J. Plant Production, Mansoura Univ., Vol. 7(12):1281 -1286, 2016

Effect of Potassium Sulfate and Calcium Borate on Improving Quality and Production of Dahlia Flowers

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ABSTRACT

The experiment was carried out at the Baramoon Experimental Research Farm, Dakahlia Governorate, Egypt, during 2015 and 2016 seasons. The aim of this research was to study the effect of potassium sulfate and calcium borate as soil and foliar fertilization on improving the quality and flower production of *Dahlia pinnata,* L. plants. Different levels of potassium sulfate at 10 and 20 g/plant as soil fertilizer and calcium borate at 5 and 10 cm/L as foliar fertilizer and companions between them were used. The soil and foliar fertilizers were applied 3 times during the growing period. The results indicated that the combined treatment of 20 g/plant potassium sulfate + 10 cm/L calcium borate significantly increased vegetative growth parameters i.e plant height, number of leaves, number of shoots, stem diameter and dry weight % of plants. It also induced an increment in flowers and tubers parameters (No. of flowers, flower diameter, flower stem length and diameter and flower adherence strength, vase life, No. of tubers/plant and tuber diameter compared with the other treatments used. Total carbohydrates and lignin (%) in flower stem were significantly increased as a result of different fertilization treatments compared to the control treatment. Application of potassium sulfate at 20 g/plant + calcium borate at 10 cm/L was superior to other treatments under this study.
Keywords: *Dahlia pinnata*, L., Potassium sulfate, Calcium borate, Vegetative growth, Flower, Fertilization.

INTRODUCTION

Dahlia (*Dahlia pinnata*, L.) belongs to the Family Asteraceae, dicotyledonous plants. It is herbaceous perennial plant with the tuberous root system. Dahlias are native to the mountainous region of Mexico. This plant is a highly valued decorative flowering plant and provides a variety of colors' to landscape areas and flower gardens. Dahlia has different type of flowers, including; orchid, anemone and ball like forms. Dahlia provides a number of flower colors and it also has single flower with two colors. It is valued for different uses like a beautiful cut flower and garden display (Ahmad *et al*., 2004).

There are several factors affecting the production of flowers and ornamental plants. The most important factor is fertilization, especially potassium (K) which is considered as an essential element involved in photosynthesis, respiration, some enzyme activation in plants and increases their ability to resist pests and diseases. In addition, it has a vital role in controlling the osmotic potential of the plant cells as well as loading and translocation of sugar through the plant organs (Bhandal and Malik, 1988).

Boron (B) is an essential micro-nutrient for crops. Boron is the second most widespread and economically important micro-nutrient deficiency in crops. Micro-nutrients such as Boron have great influence on plant growth and development. The essential physiological activities of boron is linked to strength of cell wall and development, RNA metabolism, sugar transport, hormones development, respiration, cell division, indole acetic acid (IAA) metabolism and as part of the cell membrane (Marchner, 1995). Boron also plays an important role in flowering and fruit formation (Nonnecke, 1989).

Calcium is a crucial regulator of growth and development in plants. The myriad processes in which this ion participates is large and growing and involves nearly all aspects of plant development. Calcium is an essential plant nutrient. It has many roles such as : Participates in the metabolic processes of other nutrient uptake, promotes proper plant cell elongation, strengthen cell wall structure as an essential part of plant cell wall, it forms calcium pectate compounds which give stability to cell walls and bind cells together and participates in enzymatic and hormonal processes [Hetherington and Brownlee (2004); Reddy and Reddy (2004) and Bothwell and Ng (2005)].

In order for plants to effectively utilize calcium, boron must also be present. Essentially, this means that if there is a nutritional situation in which the crop does not have sufficient levels of boron in the tissue, calcium applications will not be nearly as effective as they could be if there was sufficient boron present. Boron plays a key role in root function and low boron levels reduce the plant's ability to uptake water and nutrients from the soil, which often induces a calcium deficiency. It is wise to know the nutritional status of the crops when making applications of fertilizers. In many farming practices, boron and calcium are applied at the same time which it is something very simple and should be seriously considered (Jeremy, 2007).

