beneficial to improved flowering characters. These findings are in close conformity with the findings of Kumar *et al.* (2006) [17] and Dami Vandana *et al.* (2013) in marigold. Significantly maximum number of panicles per plant (4.23) was also observed with the application of *Azotobacter* + PSB + KMB (B_3). It might be due to the fact the bio-fertilizers produce the growth promoting substance and other acids like acetic, formic, proponic, lactic, glyconic, fumaric and succinic which were positively correlated with growth, flowering and yield. It has also been reported by Kumar *et al.* (2006) [17] marigold and Syamal *et al.* (2006) [17] in marigold.

In soil analysis, maximum available nitrogen (190.05 kg ha^{-1}), potassium (297.11 kg ha^{-1}), SOC (0.718 %) and microbial population (56.90 x 10^{-6} CFU/ml) were found significantly highest with application of *Azotobacter* + PSB + KMB (B_3) while phosphorus application, pH and EC did not exert significant influence on soil. It might be due to the fact that *Azotobacter* is free-living non-symbiotic aerobic nitrogen fixing bacteria that ultimately increased available nitrogen content in soil through biological nitrogen fixation. Moreover, phosphate solubilizing bacteria play an important role in converting insoluble phosphatic compound such as rock phosphate and basic slag particularly the chemically fixed soil phosphorus into available form. The increase of potash content in soil might be due to mobilization of potash in soil

which increased available of potash. It also increased organic carbon which enhanced soil fertility and soil structure. Application of bio-fertilizers increased total rhizopheric bacteria population (Srivastava and Govil, 2004) [16] these findings are in close conformity with the findings of Ali *et al.* (2013) in gladiolus.

3.3 Interaction effect

Interaction effect of chemical and bio-fertilizers was found non-significant with respect to growth, flowering attributes and soil properties except, yield/plant and microbial count. Combined application of chemical fertilizer and bio-fertilizers was significantly influenced the yield of golden rod. Significantly maximum number of panicles per plant (4.63) was found in treatment F_2B_3 i.e. (100 % RDF *Azotobacter* + PSB + KMB. Application of bio-fertilizers with balanced dose of chemical fertilizers increased the availability of essential plant nutrients enhanced root and shoot development and thereby growth. More photosynthesis enhanced food accumulation which might have resulted in better growth and subsequently higher number of flower and also enhanced soil fertility. It might have influenced the reproductive phase and induced yield parameters. They also synthesis the amino acid is also influenced by phytohormones which are formed in plant due to application of chemical fertilizers with bio-fertilizers which help in more yields. These findings are agree with results obtained by Kumar *et al*. (2013) [3, 5]. and Singh *et al.* (2015) [15] in marigold, Palangni Neelima *et al*. (2013) [8], Angadi (2014) [2]. in chrysanthemum, Singh (2006), Parolekar *et al*. (2012) [10] and Wasim *et al*. (2014) [19] in tuberose. Microbial population was found significantly maximum (62.10 x 10^{-6} CFU/ml) with the combined application of 100 % RDF *Azotobacter* + PSB + KMB (F_2B_3). The above findings are in agreement with Kumar *et al.* (2013) [3, 5]. in marigold, Verma *et al.* (2011) [8]. And Angadi (2014) [2] in chrysanthemum.

4. Conclusion

It can be concluded from present investigation that application of 100 % RDF along with inoculation of *Azotobacter*, PSB and KMB recorded higher flower yield in golden rod. The use of bio-fertilizers have a lot of benefits apart from the increased yield and returns but also improves the soil structure and texture, so T_8 (100 % RDF + *Azotobacter* + PSB + KMB) recommended for golden rod.

Table 1: Effect of chemical and bio-fertilizers on growth parameters on golden rod (*Solidago canadensis* L.) cv. "Local"

