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COMPARATIVE EFFICACY OF SOIL AND FOLIAR APPLIED ZINC AND BORON ON THE YIELD AND QUALITY OF FEUTRELL'S EARLY (*CITRUS RETICULATA* BLANCO)

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ABSTRACT

Background On account of early maturity (November) and consistent/ prolific bearing habit, Feutrell's Early has been considered a rewarding cultivar, but for the last many years, reduction in yield, fruit size and other quality attributes have been observed. Among the factors responsible for low yield and quality of Feutrell's Early, inadequate plant nutrition, particularly deficiency of micronutrients might be important. Furthermore, the utilization efficiency of applied micronutrients is relatively low due to alkaline calcareous soil conditions. There was a little knowledge existed for the appropriate method of micronutrients application to get good yield and quality of Feutrell's Early.

Methodology A study was conducted in the Citrus Research Institute, Sargodha, Punjab, Pakistan to find out the role of zinc (Zn) and boron (B) and identify the appropriate application method to improve the yield and fruit quality of Feutrell's Early from 2008-2011. This study was comprised of seven treatments. For soil application Zn, B and Zn + B were used @ 50, 15 and 50 + 15 g plant^{-1}, respectively while in case of foliar spray these nutrients were applied @ 1000, 60 and 1000 + 60 ppm, respectively in the month of February and September. NPK fertilizers were applied @ 1000, 500 and 500 g tree^{-1} to each treatment and also kept as a control.

Results Both Zn and B significantly ($p \leq 0.05$) improved the yield and quality of fruit whereas foliar application of B produced better results in first year, however in later years, soil application of B performed well compared to its foliar spray. Zinc application through soil or foliar method, while B only through foliar application produced significantly ($p \leq 0.05$) higher juice percentage. Total soluble solids (TSS) were found better when B and Zn + B were applied through soil application method. Peel and rag weight were remained unaffected throughout the study period.

Conclusion Both Zn and B increased the number of fruits plant^{-1}, fruit yield, juice content and TSS as compared to control. However, foliar application of B remained superior during 1st year of study but afterwards soil application of B performed better compared with foliar spray and as well as other treatments.

INTRODUCTION

Citrus is an important fruit crop and belongs to the family *Rutaceae*. Citrus occupies a prominent position in fruit industry of the world and is cultivated on an area of 9478 thousand hectares with 137 million tons productions (FAO 2014). Pakistan with an area of 192 thousand hectares under citrus cultivation produced over 2395.6 thousand tons annually (GOP 2016).Among various citrus cultivars being grown in Pakistan, the Kinnow mandarin is the leading citrus cultivar occupying about 70% share of the total citrus production (Khan et a. 2012).

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After Kinnow, the Feutrell's Early is the only the mandarin cultivar commercially grown in Pakistan. The area under mandarin cultivation in Punjab has been increased during the last five years, but average yield per plant per unit area has not been improved. Feutrell's Early is an important and domestically traded cultivar due to its physical characters including consistent bearing, pleasing and eye catching appearance, easy to peel, good taste and flavor. Since its introduction, Feutrell's Early has been observed to produce appreciable yields with good fruit quality in all parts of the province, particularly in the central and southern Punjab. Area under different varieties indicates that about 86% of the citrus is covered by Kinnow variety followed by the Musambi (10%), Feutrell's Early (4%) and Blood Red (1%) (Khan et al. 2012).

Adequate plant nutrition is an integral component of crop production. Besides macro-nutrients and micronutrients are playing an important role in plants by maintaining hormonal activity and regulating various metabolic processes. Among micronutrients, Zinc (Zn) is an essential constituent of various enzyme activities; add cell membrane integrity, formation of auxin and regulation of water relations. Boron (B) is also important in translocation of sugar from leaves to root and other plant parts. There is indirect evidence for the involvement of B in carbohydrate transport, role in flowering, pollen tube growth, nitrogen metabolism and hormonal activity. Liebig's law of minimum revealed two basic concepts in mineral nutrition: the idea of essential elements and the need of nutrition control for the purpose of rational fertilization (Srivastava and Singh 2003). A balance nutrition to plants means that all the essential nutrients are available on their demand but due to many biotic and abiotic factors, all these nutrients are not reached to the plants according to their requirement, therefore the plants do not produce a good quality fruits.

