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Impact of foliar application of potassium and its spray schedule on yield and quality of sweet orange (*Citrus sinensis*) cv. Jaffa

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Abstract: A field study was undertaken to extrapolate the impact of foliar application of potash and its spray schedule on yield and physical and chemical parameters of sweet orange cv. Jaffa at experimental orchard, Department of Horticulture, CCS Haryana Agricultural University, Hisar. The results revealed that foliar application of KNO_3 at both the doses (2 and 4%) was found significantly or marginally better than K_2SO_4 (1.5 and 3.0%) and control (water spray) in increasing the juice content. Peel content, peel thickness and rag content was found to be influenced significantly due to different treatments on K and its spray schedule. Minimum rag content (38.11%) was recorded with foliar application of KNO_3 at the rate of 4% and maximum with control. Ascorbic acid and acidity were found maximum with two foliar applications of KNO_3 at the rate of 4% in the last week of April and August. Foliar application of KNO_3 at the rate of 4% was found most effective in increasing yield of sweet orange over control and other K treatments. Spray of K in the last week of April, May and August was found superior in increasing yield closely followed by two sprays in the last week of April and August. The findings signify the importance of K spray in enhancing yield and quality of sweet orange under semi-arid north western conditions of India.

Keywords: Chemical parameters, Foliar application, Potash, Sweet orange, Yield

INTRODUCTION

Citrus fruits or their products are the part of daily human intake in one or other forms all over the world. Fresh citrus fruits act as rich source of dietary fiber and hence are recognized as important components in human healthy life (Sanofer, 2014). Citrus fruits are grown under varying agro-climatic regions of India except high hilly regions. Citrus possesses a share of 12.5% in fruit production of the country with 1.08 million ha area under cultivation and 11.15 mt production with the productivity of 10.3 t/ha (Saxena and Gandhi, 2014). The cultivation of citrus crop is gaining momentum in north-western states of India like Punjab, Haryana and Rajasthan.

Potassium is one of the most important nutrients which play a key nutritional role in determining yield and quality of citrus. Nutritional K sprays are applied to correct K deficiencies in citrus as supplement nutrient and to increase leaf K content and fruit yield while reducing rind disorders (Calvert, 1969). Foliar application of potassium fertilizers have been reported to increase juice content of Clementine citrus fruits (Hamza *et al.,* 2012), peel content and peel thickness in Kinnow (Rattanpal *et al.,* 2005; Sangwan *et al.,* 2008) and decrease in rag content in Dancy Tangerine (Singh and Singh, 1981). Foliar K sprays have been found to influence acidity (Gill *et al.,* 2005) and ascorbic acid (Sangwan *et al.,* 2008) in Kinnow. The present investigation was, thus, undertaken to evaluate the impact of foliar application of potassium and timing of its application on yield, physical and chemical parameters in sweet orange cv. Jaffa under semi-arid agroclimatic conditions of north western India.

MATERIALS AND METHODS

The present investigation was carried out at experimental orchard of Department of Horticulture, CCS Haryana Agricultural University, Hisar on fruit trees of sweet orange cv. Jaffa. The experiment comprised of four treatments of K fertilizers and its rate of application viz. potassium nitrate at 2 (T_1) and 4% (T_2), potassium sulphate at 1.5 (T_3) and 3.0% (T_4) which were compared with T_5 i.e. control (water spray). There were three spray schedules i.e. S_1 (two sprays in the last week of April and August), S_2 (two sprays in the last week of May and August) and S_3 (three sprays in the last week of April, May and August). All the fifteen treatment combinations were replicated three times taking one plant as a single unit. Uniform cultural practices and plant protection measures were followed for these trees throughout the study period as per package of practices (Anonymous, 2013).

The data on juice, peel and rag contents and peel thickness of the fruits were recorded at harvest and expressed in standard measuring units. The acidity and ascorbic acid was determined by the method described

by AOAC (2000). These chemical parameters were recorded at three harvesting stages i.e. 15 (D_1), 30 (D_2) and 45 (D_3) days after last spray.

