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Effect of Micronutrients on Growth and Yield of Sweet Corn - Greengram Cropping System

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Abstract

An investigation on the impact of micronutrients in the sweet corn-greengram cropping system was conducted at College of Agriculture, V. C. Farm, Mandya during *kharif* 2022 and 2023 followed by *rabi* 2022 and 2023. The study comprised ten treatments with three replications which was laid out in randomized block design. The pooled data showed that the foliar spray of MM_1 @ 0.1 per cent (Micronutrients mixture - Zn, Mn, Fe, Cu and B) + Humic acid @ 0.5 per cent applied at 30 DAS significantly increased the yield attributes of sweet corn, such as number of cobs plant^{-1}, fresh cob yield and green fodder yield (1.43, 181 q ha^{-1} and 281 q ha^{-1}, respectively), as well as the growth parameters of plant height, number of leaves plant^{-1} and leaf area at harvest (213.78 cm, 10.27, 4275.07 cm^2 plant^{-1}, respectively). In contrast, greengram which is grown as a sequential crop without any treatment imposition, the residual effect of foliar spray of MM_2 @ 0.2 per cent + Humic acid @ 0.5 per cent recorded significantly higher growth parameters, such as plant height and leaf area at harvest (37.55 cm and 408.78 cm^2 plant^{-1}, respectively) and yield attributes, such as number of pods plant^{-1}, seed yield and haulm yield (29.78, 996 kg ha^{-1} and 1971 kg ha^{-1}, respectively).

Keywords : Greengram, Growth, Micronutrients mixture, Yield of sweet corn

In India, maize, a member of the *Poaceae* family and an important cereal in the world's agricultural economy, ranks third in importance among cereal crops, behind rice and wheat (Biradar *et al*., 2013 and Parameshnaik *et al*., 2024). Dent corn, sweet corn, pop corn and baby corn are the various varieties of maize that are categorised according to the endosperm of the kernels (Gurunath Raddy *et al*., 2022). Growing maize, also known as sweet corn for vegetables is a recent development aimed at diversifying the value-added and food processing industries. Maize needs a lot of soil nutrients for growth and development in order to produce higher yields, but most farmers only use fertilisers that supply the major nutrients - N, P and K, paying little attention to secondary and micronutrients, which causes them to quickly deplete and necessitate periodic or annual supplies of these nutrients. Even though secondary and micronutrient requirements are lower than those of primary nutrients, a lack of these can still restrict crop growth and productivity. Additionally, sufficient amounts of these nutrients contribute to the effectiveness of fertilisers that are applied (Ramanjineyulu *et al*., 2016). The purpose of growing greengram in succession was to preserve the fertility of the soil.

From cell development to respiration, photosynthesis, chlorophyll formation, enzyme activity, hormone synthesis, nitrogen fixation and other processes, micronutrients are actively involved in the metabolic processes of plants. In order to bring stability and sustainability to the food production process, micronutrients will be crucial in providing protection. Macro and micronutrient roles are critical to yields. Proteins and all enzymes are primarily made of nitrogen. P is an essential component of ATP and ADP, two energy carrier molecules and is involved in nearly all biochemical processes. All higher plants are known to need six micronutrients: Mn, Fe, Cu, Zn, B and Mo. Their involvement in photosynthesis, N-fixation, respiration and other biochemical pathways has been extensively documented. According to Bhangare *et al*. (2019), maize (*Zea mays* L.) crops have relatively small micronutrient requirements and the range between their deficiencies and toxicities in plants and soils is relatively narrow. In order to better understand the impact of micronutrients with recommended dose of fertilizers on sweet corn productivity, a field study was conducted.

