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Growth rate and productivity of foxtail millet genotypes as influenced by biostimulants

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Abstract
An experiment was conducted in AHRS, Bavikere during late *kharif* 2021 to study the "Growth rate and productivity of foxtail millet genotypes as influenced by biostimulants". The experiment was laid out in split plot design with 12 treatment combinations in which main plot treatment includes three genotypes *viz*., SiA-3156 (G_1), HMT-100-1 (G_2) and DHFt-109-3 (G_3). Subplot treatment includes foliar application of biostimulants *viz*., humic acid @ 0.1% (F_1), panchagavya @ 3% (F_2), humic acid @ 0.1% and panchagavya @ 3% (F_3) at 30 and 60 DAS and RDF as control (F_4). The results revealed that the HMT-100-1 (G_2) in main plots, foliar application of humic acid @ 0.1% and panchagavya @ 3% (F_3) in subplots and HMT-100-1 with foliar application of humic acid @ 0.1% and panchagavya @ 3% (G_2F_3) in interactions recorded significantly higher total dry matter accumulation (leaves, stem and reproductive parts), grain yield and growth rate in terms of AGR, CGR and RGR compared to other treatment combinations.

Keywords: Foxtail millet, genotypes, foliar application, humic acid, panchagavya, growth rates

Introduction
Foxtail millet is one of the oldest cultivated small millets for both food and fodder and also regarded as an elite drought tolerant crop. It is a good source of protein (10%), dietary fiber (6.7%), fat (4%), minerals and vitamins. The prerequisite for getting higher yield in any crop is higher total dry matter accumulation and it's partitioning into various plant parts coupled with maximum translocation of photosynthates to sink. Better yield potential of the crop may be exploited through better nutrient management practices like use of biostimulants like humic acid, panchagavya *etc.* through foliar application at critical growth stages like tillering and flowering stage improves the physiological efficiency and plays a significant role in raising the amount of dry matter partitioned to the reproductive parts which in turn increases the productivity of the crop. Enhancement of yield potential through breeding programme is a long term and complicated process. Identification of foxtail millet genotypes with high physiological efficiency and better yield potential in the existing varieties is a short term approach. Hence, the present study was taken up to study the Growth rate and productivity of foxtail millet genotypes as influenced by biostimulants under late sown conditions.

Materials and Methods
An experiment was conducted at AHRS, Bavikere during late *Kharif* season of 2021 to study the "Growth rate and productivity of foxtail millet genotypes as influenced by biostimulants". The experiment was laid out in split plot design with 12 treatments replicated thrice in which main plot treatment includes three genotypes *viz*., SiA-3156 (G_1), HMT-100-1 (G_2) and DHFt-109-3 (G_3). Subplot treatment includes foliar nutrients of biostimulants *viz*., 0.1% humic acid foliar application (F_1), 3% panchagavya foliar application (F_2), 0.1% humic acid and 3% panchagavya foliar application (F_3) at 30 and 60 DAS and control (F_4). RDF and FYM are commonly applied to all the treatments. Plant Samples were collected at every 30 days interval up to harvesting stage. For the destructive sampling, five plants were selected from each plot and are digged out at different stages of crop. The samples were oven dried for 72 hours at 65°C to attain constant dry weight and then the dry weight was recorded for further use in dry matter partitioning. Harvesting and threshing operations were done manually by separating panicles from each plot and sun dried before threshing after that grain weight was recorded in kilogram and later converted to kg ha^{-1}.
The different growth indices are calculated by the formulas as follows

Absolute growth rate is computed by using the following formula

- AGR = $\frac{W2-W1}{t1-t2}$ g p $^{-1}$ day^{-1} (Radford, 1967) [6]

Where, W_1 and W_2 are dry weights of plant at time t_1 and t_2, respectively

Crop growth rate is computed by using the following formula

- CGR = $\frac{W2-W1}{(t1-t2)\times A}$ g m^{-2} day^{-1} (Watson, 1967) [10, 11]

Where, W_1 and W_2 are dry weights of plant at time t_1 and t_2, respectively and A is spacing.

Relative growth rate is computed by using the following formula

- RGR = $\frac{logeW2-logeW1}{(t1-t2)}$ g g $^{-1}$ day^{-1} (Watson, 1963) [10, 11]

Where, W_1 and W_2 are dry weights of plant at time t_1 and t_2 respectively. Log_e natural logarithm.

