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CONTROL OF EXCESSIVE FRUIT DROP AND IMPROVEMENT IN YIELD AND JUICE QUALITY OF KINNOW (*CITRUS DELICIOSA* X *CITRUS NOBILIS*) THROUGH NUTRIENT MANAGEMENT

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Abstract

Fruit yield and quality of citrus, especially KINNOW (*Citrus deliciosa* x *Citrus nobilis*) in Pakistan is not competitive with that of other countries which could be attributed mainly to the lack of appropriate nutrient management for citrus orchards. The yield losses in citrus occur mainly due to excessive fruit drop. Experiments to overcome these problems were conducted at four different sites one each in Faisalabad, Toba Tek Singh, Jhang and Sargodha districts of Punjab, Pakistan. The soil and leaf chemical analysis showed severe deficiency of Zn in Kinnow. In the present studies, effect of foliar application of Zn, K and salicylic acid (SA) alone or in combination was investigated on fruit yield, excessive fruit drop and juice quality. The fruit trees were pretreated with a selected NPK level. Zinc (0.25% $ZnSO_4$ solution), K (0.25% K_2SO_4 solution) and salicylic acid (10 μM) were sprayed at three different stages, i.e. the onset of spring/flush of leaves or flowers, fruit formation and color initiation on fruit. Overall, application of Zn, K and SA or Zn+K+SA was effective in improving the yield and quality parameters of citrus fruit at all sites. Although fruit drop was reduced by the foliar spray of Zn, K, SA or Zn+K but three foliar sprays of 10μM SA + 0.25% each of Zn and K reduced the citrus fruit drop by 30% and also improved the juice quality. Kinnow fruit yield and juice quality can be effectively enhanced with proper nutrient and hormone applications depending on site conditions.

Introduction

Pakistan grows citrus on about 170 thousand hectares of land, constituting about 30 percent of the area under all fruit trees (Yasin *et al*., 2003). Citrus is grown practically all over Pakistan, however the Punjab province has the largest area under this fruit tree. The major citrus varieties grown in Punjab are mandarins with two varieties viz. Kinnow and Feutrell covering 80 percent of the total citrus growing area (Altaf, 2006). Kinnow, Feutrell and other sweet orange varieties are the rich source of vitamin C and sugar. Pakistan stands among the top ten citrus growing countries in the world. Kinnow is grown primarily in the plains of Punjab province (Naz *et al*., 2007). Its production capacity is 9.5 tons ha^{-1} and 1.28 M tons per season which is far behind than Brazil and other citrus producing countries where it is 40 tons ha^{-1} while some other countries are getting up to 60 tons ha^{-1}. In Pakistan, Kinnow is grown under totally natural conditions to achieve the original flavor of the fruit and to preserve its quality. However, excessive fruit drop is a serious problem in Kinnow, which starts from blooming and continues till final harvesting which may be due to malnutrition, high or low temperatures stress, high rainfall, pests and diseases. Reports indicate that in Pakistan, citrus suffers deficiencies of essential nutrient elements that plants take up from the soil (Ibrahim *et al*., 2007; Ashraf *et al*., 2010; Razi *et al*., 2011). Citrus is a relatively high nutrient demanding crop (Wang *et al*., 2006) and highly responsive to applied nutrients in the form of fertilizers. Enhanced growth with improved fruit yield and quality can be obtained by the application of proper compound fertilizers because any nutrient either deficient or in excess can lead to a reduction in crop yield coupled with inferior fruit quality.

