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MULTIFACETED POTENTIAL OF K AND GA_3 ON GROWTH, PRODUCTION AND QUALITY OF F_1 HYBRID *Cucumis sativus* L. (cv. KUK-9)

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ABSTRACT

An experiment was conducted to evaluate the effect of different concentration and combination of potassium [1.0 g/l (K_1), 2.5 g/l (K_2) and 5.0 g/l (K_3)] and gibberellic acid [0.005 g/l (G_1), 0.01 g/l (G_2) and 0.015 g/l (G_3)] foliar application on growth characteristics, quality and yield of F1hybrid cucumber (cv. KUK-9).The results showed that the highest amounts for growth, biochemical attributes, fruit maturity, quality belonged to K_2 (2.5 g/l) plus G_2 (0.01 g/l) combination treatment. Plant height as well as chlorophyll content attained their greatest quantities under G_2K_2 treatment. Dry matter, TSS % and antioxidant activity showed significant differences compared with control, G_1K_1 and G_2K_2 treatment showed the greatest sum of data. Fruit mineral content were also significantly affected by different treatments. Higher fruit potassium was recorded with G_3K_3 treatment.

Key words: cucumber, heterozygote cultivars, foliar spray, fruit chemical composition, fruit size

Abbreviations: K – potassium; GA_3 – gibberellic acid

INTRODUCTION

Vegetables crops are important constituents of agriculture and nutritional security due to their short duration, nutritional richness, high yield, economic viability and ability to generate on-farm and off-farm employment. Vegetables are essential in the diet of humans in many parts of the world as they make available many vitamins (C, A, B_1, B_6, B_9, E), plant fibers, mineral elements, carbohydrates, proteins and phytochemicals [Wargovich 2000, Dias and Ryder 2011]. Cucumber (*Cucumis sativus* L.) is one of the most popular and profitable vegetable crops in the world, comprising of 70 genera and 750 species [Best 2000]. The problem of loss of minerals in vegetables during cooking does not exist in cucumber [Kimura and Itokawa 1990]. The nutritional value of cucumber fruit per 100 g edible portion is water (95%), carbohydrate (3%), protein (1 %), total fat (0.5%) and dietary fibre (1%) (USDA, National Nutrient Data Base, 2014). Cucumber fruit is a veritable source of vitamins such as vitamin A, C, K, E and minerals including potassium, manganese, phosphorus, calcium and zinc which are essential for protein, nucleic acid synthesis and also contributes to maintain blood pressure, structural development of bones [Bohl and Volpe 2010]. Furthermore, cucumber folk medicine includes treatment of diabetes, hypertension, diar-

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rhoea, gonorrhoea and also used to detoxify, as an anti-inflammatory, analgesic, antioxidant and serum lipids regulator [Abu-Reidah et al. 2012].

In cultivation of long term cucumber crop, immense labour and supply cost are intended in vine training and disease control. The introduction of parthenocarpic varieties of cucumber revolutionized its cultivation under protected cultivation in India. As, they have the advantage of unique parthenocarpic expression as no need of pollination, disease resistant, with high yield potential and high quality bitter free fruit. Nevertheless, consumers adorn nutritional qualities is at an all-time high and too many consumers are choosing foods on the basis of their health benefits. Protected cultivation of vegetables offers distinct advantage to overcome climatic diversity as faced by crop in open field and provide effective means to early maturity, prevention of insects and also enhance yield manifolds [Cheema et al. 2004]. At the same time, growers can substantially raise their income by protected cultivation of off-season vegetable crops and improve the quality of produce significantly as per the market demand [Singh et al. 2004].The cv. 'KUK-9' is a gynoecious parthenocarpic hybrid with 3–5 fruits per node, slightly ribbed and dark green fruit, show medium fruit maturation, very high yield, 16–18 cm length fruit, tolerant to powdery mildew and growing in late-spring summer and early-autumn season with open plant habit.

