The Bioscan 11(1): 589-596, 2016 (Supplement on Agronomy)
AN INTERNATIONAL QUARTERLY JOURNAL OF LIFE SCIENCES
www.thebioscan.in

EFFECT OF MINERAL NUTRIENTS AND GROWTH REGULATORS ON MANAGEMENT OF FRUIT DROP AND IMPROVEMENT OF FRUIT QUALITY IN KINNOW MANDARIN

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KEYWORDS
Kinnow
Growth regulators
Micronutrients
Fruit drop
Yield

Received on :
18.09.2015

Accepted on :
13.02.2016

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ABSTRACT
The present investigation on the effect of the foliar application of micronutrients and growth regulators on management of fruit drop concomitant with improvement of fruit quality in Kinnow mandarin was carried out at Punjab Agricultural University, Ludhiana during 2012-2013. Minimum fruit drop percent and maximum fruit retention per cent were recorded with the foliar application of $MgSO_4$ (0.6%). A significant increase in yield due to reduction in per cent fruit drop when compared to control has been recorded with the application of KNO_3 + 2,4-D (2.5 + 20μg/ml). The maximum fruit weight (232g/fruit), size (6.51x7.44cm), TSS:Acid ratio (15.0), Vitamin C (50.46 mg/100 ml juice), juice per cent (54.66%), flavonoids (24.96 mg/g equivalent); and a minimum rag per cent (20.26%) were recorded with the application of KNO_3 + 2,4-D (2.5 + 20μg/ml). Thus the synergistic effect of KNO_3 + 2,4-D (2.5% and 20μg/ml) improves fruit yield and quality in Kinnow mandarin by reducing the fruit drop.

INTRODUCTION

Citrus is one of the major economically important fruit crops in the world and is grown in developed and developing countries, constitutive of one of the main sources of vitamin C. In India, citrus is grown in an area of 106400 hectares with an annual production of 994500 MT (Anonymous, 2013-14). The major citrus variety grown in Punjab in India is Kinnow mandarin which occupies an area 48000 hactares with an annual production of 1036832 MT (Anonymous, 2013-14). Fruit drop in citrus, especially in Kinnow mandarin is a serious problem confronting the Kinnow growers. The phenomenon of fruit drop is effected by several physiological and environmental factors viz. malnutrition, high temperature, humidity, diseases and pests (Razi *et al.*, 2011; Ashraf *et al.*, 2012). Citrus trees produce very large number of flowers, however less than 1-2% of flowers produce harvestable yield (Nishikawa, 2013). Early reproductive processes in citrus are strongly affected by plant growth regulators indicating that the regulatory mechanism controlling set and abscission of ovaries and fruitlets possesses a pivotal hormonal component (Talon *et al.*, 1990). The balance between specific plant growth regulators at the abscission zone controls cell separation processes and eventually fruit drop (Brown, 1997).

The plant growth regulators have been exploited for the control of fruit drop and improvement of fruit quality in Kinnow mandarin. Reports indicate that 2,4-D could improve TSS, TSS : Acidity ratio, total sugars and ascorbic acid along with an increase in fruit retention and fruit yield per plant (Jain *et al.*, 2014). In another study, foliar application of GA_3 has been reported to increase yield by reducing the per cent fruit drop (Ullah *et al.*, 2014). The nutrient deficiency disturbs the production of plant growth regulators which ultimately control size, color and premature fruit drop. Different workers have suggested that application of suitable combination of plant growth regulators and macro and micro-nutrients for the control of excessive fruit drop and improvement of the yield and quality of citrus fruits (Doberman and Fairhurst, 2000; Saleem *et al.*, 2005). The nutrients are being exploited for their applications in other fruit crops also (Gaur *et al.*, 2014; Gurjar *et al.*, 2015). The present investigation has been under taken with the hypothesis that an effective supplement of nutrients and plant growth regulators may be necessary to produce high quality citrus fruits and control excessive citrus fruit drop. Therefore, the objective of the present study was to curtail the excessive fruit drop and enhance fruit yield and quality of Kinnow mandarin with the application of optimum dose plant growth regulators, nutrients and their combinations at an appropriate stage of growth.