Citrus fruits use large amount of K as compared to other macronutrients (Alva & Tucker, 1999) because K is involved in several basic physiological functions i.e. formation of sugars and starch, synthesis of proteins, cell division and growth and neutralization of organic acids (Liu *et al*., 2000). It improves fruit quality through enhancing fruit colour, size and juice flavour (Tiwari, 2005). Reports indicated the deficiencies of micronutrients like Zn, Cu, Fe and Mn in citrus orchards of Pakistan (Ibrahim *et al.,* 2007) and among them Zn is more acute. Literature indicated that the application of Zn increased the fruit yield and quality (Rodríguez *et al.,* 2005), so the suitable combination of macro-, micronutrients and growth regulators could control the excessive fruit drop and improve the citrus fruit yield and its quality (Doberman & Fairhurst, 2000; Saleem *et al*., 2005). Therefore, effective nutrient management of citrus is required to get desired productivity and quality of fruits that involves finding of appropriate rate, time and method of application as well as selection of suitable combination of fertilizers. Limited information on control of excessive fruit drop in citrus especially Kinnow is available. Moreover, literature on nutrient management to control fruit drop is also scanty. Therefore, present studies were conducted with an objective to estimate influence of K, Zn and salicylic acid on fruit set, fruit drop patterns, yield and juice quality of citrus (Kinnow).

Materials and Methods

Site Selection: Experiments were conducted at four sites in citrus growing belt of Punjab, Pakistan [Faisalabad

(NIAB), Jhang (Ghar More, Sargodha (75 Janubi) Toba Tek Singh (297/G.B)]. Soil samples from each site up to 60 cm depth were collected and analyzed for pH (pH_s) and electrical conductivity (EC_e). Other chemical analysis like that for organic matter (Nelson & Sommers, 1982) total N (Kjeldhal method), Na, K, Ca^{2+}, Mg^{2+}, CO_3, HCO_3 and P was carried out as described by the Anon., (1954) and Jackson (1962) (Table 1). The irrigation water was also analyzed according to Anon., (1954).

Table 1. Soil characteristics (0-60 cm) of four selected sites to study the effect of different sources of K (SOP and MOP) on the yield and quality of citrus

Soil characteristics	Values			
	Faisalabad (NIAB)	**T. T. Singh (297/G B)**	**Jhang (Ghar More)**	**Sargodha (75 Janubi)**
Physical				
Soil texture	Clay loam	Sandy clay loam	Sandy clay loam	Clay loam
Chemical				
EC_e(dS m^{-1})	0.72-0.92	0.96-0.98	0.98-1.89	1.92-3.28
pH_s	7.5-7.8	6.8-7.3	7.0-7.5	7.62-7.77
Organic matter (%)	0. 4-0.6	0.5-0.6	0.25-0.32	0.6-0.66
NO_3-N (mg kg^{-1})	10.7-14.7	17.3-17.4	7.4-11.3	14.1-15.3
P (mg kg^{-1})	8.2-10.8	8.6-11.2	7.5-9.8	9.4-11.4
K (mg kg^{-1})	108-200	80-115	78-107	82-117
Ca+Mg (meq L^{-1})	3.75-5.76	7.0-7.5	0.18-0.30	12.6-15.7
CO_3 (meq L^{-1})	Nil	Nil	Nil	Nil
HCO_3 (meq L^{-1})	3.5-4.0	3.0-6.0	2.0-2.5	1.6-3.0

Characteristics of irrigation water	
Canal water characteristics	**Values**
EC (dS m^{-1})	0.77
pH	7.9
SAR (Sodium adsorption ratio)	5.7
Na (meq L^{-1})	7.0
Ca+Mg (meq L^{-1})	3.0
K (meq L^{-1})	0.7
CO_3 (meq L^{-1})	Nil
HCO_3 (meq L^{-1})	2.0