.The data recorded on various observations on total dry matter accumulation (leaves, stem and reproductive parts), growth indices (AGR, CGR and RGR) and grain yield are subjected to analysis of variance (ANOVA) as outlined by Gomez and Gomez (1984). The level of significance used in 'F' test was at 5%.

Results and Discussion

Significant variation was recorded in the treatments with respect to drymatter accumulation in leaves, stem and reproductive parts, growth indices such as AGR, CGR and RGR at all the stages of study. The data regarding variation in drymatter partitioning as influenced by genotypes and foliar nutrition of biostimulants was presented in Table 1.

A. Dry matter accumulation in leaves

Among the genotypes, there was a significant variation in dry matter accumulation in leaves at all the growth stages. HMT-100-1 recorded the maximum dry matter accumulation in leaves (2.75, 5.32 and 6.43 g plant^{-1} at 30, 60 DAS and at harvest, respectively) compared to DHFt-109-3 and SiA-3156. Foliar application of 0.1% humic acid and 3% panchagavya along with soil application of RDF recorded significantly maximum dry matter accumulation in leaves (2.76, 5.98 and 6.55 g plant^{-1} at 30, 60 DAS and at harvest, respectively) compared to application of RDF alone (2.36, 3.88 and 4.87 g plant^{-1} at 30, 60 DAS and at harvest).

Total dry matter accumulation in leaves showed significant difference in interaction between genotypes and foliar nutrition of biostimulants. HMT-100-1 with 0.1% humic acid and 3% panchagavya foliar along with soil application RDF recorded significantly maximum dry matter accumulation in leaves (2.96, 6.72 and 7.39 g plant^{-1} at 30, 60 DAS and at harvest, respectively) compared to other treatment combinations.

B. Stem dry matter

Among genotypes, significant variation in dry matter accumulation in stem recorded in 60 DAS and at harvest except 30 DAS. HMT-100-1 recorded the significantly maximum dry matter accumulation in stem (1.18, 8.28 and 11.36 g plant^{-1} at 30, 60 DAS and at harvest, respectively) compared to DHFt-109-3 and SiA-3156. Foliar application of 0.1% humic acid and 3% panchagavya along with RDF recorded significantly maximum dry matter accumulation in stem (1.24, 8.98 and 11.81 g plant^{-1} at 30, 60 DAS and at harvest, respectively) compared to application of RDF alone (1.10, 6.43 and 8.83 g plant^{-1} at 30, 60 DAS and at harvest, respectively)

Interaction between genotypes and foliar nutrition of biostimulants varied significantly between the treatments. HMT-100-1 with 0.1% humic acid and 3% panchagavya along with soil application of RDF recorded maximum dry matter accumulation in stem (1.21, 9.71 and 12.73 g plant^{-1} at 30,60 DAS and at harvest, respectively) compared to other treatment combination.

C. Reproductive parts dry matter

Among genotypes, HMT-100-1 recorded the significantly maximum dry matter accumulation in reproductive parts (1.58 g plant^{-1} at 60 DAS and 4.74 g plant^{-1} at harvest) compared to DHFt-109-3 and SiA-3156. Foliar application of 0.1% humic acid and 3% panchagavya along with soil application of RDF recorded significantly maximum dry matter accumulation in reproductive parts (10.53 g plant^{-1} at 60 DAS and 15.67 g plant^{-1} at harvest) compared to application of RDF alone (10.53 g plant^{-1} at 60 DAS and 15.67 g plant^{-1} at harvest).

Among interactions, HMT-100-1 with 0.1% humic acid and 3% panchagavya foliar application along with soil application of RDF recorded maximum dry matter accumulation in reproductive parts (10.53 g plant^{-1} at 60 DAS and 15.67 g plant^{-1} at harvest) compared to other treatment combinations.

