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Impact of biofertilizers and plant growth regulators on phenological attributes and seed yield of fenugreek

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Abstract

Field trials were conducted during the Rabi seasons of 2021-22 and 2022-23 at ITM University, Gwalior, located at 26° 13' North latitude and 76° 14' East longitude, with an altitude of 211.52 meters above mean sea level. The research aimed to investigate the customization of input resources. The study included four levels of biofertilizers: B0 - Control, B1 - Rhizobium meliloti @ 25ml/kg, B2 - PSB @ 10ml/kg, and B3 - KMB @ 10ml/kg, applied as seed inoculation. Additionally, four levels of growth regulators (foliar spray at 20 and 40 DAS) were tested: G1 - GA3 @ 100 ppm, G2 - GA3 @ 200 ppm, G3 - NAA @ 100 ppm, and G4 - NAA @ 200 ppm. Phenological parameters, such as days to first flower emergence, days to 50% flowering, and number of flowers per plant, were evaluated. The application of B_1 (Rhizobium meliloti @ 25ml/kg seeds) significantly reduced the days to first flower emergence (39.451 days) and days to 50% flowering (47.347 days) and increased the number of flowers per plant (64.453) in the pooled analysis. Among the plant growth regulators, GA_3 @ 100 ppm (G_1) significantly reduced the days to first flower emergence (43.270 days), days to 50% flowering (50.857 days), and increased the number of flowers per plant (58.010). Regarding yield parameters, B_1 (Rhizobium meliloti @ 25ml/kg) showed the maximum pod length (21.710 cm), number of seeds per pod (19.746), test weight (16.658 g), seed yield per plot (1.058 kg), and seed yield per hectare (23.425 q/ha). For plant growth regulators, GA_3 @ 100 ppm (G_1) recorded a pod length of 20.090 cm, 16.267 seeds per pod, a test weight of 14.817 g, seed yieldper plot of 0.957 kg, and seed yield per hectare of 21.220 q/ha, surpassing G1 during both years and in pooled analysis.

Keywords:*Trigonella foenum-graecum* L., Biofertilizers, plant growth regulators, phenological attributes, seed yield, Gibberellic acid and Rhizobium

1. Introduction

Fenugreek (*Trigonella foenum-graecum* L.) is an annual adaptable herbaceous multifunctional crop grown in North India during the winter months. He main benefits of the growing of the fenugreek is fast growing and with good return per unit area. While young plants are used as a vegetable and fodder, the seed is mostly utilized as a condiment and in the pharmaceutical business, particularly in the preparation of ayurvedic medicines. Both the leaves and seeds are widely used in medicine and are recommended for the treatment of persistent diabetes, cough, diarrhea, and dysentery, ulcers, rickets, colic, arthritis, dyspepsia, enlargement of the spleen and leaver, and dropsy (Pruthi, 1979) [18]. Since it is a legume spice, its fresh, tender leaves, pods, and shoots are high in iron, calcium, protein, vitamin, and important amino acids. The seeds of fenugreek crops also is highly nutritious containing Carbohydrates (58.76%), protein (18.73%), crude fibers (7.64%), lipids (5.75%), ash (3.60%), and vitamins (C, B, and D) and minerals (P, K, Ca and Fe). India is the one of major producer of fenugreek; its production is concentrated mainly in the state of Rajasthan, Madhya Pradesh, Maharashtra, Haryana, Punjab, Gujarat and Uttar Pradesh. The current productivity of fenugreek is approx. 16 q/ha.

Gibberellins (GA3) have been used in horticulture for increasing stalk length and vegetative growth, early flowers initiation. GA_3 play an important role in enhancing the growth and yield in fenugreek (Badge *et al.* 1993)[5]. The role of NAA in enhancing the fruit set, growth and yield attributes in fenugreek (Alagukannan and Vijay Kumar, 1999)[4] have been reported. In lack of information on these aspects with respect to fenugreek and considering the importance of fenugreek for human health and national economy. Amongst PGRs, 1- naphthaleneacetic acid (NAA) is an artificial auxin that have key position in RNA synthesis, membrane permeability and water uptake, and is also involved in lots of physiological techniques along with root initiation, apical dominance, leaf senescence, leaf and fruit abscission, fruit placing and flowering, mobile elongation, mobile division, and vascular tissue improvement (Alabadí *et al.*, 2009)[3]. Bakhsh *et al*., (2011a)[6], Adam & Jahan (2011)[1] and Basuchaudhuri (2016)[7] documented that the exogenous application of obviously taking place or synthetic PGRs have an effect on the endogenous hormonal sample of a plant both via supplementation of sub-most useful levels or by interaction with their synthesis, translocation or inactivation of existing hormone ranges.

The seed inoculation of biofertilizers, such as Rhizobium, phosphate-solubilizing bacteria (PSB), and potassium-mobilizing bacteria (KMB), has been shown to enhance the growth and phenological attributes of fenugreek (Jat, 2002)[10]. When legumes are inoculated with Rhizobium meliloti, these bacteria improve plant growth by providing essential nutrients through nitrogen fixation, dissolving phosphates, and producing phytohormones. Additionally, rhizobia enhance plant protection by influencing metabolite production and boosting systemic resistance against pests and pathogens. In India, soils often contain low to medium levels of available phosphorus. PSB help by converting the unavailable form of phosphorus into one that plants can absorb. The efficiency of phosphatic fertilizers is low (20-25%) due to chemical fixation in the soil. Recently, several strains of PSB and fungi have been isolated that can solubilize sparingly soluble phosphate, promote growth, and improve phosphorus uptake by plants (Whitelaw, 2022)[22]. These phosphate-solubilizing microorganisms (PSM) secrete organic acids, which lower the pH and increase the availability of sparingly soluble phosphorus sources.

Biofertilizers enhance soil fertility by capturing atmospheric nitrogen, dissolving soil phosphorus, and promoting plant growth through the production of growth-stimulating substances. Their use increases microbial diversity in the soil, which is crucial for sustaining a healthy soil ecosystem. Additionally, biofertilizers are more cost-effective than chemical fertilizers, reducing the need for expensive chemical inputs and lowering overall agricultural production costs. When utilized, biofertilizers are environmentally friendly as they minimize pollution associated with chemical fertilizers, preventing soil and water contamination, thus maintaining ecological balance. The use of biofertilizers also supports sustainable agriculture by preserving soil health and fertility in the long run and reducing dependence on non-renewable resources. Biofertilizers promote better plant growth and yield by supplying essential nutrients naturally, improving root development, and enhancing nutrient and water absorption. Some biofertilizers increase plants' resistance to diseases by outcompeting harmful pathogens or inducing systemic resistance in plants. Additionally, certain biofertilizers are produced from agricultural and industrial waste, contributing to sustainable waste