Material and Methods

A field experiment was carried out at the College of Agriculture, V. C. Farm, Mandya, during the *kharif* and *rabi* seasons of 2022 and 2023. At an elevation of 695 meters above mean sea level, the site is situated in Karnataka's Agro Climatic Zone VI (Southern Dry Zone). The purpose of the study was to examine the impact of micronutrients on the growth and yield of a sweet corn - greengram cropping system, which consisted of ten treatments replicated three times in a randomised complete block design. The details of the treatment are: T_1 - Absolute control; T_2 - Recommended package of practices [RDF (Sweet corn - 120:60:40 NPK kg ha^{-1} and greengram - 25 : 50 : 50 NPK kg ha^{-1}), FYM @ 10 t ha^{-1} and $ZnSO_4.7H_2O$ @ 10 kg ha^{-1} was common for all treatments except absolute control]; T_3 - Foliar spray of MM_1 @ 0.1 per cent (Micronutrients mixture - Zn, Mn, Fe, Cu and B);T_4 - Foliar spray of MM_2 @ 0.2%; T_5 - Humic acid spray @ 0.5 per cent; T_6 - Biostimulant spray @ 625 ml ha^{-1}; T_7 - T_3 + Humic acid spray @ 0.5 per cent; T_8 - T_4 + Humic acid spray @ 0.5 per cent; T_9 - T_3 + Biostimulant spray @ 625 ml ha^{-1}; T_{10} - T_4 + Biostimulant spray @ 625 ml ha^{-1}. Foliar spray was done at 30 DAS.

For all treatments other than the absolute control, the recommended dose of fertilizers remained the same. In this experiment, macarena (seaweed extract) is the biostimulant used. Two weeks prior to the sweet corn sowing, FYM was applied. Greengram, on the other hand, was planted as a succession crop after the incorporation of the sweet corn stubbles and with the exception of the absolute control, the recommended dosage of fertilizers (25:50:50 NPK kg ha^{-1}) was given. The greengram variety used was KKM-3, released from ARS, Kathalagere and the sweet corn hybrid used for sowing is Sugar-75, released by Syngenta Company. Plant height (cm), leaf area (cm^2 plant^{-1}), number of cobs plant^{-1}, fresh cob yield (q ha^{-1}) and green fodder yield (q ha^{-1}) in sweet corn and plant height, leaf area (cm^2 plant^{-1}), number of pods plant^{-1}, seed yield (kg ha^{-1}) and haulm yield (kg ha^{-1}) in greengram were recorded as biometric observations and plant characteristics as indicators of crop growth and yield.

The statistical analysis of the experimental observations was conducted using Fisher's method of analysis of variance (ANOVA), as described by Gomez and Gomez (1984). The computation of critical difference (CD) values occurs when the 'F' test values are deemed significant at the five per cent significance level.

Results and Discussion

Growth Parameters of Sweet Corn and Greengram

Plant Height (cm)

The absolute control produced the shortest plant height (25.22, 67.90, 85.42 and 129.85 cm, respectively) at 30, 45, 60 DAS and at harvest in sweet corn (Table 1). The highest plant height was observed with the foliar application of MM_1 @ 0.1 per cent + Humic acid spray @ 0.5 per cent applied at 30 DAS (40.94, 132.99, 182.59 and 213.78 cm, respectively), which is significantly superior over rest of the treatments.

Taller plants with the combined foliar application of MM_1 @ 0.1 + 0.5 per cent humic acid might be

TABLE 1

Plant height (cm) of sweet corn at different growth stages as influenced by foliar application of micronutrients in sweet corn – greengram cropping system

Treatment	30 DAS			45 DAS			60 DAS			At harvest		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	23.84	26.60	25.22	67.18	68.62	67.90	84.86	85.97	85.42	129.23	130.48	129.85
T_2	36.81	39.53	38.17	95.43	95.60	95.52	128.77	131.90	130.33	186.08	187.46	186.77
T_3	37.48	40.09	38.79	121.71	119.69	120.70	155.47	158.84	157.15	190.04	192.77	191.41
T_4	24.87	27.98	26.42	87.11	89.60	88.36	117.57	120.85	119.21	162.06	164.16	163.11
T_5	37.44	40.14	38.79	118.52	114.82	116.67	139.23	143.40	141.31	188.03	190.02	189.03
T_6	37.24	39.95	38.60	100.14	101.75	100.94	138.01	140.93	139.47	186.08	188.27	187.18
T_7	39.61	42.28	40.94	132.06	133.92	132.99	180.55	184.63	182.59	208.99	218.56	213.78
T_8	37.26	39.85	38.55	100.33	104.74	102.53	143.47	148.25	145.86	190.03	191.19	190.61
T_9	37.77	40.48	39.13	126.77	127.40	127.09	172.59	177.58	175.08	195.02	200.52	197.77
T_{10}	37.40	39.98	38.69	112.90	107.23	110.06	148.60	152.10	150.35	190.49	191.85	191.17
S.Em. (±)	1.59	2.30	1.33	4.73	5.25	3.35	6.83	7.02	4.74	7.57	7.66	4.88
CD @ 5%	4.71	6.84	3.94	14.05	15.61	9.96	20.30	20.87	14.08	22.50	22.76	14.50