Current trend of high yield in agriculture would not be achieved without implementation of greater nutrient use efficiency that tailored the quantity and composition of nutrients in accordance with soil chemical composition and crop needs. Nutrient interaction often assumed to be the critical factor in influencing crop yield. Interaction among plant growth regulator and fertilizer show positive effect in optimize particular physiological and biochemical processes, stages of development and growth [Kuppusamy et al. 2009]. These days, researchers preferred the use of plant growth regulator (PGRs) that holds great prospect for meeting the demand of yield and crop quality. PGRs are natural and synthetic compound practiced on plant for influences plant growth and development. Endogenous plant growth regulators are known to control vital physiological and biochemical processes of plants [Sharma et al. 2013]. Foliar spray is the new trend in agriculture that recommended by numerous investigators as a good alternative beside conventional soil application to avoid the loss of nutrients by leaching, so results in minimizing the ground water pollution [Tomimori et al. 1995]. Foliar spray is an emerging method for crop feeding that involves applying a solution of micro- and macro-nutrients to the leaves, which allows rapid uptake regardless of soil conditions. It is usually preferred over root fertilization because of its higher efficiency and lower cost [Nasiri et al. 2010].

Although the gibberellic acid and potassium have great potentialities to improve plant growth, yield and quality attributes but their application and authentic assessments have to be accurately planned in terms of optimal concentrations, stage of application, species specificity etc. which integrate the considerable impediments in their applicability. Nutrient level affects the growth and there is a need to be analyzed to understand plant growth and interpret crop yields. Considering, the complexity of interaction not all the treatments proved beneficial and some may even depress plant growth. Keeping the above in mind, this study was designed to investigate the effect of foliar spray of different alone and combined concentrations of gibberellic acid and potassium on F1 hybrid parthenocarpic cucumber (cv. KUK-9).

MATERIALS AND METHODS

Plant material and experimental set up

The present work was carried out during three successive seasons (September to December 2013–2014, 2014–2015 and 2015–2016) in an insect-proof net house at the Centre of Excellence for Vegetables, an Indo-Israel project, at Gharaunda (Karnal) located in 29–32°N latitude and 76–59°E longitude under normal temperatures 32–34°C (day) to 17–27°C (night). The F_1 hybrid cucumber cv. 'KUK-9' was used in experiment and seed were procured from the Centre of Excellence for Vegetables. An anti-insect net house is equipped with microclimate optimization system and protected from insect pests and diseases using appropriate plant protection measure from the initial stages of crop growth until crop senescence. The soil in the field plots was sandy loam in texture (sand, silt and clay content was 82.20, 6.11 and 11.19% respectively), slightly alkaline in reaction (pH = 7.70), low to medium in electrical conductivity (E.C = 0.27 M/m), with low levels of organic carbon (0.16%) and medium levels of phosphorus (15.23 kg/ha), potassium (146.50 kg/ha) and Sulphur (52.39 ppm) and 12.3% moisture availability. The experiment was carried out in a randomized complete block design, with three replicates, using potassium and gibberellic acid in three different concentrations-namely, potassium [1.0 g/l (K_1), 2.5 g/l (K_2) and 5.0 g/l (K_3)] and gibberellic acid [0.005 g/l (G_1), 0.01 g/l (G_2) and 0.015 g/l (G_3)] alone and indifferent combinations G_1K_1, G_2K_2 and G_3K_3. So a total of ten different treatments including alone and combination of GA_3 and K were used in the experiment. The stock solutions were prepared fresh at the time of each spraying with distilled water according to the method suggested by Hurtmann and Kester [1959]. Under protected condition, the seeds were sown on raised beds of dimension 80 × 30 cm (width × height), separated at a distance of 45 cm from each other and with 40 cm spacing between two plants on the same bed. Nitrogen, phosphorous and potassium at 19 : 19 : 19 kg/ha (0–14 days) and 13 : 00 : 45 kg/ha (14 days-crop finish) was applied with the drip irrigation system for all the treatments twice a week. First spraying of K was performed after 20 days of sowing and then it was sprayed twice a week till maturity. Spraying of gibberellic acid was performed on 21, 30 and 60 days after sowing using power pump sprayer. All the other agriculture practices i.e., irrigation, hoeing and weeding were carried out throughout the growing season. Data on plant height, leaf chlorophyll and total yield were evaluated at 40, 55 and 70 days after sowing (DAS). Fruit quality parameters like percent dry matter (DM), total soluble solid (TSS) and antioxidant activity; different mineral contents were also analysed at final harvest (i.e 70 DAS). Plant height was measured from the coteledonary node to the growing tip. Total chlorophyll content in leaf estimated by Arnon [1949]. TSS % was determined using hand refractometer. Dry matter of fruit tissues was estimated according the Dubois et al. [1959] method. The antioxidant activity was evaluated by using the β-carotene bleaching method [Kaur and Kapoor 2002] with some modifications [Sengul et al. 2011]. Fruits were rinsed three times in distilled water then dried in a forced air oven at 70°C for three days. Thereafter, the fruits were ground for determinations of fruit nutrients. Potassium and sodium content was assayed using flame spectrophotometer. Total nitrogen in fruit sample was estimated by Kjeldahl's method [Singh et al. 1999, Yaduvanshi et al. 2009]. Phosphorous was extracted and measured spectrophotometrically according to Koenig and Johnson [1942] method. Calcium and magnesium elements were determined in the di-acid digest of fruit sample using atomic absorption spectrometry (AAS) using the method of AOAC [1990].

