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Morpho-physiological Responses of Chilli (*Capsicum annuum* L.) to Foliar Application of Micronutrients and Growth Regulators

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Abstract

A field experiment was conducted at Agriculture Farm of Institute of Agriculture, Visva-Bharati, Sriniketan to study the effect of micronutrients and growth regulators on chilli during *rabi* 2015-16 and 2016-17. Five levels each of different micronutrients (Control, 0.1% $ZnSO_4$, 0.2% $ZnSO_4$, 0.1% H_3BO_4 and 0.2% H_3BO_4) and growth regulators (Control, 0.5 ppm 28-Homobrassinolide, 1 ppm 28-Homobrasinolide, 10 ppm Putrescine, 20 ppm Putrescine) were used for foliar application to chilli plants. Growth parameters such as plant height, dry matter accumulation and number of branchesplant^{-1} as well as physiological parameters such as leaf area index and crop growth rate were recorded during both the years. The experimental finding revealed that application of micronutrients such as Zinc ($ZnSO_4$) and Boron (H_3BO_4) as well as growth regulators (28-Homobrassinolide and Putrescine) improved both growth and physiological parameters of chilli. Among the micronutrients, the highest value of the growth parameters such as plant height, dry matter accumulation, number of branches plant^{-1} and physiological parameters such as LAI and CGR were recorded from the application of 0.2% $ZnSO_4$ followed by 0.1% $ZnSO_4$ and 0.2% H_3BO_4; whereas, among the growth regulators highest value of these parameters were recorded from the application of 0.5ppm of 28-Homobrassinolide followed by 1 ppm of 28-Homobrassinolide. Application of 0.2% $ZnSO_4$ also recorded highest number of fruits plant^{-1} and fruit yield plant^{-1}. Highest values of these yield attributes were also recorded from the application of the growth regulator 28-Homobrassinolide (0.5 ppm).

Keywords: Chilli, growth regulator, micronutrient, growth, physiological parameters

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1. Introduction

Chilli (*Capsicum annuum* L.) is a remunerative vegetable, spice cum cash crop of the Indian subcontinent. India is the largest producer of chillies in the World contributing close to 41.95% of the total global production (Anonymous, 2019). Andhra Pradesh, Karnataka, Madhya Pradesh and Telangana are the major chilli producing states in the country (Anonymous, 2018). Chilli is used as a spice, condiment, culinary supplement, vegetable and as an ornamental plant. The red colour of Chilli is due to capsanthin, capsorubin and capxanthin pigment and the pungency is due to capsaicin (Mathew, 2002). Chillies are a good source of vitamin ‘A’, ‘B’, ‘C’ (Ascorbic acid) and ‘E’ (Tocopherol), oleoresin, carbohydrates and minerals such as calcium, phosphorus, ferrous, sodium and copper in trace amounts (Prathibha et al., 2013;

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Olatunji and Afolayan, 2018). The yield of chilli is usually reduced due to flower and fruit drop caused by hormonal and physiological imbalance in the plant (Chaudhary et al., 2006; Sreenivas et al., 2017). The soils of West Bengal are deficient of micronutrients such as Zinc and Boron (Mondal et al., 2015; Mondal and Panda, 2019). Zinc and Boron play vital role in the growth and productivity of different vegetable crops including chilli (Shilet al., 2013; Rafique et al., 2012). Zinc is involved in the biosynthesis of auxin (Indole-3-acetic acid) and it is also the metallic activator of many cellular enzymes in plants. Boron plays important role in carbohydrate metabolism, protein and nucleic acids synthesis, auxin transport and pollen germination (Panda and Mondal, 2020). Growth regulators like Brassinosteroids and polyamines are known for their role growth and yield enhancement in different crops. Brassinosteroids are known to promote seed germination, cell elongation, cell division, root growth, photo-morphogenesis, vascular differentiation and reproduction in plants (Gudesblat and Russinova, 2011 and Wei and Li, 2016). Polyamines such as Spermine, Spermidine and Putrescine play important roles in cell proliferation, growth and differentiation in plants (Handa et al., 2018; Chen et al., 2019). The information on the role of plant growth regulators and micronutrients on morphological, physiological and biochemical traits in chilli is meagre. Hence, it is important to study the influence of plant growth regulators and micronutrients on morpho-physiological and yield components in chilli to boost the productivity potential. With this background, the present investigation was aimed to find out the suitable concentration of plant growth regulators and micronutrients for increasing the yield potential in chilli.