Treatment details :

T_1 : Absolute control
T_2 : Recommended package of practices
T_3 : Foliar spray of MM_1
T_4 : Foliar spray of MM_2
T_5 : Humic acid spray @ 0.5%
T_6 : Biostimulant spray @ 625 ml ha^{-1}
T_7 : T_3 + Humic acid spray @ 0.5%
T_8 : T_4 + Humic acid spray @ 0.5%
T_9 : T_3 + Biostimulant spray @ 625 ml ha^{-1}
T_{10} : T_4 + Biostimulant spray @ 625 ml ha^{-1}

due to sufficient absorption and utilization of micronutrients, which increased nutrient uptake and the synthesis of hormones that promote growth, especially auxin. This could have led to increased growth and internode count, which in turn encouraged the development of the main shoot and increased the height of the sweet corn plant (Yogesh *et al*., 2022). Haghi *et al*. (2016) and Adarsha *et al*. (2019) reported similar observations and findings in maize. This could also be due to favourable effects on a range of biochemical processes at the cytoplasm, membrane and cell wall. Enhanced respiration and photosynthesis rates, enhanced protein synthesis and plant hormone-like activity that promotes shoot and root growth are some of these effects. These findings align with those reported by El-Shafey and El-Dein (2016), Hassan *et al*. (2019), Khan *et al*. (2019), Mahmood *et al*. (2020) and Abd-Rabboh *et al*. (2020). Taller plants were observed in the treatments that received foliar nutrition of humic acid along with RDF. This result was also consistent with those of Prashant (2021), who reported that the increase in plant height due to balanced and increased availability of nutrients, which might have played a significant role in increasing cell division and cell elongation. According to studies carried out by Karrimi *et al*. (2018) and Jolli *et al*. (2020), a high level of auxin production, including indoleacetic acid (IAA), was the primary cause of the increased plant height. Moreover, zinc is a key component of many enzyme's catalytic parts and is involved in the synthesis of tryptophan which is the precursor for the synthesis of IAA. IAA plays a role in the elongation and differentiation of cells. These outcomes concur with the maize research conducted by Verma *et al*. (2006).

TABLE 2

Plant height (cm) of succeeding greengram at different growth stages as influenced by foliar application of micronutrients in sweet corn - greengram cropping system

Treatments	30 DAS			45 DAS			At harvest		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	9.27	9.15	9.21	17.40	20.81	19.11	28.21	28.82	28.51
T_2	11.35	11.21	11.28	19.49	23.33	21.41	30.01	32.15	31.08
T_3	11.87	12.07	11.97	21.04	24.68	22.86	30.80	33.65	32.22
T_4	12.58	13.05	12.82	24.05	26.58	25.32	33.56	35.92	34.74
T_5	12.06	12.42	12.24	22.00	25.17	23.59	31.06	34.38	32.72
T_6	12.26	12.76	12.51	23.18	26.02	24.60	32.24	35.43	33.84
T_7	13.78	15.39	14.59	26.01	28.62	27.32	35.33	38.01	36.67
T_8	14.02	16.03	15.02	26.77	29.61	28.19	36.58	38.52	37.55
T_9	12.93	13.35	13.14	25.14	27.68	26.41	34.17	36.58	35.38
T_{10}	13.29	14.68	13.99	25.57	28.06	26.82	34.75	37.22	35.98
S.Em. (±)	0.55	0.86	0.40	1.27	1.19	0.97	1.38	1.79	1.07
CD @ 5%	1.63	2.56	1.20	3.76	3.54	2.87	4.09	5.33	3.17

Note : RDF alone was applied for all the treatments except absolute control

Due to the effects of micronutrients mixture, humic acid and biostimulants in the sweet corn - greengram cropping sequence, plant heights of greengram varied considerably (Table 2). The treatment that received foliar application of MM_2@ 0.2 per cent + Humic acid @ 0.5 per cent in sweet corn showed significantly higher plant heights (15.02, 28.19 and 37.55 cm, respectively), while the absolute control showed lower plant heights (9.21, 19.11 and 28.51 cm, respectively) at 30, 45 DAS and harvest in greengram.

