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Reducing Onion Bulbs Flaking and Increasing Bulb Yield and Quality by Potassium and Calcium Application

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Abstract: To investigate the onion bulb flaking during storage in order to increase exportation, a two field experiments were conducted during winter 2005-2006 and 2006-2007 growing seasons. The response of onion plants cv. Giza 20 to different sources of potassium with or without a supplemental potassium foliar spray in addition to calcium application was evaluated. The obtained results indicated that the combined soil application of potassium nitrate (KNO_3) and calcium nitrate (K_2SO_4) plus potassium chloride (KCl) as a foliar spray resulted in the highest values in vegetative growth characters (plant length, leaves number, neck diameter, leaves fresh and dry weight as well as bulb fresh and dry weight) and also gave the highest total yield and quality of onion bulb (bulb weight, diameter, length and TSS). Moreover, it significantly reduced the flaking rate during storage and increased the exportable bulbs percentage. In addition, the combined application of potassium nitrate plus potassium chloride as foliar spray increased potassium level in both leaves and bulbs. Potassium nitrate had a more significant effect in both vegetative growth and bulb quality compared with potassium sulfate. Also supplemental application of potassium chloride as a foliar spray did have a simulating effect regardless the source of potassium in soil application. On the other hand, calcium soil application significantly increased vegetative growth, bulb yield and quality however calcium chloride ($CaCl_2$) foliar spray had no significant impact on all measured parameters. Calcium nitrate was very beneficial in reducing flaking and increasing exportable portion of the yield. Potassium content in onion leaves and bulbs increased with all potassium sources but it was significantly decreased when using calcium nitrate as a soil application while there was no significant difference between control and calcium foliar spray.

Keywords: Onion, Potassium sulfate, Potassium nitrate, Calcium nitrate, Soil application, Foliar application, Storage, yield, Quality, Flaking.

INTRODUCTION

Onion (*Allium cepa L.*) is considered the third most important vegetable crop in Egypt after tomato and potato and it has a very high potential for exportation. Increasing productivity of onion with high quality is an important target by the onion growers. One of the major problems facing exportation of Egyptian onion is the occurrence of flaking where the outer protecting leaves became loose exposing the inner white leaves and hence rejected for exportation.

Both potassium and calcium play a pivotal role in plant growth and development. Potassium has a crucial role in the energy status of the plant, translocation and storage of assimilates and maintenance of tissue water relation. Also potassium plays a key role of crop quality. It improves size of fruit and stimulates root growth. It is necessary for the translocation of sugars and formation of carbohydrates. Potassium also provides resistance against pest and diseases and drought as well as frost stresses (Marschner, 1995).

With the exception of nitrogen, potassium is required by plants in much greater amounts than all other soil supplied nutrients (Tisdale *et. al.,* 1985). Potassium uptake by plants from the soil solution is regulated by several factors including soil texture, moisture conditions, pH, aeration and temperature (Mengel and kirkby, 1980) therefore, during growth development soil potassium supply is seldom adequate to support crucial processes such as sugar transport from leaves to bulbs, enzyme activation, protein synthesis and cell extension that ultimately determine bulb yield and quality (Williams and Kafkafi, 1998) thus using a simulative dose of potassium through foliar application could be a simple solution to overcome the unavailability of potassium in the plants. Previous research has demonstrated that this apparent K deficiency during fruit

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development and maturation can be mitigated through supplemental foliar K applications (Ashour and Sarhan, 1998 and Howard *et. al.* 1998). Lester *et.al* (2006) showed that foliar applied glycine amino acid complexed K sprayed weekly throughout fruit growth and maturation significantly increased muskmelon fruit firmness, ascorbic acid, free sugar, and β carotene concentrations. In addition, foliar spray of potassium as a stimulated dose had a significant effect on the dry weight of leaves and N % as well as K % in leaves tissues and significantly increased total yield and fruit quality in eggplant (Fawzy *et. al.* 2007)