2. Material and methods

The experiment was conducted at Crop Research Centre, School of Agriculture, ITM University, Gwalior, M.P. India. The research farm is situated at the 26° 13' North latitude and 76° 14' East longitude with an altitude of 211.52 meters above Mean Sea Level. The field of research farm having homogenous fertility and uniform textural make up was selected for the field experimentation. With respect to climatic condition, it is coming under light arid subtropic regions on MP, the maximum temperature goes up to 46ºC during summer and a minimum as low as 2ºC during winter. The average rainfall ranges between 70to80cm,mostofwhichisreceivedinthemonthofJuly,August,andSeptember, with few showers during Rabi season with an average maximumand minimum temperature during the growing period as 28.06ºC and 12.1ºC,respectively.Thetotalrainfallreceivedduringthecropseasonfrom November 2021 to April 2022 and November 2022 to April 2023 was 05 mm and5.8mm, respectively. The field experiment was laid down in factorial randomized block design with three replications and four levels of biofertilizers applied as seed treatment *viz.*, B_0- Control, B_1– *Rhizobium meliloti* @ 25ml/kg seeds, B_2– PSB @ 10ml/kg seeds and B_3– KMB@10ml/kg and Growth regulators (foliar spray at 20 and 40 DAS) as G_1 - GA3 @100 ppm, G_2- GA3 @200 ppm, G_3- NAA @100 ppm and G_4- NAA @200 ppm. As the treatment levels the sixteen treatment combinations were made as B_0G_1, B0G2, B0G3, B0G4, B1G1, B1G2, B1G3, B1G4, B_2G_1, B_2G_2, B2G3, B2G4, B3G1, B3G2, B3G3 and B3G4. The crop variety RMt-1 sown in 15X10cm^2 and the chemical fertilizers applied as RDF: 25:25:10 kg NPK/ ha. The irrigation was given as per requirement.

3. Results

The result comprises flowering behaviour and yield attributing traits in this experiment. The study of the fenugreek experiment conducted during 2021-22 and 2022-23.

4. Phenological parameters

Data presented in Table 1, 2 & 3 and graphical illustrated in Fig 1, 2 & 3 showed that application of bio-fertilizers and growth regulators had significant effect on days taken to first flower emergence of fenugreek during 2021-22, 2022-23 and pooled analysis.

5. Days taken to first flower emergence

The incorporation of treatment B_1 registered highly significant in early flower emergence. The earliness of flower emergence was 41.515 days, 41.930 days and 41.726 days which were 4.459, 4.210 and 4.328 percent days lower over control with the application of treatment B_1 (*Rhizobium meliloti* **@** 25ml/kg seeds**)** during theyears 2021-22, 2022-23 and pooled analysis, respectively. The treatment B_1 and B_2 also remained statistically at par. Similarly, the application of plant growth regulators significantly reduced the days taken to first flower emergence during both the years and in pooled mean. The application of GA3 @200 ppm (G_2) registered significantly lesser days taken to first flower emergence (39.236 days, 39.662 days and 39.451 days) during both the years and in pooled mean, respectively and the correspondingly it was 13.342, 12.696 and 13.019 per cent lower days over G_1 during the years 2021-22, 2022-23 and pooled analysis, respectively.

6.Days taken to 50% flowering

Data on days taken to 50% flowering, the treatment B_1 registered highly significant it was 49.748 days, 50.082 days and 49.915 days which were 3.632, 3.795 and 3.711 percent days lower over control with the application of treatment B_1 (*Rhizobium meliloti* **@** 25ml/kg seeds**)** during theyears 2021-22, 2022-23 and pooled analysis, respectively. The treatment B_1 and B_2 also remained statistically at par. The application of GA3 @200 ppm (G_2) registered significantly lesser days taken to 50% flowering (47.126 days, 47.568 days and 47.347 days) during both the years and in pooled mean, respectively and the correspondingly it was 13.598, 13.182 and 13.391 per cent lower days over G_1 during the years 2021-22, 2022-23 and pooled analysis, respectively.

7.Number of flowers per plant

Application of treatment B_1 registered highly significant increase in number of flowers per plant. The corresponding increases in number of flowers per plant were 60.183, 60.679 and 60.431 which were 3.830, 3.937 and 3.883 per cent higher over control with the application of treatment B_1 (*Rhizobium meliloti* @25ml/kg seeds**)** during theyears 2021-22, 2022-23 and pooled analysis, respectively. The treatment B_1 and B_2 also remained statistically at par. Similarly, the application of growth regulators at increasing level also significantly increased the number of flowers per plant during both the years and in pooled mean. The application of GA3 @200 ppm (G_2) registered significantly maximum number of flowers per plant (64.294, 64.612 and 64.453) during both the years and in pooled mean, respectively and the corresponding increases were 14.601, 14.992 and 14.797 per cent higher over G_1 during the years 2021-22, 2022-23 and pooled analysis, respectively.

8. Yield parameters

Data presented in Table 4, 5, 6, 7 and 8 and graphical illustrated in Fig 4, 5, 6, 7 and 8 showed that application of bio-fertilizers and growth regulators had significant effect on days taken to first flower emergence of fenugreek during 2021-22, 2022-23 and pooled analysis.

9. Number of seeds

The application of bio-fertilizers significantly increased the number of seed per pod during both the years of experimentation as well as in pooled analysis. Application of treatment B_1 registered highly significant increase in number of seed per pod. The corresponding increases in number of seed per pod were 18.938, 20.553 and 19.746which were 35.727, 35.842 and 35.767 per cent higher over control with the application of treatment B_1 (*Rhizobium meliloti* @25ml/kg seeds**)** during theyears 2021-22, 2022-23 and pooled analysis, respectively. Similarly, the application of growth regulators at increasing level also significantly increased the number of seed per pod during both the years and in pooled mean. The application of GA3 @100 ppm (G_1) registered significantly maximum number of seed per pod (17.053, 17.955 and 17.507) during both the years and in pooled mean, respectively and the corresponding increases were 9.625, 6.532 and 7.848 per cent higher over G_4 during the years 2021-22, 2022-23 and pooled analysis, respectively.

10. Number of pods

Bio-fertilizers significantly increased the number of pods per plant during both the years of experimentation as well as in pooled analysis. Application of treatment B_1 recorded highly significant increase in number of pods per plant. The number of pods per plant were 45.293, 45.488 and 45.393which were 21.468, 20.574 and 21.022 per cent higher over control with the application of treatment B_1 (*Rhizobium meliloti* **@** 25ml/kg seeds**)** during theyears 2021-22, 2022-23 and pooled analysis, respectively. Similarly, application of GA3 @100 ppm (G_1) registered significantly maximum number of pods per plant (42.823, 42.973 and 42.900) during both the years and in pooled mean, respectively and the corresponding increases were 5.366, 5.009 and 5.183 per cent higher over G_4 during the years 2021-22, 2022-23 and pooled analysis, respectively.

11. Pod length

With respect to application of treatment B_1 registered highly significant increase in pod length. The corresponding increases in pod length were 21.549cm, 21.866cm and 21.710cmwhich were 16.720cm, 16.712cm and 16.726cm per cent higher over control with the application of treatment B_1 (*Rhizobium meliloti*@ 25ml/kg seeds**)** during theyears 2021-22, 2022-23 and pooled analysis, respectively. Similarly, the application of GA3 @100 ppm (G_1) registered significantly maximum pod length (20.342cm, 20.634cm and 20.490cm) during both the years and in pooled mean, respectively and the corresponding increases were 4.195cm, 4.380cm and 4.290cm per cent higher over G_4 during the years 2021-22, 2022-23 and pooled analysis, respectively.