The data obtained during the experiment as means of three consecutive years were subjected to statistical analysis 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

The importance of potassium and gibberellic acid in plant nutrition and agricultural crop production has been well documented and foliar spray of nutrients is being considered an ideal method for intensive and profitable cultivation of crops. Maximum rise in plant height, total chlorophyll content and quality attributes obtained in plant sprayed with G_2K_2 treatment which shows much promotive effect over other alone or combination treatments. In overall treatments, interaction between K and GA_3 proved best.

Plant height

In plant breeding, height of plant is main target for enhancing seed yield, biomass and standing ability. Table 1 showed that there was significant increase in plant height with progression of stage. At 70 DAS, plant sprayed either with precise concentration of gibberellic acid (0.01 g/l) and potassium (2.5 g/l) alone resulted in increasing the plant height by 65% and 64%, respectively than the other alone treatments. Regarding the interaction, different combination of K and GA_3 were significantly differing in their response. Plants sprayed with G_2K_2 treatment showed increase in plant height by 79% and significantly taller followed by G_3K_3, $G_1K_1$and other alone treatments while the least plant height character recorded in control plants.

Table 1. Effect of foliar spray of gibberellic acid and potassium on the plant height ± SE (cm) of cucumber cv. 'KUK-9'

Treatment	Plant height		
	40 DAS	55 DAS	70 DAS
Control	153.2 ±0.5 ^{g}	164.3 ±1.0^{h}	178.0 ±0.8^{h}
G_1	195.7 ±0.6^{f} (27%)	239.0 ±1.0^{f} (45%)	285.8 ±1.0^{fg} (60%)
G_2	200.2 ±0.5^{c} (31%)	249.6 ±1.1^{d} (52%)	293.8 ±1.1^{cd} (65%)
G_3	193.5 ±0.9^{f} (26%)	236.9 ±1.1^{g} (44%)	282.6 ±1.3^{g} (59%)
K_1	196.9 ±1.7^{de} (29%)	243.5 ±0.4^{e} (48%)	288.0 ±1.0^{ef} (62%)
K_2	199.0 ±0.6^{cd} (30%)	247.1 ±1.2^{d} (50%)	291.3 ±0.8 ^{de} (64%)
K_3	194.8 ±0.5^{ef} (27%)	240.4 ± 0.8^{f} (46%)	284.7 ±0.9^{fg} (60%)
G_1K_1	205.5 ±0.9^{b} (34%)	265.3 ±0.5^{b} (61%)	300.2 ±1.3^{b} (69%)
G_2K_2	209.3 ±0.7^{a} (37%)	279.0 ±0.6^{a} (70%)	318.0 ±1.7^{a} (79%)
G_3K_3	200.7 ±0.8^{c} (31%)	255.8 ±1.1^{c} (56%)	295.3 ±0.8^{c} (66%)
F	291.65**	958.76**	1.100**

In parentheses is the percentage increase in value relative to the control
G_1: 0.005 g/l, G_2: 0.01 g/l, G_3: 0.015 g/l, K_1: 1.0 g/l, K_2: 2.5 g/l, K_3: 5.0 g/l, DAS: days after sowing
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 ** $p < 0.01$

Table 2. Effect of foliar spray of gibberellic acid and potassium on the total chlorophyll ± SE ($mg \cdot g^{-1}$ fresh weight) of cucumber leaves