Many studies reported several roles of such element in onion plant growth such as plant height, number of leaves/ plant, fresh and dry weight of whole plant, total yield and its components (Abd El-Al *et al*,. 2005; Al- Moshileh, 2001; Baloch *et al.*, 1991; Guo *et al.*, 1999; Naidu *et al.,* 2000; Singh and Mohanty, 1998; Singh *et al.*, 1989; Singh and Singh, 2000). On the other hand the high levels of potassium fertilization resulted in bulbs with higher quality and higher TSS, N, P, and K (Geetha *et al.*, 1999). Also El-Bassiouny (2006) found that using potassium sulfate plus a simulated dose of potassium oxide as foliar application resulted in the highest plant growth (plant length, number of leaves/plant, and fresh weight of leaves) and also the highest yield and bulb quality.

Concerning calcium role, calcium is an important constituent of plant tissues and has a vital role in maintaining and modulating various cell functions (Conway and Sams, 1987; Kirkby and Pilbeam, 1984; Hepler, 2005). Also physiologically, calcium is important in many fruits and vines since it is associated with reduced senescence and retardation of softening in fruits (Biggs *et al.*, 1997; Gerasopoulos and Drogoudi, 2005; Kirkby and Pilbeam, 1984). It is well documented that use of calcium is very helpful in controlling physiological disorders such as tip burn on lettuce, blossom end rot of tomatoes, rain cracking in sweet cherries, and incidence of greening and cork spot in pears (Misaghi *et al*., 1986; Raese and Drake, 2000; Raese and Sugar, 1994; Raese *et al.*, 1994; Rupert *et al.*, 1997; Wada *et al.*, 1996). As for the use of calcium in postharvest, there is several studies showed that calcium could be used as a pre- or post-harvest treatment to increase postharvest quality or control postharvest diseases in many crops such as grapefruit, mango, pears, apple, blueberry, grapes commodity (Babalar *et al.*, 1999; Haggag, 1987; Hanson *et al.*, 1993; Salem *et al.*, 1991; Sanjay *et al.*, 1998; Scott and Wills, 1975).

Regarding using calcium chloride as a foliar application; there is some contradiction in the reviews. for example in strawberry, Erincik *et al.* (1998) showed that spraying with calcium chloride had no effect on strawberry either in fruit quality or on controlling botrytis rot. While in the work of Cheour *et al*. (1990) it was found that calcium chloride application delayed ripening of strawberry fruits. Also in onion, highest bulb yields occurred with foliar application of the commercial calcium chloride solution (Fenn *et. al.*, 1991) but it was found that application of calcium chloride to onions does not appear to have any beneficial effect on yield and bulb quality and moreover application of high concentration of calcium chloride caused some foliar injuries beside the added cost on the farmer (Warncke, 2006).

It was found that high calcium levels in the soil depressed potassium uptake in several crops such as grape and cantaloupe (Garcia *et al.* 1999; Lester and Jifon, 2007)

In this work different sources and application methods of both potassium and calcium were tested for its effect on yield, quality, and flaking symptom on onion bulbs.

MATERIALS AND METHODS

Plant Material:

Two field experiments were conducted during 2005-2006 and 2006-2007 growing seasons in the Experimental farm of the National Research Center at El-Nubaria, El-Behira Governorate, Northern Egypt. Table (1) presents the main characteristics of the farm's sandy soil. Onion seedlings cv. Giza 20 were transplanted at the second week of December in the two seasons. Seedlings were planted on drip irrigated ridges with 1 m apart and 16 m long with 50 cm between drippers. Four seedlings were planted around each dripper with 7 cm apart. Each plot included 5-redges and the plot area was 80.0 m^2. Three random soil samples were taken from the field and tested before starting the experiment to establish the pH, soil texture and the total amount of nutrients present in the soil. Onion plants were supplied with the recommended dose of nitrogen (20 g N / m^2 in form of ammonium nitrate), phosphorus (12 g P_2O_5 / m^2 in form of calcium super phosphate), and potassium (25 g K_2O/ m_2 with different sources depending on the treatment). As for nitrogen, if any treatment contains nitrogen, it was subtracted from the total nitrogen added to the treatment's plot. Normal agricultural practices common in the area were followed.

