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Effect of biochar, humic acid and microbial consortia on flowering parameters of African marigold (*Tagetes erecta* L.) cv. 'Bidhan-2'

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Abstract
The present investigation was carried out at the Horticultural Research Station, Mahanandi, Dr. Y.S.R. Horticultural University during the summer season of 2021 and 2022. The experiment was carried out with three factors and two replications in a randomized block design with factorial concept to study their individual and combined influences on certain floral parameters in marigold. Among the individual treatments, soil application of biochar @ 10 t ha^{-1}, humic acid @ 4 kg ha^{-1} and *Azospirillum* @ 5 kg ha^{-1} in combination with PSB @ 5 kg ha^{-1} and *Bacillus spp.* @ 5 kg ha^{-1} recorded significantly lowest number of days to flower bud emergence, first flower opening and peak flowering in marigold and the same treatments recorded significantly highest number of days to flower senescence on the plant during 2021, 2022 and the pooled data mean in marigold in comparison to all other treatments. Among the two combination treatments, soil application of graded levels of biochar and humic acid, biochar and different microbial consortia, humic acid levels and different microbial consortia recorded significantly lowest number of days to flower bud emergence, first flower opening and peak flowering of marigold. Among the three combination treatments, soil application of biochar @ 10 t ha^{-1} in combination with humic acid @ 4 kg ha^{-1} and either of the microbial consortia recorded on par results *i.e.*, soil application of biochar @ 10 t ha^{-1} in combination with humic acid @ 4 kg ha^{-1} and *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + *Bacillus* spp. @ 5 kg ha^{-1} recorded significantly lowest number of days to first flower opening during the year 2021 and in the pooled data mean and number of days to peak flowering during 2021, 2022 and the pooled data mean, whereas the same treatment with Arka Microbial Consortium @ 15 kg ha^{-1} recorded significantly early flower bud emergence in marigold during the year 2022.

Keywords: Marigold, biochar, humic acid, biofertilizers, flower bud emergence

Introduction
African marigold (*Tagetes erecta* L.), a member of the Asteraceae family is a potential commercial flower crop grown in Andhra Pradesh for its loose flowers. Day-to-day, the crop is gaining popularity on account of its flowers used in various ways specially for garland making, veni making, for the extraction of xanthophylls, a pigment and a secondary metabolite from the petals of flower. Most of the marigold cultivars available at present do not have the tolerance or resistance to high temperature prevailing during summer months. Hence, its cultivation during summer was negligible due to lower production of quality flowers. Further, availability of varieties which are able to tolerate/resist the high temperature during summer months is the major concern. Keeping this lacuna in view, recently Bidhan Chandra Krishi Viswavidyalaya, Mohanpur has developed a marigold variety named as 'Bidhan-2' which has tolerance to high temperatures. 'Bidhan-2' was confirmed to be a heat tolerant cultivar and hence suggested for year-round cultivation under West Bengal conditions. The present investigation was aimed to fill the research gap and to make the availability of quality marigold flowers during summer season under Nandyal region *i.e.,* in the scarce rainfall zone of Rayalaseema region, Andhra Pradesh by raising a summer tolerant marigold cultivar 'Bidhan-2' in combination with incorporation of certain abiotic stress ameliorative substances in the soil *viz.,* biochar, humic acid and microbial consortia.

Materials and Methods
The present investigation was carried out at the Horticultural Research Station, Mahanandi, a constituent research institute of Dr. Y.S.R. Horticultural University near Nandyal of Rayalaseema zone during the summer season of 2021 and 2022.

