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MODULATION IN YIELD AND JUICE QUALITY CHARACTERISTICS OF CITRUS FRUIT FROM TREES SUPPLIED WITH ZINC AND POTASSIUM FOLIARLY

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□ *Citrus, especially K innow (*Citrus deliciosa × Citrus nobilis*), fruit yield and quality in Pakistan is not competitive with that of other countries which could be mainly attributed to the lack of good nutrient management for citrus orchards. The yield losses in this fruit crop occur mainly due to heavy fruit dropping. 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 and our pervious results have shown that soil amendment with potassium (K) at 75 K_2O kg ha^{-1} improved the citrus fruit yield and quality at all selected sites. In the present experiments, effect of foliar application of Zn and K alone or in combination was studied on nutrient uptake, fruit yield, fruit dropping and juice quality. The fruit trees were pretreated with a selected K level of sulfate of potash (SOP) or muriate of potash (MOP), i.e., 75 kg K_2O ha^{-1} along with recommended nitrogen (N) and phosphorus (P) doses. Zinc [Zn, 1% zinc sulfate ($ZnSO_4$) solution], K [1% potassium sulfate (K_2SO_4) solution] and Zn + K (solution containing 0.5% each of $ZnSO_4$ and K_2SO_4) were sprayed at the onset of spring and flush of leaves or flowers, fruit formation and at color initiation on fruit. Overall, application of Zn, K or Zn + K was effective in improving the nutrient uptake, yield and quality parameters of citrus fruit at all sites. Fruit dropping was also reduced by the foliar spray of Zn, K or Zn + K but the most promising results were recorded with foliar spray containing both Zn and K.*

Keywords: potassium, zinc, citrus, fruit drop, fruit yield

INTRODUCTION

Citrus is the largest fruit crop grown in Pakistan and Kinnow is the major planted species. About 94% of the total citrus is produced in the Punjab

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province (Sharif et al., 2005). Macro- and micro-nutrient deficiencies have been reported in citrus orchards of Punjab (Rashid et al., 1994). These deficiencies are usually recognized by distinctive symptoms that appear on the leaves and sometimes on fruits, branches or general growth of the tree (Ibrahim et al., 2007). Sometimes, a combination of low or excessive amount may conceal characteristic symptoms of a particular nutrient and make visual identification more intricate. In such situations, leaf analysis is the tool that provides an accurate diagnosis on the basis of which necessary nutrient management can be suggested. Most of the Pakistani soils are calcareous with pH more than 7.0 due to the presence of calcium carbonate ($CaCO_3$). These soils also contain a significant quantity of sodium (Na), which is harmful for plant growth and optimum productivity (Ibrahim et al., 2007). To have economical plant productivity on such soils, proper supply of potassium (K) along with nitrogen (N), phosphorus (P), and micronutrients is necessary.

Citrus fruits remove large amount of K as compared to other nutrients (Alva and Tucker, 1999). Potassium is transported from leaves to fruit and finally to seeds (Zeng et al., 1996). Potassium has been reported to be vital for a multitude of physiological processes like synthesis of important biomolecules such as sugars, starch and proteins and number of growth processes (Liu et al., 2000). Potassium plays a vital role in fruit development and enhancing fruit size, color and flavor (Tiwari, 2005). It helps minimize the effect of harmful environmental conditions like water stress, low temperature and flooding (Cakmak et al., 1995). Potassium helps to control the carbon dioxide (CO_2) supply to plants by stomatal regulation. It improves the efficiency of plant water and sugar use in maintaining the functioning of growth processes (Liu et al., 2000). Potassium is effectively involved in maintaining resistance to various diseases. Supply of high amount of N with low amount of K is reported to be involved in protein building blocks, and slows down fruiting, and enhances fruit drop (Zaied et al., 2006). Low supply of K considerably affects crop yield and quality. However, moderate levels of K can cause a general reduction in growth without the appearance of any visible deficiency symptoms (Mustafa and Saleh, 2006).

Deficiency of micronutrients like zinc (Zn), copper (Cu), iron (Fe), and manganese (Mn) has also been reported in citrus orchards of Pakistan (Ibrahim et al., 2007). Application of Zn improved the yield and quality of citrus fruits (Rodríguez et al., 2005), so the proper combination of N, P and K with micronutrients could further enhance the citrus fruit yield and its quality (Doberman and Fairhurst, 2000). 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 suitablecombination of fertilizers. Limited information about nutrient management of citrus orchards in Pakistan exists especially on K and Zn nutrition. Therefore, obtaining of such information regarding the effect of K and Zn supply was thought imperative to get high quality citrus fruit that would help promote citrus export of the country so as to bring about overall socio-economic gains.

MATERIALS AND METHODS

Site Selection

Studies were conducted at four sites in major citrus growing districts of Punjab province in Pakistan i.e. Faisalabad (NIAB), Toba Tek Singh (297/G.B), Jhang (Ghar More) and Sargodha (75 Janubi). Soil samples were collected up to 60 cm depth with an augur having a stainless steel cutting cylinder. Each soil sample was composite of four soil cores. Soil pH (pH_s) and electrical conductivity (EC_e) were determined with pH meter and EC meter, respectively. Organic matter was estimated by the modified Walkley-Black procedure (Nelson and Sommers, 1982) and total N by the Kjeldahl method. Sodium, K, calcium (Ca^{2+}), magnesium (Mg^{2+}), carbonate (CO_3), bicarbonate (HCO_3), and P were determined using analytical methods described by the U.S. Salinity Laboratory Staff (1954) and Jackson (1962) and summarized in Table 1.

Irrigation Water

All orchards were irrigated with canal water. Analysis of water used for irrigation purpose is briefly given in Table 2.