Table 1: Physical properties and chemical analysis of the experimental soil.

Physical properties							
Sand	Clay		Silt		Texture	F.C.%	W.P.%
90.08	9.26		0.66		Sandy	16.57	5.25
Chemical analysis							
		Meq./L					
E.C. M/moh	pH	Ca	Mg	Na	K	HCO3	Cl
1.7	8.2	7.02	0.527	0.982	0.31	1.3	0.566

Treatments:

This experiment was designed to test the effect of different sources of potassium (Potassium sulfate or potassium nitrate) with or without a supplemental foliar spray with potassium chloride on onion yield, quality parameters specially bulb flaking. also to study the effect of calcium by comparing control (without calcium) with adding calcium through soil application (as calcium nitrate), or through foliar application (as calcium chloride) on the same parameters putting in mind the synergetic effect of both factors by studying the integration effect between the two factors.

Potassium sulfate (50% K_2O, Hydro-Yara Inc.) and potassium nitrate (13.5 % N, 46 % K_2O, under the commercial name of Krista K, Hydro-Yara Inc.) were soil applied at rate of 100 kg K_2O/fed. While calcium nitrate (15.5 % N, 19% Ca, Hydro-Yara Inc.) was applied as soil application at rate of 60 kg Ca/fed. Regarding foliar application, onion plants were foliar sprayed 30 days after transplanting for three times in two weeks intervals with 1% KCl and/or 2% Ca Cl_2 .

The treatments were arranged as followed:

- K_2SO_4 soil app.
- KNO_3 soil app.
- K2SO_4 soil app. +KCl foliar app.
- KNO_3 soil app. +KCl foliar app.
- K_2SO_4 soil app. +$CaCl_2$ foliar app.
- KNO_3 soil app. +$CaCl_2$ foliar app.
- K_2SO_4 soil app. + KCl foliar app. +$CaCl_2$ foliar app.
- KNO_3 soil app. + KCl foliar app. + $CaCl_2$ foliar app.
- K_2SO_4 soil app. + Ca $(NO_3)_2$ soil app.
- KNO_3 soil app. + Ca $(NO_3)_2$ soil app.
- K_2SO_4 soil app. + Ca $(NO_3)_2$ soil app. + KCl foliar app.
- KNO_3 soil app. + $Ca(NO_3)_2$ soil app. + KCl foliar app

Parameters Recorded:

Vegetative Growth:

Random sample of ten plants from each plot were taken at 75 days after transplanting to record the vegetative growth parameters such as plant height (cm), number of leaves, diameter of bulb and nick (cm) and fresh and dry weight of whole plant.

Yield and Bulb Quality:

After harvesting and curing of onion bulbs, another sample were taken to the lab in Vegetable Research Department, NRC, to measure Bulb physical characteristics such as bulb weight (g), diameter (cm), and length (cm). In the same above sample bulb quality were evaluated by measuring total soluble solids (TSS %) which determined using a hand-held refractometer. Also, yield per feddan were calculated. After drying, a sample of bulbs and leaves from onion plants from each plot were used to measure potassium levels (%) using flam photometer. Potassium contents were determined according to the method mentioned by Brown and Lilleland (1946).

Postharvest Evaluation:

After harvesting and bulb curing, about 50 bulbs were bagged in netted plastic bags and stored in a shaded well ventilated area for rest of the monitoring period.

Flaking index were measured biweekly using a scale from 1 to 9 where 1 is no flaking were present in the sample, while 9 indicate that nearly all the bulbs have lost its protective leaves. Furthermore, the percentage of exportable bulbs in each treatment was evaluated after 60 days of storage.

Experimental Design and Statistical Analysis

The treatments were arranged in a split plot design with four replicates where, potassium treatments were arranged in main plots, while calcium treatments were distributed in the sub plots. The obtained data were statistically analyzed and means separation was done using LSD test according to the method described by Gomez and Gomez (1984).