The marigold variety selected was orange coloured 'Bidhan-2' and the experiment was laid out in a Randomized Block Design with factorial concept and replicated twice. The data were subjected to statistical analysis of variance for randomized block design with factorial concept as suggested by Panse and Sukhatme (1967) [1]. Just before transplanting of marigold seedlings, applied the unchared (rice-straw shreds) material @ 5 tonnes per hectare to all the treatments uniformly and the recommended dose of fertilizers @ 80% in the form of calcium ammonium nitrate, single super phosphate and muriate of potash to all the treatments. The entire dose of phosphorus was applied as a basal dose just before planting, whereas nitrogen and potassium were applied in five splits at an interval of 15 days from the day of transplanting. Graded levels of biochar, humic acid along with microbial consortia in the forms of Arka Microbial Consortium – a product of ICAR-Indian Institute of Horticultural Research, Hesseraghatta and a consortium of different individual microbial cultures *viz.*, *Azospirillum*, Phosphorous Solubilising Bacteria and *Bacillus* spp. (K solubilizing bacteria) were applied just before transplanting of seedlings according to the treatment combinations fixed. The experiment consisted of 18 treatment combinations comprising of rice-straw biochar (BC_0: No biochar, BC_1: 5 t ha^{-1} and BC_2: 10 t ha^{-1}), humic acid (HA_1: 2 kg ha^{-1} and HA_2: 4 kg ha^{-1}) and different microbial consortia (MC_0: No microbial consortium, MC_1 : Arka Microbial Consortium @ 15 kg ha^{-1} and MC_2: *Azospirillum* @ 5 kg ha^{-1} + PSB (*Phosphorus Solubilizing Bacteria*) @ 5 kg ha^{-1} + *Bacillus spp.* @ 5 kg ha^{-1}). The observations on the floral parameters like number of days to first flower bud initiation, number of days to first flower opening, number of days to peak flowering, number of days to first flower harvest, etc., were counted from the date of transplanting to the date of flower opening and to the date of almost 100% flowering respectively in each plot and the average was expressed as number of days. Number of days to first flower senescence on the plant was calculated as number of days taken from the date of flower bud emergence to the date on which senescence was noticed on the plant and the average was expressed as number of days.

Results and Discussion

Data pertaining to the influence of graded levels of biochar, humic acid, microbial consortia and their interaction effects on number of days to flower bud emergence, first flower opening, peak flowering and flower senescence on the plant were presented in Tables 1, 2, 3 and 4. Significant differences were noticed in the data with regard to number of days to flower bud emergence, first flower opening, peak flowering and flower senescence on the plant by soil application of graded levels of biochar, humic acid, different microbial consortia and their interaction effects.

Among the graded levels, soil application of biochar @ 10 t ha^{-1} recorded significantly lowest number of days to flower bud emergence (38.14, 37.62 and 37.88 DAT respectively during 2021, 2022 and the pooled data mean), first flower opening (46.11, 45.60 and 45.86 DAT respectively during 2021, 2022 and the pooled data mean) and peak flowering (73.94, 73.67 and 73.80 DAT respectively during 2021, 2022 and the pooled data mean) in marigold, whereas no biochar applied in soil recorded significantly highest number of days to flower bud emergence (42.58, 41.94 and 42.26 DAT respectively during 2021, 2022 and the pooled data mean), first flower opening (50.63, 50.18 and 50.40 DAT respectively during 2021, 2022 and the pooled data mean) and peak flowering (78.66, 78.53 and78.60 DAT respectively during 2021, 2022 and the pooled data mean). With regard to flower senescence on the plant, it was noticed that soil application of biochar @ 10 t ha^{-1} recorded significantly highest number of days to flower senescence (16.64, 17.24 and 16.94 days respectively during 2021, 2022 and the pooled data mean) in marigold, whereas no biochar applied in soil recorded significantly lowest number of days to flower senescence (14.77, 15.25 and 15.01 days respectively during 2021, 2022 and the pooled data mean). Based on the critical analysis of these results, it may be concluded that soil application of higher quantity of biochar enhanced the root proliferation thus improved the absorption of water and nutrients from soil. Improved water and nutrients uptake into the plant might have enhanced the rate of photosynthesis thus accumulated more quantity of photosynthates in the plant encouraged early growth and development in marigold thereby recorded early flower bud initiation, flower opening, peak flowering and delayed flower senescence on the plant. Khalil and Seleem (2018) [2] reported significantly lowest number of days to first flower opening in *Dimorphotheca ecklonis* by application of biochar. The present results were found in agreement with the earlier reports of Altaf *et al.* (2020) [3] in potted stock (*Matthiola incana*).