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

	Values			
Soil characteristics	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

TABLE 2 Characteristics of irrigation water

Canal water characteristic	Value
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

Fertilizer Treatments

Results of the previous studies (Ashraf et al., 2010) showed that citrus remove more K than N so application of K in large amount to citrus orchards is required. Secondly, severe deficiency of Zn was noticed. Therefore, experiments were conducted consecutively for two years to examine the effect of foliar application of Zn, K or Zn + K on nutrient uptake, fruit yield, fruit dropping and juice quality. The results presented are thus means of two years data. Experiments at all these sites were conducted using selected K level, i.e., 75 kg K_2O ha^{-1} as sulfate of potash (SOP) or muriate of potash (MOP) along with recommended N and P doses. The experiment on each site comprised of 100 trees on an area of one acre. Zinc (1% $ZnSO_4$ solution), K (1% K_2SO_4 solution) and Zn + K (solution with 0.5% each of $ZnSO_4$ and K_2SO_4) containing 0.02% Tween-20 were sprayed at the onset of spring season and flush of leaves or flowers, fruit formation and at color initiation on fruit, along with control sprayed with distilled water. Each row of orchard contained 10 trees; first and last tree were considered as non-experimental. Of the remaining eight trees, foliar spray of each treatment was applied on two of them selected randomly for each treatment. In this way five replications of each treatment were maintained for each of SOP and MOP treated plants. Leaf samples from all orchards were collected before and 10 days after the application of final Zn, K or Zn + K spray and analyzed for nutrient contents using the same method described by Ashraf et al. (2010).

Leaf Analyses

Leaf samples were collected before applying fertilizers and 5-month old spring flush leaves were collected after fertilizer application. Leaves were sampled from 10 randomly selected trees in an orchard and a total of 100 leaves were collected for each sample. Leaf samples were washed with distilled water, dried at 70°C and ground in a Wiley mill fitted with stainless steel cutting blades. Leaf samples were digested with sulfuric acid (H_2SO_4) and hydrogen peroxide (H_2O_2) according to Wolf (1984). Total N in the digests was determined by the Kjeldahl method while P determined by the yellow color method (Jackson, 1962). The digests were analyzed for Na and K using a flame-photometer (Jenway PFP-7, Stone, UK) while Zn was determined by atomic absorption spectrometer (NOVAA 400, Analytik Jena, Jena, Germany).

Fruit Yield and Quality

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. For fruit quality, visual observations on fruit, i.e., color brightness, skin smoothness, lesions on fruit skin, and peel thickness were noted.

Flowers at full bloom were counted to estimate the fruit set. Fruit percentage was determined by counting number of fruits formed two weeks after full bloom and by using the following formula:

Fruit set = [Total number of fruitlets/Total number of flowers] × 100

Fruit dropping was estimated 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] × 100

Fruit retention was determined by counting number of fruits retained till harvest time. The percent fruit retention was calculated using the following formula:

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

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

Juice Quality and Chemical Analysis

Juice volume was measured after mechanical extraction from fruits of equal size selected from all sites. Juice pH was measured by pH meter and brix or 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. Nitrogen, P, K, Ca, and Na contents in juice were also analyzed as described elsewhere (Ashraf et 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

The results regarding the influence of Zn, K or Zn + K spray on leaf nutrient contents show that leaf N, P, K and Zn significantly increased with

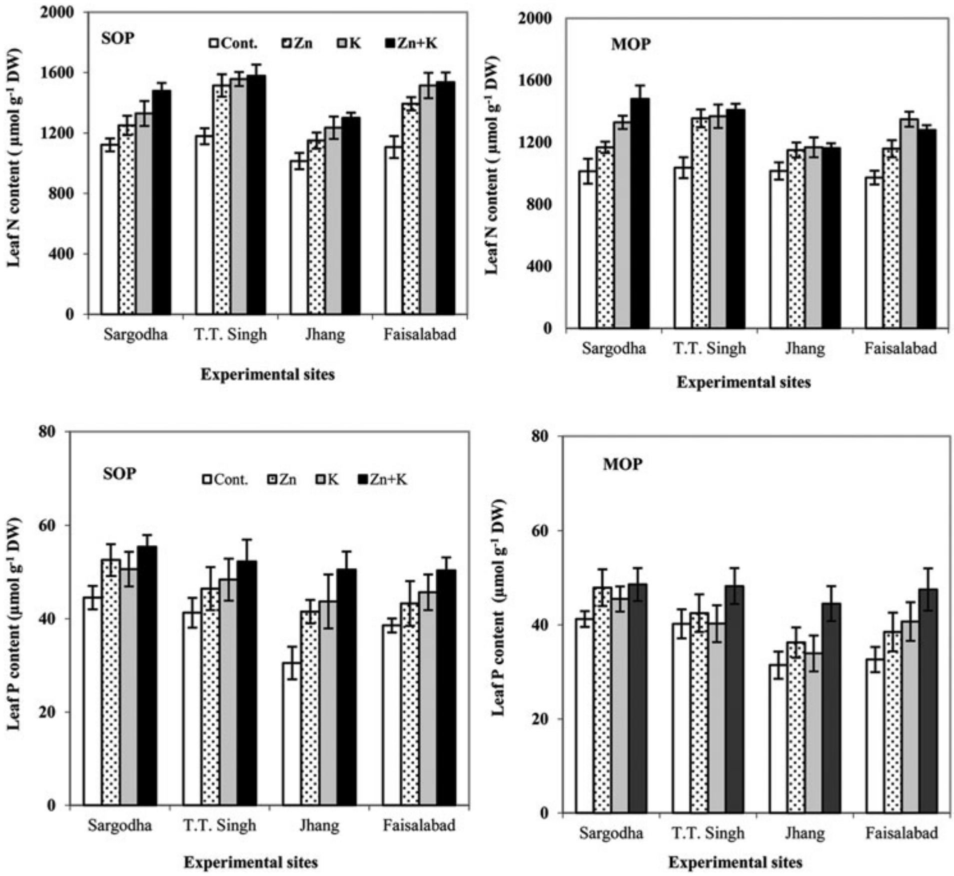

FIGURE 1 Effect of Zn, K or Zn + K foliar spray on leaf N and P contents in SOP and MOP treated plants of four experimental orchards.

