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Tanzeela Yaseen
Ph.D. Scholar, Division of Floriculture and Landscaping, SKUAST-K, Shalimar, Jammu and Kashmir, India

FU Khan
Professor, Division of Floriculture and Landscaping, SKUAST-K, Shalimar, Jammu and Kashmir, India

Raiz Ahmad Lone
Assistant Professor, Division of Floriculture and Landscaping, SKUAST-K, Shalimar, Jammu and Kashmir, India

Mohd Abass
Ph.D. Scholar, Division of Floriculture and Landscaping, SKUAST-K, Shalimar, Jammu and Kashmir, India

Divya Slathia
Assistant professor, Eternal University, Sirmour, Himachal Pradesh, India

Iqra Farooq
Ph.D. Scholar, Division of Floriculture and Landscaping, SKUAST-K, Shalimar, Jammu and Kashmir, India

Rahat
Assistant Professor, RIMT University, Punjab, India

Corresponding Author:
Tanzeela Yaseen
Ph.D. Scholar, Division of Floriculture and Landscaping, SKUAST-K, Shalimar, Jammu and Kashmir, India

Improving floral characteristics and yield of globe amaranth (*Gomphrena globosa* L.) through pinching and application of bio fertilizers and its impact on soil fertility

Tanzeela Yaseen, FU Khan, Raiz Ahmad Lone, Mohd Abass, Divya Slathia, Iqra Farooq and Rahat

Abstract
The research was carried out to evaluate the effect of pinching along with application of biofertilizers through seedling dip method in Globe amaranth and impact of biofertilizers on soil fertility. Pinching as main plot treatment with two levels P_0 (no pinching) and P_1 (Pinching) and biofertilizers as sub-plot treatment with eight levels B_0 (no biofertilizer), B_1 (*Azotobacter*), B_2 (PSB), B_3 (KSB), B_4 (*Azotobacter* + PSB), B_5 (*Azotobacter* + KSB), B_6 (PSB + KSB) and B_7 (*Azotobacter* + PSB + KSB). P_1recorded maximum fresh weight of flowers (114.39 g), seed yield per plant (19.65 g); seed yield per plot (176.87 g) and seed yield per hectare (13.27q). B_7 recorded maximum flower diameter (2.19 cm), fresh weight of flowers per plant (126.54 g), flower duration (54.29 days), number of seeds per flower head (73.88), 1000 seed weight (2.50 g), seed yield per plant (22.50 g), seed yield per plot (202.46 g) and seed yield per hectare (15.18 q). Maximum *Azotobacter*, PSB and KSB (CFU g^{-1}soilx 10^4) i.e. (44.12, 47.39 and 37.13) was recorded with treatment B_1 (*Azotobacter*), B_2 (PSB) and B_3 (KSB). Maximum available nitrogen, phosphorous and potassium (kg per ha) i.e. (297.70, 28.05, 215.50) was recorded with treatment B_1 (*Azotobacter*), B_2 (PSB) and B_5 (*Azotobacter* + KSB).

Keywords: Biofertilizers, pinching, globe amaranth, floral characteristics, soil, fertility and seed yield

Introduction
Globe amaranth (*Gomphrena globosa* L.) commonly known as Bachelor's button belongs to family *Amaranthaceae*, native to Central America including regions of Brazil, Panama and Guatemala. It is one of the most widely used dry flowers due to its everlasting nature besides for beds, borders and pots. The dried flowers are used in floral arrangements, indoor decoration and for value added products. The plant fixes carbon through the C_4 pathway. Globe amaranth is of immense value due to its medicinal properties. The flowers are rich in antioxidants and were used in folk remedy for baby gripe, cough and diabetes. The flowers also contain betacyanins which can be useful for the food industry, cosmetics, and livestock feed. Application of various horticultural practices like pinching can be used to increase yield and prolong bloom. Apical dominance is a phenomenon in which main stem is dominant over lateral. The apical bud produces auxins (IAA) that inhibits the growth of lateral buds, however if apical portion of shoot is removed at early stage, it counteracts the effect of apical dominance. Also most of the Indian soils lack proper balance of nutrients present in available form for plant uptake. Inorganic or chemical fertilizers besides being costly deteriorate soil health, ground water and environment. Nowadays, lot of emphasis is being given on the use of bio-fertilizers, as it is not only low cost input but also gives high returns and is eco-friendly. Bio-fertilizers usually consist of preparations containing live or latent cells of efficient strains of micro-organisms which include biological nitrogen fixers, Phosphorous and potash solubilisers/ mobilisers. Use of bio-fertilizers reduces per unit consumption of inorganic fertilizers and increases the quality and quantity of flowers (Syamal *et al.* 2006) [18]. Thus the standard horticultural practices eg; Pinching along with the application of biofertilizers can play important role in improving vegetative growth, flowering and seed yield in Globe amaranth.

