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(Original Article)

Differential Responses of Chrysanthemum Growth and Flowering to Varying Ratios of K/ (Ca+Mg) Under Fertigation System

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Abstract

Different K/(Ca+Mg) ratios in complete nutrient solutions were supplied at vegetative and flowering stages to optimize their critical levels for high-quality performance of chrysanthemum (*Dendranthema grandiflorum* Ramat. cv. "White Zamble") grown on mixture medium (peat moss: perlite, 2:1 v/v) under fertigation system. The treatments consisted of three ratios of 0.33, 0.55 and 0.71, were performed every 3 days at a constant volume of all nutrient solutions (300 ml/pot) during each growth season (28 weeks). A ratio of 0.71 proved to be optimal for chrysanthemum cultivation since it appeared to have the best results of vegetative characters (plant height, number of shoots and leaves per plant, leaf area, dry weights of roots and shoots, root/shoot ratio and relative growth rate), as well as inflorescence characters (days to flower, yield, fresh weight and stalk length). This ratio also followed the same pattern in relation to leaf pigments content and total carbohydrates, but this behavior was in direct contrast with flavonoids level. Although a ratio of 0.33 showed inferior results in growth and flowering, it was superior in flavonoids synthesis in leaves. The performance of a ratio of 0.55 was intermediate. The cationic ratios had an insignificant effect on phenolic compounds.

Keywords: *Chrysanthemum, Nutrient solution, Cationic ratio, Fertigation, Biochemical constituents.*

Introduction

Chrysanthemum (*Dendranthema grandiflorum* Ramat. cv. "White Zamble") belongs to Asteraceae family and is one of the most important cut-flowers or as a pot-plant for favoring decorative quality. Successful chrysanthemum production is directly related to proper nutrition. Potassium is a primary essential nutrient for chrysanthemum, it is taken up in fairly large amounts by plant and its requirements are high and affect floral characteristics by encouraging strong system, well-developed inflorescences and flower coloration. As the buds to appear, the relative demand of K increased (Gülser and Cig, 2021).

In recent years, chrysanthemum confront with some nutritional problems are visible in damage diagnosis due to exposure to mineral deficiency especially in potassium, calcium or magnesium under fertigation system with nutrient solutions

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for greenhouse crops because of direct antagonistic effects among these cations (Van der Lugt *et al*., 2020). It is believed to be induced by the relatively high levels of K usually maintained in greenhouse soils. This situation is often referred to as potassium induced-Mg or Ca deficiency (Fageria, 2001). However, reduced levels of Ca and Mg in response to luxury levels of K, and increased Mg and Ca levels in response to K deficiency have been observed by many researchers (Pal and Ghosh, 2010; Guo *et al*., 2016 and Xie *et al*., 2020). Moreover, heavy application of Ca may suppress growth by increasing availability and plant uptake of Ca thus widening the ratio between tissue Ca and Mg concentrations (Hicklenton and Cairns, 1992).

Hence, productivity and quality are relatively low under a fertigation system related to K, Ca or Mg insufficiency which is essential and limiting factor in the nutritional quality. So, it is necessary to get maximum utilize an efficiency from applied nutrient solution for optimum growth and flowering of potted chrysanthemum in drip irrigation with a fertigation regime (Nagina *et al*., 2015).

The relationship between healthy vegetative growth, flower yield with high-quality and nutrient uptake of several ornamental crops grown under antagonistic interactions of K, Ca and Mg in nutrient solution has been examined in numerous studies by Rodrigues *et al.* (2008); Nagina *et al.* (2015); Azeezahmed *et al.* (2016) and Gülser and Cig (2021) on chrysanthemum; Torre *et al.* (2001), Ouchbolagh *et al.* (2015) on rose; Van der Lugt *et al.* (2020) on carnation; Birin (2011), and Khalaj and Kanani (2018) on gerbera.

Considerable efforts have been done to define the optimal cationic ratio of K/(Ca+Mg) in the composition of a complete nutrient solution for better growth, especially when a fertigation system is used before visual symptoms of deficiencies (Diem and Godbold, 1993; Cadahía *et al*., 1995; Fontes *et al*., 1996 and Sabreen *et al*., 2003).

The cationic ratios in plant are a linear function of the corresponding ratio in the nutrient solution. Since this correlation is limited by the interactions between ions and their concentrations during the absorption and distribution processes in the plant, however, plant roots regulate nutrient uptake. The best nutrient solution achieved by a fertigation technique is to be adapted to each growth medium and plant species (Langerud and Sandvik, 1991).

From this bibliographic review, there is urgent problem in chrysanthemum nutrition which closely related to the antagonistic relationships among K, Ca and Mg which reflect systematically on growth, flowering and nutritional quality. The mechanism by which this antagonism occurs is still a matter of debate in ornamental crops (Xie *et al*., 2020 and Gülser and Cig, 2021). No standard critical values or adequate concentration ranges for K, Ca and Mg in chrysanthemum nutrition have been established (Van der Lugt *et al*., 2020). Therefore, the objective of this study was to quantify the influence of K/(Ca+Mg) ratio in a nutrient solution as an indicator believed to be adequate for optimum growth, maximum flower yield and nutritional quality.