foliar application of Zn, K or Zn + K as compared to control both in SOP or MOP treated plants at all sites (Figures 1 and 2). The plants treated with SOP through soil amendment maintained higher nutrient contents than that with MOP. Comparison among treatments indicated that foliar spray with Zn + K was the most effective one at all experimental sites in improving uptake of N, P, K and Zn, however, the highest Zn contents were observed in plants sprayed with Zn alone. The highest N contents were recorded for T. T. Singh and lowest at Jhang while the maximum P contents were found in the leaf samples collected from Sargodha followed by T. T. Singh, Faisalabad and Jhang. The highest leaf K contents were found in the plants growing at Faisalabad followed by T. T. Singh, Sargodha and Jhang. From these results, it can be concluded that application of Zn, K or Zn + K as foliar spray proved beneficial for improving the plant nutrient uptake. The improvement in nutrient uptake may be due to the involvement of K and Zn in metabolic pathways such as K plays important role in improving water

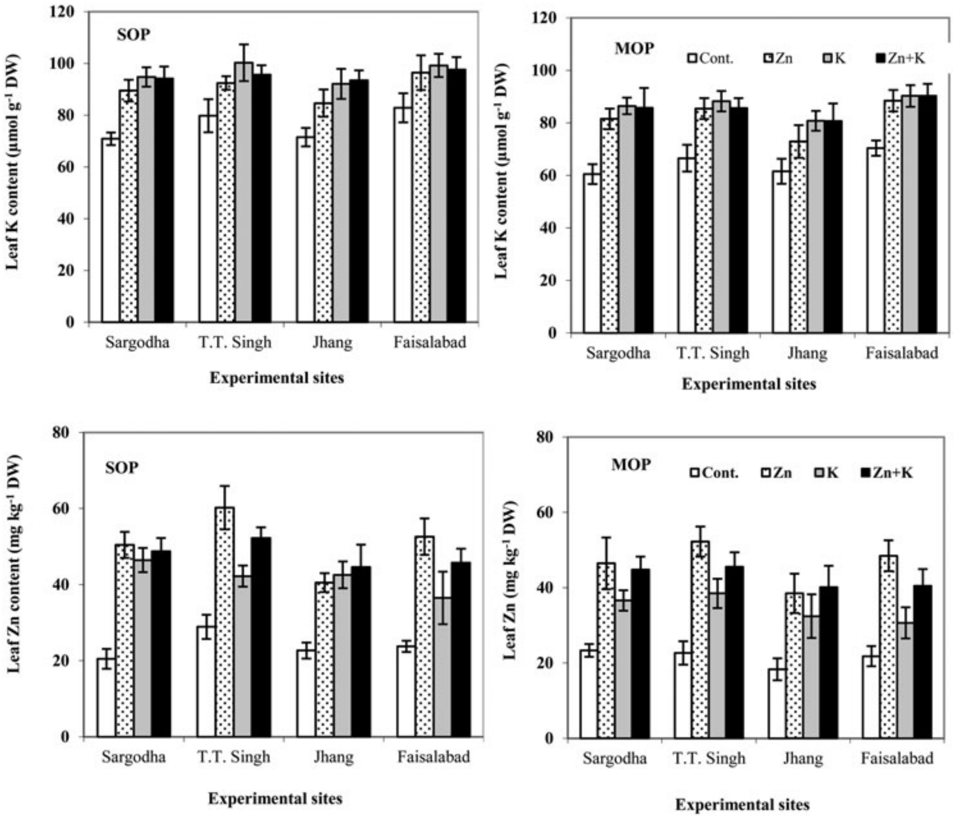

FIGURE 2 Effect of Zn, K or Zn + K foliar spray on leaf K and Zn contents in SOP or MOP treated plants of four experimental orchards.

relations of the plants and as a result of that nutrient uptake is improved (Ashraf et al., 2005). It is also involved in photosynthesis, activation of enzyme systems, protein synthesis and carbohydrate translocation (Dawood et al., 2000). Similarly Zn is a metal activator of several enzymes like carbonic anhydrase, dehydrogenase, aldolase, etc. so its application improves the nutrient uptake (Devi et al., 1996; El-Saida, 2001).

Fruit setting per tree significantly increased with the foliar application of Zn, K or Zn + K at all sites in SOP or MOP treatments, however, SOP treated plants showed more fruit setting than that of MOP at all sites (Figure 3). The highest fruit setting was recorded in the trees sprayed with Zn + K followed by Zn and K. Site variations were also noted and the highest fruit setting was recorded at T. T. Singh closely followed by Sargodha while minimum was at Jhang. Findings of the present study indicated that foliar application of Zn or K was effective in improving the citrus fruit yield by increasing the fruit setting. As most of the citrus orchards in Pakistan are deficient in these nutrient elements, so based on the present results, their foliar spray is