Material and Methods
This experiment was conducted at main campus of Sher-e-Kashmir University of Agriculture

Sciences and Technology of Kashmir in the Experimental farm (Division of Floriculture and Landscape Architecture). It is located in Shalimar, Srinagar 16 kms away from city centre (34^0 05′ N latitude and 74^0 98′ E longitude)at an altitude of 1587 meters above mean sea level having a Temperate-cum-Mediterranean and continental type climate characterized by hot summer and severe winters. The average annual precipitation is 944.6 mm (over past thirty years). More than 80% of precipitation is received from western disturbances. The experiment consisted of main plot treatment *viz* Pinching having 02 levels, P_0 (No pinching) and P_1 (Pinching); and sub-plot treatment *viz* Biofertilizers having 08 levels, B_0 (No biofertilizer), B_1 (*Azotobacter*), B_2 (Phosphate solubilising bacteria) B_3 (Potassium solubilising bacteria), B_4 (*Azotobacter* + PSB), B_5 (*Azotobacter* + KSB), B_6 (PSB + KSB) and B_7 (*Azotobacter* + PSB + KSB) with a total of 16 treatment combinations ($T_1= P_0B_0$, $T_2 = P_0B_1$, $T_3= P_0B_2$, $T_4 = P_0B_3$, $T_5= P_0B_4$, $T_6 = P_0B_5$, $T_7 = P_0B_6$, $T_8 = P_0B_7$, $T_9 = P_1B_0$, $T_{10} = P_1B_1$, $T_{11}= P_1B_2$, $T_{12} = P_1B_3$, $T_{13} = P_1B_4$, $T_{14} = P_1B_5$, $T_{15} = P_1B_6$, $T_{16} = P_1B_7$) replicated three times in Split Plot Design. All cultural operations were uniformly followed as per the standard practices. For biofertilizer application root portion of seedlings was dipped in a solution of biofertilizers (1000 ml of water) for 30 minutes before transplanting. Transplanting was done during evening, disease free seedlings of uniform size and vigour at 5-6 leaf stage were selected and sown in beds with row to row and plant to plant spacing of 30 × 40 cm accommodating 9 plants/m^2. Pinching was carried out 20 days after transplanting. In the current study data on flower diameter (cm), fresh weight of flowers per plant (g), flower duration (day), number of seeds per flower head, seed yield plant^{-1}, seed yield plot^{-1} (g), seed yield hectare^{-1} (q) and 1000-seed weight (g) are reported.

Results and Discussion

Effect on floral characteristics

Table 1. Consists the data recorded on fresh weight of flowers per plant (g). The data revealed that P_1 (pinching) recorded maximum fresh weight of flowers per plant (114.39 g). Increased Pinching arrested apical dominance which diverted plant metabolites from vertical to horizontal growth resulting in increased number of lateral branches per plant which ultimately leads to increase in number of flowers and thus fresh weight of flowers per plant. Similar results were reported by Dweepjyoti *et al.* (2018) [3] and Sheena *et al.* (2017). [7] Among different biofertilizers mean maximum fresh weight of flowers per plant i.e. (126.54 g) was recorded with B_7 (*Azotobacter* + PSB + KSB).Proper uptake of nutrients, enhanced nitrogen fixation, increased availability of phosphorous and mobilisation of potassium through *Azotobacter*, PSB and KSB improved growth and quality of flowers. Also increased growth stimulating substances like cytokinins lead to vigorous growth of the plant. More photosynthesis and enhanced food accumulation subsequently resulted in higher number of flowers and thus increased fresh weight of flowers per plant. These results are in close agreement with the findings of Vaishali *et al.* (2018) [19] and Sheergojri *et al.* (2013) [15].

The data recorded on flower duration (day) showed that P_0 (no pinching) recorded maximum flower duration (52.10 days). Arresting of apical dominance by removing of apical buds, plant again entered into vegetative phase due to which new shoots took more days to become physiologically mature and to stimulate buds which resulted in shorter flower duration. Prakash *et al* (2016) [11] and Mohanty *et al.* (2015) [6]. Again maximum flower duration i.e. (54.29 days) was recorded with B_7 (*Azotobacter* + PSB + KSB).Due to better availability and uptake of nutrients and also secretion of growth promoting hormones enhanced plant metabolic activities. This in turn increased photosynthetic activity and thus accumulation of more carbohydrates towards the sink. Yadav *et al.* (2017) [20] had the same results.