This investigation aimed to study the effect of potassium sulfate and calcium borate as soil and foliar fertilization, respectively, on improving the quality and flower production of *Dahlia pinnata*, L.

MATERIALS AND METHODS

The present study was carried out during the two successive seasons of 2014-2015 and 2015-2016 at the Baramoon Experimental Research Farm, Dakahlia Governorate, Egypt. This investigation aimed to study the effect of potassium sulfate and calcium borate as soil and foliar fertilization on the quality and flower production of *Dahlia pinnata*, L. plants.

Dahlia pinnata, L tubers of a uniform size were secured from EL-Kanater El-Khaireia and planted in a clay soil. Before planting, the following substrates has been added : 70 kg ammonium sulfate $(NH_4)2SO_4$ + 70 kg calcium sulfate $(CaSO_4)$ + 250 kg super phosphate calcium $(Ca(H_2PO_4),2CaSO_4)$ + 120 kg sulfur (SO_4) + 25 m^3 sand + 12 m^3 farmyard manure per Fadden.

The tubers were planted on 20^{th} October at 50 cm between plants and 80 cm between lines. The layout of the experiment was randomized complete block design: 9 treatments x 3 replicate x 2 lines/replicate x 6 plants/ line = 324 plants were grown in 612 m3 experiment space.

At the beginning of the study, soil samples were taken from (0-30 cm^3 depth) before adding any soil fertilization. Samples were thoroughly mixed and analyzed for the physical and chemical characteristics of the soil according to Jackson (1973). The obtained results are presented in Table (1).

Table 1. Physical and chemical characteristics of the experimental soil :

Soil properties Physical	Value	Soil properties Soluble anions (meq/L)	Value
Coarse sand	7.71	CL^-	3.56
Fine sand	18.14	HCO_3^-	3.20
Silt	33.65	$CO_3^=$	0.00
Clay	40.50	$SO_4^=$	5.16
Texture	Clay-loam	Soluble cations (meq/L)	
Chemical		Ca^{++}	4.03
Organic matter (%)	1.95	Mg^{++}	1.35
$CaCO_3$	4.55	Na^+	1.21
E.C. (dsm^{-1} at 25°)	1.12	K^+	5.33
PH (1:2.5 w/v)	8.11	Available micronutrients (ppm)	
Total – N (%)	0.20	Fe	3.62
Available – P(ppm)	11.72	Mn	1.51
		Zn	1.35
		Cu	0.52

Potassium sulfate (K_2O 48.5 %) was added three times to the soil at 10 and 20 g/plant. The first addition was done after germination on December 1st, the second on February 1st and the 3rd addition was on April 1st. Calcium borate {Ca_3 $(BO_3)2$: 10.4 % Ca O + 0.5 % B} was applied as foliar application three times at two rates of 5 and 10 cm/L. It was added on January 1st, February 1st and march 1st, respectively.

The treatments were as follows:

- Control (without any treatment).
- Potassium sulfate at 10 g/plant.
- Potassium sulfate at 20 g/plant
- Calcium borate 5 at cm/L.
- Calcium borate 10 at cm/L.
- Potassium sulfate at 10 g/plant + Calcium borate at 5 cm/L.
- Potassium sulfate at 10 g/plant + Calcium borate at 10 cm/L.
- Potassium sulfate at 20 g/plant + Calcium borate at 5 cm/L.
- Potassium sulfate at 20 g/plant + Calcium borate at 10 cm/L

At the end of experiment on 1st June and 6th June in both seasons, respectively.

The following data were recorded:

I-Vegetative growth parameters: plant height (cm), No. of leaves/plant, No. of shoots/ plant, stem diameter (cm) and plant dry weight % (it was measured by multiplying plant dry weight/plant fresh weight x 100) .

