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Manipulation of source sink relationship for management of fruit drop in kinnow mandarin

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Abstract

A field experiment to study the effect of plant growth regulators and mineral nutrients as foliar application on source-sink relationship during fruit drop was carried out in Kinnow mandarin during 2013-2014. The plant growth regulators viz., 2,4 - D and gibberellic acid (@ 20μg/ml each) and mineral nutrients viz., $FeSO_4$, $MnSO_4$, $ZnSO_4$ (@ 3.0 % each), $CaSO_4$, $MgSO_4$ (@ 0.6 % each), combination of $FeSO_4$ +$MnSO_4$ + $ZnSO_4$ (@ 0.3 % each), $MnSO_4$ + $ZnSO_4$(@ 0.1 % each), KNO_3 +2,4-D (@ 2.5 % + 20μg/ml), KNO_3 + 2,4-D (@ 5 % + 20μg/ml) were tested as foliar application on eight year old Kinnow fruit plants at Punjab Agricultural University, Ludhiana. The results revealed that there was a significant reduction in fruit drop and increase in fruit yield with the tested plant growth regulators and mineral nutrients by strengthening the sink capacity. The metabolites viz. total soluble proteins, free amino acids, total soluble sugars and starch were more in the leaves as compared to fruits at both the stages of fruit drop, ie., May and August. KNO_3 +2,4D (@ 2.5 % + 20μg/ml) application resulted in maximum metabolic content in the fruits at the two diagnostic stages.

Highlights

- The effect of plant growth regulators and mineral nutrients on fruit drop and fruit yield in Kinnow mandarin
- The effect of plant growth regulators and mineral nutrients on metabolic content in the source and sink during the periods of fruit drop

Keywords: Kinnow, mineral nutrients, plant growth regulators, fruit drop, metabolites

Kinnow mandarin, a hybrid (King x Willow leaf) occupies the prime position among the citrus fruits grown in Punjab. It occupies an area of 48,182 hectares with an annual production of 11,08,618 metric tones (Anonymous 2014-15). Kinnow is a prolific bearer with excellent fruit quality with high juice content, however excessive fruit drop in this fruit crop is a serious threat to the fruit growers. The phenomenon of flowering, fruit set and subsequent fruit drop are affected by several physiological and environmental factors viz. malnutrition, high temperature, humidity, diseases and pest (Ashraf *et al*. 2012; Razi *et al*. 2011). 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. Reports indicate the 2,4-Dichlorophenoxy acetic acid (2,4-D) improved total soluble solids (TSS), TSS : acidity ratio, total sugars and ascorbic acid along with 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 % 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 the 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 (Saleem *et al.* 2005). Hence, an effective supplement of nutrients and plant growth regulators is necessary to produce high quality citrus fruits and control excessive citrus fruit drop which involves the selection of appropriate combination of the nutrients and the plant growth regulators. In recent years, source-sink relationship is one of the most intriguing aspect among the researchers. It involves the physiological and biochemical process with significant crop management ramifications.

Modern fruit growers try to manipulate the source-sink relationship to guarantee adequate fruit production and quality (Gil 2006). Balanced maintenance between vegetative and generative growth of a tree is of great importance for growth and production of fruit plants (Park 2011). Producing and exporting organs in the plant (typically mature leaves) are known as sources, while non-photosynthetic organs (fruits, roots) and immature leaves are known as sinks (Taiz and Zeiger 2006).

The objective of the present study was to elucidate source - sink relationships in Kinnow, with emphasis on leaf (source) and fruit (sink) metabolites during peak period of fruit drop to improve the understanding of these processes in order to contribute to a possible manipulation of their relationship for management of fruit drop.

Material and Methods

The plant growth regulators viz., 2,4 - D and gibberellic acid (@ 20µg/ml each) and mineral nutrients viz., $FeSO_4$, $MnSO_4$, $ZnSO_4$ (@ 3.0 % each), $CaSO_4$, $MgSO_4$ (@ 0.6 % each), Combination of $FeSO_4$ +$MnSO_4$ + $ZnSO_4$ (@ 0.3 % each), $MnSO_4$ + $ZnSO_4$(@ 0.1 % each), KNO3 +2,4 -D (@ 2.5 % + 20µg/ml), KNO_3) + 2,4- D (@ 5 % + 20µg/ml) were sprayed on eight year old Kinnow fruit plants selected at the fruit research farm, Department of Fruit Science, PAU, Ludhiana. There were twelve treatments and the experiment was laid as per Randomized Block Design, keeping three replications per treatment and one tree per replication.

Fruit drop

The data on the number of dropped fruits was recorded at 15 days interval in May and in August. The fruits that dropped underneath of each tree were collected and counted at each stage.