Significant variation was observed in the data pertaining to number of days taken to flower bud emergence in marigold cv. 'Bidhan-2' by soil application of graded levels of humic acid. In between the two levels, soil application of humic acid @ 4 kg ha^{-1} recorded significantly early flower bud emergence (39.14, 38.56 and 38.85 DAT respectively during 2021, 2022 and the pooled data mean), lowest number of days to first flower opening (47.13, 46.64 and 46.88 DAT respectively during 2021, 2022 and the pooled data mean), lowest number of days to peak flowering (75.09, 74.92 and 75.01 DAT respectively during 2021, 2022 and the pooled data mean) and highest number of days to flower senescence on the plant (16.13, 16.67 and 16.40 days respectively during 2021, 2022 and the pooled data mean) in marigold, whereas soil application of humic acid @ 2 kg ha^{-1} recorded significantly late flower bud emergence (41.87, 41.28 and 41.58 respectively during 2021, 2022 and the pooled data mean), highest number of days to first flower opening (49.88, 49.51 and 49.70 DAT respectively during 2021, 2022 and the pooled data mean), highest number of days to peak flowering (77.85, 77.66 and 77.76 DAT respectively during 2021, 2022 and the pooled data mean) and lowest number of days to flower senescence on the plant (15.25, 15.79 and 15.52 days respectively during 2021, 2022 and the pooled data mean). Based on the critical analysis of these results, it may be concluded that soil application of higher concentration of humic acid might have created the better environment in comparison to lower quantity of humic acid in the increased production of chlorophylls content in marigold, thus promoted the rate of photosynthesis in plant through increased absorption of moisture and nutrients from soil. The present result could be corroborated with the earlier findings of Ali *et al.* (2014) [4] in tulip and Marihus *et al.* (2012) [5] in gladiolus who reported earliness in flower bud emergence and flower opening by application of humic acid. Memon *et al.* (2014) [6] observed early flower bud emergence in *Zinnia* with increased dose of humic acid application. Further, the present result has also been found in accordance with the earlier findings of Ghosh *et al.* (2022) [7] in marigold. Kulikova *et al.* (2005) [8] explained that auxin like activity of humic acid enhanced the absorption of nutrients from soil thereby enhanced the floral growth and shelf life of flower. Presence of calcium in humic acid might have reduced the rate of respiration in the floral tissue thereby reduced the membrane permeability in cellular system thus increased the membrane integrity and turgidity of the floral tissue thereby delayed the floral senescence and prevented the cellular disintegration in marigold. Further, it might also be due to enhanced synthesis of nucleic acids and proteins.

Among the different microbial consortia applied in soil, *Azospirillum* @ 5 kg ha^{-1} in combination with PSB @ 5 kg ha^{-1} and *Bacillus spp.* @ 5 kg ha^{-1} recorded significantly lowest number of days to flower bud emergence (39.84, 39.30 and 39.57 DAT respectively during 2021, 2022 and the pooled data mean), lowest number of days to first flower opening (47.86, 47.40 and 47.63 DAT respectively during 2021, 2022 and the pooled data mean), lowest number of days to peak flowering (75.60, 75.53 and 75.57 DAT respectively during 2021, 2022 and the pooled data mean) and highest number of days to flower senescence on the plant (16.63 and 16.36 days respectively during 2022 and the pooled data mean) in marigold, whereas no microbial consortia applied in soil recorded significantly more number of days to flower bud emergence (41.51, 40.99 and 41.25 DAT respectively during 2021, 2022 and pooled data mean), highest number of days to first flower opening (49.61, 49.11 and 49.36 DAT respectively during 2021, 2022 and pooled data mean), highest number of days to peak flowering (77.61, 77.42 and 77.51 DAT respectively during 2021, 2022 and pooled data mean) and lowest number of days to first flower senescence on the plant (15.71 and 15.46 days respectively during 2022 and pooled data mean). Soil application of Arka Microbial Consortium @ 15 kg ha^{-1} was found moderate in between the above two treatments for majority of the parameters recorded during the investigation. Earliness noticed in flower bud emergence, first flower opening, peak flowering of marigold and delayed senescence of flowers on the plant might be due to enhanced rate of absorption of nutrients through fixation of atmospheric nitrogen, solubilization of phosphorous and potassium in soil by application of different microbial cultures consortium in comparison to no microbial consortia as well as the Arka Microbial Consortium applied. Further, soil application of biofertilizers increased the production of growth promoting substances like auxins, gibberellins, cytokinins, vitamins and organic acids through increased microbial activity in soil. Adequate supply of phosphorus during the early stages of crop growth has been found important in laying down the primordia for reproductive parts of the plant, thus helped in early maturity of crop. Further, it helped in quick mobilization of photosynthates from source to sink thereby early transformation from vegetative phase to reproductive phase in the plant. The present results have been found in accordance with the earlier findings published by Parolekar *et al.* (2012) [9] in tuberose and Kumari *et al.* (2019) [10] in marigold. Palagani *et al.* (2013) [11] and Pandey *et al.* (2018 [12] reported significantly early flower opening in *Chrysanthemum.*