12. Seed yield

The mean data of treatment B_1 registered highly significant increase in seed yield. The seed yield were 1.027kg/plot and 22.810q/ha, 1.082kg/plot and 24.034q/ha and 1.058kg/plot and 23.425q/ha respectively in 2021-22, 2022-23 and pooled which were 126.710, 116.400 and 121.338 per cent higher over control with the application of treatment B_1 (*Rhizobium meliloti* @25ml/kg seeds**).** Similarly, the application of plant growth regulators at increasing level significantly increased the seed yield during both the years and in pooled mean. The application of GA3 @100 ppm (G_1) registered significantly maximum seed yield 0.867kg/plot and 19.256q/ha, 0.915kg/plot and 20.329q/ha and 0.893kg/plot and 19.794q/ha) during both the years and in pooled mean, respectively and which were 6.511, 6.271 and 6.436 per cent higher over G_4.

TABLE 1:DAYS TAKEN TO FIRST FLOWER EMERGENCE AS INFLUENCED BY DIFFERENT BIOFERTILIZERS AND PLANT GROWTH REGULATORS

Days taken to first flower emergence															
Years	**Year (2021-22)**					**Year (2022-23)**					**Pooled Value**				
Factors	**G1**	**G2**	**G3**	**G4**	**Mean (B)**	**G1**	**G2**	**G3**	**G4**	**Mean (B)**	**G1**	**G2**	**G3**	**G4**	**Mean (B)**
B0	43.913	44.257	45.900	47.037	45.277	44.060	44.503	46.097	47.060	45.430	43.990	44.383	46.003	47.047	45.356
B1	37.500	38.620	40.380	40.443	39.236	38.100	38.967	40.620	40.960	39.662	37.803	38.797	40.500	40.703	39.451
B2	41.693	42.047	42.160	42.500	42.100	41.980	42.380	42.747	43.120	42.557	41.840	42.213	42.457	42.813	42.331
B3	42.953	43.003	43.677	43.833	43.367	43.580	43.670	43.900	43.950	43.775	43.270	43.340	43.787	43.893	43.573
Mean (G)	41.515	41.982	43.029	43.453		41.930	42.380	43.341	43.773		41.726	42.183	43.187	43.614	
Factors	C.D.	SE(d)	SE(m)	P value		C.D.	SE(d)	SE(m)	P value		C.D.	SE(d)	SE(m)	P value	
Factor (G)	0.855	0.417	0.295	0.00000		0.681	0.332	0.235	0.00000		0.511	0.249	0.176	0.00000	
Factor (B)	0.855	0.417	0.295	0.00016		0.681	0.332	0.235	0.00001		0.511	0.249	0.176	0.00000	
Factor (G X B)	NS	0.833	0.589	0.32517		NS	0.664	0.469	0.11416		1.023	0.498	0.352	0.00802	

Note:

1. Bio fertilizer- B_0- Control, B_1-*Rhizobium meliloti* @ 25ml/kg seeds, B_2- PSB @ 10ml/kg seeds and B_3- KMB@10ml/kg seeds

1. Growth regulators (foliar spray at 20 and 40 DAS)- G_1 - GA3 @100 ppm, G_2- GA3 @200 ppm, G_3- NAA @100 ppm and G_4- NAA @200 ppm

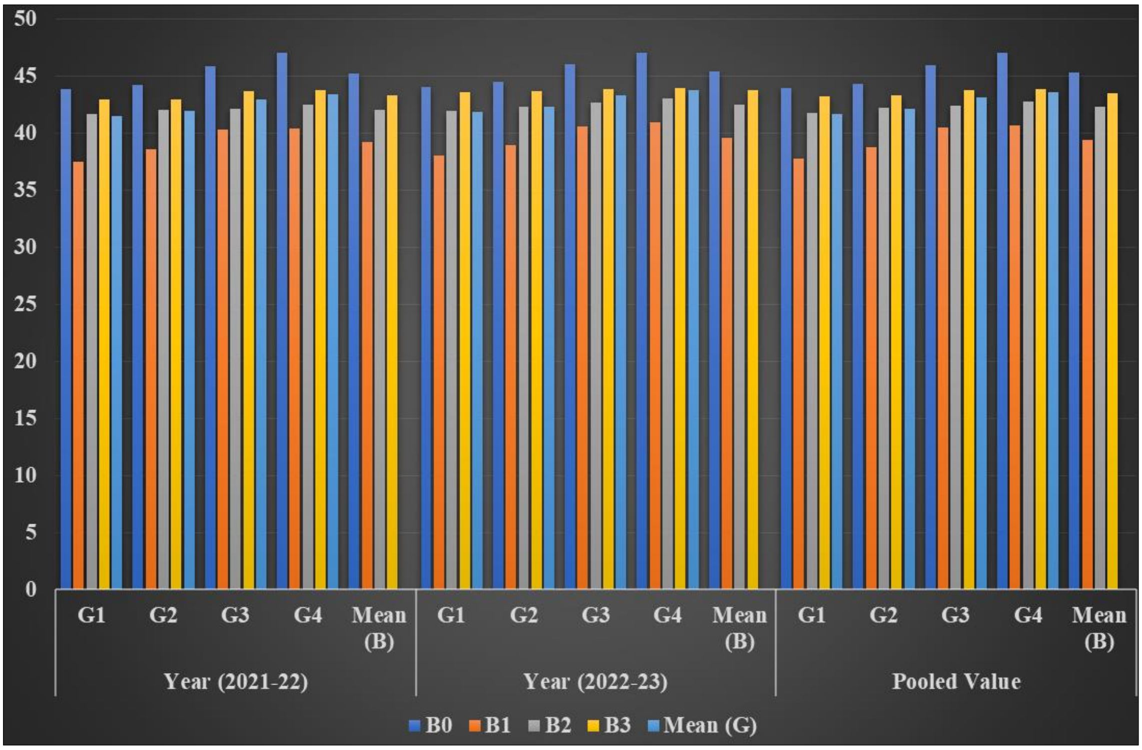

FIG 1: DAYS TAKEN TO FIRST FLOWER EMERGENCE AS INFLUENCED BY DIFFERENT BIOFERTILIZERS AND PLANT GROWTH REGULATORS

TABLE 2: DAYS TAKEN TO 50% FLOWERING AS INFLUENCED BY DIFFERENT BIOFERTILIZERS AND PLANT GROWTH REGULATORS

Days taken to 50% flowering															
Years	**Year (2021-22)**					**Year (2022-23)**					**Pooled Value**				
Factors	**G_1**	**G_2**	**G_3**	**G_4**	**Mean (B)**	**G_1**	**G_2**	**G_3**	**G_4**	**Mean (B)**	**G_1**	**G_2**	**G_3**	**G_4**	**Mean (B)**
B_0	53.107	54.523	54.973	55.567	54.543	53.407	53.660	55.677	56.420	54.791	53.257	54.093	55.327	55.993	54.668
B_1	46.320	47.020	47.267	47.897	47.126	46.853	47.370	47.793	48.253	47.568	46.587	47.197	47.530	48.073	47.347
B_2	48.863	49.287	49.410	50.307	49.467	49.057	49.447	49.683	50.497	49.671	48.960	49.367	49.547	50.400	49.568
B_3	50.700	51.197	51.390	52.720	51.502	51.010	51.460	51.730	53.060	51.815	50.857	51.327	51.560	52.890	51.658
Mean (G)	49.748	50.507	50.760	51.623		50.082	50.484	51.221	52.058		49.915	50.496	50.991	51.839	
Factors	C.D.	SE(d)	SE(m)	P value		C.D.	SE(d)	SE(m)	P value		C.D.	SE(d)	SE(m)	P value	
Factor (G)	1.214	0.592	0.418	0.00000		0.724	0.353	0.249	0.00000		0.744	0.362	0.256	0.00000	
Factor (B)	1.214	0.592	0.418	0.02990		0.724	0.353	0.249	0.00002		0.744	0.362	0.256	0.00009	
Factor (G X B)	NS	1.183	0.837	0.99900		NS	0.705	0.499	0.52133		NS	0.725	0.512	0.88825	