MATERIALS AND METHODS

Location

The present investigations were made on eight year old Kinnow trees growing in the New Orchard of Department of Fruit Science, Punjab Agricultural University Ludhiana. Thirty Six trees which were uniform in size & vigour and given

cultural practices as per Package of Practices recommended by Punjab Agricultural University, Ludhiana were selected for the present study.

Treatments

The treatments (Twelve) were applied as foliar application and the concentration of plant growth regulators, nutrients and the time of application is as per Table 1. The experimental design was Randomized complete Block Design with single tree as an experimental unit replicated three times.

Periodical fruit drop

The experimental trees were visited regularly to observe periodical fruit drop. The dropped fruits were collected and counted at fortnightly interval beginning with May and continued up to end of December.

Fruit drop (%)

The fruit drop per cent was computed at the time of harvest. Per cent fruit drop was calculated by recording the total number of dropped fruits at each stage and the total number of fruits on the tree at the time of harvest by employing the following standardized formula :

$$\text{percent fruit drop} = \frac{\text{Number of fruits droped}}{\text{Number of fruits on the tree (dropped + total fruit no. at harvest)}} \times 100$$

Physical and Biochemical attributes of the fruits

At the time of harvest, ten fruits were picked randomly from each experimental tree. These fruits were brought to the laboratory of Department of Botany for quantificati on of quality attributes. The fruits were washed and allowed to dry at room temperature. The fruit weight, fruit size, peel weight and peel thickness were recorded with electronic balance and vernier caliper. The fruit juice was extracted with a juice extractor and weighed. The fruit juice quality parameters, viz., juice per cent,total soluble solids, titratable acidity, TSS : Acid ratio, vitamin C, and flavonoids were estimated by following standard methods (Malik and Singh,1982; AOAC,1990).

Statistical analysis

For the comparison of treatments, Randomized Block Design has been applied.

The data has been analyzed statistically by using ANOVA.

RESULTS

Fruit drop and Fruit retention

The data on the effect of the various treatments on fruit drop and fruit retention is presented in Fig 1, and the data revealing decrease in fruit drop and increase in fruit retention by the treatments is presented in Table 3. The data on periodical fruit drop and the impact of different treatments on the periodical fruit drop is presented in Table 2.

In general, the maximum fruit drop in control plants was recorded during the month of May (69.53%) followed by June (21.26%) as is evident from Table 2. The same pattern of fruit drop has been observed among all the other treatments. The total number of fruits dropped in control trees were recorded to be (~ 559 fruits/tree) and the minimum (~ 423 fruits/tree) were recorded with $MgSO_4$ (0.6%). The foliar application of KNO_3 + 2,4-D (2.5% + 20 µg/ml) resulted in reduction in number of fruit drop (~ 522 fruits/tree) as compared to control.

The minimum fruit drop (37.78%) was recorded with $MnSO_4$ (0.3%) followed by 2,4-D (38.61% fruit drop). Corresponding to this, maximum fruit retention (62.21%) was recorded with $MnSO_4$ (0.3%), closely followed by 2,4-D (61.38% fruit retention) (Fig.1).

The maximum increase in fruit retention as compared to control was recorded with $MnSO_4$ (16.51 %). The combination of KNO_3 + 2,4 D (2.5 % and 20 µg/ml) resulted in 10.86 % increase in fruit retention as compared to control as is evident from Table 3.

Fruit yield

The influence of different treatments on the fruit yield has been recorded on the basis of fruit number per tree as well as fruit weight per tree (Fig. 2). The fruit yield (kg/per tree) recorded a significant increase with the foliar application of all the treatment when compared to control. The increase in fruit yield based on fruit weight recorded a significant increase due to significant increase in fruit size with the foliar application of the treatments. The maximum fruit yield (239.02 kg/tree) was recorded with the foliar application of $MnSO_4$ + $ZnSO_4$ (0.1% each).