Leaf Area (cm² plant⁻¹) of Sweet Corn and Greengram

Fig. 1 and Table 3 represents the leaf area of sweet corn and greengram at different growth stages as

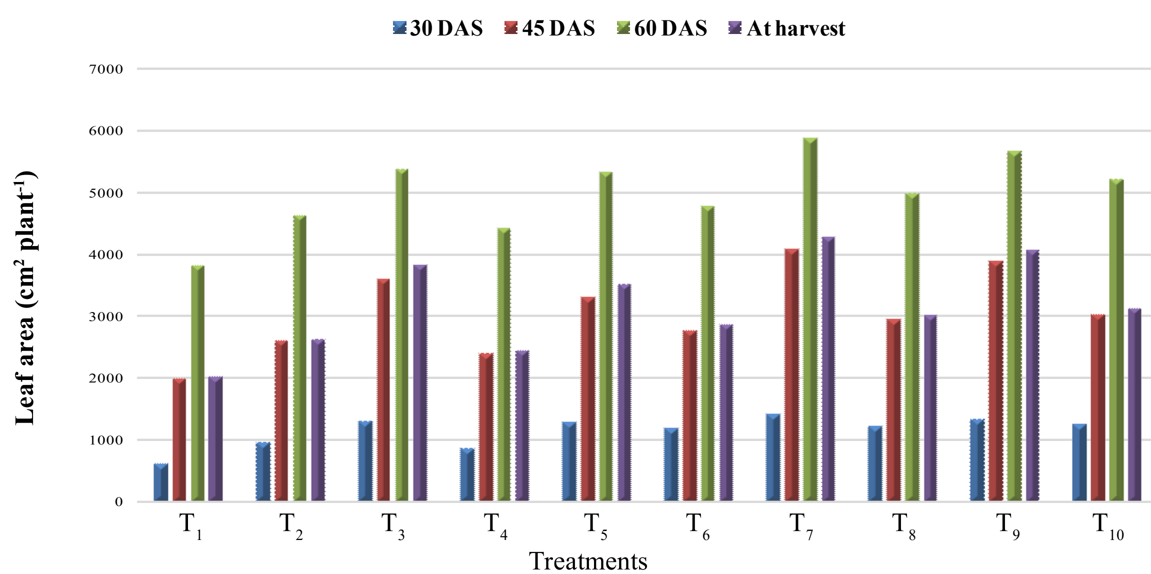

Fig. 1 : Leaf area of sweet corn as influenced by foliar application of micronutrients in sweet corn – greengram cropping system

TABLE 3

Leaf area (cm^2 plant^{-1}) of succeeding greengram at different growth stages as influenced by foliar application of micronutrients in sweet corn - greengram cropping system

Treatments	30 DAS			45 DAS			At harvest		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	98	111	105	215	230	222	202	201	201
T_2	123	129	126	246	269	257	212	206	209
T_3	125	133	129	279	300	290	231	210	221
T_4	152	164	158	379	399	389	271	287	279
T_5	130	140	135	316	328	322	215	235	225
T_6	143	156	150	343	368	355	238	260	249
T_7	180	190	185	462	482	472	378	389	384
T_8	188	195	192	478	495	487	403	415	409
T_9	164	172	168	403	427	415	297	306	301
T_{10}	176	180	178	440	457	448	319	357	338
S.Em. (±)	11.47	10.37	7.39	27.67	30.50	22.00	22.65	17.87	11.37
CD @ 5%	34.09	30.81	21.95	82.21	90.61	65.36	67.30	53.10	33.77

Note : RDF alone was applied for all the treatments except absolute control

affected by the foliar application of micronutrients on a pooled basis.

At 30, 45, 60 DAS and harvest, the foliar application of MM_1 @ 0.1 per cent in conjunction with 0.5 per cent humic acid sprayed at 30 DAS resulted in noticeably greater leaf area measurements (1424, 4082, 5885 and 4275 cm^2 plant^{-1}, respectively). Lower values were obtained with absolute control (627, 1993, 3820 and 2030 cm^2 plant^{-1}, respectively), but it was comparable to the foliar application of MM_1 @ 0.1 per cent + Biostimulant spray @ 625 ml ha^{-1} at 30 DAS (1332, 3898, 5672 and 4074 cm^2 plant^{-1}, respectively).