2. Materials and Methods

The field experiments were conducted at the Agriculture Farm, Institute of Agriculture, Visva-Bharati, Sriniketan, West Bengal, India during October to April months of both 2015-16 and 2016-17. The experiments were laid out in RBD design with 25 treatment combinations of five growth regulators and micronutrients replicated thrice. The treatments of micronutrients and growth regulators were given as foliar applications thrice during the period of crop grown namely; 30, 45 and 60 days after transplanting (DAT). Four levels each of different micronutrients (0.1% $ZnSO_4$, 0.2% $ZnSO_4$, 0.1% H_3BO_4 and 0.2% H_3BO_4) excluding both control and growth regulators (0.5 ppm 28-Homobrassinolide, 1 ppm 28-Homobrasinolide, 10ppm Putrescine, 20 ppm Putrescine) excluding both control were applied as foliar spray on chilli plants at 30th and 45th day after transplanting).The acidity of $ZnSO_4$ solution was neutralized by adding of lime to it. The seedlings of 35 days old were transplanted in 2×2m^2 sized plots at 50×50 cm^2 spacing. The recommended dose of fertilizers of 90-60-50 kg N-P_2O_5-K_2O ha^{-1} was followed in all the treatments. All the plots were demarcated by 15 cm high ridges on all sides. Irrigation channels were constructed for each plot to provide adequate irrigation independently to each plot. Irrigation and intercultural operations were carried out at regular intervals as and when required. Carbendazin (12%) + Mancozeb (63%) WP @ 2 g l^{-1} was sprayed twice at 30 and 45 DAT to for protection of the crop from diseases and Chlorpyrifos 20% EC @2ml l^{-1} was sprayed twice to avoid the pest attack. The soil of the experimental plot was sandy loam in texture. The soil was medium in available phosphorus (P_2O_5) and available potassium (K_2O) and low in available nitrogen (N). Tejaswini, a high yielding hybrid variety of chilli with a duration of 180 days was used in this experiment. Growth parameters such as plant height, dry matter accumulation per plant, number of branches per plant and physiological indices such as leaf area index (LAI) and crop growth rate (CGR) were recorded during both the years. The morpho-physiological parameters such as plant height, dry weight accumulation and leaf area index were recorded at 40, 80, 120 and 160 DAT whereas CGR was recorded during 40-80, 80-120 and 120-160 DAT. The number of branches per plant was counted at the time of harvest. The yield attributes such as number of fruits per plant and fresh fruit yield per plant were recorded at harvest. Leaf area index was calculated by the formula given by Watson (1952). The leaves were dried in a hot air oven at 65 ^{o}C for 48 hours till constant weights were obtained and then weights were recorded. The ratio of leaf area /weight of these leaves were used to measure the leaf area indices. Dry matter accumulation was determined by cutting three plants at ground level from the earmarked area in each plot kept for the purpose of destructive sampling. Plants of each plot were separated into green leaves, stems and fruits and dried in a hot air oven at 65^{o}C for 48 hours. The crop growth rate (CGR) was calculated using the formula given by Watson (1952). The analysis of variance method (Cochran and Cox, 1977; Panse and Sukhatme, 1978) was followed to statistically analyse the data. The significance of different sources of variation was tested by Error Mean Square Method of Fisher Snedecor's "F" test at probability level 0.05 (Chakravorty et al., 2016). The data thus recorded were tabulated to statistically analysed to discriminate the superiority of treatment means using least significant difference (LSD) and MS-EXCEL software.