Treatment	Leaf total chlorophyll		
	40 DAS	55 DAS	70 DAS
Control	2.00 ±0.5^{i}	2.26 ±0.5^{i}	1.93^{i} ±0.03
G_1	2.22 ±0.6^{h} (11%)	3.06 ±0.05^{ef} (35%)	2.30^{g} ±0.6 (19%)
G_2	2.38 ±0.005^{e} (19%)	3.28 ±0.5^{d} (45%)	2.60^{e} ±0.7 (35%)
G_3	2.24 ±0.5^{g} (12%)	2.56 ±0.5^{h} (13%)	2.13^{h} ±0.3 (10%)
K_1	2.34 ±0.5^{f} (17%)	3.10 ±0.8^{e} (37%)	2.46^{f} ±0.5 (27%)
K_2	2.39 ±0.5^{d} (20%)	3.42 ±0.5^{c} (51%)	2.80^{d} ±0.5 (45%)
K_3	2.24 ±0.5^{g} (12%)	2.94 ±0.3^{g} (30%)	2.30^{g} ±0.6 (19%)
G_1K_1	2.53 ±0.5^{b} (27%)	3.52 ±0.5^{b} (56%)	3.03^{b} ±0.5 (56%)
G_2K_2	2.81 ±0.6^{a} (41%)	4.10 ±0.7^{a} (81%)	3.70^{a} ±0.6 (91%)
G_3K_3	2.41 ±0.6^{c} (21%)	3.46 ±0.5^{bc} (53%)	3.00^{c} ±0.5 (55%)
F	0.146**	0.817**	0.851**

In parentheses is the percentage increase in value relative to the control
G_1: 0.005 g/l, G_2: 0.01 g/l, G_3: 0.015 g/l, K_1: 1.0 g/l, K_2: 2.5 g/l, K_3: 5.0 g/l, DAS: days after sowing
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 ** $p < 0.01$

Leaf chlorophyll content

Foliar spray of plant either alone and combined different concentration of K and GA_3 significantly increased total chlorophyll in comparison to control plants. The most pronounced effect was seen in the plants applied with G_2K_2 treatment. Higher value of total chlorophyll was recorded in G_2K_2 followed by G_1K_1 and G_3K_3 (tab. 2). In overall treatments, interaction between K and GA_3proved best. It was evident that foliar application of G_2K_2 treated plant at 55 DAS increase pigment content by 81% in comparison to control and interestingly, treatment with higher concentration (G_3K_3) proved imperceptible in holding the adequate pigment content. Among alone treatments K_2 showed best results in this character.

Fruit growth and maturation

Fruit on plants receiving supplemental foliar K and GA_3 applications reached harvestable maturity on average interval earlier than control fruit. Days to fruit initiation, maturity and harvest differed significantly in all the treatments. Plants showed a pattern of ongoing short maturity and harvest time in GA_3 either alone or in combination with K sprayed plants over control (tab. 3). Early fruit set (32.04), maturity (6.78) days and harvesting (38.82) days were recorded in plant foliar sprayed with G_2K_2. The maximum number of days (37.25) taken to fruit set, (10.82) fruit maturity and harvest (48.07) were recorded with control. Of the treatments, G_1K_1 and G_3K_3 treatments were on par with each other. Rests of the treatments were statistically similar to each other. Treatment K_2 had edge beyond individual treatments.

Fruit yield attributes

All the treatments significantly influenced the cucumber productivity (fruit length and width, average fruit weight and number of fruits per plant). Like with fruits, G_2K_2 application possessed highest fruit length (41%), fruit width (47%), average fruit weight (30%) and number of fruits per plant (57%) as compared with control (tab. 4). Intermediate results for different productivity attributes were recorded in G_1K_1 and G_3K_3 treatments. Under fruit yield attributes, K_2 (2.5 g/l) treatment performed well among other alone treatments.

Table 3. Effect of foliar spray of gibberellic acid and potassium on days taken to fruit set, days taken to fruit maturity and days taken to first harvesting of cucumber cv. 'KUK-9' (means ± SE)

Treatment	Days taken to fruit set	Days taken to edible maturity	Days taken to first harvesting
Control	37.25^{e} ±0.5	10.82^{c} ±0.5	48.07^{g} ±0.7
G_1	34.02^{bc} ±0.5 (–9%)	8.17^{b} ±1.1 (–32%)	42.19^{cd} ±1.0(–14%)
G_2	33.46^{ab} ±0.5 (–11%)	7.43^{ab} ±0.5 (–45%)	40.89^{bc} ±0.5 (–17%)
G_3	35.13^{cd} ±0.5 (–6%)	8.11^{ab} ±0.5 (–33%)	43.24^{de} ±0.5 (–11%)
K_1	35.11^{cd} ±0.6 (–6%)	8.26^{a} ±0.5 (–31%)	43.37^{ef} ±1.1 (–10%)
K_2	34.50^{bc} ±0.6 (–8%)	8.13^{b} ±1.1 (–33%)	42.63^{cd} ±0.5 (–13%)
K_3	35.80^{de} ±0.5 (–4%)	9.14^{bc} ±0.5 (–18%)	44.94^{f} ±0.5 (–7%)
G_1K_1	33.13^{ab} ±0.5 (–12%)	7.11^{a} ±0.5 (–52%)	40.24^{ab} ±1.1 (–19%)
G_2K_2	32.04^{a} ±0.5 (–16%)	6.78^{a} ±0.6 (–60%)	38.82^{a} ±0.5 (–24%)
G_3K_3	33.41^{ab} ± 1.1 (–11%)	8.03^{ab} ±0.5 (–35%)	41.44^{bc} ±1.7 (–16%)
F	6.875**	3.788**	18.678**

