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EFFICACY OF FOLIAR APPLICATION OF GA_3 AND K ON GROWTH AND BIOCHEMICAL PARAMETERS OF TWO F1 HYBRID PARTHENOCARPIC CULTIVARS OF CUCUMBER

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ABSTRACT

The experiment was conducted in anti-insect net house for three consecutive years (2013–2016) with the goal of improving the growth and biochemical contents in two F1 cultivars of cucumber, 'Sevenstar' and 'KUK 9'. Treatment was given in the form of foliar spray containing different concentrations of gibberellic acid (GA_3) [0.005 g·dm^{-3} (G_1), 0.01 g·dm^{-3} (G_2), and 0.015 g·dm^{-3} (G_3)] and potassium [1.0 g·dm^{-3} (K_1), 2.5 g·dm^{-3} (K_2), and 5.0 g·dm^{-3} (K_3)] alone and as combinations. All the treatments significantly enhanced plant growth and yield over control. The combination K_2G_2 showed a marked increase in growth parameters (leaf area, flower number, total dry matter production, growth rate, net assimilation rate) and biochemical attributes (total sugar content, starch, protein). The cultivar 'KUK 9' had more increased parameter values than the 'Sevenstar'. This study provides a direct evidence of the beneficial role of the application of potassium and gibberellic acid on growth, biochemical attributes, and yield of cucumber.

Keywords: *Cucumis sativus*; cultivars; foliar spray; biochemical attributes yield

INTRODUCTION

World people population is increasing exponentially, and there are many challenges to be confronted to maintain the mandatory food production. Vegetable crops are important constituents of agriculture and nutritional security because of their short production cycle, nutritional richness, high yield, economic viability, and ability to generate on-farm and off-farm employment. In recent time, the introduction of parthenocarpic cultivars of cucumber revolutionized its cultivation under covers, facilitating production and increasing yield (Cheema et al. 2004; Singh et al. 2004).

Crop growth, productivity, and quality mainly depend on its genetic potential and its interaction with fertigation and exogenous supplementation of growth substances in addition to its response to the environmental conditions. Foliar spray is an economical way of supplementing plant growth substances and fertilizers when they are in short supply or in unavailable form in the soil and also reduce the amount of nutrient usage (Jamal et al. 2006).

Cucumber (*Cucumis sativus* L.) is one of the most popular and profitable vegetable crops in the world (Best 2000). It is consumed because of its nutritional value and also serves as an ingredient of cosmetic industry. Its medicinal value was also reported (Talalay et al. 2007; Patil et al. 2012). 'Sevenstar' and 'KUK 9' are two important F1 hybrid parthenocarpic cultivars of a similar habit.

Despite various studies on the soil and root nutrition, unfortunately, only a few studies have been conducted on the impact of foliar application of minerals and growth regulators on the growth and yield of parthenocarpic vegetables. Keeping the above in mind, we investigated the influence of foliar application of K and GA_3 on growth and biochemical attributes of two F1 parthenocarpic cucumber cultivars.

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MATERIALS AND METHODS

The investigation was carried out at the Centre of Excellence for Vegetables, Gharaunda (Karnal), Haryana, India, located at a latitude of 29°32’ N and a longitude of 76°59’ E, under anti-insect net house from September to December for three consecutive years (2013–2014, 2014–2015, 2015–2016) at temperatures of 32–34 °C (day) and 17–27 °C (night). The experiment was conducted in anti-insect net house of 1000 m^2 area with 20–30% shade factor and 50-mesh UV-stabilized net. The present study was carried on two promising F1 cultivars of cucumber (*C. sativus* L.): ‘Sevenstar’ and ‘KUK 9’. Cucumber seeds of both the cultivars were sown during second week of September each year. The experimental layout was in a split plot design with three replicates per treatment. The plants were grown on raised beds of dimension 80 cm × 30 cm (width × height), separated at a distance of 45 cm from each other. The spacing between two plants on the same bed was 40 cm. Mulching sheet (30 μm) was used to cover the bed. Nutrient solution containing nitrogen, phosphorus, and potassium (NPK) in a ratio of 13 : 0 : 45 was applied with the drip irrigation system for all the treatments twice a week. The plants were irrigated when required, depending on the soil moisture regime. Plant protections given to all the treated plants were same. All the other agriculture practices, i.e., hoeing, trellising, and weeding, were carried out throughout the growing season. Treatment given after germination of the plant in the form of foliar application consists of three concentrations of gibberellic acid (GA_3; $C_{19}H_{22}O_6$) [0.005 $g{\cdot}dm^{-3}$ (G_1), 0.01 $g{\cdot}dm^{-3}$ (G_2), and 0.015 $g{\cdot}dm^{-3}$ (G_3)] and three concentrations of potassium in the form of muriate of potash [1.0 $g{\cdot}dm^{-3}$ (K_1), 2.5 $g{\cdot}dm^{-3}$ (K_2), and 5.0 $g{\cdot}dm^{-3}$ (K_3)]. So, a total of ten different treatments including control, GA_3 and K alone and in combinations (G_1K_1, G_2K_2 and G_3K_3) were used in the experiment. The plants were sampled at 40, 55, and 70 days after sowing and at harvest to assess various parameters.