Treatments	Plant height with panicle (cm)	Leaf area (cm^2)	Number of suckers per plant	Fresh weight of plant (g)	Dry weight of plant (g)
Level of RDF (F) (150:100:100 NPK kg/ha)					
(F_1) 75%	87.73	17.76	6.16	140.23	61.90
(F_2) 100%	94.26	20.02	6.66	159.07	70.92
S.Em±	0.542	0.165	0.048	0.900	0.432
C.D. at 5%	1.64	0.499	0.146	2.729	1.31
Level of bio-fertilizers (B)					
(B_0) No Bio-fertilizer	80.39	16.05	5.03	111.96	48.41
(B_1) Azotobacter	86.50	16.66	6.21	140.78	60.81
(B_2)Azotobacter + PSB	95.78	20.39	6.96	160.06	73.90
(B_3) Azotobacter + PSB +KMB	101.32	22.45	7.43	185.81	82.50
S.Em±	1.085	0.329	0.096	1.800	0.804
C.D. at 5%	3.29	0.998	0.291	5.458	2.62
Interaction (F x B)					
F_1B_0	78.93	15.88	4.85	109.75	43.37
F_1B_1	85.31	16.64	6.03	136.65	57.59
F_1B_2	89.64	19.00	6.70	147.25	67.17
F_1B_3	97.03	19.51	7.04	167.27	77.47
F_2B_0	81.85	16.23	5.22	114.18	51.45
F_2B_1	87.69	16.68	6.39	144.91	64.04
F_2B_2	101.92	21.79	7.23	172.86	80.64
F_2B_3	105.60	25.40	7.83	204.35	87.54
S.Em±	2.169	0.658	0.194	3.599	1.61
C.D. at 5%	NS	NS	NS	NS	NS

Table 2: Effect of chemical and bio-fertilizers on flowering and yield parameters on golden rod (Solidago canadensis L.) cv. "Local"

Treatments	Number of days taken for panicle initiation	Length of panicle (cm)	Number of panicle per plant	Vase life of panicle (days)
Level of RDF (F) (150:100:100 NPK kg/ha)				
(F_1) 75%	118.89	67.90	3.63	6.33
(F_2) 100%	112.92	73.90	3.98	6.72
S.Em. ±	0.566	0.455	0.021	0.037
C.D. at 5%	1.71	1.38	0.063	0.113
Level of bio-fertilizers (B)				
(B_0) No Bio-fertilizer	124.48	61.89	3.30	5.62
(B_1) Azotobacter	120.49	66.82	3.62	6.50
(B_2) Azotobacter + PSB	110.52	75.03	4.07	6.87
(B_3) Azotobacter + PSB + KMB	108.14	79.89	4.23	7.10

S.Em. ±	1.13	0.911	0.042	0.074
C.D. at 5%	3.58	2.76	0.127	0.226
Interaction (F x B)				
F_1B_0	125.62	60.48	3.23	5.39
F_1B_1	124.17	65.14	3.54	6.24
F_1B_2	113.53	70.70	3.79	6.75
F_1B_3	112.22	75.29	3.82	6.93
F_2B_0	123.33	63.23	3.37	5.85
F_2B_1	116.81	68.51	3.69	6.76
F_2B_2	107.50	79.35	4.35	6.98
F_2B_3	104.05	84.49	4.63	7.28
S.Em. ±	2.26	1.821	0.084	0.149
C.D. at 5%	NS	NS	0.253	NS

Table 3: Effect of chemical and bio-fertilizers on soil parameters on golden rod (*Solidago canadensis* L.) cv. "Local"

Treatments	Nitrogen (kg/ha)	Phosphorous (kg/ha)	Potassium (kg/ha)	Organic carbon (%)	Microbial count (CFU/ml) (Colonies $^{x}10^{-6}$)
Level of RDF (F) (150:100:100 NPK kg/ha)					
(F_1) 75%	168.32	12.93	260.77	0.657	50.34
(F_2) 100%	176.98	13.67	280.17	0.700	53.48
S.Em. ±	1.094	0.076	2.018	0.004	0.267
C.D. at 5%	NS	NS	NS	0.012	0.810
Level of bio-fertilizers (B)					
(B_0) No Bio-fertilizer	150.36	12.64	235.12	0.603	47.47
(B_1) Azotobacter	165.31	12.99	256.91	0.679	50.02
(B_2) Azotobacter + PSB	184.88	13.27	292.75	0.714	53.25
(B_3) Azotobacter + PSB + KMB	190.05	14.29	297.11	0.718	56.90
S.Em. ±	2.189	0.152	4.035	0.008	0.534
C.D. at 5%	6.638	NS	12.240	0.024	1.62
Interaction (F x B)					
F_1B_0	146.34	12.39	226.95	0.556	47.27
F_1B_1	158.07	12.96	245.30	0.652	50.19
F_1B_2	181.70	13.03	282.81	0.706	51.80
F_1B_3	187.17	13.32	288.04	0.716	51.70
F_2B_0	154.38	12.88	243.29	0.650	47.66
F_2B_1	172.56	13.01	268.52	0.705	49.85
F_2B_2	188.06	13.51	302.68	0.722	54.70
F_2B_3	192.93	15.26	306.17	0.721	62.10
S.Em. ±	4.377	0.303	8.071	0.016	1.03
C.D. at 5%	NS	NS	NS	NS	3.24

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