THE EFFECT OF POTASSIUM AND GIBBERELLIC ACID COMBINATION ON GROWTH AND DEVELOPMENT OF *Cucumis sativus* L. cv. 'Sevenstar'

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Abstract. *Cucumis sativus* L. (Family: Cucurbitaceae) is one of the most important consuming annual herbaceous vegetables rich in calcium, magnesium, thiamine, niacin and vitamin C. A study was carried out to evaluate the potential of exogenously applied potassium (1.0, 2.5 and 5.0 $g{\cdot}l^{-1}$) and gibberellic acid (0.005, 0.01 and 0.015 $g{\cdot}l^{-1}$) in combinations on vegetative growth and development of F1 hybrid of *Cucumis sativus* L., cv. 'Sevenstar'. Data were recorded for vine length, fresh weight, dry weight, branch number, leaves number, absolute growth rate, relative growth rate, biomass duration, chlorophyll, carotenoids, calcium and magnesium contents of leaves. Application of combinations of potassium and gibberellic acid also increased the yield quantity (% fruit set, fresh and dry weight). The treatment containing potassium at 2.5 $g{\cdot}l^{-1}$ and gibberellic acid at 0.015 $g{\cdot}l^{-1}$ was best for growth of cv. 'Sevenstar'. Therefore, it can be concluded that foliar application of potassium and gibberellic acid may be effective strategy for maximizing the growth and development of parthenocarpic cucumber.

Keywords: *Cucumis sativus*; gibberellic acid; growth; parthenocarpic; potassium

Abbreviations: GA_3 - Gibberellic acid; K – Potassium; AGR - Absolute growth rate; RGR - Relative growth rate; BMD - biomass duration

INTRODUCTION

Cucumis sativus L. (Family: Cucurbitaceae) is one of the most important consuming annual herbaceous vegetables rich in calcium, magnesium, thiamine, niacin, vitamin C, vitamin K, vitamin B_6 and pantothenic acid [25, 45].

Foliar fertilization is a method of crop feeding providing micro- and macro-nutrients, in a solution or suspension, applied to leaves allowing rapid uptake regardless of soil conditions [35]. Use of foliar feeding during growth and development can improve nutrient balance of crops, which may in turn lead to increased yield and quality [26]. Exogenous application of plant growth regulators (PGRs) is a strategy to increase yield, improve crop quality and regulate uptake, and accumulation of mineral nutrients in plants.

Potassium (K) is a key nutrient for improving productivity of vegetable crops and show significant relationship in vegetable quality attributes [7]. Potassium has significant contribution in affect various biochemical and physiological parameters such as photosynthesis, enzyme activation, cell turgor maintenance and ion homeostasis [1, 11, 17, 19, 31, 40]. Nutritional potassium foliar sprays are usually more effective in rapidly increasing the K content of leaves than ground applied fertilizers [16]. Foliar K spray is effective method to shorten the time required for minerals uptake in comparison to soil fertilization [34]. Gibberellic acid (GA_3) is a PGR play an essential role in many aspects of plant growth and development affecting photosynthesis, nitrogen utilization, seed germination and delays senescence affecting plant morphology [5, 12]. Nutrient level affects growth and needs to be analyzed to understand plant growth and interpret crop yields.

In recent time, the introduction of parthenocarpic varieties of cucumber revolutionized its cultivation under protected cultivation in India. They have the advantage of unique parthenocarpic expression as no need of pollination with high yield potential with high quality bitter free fruit. The cucumber cv. 'Sevenstar' is a parthenocarpic, smooth, hybrid with a single fruit per node, dark green fruit, very high yield, 16-18 cm length fruit, tolerant to powdery mildew and suitable to early spring and late autumn growing.