3. Results and Discussion

3.1. Effect on plant height

The effect of micronutrients and growth regulators on the height of chilli plant was studied at 40, 80, 120 and 160 DAT during 2015-16 and 2016-17 (Table 1). Application of micronutrients such as Zinc ($ZnSO_4$) and Boron (H_3BO_4) significantly increased height of chilli plant recorded at different stages of growth during both the years. Foliar application of 0.2% $ZnSO_4$ recorded significantly higher plant height over other treatments during both the years. During 2015-16, 0.2% $ZnSO_4$ recorded the tallest plant at 40 DAT (46.5 cm), 80 DAT (71.8 cm), 120 DAT (105.1 cm) and 160

Table 1: Effect of micronutrients and growth regulators on plant height and number of branches plant^{-1} of chilli

Treatments	Plant height (cm)								No of Branches per Plant of chilli	
	40 DAT		80 DAT		120 DAT		160DAT			
Micronutrients	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Control	38.31	40.51	61.56	64.81	93.51	97.31	117.15	120.37	7.7	8.4
0.1% $ZnSO_4$	41.87	45.18	65.75	70.41	100.48	104.46	121.67	126.85	9.4	10.5
0.2% $ZnSO_4$	46.50	48.75	71.83	75.11	105.09	110.29	127.85	133.67	10.8	12.3
0.1% $H3BO_4$	40.12	42.76	64.04	67.95	98.94	101.87	121.50	124.20	9.0	10.2
0.2% $H3BO_4$	43.15	44.39	68.26	71.65	102.13	106.49	123.14	128.78	10.1	11.2
SEm±	0.45	0.44	0.43	0.53	0.46	0.70	0.86	0.65	0.13	0.14
CD (p=0.05)	1.27	1.25	1.23	1.50	1.29	2.00	2.44	1.86	0.36	0.41
Growth regulators										
Control	38.13	39.73	61.89	65.87	95.31	98.29	116.93	119.79	8.4	8.8
0.5 ppm 28-Homobrassinolide	48.44	51.37	71.24	77.75	106.95	110.57	127.69	133.73	11.0	12.1
1 ppm 28-Homobrassinolide	43.47	45.57	68.44	70.84	101.07	105.65	124.35	129.05	9.9	11.3
10 ppm Putrescine	38.84	41.11	63.81	66.32	97.55	101.52	119.23	123.89	8.7	9.7
20 ppm Putrescine	41.07	43.81	66.05	69.13	99.28	104.32	123.13	127.41	9.1	10.8
SEm±	0.45	0.44	0.43	0.53	0.46	0.70	0.86	0.67	0.13	0.14
CD (p=0.05)	1.27	1.25	1.23	1.50	1.29	2.00	2.44	1.86	0.36	0.41

DAT (127.9 cm). Similar trend was followed during 2016-17, where 0.2% $ZnSO_4$ recorded highest plant height at 40 DAT (48.8 cm), 80 DAT (75.1 cm), 120 DAT (110.3 cm) and 160 DAT (133.7 cm). During both the years, application of 0.2% H_3BO_4 significantly increased plant height over 0.1% $ZnSO_4$ during the crop growing period except 80 DAT in 2016-17 and 160 DAT in 2015-16. Angami et al. (2017) also reported increase in plant height of chilli by application of Zinc. Increased plant height obtained from application of zinc may be attributed to the role of zinc in auxin biosynthesis, which plays important role in apical dominance of plants.