Table 1: Variation in dry matter accumulation in different parts of the foxtail millet as influenced by genotypes and foliar nutrition of biostimulants

Treatments	Leaf dry matter (g plant^{-1})			Stem dry matter (g plant^{-1})			Reproductive parts dry matter (g plant^{-1})	
	30 DAS	60 DAS	At harvest	30 DAS	60 DAS	At harvest	60 DAS	At harvest
Main plots- Genotypes (G)								
G1	2.37	4.26	4.90	1.24	7.26	9.49	1.15	3.69
G2	2.75	5.32	6.43	1.18	8.28	11.36	1.58	4.74
G3	2.56	4.62	5.22	1.21	7.41	10.01	1.20	3.87
S.Em. ±	0.02	0.08	0.12	0.03	0.14	0.17	0.041	0.064
C. D. at 5%	0.08	0.32	0.48	NS	0.57	0.68	0.162	0.252
Sub plots- Foliar nutrition (F)								
F1	2.64	4.85	5.78	1.28	7.94	10.78	1.32	4.19
F2	2.48	4.21	5.27	1.23	7.26	9.73	1.15	3.93
F3	2.76	5.98	6.55	1.24	8.98	11.81	1.80	4.71

F4	2.36	3.88	4.47	1.10	6.43	8.83	0.98	3.57
S.Em. ±	0.10	0.09	0.09	0.04	0.13	0.13	0.048	0.081
C. D. at 5%	NS	0.28	0.27	NS	0.40	0.40	0.142	0.241
Interaction (G x F)								
G1F1	2.53	4.16	4.84	1.36	7.31	9.62	1.13	3.51
G1F2	2.21	3.81	4.72	1.24	7.02	8.93	1.07	3.58
G1F3	2.70	5.48	5.95	1.27	8.62	11.14	1.57	4.37
G1F4	2.03	3.58	4.10	1.09	6.11	8.28	0.84	3.29
G2F1	2.84	5.27	6.82	1.28	8.29	11.70	1.51	4.94
G2F2	2.88	5.01	6.44	1.18	8.25	11.23	1.47	4.81
G2F3	2.96	6.72	7.39	1.21	9.71	12.73	2.24	5.18
G2F4	2.33	4.29	5.07	1.05	6.87	9.77	1.10	4.02
G3F1	2.54	5.13	5.67	1.20	8.21	11.02	1.32	4.12
G3F2	2.35	3.82	4.66	1.26	6.52	9.02	0.90	3.39
G3F3	2.63	5.75	6.30	1.24	8.62	11.57	1.60	4.57
G3F4	2.24	3.76	4.23	1.15	6.31	8.44	1.00	3.41
S.Em. ±	2.71	0.16	0.15	0.07	0.23	0.23	0.083	0.140
C. D. at 5%	NS	0.48	0.47	NS	0.70	0.70	0.247	0.417

G_1: SiA 3156
G_2: HMT-100-1
G_3: DHFt-109-3
F_1: RDF + Foliar application of humic acid @ 0.1% (at 30 and 60 DAS)
F_2: RDF + Foliar application of panchagavya @ 3% (at 30 and 60 DAS)
F_3: RDF + Foliar application of humic acid 0.1% and panchagavya @ 3% (at 30 and 60 DAS)
F_4: RDF (Control)

Total dry matter accumulation and grain yield

Among the three genotypes studied, HMT-100-1 recorded significantly higher total dry matter accumulation (3.93, 15.33 and 22.33 g plant^{-1} at 30, 60 DAS and at harvest respectively) and grain yield (1701 kg ha^{-1}) compared to DHFt-109-3 and SiA-3156. It was mainly attributed to differences in the growth parameters like plant height, number of tillers, leaf area. It also depends on their potentiality to utilize and translocate photosynthates from source to sink (Brunda *et al*., 2015) [12]. Genotypic variations in dry matter accumulation in foxtail millet genotypes were also reported by Vagdevi *et al*. (2020) [8], Jyothi *et al*. (2016) [13] in foxtail millet and Ahmed *et al*. (2020) [1] in proso millet.

Among the biostimulants tried, the treatment that received 0.1% humic acid and 3% panchagavya along with RDF excelled over all other treatments by registering higher total dry matter accumulation (4.00, 16.77 and 23.00 g plant^{-1} at 30, 60 DAS and at harvest respectively) and grain yield (1781 kg ha^{-1}). Whereas, significantly the lowest total dry matter accumulation (3.49, 11.29 and 16.85 g plant^{-1} at 30, 60 DAS and at harvest respectively) and grain yield (1380 kg ha^{-1}) were recorded with application of RDF alone (Table. 2). Providing additional nutrient supply through the foliar application of biostimulants like humic acid and panchagavya facilitate easy and quick absorption, assimilation and translocation of nutrients by target organs which increased the production of growth regulators in the cell system. Effective utilization of applied nutrients increased the translocation of the photosynthates from source to sink ultimately resulted in higher yield. These results are in agreements with the findings of Kumaran and Parasuraman. (2019) [4] in foxtail millet; Patel *et al.* (2021) in pearl millet; Vanitha and Mohandas (2014) [9] in paddy and Gokul and Senthilkumar (2019) [3] in finger millet.