Combination of NPK and the micronutrient application source increased the plant's physiological and metabolic activity, sparked growth and increased the leaf area per plant because it produced a greater leaf area than the control by absorbing more major nutrients. Bhangare *et al*., (2019), Asif *et al*. (2013), Manasa and Devaranavadagi (2015), Haghi *et al*. (2016) and Adarsha *et al*. (2019) reported similar findings in maize. The afore mentioned results also support the conclusions drawn by Hassan *et al*. (2019), who found that humic acid has beneficial effect on the availability of macro and micronutrients for absorption. This, in turn led to the development of vegetative growth, increased photosynthesis and an increase in the leaf area of the plant. According to Jolli *et al*. (2020), zinc and iron stimulate plant enzymes that are involved in the metabolism of carbohydrates, the preservation of cellular membrane integrity, protein synthesis and the regulation of auxin synthesis, all of which promote root and shoot growth and development. Similar outcomes were also reported by Karrimi *et al*. (2018), who noted that foliar application of zinc and iron at booting and silking along with RDF was associated with higher leaf area. This was attributed to improved nutrient absorption and translocation, which delayed senescence and abscission.

TABLE 4

Number of cobs plant^{-1}, fresh cob yield (q ha^{-1}) and green fodder yield (q ha^{-1}) of sweet corn as influenced by foliar application of micronutrients in sweet corn – greengram cropping system

Treatments	Number of cobs plant^{-1}			Fresh cob yield (q ha^{-1})			Green fodder yield (q ha^{-1})		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	1.04	1.11	1.08	54	59	56	141	128	134
T_2	1.20	1.21	1.21	152	154	153	245	168	207
T_3	1.44	1.31	1.38	163	164	163	250	248	249
T_4	1.14	1.15	1.15	148	150	149	238	162	200
T_5	1.38	1.30	1.34	162	162	162	249	238	243
T_6	1.31	1.27	1.29	155	157	156	250	182	216
T_7	1.52	1.34	1.43	177	184	181	285	277	281
T_8	1.33	1.30	1.31	157	158	158	251	199	225
T_9	1.49	1.32	1.40	172	177	175	268	260	264
T_{10}	1.34	1.30	1.32	157	159	158	253	219	236
S.Em. (±)	0.11	0.06	0.08	6.09	6.30	5.88	12.94	15.11	10.57
CD @ 5%	NS	NS	NS	18.09	18.71	17.46	38.44	44.91	31.39

Treatment details :

T_1 : Absolute control
T_2 : Recommended package of practices
T_3 : Foliar spray of MM_1
T_4 : Foliar spray of MM_2
T_5 : Humic acid spray @ 0.5%
T_6 : Biostimulant spray @ 625 ml ha^{-1}
T_7 : T_3 + Humic acid spray @ 0.5%
T_8 : T_4 + Humic acid spray @ 0.5%
T_9 : T_3 + Biostimulant spray @ 625 ml ha^{-1}
T_{10} : T_4 + Biostimulant spray @ 625 ml ha^{-1}

The residual effect of applying MM_2 (0.2%) foliarly and spraying humic acid at a rate of 0.5% on greengram produced significantly higher leaf area (192, 487 and 409 cm^2 plant^{-1}, respectively) at 30, 45 DAS and harvest, while the absolute control produced lower values (105, 222 and 201 cm^2 plant^{-1}, respectively).

Yield Parameters of Sweet Corn

Number of Cobs Plant^{-1}

The data presented in Table 5 showed that, in the sweet corn - greengram cropping sequence, the number of cobs plant^{-1} did not significantly change in response to the foliar application of micronutrients. But, when MM_1 was applied foliarly @ 0.1 per cent along with 0.5 per cent humic acid sprayed at 30 DAS, the highest number of cobs plant^{-1} (1.43) was registered and the lowest number of cobs plant^{-1} (1.08) was observed with absolute control.