Fruit weight

The data on the effect of different treatments on fruit weight is represented in Table 4. There was significant increase in fruit

Table 1: Concentrations and time of application of nutrients and growth regulators

S.No.	Treatments	Concentration	Time of Application
T1	$FeSO_4$	0.3 (%)	Mid-April,Mid-June,Mid-September
T2	$MnSO_4$	0.3 (%)	Mid-April, Mid-June,Mid-September
T3	$ZnSO_4$	0.3 (%)	Mid-April, Mid-June,Mid-September
T4	$CaSO_4$	0.6 (%)	Mid-April, Mid-June,Mid-September
T5	$MgSO_4$	0.6 (%)	Mid-April, Mid-June,Mid-September
T6	$FeSO_4 + MnSO_4 + ZnSO_4$	0.3 + 0.3 + 0.3(%)	Mid-April, Mid-June,Mid-September
T7	$MnSO_4 + ZnSO_4$	0.1 % + 0.1 %	Mid –April and Mid – August
T8	KNO_3 + 2,4 – Dichlorophenoxy acetic acid	5 % + 20 µg/ml	Sixty days after full bloom
T9	KNO_3 + 2,4 – Dichlorophenoxy acetic acid	2.5 % + 20 µg/ml	Sixty days after full bloom
T10	2,4 – Dichlorophenoxy acetic acid	20 µg/ml	End-March, End April, Mid-August, Mid-September
T11	Gibberellic acid	20 µg/ml	End-March, End April, Mid-August, Mid-September
T12	Control	Water spray	-

Table 2: Effect of nutrients and plant growth regulators on the periodical fruit drop (Total fruits dropped/tree)

Treatment	Conentration	May		June		July		Aug		Sept.		Oct.		Nov	Dec		Total
		IFN	IIFN	IFN	IIFN	IFN	IIFN	IFN	IIFN	IFN	IIFN	IFN	IIFN	IFN	IIFN	IFN	I
$FeSO_4$	0.3 (%)	175.00	110.66	80.00	30.00	25.33	12.66	10.00	0.33	1.66	1.33	2.00	1.33	2.00	2.66	1.00	445.96=446.00
$MnSO_4$	0.3 (%)	179.33	90.00	56.00	17.33	9.00	4.00	9.33	0.33	0.33	0.00	0.66	0.00	0.33	0.33	0.00	366.96=367.00
$ZnSO_4$	0.3 (%)	284.00	116.33	91.33	48.66	27.00	14.00	9.33	0.33	1.00	0.66	1.33	0.33	0.66	0.66	1.33	596.95=596.95
$CaSO_4$	0.6 (%)	228.66	160.00	53.66	21.66	18.33	8.66	9.33	0.33	1.00	0.00	0.66	0.33	0.33	0.33	0.66	503.94=503.94
$MgSO_4$	0.6 (%)	250.00	157.00	104.33	57.00	15.00	6.00	10.33	0.33	1.66	0.00	1.00	0.00	0.33	1.00	0.33	422.98=423.00
$FeSO_4$ +$MnSO_4$ +$ZnSO_4$	0.3 +0.3+0.3 (%)	212.33	110.66	73.33	35.33	24.00	8.00	9.66	0.33	1.00	0.33	1.00	0.33	0.33	0.33	0.00	444.96=445.00
$MnSO_4$ +$ZnSO_4$	0.1 + 0.1(%)	257.33	141.66	82.66	54.33	25.33	8.66	9.66	0.33	0.33	0.00	1.00	0.00	0.00	0.00	0.33	581.62=581.62
KNO_3 + 2,4 – D	5 % + 20µg/ml	199.00	135.66	65.66	32.66	12.66	5.00	9.00	0.66	0.66	0.33	0.33	0.33	0.00	0.33	0.33	462.28=463.00
KNO_3 + 2,4 – D	2.5 % + 20 µg/ml	210.00	163.33	82.33	33.33	12.00	6.00	8.66	0.00	1.33	0.33	1.00	0.00	1.66	0.66	0.66	521.62=521.62
2,4 – D	20 µg/ml	190.00	144.00	64.00	36.33	14.33	7.66	9.33	0.00	0.66	0.00	0.33	0.00	0.00	0.00	0.33	466.97=467.00
GA_3	20 µg/ml	262.66	168.33	66.33	30.33	8.33	3.33	8.66	0.00	0.00	0.33	0.33	0.00	0.66	0.00	0.00	545.29=546.00
Control	Water spray	*247.00	*141.66	**71.33	**47.33	20.66	10.00	17.33	1.00	0.33	0.33	0.33	0.33	0.66	0.00	0.33	558.62=558.62
CD(P=0.05)	–	62.62	NS	26.68	NS	12.25	NS	4.21	NS	0.68	NS	NS	NS	NS	0.76	NS	5 1.15

*May = 69.53% drop ** June= 21.26% drop

weight with the application of all the treatments as compared to control. But, a decrease in fruit weight was recorded with $ZnSO_4$ (0.3 %), $CaSO_4$ (0.6%) and $MgSO_4$ (0.6%) as compared to control. In the present study, the fruit weight was maximum (232.0 g/fruit) with KNO_3 + 2,4-D (2.5% + 20µg/ml) and this is 14.28 % increase over control.