Materials and Methods

The present investigation was carried out at the Floriculture Nursery, Faculty of Agriculture, Assiut University during two successive seasons of 2021 and 2022 to define an adequate K/(Ca+Mg) ratio in a nutrient solution under fertigation system for optimum growth, flowering, nutritional status and health-quality of chrysanthemum cv. "White Zamble".

Plant material

When the new offsets were uniformity in their size; elongated to 12-15 cm and developed 8-12 leaves and weighed 20-22 g separated carefully from the "parent" plants in mid-February 2021 and 2022 and transplanted directly into 25-plastic pots filled with peat moss and perlite (2:1 v/v), set them till the end of experiment. The experimental pots were placed under partial shade house condition (30% of natural light), ambient temperature of 18-38°C and 40-48% relative humidity during growth period of both seasons. These environmental conditions are to be favorable for chrysanthemum growth and development (Ball, 1995).

To have normal-season (fall) chrysanthemum plants ready took a single-pinch about 5-weeks after transplanting (March 21) which can lead to tall plants and this makes more uniformity. The competition demands that the 10 to 15 stems on a plant must be disbudded to one flower per stem; this produces a more desirable plant habit and a more even flower development (Ball, 1995). The plants were disbudded twice through the early-June and late-July with careful selection of the strength new shoots and the top center buds. It is possible to flower excellent in November that naturally flowering with best quality during each season. All horticultural practices as weeding and organic fungicides treatment were similarly done whenever needed.

Fertigation system design

The fertigation system has three units for the treatments; each unit consists of a 50-liter plastic tank provided with a tap, a head connector (3 cm-diameter) for supplementary solution, four long parallel lateral drip hoses (each 4.5 meters long, 16 mm diameter and drippers at 30-cm distance) and a group of 15 plastic pots (25 cm-diameter with a volume of 4.5 *l*) filled with a mixture medium comprised of peat moss and perlite in the ratio of 2:1 (v/v). Some chemical properties of the medium used are shown in Table 1. Tanks were placed 60-cm above the ground and used for the nutrient solution storage. Each lateral hose which contained 15 pots was blocked at the distant end. A manual fertigation technique is adapted to each tank by opening the tap 12 minutes to discharge the nutrient solution through drippers connected to the lateral hoses, as shown in Figure 1. A headspace of 2.5-cm above the medium was maintained in each pot to apply approximately 300 ml of nutrient solution in each drip-fertigation.

Table 1. Chemical analysis of the saturated extract of medium used in this study

pH*	EC** dSm^{-1}	O.M %	Soluble ions (mg/*l* extract)**				K/Ca+Mg
			P	K	Ca	Mg	
5.92	0.82	24.62	2.3	30	640	32	0.04

* Medium-water suspension (1:5), ** Medium-water extract (1:5)

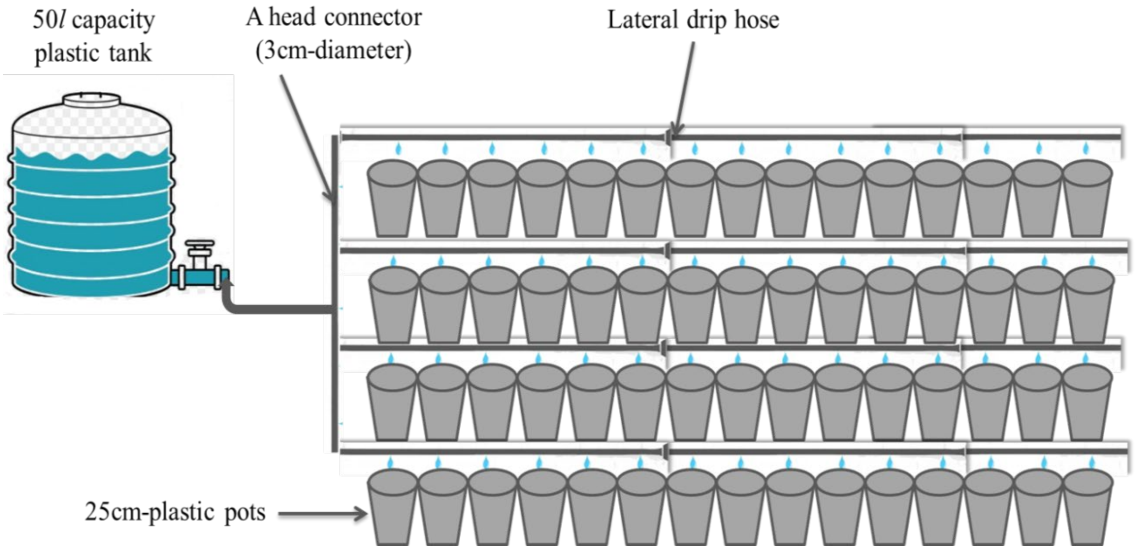

Fig.1. Sketch out of the drip fertigation unit.