Total yield per plant was recorded at harvest and expressed in kilograms per tree. The data was analyzed in factorial RBD for evaluating the different parameters.

RESULTS AND DISCUSSION

Effect on physical parameters: The juice content increased significantly with doses of KNO_3 over control (Table 1). Maximum juice content (34.42%) was registered with 2% foliar application of KNO_3. Various spray schedules were found non-significant in increasing the juice content, however maximum juice content was found with three sprays of potassium in the last week of April, May and August. These findings are also supported by Hamza *et al.* (2012) which showed an increase of 1.8% juice content in Clementine citrus fruits by 8% KNO_3 as a foliar spray applied thrice a year. However, Sangwan *et al.* (2008) reported non-significant effect on juice content of Kinnow mandarin due to K spray and Rattanpal *et al.* (2005) in contrast reported that the highest juice content (51.97%) was found in control and minimum (45.60%) in K sprayed Kinnow fruits.

There was an increase in peel content and peel thickness with an increase in K doses of KNO_3 and K_2SO_4, irrespective of spray schedule (Table 2 and 3). Maximum peel content (27.81%) and peel thickness (4.94mm) was recorded with foliar application of KNO_3 @ 4% followed by K_2SO_4 @ 3%. Three sprays of potassium in the last week of April, May and August gave maximum peel content (26.16%) and peel thickness (4.77mm) which was found at par with two sprays in the last week of may and August. Interaction effect of treatments and spraying schedule was also found significant in influencing peel content. Maximum peel content (28.83%) was recorded with two sprays of KNO_3 @ 4 % during the last week of May and August (T_2xS_2) closely followed by of (T_2xS_3). Minimum peel content (22.69 %) was recorded with interaction effect of two sprays of water (control) in the last week of May and August (T_5xS_2). Interaction effect of treatments and spraying schedule was also found significant in affecting peel thickness. Maximum peel thickness value (5.04 mm) was recorded with interaction effect of KNO_3 @ 4 % sprayed during the last week of May and August (T_2xS_2) followed by

Table 1. Effect of foliar application of potassium and spray schedule on juice content (%) of sweet orange cv Jaffa.

Treatments	Spray schedule			Mean
	S_1	S_2	S_3	
T_1 : KNO_3 2 %	34.76	34.18	34.32	34.42
T_2 : KNO_3 4 %	34.10	33.85	34.17	34.04
T_3 : K_2SO_4 1.5%	33.23	33.10	34.41	33.56
T_4 : K_2SO_4 3%	33.11	33.01	33.60	33.24
T_5 : Control (water spray)	33.02	33.05	33.30	33.12
Mean	33.64	33.44	33.96	-
CD (P=0.05)	Spray Schedule(S) = NS, Treatments(T) = 0.81, S xT= NS			

Table 2. Effect of foliar application of potassium and spray schedule on peel content (%) of sweet orange cv Jaffa.

Treatments	Spray schedule			Mean
	S_1	S_2	S_3	
T_1 : KNO_3 2 %	25.02	26.53	26.65	26.07
T_2 : KNO_3 4 %	26.55	28.83	28.04	27.81
T_3 : K_2SO_4 1.5%	25.44	25.55	25.69	25.56
T_4 : K_2SO_4 3%	26.85	27.15	27.68	27.23
T_5 : Control (water spray)	22.78	22.69	22.72	22.73
Mean	25.33	26.15	26.16	-
CD (P=0.05)	Spray Schedule(S)= 0.82, Treatments (T) = 1.27, SxT= 2.02			

Table 3. Effect of foliar application of potassium and spray schedule on peel thickness (mm) of sweet orange cv Jaffa.