Treatments: Results of the previous studies (Ashraf *et al.,* 2010 & 2011) indicated that in all the selected citrus there was a severe deficiency of K and Zn. Therefore, experiments were conducted to estimate the foliar application of Zn, K, salicylic acid (SA) and their combinations on, fruit yield, fruit dropping and juice quality. Experiments at all these sites were conducted using selected NPK levels [100 kg N ; 50 kg P_2O_5 as urea and DAP and 75 kg K_2O ha^{-1} as sulfate of potash (SOP)] as basal dose just after harvesting the fruits. At each site, 100 trees on an area of one acre were selected for Zinc (0.25 % Zn as $ZnSO_4$ solution), K (0.25 % K as K_2SO_4 solution), SA (10 µM) and their combinations containing 0.02% Tween-20 application (treatment detail is given in Table 2), which were sprayed at flower initiation, fruit formation and at color initiation on fruit, along with control sprayed with distilled water. Each orchard consisted of 100 trees and each row comprised of 10 trees; in each row first and last tree were considered as non-experimental. Of the remaining eight trees, foliar spray of each treatment was conducted on randomly selected trees. In this way ten replications of each treatment were maintained for each orchard.

Table 2. Treatments Details

Treatment	Description	Sources	Fertilizer rate kg ha^{-1} N:P2O5:K2O & Foliar sapplication
Control (C)	N+P+K	Urea+DAP+SOP	100 : 50 :75
SA	Salicylic acid	Urea+DAP+SOP Salicylic acid	-do- + foliar application of 10 µmol SA
Zn	ZnSO4	Urea+DAP+SOP Zinc sulphate	-do- + foliar application of 0.25 % Zn
K	N+ P +K	Urea+DAP+SOP	-do- + foliar application of 0.25 % K
SA+Zn	N+ P +K	Urea+DAP+SOP	-do- + foliar application of SA+Zn
SA+K	N+ P +K	Urea+DAP+SOP	-do- + foliar application of K+SA
K+Zn	N+ P +K	Urea+DAP+SOP	-do- + foliar application of K+Zn
SA+K+Zn	N+P+K	Urea+DAP+SOP	-do- + foliar application of K+Zn+Sa

Fruit drop and yield: Fruit samples from control and treated plants were collected and their circumference/diameter was measured with measuring tape to determine the fruit size. Peel thickness and juice contents were also measured. Number of flowers at full bloom were counted to determine the fruit set. Fruits were counted after two weeks of full bloom and fruit setting was calculated by using the following formula:

Fruit set (%) = [Total number of fruitlets / Total number of flowers] x 100

Fruit dropping was calculated by counting fruits again in July and percent fruit drop calculated as given below:

Fruit drop (%) = [(Total no. of fruitlets – No. of fruits in late July) / Total no. of fruit-lets] x 100

Fruit retention was estimated by counting number of fruits retained upto final harvest and following formula was used for the determination of this parameter:

Fruit retention (%) = [Number of fruits retained/total number of fruitlets] x 100

Fruit yield was recorded at harvest time, on an individual tree basis and expressed as total fruit number.

Juice quality and chemical analysis: Juice volume was estimated after mechanical extraction from fruits of equal size selected from all sites. Juice pH was determined by pH meter and total brix (total solids in the juice) were determined by refractometer. Citric acid was estimated by titrating the juice against 0.1 *N* sodium hydroxide, and ascorbic acid by reducing 2,6-dichlorophenol indophenol with the juice. N, P, K, Ca, and Na contents in juice were also analyzed as described elsewhere (Ashraf e*t al*., 2010).

All the collected data were statistically analyzed and significant means were separated by using Least Significant Difference test (Steel *et al*., 1997).

Results and Discussion

Control of fruit drop and yield: Fruit setting per tree significantly improved with the foliar application of Zn, K, SA or their combinations at all sites. The highest fruit setting was recorded in the trees sprayed with Zn + K+SA followed by K+SA and K alone. All foliarly sprayed trees had significantly increased the fruit setting. Site to site variations showed that the highest fruit setting was at T.T. Singh followed by Sargodha, Faisalabad and Jhang. Results clearly indicated that foliar supply of Zn, SA, K and their combinations were effective in improving the citrus fruit setting (Fig. 1B). Results also indicated that in nutritionally deficient orchards, foliar application of nutrients is very effective. Literature confirmed that foliarly applied nutrients or growth regulators are beneficial in enhancing the citrus fruit setting (Saleem *et al*., 2005; El-Saida, 2001; Omaima & Metwally, 2007).