Nutrient solutions preparation

Based on the solubility and compatibility of nutrient sources, stock solutions were prepared. Hence, stock solutions were prepared individually, from commercial inorganic salts (Table 2), manufactured by Van Iperen, AlexFert and Abu-Qir Fertilizers and Chemical Industries Company (purity 95-97%). Also, the micronutrients of stock solution were prepared individually consisting chelated microelements of iron-EDDHA (6% Fe), manganese EDTA (13% Mn), zinc EDTA (13% Zn), copper EDTA (12% Cu), boron EDTA (14% B) and ammonium molybdate tetrahydrate [$(NH_4)_6 MoO_{24}. H_2O$]. The stock solutions were calculated for a volume of 1000 L and will result in a 100X concentrated nutrient solution. The designated volumes of stock solutions were added per meq/l for macronutrients and per mg/l for micronutrients.

Table 2. Concentrations of salts (meq/*l*) used to prepare K/(Ca+Mg) ratios in the nutrient solutions

Salts	K/(Ca+Mg) ratios		
	0.33	0.55	0.71
KNO_3	0.1	0.5	0.5
$Ca(NO_3)_2.4H_2O$	1.2	1.2	1.2
$MgSO_4.7H_2O$	0.2	0.6	0.2
$Mg(NO_3)_2.6H_2O$	0.4	0.0	0.0
NH_4NO_3	1.0	1.0	1.0
KH_2PO_4	0.5	0.5	0.5

Fe: 2.5 mg/l; Mn: 0.5 mg/l; Zn: 0.05 mg/l; Cu: 0.02 mg/l; B: 0.5 mg/l; Mo: 0.01 mg/l; pH: 5.5-6.0; E.C: 1.8-2.0 mS/cm.

Nutrient solutions application

The required concentrations of nutrient elements (calculating for 50-liter water) for each treatment (tank) were supplied from already prepared stock solution complemental with tap water to maintain constant volume. Tanks were filled with nutrient solutions when monitored weekly. Plants were supplied with complete nutrient solutions; Hoagland formula was prepared as a basic nutrient solution with variations according to the corresponding treatments of K/(Ca+Mg) ratios of 0.33, 0.55 and 0.71. Each pot was fertigated every 3 days intervals with 300 ml nutrient solution concerning all treatments. Fertigation regime starting April 1st, however, different solutions were applied at one-half strength for 2 weeks and then at full strength continued through growth season (28 weeks). During the summer months, plants were kept well watered as needed, particularly in hot weather to maintain high-quality growth, also followed once monthly for leaching the growing medium from accumulated salts.

Experimental design

The experimental pots of three treatments of K/(Ca+Mg) ratios (60 pot/treatment) were arranged in a randomized complete block design and four replications for each treatment (15 pot/replicate).

Plant growth and flowering observations

The vegetative growth characters expressed as plant height, number of branches and number of leaves per plant were measured monthly from April to October of each season. In last-October, 30-mature leaves from each treatment were randomly collected from the middle parts of plants to measure leaf area using a digital image processing technique as described by Patil and Bodhe (2011). At the end of experiment (mid-December), plants were separated into roots and shoots, and dried at 70°C for 48h in order to determine dry weight of both plant parts. The root/shoot ratio was calculated by dividing root dry weight by shoot one. Relative growth rate (RGR) of plants was calculated according to the equation of the following formula.

$$\mathrm{RGR} = \frac{1}{\mathrm{W1}} \times \frac{\mathrm{W2} - \mathrm{W1}}{\mathrm{t2} - \mathrm{t1}}$$

Where, W_1 and W_2 are the dry weight of biomass at the beginning (t_1) and end (t_2) of the growth period (Leopold and Kriedemann, 1980). The floral characters such as days to flower were estimated from transplanting date until the appearance of 25% full bloom stage of each treatment, total number of inflorescences per plant produced during flowering period, fresh weight of inflorescences, and length of flower stalk.

Determination of bioactive compounds

Photosynthetic pigments content (chlorophylls and carotenoids) were determined according to Lichtenthaler and Wellburn, 1983. Total carbohydrates content in leaves were measured colorimetrically at 630nm wavelength by using anthrone sulphuric method (Hansen and Moller, 1975). Total flavonoids content in leaves were determined colorimetrically at 510nm by the aluminum chloride method (Marinova *et al.*, 2005) and expressed as mg rutin equivalents (mg RE/g D.M). Total phenolic compounds in leaves were determined colorimetrically using Folin reagent at 750nm and expressed as mg gallic acid equivalents (mg GAE/g D.W) as described by Strail *et al.* (2006).

Statistical analysis

Data were statistically analyzed using Statistix 8.1 analytical software, and degree of significance between treatments was tested by least significant difference (L.S.D) at 5% level of significance (Gomez and Gomez, 2010).