RESULTS AND DISCUSSIONS

Vegetative Growth:

Both K and Ca application positively affected onion growth parameters, i. e., plant length, number of leaves, neck and bulb diameter as well as fresh and dry weight of onion plant. The combined application of potassium nitrate plus potassium chloride as a foliar spray resulted in the highest values in plant length, leaves number, neck diameter, leaves fresh and dry weight as well as bulb fresh and dry weight followed by using potassium nitrate and the least value were obtained when using potassium sulfate alone. On the other hand, potassium application had no significant effect on bulb diameter (Tables 2 and 3). This result may be due to the role of potassium on promotion vegetative growth of onion plants and increasing mineral uptake by onion plants (El-Bassiony 2006; EL-Desuki *et. al.* 2006; Fawzy *et. al.* 2007; Marschner, 1995). However, calcium soil application significantly increase plant length, leaves number, leaves fresh and dry weight as well as bulb fresh and dry weight with no significant difference between control (no calcium added) and foliar application with $CaCl_2$.Similar results were obtained by Fenn *et. al.*, (1986). On the other hand, calcium application had no significant effect on both neck and bulb diameter during the vegetative stage (Tables 2 and 3). Concerning K and Ca interaction, there was no significant interaction in all vegetative parameters except for leaves and bulbs dry weight where the best treatment was the combined application of KNO_3 plus foliar spry with KCl with soil application of calcium nitrate (Tables 2 and 3). The results of the second season followed the same trend as the first season.

Table 2: Effect of potassium and calcium fertilizers on vegetative growth of onion plants during 2005-2006 and 2006-2007 seasons.

Treatments		2005-2006				2006-2007			
		Plant length (cm)	No. of eaves l /plant	Neck diameter (cm)	Bulb diameter (cm)	Plant length (cm)	No. of leaves /plant	Neck diameter (cm)	Bulb diameter (cm)
					K treatments				
K_2SO_4		60.22	12.11	2.53	4.47	60.33	11.00	2.47	4.18
KNO_3		65.33	12.74	2.60	4.94	64.56	11.78	2.58	3.93
K_2SO_4+KCL		61.10	12.59	2.54	4.44	61.67	11.56	2.43	4.54
KNO_3+KCL		68.44	13.47	2.74	4.80	67.78	12.01	2.76	4.82
LSD at 5%		1.91	0.67	0.31	NS	2.26	0.22	0.15	NS
					Ca treatments				
Without Ca		61.67	12.50	2.68	4.46	62.67	11.00	2.39	3.89
Ca Soil app.		68.66	13.10	2.66	4.58	65.75	12.59	2.63	4.58
Ca foliar		61.00	12.58	2.48	4.21	62.33	11.17	2.65	4.63
LSD at 5%		3.73	0.52	NS	NS	2.71	1.13	NS	NS
					Interaction				
K_2SO_4	Without Ca	60.67	12.00	2.63	5.03	57.33	11.00	2.43	3.90
	Ca Soil app.	64.33	12.67	2.60	4.17	61.67	12.00	2.37	4.10
	Ca foliar	55.67	11.67	2.37	4.20	62.00	10.00	2.60	4.53
KNO_3	Without Ca	67.33	12.67	2.57	4.23	67.00	9.33	2.50	3.17
	Ca Soil app.	69.67	13.00	2.60	4.40	65.00	13.67	2.63	4.77
	Ca foliar	59.00	12.54	2.63	3.20	61.67	12.33	2.60	3.87
K_2SO_4+KCL	Without Ca	56.67	11.67	2.20	3.33	64.67	11.67	2.20	3.43
	Ca Soil app.	66.63	12.76	2.90	4.60	60.33	12.00	2.40	4.60
	Ca foliar	60.00	13.33	2.53	5.40	60.00	11.00	2.70	5.60
KNO_3+KCL	Without Ca	62.00	13.67	3.30	5.23	61.67	12.00	2.43	5.07
	Ca Soil app.	74.00	13.96	2.53	5.13	76.00	12.70	3.13	4.87
	Ca foliar	69.33	12.78	2.40	4.03	65.67	11.33	2.70	4.53
LSD at 5%		NS	NS	NS	NS	5.41	NS	NS	NS

Table 3: Effect of potassium and calcium fertilizers on fresh and dry weight of onion plants during 2005-2006 and 2006-2007 seasons.