II. Flowering parameters: No. of flowers (The average number of flowers was counted during three months from the 1st of January till the end of March). Flower diameter (cm), Flower stem diameter (cm), flower stem length (cm), flower adherence strength g/cm3 (It was measured by using Tenso lab), dry weight % of flowers and vase life (day)

III. Tubers parameters: tuber number, tuber diameter (cm) and dry weight %.

IV. Chemical analysis was determined in dry samples: Total carbohydrates (mg/g d.w.) in flower stem according to Hedge and Hofreiter (1962). Lignin % in flower stem was determined according to A.O.A.C. (1984).

Statistical analysis:

The data were subjected to analysis of variance of the sample experiment in a randomized complete block design according to Snedecor and Cochran (1990) and differences between means were compared using L.S.D. at 5 % level of probability.

RESULTS AND DISCUSSION

I- Effect of potassium sulfate and calcium borate on vegetative growth parameters of *Dahlia pinnata*, L. plants

It is clear from Table (2) that all potassium sulfate and calcium borate treatments significantly increased vegetative growth parameters than the control treatment in the two seasons. Potassium sulfate at 20 gm / plant combined with calcium borate at 10 cm /L gave the highest significant values of plant height (81.07 and 86.03 cm), number of leaves / plant (52.0 and 56.7), number of branches per plant (13.7 and 15.3), stem diameter (2.6 and 2.7 cm) in both seasons, respectively than the other treatments. In this respect, Mohammed (2013) reported that, potassium treatments had positive effect on plant height of *Dahlia pinnata*, L. Also, Jadav *et al.* (2010) on sesame (*Sesamum indicum*, L.) reported that, number of branches /plant was increased significantly with increasing levels of potassium. Regarding to the effect of boron, Yousif *et al.* (2012) reported that, number of branches was significantly affected by boron application and the highest value of the number of branches was when using boron at the highest concentration 600 mg. l^{-1}. Also, Abdur and Ihsan-ul (2012) demonstrated that using borax, either alone or in combination with $CaCl_2$, resulted in a significant increase in the number of branches of tomato plants. Badran *et al.* (1985) on *Polianthus tuberosa*, L. mentioned that the role of potassium in an increasing number of leaves / plant was explained as potassium is involved in some physiological processes such as cell division, stomata opening and synthesis of carbohydrates.

It is obvious from Fig. (1) that no clear trend in vegetative growth dry weight % was observed in most cases. However, potassium sulfate at 20 g/plant + Calcium borate at 5 cm/L treatment had lower value.

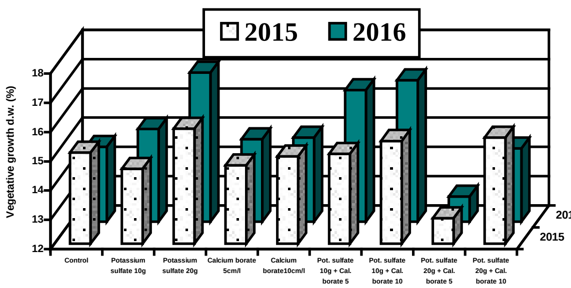

Fig. 1. Effect of potassium sulfate and calcium borate on vegetative growth dry weight % of *Dahlia pinnata*, L. during 2015 and 2016 seasons.

II- Effect of potassium sulfate and calcium borate on flower parameters of *Dahlia pinnata*, L. plants

It is clear from data in Table (3) that number of flowers and flower diameter were significantly increased by most applications compared with the control treatment. The combined application of potassium sulfate at 20 g/plant + calcium borate at 10 cm/L resulted in significant increase of number of flowers / plant (47.3 and 52.0) and flower diameter (12.5 and 13.5 cm), respectively in both seasons, followed by potassium sulfate at 20 g /plant + calcium borate at 5 cm per plant. However, the control treatment had lowest values of number of flowers and flower diameter during the two seasons. This is in agreement with Yousif *et al*. (2012) on *Dahlia variabills*, Mohammed (2013) on *Dahlia pinnata*, Sajid *et al*. (2010) on lily plant and Suganiya and Kumuthini (2015) on *Solanum melongina* plants.