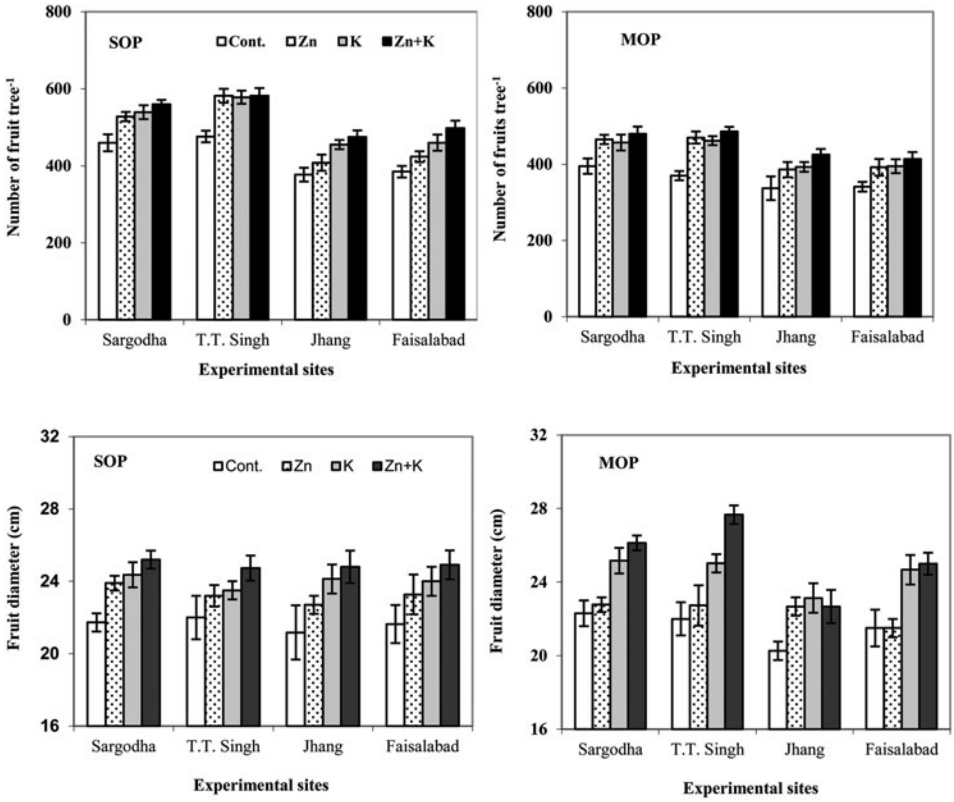

FIGURE 3 Effect of Zn, K or Zn + K foliar sprays on number of fruit and fruit size in SOP or MOP treated plants of four experimental orchards.

recommended. There are many reports which show that foliar application of Zn and K has been beneficial in enhancing the citrus fruit setting (El-Saida, 2001; Omaima and Metwally, 2007).

Foliar application of Zn, K, or Zn + K was found effective in reducing fruit dropping in all the selected orchards (Figure 3). In SOP treated plants, fruit dropping was lesser than that in MOP treated plants. Maximum fruit dropping was recorded in plants which were not sprayed with Zn or K. The lowest fruit dropping was recorded in case of Zn + K foliar application closely followed by that of K and Zn. The maximum fruit dropping was recorded at Jhang while minimum at Sargodha. Citrus fruit dropping is a serious problem in Pakistan and different workers have suggested different types of treatments but the farmers are not satisfied with the results of the recommended chemicals or their formulations, however, the present study showed pronounced effect of fertilizer sprays on fruit dropping.

Fruit retention significantly increased with the foliar application of Zn, K or Zn + K in SOP and MOP pretreated plants. SOP treated plants retained more fruits than that of MOP pretreated plants at all sites (Figure 3). Maximum fruit retention was noted in the plants sprayed with K followed by Zn + K and Zn. Fruit retention also varied from site to site and it was the highest at Sargodha, followed by T. T. Singh, Faisalabad and Jhang. From these results it can be concluded that foliar application of Zn or K is effective in fruit retention, which ultimately increases the fruit yield. So for improving the socio-economic conditions of the farmers and for decreasing cost to benefit ratio, application of K and Zn would be beneficial. El-Baz (2003) and Omaima and Metwally (2007) also reported that foliar application of K, Zn or Zn + K is effective in enhancing the fruit retention per tree.

Number of fruits per tree significantly increased with the foliar application of Zn, K or Zn + K in SOP or MOP pretreated plants at all experimental sites (Figure 4). SOP treated plants bore higher number of fruits than that of MOP treated plants at all sites (Figure 4). The highest fruit numbers were recorded in plants sprayed with Zn + K followed by Zn or K. Site variations were also noted and maximum number of fruits per tree was observed in