		2005-2006				2006-2007			
		Fresh weight (g)		Dry weight (g)		Fresh weight (g)		Dry weight (g)	
		Leaves	Bulb	Leaves	Bulb	Leaves	Bulb	Leaves	Bulb
				K treatments					
K_2SO_4		115.74	80.73	5.25	5.27	92.33	92.50	5.45	6.11
KNO_3		139.41	116.22	5.46	7.39	107.47	93.44	5.24	6.33
K_2SO_4+KCL		105.14	78.41	5.38	6.58	94.05	97.87	5.88	6.28
KNO_3+KCL		151.55	128.89	8.21	8.15	115.65	112.43	5.56	6.98
LSD at 5%		11.86	31.88	0.56	0.53	17.05	9.16	NS	0.22
			Ca treatments						
	Without Ca		119.01	92.39	5.38	6.17	97.92	83.48	5.315.86
	Ca Soil app.	141.43	97.53	7.61	7.70	119.85	112.95	5.65	6.91
	Ca foliar	123.45	91.72	5.24	6.68	89.35	100.75	5.63	6.51
LSD at 5%		20.79	0.8	0.47	0.67	14.86	2.25	NS	0.38
				Interaction					
K_2SO_4	Without Ca	105.40	100.8	5.440	5.20	79.59	78.62	5.02	4.91
	Ca Soil app.	115.09	87.22	5.30	5.41	94.99	112.25	5.78	6.53
	Ca foliar	126.73	54.17	5.03	5.21	102.40	86.63	5.54	6.89
KNO_3	Without Ca	135.17	84.20	5.42	6.23	118.03	70.86	5.15	6.96
	Ca Soil app.	161.33	99.23	5.54	9.59	119.15	106.8	5.59	6.31
	Ca foliar	121.73	79.01	5.43	6.36	85.23	102.67	4.97	5.71
K_2SO_4+	Without Ca	90.830	48.14	5.34	6.52	94.70	71.07	5.44	5.35
KCL	Ca Soil app.	120.30	71.77	5.40	5.95	118.45	114.67	5.69	6.20
	Ca foliar	104.30	115.33	5.39	7.26	69.00	107.86	6.50	7.30
KNO_3+	Without Ca	144.62	136.42	5.33	6.71	99.37	113.37	5.64	6.23
KCL	Ca Soil app.	169.00	131.89	14.18	9.86	146.82	118.09	5.55	8.59
	Ca foliar	141.04	118.36	5.12	7.89	100.76	105.83	5.50	6.13
LSD at 5%		NS	NS	0.94	1.34	NS	24.51	1.72	0.76

Table 4: Effect of potassium and calcium fertilizers on yield and quality of onion plants during 2005-2006 and 2006-2007 seasons.