Treatments	Spray schedule			Mean
	S_1	S_2	S_3	
T_1 : KNO_3 2 %	4.60	4.74	4.79	4.71
T_2 : KNO_3 4 %	4.75	5.04	5.04	4.94
T_3 : K_2SO_4 1.5%	4.62	4.84	4.96	4.81
T_4 : K_2SO_4 3%	4.85	4.96	5.00	4.94
T_5 : Control (water spray)	4.11	4.04	4.04	4.06
Mean	4.57	4.73	4.77	-
CD (P=0.05)	Spray Schedule(S) = 0.22, Treatments(T) = 0.29, SxT= 0.58			

Table 4. Effect of foliar application of potassium and spray schedule on rag content (%) of sweet orange cv Jaffa.

Treatments	Spray schedule			Mean
	S_1	S_2	S_3	
T_1 : KNO_3 2 %	40.22	39.29	39.02	39.51
T_2 : KNO_3 4 %	39.22	37.32	37.79	38.11
T_3 : K_2SO_4 1.5%	41.33	41.35	39.90	40.86
T_4 : K_2SO_4 3%	40.04	39.84	38.72	39.53
T_5 : Control (water spray)	44.20	44.26	43.98	44.15
Mean	41.00	40.41	39.88	-
CD (P=0.05)	Spray Schedule(S)= 1.09 , Treatments (T) = 1.55 , SxT= 2.69			

Table 5. Effect of foliar application of potassium, spray schedule and harvesting stages on acidity (%) of sweet orange cv Jaffa.

5A: Harvesting stages x Treatments.

Treatments / Harvesting stages	KNO_3		K_2SO_4		Control (water spray)	Mean
	2%	4%	1.5%	3%		
D_1: 15	1.34	1.53	1.17	1.34	1.21	1.32
D_2: 30	1.14	1.22	1.07	1.15	1.12	1.14
D_3: 45	0.87	1.03	0.97	1.07	0.97	0.98
Mean	1.12	1.26	1.07	1.19	1.10	-
CD (P=0.05)	Harvesting stage(H)= 0.03, Treatments (T) = 0.04, HxT= 0.07					

5B: Harvesting stages x Spray schedule.

Harvesting stages	Spray schedule			Mean
	S_1	S_2	S_3	
D_1: 15	1.39	1.29	1.28	1.32
D_2: 30	1.17	1.12	1.13	1.14
D_3: 45	1.02	0.98	0.94	0.98
Mean	1.19	1.13	1.12	-
CD (P=0.05)	Harvesting stage (H)= 0.03, Spray schedule (S) = 0.03, HxS= NS			

5C: Treatments x Spray schedule.

Treatments	Spray schedule			Mean
	S_1	S_2	S_3	
T_1 : KNO_3 2 %	1.19	1.15	1.02	1.12
T_2 : KNO_3 4 %	1.29	1.27	1.22	1.26
T_3 : K_2SO_4 1.5%	1.14	1.02	1.05	1.07
T_4 : K_2SO_4 3%	1.24	1.12	1.20	1.19
T_5 : Control (water spray)	1.11	1.08	1.10	1.10
Mean	1.19	1.13	1.12	-
CD (P=0.05)	Treatment (T)= 0.04, Spray schedule (S) = 0.03, TxS= 0.07			

(T_2xS_3), (T_4xS_3), (T_4xS_2) and (T_3xS_3). Lowest peel thickness value (4.04 mm) was recorded with interaction effect of two sprays of water (control) in the last week of May and August (T_5xS_2) and with three sprays of water (control) in the last week of April, May and August (T_5xS_3).The increased peel content might be due to the role of potassium in enhancing cell wall construction (Boman and Hebb, 1998) which is evident from the increased peel thickness (Table 3) in the present investigation. Sangwan *et al.* (2008) observed maximum peel content (25.7%) and peel thickness (3.74 mm) with 2% KNO_3 sprayed thrice in Kinnow mandarin. Likewise, Rattanpal *et al.* (2005) obtained maximum peel content (28.20%) in Kinnow fruits with 5% KNO_3 sprayed 60 days after full bloom. Kumar and Kumar (2007) observed the highest peel weight (8.9 g) with foliar application of K_2SO_4 at 1.5% and the lowest (7.2 g) in control in banana.