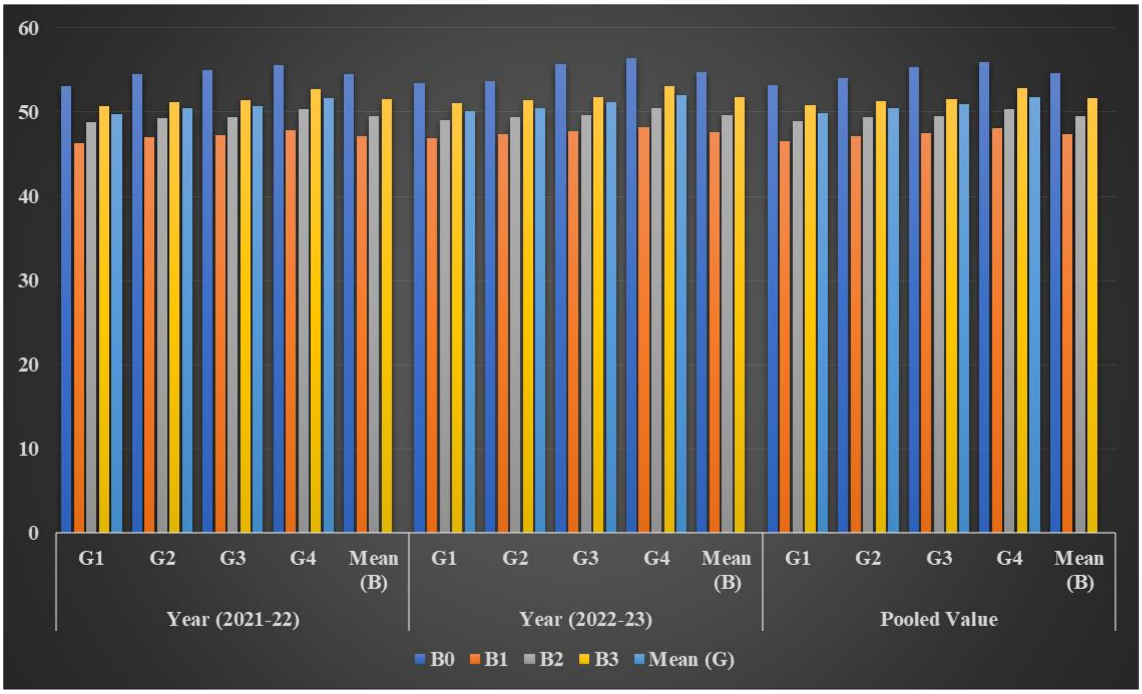

FIG 2:DAYS TAKEN TO 50% FLOWERING AS INFLUENCED BY DIFFERENT BIOFERTILIZERS AND PLANT GROWTH REGULATORS

TABLE 3:NUMBER OF FLOWERS PER PLANT (AT 60 TO 70 DAS) AS INFLUENCED BY DIFFERENT BIOFERTILIZERS AND PLANT GROWTH REGULATORS

No. of flowers per plant															
Years	**Year (2021-22)**					**Year (2022-23)**					**Pooled Value**				
Factors	**G_1**	**G_2**	**G_3**	**G_4**	**Mean (B)**	**G_1**	**G_2**	**G_3**	**G_4**	**Mean (B)**	**G_1**	**G_2**	**G_3**	**G_4**	**Mean (B)**
B_0	56.627	56.280	56.150	55.350	56.102	57.087	56.200	56.117	55.350	56.188	56.857	56.240	56.133	55.350	56.145
B_1	65.707	65.163	64.660	61.647	64.294	66.097	65.440	64.997	61.913	64.612	65.900	65.303	64.830	61.780	64.453
B_2	60.627	59.383	58.723	58.150	59.221	61.287	60.110	59.187	58.817	59.850	60.957	59.747	58.957	58.483	59.536
B_3	57.773	57.480	57.033	56.707	57.248	58.247	58.090	57.697	57.440	57.868	58.010	57.787	57.367	57.073	57.559
Mean (G)	60.183	59.577	59.142	57.963		60.679	59.960	59.499	58.380		60.431	59.769	59.322	58.172	
Factors	C.D.	SE(d)	SE(m)	P value		C.D.	SE(d)	SE(m)	P value		C.D.	SE(d)	SE(m)	P value	
Factor (G)	0.915	0.446	0.315	0.00000		0.751	0.366	0.259	0.00000		0.802	0.391	0.276	0.00000	
Factor (B)	0.915	0.446	0.315	0.00023		0.751	0.366	0.259	0.00001		0.802	0.391	0.276	0.00003	
Factor (G X B)	NS	0.892	0.631	0.33810		NS	0.732	0.518	0.08236		NS	0.782	0.553	0.15535	