The data presented showed that P_0 (no pinching) recorded maximum flower diameter (2.17 cm). This might be due to less number of flowers thus larger in size. Among different biofertilizers mean maximum flower diameter i.e. (2.19 cm) was recorded with B_7 (*Azotobacter* + PSB + KSB) which was statistically at par with B_6 (PSB + KSB) i.e. (2.18 cm) and B_4 (*Azotobacter* + PSB) i.e. (2.17 cm). The proper uptake of nutrients ultimately resulted in maximum flower diameter. Vaishali *et al.* (2018) [19] and Sheergojri *et al.* (2013) [15] obtained similar results.

Seed yield characteristics

The data presented in Table1. Indicated that P_0 (no pinching) resulted in maximum number of seeds per flower head and 1000-seed weight (g) i.e. (73.04 and 2.48). It is attributed to the fact that less number of flowers was produced in no pinching treatments as compared to pinching, resulting in accumulation of more photosynthates which were utilized for production of more dry matter which lead to increase in size of flower, holding bigger and more number of seeds. However in pinched plants accumulation of photosynthates were utilized for production of more number of lateral branches and flowers. Thus the sharing of photo assimilates among increased number of branches in pinched plants resulted in comparatively less number of seeds per flower head and 1000-seed weight (g). Similar results were obtained by Prakash *et al.* (2016) [11].

Among biofertilizers mean maximum number of seeds per flower head and 1000-seed weight (g) i.e. (73.88 and 2.50) was recorded with B_7 (*Azotobacter* + PSB + KSB).Increased nitrogen fixation by *Azotobacter*, and the role of PSB and KSB to solubilize fixed phosphorous and mobilize potassium in the soil resulted in better availability and uptake of nutrients. Also secretion of growth promoting hormones enhanced plant metabolic activities. This in turn increased photosynthetic activity and thus accumulation of more carbohydrates towards the sink. These results are in close agreement with the findings of Yadav *et al.* (2017) [20], Syamal *et al.* (2006) [18]

The perusal of data indicated that P_1 (pinching) recorded maximum seed yield plant^{-1}(g), plot^{-1} (g) and hectare^{-1} (q) i.e. (19.65 g, 176.87 g and 13.27 q).The increase in seed yield is due to arresting of apical dominance by pinching of plants which resulted in more number of branches, more number of flowers per plant which ultimately increased seed yield. Thus we can say that there was proportionate increase in yield-contributing characters which was also reported by Parhi *et al.* (2016) [9].

Among different biofertilizers mean maximum seed yield plant^{-1}, plot^{-1} (g) and hectare^{-1} (q) i.e. (22.50 g, 202.46 g and 15.18 q) was recorded with B_7 (*Azotobacter* + PSB + KSB) which might have resulted due to enhanced nitrogen fixation. Nitrogen plays an important role in increase in seed yield; it's an important component of protein, nucleic acids and chlorophyll. Availability of Phosphorous and potassium, proper root growth for uptake of other nutrients were some other factors. The results are similar with those of Yadav *et al.* (2017) [20] and Singh *et al.* (2015) [17]. Table2. Consists the data which showed the interaction of pinching and biofertilizers and its effect on various flower characters. The data revealed no significant effect however the interaction was found to be beneficial in improving various floral characteristics and seed yield.

Biological and physicochemical properties of soil

The data pertaining to biological and physicochemical properties of soil as effected by different treatments is presented in Table 3. Maximum *Azotobacter*, PSB and KSB (CFU g^{-1}soilx 10^4) i.e. (44.12, 47.39 and 37.13) was recorded with treatment B_1 (*Azotobacter*), B_2 (PSB) and B_3 (KSB) whereas minimum *Azotobacter*, PSB and KSB (CFU g^{-1}soilx 10^4) i.e. (17.99, 29.55 and 22.76) was recorded with B_0 (no biofertilizer).This might be due to the fact that application of biofertilizers increased the bacterial population by colonizing the soil rhizosphere. These findings are supported by Patrick (2016) [10]

The data presented in Table 3. revealed that there was no significant influence of treatments on soil pH, EC(dSm^{-1}) and Organic carbon (%). However, slight change in pH due to application of biofertilizers. This might be attributed to the secretion of certain organic acids by microorganisms which may also decrease the soil pH. These findings are supported by Ramalakshmi *et al.* (2008) [14] and Babu *et al.* (2007) [1]. Also slight increase in E.C (dS m^{-1}) was observed due to increase in the microbial population in root zone which enhanced microbial decomposition of organic matter Prasanna (2012) [12].