Results and Discussion

Vegetative growth characteristics

Significant responses to the ratios of K/(Ca+Mg) in the nutrient solutions were observed for growth parameters expressed as plant height, number of branches and leaves per plant, and leaf area in both seasons (Table 3). Apparently, both K/(Ca+Mg) ratios of 0.55 and 0.71 were higher growth stimulation than a ratio of 0.33. However, the maximum results were occurred by a ratio of 0.71 resulted in significant increases in all traits as compared to a ratio of 0.55. Clearly, it was necessary to fertigate cut-chrysanthemum crops with a high K level in the nutrient solution under fertigation system which is probably the most important and expresses better performance rather than at low K concentration. Since the superior growth was associated with high K/(Ca+Mg) ratio of 0.71 that provided the plants with available cations at adequate levels and reduced the negative interactions among them (Fageria, 2001). A positive growth response to high K level has been found in similar studies (Cadahía *et al.*, 1995 and Fontes *et al.*, 1996) showing the importance of critical K/(Ca+Mg) ratio in plant nutrition.

Table 3. Vegetative growth characteristics of fertigated chrysanthemum plant as affected by K/(Ca+Mg) ratios in nutrient solutions during 2021 and 2022 seasons

K/(Ca+Mg) ratios	Plant height (cm)		Branch No./plant		Leaf No./plant		Leaf area (cm^2)	
	2021	2022	2021	2022	2021	2022	2021	2022
0.33	74.4	83.9	2.50	3.25	211	242	7.04	8.04
0.55	83.2	91.5	2.63	4.03	276	282	8.44	9.83
0.71	92.2	98.0	2.98	4.37	297	296	10.29	11.72
L.S.D $_{0.05}$	6.6	3.0	0.19	0.34	42	15	0.90	0.91

Shoot growth and development

Apparently, during seasonal growth of chrysanthemum plants starting from April up to October exhibit a quite marked periodicity in growth rate of plant height, number of branches and leaves per plant depending on the ratio of K/(Ca+Mg) in nutrient solution (Fig 2. a, b, c). It is clear that elevated ratio of 0.71 in the nutrient solution was the most effective in increasing the vegetative measurements.

In general, the shortest plants with a few branches and leaves were produced by a ratio of 0.33, however a ratio of 0.55 showed intermediate results. On other side, the growth rate was more accelerated through the period extending from April to August (vegetative stage) than that of September to October (flowering stage).

It is interesting to note that the favorable dry growth obtained by the best ratio of 0.71 also followed a similar pattern to that of fresh one resulting in significant increases in dry weight of roots and shoots per plant, root/shoot ratio, and relative growth rate (Table 4 and Figs.2d and 3). The reduction was apparently associated with a ratio of 0.33.

The best ratio improved the vegetative growth processes reflected in more dry matter accumulation in plant tissues. So, this treatment is important for plant and its morphology, as well as for optimum physiological functioning and dry matter partitioning between shoots and roots. Similar observations were reported by Hartmann *et al.* (2002) who found that large root size enhances shoot growth rate, and root reduction has been associated with shoot stunting.

Table 4. Root and shoot characteristics of fertigated chrysanthemum plant as affected by K/(Ca+Mg) ratios in nutrient solutions during 2021 and 2022 seasons

K/(Ca+Mg) ratios	Root dry wt. (g/plant)		Shoot dry wt. (g/plant)		Root/shoot ratio		RGR (mg/day)	
	2021	2022	2021	2022	2021	2022	2021	2022
0.33	1.27	3.21	12.62	15.13	0.106	0.214	5.96	8.87
0.55	1.68	4.73	14.76	18.75	0.142	0.250	7.78	12.67
0.71	3.23	5.69	18.99	22.87	0.169	0.248	11.74	16.41
L.S.D $_{0.05}$	0.54	0.96	2.41	2.74	0.052	N.S.	1.96	2.10

Growth relationship between shoot and root system is very important to produce vigorous growth and better-quality. This observation could be attributed to the large size of root system which enhance the absorption of high rates of nutrients and water that metabolized and translocated toward the growing tip for the photosynthetic apparatus (Mertens and Wright, 1978). Furthermore, Marschner *et al.* (1996) explained that the rhythmic growth of plant was occurred by root absorption of nitrogen which reacts with carbohydrates to promote its development. Subsequently more nutrients absorption by roots, and then transported to the shoot since it combines with carbohydrates to form protein led to stimulate shoot growth. Taiz and Zeiger (2010) revealed that products of photosynthesis are largely used in other parts of the plant, a considerable amount of carbohydrates translocated to roots that control mechanisms to regulate the use of energy absorbed by the plant reflecting on more vegetative growth led to increase the photosynthetic capacity caused large export to roots.