Among the treatments, soil application of biochar @ 10 t ha^{-1} in combination with humic acid @ 4 kg ha^{-1} recorded significantly early flower bud emergence (37.62, 37.00 and 37.31 DAT respectively recorded during 2021, 2022 and the pooled data mean), lowest number of days to first flower opening (45.45, 45.07 and 45.26 DAT respectively recorded during 2021, 2022 and the pooled data mean) and lowest number of days to peak flowering (73.36, 73.09 and 73.22 DAT respectively recorded during 2021, 2022 and the pooled data mean) in marigold, whereas soil application of humic acid @ 2 kg ha^{-1} alone without biochar recorded significantly late flower bud emergence (44.05, 43.28 and 43.67 DAT respectively during 2021, 2022 and the pooled data mean), highest number of days to first flower opening (51.92, 51.79 and 51.86 DAT respectively during 2021, 2022 and the pooled data mean) and highest number of days to peak flowering (80.10, 79.95 and 80.03 DAT respectively during 2021, 2022 and the pooled data mean). However, number of days to flower senescence on the plant was found non-significant during both the years of study as well as in the pooled data mean. Based on the critical analysis of these results, it may be concluded that soil application of higher quantities of biochar and humic acid in combination, significantly influenced the early flower bud emergence, number of days to flower opening and number of days to peak flowering in marigold. This may be attributed to improved soil physical, chemical and biological properties which in turn enhanced the plant's access to soil resources such as water and nutrients. Karimi *et al.* (2020) [13] recorded significantly lowest number of days to flower bud emergence and early flower opening in calendula by combined application of biochar and humic acid at their higher rates.

Significant changes were noticed in the flower bud emergence of marigold by combined soil application of graded levels of biochar and different microbial consortia during 2nd year of study and the pooled data analysis, whereas the data were found non-significant during 1st year of study *i.e.*, 2021. Among the different treatment combinations, soil application of biochar @ 10 t ha^{-1} in combination with *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + *Bacillus spp.* @ 5 kg ha^{-1} recorded significantly early flower bud emergence (36.50 and 36.84 DAT respectively during 2022 and the pooled data mean), lowest number of days to first flower opening (45.10, 44.57 and 44.84 DAT respectively during 2021, 2022 and the pooled data mean) and lowest number of days to peak flowering (72.58, 72.51 and 72.55 DAT respectively during 2021, 2022 and the pooled data mean) in marigold, whereas no soil application of biochar and microbial consortia recorded significantly late flower bud emergence (42.40 and 42.80 DAT respectively during 2022 and the pooled data mean), highest number of days to first flower opening (51.19, 50.75 and 50.97 DAT respectively during 2021, 2022 and the pooled data mean) and highest number of days to peak flowering (79.35, 79.10 and 79.23 DAT respectively during 2021, 2022 and the pooled data mean). However, non-significant differences were noticed in the flower senescence on the plant during both the years of study as well as in the pooled data mean. Based on the critical analysis of these results, it may be concluded that soil application of different individual microbial cultures consortia in the presence of higher amount of biochar recorded a compositive impact on early flower bud emergence, early flower opening and early peak flowering in marigold, which might be attributed to the improved physical, chemical and biological properties of soil which in turn enhanced the plant's access to soil resources such as water and nutrients. Soil application of biochar in combination with microbial consortium might have altered the C:N ratio in better way which helped in the maintenance of balanced vegetative and reproductive phases, thereby promoted early flowering.

Among the treatments, soil application of humic acid @ 4 kg ha^{-1} in combination with Arka Microbial Consortium @ 15 kg ha^{-1} recorded significantly early flower bud emergence (38.44, 37.69 and 38.06 DAT respectively during 2021, 2022 and the pooled data mean) and lowest number of days to peak flowering (74.43, 74.21 and 74.32 DAT respectively during 2021, 2022 and the pooled data mean) in marigold, however soil application of humic acid @ 4 kg ha^{-1} in combination with *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + *Bacillus spp.* @ 5 kg ha^{-1} recorded significantly lowest number of days to first flower opening (46.66, 46.15 and 46.40 DAT respectively during 2021, 2022 and the pooled data mean). Soil application of humic acid @ 2 kg ha^{-1} only without any microbial consortia recorded significantly highest number of days to flower bud emergence (42.77, 42.18 and 42.48 DAT respectively during 2021, 2022 and the pooled data mean), highest number of days to first flower opening (50.78, 50.42 and 50.60 DAT respectively during 2021, 2022 and the pooled data mean) and highest number of days to peak flowering (78.84, 78.56 and 78.70 DAT respectively during 2021, 2022 and the pooled data mean). Non-significant differences were noticed in number of days to flower senescence on the plant during both the years of study as well as in the pooled data mean. Based on the critical analysis of these results, it may be concluded that early flower bud emergence with lowest number of days to peak flowering in marigold was noticed during summer by soil application of higher quantity of humic acid in combination with Arka Microbial Consortia. But, soil application of higher quantity of humic acid in combination with different individual microbial cultures consortium recorded significantly lowest number of days to first flower opening. It may be attributed that soil application of higher quantity of humic acid in combination with either of the microbial consortium increased the absorption of moisture and nutrients from soil thus maintained balanced nutrition to the plant. The present result obtained in marigold could be corroborated with the earlier findings of Sharukhkhan (2019) [14] in *Chrysanthemum* by soil application of Arka Microbial Consortium. Several research workers reported that better source-sink relation is the most essential for faster mobilization of photosynthates in the plant thereby early transformation may take place from vegetative to reproductive phase, as noticed in *Chrysanthemum* (Airadevi, 2014) [15] and marigold (Rathi *et al.*, 2005) [16].