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

G_1: 0.005 g/l, G_2: 0.01 g/l, G_3: 0.015 g/l, K_1: 1.0 g/l, K_2: 2.5 g/l, K_3: 5.0 g/l, DAS: days after sowing

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 ** $p < 0.01$

Table 4. Effect of foliar spray of gibberellic acid and potassium on fruit length and diameter, average fruit weight, number of fruits per plant and total yield of cucumber cv. 'KUK-9' (means ± SE)

Treatment	Fruit length (cm)	Fruit diameter (cm)	Average fruit weight (g)	Average number of fruit per plant	Total yield (kg/plant)
Control	15.1 ±0.5 ^{d}	8.5 ±0.6^{c}	136.6^{g} ±1.6	27.33 ±2.1^{e}	3.72 ±0.5^{e}
G_1	18.5 ±0.6^{bc} (23%)	9.7 ±0.6^{b} (14%)	140.3 ±1.0^{ef} (3%)	35.48 ±1.8^{cd} (30%)	4.97 ±0.1^{d} (34%)
G_2	19.3 ±0.6^{bc} (28%)	10.0 ±0.5^{bc} (18%)	143.5 ±1.9^{d} (5%)	38.72 ±1.1^{b} (42%)	5.55 ±0.3^{cd} (49%)
G_3	18.3 ±0.7^{c} (21%)	9.5 ±0.6^{b} (12%)	139.3 ±0.9^{fg} (2%)	34.78 ±1.6^{d} (27%)	4.84 ±0.1^{d} (30%)
K_1	19.0 ±0.5^{bc} (26%)	9.6 ±0.6^{b} (13%)	142.0 ±2.3^{e} (4%)	37.30 ±0.6^{bc}(36%)	5.25 ±0.2^{cd} (41%)
K_2	19.5 ±0.6^{ab} (29%)	10.3 ±0.6^{bc} (21%)	146.4 ±0.8^{d} (7%)	39.59 ±1.7^{b} (42%)	5.78 ±0.1^{c} (55%)
K_3	18.3 ±0.5^{c} (22%)	9.1 ±0.6^{b} (7%)	140.6 ±1.1^{f} (3%)	36.82 ±1.4^{cd} (35%)	5.16 ±0.1^{d} (39%)
G_1K_1	20.5 ±0.6^{ab} (36%)	11.5 ±0.6^{ab} (35%)	165.3 ±1.1^{b} (21%)	41.08 ±2.6^{ab} (50%)	6.79 ±0.1^{ab} (83%)
G_2K_2	21.3 ±0.6^{a} (41%)	12.5 ±0.6^{a} (47%)	177.3 ±0.4^{a} (30%)	43.04 ±1.5^{a} (57%)	7.62 ±0.6^{a} (105%)
G_3K_3	19.2 ±0.6^{bc} (27%)	10.4 ±0.6^{bc} (22%)	159.4 ±0.7^{c} (17%)	39.86 ±1.5^{b} (46%)	6.34 ±0.5^{bc} (70%)
F	7.056**	3.403**	109.9**	6.571**	9.468**

In parentheses is the percentage increase in value relative to the control.
G_1: 0.005 g/l, G_2: 0.01 g/l, G_3: 0.015 g/l, K_1: 1.0 g/l, K_2: 2.5 g/l, K_3: 5.0 g/l, DAS: days after sowing
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 ** $p < 0.01$

Table 5. Effect of foliar spray of gibberellic acid and potassium on fruit quality parameters of cucumber cv. 'KUK-9'