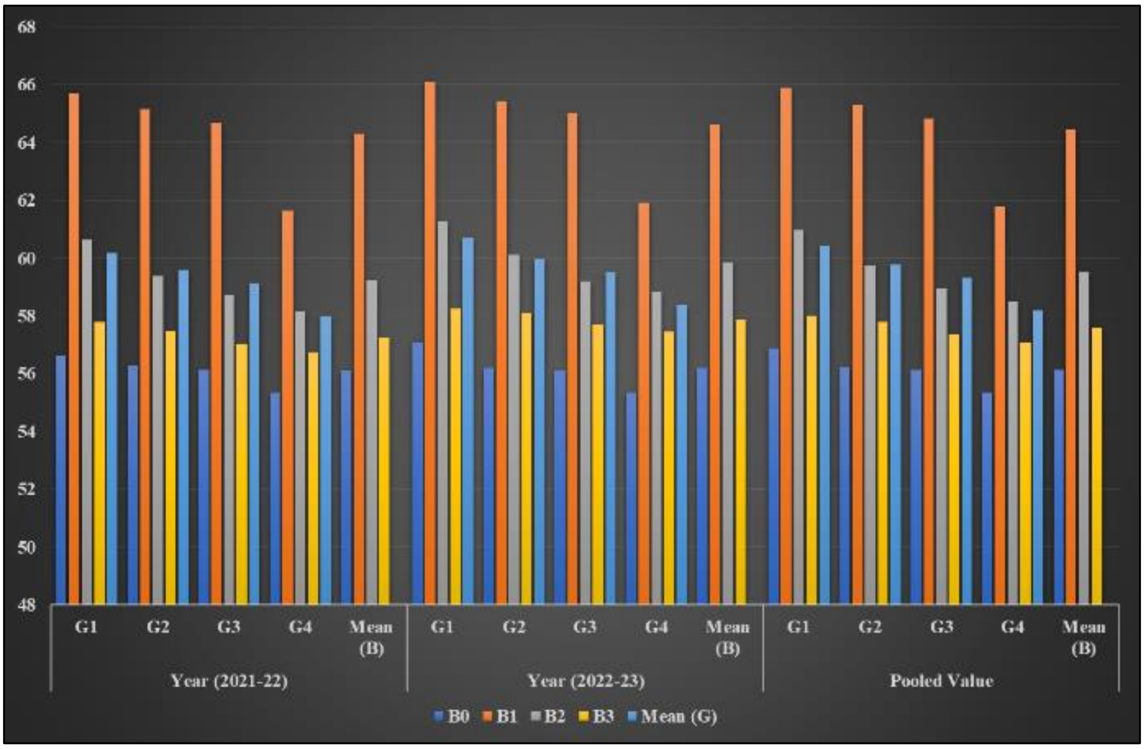

FIG 3:NUMBER OF FLOWERS PER PLANT AS INFLUENCED BY DIFFERENT BIOFERTILIZERS AND PLANT GROWTH REGULATORS

TABLE 4:POD LENGTH AS INFLUENCED BY DIFFERENT BIOFERTILIZERS AND PLANT GROWTH REGULATORS

Pod length															
Years	**Year (2021-22)**					**Year (2022-23)**					**Pooled Value**				
Factors	**G1**	**G2**	**G3**	**G4**	**Mean (B)**	**G1**	**G2**	**G3**	**G4**	**Mean (B)**	**G1**	**G2**	**G3**	**G4**	**Mean (B)**
B0	19.007	18.673	18.360	17.807	18.462	19.203	19.090	18.590	18.057	18.735	19.107	18.883	18.477	17.930	18.599
B1	22.010	21.710	21.593	20.883	21.549	22.397	22.057	21.900	21.110	21.866	22.203	21.887	21.750	21.000	21.710
B2	20.370	20.240	20.200	20.160	20.243	20.743	20.647	20.493	20.270	20.538	20.560	20.443	20.347	20.217	20.392
B3	19.980	19.653	19.480	19.243	19.589	20.193	20.003	19.860	19.633	19.923	20.090	19.830	19.673	19.440	19.758
Mean (G)	20.342	20.069	19.908	19.523		20.634	20.449	20.211	19.768		20.490	20.261	20.062	19.647	
Factors	C.D.	SE(d)	SE(m)	P value		C.D.	SE(d)	SE(m)	P value		C.D.	SE(d)	SE(m)	P value	
Factor (G)	0.377	0.184	0.130	0.00000		0.292	0.142	0.101	0.00000		0.245	0.119	0.084	0.00000	
Factor (B)	0.377	0.184	0.130	0.00112		0.292	0.142	0.101	0.00001		0.245	0.119	0.084	0.00000	
Factor (G X B)	NS	0.368	0.260	0.77163		NS	0.285	0.201	0.53230		NS	0.238	0.169	0.27523	

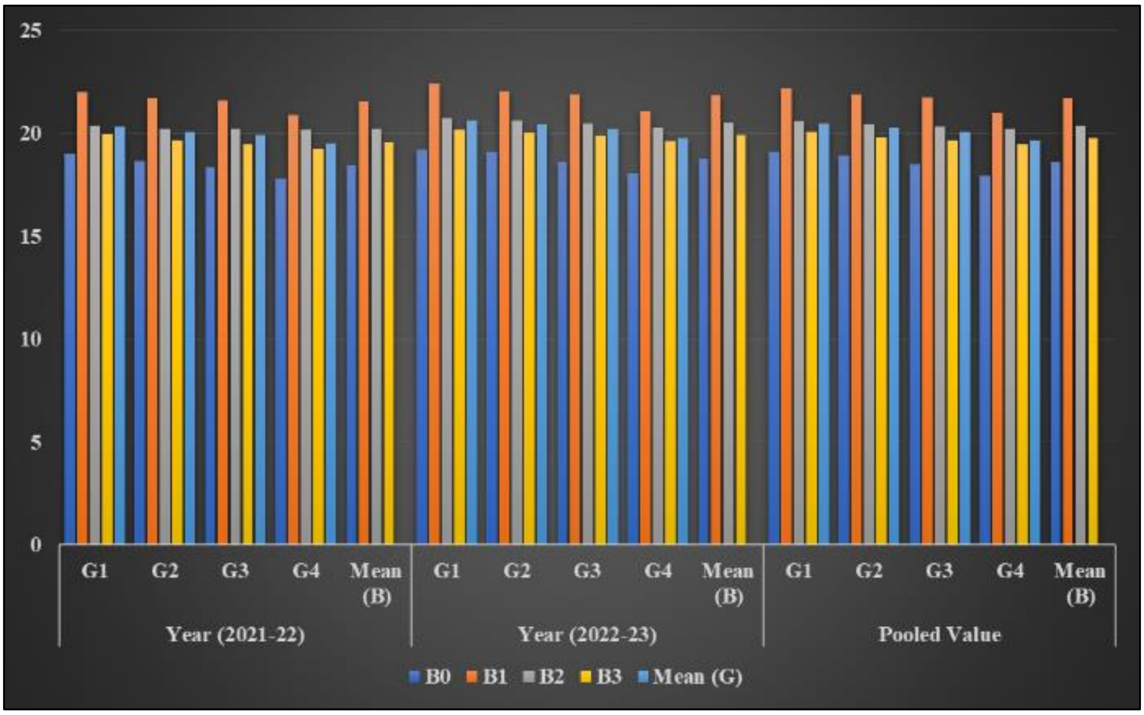

FIG 4:POD LENGTH AS INFLUENCED BY DIFFERENT BIOFERTILIZERS AND PLANT GROWTH REGULATORS

TABLE 5:NUMBER OF SEED PER POD AS INFLUENCED BY VARIOUS BIOFERTILIZERS AND PLANT GROWTH REGULATORS

Number of seed per pod															
Years	**Year (2021-22)**					**Year (2022-23)**					**Pooled Value**				
Factors	**G1**	**G2**	**G3**	**G4**	**Mean (B)**	**G1**	**G2**	**G3**	**G4**	**Mean (B)**	**G1**	**G2**	**G3**	**G4**	**Mean (B)**
B0	14.713	14.053	13.823	13.223	13.953	15.610	15.480	14.913	14.517	15.130	15.167	14.767	14.370	13.873	14.544
B1	19.693	19.580	18.517	17.960	18.938	21.027	20.913	20.360	19.913	20.553	20.360	20.247	19.440	18.937	19.746
B2	17.947	17.153	16.417	16.117	16.908	18.513	17.960	17.583	17.293	17.838	18.233	17.560	17.000	16.707	17.375
B3	15.860	15.663	15.507	15.127	15.539	16.670	16.590	16.377	15.693	16.333	16.267	16.130	15.943	15.413	15.938
Mean (G)	17.053	16.613	16.066	15.607		17.955	17.736	17.308	16.854		17.507	17.176	16.688	16.233	
Factors	C.D.	SE(d)	SE(m)	P value		C.D.	SE(d)	SE(m)	P value		C.D.	SE(d)	SE(m)	P value	
Factor (G)	0.728	0.355	0.251	0.00000		0.574	0.280	0.198	0.00000		0.590	0.287	0.203	0.00000	
Factor (B)	0.728	0.355	0.251	0.00186		0.574	0.280	0.198	0.00236		0.590	0.287	0.203	0.00066	
Factor (G X B)	NS	0.710	0.502	0.95481		NS	0.559	0.396	0.99923		NS	0.575	0.406	0.98817	