Fruit size

The fruit length ranged between 5.80 to 6.53 cm and fruit breadth ranged between 5.61 to 7.44 cm with different treatments (Table 4). The maximum fruit length (6.53 cm) was recorded in the fruits treated with GA_3 (20µg/ml) followed by 6.51 cm by KNO_3 + 2,4-D (2.5% + 20µg/ml). The fruit breadth was maximum (7.44 cm) with foliar application of KNO_3 + 2,4-D (2.5% + 20µg/ml). However, the foliar application of all the nutrients and plant growth regulators recorded significant increase in fruit length and fruit breadth as compared with control (except for fruit breadth in $FeSO_4$ and $MnSO_4$ + $ZnSO_4$).

Peel characters

There was variation in peel thickness (mm) and peel per cent with foliar application of nutrients and plant growth regulators (Table 4). The minimum peel per cent (19.73) and peel thickness (1.60 mm) were recorded from the fruits which were given foliar application of $MnSO_4$ (0.3%).

Juice and Rag content

The changes recorded in juice per cent and rag per cent with the foliar application of nutrients and plant growth regulators are represented in Table 4. A significant increase in juice per cent has been recorded with the foliar application of $ZnSO_4$ (0.3%), $CaSO_4$ (0.6%), $MgSO_4$ (0.6%), combination of $FeSO_4$ + $MnSO_4$ + $ZnSO_4$ (0.3% each), GA_3 (20µg/ml), 2,4-D (20µg/ml) and combination of two doses of KNO_3 (2.5 + 5%) with 2,4-D (20µg/ml). The maximum juice (54.66%) was recorded from the fruits of the tree which were given foliar application of KNO_3 + 2,4-D (2.5% + 20µg/ml). This treatment is closely followed by 2,4-D (20µg/ml) with 53.83% juice recovery. The rag per cent decreased significantly in almost all the treatments (except 0.3% $MnSO_4$) as compared to control. The minimum rag percentage (20.26) was recorded from the fruits which were given KNO_3 (2.5%) + 2,4-D (20µg/ml).

Acidity, TSS, TSS: acid ratio, reducing sugars

The acidity percent decreased, whereas the TSS per cent and reducing sugars increased with the foliar application of all the treatments, but, TSS recorded decrease with $MnSO_4$ + $ZnSO_4$ (0.1% each). Corresponding to high TSS and low acidity with the foliar application of nutrients and plant growth regulators, there was an increase in TSS: Acid ratio with all the treatments (Table 5). The reduction in acidity with the foliar applications of treatments was non significant, however minimum acidity (0.70%) was recorded in the juice of the fruits which were picked from the trees which are given foliar application of KNO_3 (2.5%) + 2,4-D (20µg/ml) followed by (0.3%) $MnSO_4$ (0.77% Acidity). A significant maximum (11.30 %) TSS was recorded in the juice of fruits that were picked from the trees that were sprayed with GA_3 (20µg/ml).

DISCUSSION

A significant increase in reducing sugar was observed with

Table 3: The effect of nutrients and plant growth regulators on the percent decrease of fruit drop and percent increase of fruit retention in Kinnow mandarin

Treatments	Concentration	Decrease in fruit drop over control (%)	Increase in fruit retention over control (%)
$FeSO_4$	0.3 (%)	11.69	10.81
$MnSO_4$	0.3 (%)	23.37	16.51
$ZnSO_4$	0.3 (%)	14.80	12.90
$CaSO_4$	0.6 (%)	8.62	7.52
$MgSO_4$	0.6 (%)	9.41	5.09
$FeSO_4 + MnSO_4 + ZnSO_4$	0.3 +0.3+0.3 (%)	16.94	14.79
$MnSO_4 + ZnSO_4$	0.1 + 0.1(%)	11.60	10.11
KNO_3 + 2,4 – Dichlorophenoxy acetic acid	5 % + 20 µg/ml	16.73	14.17
KNO_3 + 2,4 – Dichlorophenoxy acetic acid	2.5 % + 20 µg/ml	12.46	10.86
2,4 – Dichlorophenoxy acetic acid	20 µg/ml	17.16	14.96
Gibberellic acid	20 µg/ml	12.80	11.18
Control	Water spray	-	-