Maximum available nitrogen (297.70 kg ha^1) was recorded with treatment B_1 (*Azotobacter*) which was statistically at par with B_4 (*Azotobacter* + PSB) i.e. (294.67 kg ha^1). *Azotobacter* is a free-living bacterium which may add 20-30 kg N per ha in a field of non-legume crop through nitrogen fixation by utilizing carbon for its metabolism under favourable conditions Naseri and Mirzaei (2010) [8].

Maximum available phosphorous (28.05 kg ha^1) was recorded with treatment B_2 (PSB) which was statistically at par with B_6 (PSB + KSB) i.e. (27.08 kg ha^1).This might be due to solubilisation of phosphorous by PSB through secretion of organic acids. These acids act as chelating agents and form stable complexes with Fe and Al, thus releasing unavailable forms of P to the soil making it available for uptake by plants. Barman *et al.* (2003) [2] in tuberose and Hu *et al.* (2006) [5]

Maximum available potassium was recorded with treatment B_5 (*Azotobacter* + KSB) i.e. (215.50 kg ha^1) which was statistically at par with B_6 (PSB+ KSB) i.e. (214.14 kg ha^1). This might be due to mineralisation of unavailable form of K due to inoculation with KSB which has significantly increased the K content in rhizosphere of the soil. KSB were capable of solubilizing rock K, synthetic K through production of organic acids and enzymes. Friedrich *et al.* (2004) [4] and Sheng *et al.* (2005) [16]

Table 1: Effect of pinching and biofertilizer application on floral characters and seed yield in Globe amaranth (*Gomphrena globosa* L.)

Treatment	Flower diameter (cm)	Fresh weight of flowers $plant^{-1}$ (g)	Flower duration (day)	Number of seeds flower $head^{-1}$	Seed yield $plant^{-1}$ (g)	Seed yield $plot^{-1}$ $(g)^1$	Seed yield ha^{-1} (q)	1000-seed weight (g)
Main Plot –Pinching								
No pinching (P_0)	2.17	108.10	52.10	73.04	18.91	170.17	12.73	2.48
Pinching (P_1)	2.11	114.39	49.20	69.24	19.65	176.87	13.27	2.44
CD ($P_{\leq 0.05}$)	0.04	3.18	1.18	1.62	0.96	11.31	0.85	0.05
Sub Plot – Biofertilizers								
No biofertilizer (B_0)	2.04	88.46	46.22	67.24	14.76	132.63	9.95	2.43
Azotobacter (B_1)	2.14	100.96	47.81	69.81	17.73	159.57	11.93	2.44
PSB (B_2)	2.16	106.13	49.59	69.41	18.62	167.58	12.57	2.46
KSB (B_3)	2.14	111.36	50.63	71.32	18.51	166.55	12.50	2.45
Azotobacter+PSB (B_4)	2.17	121.93	51.33	72.25	21.30	191.17	14.38	2.49
Azotobacter+KSB (B_5)	2.16	118.23	52.18	72.43	20.48	184.32	13.87	2.48
PSB+KSB (B_6)	2.18	116.34	53.16	72.81	20.38	183.38	13.70	2.49
Azotobacter+PSB+KSB (B_7)	2.19	126.54	54.29	73.89	22.50	202.46	15.18	2.50
CD ($P_{\leq 0.05}$)	0.02	3.49	0.85	1.47	1.22	10.94	0.82	0.05

Table 2: Interaction effect of pinching and biofertilizer application on floral characters and seed yield in Globe amaranth (*Gomphrena globosa* L.)

Treatment	Flower diameter (cm)	Fresh weight of flowers $plant^{-1}$ (g)	Flower duration (day)	Number of seeds flower $head^{-1}$	Seed yield $plant^{-1}$ (g)	Seed yield $plot^{-1}$ $(g)^1$	Seed yield ha^{-1} (q)	1000-seed weight (g)
P_0 B_0	2.10	86.68	47.67	69.47	14.64	131.55	9.74	2.44
P_0 B_1	2.17	97.57	48.91	71.73	17.34	156.14	11.70	2.45
P_0 B_2	2.18	100.82	50.76	71.33	18.14	163.26	12.24	2.47
P_0 B_3	2.16	107.92	52.07	73.60	18.20	163.80	12.29	2.47
P_0 B_4	2.20	119.70	52.88	74.16	21.00	189.00	14.08	2.51
P_0B_5	2.18	116.03	53.86	74.21	20.14	181.26	13.59	2.51
P_0B_6	2.20	113.04	54.66	74.55	19.80	178.20	13.36	2.52
P_0B_7	2.21	123.05	55.96	75.29	22.02	198.18	14.86	2.53
P_1B_0	1.97	90.23	44.77	65.00	14.87	133.70	10.15	2.42
P_1B_1	2.12	104.36	46.70	67.89	18.11	162.99	12.15	2.43
P_1B_2	2.13	111.44	48.43	67.48	19.10	171.90	12.89	2.44
P_1B_3	2.11	114.79	49.19	69.04	18.81	169.29	12.70	2.43