At each sampling stage, selected plant from each treatment were uprooted and separated into their components and chopped into small pieces to enable drying. They were oven dried at 70 °C to a constant weight and then the dry weight of the plant was measured as total dry matter and expressed as gram per plant. Leaf area per plant (in cm^2) was determined by using portable leaf area meter (Systronics 211, Ahmedabad, India). Crop growth rate (CGR) was calculated by adopting the formula given by Watson (1958). Net assimilation rate (NAR) was calculated by using the method of Gregory (1926). Total soluble carbohydrate in fruits was estimated by using the method of Yemm and Willis (1954). Starch content of fruits was estimated by using the method of Hassid and Neufeld (1964). The methodology of Folin–Ciocalteu reagent (Lowry et al. 1951) was used for the estimation of fruit total soluble protein content.

Each experiment consisted of three replicates per treatment. Data were analyzed as means of three consecutive years (September–December 2013–2014, 2014–2015, 2015–2016) using one-way analysis of variance, and the differences were computed using Duncan’s multiple range test at $p = 0.05$. All statistical analyses were performed using the SPSS software (version 11.5).

RESULTS

Leaf area

In both cultivars, leaf area increased with the progression of growth stages and found to be highest at 70 DAS (days after sowing). Larger leaves were recorded for the ‘KUK 9’ (Table 1). Each single and combined application of GA_3 and K significantly increased the leaf area at all the stages. Increase in leaf area because of interaction of GA_3 and K was observed for all three combination with G_2K_2 (0.01 $g{\cdot}dm^{-3}$ GA_3 + 2.5 $g{\cdot}dm^{-3}$ K) being the highest (68, 60 and 74% in ‘Sevenstar’ and 65, 104 and 102% in ‘KUK 9’, respectively, to DAS). Maximum increase in leaf area was observed in ‘KUK 9’ at 40, 55, and 70 DAS of growth under G_2K_2 (0.01 $g{\cdot}dm^{-3}$ GA_3 + 2.5 $g{\cdot}dm^{-3}$ K) treatment and also established its superiority over other treatments.

Dry weight of aerial parts

The total dry weight increased with the advancement of growth stage. Cultivar ‘KUK 9’ showed higher total dry matter production when compared to ‘Sevenstar’ (Table 2). The application of GA_3 or K alone as showed parallel response. More effective were combined application. The highest percentage of increase was recorded in plants treated with G_2K_2 (56–70% in ‘Sevenstar’ and 56–86% in ‘KUK 9’).

Table 1. Effect of foliar spray with GA_3 and K on the leaf area (cm^2) of cucumber at different growth stages