The treatments of growth regulators (28-Homobrassinolide and Putrescine) significantly influenced the plant height during both the years. Foliar application of 0.5 ppm of 28-Homobrassinolide recorded significantly higher plant height over other treatments during both the years. Among different treatments of growth regulators, the tallest plants were recorded from the application of 0.5ppm of 28-Homobrassinolide (48.4 cm, 71.2 cm, 107.0 cm and 133.7 cm at 40, 80, 120 and 160 DAT respectively during 2015-16 and 51.4 cm, 77.8 cm, 110.6 cm and 133.7 cm at 40, 80, 120 and 160 DAT respectively during 2016-17).The effect of Purescine (10 ppm) on plant height was found to be at par with control at 40 DAT during 2015-16 and at 80 DAT during 2016-17. The plant height recorded from 1 ppm Homobrassinolide was at par with 10 ppm of Putrescine at 160 DAT during 2015-16 and at 120 and 160 DAT during 2016-17. Increased plant height by application of Brassinosteroids may be attributed to its role in cell elongation and cell division in plants (Gudesblat and Russinova, 2011; Wei and Li, 2016). Bera et al. (2014) also reported increase in plant height of sunflower by application of Homobrassinolide. This result also corroborates the finding of Kumari and Thakur (2018). Tatte et al. (2016) also reported increase in plant height of rose by application of polyamines such as spermine and spermidine.

3.2. Effect on number of branches plant^{-1}

The effect of micronutrients and growth regulators on the number of branches plant^{-1} of chilli was studied at harvest during both the years (Table 1). Application of micronutrients such as Zinc ($ZnSO_4$) and Boron (H_3BO_4) significantly increased the number of branches plant^{-1} over control. Foliar application of 0.2% $ZnSO_4$ recorded significantly higher number of branches plant^{-1} over other treatments during both the years. During 2015-16, 0.2% $ZnSO_4$ recorded highest number of branches plant^{-1} (10.8). Similar trend was followed during 2016-17 where application of 0.2% $ZnSO_4$ recorded highest number of branches plant^{-1} (12.3). During both the years, 0.2% H_3BO_4 significantly increased number of branches plant^{-1} over 0.1% $ZnSO_4$. Angami et al. (2017) also reported increase in number of branches of chilli by application of Zinc ($ZnSO_4$).

The treatments of growth regulators (28-Homobrassinolide and Putrescine) significantly influenced the number of branches plant^{-1} during both the years. Foliar application of

0.5 ppm of 28-Homobrassinolide recorded significantly higher number of branches plant^{-1} over other treatments during both the years. Among different treatments of growth regulators, highest number of branches plant^{-1} was recorded from the application of 0.5 ppm of 28-Homobrassinolide (11.0 and 12.1 during 2015-16 and 2016-17 respectively). Patil et al. (2018) also reported increase in number of branches plant^{-1} of Indian mustard by application of Brassinosteroid. This result also corroborates the findings of Kumari and Thakur (2018). Tatte et al. (2016) also reported increase in number of branches plant^{-1} of rose by application of polyamines such as spermine and spermidine.

3.3. Effect on dry matter accumulation

The effect of micronutrients and growth regulators on the dry matter accumulation of chilli was studied at 40, 80, 120 and 160 DAT during both the years (Table 2). Application of micronutrients such as Zinc ($ZnSO_4$) and Boron (H_3BO_4) significantly increased dry matter accumulation at different stages of growth over control during both the years. Foliar application of 0.2% $ZnSO_4$ recorded significantly higher dry matter accumulation over other treatments during both the years. During 2015-16, 0.2% $ZnSO_4$ recorded highest dry matter accumulation per sqr mtr at 40DAT (24.13 g), 80 DAT (95.49 g), 120 DAT (274.00 g) and 160 DAT (407.73 g). Similar trend was followed during 2016-17, where application of 0.2% $ZnSO_4$ recorded highest dry matter accumulation at 40DAT (26.21 g), 80 DAT (102.37 g), 120 DAT (287.65 g) and 160 DAT (414.75 g). During both the years, application of 0.2% H_3BO_4 significantly increased dry matter accumulation over 0.1% $ZnSO_4$ recoded at 160 DAT. Bhatt and Srivastava (2005) and Saravaiya et al. (2014) also reported increase in dry matter accumulation in tomato by application of micronutrients such as zinc and boron. This result corroborates the findings of Ranjbar and Bahmaniar (2007). Increased dry matter accumulation in plants obtained by application of zinc may be attributed to the role of zinc in auxin biosynthesis which promotes plant growth and stem elongation.