Biochemical Parameters

In order to quantify the metabolites of the leaves (source) and fruits (sink), the leaf and fruit samples were collected in the month of May and August. The experimental samples were processed for the analysis of total soluble sugars, free amino acids, starch and total soluble proteins. The total soluble sugars were estimated by the method of Dubois *et al.* (1956). To quantify total soluble proteins the method given by Lowry *et al.* (1951) was followed. The free amino acids and Starch were determined by the method described by Lee and Takahashi (1966) and McCready *et al*. (1950) respectively.

Fruit yield per tree

Fruit yield on the basis of fruit weight was recorded at the time of harvest from each tree and represented as Kg/tree. Total number of fruits were counted on each tree and the average number of fruits per tree were calculated from the replicated data and represented as number/tree.

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

The data has been analyzed statistically by using ANOVA.

Results and Discussion

The results found from the present investigation along with the relevant discussion is given with following headings:

Table 1: Effect of mineral nutrients and plant growth regulators on the fruit drop during May and August (Number)

Treatments	Concentration	May (Total number of fruit drop)			August (Total number of fruit drop)		
		I	II	Total	I	II	Total
$FeSO_4$	0.3 (%)	278.33	80.66	359.00	9.00	0.66	9.66
$MnSO_4$	0.3 (%)	248.33	74.00	322.33	9.33	0.66	9.99
$ZnSO_4$	0.3 (%)	361.66	116.66	445.00	9.33	0.33	9.66
$CaSO_4$	0.6 (%)	370.33	140.66	511.00	9.00	0.66	9.66
$MgSO_4$	0.6 (%)	389.00	107.00	596.00	10.33	0.66	11.00
$FeSO_4$ +$MnSO_4$ +$ZnSO_4$	0.3 +0.3+0.3 (%)	207.33	131.66	339.00	9.00	0.66	9.66
$MnSO_4$ +$ZnSO_4$	0.1 + 0.1(%)	364.00	118.00	482.00	10.33	0.66	11.00
KNO_3 + 2,4 – D	5 % + 20mg/ml	314.66	114.33	429.00	8.66	0.66	9.33
KNO_3 + 2,4 – D	2.5 % + 20 mg/ml	340.66	146.33	484.33	7.66	0.33	8.00
2,4 – D	20 mg/ml	316.33	119.00	435.33	9.33	0.00	9.33
Gibberellic acid	20 mg/ml	400.33	144.00	544.33	8.00	0.00	8.00
Control	Water spray	572.00	124.33	696.33	18.00	0.66	18.66
CD(P=0.05)	-	44.91	36.55	9.52	1.25	NS	1.55