Cultivar	Treatments	Days after sowing		
		40	55	70
'Sevenstar'	Control	37.03 ± 0.58i	49.10 ± 0.06i	51.3 ± 0.58h
	G_1	46.20 ± 0.61f (25%)	60.20 ± 0.05g (23%)	62.4 ± 0.12f (22%)
	G_2	48.13 ± 0.59e (30%)	62.20 ± 0.06e (27%)	64.4 ± 0.06e (25%)
	G_3	45.10 ± 0.06g (22%)	56.40 ± 0.06i (15%)	60.2 ± 0.58g (17%)
	K_1	47.33 ± 0.33ef (28%)	61.16 ± 0.09ef (25%)	64.3 ± 0.33e (25%)
	K_2	50.33 ± 0.33d (36%)	64.60 ± 0.06d (32%)	67.7 ± 0.05d (66%)
	K_3	44.00 ± 0.58h (19%)	59.83 ± 0.09gh (22%)	63.7 ± 0.03ef (23%)
	G_1 K_1	57.00 ± 0.58b (54%)	71.63 ± 0.32b (46%)	75.8 ± 0.04b (47%)
	G_2 K_2	62.33 ± 2.19a (68%)	78.36 ± 0.19a (60%)	89.3 ± 0.33a (74%)
	G_3 K_3	54.10 ± 0.06c (46%)	66.00 ± 0.58c (34%)	69.5 ± 0.06c (68%)
	F	13.186*	16.921*	1.130*
'KUK 9'	Control	45.10 ± 0.06h	51.3 ± 0.05i	53.2 ± 0.19j
	G_1	58.20 ± 0.06f (29%)	81.66 ± 0.56g (59%)	83.2 ± o.05g (56%)
	G_2	61.10 ± 0.06de (35%)	86.56 ± 0.12e (68%)	88.1 ± 0.05e (65%)
	G_3	55.43 ± 0.03g (23%)	76.36 ± 0.03h (48%)	79.2 ± 0.06i (48%)
	K_1	60.13 ± 0.03e (33%)	82.66 ± 0.33f (55%)	85.7 ± 0.03f (61%)
	K_2	62.50 ± 0.06d (39%)	89.66 ± 1.33d (68%)	93.1 ± 0.58d (75%)
	K_3	57.60 ± 0.67f (28%)	78.33 ± 0.15h (47%)	81.0 ± 0.07h (52%)
	G_1 K_1	69.03 ± 0.09b (53%)	98.16 ± 0.12b (84%)	99.1 ± 0.05b (86%)
	G_2 K_2	74.33 ± 0.09a (65%)	104.60 ± 0.21a (96%)	107.2 ± 0.06a (101%)
	G_3 K_3	64.30 ± 0.06c (43%)	96.56 ± 0.87c (81%)	97.6 ± 0.08c (83%)
	F	1.300*	7.298*	5.516*

In parentheses is the percentage increase in value relative to the control.
G1: 0.005 $g \cdot dm^{-3}$, G2: 0.01 $g \cdot dm^{-3}$, G3: 0.015 $g \cdot dm^{-3}$, K1: 1.0 $g \cdot dm^{-3}$, K2: 2.5 $g \cdot dm^{-3}$, K3: 5.0 $g \cdot dm^{-3}$, DAS: days after sowing
Values for each cultivar separately within a column followed by the same letter are not significantly different from each other according to Duncan's Multiple Range Test at the $p = 0.05$ level. *F*-value of *F* statistics from analysis of variance with significance ***$p < 0.001$

Table 2. Effect of foliar spray with GA_3 and K on the total dry weight (g·plant^{-1}) of cucumber at different growth stages