Higher demand for food as expected consequences of population growth. Therefore, efforts are being made to use conventional methods of applying nutrient for increasing the yield per unit area. Despite various studies on the soil and root nutrition, unfortunately, few studies have been conducted on the effects of foliar application on the growth and yield of parthenocarpic vegetables. Keeping the above in mind, the present research was carried out to study the effect of foliar application of K and GA_3 on growth and development of F1 hybrid parthenocarpic cucumber cv. 'Sevenstar'.

MATERIALS AND METHODS

The investigation was carried out in an anti-insect net house at the Centre of Excellence for Vegetables Indo-Israel, Gharaunda (Karnal) at Lat. of 29º32' North, Long. 76º59' East from September to December 2014. Normal temperatures are 32-34°C to 17°-27°C. The F1 hybrid parthenocarpic cucumber cv. 'Sevenstar' was used. Seed were obtained from the Indo-Israel centre. The sandy loamy soil with good holding capacity used. The parthenocarpic cucumber hybrid were grown on raised beds having dimension of 80×30×45 cm (width, height and distance) at spacing of 40×30 cm. Treatments included foliar application of 3 concentrations of gibberellic acid [0.005 (G_1), 0.01(G_2), and 0.015 (G_3) $g{\cdot}l^{-1}$] and (G_0) control (0.0 $g{\cdot}l^{-1}$) with 3 concentrations of potassium fertilizer 1 (K_1), 2.5 (K_2) and 5 (K_3) $g{\cdot}l^{-1}$ and a (K_0) control (0.0 g/l^{-1}).

The experiment had 4 treatment combinations: G_0K_0, G_1K_1, G_2K_2, G_3K_3 used for both cultivars. K and GA_3 were prepared with distilled water and applied to foliage with a power spray/knap sack spray pump until complete wetting. Treatments were applied in the morning with a single day interval. The application of K was twice a week; with the first application beginning 20 days after direct sowing and followed with a twice weekly schedule. Application of GA_3 was conducted twice as first application was done at 30 days after direct sowing and second application was done after interval of 60 days. Data on vine length, root length, number of branches, number of leaves, fresh and dry weight, Absolute growth rate, Relative growth rate and Biomass duration, leaf- chlorophyll, carotenoid, calcium, magnesium contents and fruit yield (fruit set %, fresh and dry weight) were recorded at final harvest after 70 days.

Vine length and root length was measured from the coteledonary node to the growing tip. Total numbers of leaves and branches originating from main stem of each plant were counted. Vine length was measured from the cotyledonary node to the growing tip. Root length was measured from the coteledonary node to the growing tip. The total numbers of branches originating from main stem of each plant at harvest were counted. Total numbers of green leaves on the entire plant were counted. Fresh weight of plants was recorded at various days after sowing from uprooted plants that were separated into their components and weighed. Dry weight per plant was determined after plants were uprooted and separated into their components. Tissues were dried in a forced air oven at 70˚C until a constant weight was obtained and weighed again. Absolute growth rate (AGR) is the dry matter production per unit time, calculated using the formula of Radford [36]. Relative growth rate (RGR) is the rate of increase in dry weight per unit dry weight already accumulated and calculated using the formula of Blackman [8]. The biomass duration (BMD) was calculated using the formula of Sestak *et al.* [39].

Leaf chlorophyll content was measured as described by Arnon [4]. Carotenoid content in leaves was measured as described by Lichtenthaler and Welburn [29]. Leaves were dried to a constant weight at 70˚C and ground to a powder using a small mortar and pestle so that it would pass through a 1.0 mm sieve size. Sample, 0.5 g, of well-mixed, dry, ground plant material were weighed and the ash dissolved in 5 mL of 2N HCl for determination of Ca and Mg. Concentrations were determined using an atomic absorption spectrophotometer (model 2380, Perkin-Elmer, Waltham, Massachusetts, U.S). Reference standards for the elements, blanks and repeats of samples were digested the same way as the actual samples and served as internal positive controls.