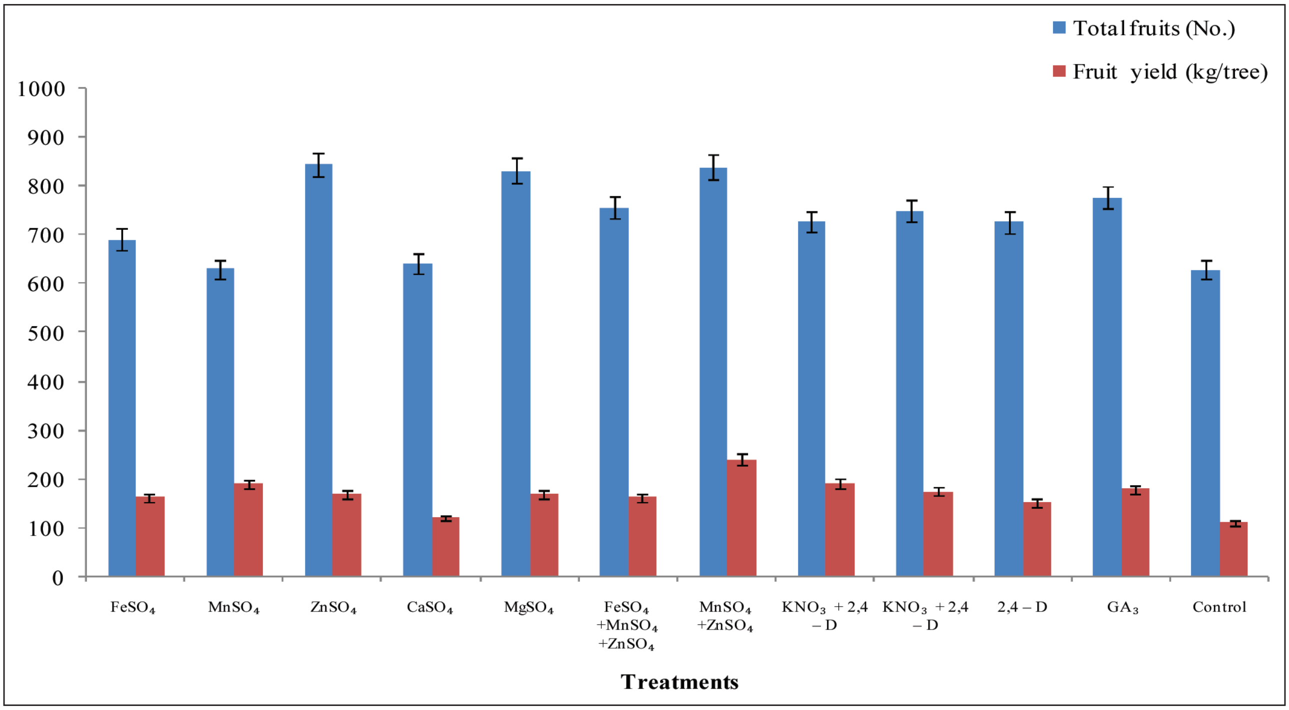

Fig. 1: Effect of mineral nutrients and plant growth regulators on the fruit yield in Kinnow mandarin

Table 2: Effect of mineral nutrients and plant growth regulators on the free amino acids, starch, total sugars and protein content in leaves of Kinnow mandarin during May

Treatments	**Concentration**	Free Amino Acid (mg/g drywt)	Starch (mg/g dry wt)	Total Soluble Sugars (%)	Total Soluble Proteins (mg/g fresh wt)
$FeSO_4$	0.3 (%)	0.47	0.25	0.14	0.42
$MnSO_4$	0.3 (%)	0.60	0.24	0.28	0.47
$ZnSO_4$	0.3 (%)	0.64	0.30	0.56	0.59
$CaSO_4$	0.6 (%)	0.53	0.26	0.40	0.44
$MgSO_4$	0.6 (%)	0.57	0.22	0.34	0.49
$FeSO_4$ +$MnSO_4$ +$ZnSO_4$	0.3 +0.3+0.3 (%)	0.70	0.38	0.61	0.62
$MnSO_4$ +$ZnSO_4$	0.1 + 0.1(%)	0.67	0.38	0.50	0.53
KNO_3 + 2,4 – D	5 % + 20mg/ml	0.77	0.43	0.40	0.51
KNO_3 + 2,4 – D	2.5 % + 20 mg/ml	0.79	0.49	0.37	0.46
2,4 – D	20 mg/ml	0.72	0.40	0.71	0.79
Gibberellic acid	20 mg/ml	0.66	0.37	0.54	0.62
Control	Water spray	0.61	0.26	0.29	0.30
CD(P=0.05)	_	0.20	0.28	0.72	0.25

Table 3: Effect of mineral nutrients and plant growth regulators on the amino acid, starch, total sugars and protein content in fruits of Kinnow mandarin during May

Treatments	Concentration	Free Amino acid (mg/g dry wt)	Starch (mg/g dry wt)	Total Soluble Sugars (%)	Total Soluble Proteins (mg/g fresh wt)
$FeSO_4$	0.3 (%)	0.51	0.29	0.31	0.56
$MnSO_4$	0.3 (%)	0.49	0.27	0.30	0.49
$ZnSO_4$	0.3 (%)	0.63	0.43	0.61	0.63
$CaSO_4$	0.6 (%)	0.55	0.31	0.46	0.52
$MgSO_4$	0.6 (%)	0.60	0.28	0.38	0.49
$FeSO_4$ +$MnSO_4$ +$ZnSO_4$	0.3 +0.3+0.3 (%)	0.63	0.46	0.67	0.63
$MnSO_4$ +$ZnSO_4$	0.1 + 0.1(%)	0.61	0.36	0.56	0.55
KNO_3 + 2,4 – D	5 % + 20mg/ml	0.71	0.47	0.74	0.70
KNO_3 + 2,4 – D	2.5 % + 20 mg/ml	0.75	0.51	0.82	0.80
2,4 – D	20 mg/ml	0.70	0.40	0.66	0.63
Gibberellic acid	20 mg/ml	0.69	0.45	0.61	0.70
Control	Water spray	0.49	0.32	0.38	0.49
CD(P=0.05)	_	0.43	0.28	0.33	0.50

Table 4: Effect of mineral nutrients and plant growth regulators on the free amino acids, starch, total soluble sugars and total soluble protein content in leaves of Kinnow mandarin during August