P_1B_4	2.14	124.16	49.77	70.35	21.60	194.40	14.58	2.46
P_1B_5	2.14	120.43	50.51	70.64	20.82	187.38	14.15	2.45
P_1B_6	2.15	119.65	51.65	71.07	20.95	188.55	14.04	2.46
P_1B_7	2.17	130.03	52.61	72.48	22.97	206.73	15.50	2.47
CD ($P_{\leq 0.05}$)	0.01	N.S	N.S	1.01	1.95	13.49	1.31	N.S

Fig 1: Biofertilizer treatment to seedlings

Fig 2: 1000-seed weight (g)

Fig 3: Globe amaranth (*Gomphrena globosa* L.) at full bloom stage

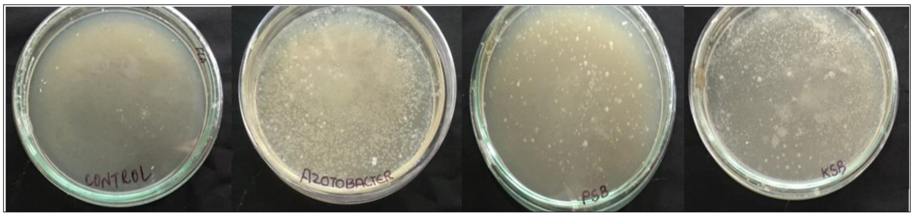

Fig 5: Colonies of different bacteria (*Azotobacter*, PSB and KSB)

Table 3: Effect of pinching and biofertilizers application on biological and physicochemical properties of soil

sTreatment	*Azotobacter* sp. (CFU g^{-1} soilx 10^4)	PSB (CFU g^{-1} soilx 10^4)	KSB (CFU g^{-1}soilx 10^4)	Soil pH	Soil EC (ds m^{-1})	Organic carbon (%)	Available nitrogen (kg ha^1)	Available phosphorous (kg ha^1)	Available potassium (kg ha^1)
Main Plot –Pinching									
No pinching (P_0)	32.99	37.88	32.70	6.66	0.17	0.70	292.50	24.50	206.99
Pinching (P_1)	32.39	37.95	32.44	6.65	0.18	0.70	292.96	24.57	206.04
CD ($P_{\leq 0.05}$)	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S	N.S
Sub Plot – Biofertilizers									
No biofertilizer (B_0)	17.99	29.55	22.76	6.65	0.15	0.68	288.74	20.53	197.57
Azotobacter (B_1)	44.12	33.98	32.94	6.64	0.17	0.71	297.70	22.18	200.75
PSB (B_2)	28.07	47.39	31.30	6.66	0.16	0.70	293.02	28.05	199.99
KSB (B_3)	27.20	31.94	37.13	6.68	0.17	0.70	291.50	23.13	214.00
Azotobacter + PSB (B_4)	41.41	43.42	31.86	6.64	0.18	0.70	294.67	26.08	201.17
Azotobacter + KSB (B_5)	37.69	31.79	35.35	6.68	0.18	0.70	293.44	23.01	215.50
PSB+KSB (B_6)	26.81	43.38	35.62	6.62	0.19	0.71	290.82	27.08	214.14
Azotobacter + PSB+KSB (B_7)	38.23	41.87	33.60	6.65	0.19	0.70	291.94	26.19	213.00
CD ($P_{\leq 0.05}$)	1.58	1.71	1.50	N.S	N.S	N.S	3.03	0.98	1.53

Conclusion

Through simple cultural practices like pinching, flower yield could be increased. Pinching 20 days after transplanting in Globe amaranth had significant effect on number of flowers per plant and seed yield. It resulted in the production of uniform flowers and compact growth. Biofertilizer treatment B_7 (Azotobacter + PSB + KSB) was significantly superior than other biofertilizer treatments. Application of Biofertilizers as seed inoculant, proliferated and contributed to nutrient cycling which promoted soil fertility and enhanced crop yield. Also Interaction effect of P_1 (pinching) and B_7 (*Azotobacter* + PSB + KSB) was found beneficial in improving various floral characteristics and yield. Considering the cost-effective and eco-friendly nature of biofertilizers, more research should be carried out to identify potential strains.

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