Table 2: Effect of micronutrients and growth regulators on the dry matter accumulation of chilli

Treatments	Dry matter accumulation (g m^{-2})							
	40 DAT		80 DAT		120 DAT		160 DAT	
Micronutrients	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Control	18.73	21.41	79.23	86.10	233.35	239.30	327.09	343.35
0.1% $ZnSO_4$	21.41	24.59	89.18	94.09	260.18	268.22	375.33	389.83
0.2% $ZnSO_4$	24.13	26.21	95.49	102.37	274.00	287.65	407.73	415.17
0.1% $H3BO_4$	20.51	22.63	86.31	91.50	251.74	260.28	356.41	370.38
0.2% $H3BO_4$	21.36	24.08	88.23	95.51	261.69	272.38	381.17	398.06
SEm±	0.38	0.27	0.94	1.15	1.48	1.50	4.23	3.15
CD (*p*=0.05)	1.07	0.77	2.68	3.28	4.22	4.27	12.02	8.95
Growth regulators								
Control	19.86	21.93	79.65	86.33	229.21	242.59	329.45	344.71
0.5 ppm 28-Homobrassinolide	23.11	26.43	99.31	104.47	281.03	290.65	411.25	425.77
1 ppm 28-Homobrassinolide	22.01	25.34	90.30	97.90	270.19	274.93	396.42	403.19
10 ppm Putrescine	20.26	22.15	81.47	88.35	238.84	255.11	341.70	360.71
20 ppm Putrescine	20.90	23.07	87.71	92.53	261.67	264.54	368.91	382.41
SEm±	0.38	0.27	0.941	1.15	1.48	1.50	4.23	3.13
CD (*p*=0.05)	1.07	0.77	2.68	3.28	4.22	4.27	12.02	8.89

The treatments of growth regulators (28-Homobrassinolide and Putrescine) significantly influenced the dry matter accumulation during both the years. Foliar application of 0.5 ppm of 28-Homobrassinolide recorded significantly higher dry matter accumulation over other treatments during both the years. Among different treatments of growth regulators, highest dry matter accumulation was recorded from the application of 0.5 ppm of 28-Homobrassinolide (23.11 g, 99.31 g, 281.03 g and 411.25 g at 40, 80, 120 and 160 DAT respectively during 2015-16 and 26.43 g, 104.47 g, 290.65 g and 425.77 g at 40, 80, 120 and 160 DAT respectively during 2016-17). Increased dry matter accumulation in chilli plants by application of Brassinosteroids may be attributed to its role in cell elongation, cell division and vascular differentiation in plants (Gudesblat and Russinova, 2011 and Wei and Li, 2016). Patil et al. (2018) also reported increase in dry matter accumulation of chilli by application of Homobrassinolide. This result also corroborates the finding of Hayat et al. (2001).

3.4. Effect on leaf area index

The effect of micronutrients and growth regulators on the leaf area index (LAI) of chilli was studied at 40, 80, 120 and 160DAT during both the years (Table 3). Application of micronutrients such as Zinc ($ZnSO_4$) and Boron (H_3BO_4) significantly increased LAI of chilli recorded at different stages of growth. Foliar application of 0.2% $ZnSO_4$ recorded significantly higher LAI over other treatments during both the years. During 2015-16, 0.2% $ZnSO_4$ recorded highest value of LAI at 40 DAT (0.250), 80 DAT (1.338), 120 DAT (3.258) and 160 DAT (2.455 cm). Similar trend was followed during 2016-17, where application of 0.2% $ZnSO_4$ recorded higest LAI at 40 DAT (0.274), 80 DAT (1.672), 120 DAT (3.480) and 160 DAT (2.517). During both the years, the effect of 0.2% H_3BO_4 on the dry matter accumulation was at par with 0.1% $ZnSO_4$. Gollagi et al. (2009) also reported increase in leaf area of chilli by application of Zinc. Increased leaf area of chilli obtained by application of zinc may be attributed to the role of zinc in biosynthesis of auxin, which promotes plant growth. The treatments of growth regulators (28-Homobrassinolide and Putrescine) significantly influenced the leaf area index during both the years.