Interaction effect of K treatments and spray schedule was found significant at 5% level of significance. Maximum peel thickness (5.04 mm) was recorded with interaction effect of KNO_3 at the rate of 4 % sprayed during the last week of May and August (T_2xS_2) followed by (T_2xS_3), (T_4xS_3), (T_4xS_2) and (T_3xS_3). Lowest peel thickness (4.04 mm) was recorded with interaction effect of two sprays of water (control) in the last week of May and August (T_5xS_2) which was at par with three sprays of water (control) in the last week of April, May and August (T_5xS_3).

All the potassium treatments decreased rag content

Table 6. Effect of foliar application of potassium, spray schedule and harvesting stages on ascorbic acid (mg/100ml of juice) of sweet orange cv Jaffa.

6A: Harvesting stages x Treatments.

Treatments / Harvesting stages	KNO_3		K_2SO_4		Control (water spray)	Mean
	2%	4%	1.5%	3%		
D_1: 15	48.65	51.42	49.22	50.19	50.92	50.08
D_2: 30	49.53	52.14	50.78	51.74	50.49	50.93
D_3: 45	57.44	61.33	54.72	55.82	51.03	56.07
Mean	51.87	54.85	51.57	52.58	50.81	-
CD (P=0.05)	Harvesting stage (H)= 0.69, Treatments (T) = 0.90, HxT= 1.55					

6B: Harvesting stages x Spray schedule.

Harvesting stages	Spray schedule			Mean
	S_1	S_2	S_3	
D_1: 15	50.30	50.37	49.56	50.08
D_2: 30	50.53	50.04	52.23	50.93
D_3: 45	58.90	55.12	54.19	56.07
Mean	53.24	51.77	52.00	-
CD (P=0.05)	Harvesting stage (H)= 0.09, Spray schedule (S) = 0.09, HxS= 1.20			

6C: Treatments x Spray schedule.

Treatments	Spray schedule			Mean
	S_1	S_2	S_3	
T_1 : KNO_3 2 %	52.87	51.48	51.27	51.87
T_2 : KNO_3 4 %	55.18	53.36	56.01	54.85
T_3 : K_2SO_4 1.5%	52.54	50.98	51.20	51.57
T_4 : K_2SO_4 3%	55.32	52.09	50.34	52.58
T_5 : Control (water spray)	50.31	50.97	51.16	50.81
Mean	53.24	51.77	52.00	-
CD (P=0.05)	Treatment (T)= 0.90, Spray schedule (S) = 0.69, TxS= 1.55			

Table 7. Effect of foliar application of potassium and spray schedule on yield (kg/plant) of sweet orange cv Jaffa.

Treatments	Spray schedule			Mean
	S_1	S_2	S_3	
T_1 : KNO_3 2 %	71.24	67.91	72.34	70.50
T_2 : KNO_3 4 %	76.90	71.05	76.32	74.76
T_3 : K_2SO_4 1.5%	67.88	66.12	68.79	67.60
T_4 : K_2SO_4 3%	69.71	69.05	70.47	69.74
T_5 : Control (water spray)	65.21	64.60	65.66	65.16
Mean	70.19	67.75	70.72	-
CD (P=0.05)	Spray Schedule (S) = 2.32 , Treatments (T) = 3.45, SxT= 5.62			

over control and there was a decreasing trend with an increase in potassium doses of KNO_3 and K_2SO_4, irrespective of spray schedule (Table 4). Minimum rag content (38.11%) was recorded with foliar application of KNO_3 @ 4%. Minimum rag content (39.88%) was recorded with three sprays of potassium in the last week of April, May and August which was significantly less than that of two sprays during April and August. Interaction effect of treatments and spraying schedule was also found significant. Minimum rag content (37.32%) was recorded with interaction effect of KNO_3 @ 4 % sprayed during the last week of May and August (T_2xS_2) followed by (T_2xS_3). Maximum rag content (43.98 %) was recorded with interaction effect of three sprays of water (control) in the last week of April, May and August (T_5xS_3). The decreased rag content might be due to increased peel content by potassium application. Similarly, Singh and Singh (1981) reported minimum rag content (21%) in Dancy tangerine with 1% spray of KNO_3. In contrast, Sangwan *et al.* (2008) reported increased rag content (25.30%) with 2% spray of KNO_3 in Kinnow mandarin.