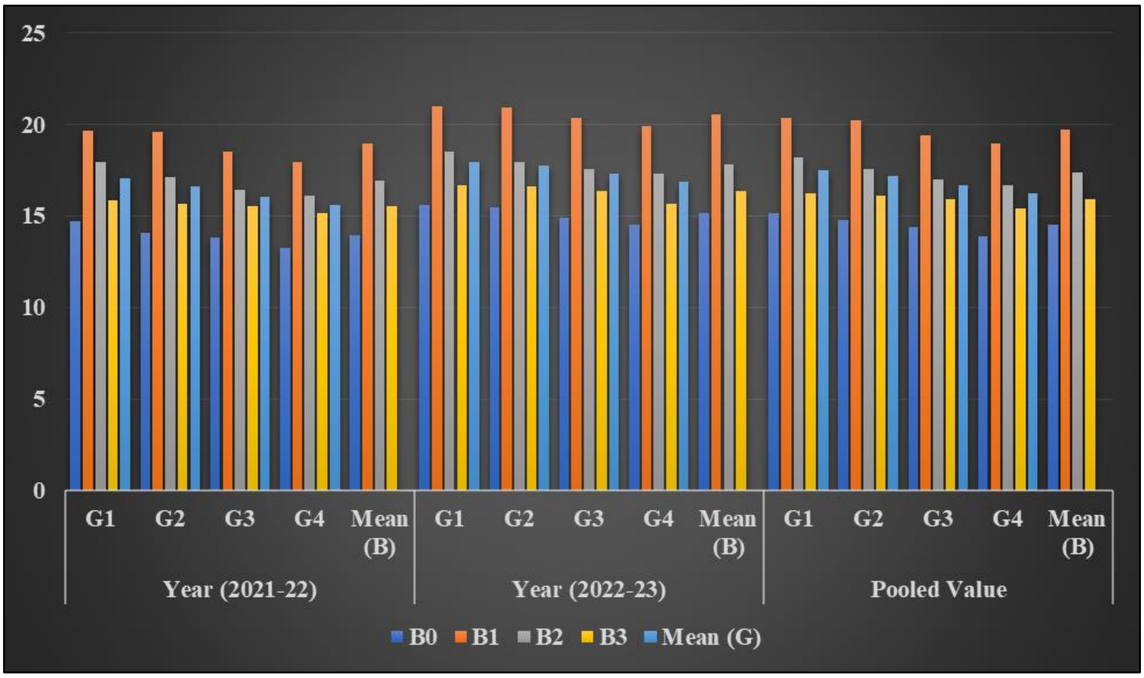

FIG 5:NUMBER OF SEED PER POD AS INFLUENCED BY VARIOUS BIOFERTILIZERS AND PLANT GROWTH REGULATORS

TABLE 6:TEST WEIGHT (1000 SEED WEIGHT) OF SEED (G) AS INFLUENCED BY VARIOUS BIOFERTILIZERS AND PLANT GROWTH REGULATORS

Test weight (1000 seed weight) of seed (g)															
Years	**Year (2021-22)**					**Year (2022-23)**					**Pooled Value**				
Factors	**G1**	**G2**	**G3**	**G4**	**Mean (B)**	**G1**	**G2**	**G3**	**G4**	**Mean (B)**	**G1**	**G2**	**G3**	**G4**	**Mean (B)**
B0	13.063	12.730	12.417	11.787	12.499	14.827	14.620	13.650	13.553	14.163	13.947	13.680	13.037	12.673	13.334
B1	15.660	15.323	14.857	14.733	15.143	18.847	18.293	17.917	17.627	18.171	17.253	16.810	16.387	16.183	16.658
B2	14.637	14.523	14.307	14.067	14.383	16.737	16.633	16.420	16.113	16.476	15.690	15.580	15.367	15.093	15.433
B3	13.973	13.850	13.723	13.487	13.758	15.660	15.287	15.227	15.023	15.299	14.817	14.570	14.477	14.257	14.530
Mean (G)	14.333	14.107	13.826	13.518		16.518	16.208	15.803	15.579		15.427	15.160	14.817	14.552	
Factors	C.D.	SE(d)	SE(m)	P value		C.D.	SE(d)	SE(m)	P value		C.D.	SE(d)	SE(m)	P value	
Factor (G)	0.588	0.287	0.203	0.00000		1.688	0.822	0.582	0.00027		0.911	0.444	0.314	0.00000	
Factor (B)	0.588	0.287	0.203	0.04469		NS	0.822	0.582	0.67407		NS	0.444	0.314	0.23632	
Factor (G X B)	NS	0.573	0.405	0.99503		NS	1.645	1.163	0.99999		NS	0.888	0.628	0.99974	