Foliar application of SA, Zn, K and their combination reduced the fruit drop at all the selected sites (Fig. 1C). Fruit drop was the highest in plants which were sprayed with distilled water i.e. control. The lowest fruit drop was recorded in those trees which were treated with Zn + K+SA closely followed by K+Zn and K+SA. The maximum fruit drop was recorded at Jhang followed by Faisalabad and Sargodha while it was the minimum at T.T. Singh. Citrus fruit drop is a serious problem in Punjab, Pakistan especially in Kinnow which may be due to different reasons and nutrients deficiency is one of the most serious one. Different types of treatments have been suggested by different workers (Sattar, 1999; Saleem *et al*., 2005; Modise *et al*., 2009). Agustí *et al*., (2006) and Modise *et al*. (2009) used 2,4-D to control the fruit drop in citrus while El-Otmani (1992) suggested combination of 2,4-D and GA_3. Similarly low-biuret urea was recommended by Saleem *et al*. (2008) while urea and GA_3 was used by Ibrahim *et al.* (2011) to control the excessive fruit drop in different varieties of citrus.

Fruit retention was also higher in plants where Zn, SA, K or their combinations were foliarly applied (Fig. 1D). Maximum fruit retention was noted under K+SA+Zn treatment in all selected orchards. Fruit retention was different in different selected orchards. The highest fruit retention was noted in orchard of T.T. Singh followed by Sargodha, Faisalabad and Jhang. So application of Zn, K and SA is effective in retention of fruit upto final harvest resulting increases in fruit yield. El-Baz (2003), Omaima and Metwally (2007) and Ashraf *et al*. (2011) also suggested that foliar application of K, Zn or Zn + K is effective in enhancing the fruit retention per tree. In present study, foliar application of Zn+K+SA was more effective than Zn+K. In contrast to these, different combinations of nutrients and plant growth regulators (PGR) are available in literature, e.g., 2,4-D (Agustí *et al*., 2006; Modise *et al*., 2009) low-biuret urea and GA3 (Saleem *et al*.,2008) urea and GA_3 (Ibrahim *et al*., 2011).

Trees sprayed with SA, Zn, K or their combinations produced higher number of fruits than control at all experimental sites (Fig. 1A). The highest fruit numbers were found in trees sprayed with Zn+SA + K followed by K+Zn. Site variations for number of fruit per tree were also recorded and the maximum fruits per tree were obtained from the orchard of T.T. Singh followed by Sargodha. Number of fruits recorded for Faisalabad and Jhang were similar. Findings of the present study showed that to obtain higher citrus fruit yield, foliar application of Zn+SA+K is necessary. Literature also indicated that nutrient management can increase the fruit yield by enhancing fruit number, retention and reducing fruit drop (Srivastava & Singh, 2006; Saleem *et al*., 2008; Ashraf *et al*., 2010 & 2011). Reports indicated that foliar application of macro- and micronutrient and PGR increased fruit yield in citrus (Tariq *et al*., 2007; Ashraf *et al*., 2011, Ibrahim *et al*., 2011).