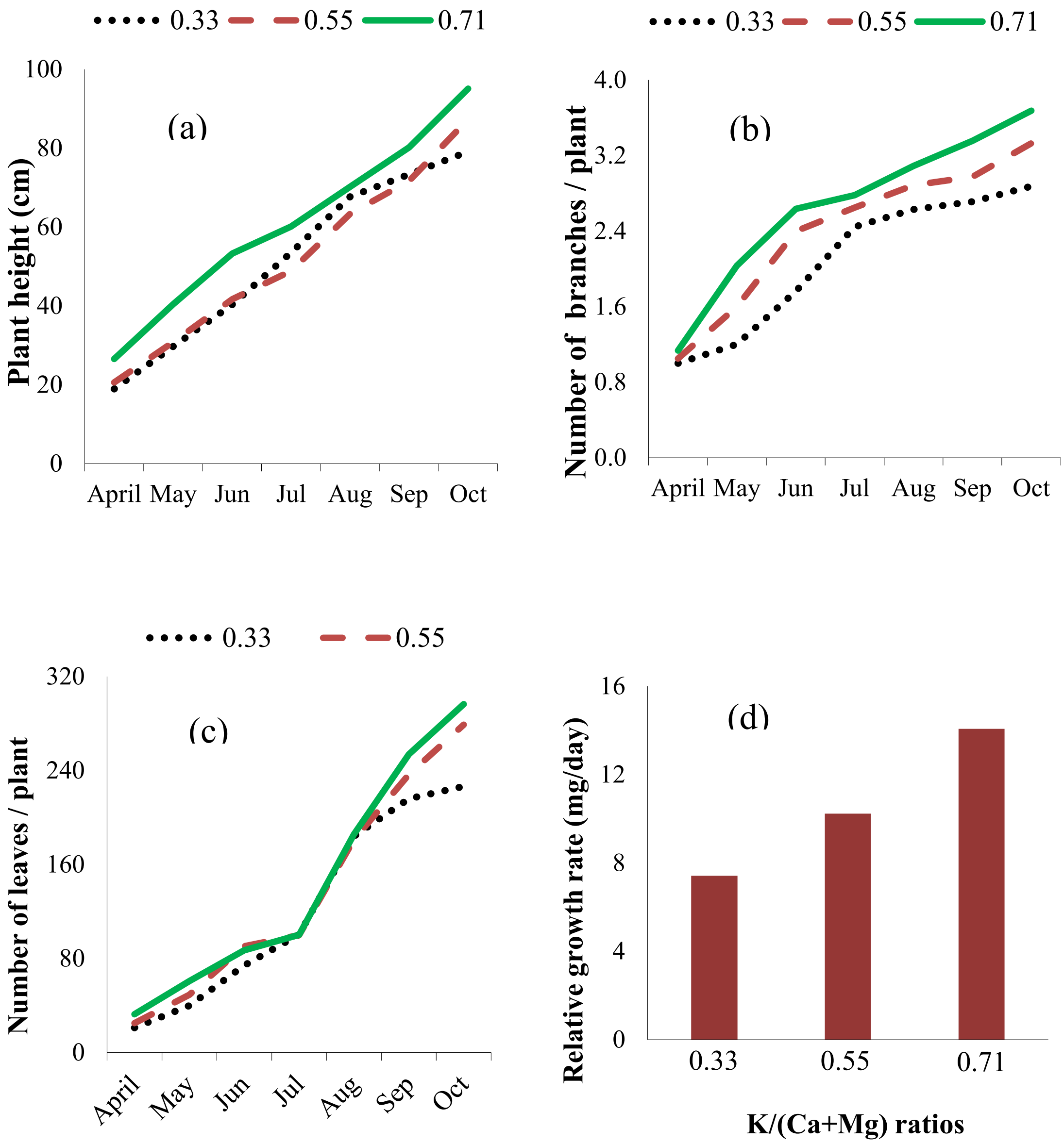

Fig 2. Shoot growth and development of chrysanthemum plant through seasonal growth and relative growth rate at the end of experiment (average of both seasons) as affected by K/Ca+Mg ratios in nutrient solutions.