Treatments	**Concentration**	Free Amino acid (mg/g dry wt)	Starch (mg/g dry wt)	Total Soluble Sugars (%)	Total Soluble Proteins (mg/g fresh wt)
$FeSO_4$	0.3 (%)	0.52	0.23	0.14	0.44
$MnSO_4$	0.3 (%)	0.61	0.22	0.26	0.46
$ZnSO_4$	0.3 (%)	0.63	0.31	0.54	0.59
$CaSO_4$	0.6 (%)	0.53	0.25	0.40	0.44
$MgSO_4$	0.6 (%)	0.58	0.21	0.34	0.49
$FeSO_4$ +$MnSO_4$ +$ZnSO_4$	0.3 +0.3+0.3 (%)	0.70	0.37	0.61	0.61
$MnSO_4$ +$ZnSO_4$	0.1 + 0.1(%)	0.66	0.38	0.51	0.52
KNO_3 + 2,4 –D	5 % + 20mg/ml	0.76	0.43	0.40	0.51
KNO_3 + 2,4 – D	2.5 % + 20 mg/ml	0.78	0.49	0.36	0.46
2,4 – D	20 mg/ml	0.71	0.40	0.70	0.78
Gibberellic acid	20 mg/ml	0.64	0.36	0.54	0.61
Control	Water spray	0.61	0.24	0.29	0.30
CD(P=0.05)	–	0.02	0.02	0.21	0.16

Table 5: Effect of mineral nutrients and plant growth regulators on the free amino acid, starch, total soluble sugars and total soluble protein content in fruits of Kinnow mandarin during August

Treatments	Concentration	Free Amino acid (mg/g dry wt)	Starch (mg/g dry wt.)	Total Soluble Sugars (%)	Total Soluble Proteins (mg/g fresh wt)
$FeSO_4$	0.3 (%)	0.52	0.28	0.31	0.56
$MnSO_4$	0.3 (%)	0.49	0.27	0.30	0.48
$ZnSO_4$	0.3 (%)	0.62	0.44	0.62	0.63
$CaSO_4$	0.6 (%)	0.54	0.31	0.46	0.51
$MgSO_4$	0.6 (%)	0.61	0.27	0.36	0.50
$FeSO_4$ +$MnSO_4$ +$ZnSO_4$	0.3 +0.3+0.3 (%)	0.64	0.45	0.67	0.63
$MnSO_4$ +$ZnSO_4$	0.1 + 0.1(%)	0.54	0.35	0.54	0.55
KNO_3 + 2,4 – D	5 % + 20mg/ml	0.70	0.47	0.74	0.71
KNO_3 + 2,4 – D	2.5 % + 20 mg/ml	0.80	0.52	0.81	0.81
2,4 – D	20 mg/ml	0.62	0.41	0.66	0.63
Gibberellic acid	20 mg/ml	0.70	0.45	0.61	0.71
Control	Water spray	0.48	0.32	0.38	0.48
CD(P=0.05)	–	0.43	0.014	0.017	0.022

Fruit drop

The data on fruit drop and the impact of different plant growth regulators and mineral nutrients on the fruit drop is presented in Table 1. In general, the maximum fruit drop in control plants was recorded during the month of May. The plant growth regulators and mineral nutrients reduced the fruit drop significantly as compared to control. The total number of fruits dropped in control trees were recorded to be 696.33 fruits/tree in May and the minimum (322.33 fruit/tree) were recorded with $MnSO_4$ (0.3%). The number of fruits that dropped in KNO_3+2,4-D (2.5%+20µg/ml) were low (484.33fruit/tree) as compared to control. Fruit drop is a major limiting factor for the yield in Kinnow mandarin. The deficiency of the mineral nutrients disturbs the production of plant growth regulators which ultimately control fruit drop. Reduction in fruit drop with gibberellic acid and 2,4-D has earlier been reported by Saleem *et al.* (2007) in *Citrus sinensis* cv. Blood red. The application of the combination of mineral nutrients and plant growth regulators for reduction of fruit drop has been documented by Saleem *et al.* (2005) in mandarin cultivars.

Fruit yield

The influence of mineral nutrients and plant growth regulators on the fruit yield is presented in Figure 1. There was a significant increase in number of fruits per tree with the foliar application of all the treatments. The maximum increase in total number of fruits has been recorded with the foliar application of $ZnSO_4$ (0.3%). This is closely followed by $MnSO_4$+ $ZnSO_4$ (0.1% of each). The fruit yield (kg/per tree) recorded a significant increase with the foliar application of all the treatment as compared to control. The increase in fruit yield based on fruit weight could be due to a significant increase in the 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). 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). Foliar application of 2,4-D (Jain *et al.* 2014) and Gibberellic acid (Ullah *et al.* 2014) has been reported to increase fruit yield in Nagpur mandarin and Sweet orange respectively.