Among the interactions, combination of HMT-100-1 with foliar application of 0.1% humic acid and 3% panchagavya along with RDF recorded significantly higher total dry matter accumulation (4.17 g, 18.67 g and 25.30 g plant^{-1} at 30, 60 DAS and at harvest respectively) and grain yield (2028 kg ha^{-1}) compared to other treatment combinations. Combined effect of the genetic potential of the genotype to adopt for the climate of that area and additional supply of nutrient through the biostimulants along with the RDF made significant increase in the yield of the crop. The results are in conformity with the findings of Athish *et al.* (2019) [14] in foxtail millet; Ahmed *et al.* (2012) [1] in proso millet.

Table 2: Total dry matter accumulation (g plant^{-1}) and grain yield (kg ha^{-1}) of foxtail millet as influenced by genotypes and foliar nutrition of biostimulants

Treatments	Total dry matter accumulation 9g plant^{-1})			Grain yield (kg ha^{-1})
	30 DAS	60 DAS	At harvest	
Main plots – Genotypes(G)				
G_1	3.61	12.68	18.03	1408.2
G_2	3.93	15.33	22.33	1701.0
G_3	3.80	13.23	19.08	1538.7
S.Em. ±	0.03	0.38	0.38	39.57
C. D. at 5%	0.14	1.51	1.52	159.54
Sub plots – Foliar nutrition(F)				
F_1	3.92	14.31	20.64	1550.6
F_2	3.70	12.62	18.76	1485.4
F_3	4.00	16.77	23.00	1781.2
F_4	3.49	11.29	16.85	1380.1

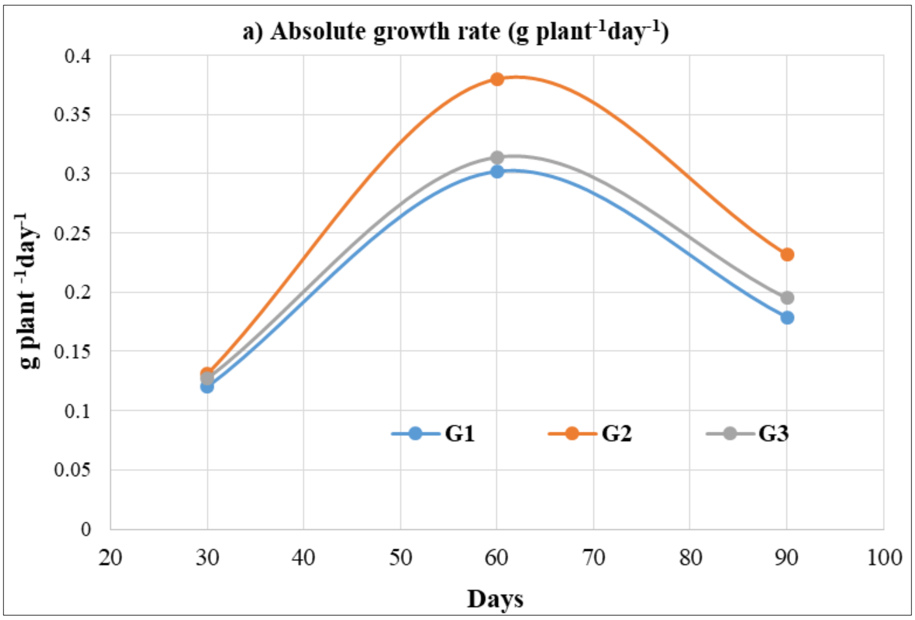
S.Em. ±	0.13	0.22	0.27	31.77
C. D. at 5%	NS	0.66	0.81	95.39
Interaction (G x F)				
G_1F_1	3.90	12.60	17.97	1423.5
G_1F_2	3.45	11.90	17.14	1376.2
G_1F_3	3.97	15.67	21.36	1508.5
G_1F_4	3.13	10.53	15.67	1324.7
G_2F_1	4.12	15.67	23.15	1719.2
G_2F_2	4.06	14.73	22.06	1626.0
G_2F_3	4.17	18.67	25.30	2028.1
G_2F_4	3.37	12.27	18.79	1430.6
G_3F_1	3.74	14.67	20.81	1509.2
G_3F_2	3.60	11.23	17.07	1453.8
G_3F_3	3.87	15.97	22.33	1806.9
G_3F_4	3.99	11.07	16.09	1385.0
S.Em. ±	0.22	0.38	0.47	55.03
C. D. at 5%	NS	1.14	1.41	163.50