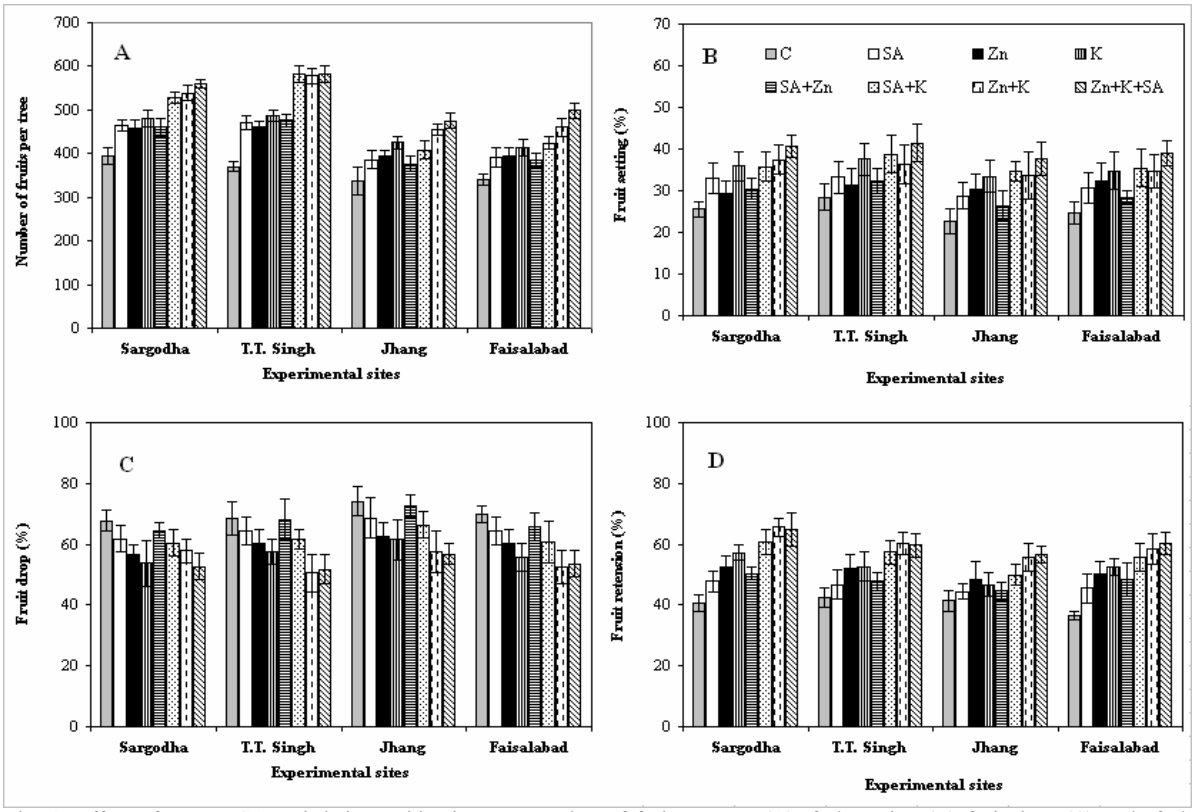

Fig. 1. Effect of Zn, K, SA and their combinations on number of fruit per tree (A), fruit setting (B) fruit drop (C) and fruit retention (D) of Kinnow plants growing in four different orchards.

Application of SA, Zn, K or their combinations significantly increased the juice volume/contents per fruit at all sites (Fig. 2 A). The maximum juice contents were obtained from those plants which were foliarly sprayed with Zn+SA + K. Juice volume also varied from site to site; it was the highest in case of Sargodha orchards followed by T.T. Singh, Faisalabad and Jhang. Results showed that foliar application of Zn +SA+ K was effective in enhancing juice volume/contents. Findings of Omaima & Metwally (2007) and Ashraf *et al*., (2011) confirmed the above results and proved that foliar application of Zn + K enhances the juice content while Rehman *et al*. (1999) reported that only Zn application significantly increased juice contents/volume in orange. While Saleem *et al*., (2008) suggested that low-biuret urea (LBU) application as a foliar spray increased yield of marketable fruits and quality of Sweet Orange (*Citrus sinensis* L. Osbeck.). The juice contents/volume is very important character because juice industry prefers fruits with with higher juice contents and so it is obvious that the orchards having fruits containing more juice fetch more prices.