		2005-2006				2006-2007			
Treatments		Total yield (ton/fed.)	Bulb weight (g)	Bulb diameter (cm)	Bulb length (cm)	Total yield (ton/fed.)	Bulb weight (g)	Bulb diameter (cm)	Bulb length (cm)
				K treatments					
K_2SO_4		14.39	97.92	8.04	5.81	15.83	107.66	7.82	6.13
KNO_3		17.62	119.85	8.62	6.49	16.46	111.98	8.29	6.21
K_2SO_4+KCL		16.03	109.07	8.49	6.29	13.99	95.20	8.21	6.87
KNO_3+KCL		24.75	168.39	8.90	6.91	19.78	134.56	9.67	7.09
LSD at 5%		2.15	29.26	0.31	0.31	2.63	15.83	0.5	NS
				Ca treatments					
	Without Ca	15.41	104.83	8.03	5.90	13.89	94.48	7.84	5.78
	Ca Soil app.	20.75	141.18	9.06	6.55	20.93	142.41	8.92	6.58
	Ca foliar	18.44	125.41	8.45	6.68	14.72	100.17	8.73	7.36
LSD at 5%		1.29	24.81	NS	NS	2.59	35.25	0.48	NS
				Interaction					
K_2SO_4	Without Ca	11.04	75.09	7.40	5.70	11.59	78.83	6.73	5.13
	Ca Soil app.	13.22	89.95	8.90	5.63	23.27	158.29	7.63	5.70
	Ca foliar	18.92	128.72	7.83	6.10	12.62	85.87	9.10	7.57
KNO_3	Without Ca	16.45	111.88	8.00	6.20	13.39	91.09	7.90	5.53
	Ca Soil app.	19.38	131.83	9.67	6.95	23.32	158.64	9.00	7.17
	Ca foliar	17.03	115.84	8.19	6.33	12.67	86.20	7.97	5.93
K_2SO_4+	Without Ca	11.59	78.87	7.97	5.83	11.55	78.56	7.53	5.77
KCL	Ca Soil app.	22.50	153.04	8.23	6.47	15.45	105.12	9.53	6.67
	Ca foliar	14.01	95.30	9.27	6.57	14.98	101.93	7.57	8.17
KNO_3+	Without Ca	22.56	153.49	8.77	5.87	19.03	129.44	9.20	6.70
KCL	Ca Soil app.	27.92	189.9	9.43	7.13	21.69	147.57	9.50	6.80
	Ca foliar	23.78	161.78	8.50	7.73	18.62	126.66	10.30	7.77
LSD at 5%		6.58	NS	NS	NS	5.18	20.5	0.97	NS

Yield and Bulb Quality:

Results in Table (4) showed that, the total bulb yield as well as bulb quality (bulb height, diameter and weight) and TSS were significantly increased by application of KNO_3 plus the additional simulative dose of potassium foliar application with KCl as compared with the sole application of potassium sulfate. As for calcium application effect, soil application of calcium nitrate gave the highest total yield, bulb weight, and TSS in the first season and the highest total yield, bulb weight and diameter, and TSS in the second season,

Table 5: Effect of potassium and calcium fertilizers on TSS and K % of onion plants during 2005-2006 and 2006-2007 seasons.

Treatments		2005-2006 TSS	2005-2006 K % Leaves	2005-2006 K % Bulb	2006-2007 TSS	2006-2007 K % Leaves	2006-2007 K % Bulb
			K treatments				
K_2SO_4		11.55	1.55	1.54	11.94	1.54	1.69
KNO_3		12.25	1.72	1.74	14.36	1.67	1.80
K_2SO_4+KCL		13.02	1.69	1.75	13.22	1.58	1.84
KNO3+KCL		13.94	1.73	1.85	14.22	1.69	1.73
LSD at 5%		0.79	0.06	0.09	1.12	0.03	0.05
			Ca treatments				
	Without Ca	12.37	1.70	1.82	13.21	1.62	1.87
	Ca Soil app.	13.04	1.57	1.59	13.93	1.47	1.65
	Ca foliar	12.67	1.75	1.75	13.17	1.78	1.78
LSD at 5%		0.26	0.06	0.09	0.78	0.17	0.11
			Interaction				
K_2SO_4	Without Ca	11.33	1.67	1.56	11.83	1.56	1.82
	Ca Soil app.	12.00	1.44	1.52	12.00	1.53	1.62
	Ca foliar	11.33	1.53	1.53	12.00	1.54	1.62
KNO_3	Without Ca	12.40	1.72	1.92	14.67	1.63	1.81
	Ca Soil app.	11.67	1.62	1.54	13.73	1.42	1.61
	Ca foliar	12.67	1.81	1.77	14.67	1.96	1.98
K_2SO_4+KCL	Without Ca	12.07	1.72	1.90	12.33	1.62	1.86
	Ca Soil app.	13.67	1.53	1.56	15.00	1.44	1.74
	Ca foliar	13.33	1.81	1.78	12.33	1.67	1.91
KNO_3+KCL	Without Ca	13.67	1.69	1.90	14.00	1.65	1.97
	Ca Soil app.	14.83	1.67	1.73	15.00	1.49	1.61
	Ca foliar	13.33	1.84	1.91	13.67	1.93	1.62
LSD at 5%		1.24	NS	NS	1.57	NS	NS