All the experiments were conducted with five replicates per treatment and repeated thrice. The data were analyzed statistically using one-way analysis of variance (ANOVA) and the differences contrasted using a Duncan's multiple range tests at $P \leq 0.05$. All statistical analyzes were performed using the SPSS (version 11.5) program.

RESULTS

Applying K and GA_3 exogenously to cucumber increased all growth characters compared to the control. Different growth enhancement parameters like vine length, branch number, leaves number, fresh and dry weight of plant were recorded from G_2K_2 followed by G_1K_1 and G_3K_3 treatments (Table 1 and 2). The lowest value of all the above mentioned parameters was obtained from G_0K_0 control.

Table 1. Effect of foliar spray of potassium and gibberellic acid potassium on vine and root length, number of branch and leaves of parthenocarpic cucumber cv. sevenstar

Treatment	Vine length (cm)	Root length (cm)	No. of branch	No. of leaves
Control	271.0^{d}	20.0^{b}	31.0^{b}	140.3^{d}
G_1K_1	320.0^{b}	21.5^{b}	34.0^{b}	162.1^{b}
G_2K_2	324.0^{a}	26.3^{a}	36.3^{a}	165.0^{a}
G_3K_3	316.0^{bc}	21.0^{b}	33.0^{b}	161.6^{c}
LSD (P≤0.05)	6.97	2.33	5.97	15.40
ANOVA (F3,8)	132.46**	13.758**	1.463**	47.461**

C: Control, G_1: 0.005 $g \cdot l^{-1}$ G_2:0.01 $g \cdot l^{-1}$ G_3: 0.015 $g \cdot l^{-1}$ K_1: 1.0 $g \cdot l^{-1}$ K_2: 2.5 $g \cdot l^{-1}$ K_3: 5.0 $g \cdot l^{-1}$
‡: each value is mean of five replicates, values in column followed by same letter are not significantly different, P≤0.05, least significant difference (L.S.D) test

Table 2. Effect of foliar spray of potassium and gibberellic acid on fresh and dry weight of stem and root parthenocarpic cucumber cv. sevenstar

Treatment	Fresh weight of stem/ plant (g)	Fresh weight of root/plant(g)	Dry Weight of stem /plant (g)	Dry weight of root/plant (g)
Control	466^{cd}	8.1^{d}	67.0^{cd}	0.71^{d}
G_1K_1	548^{b}	10.1^{b}	81.3^{b}	0.76^{b}
G_2K_2	584^{a}	10.6^{a}	107.0^{a}	0.91^{a}
G_3K_3	490^{c}	8.7^{c}	70.3^{c}	0.73^{c}
LSD (P≤0.05)	6.499	0.32	5.155	0.938
ANOVA (F3,8)	728.193**	150.85**	135.95**	4.346**

C: Control, G_1: 0.005 $g \cdot l^{-1}$ G_2:0.01 $g \cdot l^{-1}$ G_3: 0.015 $g \cdot l^{-1}$ K_1: 1.0 $g \cdot l^{-1}$ K_2: 2.5 $g \cdot l^{-1}$ K_3: 5.0 $g \cdot l^{-1}$
‡: each value is mean of five replicates, values in column followed by same letter are not significantly different, P≤0.05, least significant difference (L.S.D) test

Table 3. Effect of foliar spray of potassium and gibberellic acid on growth parameters on parthenocarpic cucumber cv. sevenstar

Treatment	Absolute growth rate (g day1) /plant	Relative growth rate (g g-1day-1) /plant	Biomass duration (BMD, g days)
Control	0.090^{d}	0.026^{d}	831.4^{d}
G_1K_1	0.293^{b}	0.029^{b}	923.4^{b}
G_2K_2	0.346^{a}	0.032^{a}	9.28^{a}
G_3K_3	0.246^{c}	0.028^{c}	894.7^{c}
LSD (P≤0.05)	0.399	0.0044	0.292
ANOVA (F3,8)	81.549**	3.034**	2.476**