Cultivars	Treatments	Days after sowing		
		40	55	70
‘Sevenstar’	Control	25.53 ± 0.01g	39.93 ± 0.01h	69.17 ± 0.06j
	G_1	28.82 ± 0.06f (13%)	46.53 ± 0.02f (17%)	73.35 ± 0.05h (6%)
	G_2	29.53 ± 0.03ef (16%)	50.05 ± 0.03e (25%)	76.10 ± 0.03f (10%)
	G_3	28.21 ± 0.01f (10%)	43.63 ± 0.02g (9%)	70.78 ± 0.02i (2%)
	K_1	30.45 ± 0.03e (19%)	49.19 ± 0.03ef (23%)	77.36 ± 0.01e (12%)
	K_2	32.13 ± 0.07d (26%)	54.06 ± 0.05d (35%)	79.93 ± 0.1d (16%)
	K_3	29.34 ± 0.02ef (15%)	46.48 ± 0.05f (16%)	75.55 ± 0.05g (9%)
	$G_1 K_1$	36.12 ± 0.01b (41%)	60.25 ± 0.02b (51%)	92.30 ± 0.01b (33%)
	$G_2 K_2$	39.91 ± 0.02a (56%)	72.58 ± 0.05a (82%)	117.59 ± 0.06a (70%)
	$G_3 K_3$	34.01 ± 0.09c (34%)	58.37 ± 0.03c (46%)	82.39 ± 0.01c (19%)
	F	8.291*	5.776*	1.299*
‘KUK 9’	Control	29.38 ± 0.1j	42.70 ± 0.02j	70.67 ± 0.02h
	G_1	32.44 ± 0.2g (34%)	51.20 ± 0.05g (20%)	78.86 ± 0.05f (12%)
	G_2	35.67 ± 0.05e (21%)	55.74 ± 0.02e (31%)	80.77 ± 0.05e (14%)
	G_3	30.14 ± 0.01i (3%)	48.97 ± 0.06i (15%)	75.01 ± 0.04g (6%)
	K_1	34.59 ± 0.05f (18%)	53.28 ± 0.03f (25%)	80.31 ± 0.05e (14%)
	K_2	37.40 ± 0.2d (27%)	58.42 ± 0.02d (37%)	82.79 ± 0.06d (17%)
	K_3	31.05 ± 0.02h (6%)	50.66 ± 0.06h (19%)	78.77 ± 0.05f (11%)
	$G_1 K_1$	41.32 ± 0.03b (41%)	67.35 ± 0.03b (58%)	96.57 ± 0.04b (37%)
	$G_2 K_2$	45.96 ± 0.04a (56%)	80.90 ± 0.04a (89%)	129.51 ± 0.06a (83%)
	$G_3 K_3$	39.24 ± 0.06c (34%)	63.80 ± 0.05c (49%)	85.20 ± 0.05c (21%)
	F	5.059*	5.620*	9.735*

Note: see Table 1

Crop growth rate and net assimilation rate

The results of the present study revealed for both cultivars an increase in crop growth rate (CGR) from day 40 to 55 followed by a sharp decline (Table 3). The values of CGR increased with increasing concentration of GA_3 and K applied singly, but the values were higher at GA_3K combination, with the highest for G_2K_2. The increase over the control was especially high (212 and 239% for ‘Sevenstar’ and ‘KUK 9’, respectively) between 55 and 70 DAS. A similar tendency was recorded for NAR. Each application of single GA_3 and K increased NAR in comparison with control, but with G_2K_2, the increases reached 131% (‘Sevenstar’) and 134% (‘KUK 9’) at the period 55–70 DAS (Table 3).

Table 3. Effect of foliar spray with GA_3 and K on the crop growth rate ($g \cdot m^{-2} \cdot day^{-1}$) and Net assimilation rate ($g \cdot m^{-2} \cdot day^{-1}$) at different growth stages of cucumber