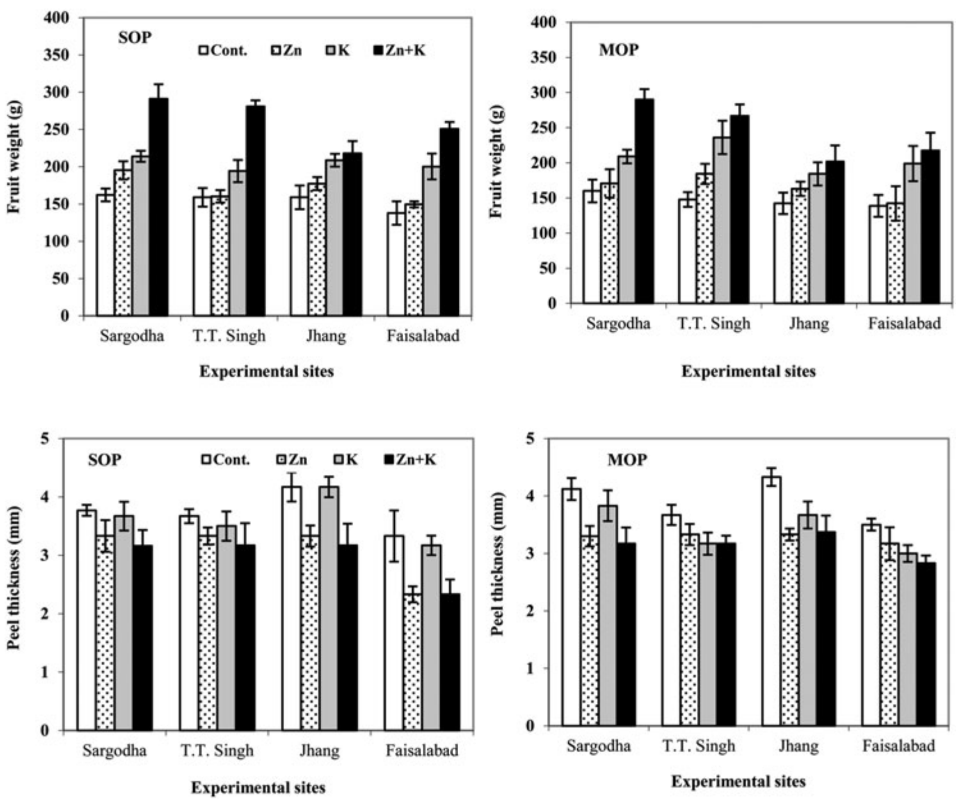

FIGURE 4 Effect of Zn, K or Zn + K foliar sprays on fruit weight and peel thickness in SOP or MOP treated plants of four experimental orchards.

plants of T. T. Singh followed by Sargodha, Faisalabad and Jhang. Findings of the present study indicated that to have higher citrus fruit yield, foliar application of Zn or K is effective. Literature also indicated that proper nutrient management increased the citrus fruit yield by increasing fruit number, retention and weight (Srivastava and Singh, 2006). Tariq et al. (2007) also reported that foliar spray of micronutrients enhanced the number of fruits per tree of sweet orange (*Citrus sinensis* L.).

The fruit weight significantly increased with Zn, K or Zn + K foliar spray at all sites under SOP or MOP treatments. However, the plants pretreated with SOP had higher fruit weight than that of MOP treated ones at all sites. Although fruit weight was enhanced by Zn or K but Zn + K foliar application provided highly significant results by enhancing fruit weight to the maximum (Figure 5). Site to site variations were significant and the highest fruit weight was recorded at Sargodha followed by T. T. Singh, Faisalabad and Jhang. From the results, it can be concluded that foliar application of Zn along with K is effective in enhancing the fruit weight.Although under the present project, the plants were fertigated with Zn but the soil and leaf chemical analysis indicated that the plants were still deficient in Zn. Rodríguez et al. (2005) reported that application of Zn and K increased the fruit size, weight and fruit yield per tree. Similarly, Omaima and Metwally (2007) also reported increase in citrus fruit weight due to Zn and K which is due to their involvement in photosynthesis, nucleic acid metabolism and protein carbohydrate biosynthesis. All these are necessary to have better fruit yield and quality (Krauss and Jiyun, 2000). El-Saida (2001) and El-Baz (2003) also noted an increase in fruit weight and citrus fruit yield by Zn and K foliar application in mandarin. So to have fruits with higher weight, Zn + K application as foliar spray can be recommended.

The fruit circumference/diameter significantly increased with foliar application of Zn, K or Zn + K at all sites (Figure 4). However, fruit diameter was higher in MOP treated plants than that with SOP. The highest fruit diameter was recorded in plants sprayed with Zn + K under MOP soil amendment at all sites, however, the fruit size under SOP or MOP treatment did not differ significantly. Fruit diameter varied from site to site and the fruit with maximum diameter was found at Sargodha closely followed by T. T. Singh and Faisalabad while it was minimum at Jhang. From these results it can be concluded that Zn + K foliar application was effective in enhancing the fruit size and weight. These results confirm the earlier findings of many other workers. For example, Abd El-Moneim et al. (2007) reported that foliar application of Zn is effective in enhancing the fruit size, weight and yield of Washington Navel Orange. Rodríguez et al. (2005) and Tariq et al., 2007 found an increase in fruit size by the application of micronutrients. Large sized fruits have more importance than smaller ones due to their high market value and fetch higher price which may increase the profit margin of farmers. The improvement in fruit quality due to application of Zn, K or