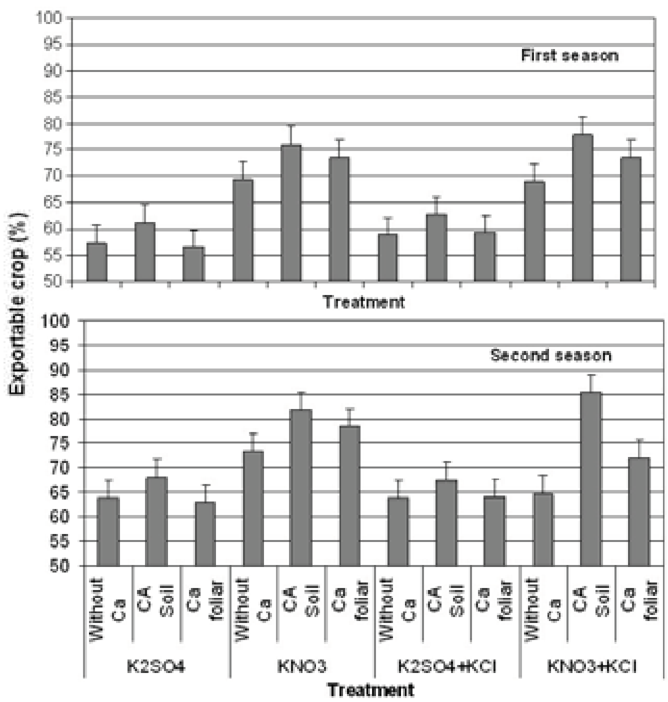

Fig. 1: Effect of potassium and calcium fertilization on percentage of the onion exportable crop after 2 months of storage. Vertical bars present LSD value at p ≥ 5%.

whereas there was no significant difference in bulb diameter in the first season and in bulb length in both seasons. Regarding factors interaction, there was no significant interaction in bulb diameter in the first season and also bulb length in both seasons. There was a significant interaction in total yield, bulb weight, and TSS in both seasons and in bulb diameter. Generally, the best treatment was found when using potassium nitrate plus potassium chloride in addition to calcium nitrate.

Potassium content in both leaves and bulbs were affected by both potassium and calcium application. Using potassium nitrate as a soil application plus potassium chloride as a foliar application gave the highest value of potassium content in leaves and bulbs in both seasons, whereas the lowest value was obtained by using potassium sulfate only. Adding calcium as a soil application reduced potassium level in both leaves and bulbs and this may be due to the antagonism between calcium and potassium in the soil and these results was in agreement with Garcia *et. al.* (1999) and Lester and Jifon (2007). The interaction between potassium and calcium treatments on potassium levels in leaves and bulbs was not significant in both seasons.

Postharvest Evaluation:

When exportable crop percentage was evaluated (Fig. 1), there was a significant interaction between potassium and calcium treatments. Same trend as bulb yield were found where application of potassium nitrate and calcium nitrate plus foliar application of potassium chloride gave the highest exportable crop followed by soil application of potassium nitrate and calcium nitrate with no significant difference between them. The lowest values were obtained from potassium sulfate with or without calcium chloride as a foliar application with no significant difference between them. This trend was obtained in both seasons with a general slight increase in exportable crop in the second season (Fig. 1).