It is obvious from Fig. (2) that potassium sulfate at 10 g/plant + calcium borate at 15 cm/L, gave the highest values of flower dry weight % of *Dahlia pinnata*, L. compared to the other treatments.

Table 2. The effect of potassium sulfate and calcium borate on vegetative growth parameters of *Dahlia pinnata*, L. plants in 2015and 2016 seasons

Treatments	Plant height (cm)		No. of leaves /plant		No. of shoots /plant		Stem diameter(cm)	
	1st season	2nd season	1st season	1st season	2nd season	2nd season	1st season	2nd season
Control	40.37	42.70	22.0	5.5	5.6	23.3	3.3	3.3
Potassium sulfate at 10g/plant	49.47	52.53	30.0	8.5	8.8	35.3	6.7	7.3
Potassium sulfate at 20g/plant	61.57	66.06	34.7	8.4	9.8	37.3	6.7	8.7
Calcium borate at 5 cm/L	48.50	50.63	23.3	6.5	6.8	28.7	5.0	3. 7
Calcium borate at 10 cm/L	48.40	49.70	26.0	7.3	7.8	33.3	4.3	4.7
Potassium sulfate at10g/plant + Calcium borate at 5 cm/L	63.47	65.83	32.0	10.6	11.4	38.7	8.3	10.3
Potassium sulfate at 10g/plant + Calcium borate at 10 cm/L	65.26	68.43	36.7	9.6	10.6	37.3	8.7	8.3
Potassium sulfate at 20 g/plant + Calcium borate at 5 cm/L	73.93	78.37	41.3	11.6	12.3	43.3	11.0	12.7
Potassium sulfate at 20 g/plant + Calcium borate at 10cm/L	81.07	86.03	52.0	12.5	13.5	56.7	13.7	15.3
L.S.D. at 5 %	1.22	0.67	3.55	0.16	0.12	2.37	0.63	0.62

Table 3. Effect of potassium sulfate and calcium borate on No. of flowers /plant and flower diameter of *Dahlia pinnata*, L. in 2015 and 2016 seasons.

Treatments	No. of flowers/plant		Flower diameter (cm)	
	1st season	2nd season	1st season	2nd season
Control	12.0	14.0	0.87	0.98
Potassium sulfate at 10g/plant	12.3	15.0	1.46	1.48
Potassium sulfate at 20g/plant	24.0	25.7	1.94	1.97
Calcium borate at 5 cm/L	16.0	17.0	0.98	1.03
Calcium borate at 10 cm/L	17.7	18.7	1.18	1.44
Potassium sulfate at 10g/plant + Calcium borate at 5 cm/L	20.0	22.7	1.66	1.69
Potassium sulfate at 10g/plant + Calcium borate at 10 cm/L	18.7	22.0	1.76	1.79
Potassium sulfate at 20 g/plant+ Calcium borate at 5 cm/L	35.0	34.3	2.28	2.34
Potassium sulfate at 20g /plant + Calcium borate at 10 cm/L	47.3	52.0	2.60	2.70
L.S.D. at 5 %	0.90	2.13	0.044	0.023

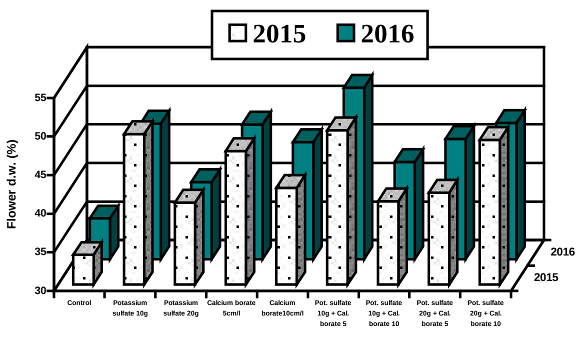

Fig. 2. Effect of potassium sulfate and calcium borate on flowers dry weight % of *Dahlia pinnata*, L. during 2015 and 2016 seasons.