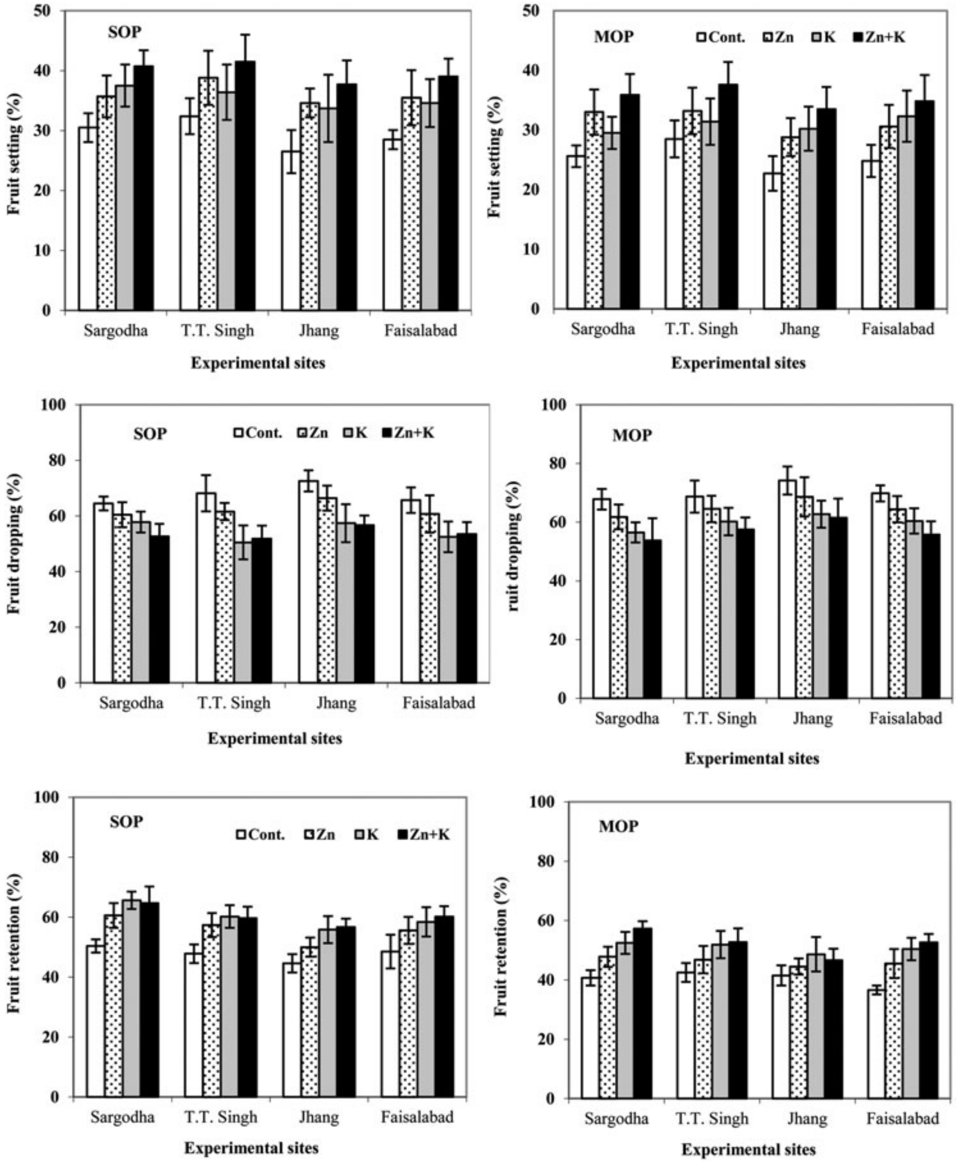

FIGURE 5 Effect of Zn, K or Zn + K foliar sprays on fruit setting, dropping and retention on SOP and MOP treated plants of four experimental orchards.

Zn + K could have been due to their role in enhancing photosynthesis, carbohydrate and enzyme synthesis (El-Saida, 2001; Omaima and Metwally, 2007).

Peel thickness was reduced due to foliar application of Zn, K or Zn + K under SOP and MOP treatments in all the selected citrus orchards (Figure 5); however, the reduction in peel thickness was not significant. MOP treated plants had more thick fruit peel than that treated with SOP. It was also affected by the variations in experimental sites. The highest peel thickness was found in the fruits of Jhang followed by that of Sargodha, T. T. Singh and Faisalabad. In contrast to the present findings, Omaima and Metwally (2007) found non-significant increase in peel thickness in citrus. The results of the previous year study also shows increase in peel thickness with the application of Zn through fertigation. The decrease in peel thickness in the present study was non-significant which could have been due to harsh climatic conditions as the winter of that year was more severe than the previous one. Interaction of some macronutrients with micronutrients could be another reason. Although fruits with thick peel have more shelf life than those with thin peel but consumers like fruits with thin peel because this type of fruit contains higher amount of juice. Tariq et al. (2007) also reported non-significant reduction in peel thickness due to foliar application of Zn. Contradictory reports have been presented by Rodríguez et al. (2005) who found that application of Zn increased peel thickness.

Application of Zn, K or Zn + K as foliar spray significantly increased the juice volume/contents in SOP or MOP treated plants at all sites (Figure 6). The K source SOP as soil amendment was more effective in enhancing the juice volume than that of MOP treated plants.

The highest juice volume was recorded in those plants where foliar spray of Zn + K was applied. Juice volume also varied from site to site; the highest juice volume was noted for Sargodha followed by T. T. Singh, Faisalabad and Jhang. Results showed that foliar application of Zn + K is effective in increasing the juice volume. Omaima and Metwally (2007) reported that foliar application of Zn + K enhanced the juice content while Rehman et al. (1999) found that Zn application alone significantly increased juice volume in orange. The business of juice industries is closely dependent on juice volume so they select fruits with higher juice contents and it is obvious that the orchards with fruits containing more juice provide more economic returns.

The juice pH was not influenced by the application of Zn, K or Zn + K under SOP or MOP treated plants at all sites (Figure 6). Site to site variations were present and the EC of T. T. Singh fruit juice was higher than the other sites. EC of citrus juice increased with the foliar application of Zn, K or Zn + K at all sites in both SOP and MOP treated plants.

Juice total soluble solids (TSS) increased with Zn, K or Zn + K application in both SOP and MOP treated plants at all sites (Figure 6). The highest TSS was recorded under Zn + K treatment. The comparison of potash sources indicated that increase in juice TSS was more pronounced in SOP treated plants than MOP. Juice TSS also varied from site to site and the highest juice TSS values were obtained for Sargodha followed by T. T. Singh, Faisalabad and Jhang. From the results it can be concluded that application of Zn and K as foliar spray is effective in increasing the juice TSS. El-Khawag (2007)