C: Control, G_1: 0.005 g·l^{-1} G_2:0.01 g·l^{-1} G_3: 0.015 g·l^{-1} K_1: 1.0 g·l^{-1} K_2: 2.5 g·l^{-1} K_3: 5.0 g·l^{-1}
‡: each value is mean of five replicates, values in column followed by same letter are not significantly different, P≤0.05, least significant difference (L.S.D) test

Table 4. Effect of foliar spray of potassium and gibberellic acid of chlorophyll, carotenoid and minerals contents of parthenocarpic cucumber cv. sevenstar

Treatment	Chlorophyll a (mg g^{-1} FW) /plant	Chlorophyll b (mg g^{-1} FW) /plant	Carotenoid (mg g^{-1} FW) /plant	Calcium (%)	Magnesium (%)
Control	1.03^{d}	0.54^{d}	0.46^{d}	1.15^{d}	0.28^{b}
G_1K_1	1.55^{b}	0.83^{b}	0.68^{b}	1.48^{b}	0.33^{a}
G_2K_2	1.69^{a}	1.14^{a}	0.74^{a}	1.90^{a}	0.32^{a}
G_3K_3	1.30^{bc}	0.71^{bc}	0.54^{c}	1.42^{c}	0.29^{b}
LSD (P≤0.05)	0.047	0.033	0.348	0.06	0.133
ANOVA (F3,8)	4.308**	591.07**	143.54**	2.898**	33.831**

C: Control, G_1: 0.005 g·l^{-1} G_2:0.01 g·l^{-1} G_3: 0.015 g·l^{-1} K_1: 1.0 g·l^{-1} K_2: 2.5 g·l^{-1} K_3: 5.0 g·l^{-1}
‡: each value is mean of five replicates, values in column followed by same letter are not significantly different, P≤0.05, least significant difference (L.S.D) test

Table 5. Effect of foliar spray of potassium and gibberellic acid of fruit yield attributes of parthenocarpic cucumber cv. sevenstar

Treatment	Fruit set %	Fresh weight of fruit (g)	Dry weight of fruit (g)
Control	68.0^{d}	113^{c}	19.0^{c}
G_1K_1	82.7^{b}	143^{b}	28.4^{b}
G_2K_2	85.9^{a}	162.8^{a}	39.8^{a}
G_3K_3	79.1^{c}	137.9^{bc}	25.6^{bc}
LSD (P≤0.05)	0.43	1.645	2.20
ANOVA (F3,8)	3.408**	2.168	164.5**

C: Control, G_1: 0.005 g·l^{-1} G_2:0.01 g·l^{-1} G_3: 0.015 g·l^{-1} K_1: 1.0 g·l^{-1} K_2: 2.5 g·l^{-1} K_3: 5.0 g·l^{-1}
‡: each value is mean of five replicates, values in column followed by same letter are not significantly different, P≤0.05, least significant difference (L.S.D) test

Growth analysis is necessary to understand plant growth in quantitative terms and to interpret crop yields under different nutrient levels. The AGR and RGR was highest in treatment G_2K_2 followed by G_1K_1 and G_3K_3 (Table 3). The lowest AGR and RGR were noticed in G_0K_0. Biomass duration (BMD) had higher values in cv. 'Sevenstar' F1 in G_2K_2 treatment followed by G_1K_1. Among the biochemical attributes, the combination of K and GA_3 also increased leaf chlorophyll a, b and carotenoids contents over control and best results were obtained with G_2K_2 treatment followed by G_1K_1 and G_3K_3 (Table 4).

The higher value of calcium content was also obtained with G_2K_2 followed by G_1K_1 and G_3K_3, while higher content of magnesium was noted with G_1K_1 followed by G_2K_2 and G_3K_3 (Table 4). In terms of different yield parameters, the highest value of fruit set percent, fruit fresh and dry weight was obtained with the combination G_2K_2 followed by G_1K_1 and G_3K_3 (Table 5). The control treatment (G_0K_0) showed lowest value in all the parameters studied.