Effect on chemical parameters: The acidity was influenced significantly by potassium doses from various sources (Table 5). Maximum acidity (1.26 %) was recorded with KNO_3@ 4% (T_2) and minimum value (1.07%) was recorded with K_2SO_4 @ 1.5% (T_3) which was at par with control (1.10%) when considered irre-

spective of the harvesting stages and spray schedule. Treatment KNO_3 @ 2% (T_1) was statistically at par with control. There was increase in acidity content with an increase in K doses. This may be due to synthesis of more organic acids at higher doses of K. In acidity an increasing trend was observed with increasing days after last spray. Maximum acidity (1.32%) was recorded at harvesting stage D_1 (15 days after last spray) and minimum value (0.98%) was recorded at harvesting stage D_3 (45 days after last spray). Interaction effect of treatments and harvesting stages was also found significant. Maximum acidity (1.53%) was found with foliar application of KNO_3 @ 4% recorded at 15 days after last spray (T_2xD_1) and minimum acidity (0.87%) was with interaction of KNO_3 @ 2% recorded at 45 days after last spray (T_1xD_3). Two sprays in the last week of April and August (S_1) resulted in maximum acidity (1.19%). Minimum acidity (1.12%) was found with three sprays in the last week of April, May and August (S_3) which was statistically at par with two sprays in the last week of May and August (S_2). Interaction effect of spray schedule and harvesting stages was found non-significant. However, numerically, maximum acidity (1.39%) was found with two sprays of potassium in the last week of April and August recorded at 15 days after last spray (S_1xD_1) and minimum acidity (0.94%) was with three sprays of potassium in the last week of April, May and August recorded at 45 days after last spray (S_3xD_3). The interaction effect of treatments and spray schedule depicted that maximum acidity (1.29%) was found with interaction of KNO_3 @ 4% sprayed during the last week April and August (T_2xS_1) followed by (T_2xS_2), (T_2xS_3) and (T_4xS_1). Minimum acidity (1.02%) was recorded with interaction effect of two sprays of K_2SO_4 @ 1.5% during the last week of May and August (T_3xS_2) and with interaction of three sprays of KNO_3 @ 2% in the last week of April, May and August (T_1xS_3). Similar findings were reported by Gill *et al.* (2005) in Kinnow mandarin. He found maximum acid content (0.87%) with 2% KNO_3. Sangwan *et al.* (2008) also reported maximum acidity (0.88%) with foliar application of KNO_3 at 2% in Kinnow mandarin.