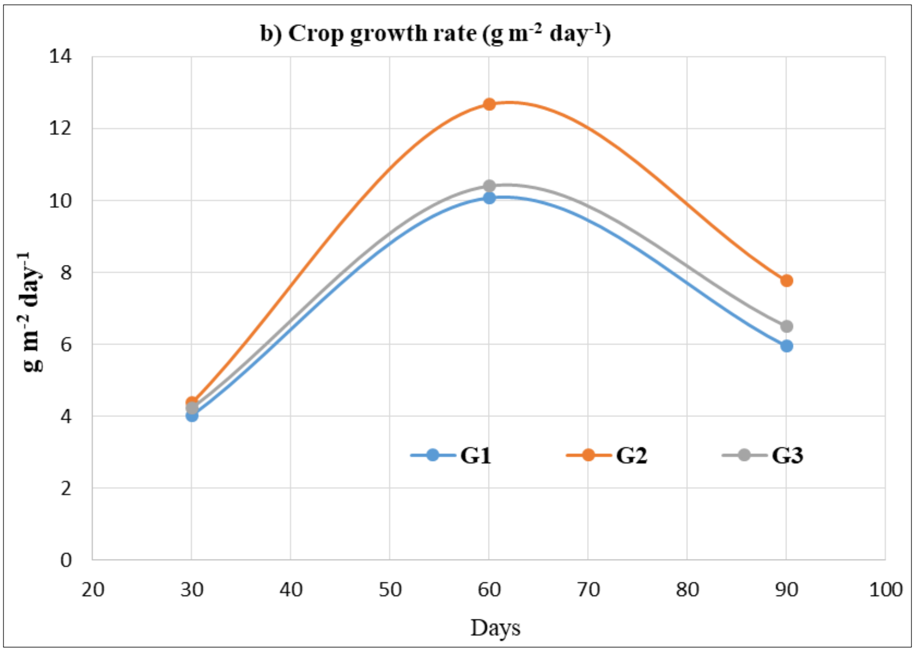
Growth indices

There was increase in AGR, CGR and RGR from initial to 30 DAS and 30 to 60 DAS. However, they decreased after 60 DAS to harvest due to senescence and accumulation of photosynthates was concentrated on reproductive parts which has reduced the vegetative growth

Among genotypes, significantly higher absolute growth rate (0.131, 0.380 and 0.232 g plant^{-1} day^{-1} at 30, 60 DAS and at harvest, respectively), crop growth rate (4.36,12.67 and 7.77 g m^{-2} day^{-1} at 0-30DAS, 30-60 DAS and 60 DAS- at harvest, respectively) and relative growth rate (0.0455, 0.0450 and 0.0128 g g^{-1} day^{-1} 0-30DAS, 30-60 DAS and 60 DAS- at harvest, respectively) recorded in HMT-100-1 compared to DHFt-109-3 and SiA-3156.(Fig. 1)

Foliar nutrition of biostimulants significantly influenced the AGR, CGR and RGR at 60 DAS and at harvest except at 30 DAS, 0.1% humic acid and 3% panchagavya application along with soil application of RDF recorded significantly higher absolute growth rate (0.425 g plant^{-1} day^{-1} at 30 - 60 DAS and 0.216 g plant^{-1} day^{-1} at 60 DAS- at harvest), crop growth rate (14.07 g m^{-2} day^{-1} at 30 - 60 DAS and 7.23 g m^{-2} day^{-1} at 60 DAS- at harvest) and relative growth rate (0.0477 g g^{-1} day^{-1} at 30 - 60 DAS and 0.0136 g g^{-1} day^{-1} at 60 DAS- at harvest) compared to application of RDF alone.(Fig. 2) The improvement in growth indices with foliar application of humic acid and panchagavya was might be due to synergistic effect shown by the inorganic (RDF) and organic nutrients (biostimulants) enhanced physiological activity of the plants. The nutrients applied are taken-up directly by their target organs, providing a specific and rapid response by increasing nitrogen content in the plant system might have resulted in more synthesis of amino acid and nucleic acids *etc*., in meristematic tissues enabled greater absorption, assimilation, translocation and metabolization of nutrients ultimately leads to increase in cell division and multiplication there by accumulating more and more amount of dry matter in the plants which resulted in higher growth and development. These findings are in consonance with Chintana *et al*. (2021) [2] in groundnut; Shivashankar *et al*. (2020) [7] in finger millet and Niketa *et al*. (2016) [5] in pearl millet.