Treatment	Dry matter (%)	Antioxidant activity (%)	TSS (%)
Control	3.82 ±0.55^{e}	35.2 ±2.03^{e}	3.08 ±0.01^{f}
G_1	4.47 ±0.04^{bc} (17%)	37.8 ±0.05^{cd} (7%)	4.45 ±0.03^{de} (44%)
G_2	4.73 ±0.03^{b} (24%)	38.6 ±0.07^{bc} (10%)	4.61 ±0.02^{c} (50%)
G_3	3.99 ±0.17^{cd} (4%)	36.5 ±0.05^{d} (4%)	4.38 ±0.01^{e} (42%)
K_1	4.49 ±0.09^{bc} (18%)	37.9 ± 0.05^{de} (8%)	4.52 ±0.01^{d} (47%)
K_2	4.75 ±0.04^{b} (24%)	38.7 ±0.14^{bc} (10%)	4.64 ±0.01^{c} (51%)
K_3	4.03 ±0.14^{d} (5%)	37.1 ±0.06^{cd} (5%)	4.45 ±0.02^{de} (44%)
G_1K_1	4.98 ±0.03^{ab} (30%)	40.1 ±0.11^{ab} (14%)	4.76 ±0.01^{b} (55%)
G_2K_2	5.73 ±0.05^{a} (50%)	40.6 ±0.01^{a} (16%)	4.88 ±0.06^{a} (58%)
G_3K_3	4.96 ±0.02^{b} (30%)	39.4 ±0.48^{bc} (12%)	4.67 ±0.01^{bc} (52%)
F	7.67**	5.96**	37.90**

In parentheses is the percentage increase in value relative to the control
G_1: 0.005 g/l, G_2: 0.01 g/l, G_3: 0.015 g/l, K_1: 1.0 g/l, K_2: 2.5 g/l, K_3: 5.0 g/l, DAS: days after sowing
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 ** $p < 0.01$

Fruit quality attributes

The finding regarding fruit quality attributes, immense improvement was found in treatment combination G_2K_2 over other treatments and control. Fruit dry matter, TSS and antioxidant activity was significantly higher in treated plants over control (tab. 5). The treatment G_2K_2 led to significant increment followed by G_1K_1 and G_3K_3 in dry matter (50%), TSS (58%) and antioxidant activity (16%) corresponding to control which show decrement. Treatment K_2 showed best results above rest of alone treatments.

Fruit minerals

K and GA_3 combined foliar application meaningfully affected mineral content of fruits (tab. 6). Similar with other traits, the greatest N, P and Ca content of fruit issue belonged to G_2K_2. Potassium content of plants was influenced by the treatments and the highlighted data (67%) for this trait owned by G_3K_3 application. Sodium and magnesium content in fruits varied with the treatment states of individual potassium application. The lowest Na and Mg content were observed under the K_3 treatment containing highest K level that was slightly above the control plants. The highest content of Na and Mg coexisted with lowest K in the leaves sprayed by the combination G_1K_1. Treatment G_2 was performed better in terms of Na and Mg content over rests of the treatments.

Table 6. Effect of foliar spray of gibberellic acid and potassium on the fruit mineral composition (mg^{-1}DW) of cucumber cv. 'KUK-9'