\Ascorbic acid was influenced significantly by potassium doses from various sources when analyzed irrespective of harvesting stages and spray schedule (Table 6). Maximum ascorbic acid (54.85 mg/100ml) was recorded with KNO_3@ 4% (T_2). Minimum value (50.81 mg/100ml) was recorded with control. Treatment KNO_3 @ 2% (T_1) was statistically at par with K_2SO_4 @ 1.5% (T_3) and K_2SO_4 @ 3% (T_4). Observations recorded at different harvesting stages significantly influenced ascorbic acid in sweet orange, when considered irrespective of treatments and spray schedule. Ascorbic acid increased with an increase in days after last spray. Maximum ascorbic acid (56.07 mg/100ml) was recorded at harvesting stage D_3 (45 days after last spray) and minimum value (50.08 mg/100ml) was recorded at harvesting stage D_1 (15 days after last spray). Interaction effect of treatments and harvesting stages was also found significant. Maximum ascorbic acid (61.33 mg/100ml) was found with foliar application of KNO_3 @ 4% recorded at 45 days after last spray (T_2xD_3) and minimum ascorbic acid (48.65 mg/100ml) was with KNO_3 @ 2% recorded at 15 days after last spray (T_1xD_1). Ascorbic acid was significantly influenced by potassium spray schedules when considered irrespective of harvesting stages and treatments. Two sprays in the last week of April and August (S_1) resulted in maximum ascorbic acid (53.24 mg/100ml). Minimum ascorbic acid (51.77 mg/100ml) was found with two sprays in the last week of May and August (S_2) which was statistically at par with three sprays in the last week of April, May and August (52.00 mg/100ml) i.e. S_3. Within the interaction effect of spray schedule and harvesting stages maximum ascorbic acid (58.90 mg/100ml) was found with two sprays of potassium in the last week of April and August recorded at 45 days after last sprayl (S_1xD_3) and minimum ascorbic acid (50.04 mg/100ml) was with two sprays of potassium in the last week of May and August recorded at 30 days after last spray (S_2xD_2). The interaction between treatments and spray schedules was also found significant. Maximum ascorbic acid (56.01 mg/100ml) was found with interaction of KNO_3 @ 4% sprayed during the last week of April, May and August (T_2xS_3) closely followed by (T_4xS_1) and (T_2xS_1). Minimum ascorbic acid (50.31 mg/100ml) was recorded with interaction effect of two sprays of water (control) in the last week of April and August (T_5xS_1). Increased ascorbic acid with foliar application of potassium might be related with improved sugar metabolism (Mengal, 1997). Another probable reason might be the role of potassium in activating the synthesis of ascorbic acid somewhere between D-Glucose to L-Ascorbate (Harold and George, 1966). Similar findings were observed by Sangwan *et al.* (2008). They found maximum ascorbic acid (26.3 mg/100ml juice) with KNO_3 at the rate of 2% in Kinnow mandarin. Kundu and Biswas (2009) found the highest ascorbic acid content of 70.06 mg/100ml of juice with the application of potash at the rate of 100 g per plant.

Effect on yield: Yield increased significantly with all potassium treatments over control and there was an increase in fruit yield with an increase in K doses of KNO_3 and K_2SO_4, irrespective of spray schedule (Table 7). Maximum yield (74.76 kg) was recorded with 4% spray of KNO_3. Similarly, increased frequency of K sprays increased the yield. Maximum yield (70.72 kg) was observed with three sprays of potassium in the last week of April, May and August

which was at par with two sprays during April and August but significantly superior to the sprays done during the month of May and August. The increase in yield might be attributed to increased fruit reserves in the plant due to the foliar application of K. Maximum yield (76.90 kg/tree) was recorded with the interaction of 4% KNO_3 sprayed during the last week of April and August (T_2xS_1) which was found at par with (T_2xS_3) and (T_1xS_3). Minimum yield (64.60 kg/tree) was recorded with interaction effect of two sprays of water (control) in the last week of May and August (T_5xS_2). Similar results were also observed by Sangwan *et al.* (2008) where they found maximum yield (73.65 kg/ tree) with KNO_3 @ 2% and minimum (61.70 kg/tree) in control in Kinnow mandarin. Omaima and El-Metwally (2007) also reported 16.26% increase in fruit yield of Washington Navel orange when sprayed thrice with K. Dutta *et al.* (2011) reported maximum fruits (184 fruits/ tree) with foliar application of K_2SO_4@ 1% in mango.

Conclusion

Besides yield, quality of citrus fruits is of prime importance for nutritional security, longevity of the fruit and premium marketing. The present study infers that foliar application of KNO_3 @ 4% sprayed thrice in the last week of April, May and August enhanced the yield and quality of sweet orange which was at par with two sprays done in the last week of April and August but superior to the sprays done in the last week of May and August. This treatment increased the juice content, ascorbic acid, acidity and yield of the fruits. The study also reflects that the initial spray should be done in the month of April instead of May as the fruits already gain considerable growth and size till May spray. This study may help in giving further impetus in increasing the acreage under citrus fruits in semi-arid agroclimatic regions of north western India where there is a need to diversify the existing cropping systems and nutritional security of the country.

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