Table 3: Effect of micronutrients and growth regulators on leaf area index of chilli

Treatments	Leaf area index							
	40 DAT		80 DAT		120 DAT		160 DAT	
Micronutrients	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Control	0.192	0.214	0.964	1.224	2.366	2.562	1.876	1.925
0.1% $ZnSO_4$	0.232	0.257	1.216	1.430	2.706	3.078	2.246	2.160
0.2% $ZnSO_4$	0.250	0.274	1.338	1.672	3.258	3.480	2.451	2.517
0.1% $H3BO_4$	0.225	0.242	1.114	1.387	2.597	2.887	2.181	2.119
0.2% $H3BO_4$	0.216	0.236	1.205	1.451	2.776	3.126	2.280	2.228
SEm±	0.008	0.008	0.028	0.037	0.073	0.056	0.046	0.049
CD (*p*=0.05)	0.022	0.024	0.081	0.106	0.208	0.159	0.132	0.140
Growth regulators								
Control	0.201	0.228	1.056	1.268	2.492	2.535	1.801	1.946
0.5 ppm 28-Homobrassinolide	0.245	0.264	1.383	1.705	3.129	3.386	2.562	2.481
1 ppm 28-Homobrassinolide	0.240	0.256	1.209	1.502	2.857	3.301	2.341	2.322
10 ppm Putrescine	0.211	0.236	1.078	1.301	2.558	2.850	2.185	2.119
20 ppm Putrescine	0.217	0.239	1.112	1.387	2.667	3.061	2.138	2.082
SEm±	0.008	0.008	0.028	0.037	0.073	0.056	0.046	0.049
CD (*p*=0.05)	0.022	0.024	0.081	0.106	0.208	0.159	0.132	0.140

Foliar application of 0.5 ppm of 28-Homobrassinolide recorded significantly higher LAI over other treatments during both the years. Among different treatments of growth regulators, highest value of LAI were recorded from the application of 0.5ppm of 28-Homobrassinolide (0.245, 1.383, 3.129 and 2.562 at 40, 80, 120 and 160 DAT respectively during 2015-16 and 0.264, 1.705, 3.386 and 2.481 at 40, 80, 120 and 160 DAT respectively during 2016-17). The effect of 1 ppm of 28-Homobrassinolide and 20 ppm Putrescine on LAI at 40-80 DAT were at par during both the years and at 120 DAT dring 2015-16. Increased leaf area by application of Brassinosteroids may be due to its role in cell elongation and cell division in plants (Gudesblat and Russinova, 2011 and Wei and Li, 2016). Patil et al. (2018) also reported increase in leaf area index of chilli by application of Homobrassinolide.

3.5. Effect on crop growth rate

The effect of micronutrients and growth regulators on the crop growth rate (CGR) of chilli was studied during 40-80, 80-120 and 120-160 DAT in both the years (Table 4). Application of micronutrients such as Zinc ($ZnSO_4$) and Boron (H_3BO_4) significantly increased CGR recorded during different stages of growth. Foliar application of 0.2% $ZnSO_4$ recorded significantly higher CGR over other treatments during both the years. During 2015-16, 0.2% $ZnSO_4$ recorded highest value of CGR during 40-80 DAT (1.784), 80-120 DAT (4.463) and 120-160 DAT (3.343). Similar trends were folowed in 2016-17, where application of 0.2% $ZnSO_4$ recorded highest CGR during 40-80 DAT (1.904), 80-120 DAT (4.632) and 120-160 DAT (3.188). During both the years, the effect of 0.2% H_3BO_4 on crop growth rate of chilli was at par with 0.1% $ZnSO_4$. Gollagi et al. (2009) also reported increase in crop growth rate of chilli by application of Zinc. Increased CGR of chilli obtained by application of zinc may be attributed to the role of zinc in biosynthesis of auxin, which promotes plant growth and