Table 4: Effect of different treatments on Physical attributes of fruits of Kinnow mandarin

Treatments	Concentration	Fruit weight (g/Fruit)	Fruit length (cm)	Fruit breadth (cm)	Peel thick ness (mm)	Peel percent (%)	Juice percent (%)	Rag percent (%)
$FeSO_4$	0.3 (%)	213.3	6.13	5.61	1.70	21.36	45.63	32.96
$MnSO_4$	0.3 (%)	221.7	6.24	6.10	1.60	19.73	44.90	38.70
$ZnSO_4$	0.3 (%)	200.0	6.20	6.40	2.10	22.76	51.13	26.10
$CaSO_4$	0.6 (%)	186.1	6.25	7.30	2.16	21.09	48.96	29.93
$MgSO_4$	0.6 (%)	173.4	6.44	6.30	2.00	24.73	49.50	25.63
$FeSO_4 + MnSO_4 + ZnSO_4$	0.3 +0.3+ 0.3 (%)	213.3	6.35	7.25	2.26	25.73	50.53	23.60
$MnSO_4 + ZnSO_4$	0.1 + 0.1(%)	221.8	5.80	5.95	2.40	21.00	45.50	33.50
KNO_3 + 2,4 – Dich lorophenoxy acetic acid	5 % + 20µg/ml	230.0	6.28	6.28	2.46	22.10	50.40	28.40
KNO_3 + 2,4 – Dich lorophenoxy acetic acid	2.5 % + 20 µg/ml	232.0	6.51	7.44	2.73	24.90	54.66	20.26
2,4 – Dichlorophenoxy acetic acid	20 µg/ml	225.0	6.50	7.35	2.66	23.56	53.83	22.56
Gibberellic acid	20 µg/ml	231.8	6.53	7.19	2.40	25.63	52.59	21.63
Control	Water spray	203.3	5.40	5.60	1.93	19.83	43.16	37.00
CD(P = 0.05)	_	09.30	0.36	0.47	0.46	2.52	2.82	4.15

Table 5: Effect of different treatments on quality attributes of Kinnow fruit juice

Treatments	Concentration	Acidity (%)	TSS (%)	TSS: acid ratio	Acid reducing sugars (%)	Vitamin C (mg/100ml)	Flavonoids (mg/g equivalent)
$FeSO_4$	0.3 (%)	0.84	10.80	12.85	1.73	25.90	22.66
$MnSO_4$	0.3 (%)	0.77	10.13	13.15	2.31	25.20	23.96
$ZnSO_4$	0.3 (%)	0.80	10.06	13.25	2.36	36.73	25.23
$CaSO_4$	0.6 (%)	0.98	11.00	11.20	2.54	30.56	23.10
$MgSO_4$	0.6 (%)	0.98	10.60	10.80	2.25	35.60	23.70
$FeSO_4 + MnSO_4 + ZnSO_4$	0.3 +0.3+0.3 (%)	0.82	10.40	12.60	2.24	35.00	23.13
$MnSO_4 + ZnSO_4$	0.1 + 0.1(%)	0.87	8.80	10.10	3.00	32.10	22.80
KNO_3+2,4– Dichloro phenoxy acetic acid	5 % + 20 µg/ml	0.85	10.46	12.30	1.63	41.96	25.40
KNO_3+2,4– Dichloro phenoxy acetic acid	2.5 % + 20 µg/ml	0.70	10.50	15.00	2.61	50.46	24.96
2,4– Dichlorophe noxy acetic acid	20 µg/ml	0.83	9.60	11.50	3.07	48.76	24.23
Gibberellic acid	20 µg/ml	0.94	11.30	12.00	2.85	50.20	24.80
Control	Water spray	0.99	9.40	9.50	1.56	30.43	22.50
CD(P = 0.05)	_	NS	1.19	1.04	0.49	4.10	1.18

Table of Fig. 1: Effect of nutrients and plant growth regulators on the fruit drop and fruit retention in Kinnow mandarin