The results in Table (4) indicated that all treatments under this study were significantly increased flower stem length, flower stem diameter and flower adherence strength than the control treatment. The combined treatment of potassium sulfate at 20 g/ plant + calcium borate at 10 cm/L gave the highest values of flower stem length (35.2 and 37.7 cm), flower stem diameter (1.27 and 1.50 cm) and flower adherence strength (1904.0 and 1952.0 g/cm3) in comparison with the other treatments in the two seasons, respectively. Whereas, the untreated plants gave the lowest values of flower parameters mentioned above. These results agree with Aly and Gomaa (2008) on *Dianthus caryophyllus*, they found that plants treated with foliar nutrition showed significant increase in stem length and diameter. Also, Hassan (2015) illustrated that all fertilization treatments significantly increased berry adherence strength of the Superior seedless grape compared with control treatment. The superiority was in the combination treatment of folic acid + microelements + bio-fertilizers, the concerned values for berry adherence strength were 1180.5 and 1260.4 g/cm^2 in both seasons, respectively.

It is obvious from Fig. (3) that potassium sulfate at 20 g/plant + calcium borate at 10 cm/L, potassium sulfate at 20 g/plant + calcium borate at 5 cm/L and potassium sulfate at 20 g/plant increased the vase life of *Dahlia pinnata*, L. as compared to the other treatments, respectively.

Table 4. Effect of potassium sulfate and calcium borate on flower stem length (cm) , flower stem diameter (cm) and flower adherence strength (g/cm^3) *Dahlia pinnata*, L. plants in 2015 and 2016 seasons.

Treatments	Flower stem length (cm)		Flower stem diameter (cm)		Flower adherence strength (g/cm^3)	
	1st season	2nd season	1st season	2nd season	1st season	2nd season
Control	10.3	11.5	0.56	0.63	417.7	417.7
Potassium sulfate at 10g/plant	15.5	16.4	0.84	0.88	545.3	584.0
Potassium sulfate at 20g/plant	16.6	17.5	0.73	0.78	685.7	723.0
Calcium borate at 5 cm/L	12.7	13.7	0.62	0.68	476.0	494.0
Calcium borate at 10 cm/L	14.6	15.6	0.73	0.78	521.7	564.7
Potassium sulfate at10g/plant + Calcium borate at 5 cm/L	19.6	20.4	0.98	0.99	665.3	696.0
Potassium sulfate at 10g/plant + Calcium borate at 10 cm/L	17.7	17.3	0.84	0.88	714.0	764.3
Potassium sulfate at 20 g/plant + Calcium borate at 5 cm/L	20.6	22.7	0.97	1.20	985.3	1016.0
Potassium sulfate at 20 g/plant + Calcium borate at 10 cm/L	35.2	37.7	1.27	1.50	1904.0	1952.0
L.S.D. at 5 %	0.82	0.42	0.05	0.05	2.36	3.95

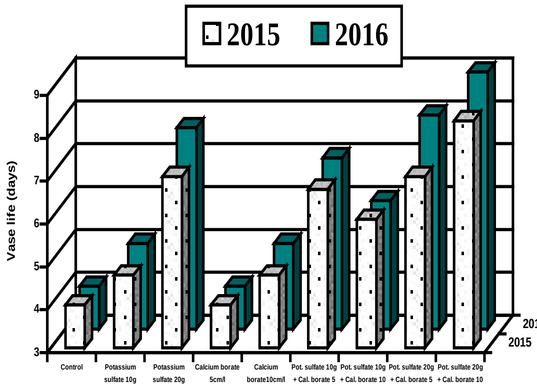

Fig. 3. Effect of potassium sulfate and calcium borate on vase life (days) of *Dahlia pinnata*, L. cut flowers during 2015 and 2016 seasons.