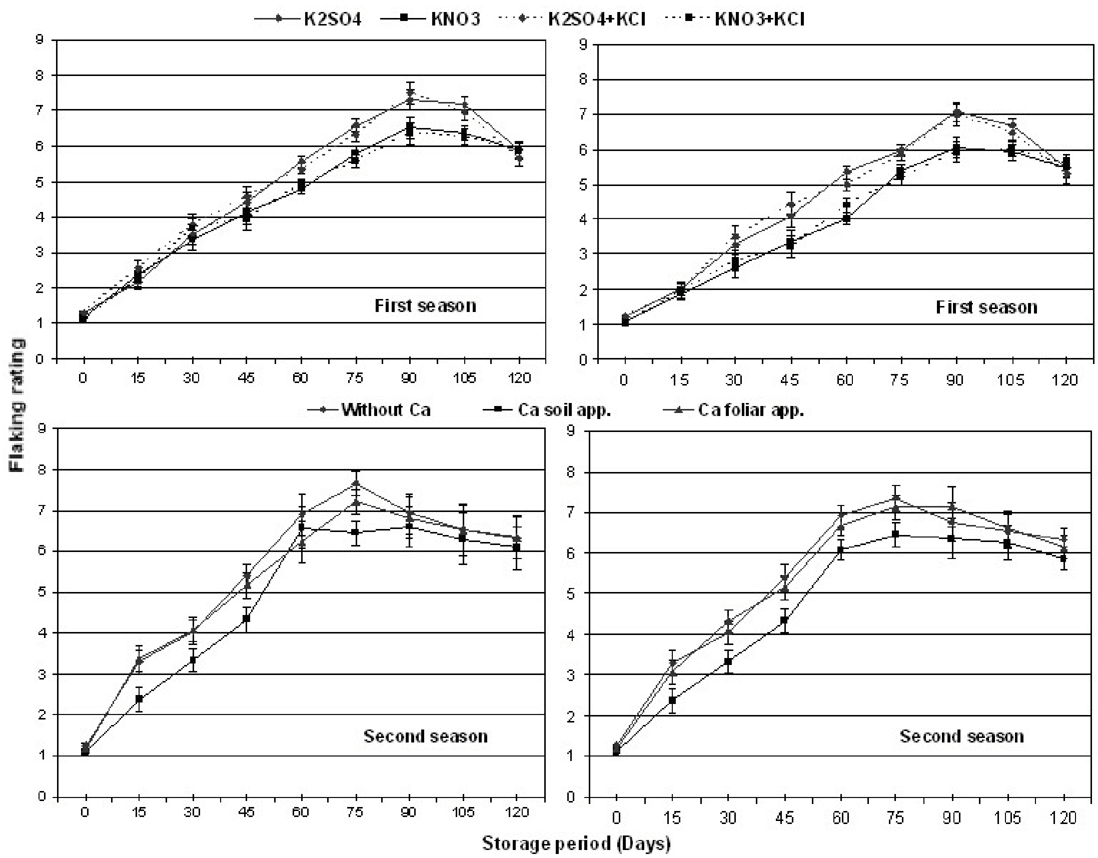

Fig. 2: Effect of potassium and calcium fertilization on flaking index on onion bulbs stored for 120 days. Flaking were evaluated using a 1 to 9 rating where 1 has nearly no flaking and 9 means that nearly all the bulbs had lost its outer protective leaves. Vertical bars present LSD value at p ≥ 5% at each sampling date.

Potassium treatments had no significant on the flaking after harvesting and curing but using potassium nitrate or potassium nitrate plus potassium chloride had a significant reduction in flaking rate after about 45 days of storage compared to using potassium sulfate with or without foliar potassium chloride and this effect vanished after about 105 days of storage and this might be due to the dryness of the first two leaves of the bulb forming new protective leaves. Although having a new protecting leaves formed enable the bulb to continue its life but on the other hand it reduces its fresh weight (Fig. 2). On the other hand, soil application of calcium had a more apparent significant effect on reducing flaking of onion bulbs during storage while applying calcium through foliar application had no significant effect compared to the control (Fig. 2). This result was in agreements with Warncke (2006) who concluded that using $CaCl_2$ on onion had no effect on onion bulbs yield and quality and it will be an extra cost on the farmers. This significant effect of Ca soil application softened after about 90 days of storage because of the same previous reason. There was no significant interaction between K and Ca treatments thus the effect of the individual factors was presented (Fig. 2)

Based on the results of this experiment it, it is recommended to use potassium nitrate as an alternative of potassium sulfate. Using a supplemental dose of potassium as a foliar spray had a significant effect on the onion yield. On the other hand, using calcium in source of calcium nitrate is very beneficial in reducing flaking and increasing exportable portion of the yield

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