It may be concluded from results that the sustained escalation in the observed parameters expectedly culminated in maximization of the process of biomass accumulation leading to higher productivity and chlorophyll, carotenoid, calcium content of cucumber plant, particularly by application of treatment G_2K_2 for the more appropriate growth and development of cucumber plant.

DISCUSSION

The increase in plant growth might be attributed to increased cell division and cell elongation induced by the foliar application of GA_3 and potassium. The results are in agreement with the findings of previous workers [22, 32, 37].

GA_3 works by promoting stem elongation [3, 41]. Cell enlargement and cell division are important processes that enhance height due to application of K and GA_3 [10]. Mazumdar [32] also noticed growth enhancement in cabbage from application of gibberellic acid and potassium. Kumar *et al.* [27] also observed that foliar application of K influenced numbers of leaves in tomato.

Mazumdar [32] and Kazemi [22] also noticed an increase in stem fresh weight with increased K and GA_3. Potassium and GA_3 promote DNA, RNA, protein synthesis, ribose and polyribosome multiplication which contribute toward biomass production in vegetative parts. They enhance enzyme activity acceleration [31] resulting in biomass accumulation in plants. Gibberellic acid regulates nutrient transport, inducing stem elongation, increased dry matter production, weight, leaf area expansion and flowering [21, 24, 41, 43].

Growth analysis indicated that the most AGR and RGR would lead to higher photosynthetic efficiency producing higher dry matter and enhancement crop yield [20]. The RGR represents efficiency of plants to produce new dry weight. At the beginning of growth, all plant weight and cells play roles in production, but as the time passes dead tissues and mature cells that play no role in production will also increase over time. The decrease of RGR during the growth season is due to increase in structural, rather than photosynthetic tissues [6, 38].

Maintenance of dry matter over time is essential for prolonged supply of photosynthates to developing sinks. Potassium and GA_3 accelerate enzyme activity which results in increases in biomass accumulation in plants and contributes to improvement in ability of treated plants to produce biomass [31].

The adequate supply of potassium increased the chlorophyll content of plant. Zhang *et al.* [46] and Lin and Danfeng [30] reported an increase in net photosynthetic rate and chlorophyll content with increasing K level. Photosynthesis and carbohydrate synthesis increased due to chlorophyll content in response to growth regulators treatment [28]. The increase in amount of carotenoid in *Daucus carota* L. due to application of potassium and gibberellic acid has also been reported by Ali *et al.* [2]

An increase in membrane permeability would facilitate absorption and utilization of mineral nutrients and transport of assimilates in the plant. The gibberellic acid induced increases in calcium by increasing the influx of Ca^{2+} at the plasma membrane and enhancing calcium activity by increased Ca^{2+} use efficiency in plants [23, 33, 42] Higher K levels can suppress Mg uptake as indicated by low Mg concentration in leaves.

The reason of this increment in fruit set %, fresh and dry weight of fruit might be interpreted that plants during flowering and fruit setting stages are in need of critical demand of their physiological activation which require high amount of K and other nutrients to perform the biological operations as increase in photosynthesis due to couple with chlorophyll synthesis [18]. An adequate quantity of K plays major role in crop growth and development by activating abundant enzymes controlling the cell osmoregulation and the stomatal movement of photosynthesis [9, 13]. The role of GA_3 in improving fruit quantity namely, fresh weight and dry weight may be due to its important role in enhancing cell division and elongation [15, 44] which had a positive effect on yield of fruits [14].

It may be concluded from results that the sustained escalation in the observed parameters expectedly culminated in maximization of the process of biomass accumulation leading to higher productivity and chlorophyll, carotenoid, calcium content of cucumber plant, particularly by application of treatment G_2K_2 for the more appropriate growth and development of cucumber plant.

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