Cultivar	Treatments	Crop growth rate ($g \cdot m^{-2} \cdot day^{-1}$)		Net assimilation rate ($g \cdot m^{-2} \cdot day^{-1}$)	
		days after sowing			
		40-55	55-70	40-55	55-70
'Sevenstar'	Control	1.50 ± 0.006j	0.08 ± 0.003i	0.239 ± 0.0012j	0.101 ± 0.0003i
	G_1	1.62 ± 0.006f (8%)	0.19 ± 0.007f (138%)	0.251 ± 0.0003h (5%)	0.214 ± 0.0005g (112%)
	G_2	1.65 ± 0.012e (10%)	0.21 ± 0.006d (163%)	0.261 ± 0.0008e (9%)	0.220 ± 0.0006e (118%)
	G_3	1.59 ± 0.009h (6%)	0.16 ± 0.015h (100%)	0.248 ± 0.0011i (4%)	0.211 ± 0.0003h (109%)
	K_1	1.64 ± 0.006ef (9%)	0.20 ± 0.009e (150%)	0.255 ± 0.0005f (7%)	0.220 ± 0.0011e (118%)
	K_2	1.66 ± 0.006d (11%)	0.22 ± 0.006c (175%)	0.262 ± 0.0007d (10%)	0.221 ± 0.0005d (119%)
	K_3	1.61 ± 0.012g (7%)	0.18 ± 0.015g (125%)	0.251 ± 0.0003g (5%)	0.215 ± 0.0012f (113%)
	$G_1 K_1$	1.70 ± 0.009b (13%)	0.23 ± 0.012b (188%)	0.270 ± 0.0006b (13%)	0.229 ± 0.0057b (127%)
	$G_2 K_2$	1.79 ± 0.007a (19%)	0.25 ± 0.003a (213%)	0.276 ± 0.0008a (15%)	0.234 ± 0.0054a (132%)
	$G_3 K_3$	1.68 ± 0.003c (12%)	0.21 ± 0.015d (163%)	0.265 ± 0.0005c (11%)	0.227 ± 0.0003c (125%)
	F	29.387*	18.357*	51.138*	29.793*
'KUK 9'	Control	1.54 ± 0.006g	0.09 ± 0.009i	0.247 ± 0.0002h	0.106 ± 0.0006j
	G_1	1.64 ± 0.012e (6%)	0.22 ± 0.006f (144%)	0.273 ± 0.0013f (11%)	0.216 ± 0.0010gh (104%)
	G_2	1.68 ± 0.015d (9%)	0.25 ± 0.012c (178%)	0.280 ± 0.0008d (13%)	0.223 ± 0.0005e (110%)
	G_3	1.61 ± 0.012f (5%)	0.19 ± 0.009h (111%)	0.268 ± 0.0006g (9%)	0.212 ± 0.0013h (100%)
	K_1	1.66 ± 0.006de (8%)	0.23 ± 0.003e (156%)	0.275 ± 0.0005de (11%)	0.221 ± 0.0004f (108%)
	K_2	1.70 ± 0.012c (10%)	0.24 ± 0.003d (167%)	0.281 ± 0.0011c (14%)	0.226 ± 0.0023d (113%)
	K_3	1.63 ± 0.009e (6%)	0.21 ± 0.003g (133%)	0.272 ± 0.0005f (10%)	0.218 ± 0.0017g (106%)
	$G_1 K_1$	1.75 ± 0.012b (14%)	0.26 ± 0.006b (189%)	0.289 ± 0.0020b (17%)	0.231 ± 0.0011b (118%)
	$G_2 K_2$	1.81 ± 0.003a (18%)	0.30 ± 0.006a (233%)	0.299 ± 0.0012a (21%)	0.249 ± 0.0004a (135%)
	$G_3 K_3$	1.72 ± 0.006c (12%)	0.25 ± 0.006c (178%)	0.277 ± 0.0005e (12%)	0.229 ± 0.0014c (116%)
	F	27.688*	37.605*	31.139*	29.642*

Note: see Table 1

Number of flowers and fruit yield

Number of flowers per plant also showed significant variation with different treatments (Table 4). Higher flowers numbers per plant were exhibited by 'KUK 9' over 'Sevenstar'. The number of flowers per plant was the least in control plants and increased after GA_3 or K treatment (Table 4). Maximum number of flowers in 'Sevenstar' was 46 and in 'KUK 9' was 60, which was 22 and 51% more than that recorded in control. Together with the number of flowers, fruit yield per plant was also increased (Pal et al. 2016).

Total soluble carbohydrates, total soluble proteins, and starch contents

The contents of all the three parameters in plants sprayed with GA_3 and K significantly exceeded values for control plants. The contents were highest in both the cultivars at single application of G_2 and K_2 and G_2K_2 in combination. The contents of total soluble carbohydrates in G_2K_2 combination were higher by 53% in 'Sevenstar' and 61% in 'KUK 9' over the control. Records for total soluble proteins were higher by 48% in 'Sevenstar' and by 35% in 'KUK 9'. Starch increased the most – by 105% in 'Sevenstar' and 95% in 'KUK 9' (Table 4).

Table 4: Effect of foliar spray of gibberellic acid and potassium on the no. of flowers, fruit total soluble carbohydrates, starch and total soluble proteins (mg·g^{-1} DW) content and fruit yield (t·ha^{-1}) of cucumber