Treatments	Fruit mineral composition					
	N	P	K	Ca	Na	Mg
Control	33.6 ±1.8^{b}	4.9 ±0.04^{i}	34.4 ±0.5^{b}	10.1 ±0.6^{b}	1.8 ±0.05^{d}	0.23 ±0.04^{i}
G_1	44.8 ±1.5^{ab} (33%)	5.3 ±0.02^{g} (8%)	44.3 ±0.5^{ab} (29%)	12.8 ±0.6^{ab} (27%)	2.6 ±0.17^{bc} (56%)	0.28 ±0.01^{b} (22%)
G_2	46.7 ±1.2^{ab} (39%)	5.6 ±0.01^{e} (14%)	45.6 ±0.7^{ab} (33%)	13.0 ±0.1^{ab} (29%)	3.1 ±0.08^{a} (67%)	0.29 ±0.01^{a} (26%)
G_3	45.1 ±1.4^{ab} (34%)	5.2 ±0.01^{h} (6%)	40.1 ±0.1^{ab} (17%)	12.4 ±0.4^{ab} (23%)	2.6 ±0.11^{ab} (44%)	0.26 ±0.01^{d} (13%)
K_1	48.3 ±1.5^{ab} (43%)	5.7 ±0.01^{d} (16%)	47.6 ±0.5^{ab} (38%)	12.9 ±0.1^{ab} (28%)	2.6 ±0.14^{bc} (44%)	0.27 ±0.02^{e} (17%)
K_2	49.5 ±1.9^{ab} (47%)	5.8 ±0.01^{c} (18%)	51.1 ±0.1^{ab} (49%)	13.2 ±0.4^{ab} (31%)	2.3 ±0.12^{cd} (28%)	0.26 ±0.03^{f} (13%)
K_3	47.6 ±0.7^{ab} (42%)	5.4 ±0.01^{f} (10%)	56.8 ±0.2^{ab} (65%)	12.6 ±0.1^{ab} (25%)	2.1 ±0.14^{cd} (17%)	0.24 ±0.02^{g} (4%)
G_1K_1	51.1 ±1.1^{a} (52%)	6.1 ±0.01^{b} (24%)	48.8 ±0.3^{ab} (42%)	14.6 ±1.6^{ab} (45%)	2.9 ±0.14^{a} (61%)	0.29 ±0.01^{a} (26%)
G_2K_2	54.3 ±1.0^{a} (62%)	6.4 ±0.03^{a} (31%)	50.1 ±0.12^{ab} (46%)	16.5 ±0.4^{a} (63%)	2.5 ±0.11^{bc} (39%)	0.28 ±0.01^{c} (22%)
G_3K_3	49.6 ±1.2^{ab} (48%)	5.9 ±0.12^{c} (20%)	57.6 ±0.17^{a} (67%)	13.9 ±0.1^{ab} (38%)	2.3 ±0.05^{cd} (28%)	0.24 ±0.01^{h} (4%)
F	15.02 **	58.01**	281.6**	5.83**	11.7**	1.475**

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

G_1: 0.005 g/l, G_2: 0.01 g/l, G_3: 0.015 g/l, K_1: 1.0 g/l, K_2: 2.5 g/l, K_3: 5.0 g/l, DAS: days after sowing

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 ** $p < 0.01$

DISCUSSION

Crop growth, productivity and quality mainly depend on its genetic potential and its interaction to 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. Any discontinuance in nutrient supply to plants leads to negative impact on yield and quality.

Applying gibberellic acid and potassium exogenously alone or in combination to cucumber increased all different growth characters in cucumber. Plant growth promotion by gibberellic acid and potassium could be interpreted upon its effect on fast growth that occurs as a result of both the superlative number of cells formed and elongation of individual cells [Eman et al. 2007]. Plant height is a very important factor for good plant growth and ultimate yield which affect the number of leaves, flowers, vegetative and other reproductive attributes. Promotion in overall growth parameters in the plants supplemental with gibberellic acid might be attributed to the induction of inherent genetic potential of the plant by exogenous plant growth regulator application causing an increase in cell endogenous gibberellins level, cell division and cell wall extensibility [Buchanan et al. 2000]. Gibberellic acid works by promoting stem elongation [Shah et al. 2006]. Presumably, similar results of gibberellic acid on plant height have been widely reported for many crops, including brinjal [Sorte et al. 2001], chilli [Natesh et al. 2005], okra [Ilias et al. 2007].

Total chlorophyll content of leaves increased up to fruiting stage and then declined with advancement of stage. Decrease in chlorophyll content at later growth stage may be associated with breakdown of chlorophyll for the remobilization of nitrogen from chlorophyll-binding proteins to proceed throughout senescence [Hortensteiner 2006]. Similar results reported by Ma and Shi [2011] in *Stevia rebaudiana* and Kataria and Singh [2014] in *Vigna radiata*. Photosynthesis and carbohydrate synthesis increased due to chlorophyll content in response to growth regulators treatment [Lamrani et al. 1996]. Proficiency of photosynthetic process mainly depends on the quantity and maintenance of the numerous types of chlorophyll. Gibberellic acid application has been found to activate the accumulation of osmoprotectant and antioxidant defense system which is responsible for enhancing chlorophyll content [Khan et al. 2010]. Gibberellic acid application leads to increase in Rubisco content and its activity which enhances photosynthesis, also improved photosynthetic rate in leaves which shows the efficiency of gibberellic acid in increasing photosynthesis [Khan 1998, Ashraf et al. 2002]. Inadequate application of GA_3 considerably decrease the photosynthetic rates, changes in the reaction centers of Photosystem II and suppress the enzymatic processes of the calvin system [Ouzounidou et al. 2010]. Gibberellic acid applied enhanced percentage of total chlorophyll content in leaves of *Trigonella foenum-graecum* [Dar et al. 2015]. Vanbel [1990] found that an adequate supply of K plays a key function in chlorophyll formation. Potassium is particularly significant to photosynthesis as it activates several enzymes involved in this process [Tucker 1994]. Therefore, potassium supplied at appropriate concentration increase chlorophyll content and photophosphorylase activity, control proton gradient of thylakoid membranes and improved photosynthetic phosphorylation [Xu et al. 2011].