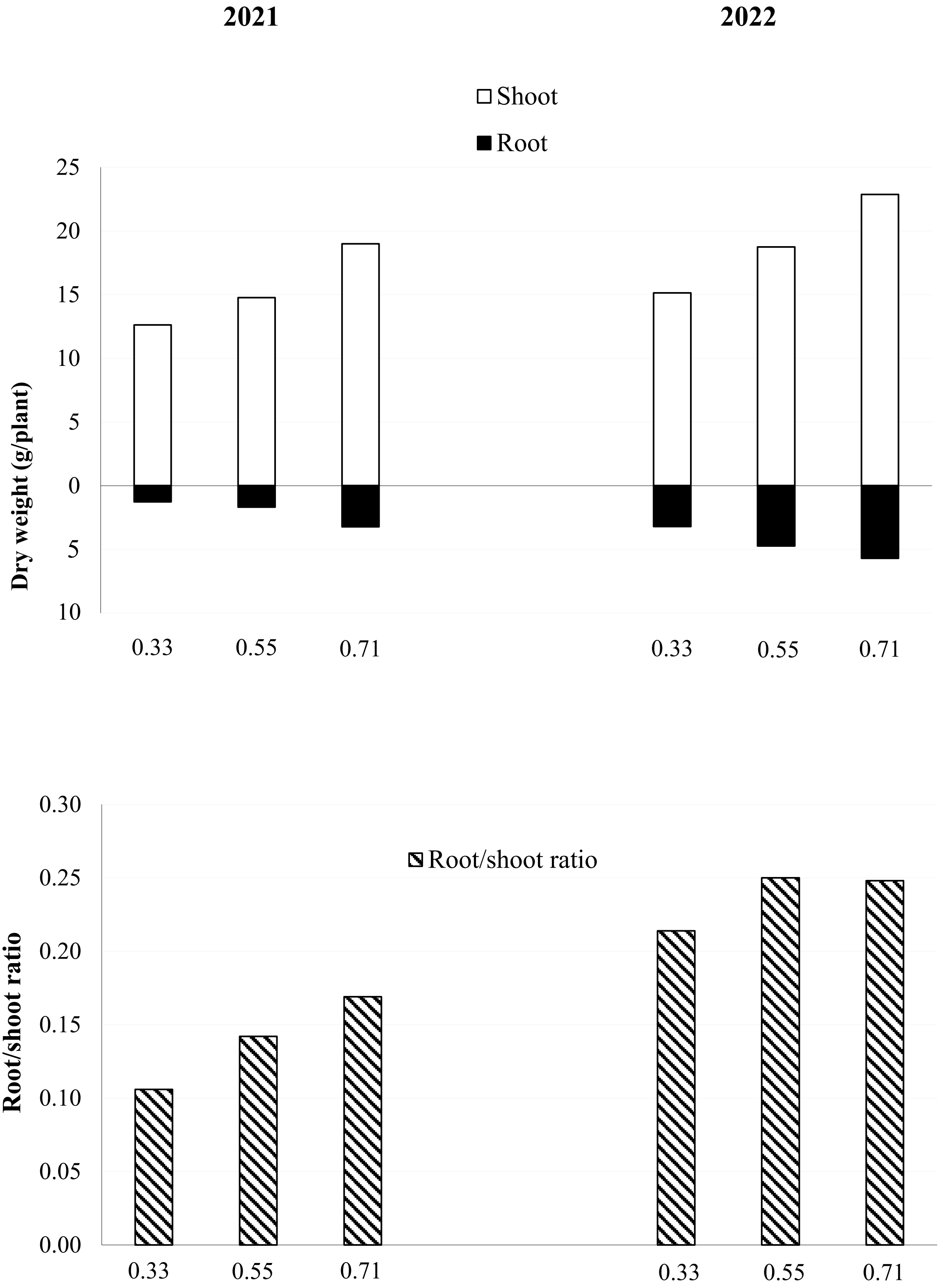

Fig. 3. Growth relationship between root-shoot partitioning of chrysanthemum plant as affected by K/Ca+Mg ratios in nutrient solutions during 2021 and 2022 seasons.

Floral characteristics

As evident from data presented in Table 5, the floral characters were considerably responded to K/Ca+Mg ratios resulting in significant influences among them. The greater earliness would refer to an earlier morphological differentiation of flowers and hence to the formation of the first flower at a lower mode (Leopold and Kriedemann, 1980). It is quite clear that number of days to flower was significantly affected by the ratios in the nutrient solution. Higher response to earliness was obviously to taking placate with a ratio of 0.71. It was more favorable in accelerating and advancing the flowering whereas it significantly induced earlier flowering by about 6 and 11 days than 0.55 and 0.33, respectively. Some earlier studies declared the favorable effects of different K/(Ca+Mg) ratios in nutrient solutions for fertigating some cut-flower crops such as chrysanthemum (Rodrigues *et al.*, 2008), rose **(**Ouchbolagh *et al.*, 2015) and gerbera (Birin, 2011).

Although the worst ratio (0.33) produced significantly higher inflorescence yield than the superior one (0.71), the later gave significant heavier fresh inflorescences with longer stalks than those of 0.33 and 0.55, both laters mostly cleared insignificant differences between them in these inflorescence traits. These results are in partial agreement with those obtained by Azeezahmed *et al.* (2016) on chrysanthemum, Starkey and Pedersen (1997) on rose, and Khalaj and Kanani (2018) on gerbera.

Table 5. Inflorescence characteristics of fertigated chrysanthemum plant as affected by K/(Ca+Mg) ratios in nutrient solutions during 2021 and 2022 seasons

K/(Ca+Mg) ratios	Days to flower		Inflorescence No./plant		Inflorescence fresh wt.(g/plant)		Inflorescence stalk length(cm)	
	2021	2022	2021	2022	2021	2022	2021	2022
0.33	233	235	15.55	13.32	34.64	33.68	41.43	41.39
0.55	228	229	11.48	9.89	32.55	37.47	44.68	45.72
0.71	222	224	12.66	11.88	64.73	62.67	52.42	52.38
L.S.D $_{0.05}$	2	3	1.31	1.29	7.21	4.39	6.98	3.11

The most striking relationship is observed between the vigorous growth occurred by a ratio of 0.71 which cleared a positive coordination with inflorescence yield and high-quality. This stimulative effect could be explained on the basis of encouraging growth and increasing the plant capacity for building metabolites which have been given particular attention on the physiological dynamics and biochemical processes within the plant controlling carbohydrate synthesis which is necessary for flower initiation and blooming, similarly an increase in the product of photosynthesis will positively associate with an increase in flower formation. This explanation was supported by Raghavan (2000) and Öpik *et al.* (2005).