Table 4: Effect of micronutrients and growth regulators on the crop growth rate of chilli

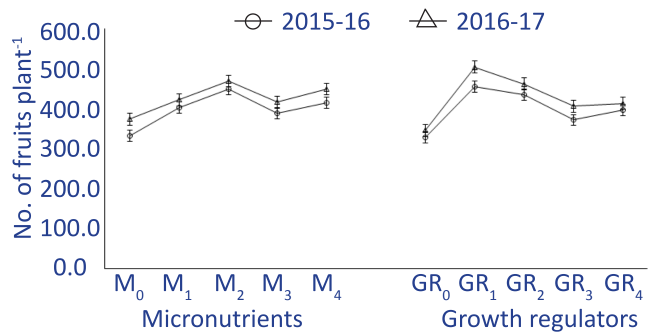
Treatments	Crop growth rate (g m^{-2} day^{-1})					
	40-80 DAT		80-120 DAT		120-160 DAT	
Micronutrients	2015-16	2016-17	2015-16	2016-17	2015-16	2016-17
Control	1.513	1.617	3.853	3.830	2.344	2.598
0.1% $ZnSO_4$	1.694	1.738	4.275	4.353	2.879	3.040
0.2% $ZnSO_4$	1.784	1.904	4.463	4.632	3.343	3.188
0.1% $H3BO_4$	1.645	1.722	4.136	4.220	2.617	2.753
0.2% $H3BO_4$	1.672	1.786	4.336	4.422	2.987	3.142
SEm±	0.025	0.029	0.030	0.047	0.108	0.080
CD (*p*=0.05)	0.071	0.084	0.084	0.134	0.307	0.228
Growth regulators						
Control	1.495	1.610	3.739	3.907	2.506	2.553
0.5 ppm 28-Homobrassinolide	1.905	1.951	4.543	4.655	3.256	3.378
1 ppm 28-Homobrassinolide	1.707	1.814	4.497	4.426	3.156	3.206
10 ppm Putrescine	1.530	1.655	3.934	4.169	2.572	2.640
20 ppm Putrescine	1.670	1.736	4.349	4.300	2.681	2.947
SEm±	0.025	0.029	0.030	0.047	0.108	0.080
CD (*p*=0.05)	0.071	0.084	0.084	0.134	0.307	0.228

increases biomass production.

The treatments of growth regulators (28-Homobrassinolide and Putrescine) significantly influenced the crop growth rate during both the years. Foliar application of 0.5 ppm of 28-Homobrassinolide recorded significantly higher CGR over other treatments during both the years. Among different treatments of growth regulators, highest values of CGR were recorded from the application of 0.5ppm of 28-Homobrassinolide (1.905, 4.543 and 3.256 during 40-80, 80-120, 120-160 DAT respectively in 2015-16 and 1.951, 4.655 and 3.378 during 40-80, 80-120, 120-160 DAT respectively in 2016-17). The effect of 1 ppm of 28-Homobrassinolide and 20 ppm Putrescine on CGR at 40-80 DAT were at par during both the years and at 80-120 DAT dring 2016-17. Patil et al. (2018) also reported increase in crop growth rate of chilli by application of Homobrassinolide.

3.6. *Effect on yield attributes*

The effect of micronutrients and growth regulators on the number of fruits plant^{-1} and fresh fruit yield plant^{-1} of chilli was studied cumulatively as fruits harvested in different pickings during both the years (Figure 1 and 2). Application of micronutrients such as Zinc ($ZnSO_4$) and Boron (H_3BO_4) significantly increased the number of fruits plant^{-1} and fresh fruit yield plant^{-1} of chilli during both the years. Foliar application of 0.2% $ZnSO_4$ recorded significantly higher number of fruits plant^{-1} over other treatments during both the years. During both the years, 0.2% $ZnSO_4$ recorded highest number of fruits plant^{-1} followed by 0.2% H_3BO_4 and