Significant differences were noticed in the interaction effects of data with regard to number of days to flower bud emergence in marigold by soil application of graded levels of biochar, humic acid and different microbial consortia during 2nd year of study *i.e.*, 2022 only, whereas the data were found non-significant during 1st year of study *i.e.*, 2021 and in the pooled data mean. Among the treatments, soil application of biochar @ 10 t ha^{-1} in combination with humic acid @ 4 kg ha^{-1} and Arka Microbial Consortium @ 15 kg ha^{-1} recorded significantly early flower bud emergence (36.03 DAT during 2022) in marigold, whereas soil application of humic acid @ 2 kg ha^{-1} only without application of any biochar and microbial consortia recorded significantly late flower bud emergence (46.67 DAT during 2022). Significant differences were noticed in the data among the interaction effects of soil application of graded levels of biochar, humic acid and different microbial consortia with respect to number of days to first flower opening in marigold during the year 2021 and in the pooled data mean, whereas non-significant differences were noticed in the data during 2nd year *i.e.*, 2022. Among the treatments, soil application of biochar @ 10 t ha^{-1} in combination with humic acid @ 4 kg ha^{-1} and *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + *Bacillus spp.* @ 5 kg ha^{-1} recorded significantly lowest number of days to first flower opening (44.33 and 44.21 DAT respectively during 2021 and the pooled data mean) in marigold, whereas soil application of humic acid @ 2 kg ha^{-1} alone without biochar and microbial consortia recorded significantly highest number of days to first flower opening (52.55 and 52.43 DAT respectively during 2021 and the pooled data mean). Significant differences were observed among the interaction effects of soil application of graded levels of biochar, humic acid and different microbial consortia with respect to number days to peak flowering in marigold during both the years of study as well as in the pooled data mean. Among the treatments, soil application of biochar @ 10 t ha^{-1} in combination with humic acid @ 4 kg ha^{-1} and *Azospirillum* @ 5 kg ha^{-1} + PSB @ 5 kg ha^{-1} + *Bacillus* spp. @ 5 kg ha^{-1} recorded significantly lowest number of days to peak flowering (72.13, 71.88 and 72.01 DAT respectively during 2021, 2022 and the pooled data mean) in marigold, whereas soil application of humic acid @ 2 kg ha^{-1} alone with no biochar and microbial consortia recorded significantly highest number of days to peak flowering (80.96, 80.68 and 80.82 DAT respectively during 2021, 2022 and the pooled data mean). Based on the critical analysis of these results, it may be concluded that soil application of higher amounts of biochar and humic acid in combination with either of the microbial consortia helped the marigold plants to attain early maturation due to balanced C:N ratio maintained in the plant thus recorded early flower bud emergence in comparison to without soil application of biochar and microbial consortia. The reason may be due to improved source-sink relationship through enhanced absorption of water, nutrients and growth promoting substances produced by the microbial activities in soil led to an increase in the rate of photosynthesis in plant thereby recorded good balance between vegetative and reproductive phases.

Table 1: Influence of biochar, humic acid, microbial consortia and their interaction effects on number of days to flower bud emergence in marigold (*Tagetes erecta* L.) cv. 'Bidhan-2'

Treatments	**Number of days to flower bud emergence recorded during experimentation (2020-22)**								
	First year (2021)			**Second year (2022)**			**Pooled data mean**		
Treatments	**HA_1**	**HA_2**	**Mean**	**HA_1**	**HA_2**	**Mean**	**HA_1**	**HA_2**	**Mean**
BC_0	44.05	41.11	42.58	43.28	40.60	41.94	43.67	40.85	42.26
BC_1	42.89	38.71	40.80	42.34	38.10	40.22	42.61	38.41	40.51
BC_2	38.67	37.62	38.14	38.24	37.00	37.62	38.46	37.31	37.88
Mean	41.87	39.14		41.28	38.56		41.58	38.85	