Cultivar	Treatments	No. of flower	Total soluble carbohydrate (mg·g^{-1} DW)	Starch (mg·g^{-1} DW)	Total soluble protein (mg·g^{-1} DW)	Fruit yield (t·ha^{-1})
'Sevenstar'	Control	38.0 ± 0.52i	2.18 ± 0.006l	0.40 ± 0.003l	0.42 ± 0.006l	23.07 ± 0.43i
	G_1	40.9 ± 0.06f (8%)	2.29 ± 0.006h (5%)	0.51 ± 0.006g (28%)	0.53 ± 0.004f (26%)	29.28 ± 0.32f (28%)
	G_2	41.5 ± 0.42e (9%)	3.19 ± 0.006c (46%)	0.57 ± 0.006f (43%)	0.54 ± 0.005e (29%)	30.54 ± 0.05e (29%)
	G_3	39.8 ± 0.61g (5%)l	2.86 ± 0.003g (31%)l	0.47 ± 0.012h (18%)	0.51 ± 0.006h (21%)	27.01 ± 0.08h (26%)
	K_1	41.0 ± 0.03j (8%)	3.00 ± 0.003e (38%)	0.60 ± 0.003e (50%)	0.54 ± 0.001e (29%)	28.11 ± 0.22g (27%)
	K_2	42.9 ± 0.18d (13%)	3.22 ± 0.05b (48%)	0.63 ± 0.009d (58%)	0.57 ± 0.005d (36%)	31.74 ± 0.03d (30%)
	K_3	39.5 ± 0.44h (4%)	2.89 ± 0.015f (33%)	0.57 ± 0.006f (43%)	0.52 ± 0.007g (24%)	27.21 ± 0.41h (26%)
	G_1 K_1	45.9 ± 0.21b (21%)	3.19 ± 0.006c (46%)	0.78 ± 0.006b (95%)	0.60 ± 0.003b (43%)	39.88 ± 0.05b (38%)
	G_2 K_2	46.4 ± 0.33a (22%)	3.34 ± 0.012a (53%)	0.82 ± 0.006a (105%)	0.62 ± 0.003a (48%)	45.35 ± 0.82a (44%)
	G_3 K_3	44.0 ± 0.23c (16%)	3.15 ± 0.003c (44%)	0.76 ± 0.006c (90%)	0.59 ± 0.006c (40%)	34.95 ± 0.66c (33%)
	F	6.679*	148.56*	1.990*	84.52*	23.575*
'KUK 9'	Control	39.7 ± 0.08h	2.29 ± 0.006k	0.43 ± 0.003i	0.48 ± 0.004i	24.81 ± 0.62i
	G_1	55.4 ± 0.22f (40%)	3.01 ± 0.006ij (31%)	0.52 ± 0.003g (21%)	0.54 ± 0.005g (13%)	33.15 ± 0.23g (32%)
	G_2	56.8 ± 0.05e (43%)	3.32 ± 0.012e (45%)	0.62 ± 0.023e (44%)	0.56 ± 0.006e (17%)	37.01 ± 0.04e (36%)
	G_3	53.8 ± 0.06g (36%)	2.89 ± 0.025kl (26%)	0.48 ± 0.012e (12%)	0.52 ± 0.003h (8%)	32.28 ± 0.07h (31%)
	K_1	56.1 ± 0.11d (41%)	3.12 ± 0.009h (36%)	0.58 ± 0.01f (35%)	0.55 ± 0.006f (15%)	35.01 ± 0.21f (34%)
	K_2	57.3 ± 0.43d 44%)	3.38 ± 0.012d (48%)	0.67 ± 0.006d (56%)	0.59 ± 0.005d (23%)	38.55 ± 0.16d (37%)
	K_3	55.5 ± 0.07e (40%)	3.06 ± 0.006i (34%)	0.52 ± 0.005h (21%)	0.53 ± 0.001g (10%)	34.41 ± 0.43g (33%)
	G_1 K_1	59.8 ± 0.02b (50%)	3.52 ± 0.006b (54%)	0.82 ± 0.009b (91%)	0.63 ± 0.002b (31%)	45.28 ± 0.11b (44%)
	G_2 K_2	60.0 ± 0.05a (51%)	3.68 ± 0.009a (61%)	0.84 ± 0.012a (95%)	0.65 ± 0.003a (35%)	50.82 ± 0.25a (49%)
	G_3 K_3	58.2 ± 0.16c (47%)	3.42 ± 0.006c (49%)	0.80 ± 0.006c (86%)	0.60 ± 0.003c (25%)	42.28 ± 0.09c (41%)
	F	8.882*	151.79*	1.952*	66.076*	33.894*

In parentheses is the percentage increase in value relative to the control.