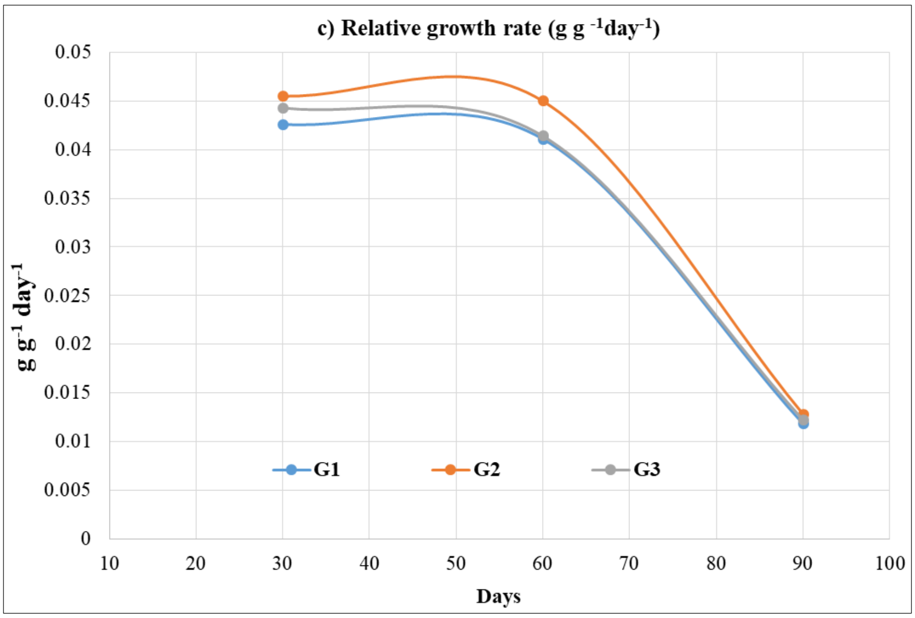
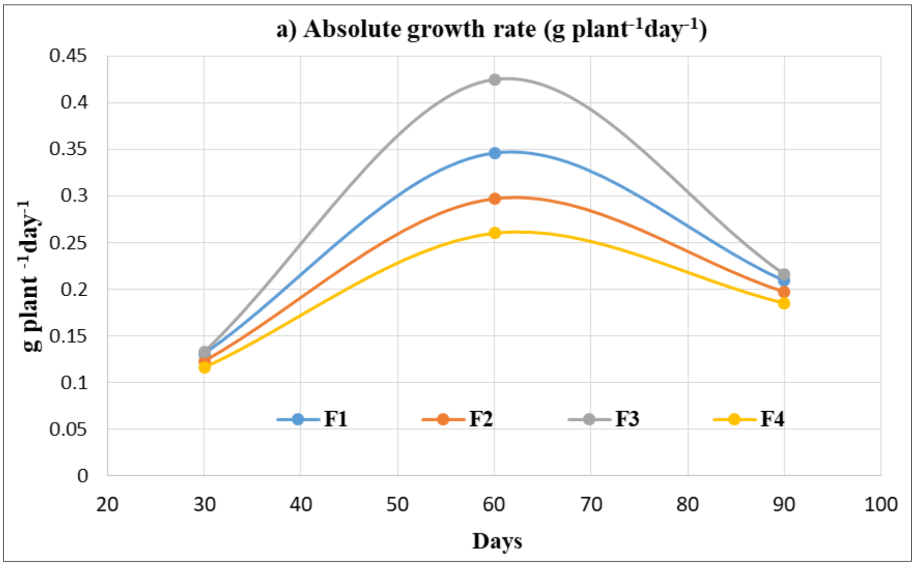
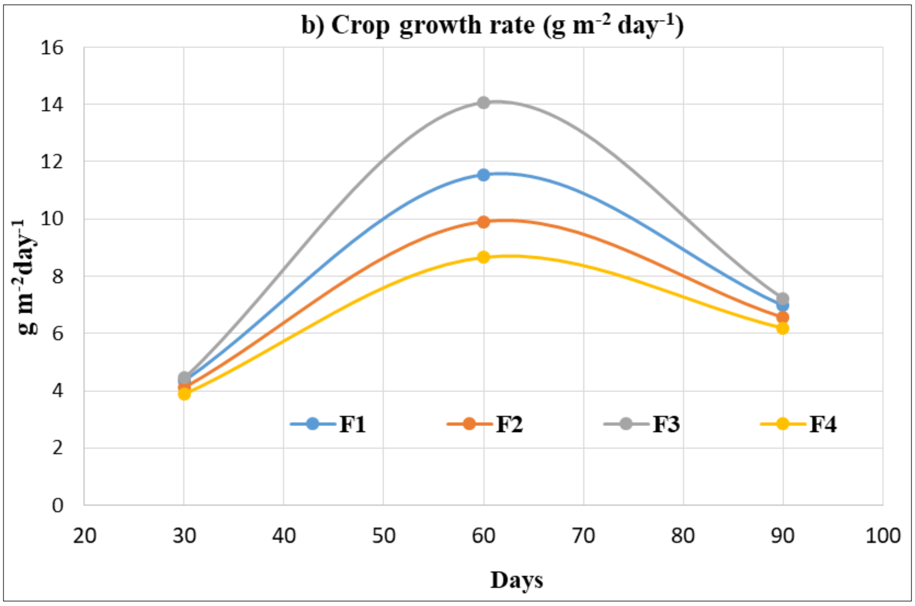