Treatments	MC_0	MC_1	MC_2	Mean	MC_0	MC_1	MC_2	Mean	MC_0	MC_1	MC_2	Mean
BC_0	43.20	42.39	42.15	42.58	42.40	41.68	41.74	41.94	42.80	42.04	41.94	42.26
BC_1	41.90	40.30	40.20	40.80	41.29	39.69	39.68	40.22	41.60	39.99	39.94	40.51
BC_2	39.45	37.81	37.18	38.14	39.29	37.08	36.50	37.62	39.37	37.44	36.84	37.88
Mean	41.51	40.16	39.84		40.99	39.48	39.30		41.25	39.82	39.57	

Treatments	MC_0	MC_1	MC_2	Mean	MC_0	MC_1	MC_2	Mean	MC_0	MC_1	MC_2	Mean
HA_1	42.77	41.89	40.95	41.87	42.18	41.27	40.40	41.28	42.48	41.58	40.68	41.58
HA_2	40.26	38.44	38.73	39.14	39.80	37.69	38.21	38.56	40.03	38.06	38.47	38.85
Mean	41.51	40.16	39.84		40.99	39.48	39.30		41.25	39.82	39.57	

Treatments	BC_0		BC_1		BC_2		BC_0		BC_1		BC_2		BC_0		BC_1		BC_2	
	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2
MC_0	44.87	41.53	43.70	40.10	39.75	39.15	43.67	41.13	42.96	39.62	39.93	38.65	44.27	41.33	43.33	39.86	39.84	38.90
MC_1	44.03	40.76	42.76	37.83	38.87	36.75	43.33	40.03	42.37	37.00	38.13	36.03	43.68	40.40	42.56	37.41	38.50	36.39
MC_2	43.26	41.03	42.20	38.20	37.40	36.97	42.83	40.65	41.70	37.67	36.67	36.33	43.04	40.84	41.95	37.94	37.04	36.65

Source	S.Em±	CD @ 5%	S.Em±	CD @ 5%	S.Em±	CD @ 5%
BC	0.13	0.41	0.05	0.15	0.07	0.22
HA	0.11	0.33	0.04	0.12	0.06	0.18
MC	0.19	0.41	0.05	0.15	0.07	0.22
BC x HA	0.13	0.58	0.07	0.21	0.10	0.31
BC x MC	0.24	NS	0.09	0.26	0.12	0.38
HA x MC	0.19	0.58	0.07	0.21	0.10	0.31
BC x HA x MC	0.34	NS	0.12	0.37	0.18	NS

Table 2: Influence of biochar, humic acid, microbial consortia and their interaction effects on number of days to first flower opening in marigold (*Tagetes erecta* L.) cv. 'Bidhan-2'

Treatments	Number of days to first flower opening recorded during experimentation (2020-22)								
	First year (2021)			Second year (2022)			Pooled data mean		
Treatments	HA_1	HA_2	Mean	HA_1	HA_2	Mean	HA_1	HA_2	Mean
BC_0	51.92	49.34	50.63	51.79	48.57	50.18	51.86	48.95	50.40
BC_1	50.96	46.60	48.78	50.61	46.29	48.45	50.78	46.44	48.61
BC_2	46.77	45.45	46.11	46.14	45.07	45.60	46.46	45.26	45.86
Mean	49.88	47.13		49.51	46.64		49.70	46.88	

Treatments	MC_0	MC_1	MC_2	Mean	MC_0	MC_1	MC_2	Mean	MC_0	MC_1	MC_2	Mean
BC_0	51.19	50.44	50.26	50.63	50.75	50.01	49.78	50.18	50.97	50.23	50.02	50.40
BC_1	50.07	48.05	48.22	48.78	49.60	47.90	47.85	48.45	49.83	47.97	48.03	48.61
BC_2	47.58	45.66	45.10	46.11	46.98	45.27	44.57	45.60	47.28	45.47	44.84	45.86
Mean	49.61	48.05	47.86		49.11	47.72	47.40		49.36	47.89	47.63	

Treatments	MC_0	MC_1	MC_2	Mean	MC_0	MC_1	MC_2	Mean	MC_0	MC_1	MC_2	Mean
HA_1	50.78	49.81	49.06	49.88	50.42	49.47	48.65	49.51	50.60	49.65	48.86	49.70
HA_2	48.44	46.29	46.66	47.13	47.80	45.97	46.15	46.64	48.12	46.13	46.40	46.88
Mean	49.61	48.05	47.86		49.11	47.72	47.40		49.36	47.89	47.63	