Metabolites in leaves and fruits during May

The effect of mineral nutrients and plant growth regulators on the metabolites of the source (leaves) and the sinks (fruits) of Kinnow mandarin were analysed during the peak period of drop i.e during May and August. In general, the amount of starch, total soluble sugars and total soluble protein content that was recorded in the leaves is low and these metabolites were high in the fruits as observed in the control as well as all the treatments (Table 2 and 3). There is no definite trend observed in the content of free amino acids which may be because of their differential utilization for their possible role in protein synthesis. In the leaves, the maximum starch content (0.49 mg/dry weight) was recorded with KNO_3 (2.5%)+ 2,4-D (20mg/ml). The maximum starch content in the fruits (0.51mg/g dry weight) has also been recorded with the same treatment. The treatment 2,4-D (20mg/ml) recorded maximum increase in total soluble sugar content in the leaves (0.71% as in Table 2), whereas KNO_3 (2.5%)+ 2,4-D (20mg/ml) recorded maximum increase of total soluble sugars in fruits (0.82% as in Table 3). Similarly, maximum total soluble protein content in the leaves (0.79 mg/fresh weight) and in the fruit (0.80 mg/ fresh weight) has been recorded with the foliar applications of 2,4-D (20µg/ml) and KNO_3+2,4-D (2.5%+20 mg/ml) respectively.

Metabolites in leaves and fruits during August

The effect of mineral nutrients and plant growth regulators on the free amino acids, starch, total soluble sugar and total soluble protein content in the leaves and fruits of Kinnow mandarin during August is presented in Tables 4 and 5. In general, the amount of starch, total soluble sugars and total soluble protein content is recorded to be more in the fruits as compared to leaves at this stage. The variation in the free amino acid content is inconsistent as observed during May sampling.

However, the content of all the metabolites in general, is higher in the samples collected from treatments as compared to the samples collected from unsprayed check. The free amino acids were maximum (0.80 mg/g dry weight) as recorded in fruits of trees that were given foliar application of (2.5%) KNO_3 + 2,4-D (20mg/ml). The same treatment resulted in accumulation of maximum amino acid content (0.78mg/g dry weight) in the leaves. The total soluble protein content in the leaves was recorded to be maximum (0.78mg/g dry weight) with the foliar application of 2,4 –D (20mg/ml) and it was recorded to be (0.81 mg/g dry weight) with the foliar application of KNO_3 (2.5%)+ 2,4-D (20mg/ml). The proteins from the source (leaves) may be translocated to the sink (fruits) with the application of combination of KNO_3(2.5%)+2,4-D(20µg/ml).

An organ that produces more assimilates than it requires for its own metabolism and growth is the source whereas a sink is the importer or consumer of photoassimilates (Hopkins 1999). This accounts for the low content of metabolites in the leaves as compared to fruits. As the leaf approaches its maximum size, its own metabolic demand diminishes and it becomes an exporter. The mature leaf serves as a source of photoassimilates for the sink (fruit). The hormone auxin (2,4-D being a synthetic auxin) has been reported to influence the translocation of photoassimilates stimulating their loading and unloading (Roa *et al.* 2015).

The main source of nutrition is leaves. The fruits accumulate carbohydrates, generally starch and sugar (Kozlowski and Pallard 1997) which depend on the stage of fruit, cultivar, growing conditions and leaf fruit ratio. Different tree organs compete for carbohydrates produced by leaves but fruits have greater sink strength as compared to other organs (Ho 1996). The distribution of assimilates depends on number of factors including adequate supply of nutrients and hormonal balance (Taiz and Zeiger 2006).

Conclusion

It may thus be concluded that the foliar application of plant growth regulators viz., 2,4- D and gibberellic acid (@ 20µg/ml each) and mineral nutrients viz., $FeSO_4$, $MnSO_4$, $ZnSO_4$ (@ 3.0 % each), $CaSO_4$, $MgSO_4$ (@ 0.6 % each), Combination of $FeSO_4$ +$MnSO_4$ + $ZnSO_4$ (@ 0.3 % each), $MnSO_4$ + $ZnSO_4$(@ 0.1 % each), KNO_3 +2,4D (@ 2.5 % + 20µg/ml), KNO_3 + 2,4- D (@ 5 % + 20µg/ml) reduced fruit drop and increased fruit yield by manipulation of the translocation of photoassimilates from the source (leaf) to the sink (fruit). However, KNO_3 +2,4D (@ 2.5 % + 20µg/ml) resulted in stronger sink strength among the different treatments tested.

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