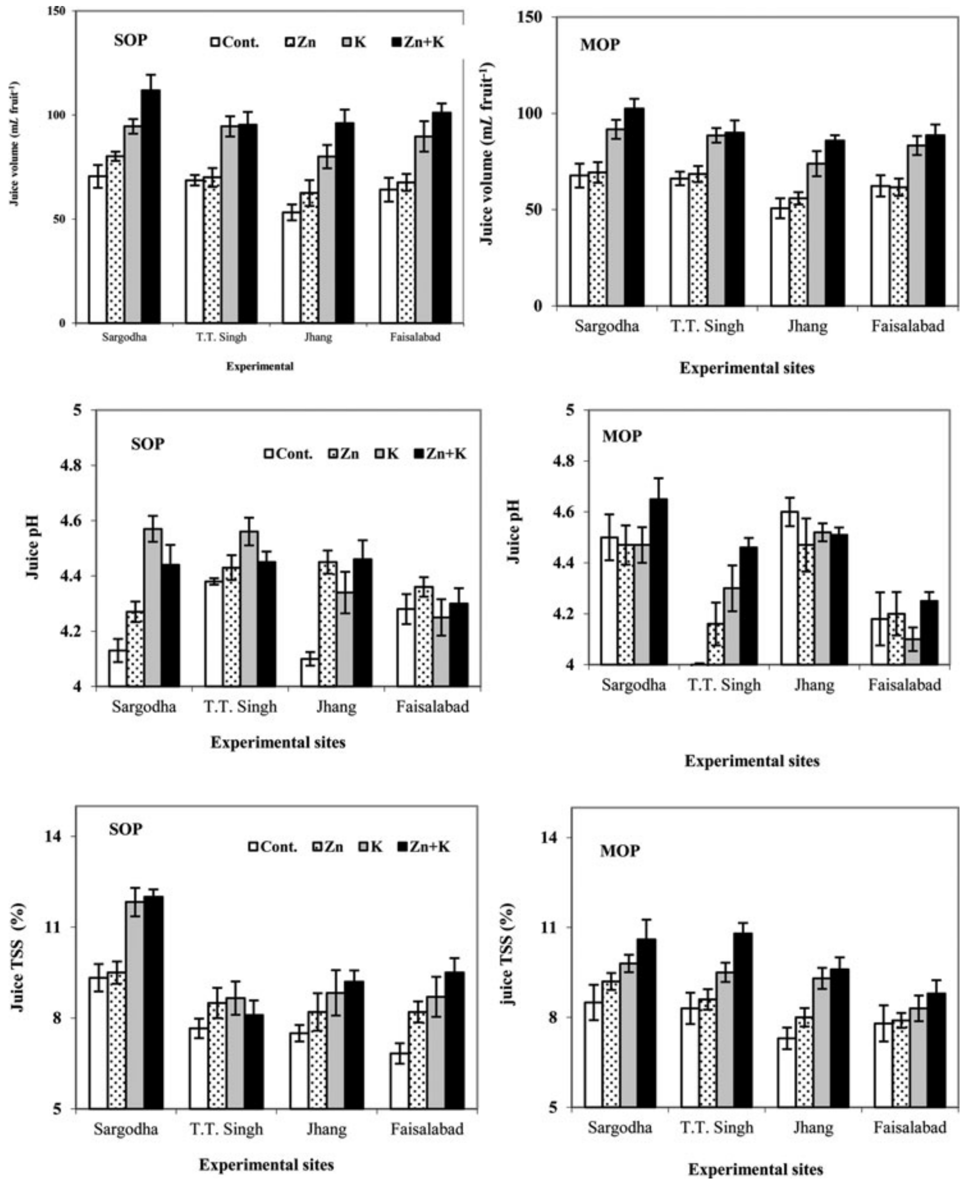

FIGURE 6 Effect of foliar application of Zn, K or Zn + K on juice volume, pH and TSS in SOP and MOP treated plants of four experimental orchards.

also showed that TSS increased with those of foliar application of Zn in pomegranate. They reported that soil application of $ZnSO_4$ considerably reduced total titratable acidity in juice. So, foliar application of Zn along with SOP treatment can be recommended for improving the juice quality.

Ascorbic acid concentration in fruit juice increased with foliar application of Zn, K or Zn + K to SOP or MOP treated plants (Figure 7). Juice