Fig 1: a) Absolute growth rate b) Crop growth rate c) Relative growth rate of foxtail millet as influenced by genotypes





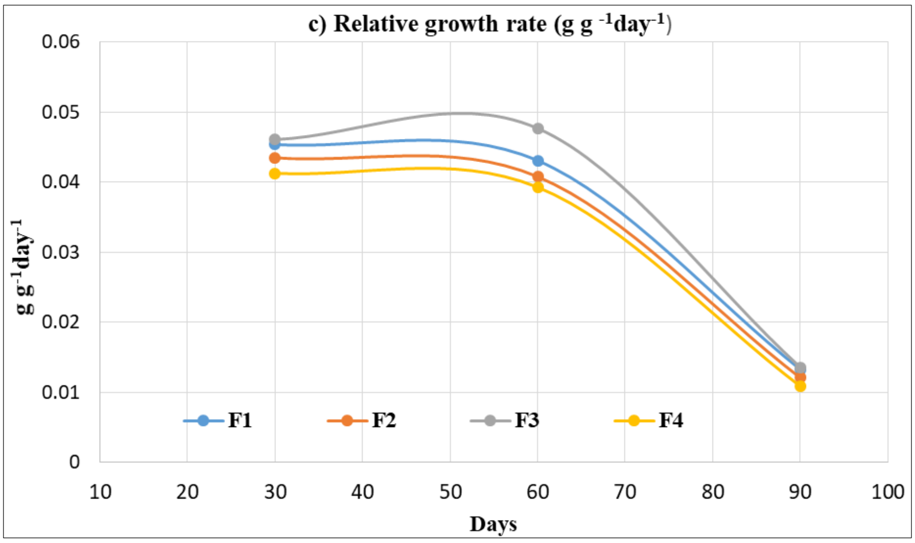


Fig 2: a) Absolute growth rate b) Crop growth rate c) Relative growth rate of foxtail millet as influenced by biostimulant

Conclusion

Growth and development of the crop depends on total dry matter accumulation and its partitioning to different plant parts at different growth stages which is attributed to increase in growth rate such as absolute growth rate, crop growth rate, relative growth rate. Foliar application of the biostimulants like humic acid and panchagavya significantly increased total dry matter accumulation in different foxtail millet genotypes ultimately increased grain and straw yield. From the present investigation it can be concluded that HMT-100-1 with foliar application of 0.1% humic acid and 3% panchagavya along with RDF excelled over all other treatments by registering better dry matter partitioning, higher growth indices and grain yield compared to other treatment combinations.

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