The juice pH was non-significantly increased by the application of Zn, K, SA or their combinations (Fig. 2 B). Site to site variations also showed non-significant pattern. However, juice total soluble solids (TSS) improved significantly with Zn, SA, K and their combinations at all sites (Fig. 2 C). The highest TSS was recorded under Zn+SA + K treatment. Site to site variation showed that the highest juice TSS values were recorded for Sargodha followed by T.T. Singh, Faisalabad and Jhang. From the results it can be concluded that application of Zn+SA+ K is effective in improving the juice TSS. Ashraf *et al*., (2011) proved that Zn+K increased the TSS in citrus juice while El-Khawag (2007) reported that application of Zn enhanced the TSS of pomegranate juice. From the present study it is very clear that when Zn+K applied in combination of SA their effect in improving juice TSS further increased which is necessary for improving the juice quality.

Results of present study proved that Zn, K, SA alone or in combination enhanced the ascorbic acid concentration in juice of Kinnow; it was the maximum in those trees which were foliarly sprayed with Zn+SA+ K (Fig. 3 A). Ascorbic acid content varied from orchard to orchards; fruit obtained from Sargohda orchard had higher ascorbic acid content than all other orchards. Minimum ascorbic acid concentrations were noted for Faisalabad. It is very clear from these results that foliar application of Zn+SA+K is effective in increasing the ascorbic acid concentrations of juice. Literature also confirmed that Zn application markedly improved the juice ascorbic acid contents (Nakhlla, 1998; Abd El-Moneim *et al*., 2007). Ashraf *et al*., (2012) recommended Zn+K as foliar spray to improve the ascorbic acid of Kinnow juice. Present findings proved that application of Zn+SA+K is more effective than Zn+K or other combinations reported by other workers (Agustí *et al*., 2006; Saleem *et al*., 2008; Modise *et al*., 2009; Ibrahim *et al*., 2011).

Concentrations of citric acid in citrus fruit juice decreased with Zn, SA, K or their combinations in all orchards, however, spray with Zn or Zn+K showed the similar values for citric acid as that in control (Fig. 3B). Minimum citric acid concentration was recorded for the

plants sprayed with Zn+SA+K followed by SA+Zn, SA+K and SA alone. Citric acid concentration also influenced by the experimental sites; the maximum citric acid was recorded for the fruits obtained from Faisalabad and Jhang. The juice TSS/acid ratio increased with the application of SA, Zn, K alone and their combinations in all selected orchards (Fig. 3 C). Fruit with the highest juice TSS/acid ratio was recorded for Zn+SA+K treatment. It also varied from site to site and was the maximum for Sargodha, followed by T.T. Singh. The Faisalabad and Jhang sites maintained the minimum TSS/acid ratio. From the results it is very clear that the most effective treatment was Zn+SA+K where the highest TSS/acid ratios were recorded. The high TSS/acid ratio is necessary for good quality juice. Citrus juice factories also prefer those fruit having high TSS/acid ratio therefore, application of Zn+SA+K is suggested to improve the TSS/acid ratio. Abd-Allah (2006) also found an improvement in TSS/acid ratio with the application of K in combination with micronutrients; while Ashraf *et al*. (2012) suggested Zn+K and other workers recommended different combinations.

The overall results of the experiments of 2008-09 show that Zn and K when applied along with 10µM SA improved citrus fruit yield and juice quality and reduced the excessive fruit dropping.