Although a clear antagonism among K, Ca and Mg was found, a ratio of 0.71 attempts to maintain an adequate element concentration by balancing K against Ca+Mg. Since at high K, an osmotic balance between the cytoplasm and vacuole would seem to occur that may be maintained by synthesis of organic molecules, in particular polyamines increased strongly in response to high potassium level

(Diem and God bold, 1993). So, the beneficial effect of a ratio of 0.71 was related to adequate levels of K, Ca and Mg in the nutrient solution, it appeared to give a consistent measure of chrysanthemum growth and flowering responses (Xie *et al*., 2020).

If the increased concentrations of cations except K, the plants are able to maintain the cation-anion balance, but not the growth rate (Hicklenton and Cairns, 1992). Therefore, define the critical K/(Ca+Mg) ratio in nutrient solution is associated with better growth due to its vital roles in supply the plants with sufficient concentrations of these cations for optimum growth (Nagina *et al*., 2015 and Gülser and Cig, 2021).

There is indirect evidence that protein synthesis require K reflects that the developmental biology of flowering plants (Raghavan, 2000) and carbohydrate metabolism (Sugiyama and Goto, 1966). Calcium functions can be divided into four main areas: (1) plays a decisive role in the maintenance of cell membrane integrity; (2) effects on enzymes; (3) effects on cell walls; and (4) interactions of calcium with phytohormones (Barker and Pilbeam, 2015). Magnesium is also essential nutrient for plant, it has major physiological and molecular roles in plants, such as being a component of the chlorophyll molecule, a cofactor of many enzymatic processes associated with phosphorylation, dephosphorylation, and the hydrolysis of various compounds, and as a structural stabilizer for various nucleotides.

Bioactive phytochemical constituents

Various responses of chrysanthemum plants to K/(Ca+Mg) ratios were observed in relation to bioactive phytochemical constituents such as leaf pigments, carbohydrates, flavonoids and phenolics (Table 6). Obviously, total chlorophyll content (a+b), carotenoids, and carbohydrates were significantly higher in a ratio of 0.71 than in other ratios. In contrast, a ratio of 0.33 showed inferior results, but a ratio of 0.55 revealed intermediate performance resulting in a significant increase compared to a ratio of 0.33 in most cases. Clearly, the most favorable influences were pronouncedly occurred by the higher concentration of K than Ca+Mg in a ratio 0.71. Similar results were reported by Cadahía *et al.* (1995) on conifer, and Liu *et al.* (2007) on chrysanthemum; they concluded that sufficient K-supply during plant life cycle had beneficial effect on photosynthesis and chlorophyll content. In contrary, a ratio of 0.33 significantly increased total flavonoids content in leaves compared to both ratios of 0.55 and 0.71, however, the laters showed insignificant differences between them. Total phenolic compounds were not affected by any ratio.

As already outlined in the experimental results, such favorable influences of a ratio of 0.71 could be reflected systematically in growth and floral characteristics of chrysanthemum. This is due to supply the plants with K, Ca and Mg nutrients at adequate levels required for promoting plant metabolism. The vital roles of these cations in improving plant growth and flowering are almost endless, any important parameter in chrysanthemum seems to be affected beneficially (Liu *et al*., 2007 and 2011; Gülser and Cig, 2021). The elevated synthesis of chlorophyll is closely associated with the adequate Mg-supply and its concentration in leaves (Vanek *et al*., 2012). Magnesium plays two very essential roles in the plant is found in the important processes of photosynthesis and carbohydrate metabolism (Gibson, 2005). Magnesium is a constituent of the chlorophyll molecule, without which photosynthesis would not occur. Chlorophyll level in leaves was significantly reduced in many plants under Mg-deficiency which developed the typical chlorosis symptoms. The role of Mg at adequate concentration is closely correlated with chlorophyll synthesis (Taiz and Zeiger, 2010).

Table 6. Bioactive phytochemicals content in Leaves of fertigated chrysanthemum plant as affected by K/(Ca+Mg) ratios in nutrient solutions during 2021 and 2022 seasons

K/(Ca+Mg) ratios	Pigments (mg/gF.W)				Carbohydrates (%)		Antioxidants			
	Chlorophylls (a+b)		Carotenoids				Flavonoids (mgRE/gD.W)		Phenolics (mgGAE/gD.W)	
	2021	2022	2021	2022	2021	2022	2021	2022	2021	2022
0.33	0.535	1.028	0.087	0.258	11.65	10.39	0.680	0.606	2.58	2.76
0.55	0.980	1.147	0.242	0.286	13.80	13.21	0.179	0.225	2.46	2.56
0.71	1.533	0.238	0.358	0.532	14.53	15.80	0.211	0.209	3.29	3.03
L.S.D $_{0.05}$	0.354	0.163	0.103	0.045	1.34	1.95	0.143	0.161	N.S.	N.S.

Of great interest to note the best coordination between leaf pigments content and carbohydrates accumulation. As evident above, the functional roles of K and Mg and their specific effects on chlorophyll formation. Chlorophyll is a limited factor for photosynthesis which takes place in leaves, an increase in chlorophyll content was associated with an increase in carbohydrate synthesis. Taiz and Zeiger (2010) demonstrated that carbohydrates are one principal product of photosynthesis. The need for chlorophyll is therefore a photosynthetic requirement, hence chlorophyll controls carbohydrates, similarly, an increase in the product of photosynthesis will positively correlate with an increase in chlorophyll synthesis. Potassium is required for carbohydrate translocation; this process requires energy in the form of ATP which requires K for its synthesis. The translocation of sugars from leaves is greatly reduced in K-deficient plants (Sugiyama and Goto, 1966).