G1: 0.005 g·dm^{-3}, G2: 0.01 g·dm^{-3}, G3: 0.015 g·dm^{-3}, K1: 1.0 g·dm^{-3}, K2: 2.5 g·dm^{-3}, K3: 5.0 g·dm^{-3}

Values within a column followed by the same letter are not significantly different from each other according to Duncan's Multiple Range Test at the p = 0.05 level. *F*-value of *F* statistics from analysis of variance with significance ***p < 0.001

DISCUSSION

Plant growth, productivity, and quality mainly depend on its genetic potential and interaction with fertigation and exogenous supplementation of growth substances in addition to its response with the environmental conditions. Adequate and balanced use of nutrients ensures the overall improvement of any crop in terms of growth, yield, and quality.

Gibberellic acid regulates nutrient transport, induces stem elongation, and increases dry matter production, leaf area expansion, and flowering (Khan & Samiullah 2003; Shah et al. 2006). Adequate supply of potassium can enhance all the growth attributes of crop plant by increasing the rate of photosynthesis, accumulating sugar, and decreasing the rate of respiration (Tawfik 2008). Similarly, Majumdar (2013) and Kumar et al. (2014) also observed that foliar application of gibberellic acid and potassium in combination influenced plant growth and its attributes.

Foliar application of gibberellic acid on mustard plants stimulated more leaf area and ultimately led plants to have a better chance of trapping sunlight and increased dry matter production (Khan et al. 1998). Zhou et al. (1999) also reported a similar increase in the leaf area of sugarcane plants in response to GA_3 treatment. A progressive increment in leaf area under sustained supply of potassium could be due to high maintenance of nutrient concentration in leaf tissues (Ashraf et al. 2002).

Growth attributes such as CGR and NAR were maximum at fruiting stage in both the cultivars, whereas other parameters such as leaf area index (LAI) and total dry matter showed progressive increase with the time. Higher CGR and NAR may be ascribed to influence characteristics involved in growth and development of crop plants by interaction of phytohormones and nutrients (Mir et al. 2010). The increment in plant biomass in the present study could presumably be the result of enhancing the uptake of nutrients, improved photosynthesis, and translocation of essential photoassimilates to respective parts of plant. Similar to our results, other investigators also noticed a significant increase in total dry matter accumulation by gibberellic acid in mustard and soybean (Khan et al. 1998; Rahman et al. 2004). Maintenance of dry matter over time is essential for prolonged supply of assimilates to developing sinks. K and GA_3 accelerate enzyme activity resulting in an increase in biomass accumulation in plants and contribute to the improvement in ability of treated plants to produce biomass (Marschner & Marschner 2012).

Early and uniform flowering in plant results in reducing overall production cost. Some research experiment proved that gibberellic acid activates α-amylase enzyme that degrades starch into sugars and promotes flowering (Kucera et al. 2005). A significant increase in the number of flowers with applied gibberellic acid over control was observed in tuberose (Tyagi & Singh 2008). Kazemi (2014) also observed that number of flowers and inflorescences in tomato increased when plants were treated with potassium. Potassium is a vital nutritional element; it often interacts with the availability and uptake of other nutrients which in turn affects the total yield. Potassium enhanced the fruit weight and number of fruits per plant (Bhargava et al. 1993). Dhillon et al. (1999) reported that leaf nutrient status, crop yield, and quality pointed out that fruit number and yield increased in grapes with the increment in potassium doses. Furthermore, it is required for the activation of enzymes ramified in sugar biosynthesis and sugar translocation and so it manages the mobilization in plant tissues that reflected on yield and its components (Elmarzugi et al. 2014).

The research conducted on various crops showed similar findings about the improvement in soluble sugar, starch, and protein with gibberellic acid and potassium because these stimulates the growth and development of a plant via regulation of DNA and RNA levels, increased intensity of cell division, and biosynthesis of enzymes, proteins, carbohydrates, and photosynthetic pigments (Arteca 1996; Kazemi 2014).

CONCLUSIONS

On the basis of our experiment, it is right to conclude that foliar application of GA_3 (0.01 $g \cdot dm^{-3}$) and K (2.5 $g \cdot dm^{-3}$) at proper interval of time (60 DAS) assures the best balance between GA_3 and K, showing pronounced effects on plant growth and development, yield, and quality attributes, thus benefits marketability of cucumber. All these findings lead us to recommend this combination under field conditions, and farmers should apply this combination to enhance productivity in cucumber crop.

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