The combination of gibberellic acid and potassium significantly enhanced cucumber productivity over alone treatments and control. Our findings are in agreement with the results of Kazemi [2014] and Mazumdar [2013], which revealed an increase in fruit weight, number of fruits per plant and total yield of tomato and cabbage using different combinations of K and GA_3. This increment 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 [Ding et al. 2006]. Plant growth hormones influences leaf light interception, CO_2 fixation, mineral uptake, delay senescence, reduction in competition for nutrients and photo assimilates within plant organ and also well-developed chloroplast enhance photosynthetic efficiency. This could enhance in productivity of mother plant results in boosting yield of plant [El-otmani et al. 2000]. In fruit growing, GA_3 is frequently applied as it affects the shape of fruits and increase number of fruit and weight per plant [Davies and Zalman 2006]. The role of GA_3 in improving fruit quantity namely, fruit weight and fruit size may be due to its important role in enhancing cell division and elongation [Eman et al. 2007] which had a positive effect on yield of fruits [El-sese 2005]. Deckers and Schoofs [2002] also reported that foliar application of plant growth regulating substances, particularly GA_3, have positive effect on yield and quantity.

Potassium is vital nutritional element; often interact with the availability and uptake of other nutrients which in turn affect the total yield. Investigation has shown that potassium involved in many physiological processes, positive impact on photosynthesis and assimilates transport that directs consequences on crop productivity [Akram et al. 2009]. 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 with increment in potassium doses. Majumdar et al. [2000] recognized that potassium enhanced the foliage and discursively elevated the photosynthesis and in such a way increased the crop yield.

Research conducted in other crops with gibberellic acid and potassium around the world showed similar findings about the improvement in soluble sugar because these stimulates the growth and development of a plant via regulation of DNA and RNA levels, increased intensity of cell division, biosynthesis of enzymes, proteins, carbohydrates and photosynthetic pigments [Arteca 1996, Kazemi 2014]. Potassium fertilizer affects the fruit quality rate by playing stimulatory role on the synthesis of specific components required in the fruit maturation. Forthwith, potassium is mandatory for various physiological processes like enzyme activation, controlling cell water content, carbohydrates biosynthesis, regulation of osmotic pressure and stomata movement which further influences the fruit quality and its attributes [Zhao et al. 1995].

Total Soluble Solid (TSS) content is best tool for indication of ripeness and fruit quality besides the total sugars. High sugar and TSS usually leads to high quality production. Increase in TSS depends on higher sugar import and accumulation, as reported by Balibrea et al. [2006] Evidences confirm that the application of plant growth regulators like gibberellins can significantly increase the total soluble contents of the fruit [Huang and Huang 2005]. Potassium plays an important role in enhancing the quality of tomato fruit by increasing reducing sugars and TSS [Caretto et al. 2008].

Potassium content in fruit increased at high level of potassium whereas other mineral (N, P, Ca, Na, Mg) show reduction at high K level. The results are in accordance with Hunsche et al. [2003] who also found that K^+ content in fruit increased in a linear fashion with increasing potassium doses but Ca and Mg concentration remained unchanged. Nava and Dechen [2009] also observed that K application at high level also reduced Ca concentration in apple fruit. Progressive increase in Na and Mg contents in tomato fruits resulted in response to the decrease in potassium levels as suggested by Pujos and Morard [1997]. Potassium foliar spray proved to be effective in enhancing nutritional status so as to improve the fruit quality. Gibberellic acid pertinence significantly promotes the fruit calcium [Belakbir 1998]. Calcium play significant role in controlling the fruit firmness which is an important quality attributes.

CONCLUSION

From the grower's perspective, foliar application of appropriate concentration and combination of K + GA_3 at proper timing assures pronounced effects on plant growth and development, yield and quality, thus benefits marketability. The information gained can be applied for the improvement in other cucumber cultivars and vegetables. All these findings lead us to recommend this combination under field conditions and farmers should apply this combination to enhance productivity in cucumber crop. Considering the promoting effects of G_2K_2 foliar application upon most of the studied traits would be preferable foliar application levels for promoting the agronomic attributes, quality and yield of this value-added multidisciplinary vegetable crop.

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