Treatments	Concentration	Fruit drop (%)	Fruit retention (%)
$FeSO_4$	0.3 (%)	41.16	58.83
$MnSO_4$	0.3 (%)	37.78	62.21
$ZnSO_4$	0.3 (%)	39.71	60.28
$CaSO_4$	0.6 (%)	42.59	57.41
$MgSO_4$	0.6 (%)	42.22	53.11
$FeSO_4 + MnSO_4 + ZnSO_4$	0.3 + 0.3 + 0.3 (%)	38.71	61.29
$MnSO_4 + ZnSO_4$	0.1 + 0.1(%)	41.20	58.79
KNO_3 + 2,4 – Dichlorophe noxy acetic acid	5 % + 20µg/ml	38.81	60.96
KNO_3 + 2,4 – Dichlorophe noxy acetic acid	2.5 % + 20 µg/ml	40.80	59.19
2,4 – Dichlorophenoxy acetic acid	20 µg/ml	38.61	61.38
Gibberellic acid	20 µg/ml	40.64	59.36
Control	Water spray	46.61	53.39
CD(P = 0.05)	_	2.75	2.83

Table of fig. 2: Effect of nutrients and plant growth regulators on the total fruits and fruit yield in Kinnow mandarin

Treatments	Concentrations	Total fruit (No.)	Fruit yield(kg/tree)
$FeSO_4$	0.3 (%)	691.00	160.74
$MnSO_4$	0.3 (%)	630.00	188.84
$ZnSO_4$	0.3 (%)	844.33	204.69
$CaSO_4$	0.6 (%)	641.33	119.92
$MgSO_4$	0.6 (%)	831.33	168.38
$FeSO_4 + MnSO_4 + ZnSO_4$	0.3 + 0.3 + 0.3 (%)	756.33	161.81
$MnSO_4 + ZnSO_4$	0.1 + 0.1(%)	838.33	239.02
KNO_3 + 2,4 – Dichlorophe noxy acetic acid	5 % + 20 µg/ml	727.33	189.84
KNO_3 + 2,4 – Dichlorophe noxy acetic acid	2.5 % + 20 µg/ml	748.00	173.88
2,4 – Dichlorophenoxy acetic acid	20 µg/ml	726.33	150.22
Gibberellic acid	20 µg/ml	776.33	179.36
Control	Water spray	628.00	109.06
CD(P = 0.05)	_	152.13	39.74

most of the treatments, the maximum reducing sugar (3.07%) was recorded in the juice of fruits that were picked from the trees which were given foliar application of 2,4-D (20μg/ml). The maximum TSS: Acid ratio (15.0) was recorded with the foliar application of KNO_3 (2.5%) + 2,4-D (20μg/ml), whereas minimum TSS: Acid ratio (10.1) was recorded $MnSO_4$(0.1%) + $ZnSO_4$(0.1%). In the present investigation, the high TSS: Acid ratio (15.0) and high reducing sugar (3.07%) with the application of KNO_3 + 2,4-D (0.5% + 20 μg/ml) and 2,4-D (20μg/ml) respectively suggests these treatments, as good for improvement of TSS :Acid ratio of fruit juice.

Flavonoids and vitamin C

In the present investigation, maximum Vitamin C (50.46 mg/ml juice) was recorded in the fruits which were picked from the trees sprayed with KNO_3 (2.5%) + 2,4-D (20μg/ml) (Table 5). This increase in Vitamin C is at par with GA_3 (20μg/ml). However, there was a decrease in Vitamin C content with the foliar application of $FeSO_4$ (0.3%) and $MnSO_4$ (0.3 %).

All the treatments recorded an increase in the content of flavonoids as compared to control and eight among the twelve treatments recorded a significant increase. The maximum content of flavonoids (25.40 mg/g equivalent) was recorded from juice of fruit picked from the trees treated with KNO_3 (0.5%) + 2,4-D (20μg/ml).