III- Effect of potassium sulfate and calcium borate on tubers parameters of *Dahlia pinnata*, L. :

Results in Table (5) showed that the number of tubers/plant and tuber diameter (cm) were affected by the interaction between potassium sulfate and calcium borate at the highest rates. These treatments recorded significantly increasing number of tubers/plant and tubers diameter when compared with control treatment in both seasons. The highest number of tubers/ plant (7.7 and 8.7) and tubers diameter (12.14 and 12.98 cm) resulted from 20 g/plant potassium sulfate combined with 10 cm/L calcium borate treatment in the two seasons, respectively. Our data go in line with Salim *et al*. (2014) reported that, in the most cases, the foliar applications of different potassium sources exhibited highly significant increases of number of tubers/ plant in Potato plants. Similarly, Muhammad *et al*. (2014) on *Dahlia hybrida*, reported that foliar application of macro and micro nutrients enhanced the production of tubers/ plant. Regarding to the effect of boron, Shampa (2013) mentioned that the number of bulbs/ plant of Tuberose plants were influenced by the application of different boron rate, and boron at 2.0 kg/ha showed the highest number of bulbs/ plant.

Table 5. Effect of potassium sulfate and calcium borate on No. of tubers / plant and tuber diameter (cm) of *Dahlia pinnata*, L. plants in 2015 and 2016 seasons.

Treatments	No. of tubers / plant		Tuber diameter (cm)	
	1st season	2nd season	1st season	2nd season
Control	3.7	3.3	3.13	3.21
Potassium sulfate at 10g/plant	6.7	7.3	5.17	4.79
Potassium sulfate at 20g/plant	6.7	8.7	5.13	6.56
Calcium borate at 5 cm/L	6.0	6.7	3.58	3.66
Calcium borate at 10 cm/L	5.7	7.0	3.89	3.93
Potassium sulfate at 10g/plant + Calcium borate at 5 cm/L	6.3	6.7	6.13	6.55
Potassium sulfate at 10g/plant + Calcium borate at 10 cm/L	5.3	6.3	4.95	5.86
Potassium sulfate at 20 g/plant + Calcium borate at 5 cm/L	6.3	7.7	8.97	9.26
Potassium sulfate at 20 g/plant + Calcium borate at 10 cm/L	7.7	8.7	12.14	12.98
L.S.D. at 5 %	0.63	0.63	0.10	0.41

Concerning to the effect of potassium sulfate and calcium borate and the combination between them at different rates on tuber dry weight %, the results in Fig (4) indicated that there is no clear trend could be observed in most cases. However, Calcium borate at 5 cm/L treatment produced lower value. Singh and Lal (2012) cleared that the average tuber weight of potato increased with increasing potassium level up to 100 kg K_2O/ ha.

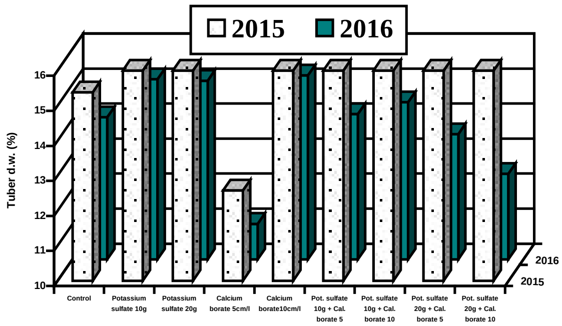

Fig. 4. Effect of potassium sulfate and calcium borate on tuber dry weight % of *Dahlia pinnata*, L. during 2015 and 2016 seasons.

IV- Effect of potassium sulfate and calcium borate on total carbohydrates (mg/g d.w.) and Lignin (%) in flower stem of *Dahlia pinnata*, L. plants

It is evident from Table (6) that significant differences were observed on total carbohydrates in flowers stem among the fertilization treatments. Furthermore, values of total carbohydrates were signify cantly improved in response to the combination between potassium sulfate and calcium borate treatments. The best results were obtained due to fertilization with potassium sulfate at 20 g/ plant + calcium borate at 10 cm/L which gave the highest values of total carbohydrates (10.70 and 10.74 mg/g d.w.) in the two seasons, respectively. Whereas, foliar application with calcium borate solely at 5 cm/plant gave the lowest contents of total carbohydrates compared to the other treatments or the control. The increment in total carbohydrates content may be due to potassium which intensifies the synthesis of carbohydrates, promotes the synthesis and accumulation of thiamin and riboflavin and is essential for the activity of guard cells (Yagodin, 1984). In this respect, Mohammed (2013) reported that, potassium at the highest rates (8 and 16 g/plant) increased total carbohydrates in leaves and tubers of *Dahlia pinnata* plants compared with control treatment.