Treatments	BC_0		BC_1		BC_2		BC_0		BC_1		BC_2		BC_0		BC_1		BC_2	
	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2
MC_0	52.55	49.83	51.90	48.24	47.90	47.26	52.30	49.20	51.83	47.37	47.13	46.83	52.43	49.15	51.87	47.80	47.52	47.04
MC_1	52.13	48.76	50.76	45.33	46.55	44.77	52.06	47.96	50.13	45.67	46.24	44.30	52.09	48.36	50.44	45.50	46.40	44.54
MC_2	51.10	49.42	50.22	46.22	45.87	44.33	51.02	48.55	49.87	45.83	45.06	44.08	51.06	48.98	50.05	46.02	45.47	44.21

Source	S.Em±	CD @ 5%	S.Em±	CD @ 5%	S.Em±	CD @ 5%
BC	0.03	0.10	0.08	0.25	0.05	0.15
HA	0.03	0.08	0.07	0.20	0.04	0.12
MC	0.03	0.10	0.08	0.25	0.05	0.15
BC x HA	0.05	0.15	0.12	0.36	0.07	0.21
BC x MC	0.06	0.18	0.14	0.44	0.08	0.26
HA x MC	0.05	0.15	0.12	0.36	0.07	0.21
BC x HA x MC	0.08	0.26	0.21	NS	0.12	0.36

Table 3: Influence of biochar, humic acid, microbial consortia and their interaction effects on number of days to peak flowering in marigold (*Tagetes erecta* L.) cv. 'Bidhan-2'

Treatments	Number of days to peak flowering recorded during experimentation (2020-22)								
	First year (2021)			Second year (2022)			Pooled data mean		
Treatments	HA_1	HA_2	Mean	HA_1	HA_2	Mean	HA_1	HA_2	Mean
BC_0	80.10	77.22	78.66	79.95	77.11	78.53	80.03	77.17	78.60
BC_1	78.94	74.69	76.81	78.80	74.58	76.69	78.87	74.64	76.75
BC_2	74.52	73.36	73.94	74.25	73.09	73.67	74.39	73.22	73.80
Mean	77.85	75.09		77.66	74.92		77.76	75.01	

Treatments	MC_0	MC_1	MC_2	Mean	MC_0	MC_1	MC_2	Mean	MC_0	MC_1	MC_2	Mean
BC_0	79.35	78.48	78.15	78.66	79.10	78.37	78.12	78.53	79.23	78.43	78.14	78.60
BC_1	78.05	76.31	76.09	76.81	77.76	76.33	75.98	76.69	77.90	76.33	76.04	76.75
BC_2	75.43	73.81	72.58	73.94	75.41	73.09	72.51	73.67	75.42	73.45	72.55	73.80
Mean	77.61	76.20	75.60		77.42	75.93	75.53		77.51	76.07	75.57	
Treatments	**MC_0**	**MC_1**	**MC_2**	**Mean**	**MC_0**	**MC_1**	**MC_2**	**Mean**	**MC_0**	**MC_1**	**MC_2**	**Mean**
HA_1	78.84	77.98	76.75	77.85	78.56	77.66	76.78	77.66	78.70	77.82	76.77	77.76
HA_2	76.38	74.43	74.46	75.09	76.28	74.21	74.29	74.92	76.33	74.32	74.38	75.01
Mean	77.61	76.20	75.60		77.42	75.93	75.53		77.51	76.07	75.57	

Treatments	BC_0		BC_1		BC_2		BC_0		BC_1		BC_2		BC_0		BC_1		BC_2	
	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2
MC_0	80.96	77.75	79.88	76.22	75.67	75.19	80.68	77.53	79.54	75.98	75.48	75.33	80.82	77.64	79.71	76.10	75.58	75.26
MC_1	80.14	76.83	78.93	73.70	74.87	72.75	80.05	76.70	78.79	73.88	74.14	72.05	80.10	76.77	78.86	73.79	74.51	72.40
MC_2	79.21	77.10	78.03	74.15	73.03	72.13	79.13	77.11	78.07	73.90	73.14	71.88	79.17	77.11	78.05	74.03	73.09	72.01