M_0: control (no micronutrient); M_1: 0.1% $ZnSO_4$, M_2: 0.2% $ZnSO_4$, M_3: 0.1% H3BO4, M_4: 0.2% $H3BO_4$, G_0: control (no growth regulator), G_1: 0.5 ppm 28-Homobrassinolide, G_2: 1 ppm 28-Homobrasinolide, G_3: 10 ppm Putrescine and G_4: 20 ppm Putrescine)

Figure 1: Effect of micronutrients and growth regulators on the number of fruits plant^{-1}

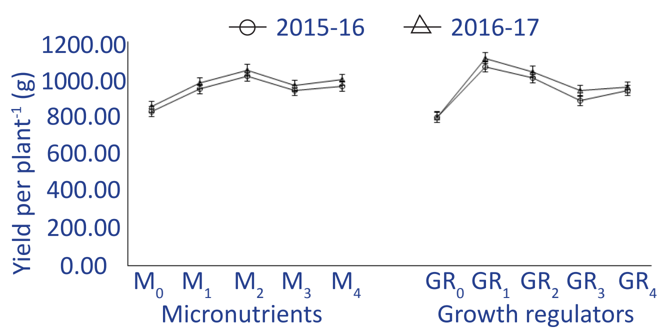


Figure 2: Effect of micronutrients and growth regulators on fresh fruit yield plant^{-1}

0.1% $ZnSO_4$. Angami et al. (2017) and Dongre et al. (2000) also reported increase in number of fruits plant^{-1} and fruit yield plant^{-1} of chilli by application of Zinc ($ZnSO_4$). Shil et al. (2013) also reported increase in chilli yield by application of Zinc and Boron.

The treatments of growth regulators (28-Homobrassinolide and Putrescine) significantly influenced the number of fruits plant^{-1} and fresh fruit yield plant^{-1} during both the years. Foliar application of 0.5 ppm of 28-Homobrassinolide recorded significantly number of fruits plant^{-1} over other treatments during both the years. Among different treatments of growth regulators, highest number of fruits plant^{-1} was recorded from the application of 0.5 ppm of 28-Homobrassinolide followed by 1 ppm of 28-Homobrassinolide and 20 ppm Putrescine, whereas lowest number of fruits plant^{-1} was recorded from control. Patil et al. (2018) also reported increase in fruit (siliqua) yield plant^{-1} of Indian mustard by application of Brassinosteroid. Foliar application of 0.2% $ZnSO_4$ recorded significantly higher fresh fruit yield plant^{-1} over other treatments during both the years. During both the years, the highest fresh fruit yield plant^{-1} was recorded from the application of 0.2% $ZnSO_4$ followed by 0.2% H_3BO_4 and 0.1% $ZnSO_4$. 28-Homobrassinolide (0.5 ppm) was found to be the best treatment in terms of fresh fruit yield plant^{-1} and was significantly higher over other treatments of growth regulators. This result corroborates the findings of Sairam (1994), Vidya Vardhini and Ram Rao (2001), Pramanik and Bera (2012) and Serna et al. (2012). Increased fruit yield by application of Brassinosteroids may be due to its role in cell division and reproduction in plants (Gudesblat and Russinova, 2011 and Wei and Li, 2016). The lowest fresh fruit yield plant^{-1} was recorded from control in both the years.

4. Conclusion

Foliar application of the micronutrients such as $ZnSO_4$ and growth regulator 28-Homobrassinolide improved most of the growth and physiological parameters of chilli. However, 0.5% of 28-Homobrassinolide was found to be the best treatment of growth regulator, whereas 0.2% $ZnSO_4$ was best treatment of micronutrient in terms of morpho-physiological parameters of chilli such as plant height, number of brances plant^{-1}, dry matter accumulation, LAI , CGR, number of fruits plant^{-1} and fruit yield plant^{-1}.

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