Data in Table (6) indicated that, all treatments at different rates showed significant differences for lignin % in flower stem under the present study. The maximum lignin % was recorded in the combined treatment of potassium sulfate 20 g/plant + calcium borate 10 cm/L. On the other hand, the minimum lignin % was recorded in the control plants. It can be noticed that lignin % increased due to increasing in calcium borate rate. This may be due to the role of boron in the lignin synthesis which can be related to the formation of borate complexes with phenols and regulating the rate of free phenols that are precursors of the lignin synthesis (Shkolnik, 1984).

Table 6. Effect of potassium sulfate and calcium borate on total carbohydrates (mg/g d.w) and Lignin (%) in flower stem of *Dahlia pinnata*, L. plants in 2016 and 2016 seasons.

Treatments	Total carbohydrates (mg/g d.w) in flower stem		Lignin (%)in flower stem
	1st season	2nd season	2016
Control	9.43	9.73	1.08
Potassium sulfate at 10g/plant	9.60	9.80	1.17
Potassium sulfate at 20g/plant	9.89	9.92	1.46
Calcium borate at 5 cm/L	9.27	9.37	1.73
Calcium borate at 10 cm/L	9.70	9.80	2.05
Potassium sulfate at 10g/plant + Calcium borate at 5 cm/L	10.60	10.77	1.89
Potassium sulfate at 10g/plant + Calcium borate at 10 cm/L	10.24	10.26	2.35
Potassium sulfate at 20 g/plant + Calcium borate at 5 cm/L	10.53	10.57	2.46
Potassium sulfate at 20 g/plant + Calcium borate at 10 cm/L	10.71	10.74	2.62
L.S.D. at 5 %	0.139	0.095	0.003

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تأثير سلفات البوتاسيوم و بورات الكالسيوم على تحسين جودة وإنتاج أزهار الداليا

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أجريت هذه التجربة فى المزرعة البحثية بالبرامون - محافظة الدقهلية –مصر خلال موسمى ٢٠١٥ و ٢٠١٦. بهدف دراسة تأثير سلفات البوتاسيوم و بورات الكالسيوم على تحسين جودة وإنتاج أزهار الداليا . استخدم مستويات مختلفة من التسميد الأرضى بسلفات البوتاسيوم (١٠ & ٢٠ جرام/نبات) و التسميد بالرش ببورات الكالسيوم (٥ & ١٠ سم٣/لتر) اضيفت ثلاث مرات خلال موسم النمو . أوضحت النتائج مايلى: المعاملة بسلفات البوتاسيوم ٢٠ جرام/نبات + بورات الكالسيوم ١٠ سم/لتر أدت إلى زيادة معنوية فى صفات النمو الخضرى لنبات الدليا (إرتفاع النبات و عدد الأوراق/ نبات و عدد الأفرع للنبات و قطر الساق). أيضاً أحدثت هذه المعاملة زيادة فى القياسات الزهرية والدرنية (عدد الأزهار ، قطر الزهرة ، طول وقطر الحامل الزهرى ، قوة شد الأزهار ، عدد الدرنات للنبات ، قطر الدرنة) بالمقارنة بباقى المعاملات الأخرى . الكربوهيدرات الكلية والنسبة المئوية للجنين قد إرتفعت نتيجة لمعاملات التسميد بمستوياتها المختلفة من سلفات البوتاسيوم وبورات الكاسيوم مقارنة بالنباتات الغير معاملة (الكنترول). وقد تفوقت المعاملة بسلفات البوتاسيوم ٢٠ جرام/نبات + بورات الكالسيوم ١٠ سم٣/لتر على المعاملات الاخرى خلال موسمى النمو.