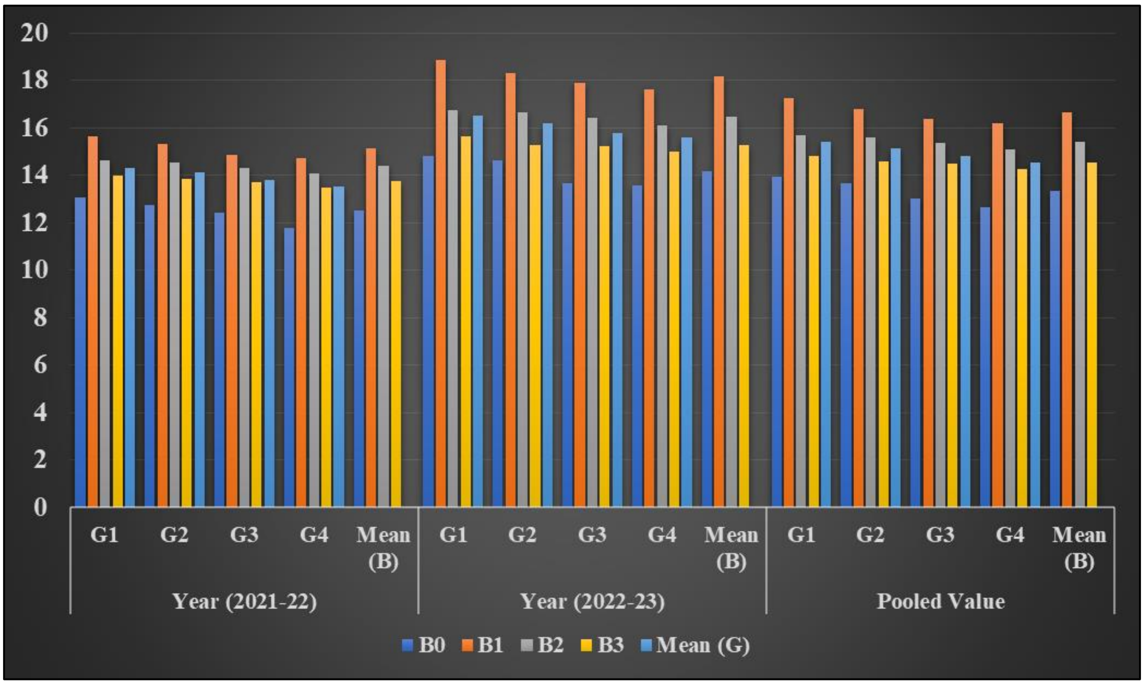

FIG 6: TEST WEIGHT (1000 SEED WEIGHT) OF SEED (G) AS INFLUENCED BY VARIOUS BIOFERTILIZERS AND PLANT GROWTH REGULATORS

TABLE 7:SEED YIELD (KG/PLOT) AS INFLUENCED BY VARIOUS BIOFERTILIZERS AND PLANT GROWTH REGULATORS

Seed yield (kg/plot)															
Years	**Year (2021-22)**					**Year (2022-23)**					**Pooled Value**				
Factors	**G1**	**G2**	**G3**	**G4**	**Mean (B)**	**G1**	**G2**	**G3**	**G4**	**Mean (B)**	**G1**	**G2**	**G3**	**G4**	**Mean (B)**
B0	0.477	0.470	0.453	0.413	0.453	0.547	0.537	0.463	0.453	0.500	0.513	0.507	0.460	0.433	0.478
B1	1.053	1.027	1.017	1.010	1.027	1.097	1.090	1.077	1.063	1.082	1.077	1.063	1.050	1.040	1.058
B2	1.003	0.980	0.960	0.947	0.973	1.040	1.030	1.023	1.000	1.023	1.023	1.010	0.993	0.973	1.000
B3	0.933	0.923	0.910	0.887	0.913	0.977	0.970	0.947	0.927	0.955	0.957	0.950	0.930	0.910	0.937
Mean (G)	0.867	0.850	0.835	0.814		0.915	0.907	0.878	0.861		0.893	0.883	0.858	0.839	
Factors	C.D.	SE(d)	SE(m)	P value		C.D.	SE(d)	SE(m)	P value		C.D.	SE(d)	SE(m)	P value	
Factor (G)	0.028	0.014	0.010	0.00000		0.033	0.016	0.011	0.00000		0.022	0.011	0.008	0.00000	
Factor (B)	0.028	0.014	0.010	0.00446		0.033	0.016	0.011	0.00740		0.022	0.011	0.008	0.00011	
Factor (G X B)	NS	0.027	0.019	0.99548		NS	0.032	0.023	0.84419		NS	0.022	0.015	0.89616	

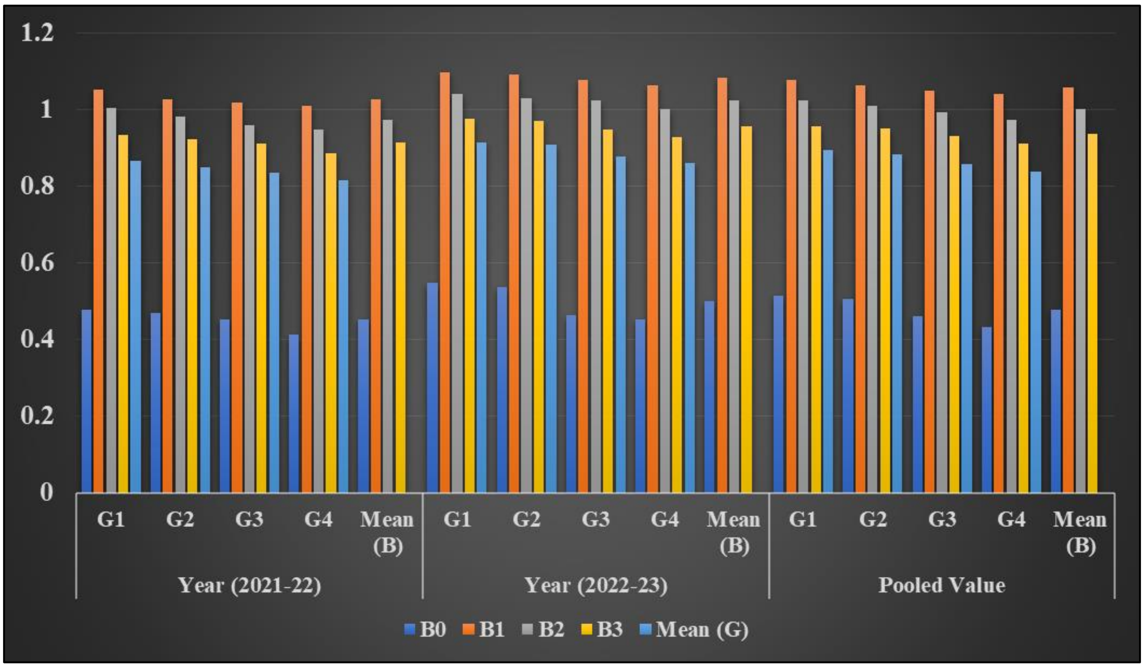

FIG 7:SEED YIELD (KG/PLOT) AS INFLUENCED BY VARIOUS BIOFERTILIZERS AND PLANT GROWTH REGULATORS

TABLE 8:SEED YIELD (Q/HA) AS INFLUENCED BY VARIOUS BIOFERTILIZERS AND PLANT GROWTH REGULATORS

Seed yield (q/ha)															
Years	**Year (2021-22)**					**Year (2022-23)**					**Pooled Value**				
Factors	**G_1**	**G_2**	**G_3**	**G_4**	**Mean (B)**	**G_1**	**G_2**	**G_3**	**G_4**	**Mean (B)**	**G_1**	**G_2**	**G_3**	**G_4**	**Mean (B)**
B_0	10.590	10.440	10.067	9.107	10.051	12.143	11.923	10.290	10.070	11.107	11.367	11.187	10.180	9.593	10.582
B_1	23.403	22.810	22.587	22.440	22.810	24.367	24.220	23.923	23.627	24.034	23.887	23.517	23.260	23.037	23.425
B_2	22.293	21.773	21.330	21.033	21.608	23.107	22.883	22.737	22.220	22.737	22.703	22.330	22.037	21.630	22.175
B_3	20.737	20.513	20.220	19.697	20.292	21.700	21.553	21.037	20.587	21.219	21.220	21.037	20.633	20.143	20.758
Mean (G)	19.256	18.884	18.551	18.069		20.329	20.145	19.497	19.126		19.794	19.518	19.028	18.601	
Factors	C.D.	SE(d)	SE(m)	P value		C.D.	SE(d)	SE(m)	P value		C.D.	SE(d)	SE(m)	P value	
Factor (G)	0.621	0.303	0.214	0.00000		0.739	0.360	0.255	0.00000		0.478	0.233	0.165	0.00000	
Factor (B)	0.621	0.303	0.214	0.00372		0.739	0.360	0.255	0.00724		0.478	0.233	0.165	0.00008	
Factor (G X B)	NS	0.605	0.428	0.99220		NS	0.721	0.510	0.84289		NS	0.466	0.329	0.87280	