Source	S.Em±	CD @ 5%	S.Em±	CD @ 5%	S.Em±	CD @ 5%
BC	0.01	0.04	0.02	0.06	0.01	0.03
HA	0.01	0.04	0.01	0.05	0.01	0.02
MC	0.01	0.04	0.02	0.06	0.01	0.03
BC x HA	0.02	0.06	0.03	0.09	0.01	0.04
BC x MC	0.02	0.08	0.03	0.11	0.01	0.05
HA x MC	0.02	0.06	0.03	0.09	0.01	0.04
BC x HA x MC	0.04	0.11	0.05	0.15	0.02	0.07

Table 4: Influence of biochar, humic acid, microbial consortia and their interaction effects on number of days to first flower senescence on the plant in marigold (*Tagetes erecta* L.) cv. 'Bidhan-2'

Treatments	Number of days to first flower senescence on the plant recorded during experimentation (2020-22)								
	First year (2021)			Second year (2022)			Pooled data mean		
Treatments	**HA_1**	**HA_2**	**Mean**	**HA_1**	**HA_2**	**Mean**	**HA_1**	**HA_2**	**Mean**
BC_0	14.39	15.15	14.77	14.86	15.64	15.25	14.63	15.39	15.01
BC_1	14.94	16.38	15.66	15.50	16.90	16.20	15.22	16.64	15.93
BC_2	16.42	16.86	16.64	17.01	17.48	17.24	16.72	17.17	16.94
Mean	15.25	16.13		15.79	16.67		15.52	16.40	

Treatments	MC_0	MC_1	MC_2	Mean	MC_0	MC_1	MC_2	Mean	MC_0	MC_1	MC_2	Mean
BC_0	14.33	14.83	15.15	14.77	14.73	15.40	15.62	15.25	14.53	15.12	15.38	15.01
BC_1	15.27	15.74	15.97	15.66	15.74	16.36	16.50	16.20	15.51	16.05	16.24	15.93
BC_2	16.02	16.75	17.17	16.64	16.66	17.30	17.77	17.24	16.34	17.02	17.47	16.94
Mean	15.20	15.77	16.09		15.71	16.35	16.63		15.46	16.06	16.36	
Treatments	**MC_0**	**MC_1**	**MC_2**	**Mean**	**MC_0**	**MC_1**	**MC_2**	**Mean**	**MC_0**	**MC_1**	**MC_2**	**Mean**
HA_1	14.90	15.22	15.64	15.25	15.42	15.72	16.23	15.79	15.16	15.47	15.94	15.52
HA_2	15.51	16.33	16.55	16.13	16.00	16.98	17.03	16.67	15.76	16.66	16.79	16.40
Mean	15.20	15.77	16.09		15.71	16.35	16.63		15.46	16.06	16.36	

Treatments	BC_0		BC_1		BC_2		BC_0		BC_1		BC_2		BC_0		BC_1		BC_2	
	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2	HA_1	HA_2
MC_0	14.09	14.58	14.67	15.87	15.94	16.10	14.53	14.93	15.15	16.66	16.58	16.75	14.31	14.75	14.9 1	16.10	16.26	16.42
MC_1	14.33	15.33	14.96	16.53	16.37	17.13	14.67	16.13	15.61	17.10	16.87	17.73	14.50	1 5.73	15.29	16.81	16.62	17 .43
MC_2	14.76	15.53	15.20	16.75	16.97	17.37	15.37	15.87	15.75	17.26	17.58	17.97	15.06	15.70	15.48	17.01	17.27	17.67

Source	S.Em±	CD @ 5%	S.Em±	CD @ 5%	S.Em±	CD @ 5%
BC	0.24	0.72	0.15	0.47	0.13	0.39
HA	0.19	0.58	0.13	0.38	0.10	0.32
MC	024	NS	0.15	0.47	0.13	0.39
BC x HA	0.34	NS	0.22	NS	0.18	NS
BC x MC	0.41	NS	0.27	NS	0.22	NS
HA x MC	0.34	NS	0.22	NS	0.18	NS
BC x HA x MC	0.59	NS	0.39	NS	0.32	NS

Conclusion

In conclusion, our study utilized a randomized block design with factorial elements to explore the impacts of different treatments on marigold's floral parameters. Among individual treatments, combining biochar, humic acid, and specific microbial combinations led to faster flower bud emergence, first flower opening, and peak flowering. These treatments also extended flower lifespan, with the highest days to flower senescence. Regarding combination treatments, applying biochar and humic acid or various microbial consortia yielded quicker flower development. Notably, combining biochar, humic acid, and a microbial consortium containing Azospirillum, PSB, and Bacillus spp. consistently showed exceptional results in terms of reduced time to first flower opening and peak flowering across the years. This research provides valuable insights for optimizing marigold cultivation techniques to enhance flowering attributes.

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