The application of plant growth regulators for reduction of fruit drop and improvement of fruit quality in citrus has been an instrument for the researchers (Kaur *et al*., 2007; Saleem *et al*.,2008, Jain *et al*., 2015). The maximum fruit drop during the current investigation was recorded during the months of May followed by June and the rest of the drop was distributed in the other months. The maximum fruit drop observed during May and June followed by August for Kinnow mandarin is reported earlier by Kaur *et al*. (2000). Fruit retention depends upon the overall health of the tree and the fruit drop could be due to some nutritional as well as physiological problems. The fruit drop could also be due to low activity or limited supply of auxin to the developing fruits as reported by Lima and Davies (1984) in Navel orange. The findings in the present study have revealed an increase in fruit retention with the foliar application of nutrients and plant growth regulators. Earlier reports on increase in fruit yield by enhancing the fruit retention and reduction of fruit drop in citrus support the present investigation (Srivastava and Singh, 2006). The combination of KNO_3 + 2,4 D (2.5 % and 20 µg/ml) which resulted in 10.86 % increase in fruit retention as compared to

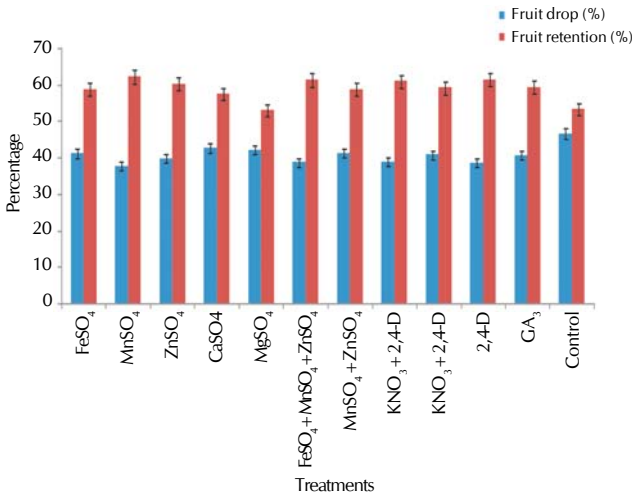

Figure 1: The effect of nutrients and plant growth regulators on fruit drop and fruit retention in Kinnow mandarin.

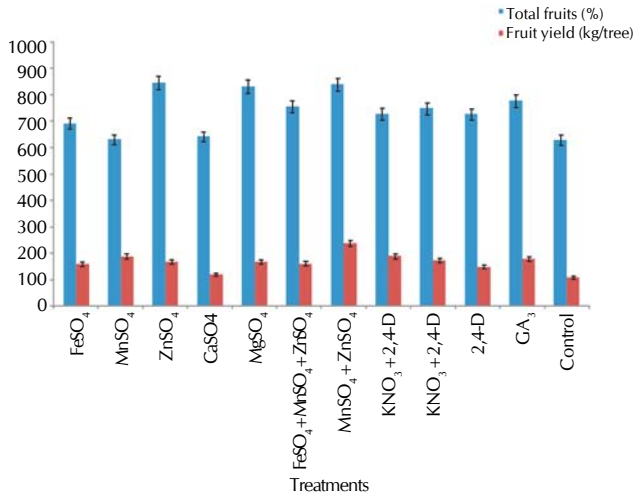

Figure 2: The effect of nutrients and plant growth regulators on total fruit (Number) and fruit yield (Kg/tree) of Kinnow mandarin

control is close to $MnSO_4$ (0.3 %) which resulted in maximum fruit retention (16.51 % increase over control) as is evident from Table 3. The combination of nutrients and plant growth regulators have been tried earlier for the control of fruit drop in citrus (Modise *et al.*, 2009) and increase in fruit retention. Corresponding to higher fruit retention, the nutrients and plant growth regulators mediated an increase in the fruit yield (Fig 2). The increase in fruit yield based on fruit weight recorded a significant increase due to significant increase in fruit size with the foliar application of the treatments. Similar increase in yield and reduction of fruit drop with the application of Zn (75μg/ml), Fe (75μg/ml) and Mn (50 μg/ml) alone or in combination has earlier been reported by Khurshid *et al.* (2008).

There was significant increase in fruit weight (Table 4) with the application of almost of all the treatments. Jain *et al.* (2014) reported increase in fruit weight with the application of 2,4-D in Nagpur mandarin. Increase in fruit weight with 2,4-D (20μg/ml) has also been reported by Singh and Gupta (1972) in sweet orange. In the present study, the fruit weight was maximum with KNO_3 + 2,4-D (2.5% + 20μg/ml) which is 14.28 % increase over control. The increased fruit weight is attributed to increase in fruit size with this treatment. The sink strength has been reported to increase by auxin treatment by Agusti *et al.* (1996). The application of KNO_3, 2,4-D and Gibberellic acid have been reported to improve the fruit growth in Nagpur mandarin by Huchche (2005).