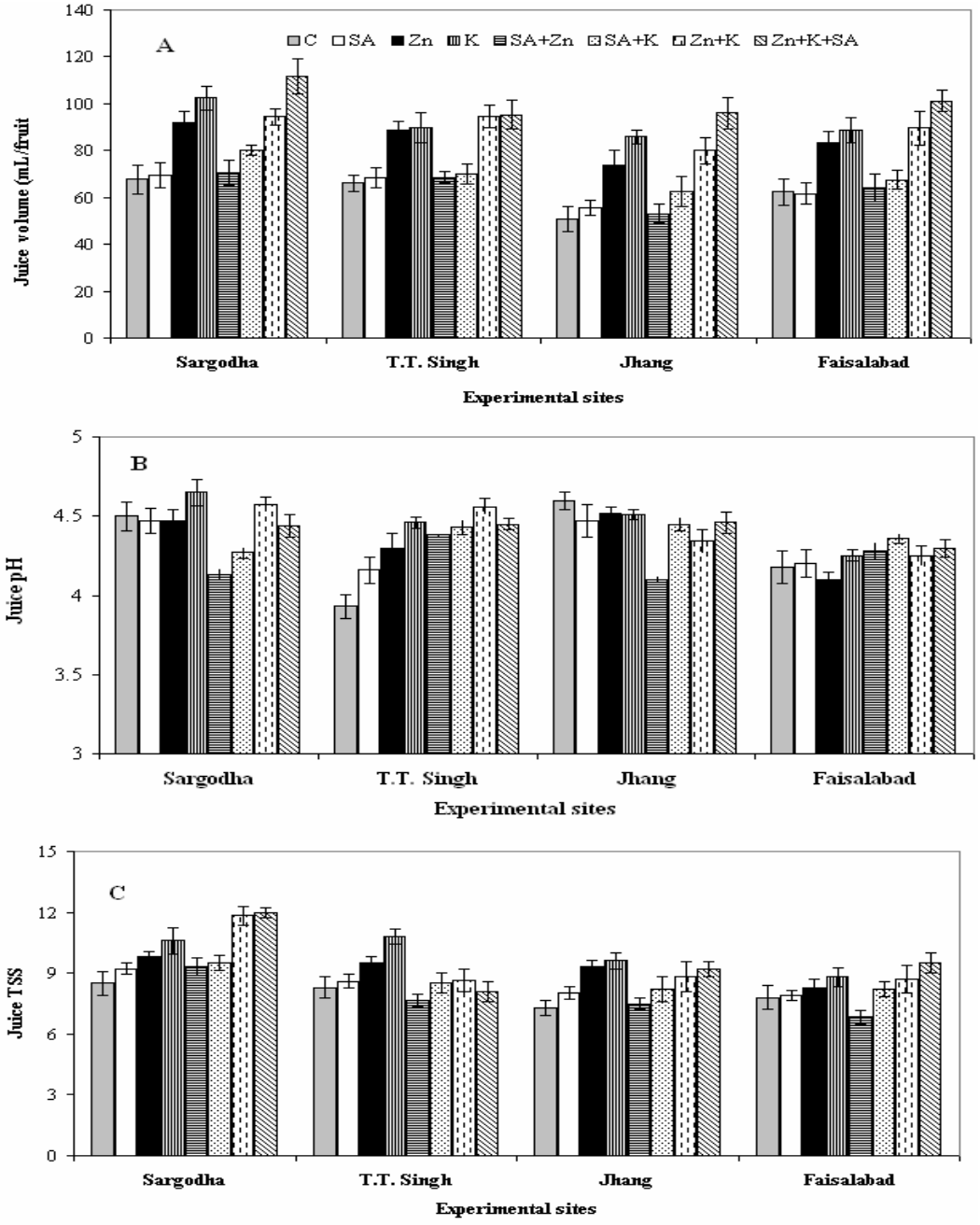

Fig. 2 Effect of foliar application of Zn, K SA and their combinations on juice volume (A), pH (B)and TSS (C) of Kinnow plants growing in four different orchards