Fresh Cob and Green Fodder Yield (q ha^{-1}) of Sweet Corn

In terms of increasing the yield of fresh cob and green fodder, the foliar application of MM_1@ 0.1 per cent plus humic acid @ 0.5 per cent sprayed at 30 DAS (181 and 281 q ha^{-1}, respectively) was statistically superior and on par with the foliar application of MM_1 @ 0.1 per cent + Biostimulant spray @ 625 ml ha^{-1} at 30 DAS (175 and 264 q ha^{-1}, respectively) (Table 5). On the other hand, under absolute control, which did not receive any outside nutrient sources, a lower yield of fresh cob and green fodder was noted (56 and 134 q ha^{-1}, respectively).

TABLE 5

Number of pods plant^{-1}, seed yield (kg ha^{-1}) and haulm yield (kg ha^{-1}) of succeeding greengram as influenced by foliar application of micronutrients in sweet corn – greengram cropping system

Treatments	Number of pods plant^{-1}			Seed yield (kg ha^{-1})			Haulm yield (kg ha^{-1})		
	2022	2023	Pooled	2022	2023	Pooled	2022	2023	Pooled
T_1	13.15	13.86	13.51	398	398	398	1083	1018	1051
T_2	16.47	18.06	17.26	726	727	727	1665	1656	1660
T_3	19.29	21.77	20.53	775	776	775	1765	1746	1756
T_4	26.02	28.22	27.12	831	831	831	1843	1834	1839
T_5	21.85	23.62	22.73	815	816	815	1830	1827	1829
T_6	24.23	26.10	25.17	828	828	828	1839	1829	1834
T_7	28.31	29.48	28.89	935	937	936	1914	1981	1948
T_8	29.02	30.53	29.78	995	997	996	1920	2022	1971
T_9	26.91	28.73	27.82	880	881	881	1864	1963	1914
T_{10}	27.37	29.05	28.21	920	921	921	1894	1945	1919
S.Em. (±)	1.80	1.74	1.11	31.73	26.59	28.41	117.54	159.25	90.45
CD @ 5%	5.36	5.18	3.30	94.27	79.01	84.42	349.23	473.15	268.75

Note : RDF alone was applied for all the treatments except absolute control

The application of micronutrients mixture allowed maize plants to reach maximum yield and yield attributes, which was primarily responsible for the significantly higher fresh cob and green fodder yield (Ghaffari *et al*., 2011 and Jolli *et al*., 2020). According to Esfahani *et al*. (2014), increased photosynthetic qualities and increased grain production are both benefits of the more efficient mixed application of micronutrients. Sweet corn yields more fresh cob and green fodder when humic acid is added because it improves nutrient uptake and encourages stronger root and shoot growth. Larger and more numerous cobs are produced per plant as a result of increased nutrient availability and improved photosynthetic efficiency (Reddy *et al*., 2018).

Yield Parameters of Greengram

Number of Pods Plant^{-1}

Due to varying treatment effects in greengram, the number of pods plant^{-1} varied significantly (Table 5). In the absolute control, there were noticeably fewer pods plant^{-1} (13.51). Nonetheless, a higher number of pods plant^{-1} was observed in the residual effect of foliar application of MM_2 @ 0.2 per cent + Humic acid @ 0.5 per cent (29.78).

Seed and Haulm Yield (kg ha^{-1}) of Greengram

The pooled analysis as well as during both seasons showed notable differences in the greengram seed and haulm yields among the various treatments. The results showed that the absolute control had the lowest values (398 and 1051 kg ha^{-1}, respectively), while the residual effect of foliar application of MM_2 @ 0.2 per cent combined with spraying of humic acid @ 0.5 per cent recorded significantly superior seed and haulm yield of 996 and 1971 kg ha^{-1}, respectively.

Through their interactions with important metabolic processes, micronutrients were essential in maintaining the balanced internal mechanisms of plant growth and development. Thereby, encouraging the translocation of photoassimilates to the sink, *i.e.*, kernels and optimising the source-sink relationship within the plant.

It can be inferred that the treatments had varying effects on the parameters of growth and yield in sweet corn and greengram when subjected to source-sink manipulation. Thus, foliar spraying of MM_1 @ 0.1 per cent + 0.5 per cent humic acid (sweet corn) and foliar spraying of MM_2 @ 0.2 per cent + 0.5 per cent humic acid (greengram) was the most effective treatments among the others for increasing the yield of both the crops.

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