The foliar application of all the nutrients and plant growth regulators recorded significant increase in fruit length and fruit breadth as compared with control (except for fruit breadth in $FeSO_4$ and $MnSO_4$ + $ZnSO_4$). Chundawat and Randhawa (1972) also reported increase in fruit size in Saharanpura grapefruit in response to plant growth regulators. Increase in fruit size in sweet lime has also been observed by Kumar *et al.* (1975) with the foliar application of GA_3 (250-100 μg/ml). Gibberellins activate cell division and cell enlargement processes in vegetative organs and thus are associated with growth (Talon and Zeevart, 1992).

In the present study, the peel thickness and peel per cent have been recorded to increase with the treatments there by adding to the overall fruit weight. The peel thickness is effected by many factors and it may vary in different situations. Chundawat and Randhawat (1972) reported increase in peel thickness in Saharanpur species of fruit with the foliar application of GA_3 and 2,4-D.

The changes recorded in juice per cent and rag per cent with the foliar application of micronutrients and plant growth regulators which are represented in Table 4 reveal a significant increase in juice per cent and decrease in rag percent as compared to control. Jain *et al.* (2014) in their experiment on Nagpur mandarin, reported maximum juice recovery with the spray of GA_3 (100µg/ml) followed by 2,4-D (30μg/ml). 2,4-D application has also been reported to increase juice percentage in Kinnow (Singh and Mishra, 1986).

The acidity percent decreased, whereas the TSS per cent and reducing sugars increased with the foliar application of all the treatments but, TSS recorded decrease with $MnSO_4$ + $ZnSO_4$ (0.1% each). Corresponding to high TSS and low acidity with the foliar application of nutrients and plant growth regulators, there was an increase in TSS: Acid ratio with all the treatments (Table 5). The maximum TSS: Acid ratio (15.0) was recorded with the foliar application of KNO_3 (2.5%) + 2,4-D (20μg/ml). Similar increase in TSS, reducing sugars and decrease in acidity has been observed by Kaur *et al.* (2000) in Kinnow mandarin. An increase in TSS of citrus juice has been reported by Ashraf *et al.* (2012) with Zn and K. A high TSS: Acid ratio is necessary for good juice quality. The citrus juice factories also prefer the juice with high TSS: acid ratio. In the present investigation, the high TSS: acid ratio (15.0) and high reducing sugar (3.07%) with the application of KNO_3 + 2,4-D (0.5% + 20 μg/ml) and 2,4-D (20μg/ml) respectively suggests these treatments, as good for improvement of TSS :Acid ratio of fruit juice. Ashraf *et al.* (2012) suggested the application of Zn + K to attain high TSS: acid ratio of fruit juice. The maximum Vitamin C has also been recorded in the fruits which were picked from the trees sprayed with KNO_3 (2.5%) + 2,4-D (20 μg/ml) Table 5. All the treatments recorded an increase in the content of flavonoids as compared to control.

A positive correlation between Vitamin C and total soluble solids in the juice of Valencia orange has been reported as early as 1951 by Sites and Reitz (1951). In the present investigation also a very high TSS: Acid ratio (15.0) with KNO_3(2.5%) + 2,4-D(20µg/ml) along with high Vitamin C (50.46mg/100ml) has been observed. Potassium and auxins as foliar spray have been suggested for the improvement of Vitamin C of Kinnow juice by Ashraf *et al*. (2012) and Kaur *et al*. (2000) respectively. Due to foliar application of plant growth regulators and micronutrients, Singh and Mishra (1986) observed an increase ascorbic acid content in Kinnow mandarin. Chundawat and Randhawa (1972 and 1973) reported that 2,4-D, 2,4,5-T and CIPA increased the vitamin C content as compared to control in grapefruit. Chundawat *et al*. (1975) and Daulta *et al*.(1986) also found similar improvement in Kinnow fruits in the vitamin C content.

It may thus be concluded that the foliar application of KNO_3 (2.5%) + 2,4-D (20µg/ml) on Kinnow mandarin trees had a positive effect on the fruit quality and yield by reducing fruit drop.

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