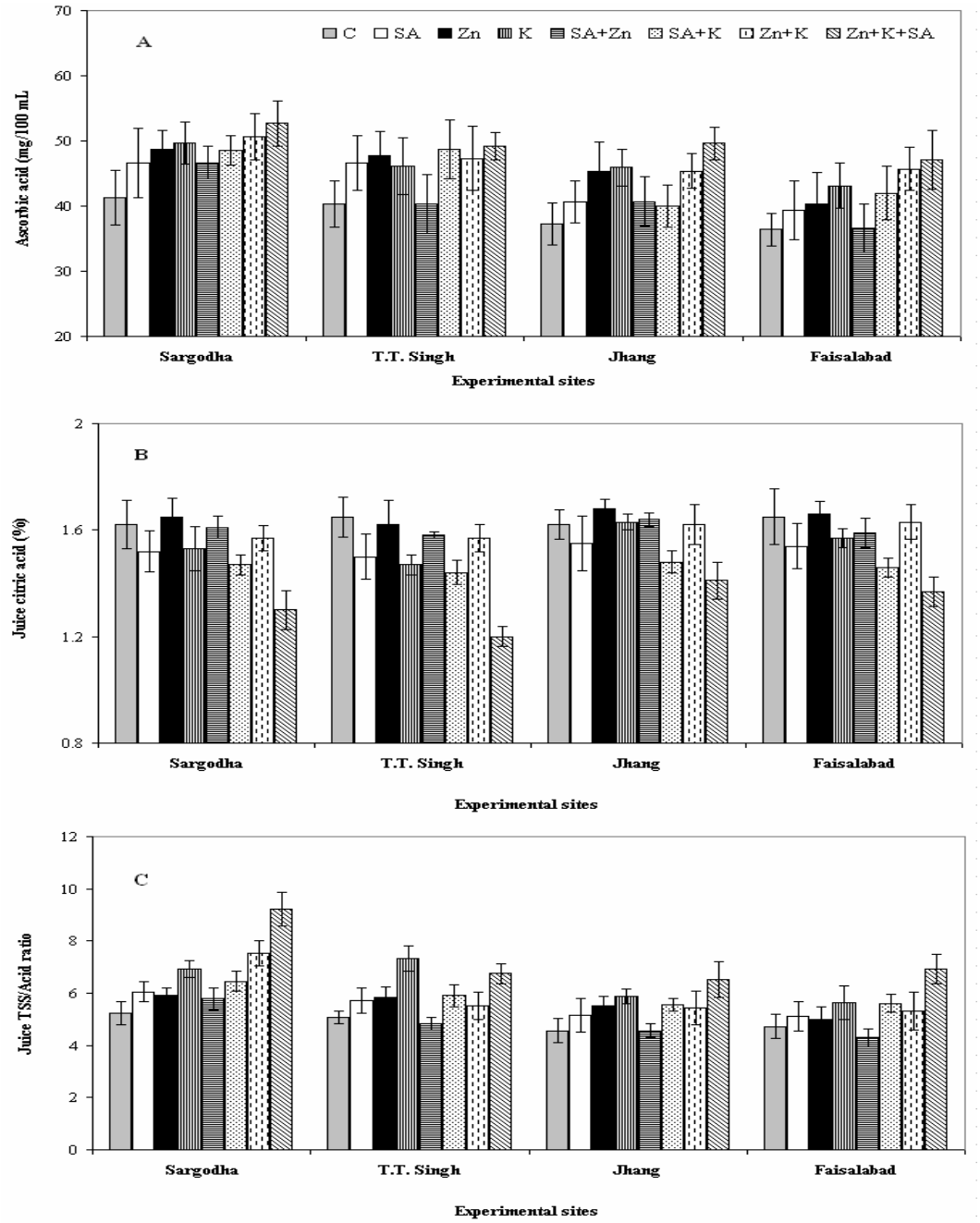

Fig. 3. Effect of Zn, K SA and their combinations foliar spray on juice ascorbic acid (A), citric acid (B) and TSS/acids ratio (C) of Kinnow plants growing in four different orchards.

Conclusions

Foliar application of Zn+K+SA [Zn (0.25 % Zn as $ZnSO_4.H_2O$ solution), K (0.25% K as K_2SO_4 solution), and salicylic acid (10µM)] is effective in reducing excessive Kinnow fruit drop, improving fruit yield and juice quality by increasing juice volume/contents, pH, TSS, ascorbic acid and TSS/acid ratio of juice. Therefore, foliar application of Zn + K+SA is recommended at the onset of flowers, fruit formation and at the stage of color initiation on fruit.

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