A direct relationship between the favorable flowering with batter-quality and high inflorescence yield and the highest leaf carbohydrate content in chrysanthemum was found under the balanced ratio of 0.71. Similar observations were supported by Öpik *et al.* (2005) who stated that more carbohydrate accumulation in leaves could be reflected beneficially on promoting plant growth and favorite the flowering.

Actually, K is one of the most important factors that influences chrysanthemum metabolism in leaves. Its roles in physiology can be distributed between the primary and secondary metabolites, in which K is mainly present (Liu *et al*., 2007 and 2011; Gülser and Cig, 2021). Consequently, plant flavonoids constitute one of the largest groups of naturally occurring phenolics, possessing ideal chemical structure as antioxidants (Liu *et al*., 2010). Apparently, total flavonoids content in leaves of chrysanthemum significantly decreased with increasing K/(Ca+Mg) ratio. Such an increase in flavonoids accumulation induced by a ratio of 0.33 is equivalent approximately 3-fold in leaf cells higher than in the ratios of 0.55 and 0.71 (Table 4). These findings indicated that the biosynthesis of flavonoids was increased with a decrease in K concentration in the nutrient solution since this function is likely to be K-deficiency. A flavonoid-rich diet has been associated with a lower carbohydrate accumulation. These relations of this compartment were closely correlated with the worst growth and flowering obtained by a ratio of 0.33. These results are in harmony with those reported on chrysanthemum by Liu *et al.* 2010 and 2011. They demonstrate that K-deficiency can reduce the physiological resistance and decrease the physiological K-deficiency leaf blight which can reduce the production of inflorescences. This explanation confirms that chrysanthemum plant needs large amounts of K during its growth which may exert beneficial health since K-deficiency inhibits the synthesis of flavonoids in leaves.

In conclusion, the nutritional quality corresponded to adequate K/(Ca+Mg) ratio of 0.71 for chrysanthemum nutrition plays an essential roles in metabolism and that takes place more important with growth, development and flowering.

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الاستجابات المختلفة لنمو وإزهار الأراولا للنسب المتغيرة من البوتاسيوم:(كالسيوم+مغنيسيوم) تحت نظام الري التسميدي

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الملخص

أجريت الدراسة بهدف تحديد التركيزات المثلى لنمو وإزهار الأراولا صنف "White Zamble" من عناصر البوتاسيوم، الكالسيوم والمغنسيوم للتأثيرات المتضادة في امتصاصهم، وذلك بدراسة 3 نسب مختلفة بوتاسيوم:(الكالسيوم+المغنسيوم) وهي: 0.33، 0.55، 0.71 في محاليل غذائية.

تم فصل خلفات متجانسة النمو من أمهات نباتات الأراولا وزرعت (منتصف فبراير) في أصص بلاستيك ذات قطر 25 مملوءة ببيئة مكونة من بيت موس+بيرليت (1:2على أساس الحجم) وحفظت في صوبة سيران وظلت بها خلال موسمي النمو، وخلال هذه الفترة تم قرط النباتات. وفي بداية ابريل أضيفت المحاليل المغذية بنظام الري التسميدي بمعدل 300 مل/أصيص كل 3 أيام حتى نهاية اكتوبر.

أوضحت النتائج ما يلي:

- اختلفت استجابة الأراولا حسب نسبة الكاتيونات المستعملة في المحلول المغذى وقد أظهرت النسبة 0.71 تأثيراً منشطاً بزيادة جوهرية في مواصفات النمو الخضرية مقارنة بالنسبتين0.33، 0.55

- أعطت النسبة 0.33 أدنى قياسات النمو الخضرية، بينما كانت النسبة 0.55 وسطية في تأثيراتها وأظهرت النسبة 0.71 تفوقاً ملموساً في النمو بالمقارنة بسابقتها في معظم الحالات.

- ارتبطت المواصفات الزهرية بالمواصفات الخضرية بشدة حيث أظهرت النسبة 0.71 تفوقاً ملحوظاً تلتها في ذلك النسبة 0.55 بينما سلكت النسبة 0.33 نفس الأداء المنخفض.

- هناك تغييرات معنوية في النظام الأيضي للنبات، واتضح ذلك في زيادة تخليق صبغات البناء الضوئي، والكربوهيدرات الكلية في أوراق النباتات المعاملة بنسبة 0.71 مقارنة بمثيلتها النامية تحت تأثير النسبتين الأخرتين.

- هناك علاقة مباشرة بين النقص الملحوظ في قياسات النمو الخضرية والزهرية الناتج عن النسبة 0.33 وزيادة محتوى أوراقها من الفلافونيدات الكلية مقارنة بالنسبتين 0.55، 0.71 بينما لم يكن هناك فروقاً جوهرية في مستوى الفينولات الكلية بالأوراق.