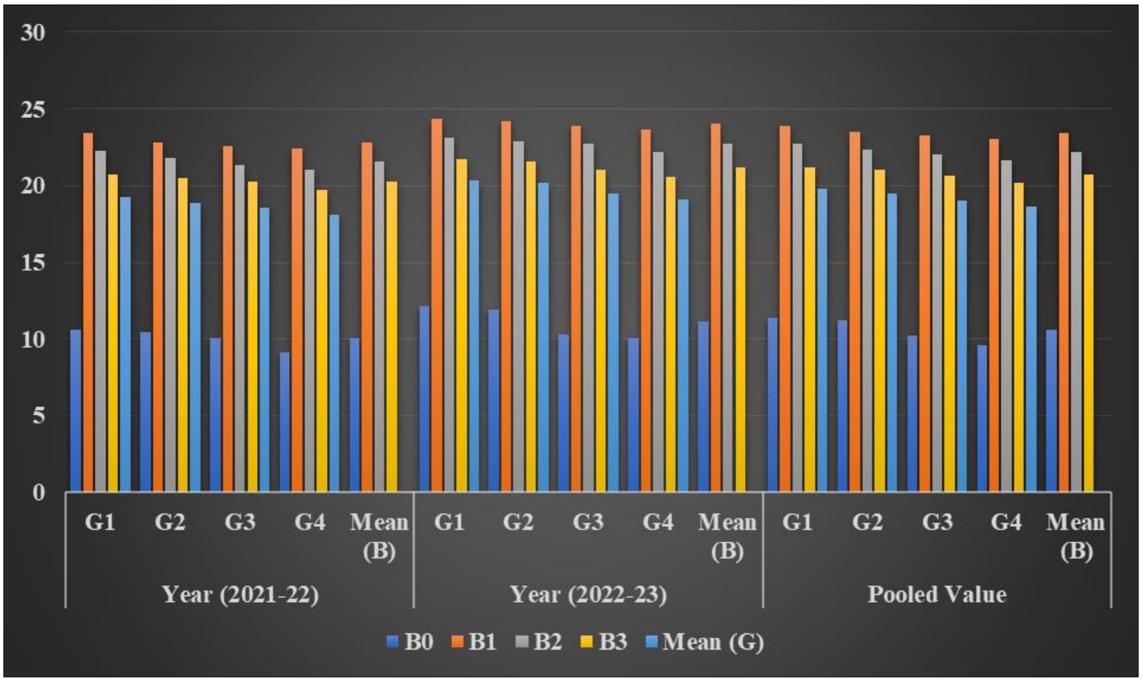

FIG 8:SEED YIELD (Q/HA) AS INFLUENCED BY VARIOUS BIOFERTILIZERS AND PLANT GROWTH REGULATORS

Discussions

Phenological parameters

The phenological parameters like days taken to first flower emergence, days taken to 50% flowering and number of flowers per plant was evaluated during the investigation of the phenological parameters. The application of B_1 (*Rhizobium meliloti* @ 25ml/kg seeds) significantly increased the days taken to first flower emergence, days taken to 50% flowering and number of flowers per plant over control during both the years and in pooled analysis. The beneficial response of *Rhizobium meliloti* @ 25ml/kg seeds to growth parameters and growth might be due to rhizobium facilitate better plant nutrient management by synthesis of atmospheric nitrogen to the useful form of nitrogen and same time it is also help the plant to increase nutrient uptake and releasing of plant hormone. These are the positive response may induce the earliness flowering, 50% flowering and number of flowers per plant. The close findings are Meena *et al.* (2015)[11] and Nair *et al.* (2021)[15]. The significantly maximum increase in days taken to first flower emergence, days taken to 50% flowering and number of flowers per plant of the crop was also observed with the application of GA3 @200 ppm (G_2) over G_1 during both the years and in pooled analysis. The phenological parameters like days taken to first flower emergence, days taken to 50% flowering and number of flowers per plant were highest might be due to the application of GA3-200ppm may facilitate to improve cell multiplication, synthesis of essential amino acids, proteins and modified the physiology of the plant to facilitate early phenological effect. The all the growth parameters were also highest recorded in the same treatment and this may also help to induce early flowering. It may also be noted that irrespective of the concentration, gibberellic acid proved more effective in improving the phenological parameters than other treatments. The maximum. The close findings are Yugandhar *et al.* (2014)[23], Tania *et al.* (2015)[21] and Parmar *et al.* (2018)[16].

Yield parameters

The application of B_1 (*Rhizobium meliloti* @ 25ml/kg seeds) significantly increased the pod length, number of seed per pod, test weight (1000 seed weight) of seed, seed yield (kg/plot) and seed yield (q/ha) over control during both the years and in pooled analysis. The highest yield parameters were recorded in the treatment incorporation of rhizobium might be due to the, rhizobium provide most of major essential nutrient by synthesis of atmospheric unused form of nitrogen in useful form of nitrogen (NO_3^-) to the plants along with this function the biofertilizers rhizobium stored some water in root nodules that is helpful for nutrient uptake and mobilization of other essential macro and micro nutrients. The all available nutrients increase the photosynthetic rate for accumulation of food as starch and this stored starch used for formation of pods, pod length and seeds. The various biofertilizers fixed the nitrogen to the plant root nodules and solubilized available phosphorus to plants this helps to increase in yield. Nitrogen accelerates the growth, development and reproductive phases of the fenugreek. Qualitatively it is also induced for protein synthesis, thus promoting number of pod and seed weight per pod this result increase in yield. The close findings are Jat (2004)[9] and Mehta*et al.*(2010a)[14],Mehta *et al.* (2012b)[13] and Patel *et al.* (2021)[17].

The significantly maximum increase in pod length, number of seed per pod, test weight (1000 seed weight) of seed, seed yield (kg/plot) and seed yield (q/ha) observed with the application of GA3 @100 ppm (G_1) over G_4 during both the years and in pooled analysis. The other growth, phenological and root parameters were also maximum noted in same treatment because the G_1 increase the cell multiplication, cell enlargement and cell elongation. Same time also induce for formation of chlorophyl and increase the formation of stored food material. The PGR GA3 accelerate the growth, reproductive to induce early bolting and early seed set. This condition leads to assimilation of food in seeds and increase the crop yield and productivity per unit area. The similar result was also reported by Deore and Bharud (1990)[8], Shah and Samiullah (2006)[19], Akter *et al.* (2007)[2], Singh *et al.* (2012)[20], Meena *et al.* (2013)[12] and Tania *et al.* (2015)[21].

Conclusion

It is concluded that the seed treatment by biofertilizers rhizobium significantly reduced the days taken to anthesis and maximise number of flower plant. Based on data it is also concluded that the application of GA3 at 20 and 40 days after seed sowing, induced early flowering because it is induced early bolting. It is also concluded that the biofertilizers *Rhizobium meliloti* produced maximum yield attributes and yield. With respect to plant growth regulators, GA_3 200 ppm found best.

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