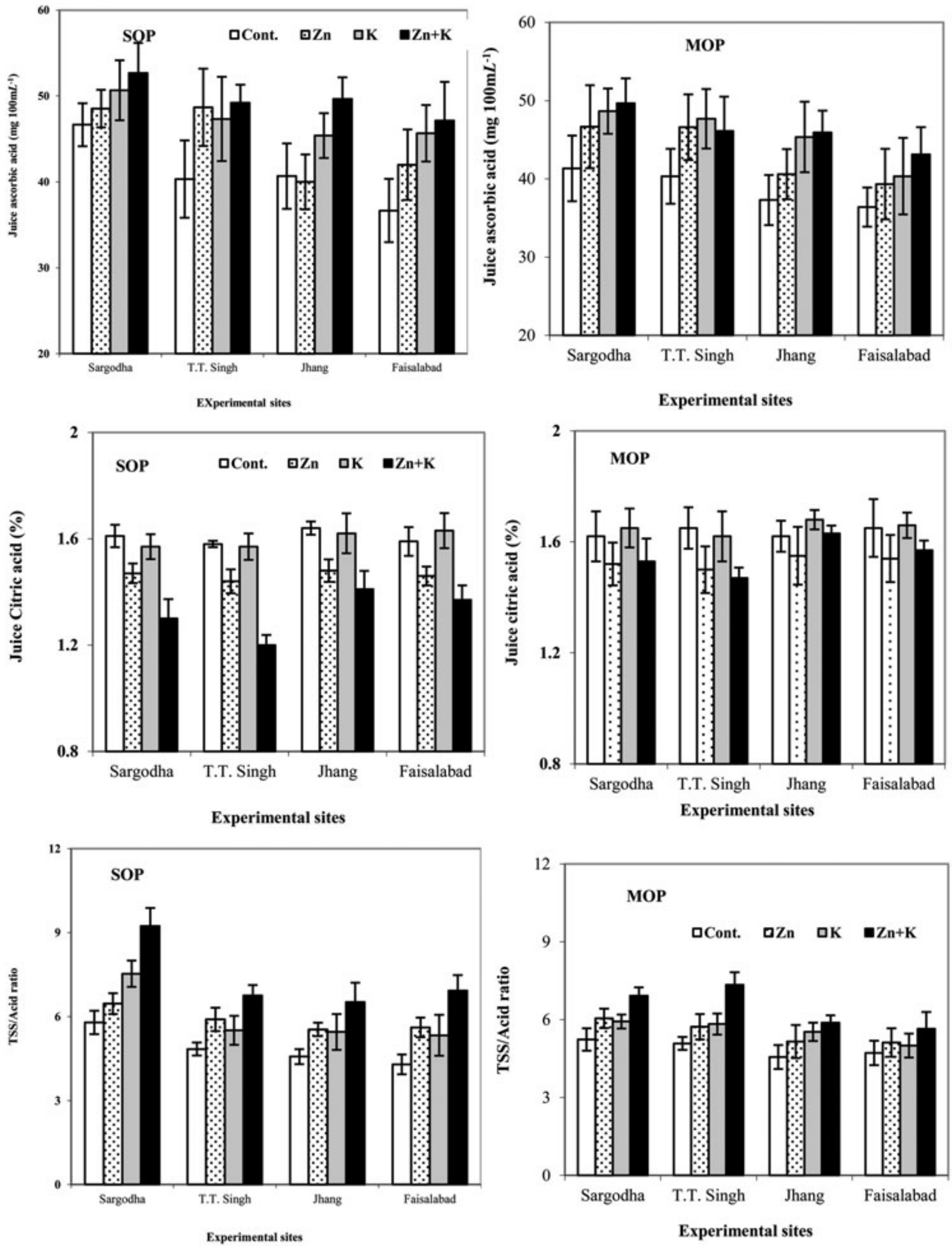

FIGURE 7 Effect of Zn, K or Zn + K foliar spray on juice ascorbic acid, citric acid and TSS/acids ratio in SOP or MOP treated plants at four experimental orchards.

ascorbic acid increased with increase in Zn levels. In case of SOP treatment, the highest ascorbic acid concentration was recorded for the plants sprayed with Zn + K. Site to site variations indicated that the fruit at Sargohda maintained the highest ascorbic acid contents followed by T. T. Sihgh, Jhang and Faisalabad. From these results it can be inferred that foliar application of Zn + K is effective in increasing the juice ascorbic acid concentration. Available literature indicates that application of Zn markedly enhances the juice ascorbic acid contents (Nakhlla, 1998; Abd El-Moneim et al., 2007).

Citric acid concentration in citrus fruit juice decreased with Zn or Zn + K application in SOP or MOP treated plants at all sites, however, spray with K alone did not significantly influence citric acid (Figure 7). Minimum citric acid concentration was recorded for the plants sprayed with $ZnSO_4$ and followed by Zn + K while the highest citric acid was recorded in case of plants which were not sprayed with K or Zn. Juice citric acid concentration also changed with the change in experimental site; the highest citric acid concentration was noted for Jhang followed by Faisalabad, Sargodha and T. T. Singh.

The TSS/acid ratio of juice increased with the application of Zn and K alone or combined in case of both SOP and MOP treated plants at all experimental sites (Figure 7). The potash source SOP was more effective in enhancing the TSS/acid ratio than that of MOP. The highest juice TSS/acid ratio was found with Zn + K foliar spray. This ratio was the highest for Sargodha, followed by T. T. Singh, Faisalabad and Jhang. From the results it can be concluded that application of Zn or Zn + K is beneficial in enhancing TSS/acid ratio which is necessary for improving the juice quality. Since citrus juice factories prefer citrus fruit having high TSS/acid ratio so application of Zn and Zn + K is advisable to improve the TSS/acid ratio. Abd-Allah (2006) also reported an increase in TSS/acid ratio with the application of K in combination with micronutrients.

The overall results of the experiments of 2006–07 show that K when applied along with recommended doses of N and P increased their availability in soil and improved uptake by citrus plants. Furthermore, application of SOP was more beneficial than MOP because it enhanced appreciably the quality of citrus fruit by improving its weight and size, ascorbic acid (vitamin C) content, juice percentage and the TSS/Acid ratio of fruit juice thus leading to an increase in yield and economical returns from citrus orchards. It was inferred that application of SOP at 75 K_2O ha^{-1} is more appropriate than the other levels of K to enhance fruit yield and quality.

From the results of the experiments conducted during 2007–08, it is concluded that application of SOP as soil amendment along with recommended doses of N and P is more effective in enhancing the citrus fruit yield and quality than MOP which can be further improved by applying Zn through fertigation. The most promising results were obtained with soil application of 50 g $ZnSO_4.H_2O$ to plants pretreated with SOP.

Results of the experiments during 2008–09 revealed that foliar application of K (1% K_2SO_4 solution), Zn (1% $ZnSO_4$ solution) and Zn + K (solution containing 0.5% each of $ZnSO_4$ and K_2SO_4) at the onset of spring season and flush of leaves or flowers, fruit formation and at color initiation on fruit is effective in reducing the citrus fruit dropping, improving fruit diameter, number, weight, color and juice quality by enhancing juice volume, juice percentage, pH, TSS, ascorbic acid and TSS/acid ratio of juice. The most promising results were obtained with foliar application of Zn + K that point to their greater cumulative effect.

CONCLUSIONS

The application of Zn (1% solution of $ZnSO_4.H_2O$), K (1% solution of K_2SO_4), and Zn + K (0.5% each of their salts) as a foliar spray is effective in reducing citrus fruit dropping, improving the fruit yield and juice quality by enhancing juice volume, pH, TSS, ascorbic acid and TSS/acid ratio of juice. The effect of combined application of K and Zn through foliar spray was relatively more pronounced for these parameters. Therefore, foliar application of Zn + K is recommended at the onset of spring season and flush of leaves or flowers, fruit formation and at the stage of color initiation on fruit.

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