Among different soil factors, soil pH is potentially most important which is responsible for low fertilizer use efficiency in Pakistan and many other regions. Moreover, calcareousness of soil is also important to affect micronutrient availability to plants (Zekri and Obreza 2003). A soil and plant survey of citrus orchards in Sargodha district has been conducted and found that out of 334 soil samples, 80% were low in Zn and 66% in B while according to plant analysis, 100% orchards were deficient in Zn and 50% in B (Ibrahim et al. 2004). Resetting and little leaf are the characteristic symptoms of the Zn deficiency of fruit trees (Swietlik 2002). Deficiency of Zn and copper (Cu) was found in 90 and 62% sites, respectively through soil analysis during the survey of 40 orchards of Sargodha District (Zaka et al. 2004). In some cases, soil application of micronutrients is not helpful in removing deficiency of required elements, particularly in alkaline calcareous soil. In that case, foliar application of micronutrients is often helpful to cover the deficiency of that nutrient at rapid rate.

The present research was undertaken to evaluate the efficiency of soil and foliar application of Zn and B as well as their effect on fruit yield and quality of Feutrell's Early under agro-climatic conditions of district Sargodha, Pakistan.

MATERIALS ANDMETHODS

The experiment was conducted on 20 years old trees of citrus [cv. Feutrell's Early (*Citrus reticulata*)] in experimental area of Citrus Research Institute, Sargodha, Pakistan. The plants remained under study for the period of three consecutive years from 2008-2011. The experiment was laid out according to the randomized complete block design (RCBD) with seven treatments and three replications having five plants per treatment. The total numbers of plants in this study were 105. Treatments included T1: Control (untreated), T2: Zn soil application @ 50 g plant^{-1}, T3: B soil application @ 15 g plant^{-1}, T4: Zn + B soil application @ 50 + 15 g plant^{-1}, T5: Zn foliar application @ 1000 ppm, T6: B foliar application @ 60 ppm, T7: Zn + B foliar application @ 1000 ppm + 60 ppm of each. Recommended dose of NPK @ 1000-500-500 g plant^{-1} was applied to each treatment as NPK (17: 17: 17) during February – March. Nitrogen was applied in two equal splits, first during February-March and then during August-September. Second dose of nitrogen was applied as urea. Zn was applied through soil @ 50 g plant^{-1} as $ZnSO_4$ (33%) and B @ 15 g plant^{-1} as borax (11%) alone or in combination. B @ 60 ppm plant^{-1} and Zn @ 1000 ppm plant^{-1} were sprayed alone or combination of both. Two liters of water plant^{-1} was used for spraying the plants. Micronutrients were sprayed before flowering (February) and in September. At maturity, the data for number of fruit per tree and fruit weight were recorded. After harvesting, juice percentage, total soluble solid (TSS), rag weight and peel weight were measured. The juice from each fruit was extracted by using a rotary citrus squeezer and filtered through 0.8 mm pore size sieve. By using a digital calibrated scale, the filtered juice weight was recorded in grams and juice percentage was expressed by the following expression (Lacey et al. 2009).

$$Juice\ percentage = \frac{\text{Juice weight (g)}}{\text{Fruit weight (g)}}\ x\ 100$$

The rag weight was determined with this formula:

$$Rag\ weight\ (g) = Fruit\ weight - (Juice\ weight + Peel\ weight)$$

TSS was determined by using a calibrated Atago Analog Refractometer and expressed as percentage of sucrose in an equivalent solution. The acidity was determined by titration with standard 0.1 N NaOH using a known volume of representative sample of juice. Phenolphthalein as an indicator was used to check the persistent pink color.

Soil samples were collected from 0-15 and 15-30 cm depth at the initiation of experiment and after harvesting the fruit each year. Soil samples were air dried, ground, passed through 2 mm sieve and then analyzed for pH and EC (Ryan et al. 2007), organic matter (Walkley and Black 1934)], phosphorus (Watanabe and Olsen1965), Zn, Cu, iron (Fe) and manganese (Mn) by DTPA extraction (Linsay and Norwell 1978), B by the dilute hydrochloric acid method as described in Bingham (1982).

Leaf samples were collected from six month old spring flushes of all the experimental plants. Leaves were washed with distilled water, dried at 65°C and ground. The ground plant material was digested by wet digestion through di-acids nitric acid: perchloric acid mixture (2: 1) with minor modification in Rashid (1986) as described in Ryan et al. (2007) and analyzed for Zn while B by Bingham (1982). All the data were processed to analysis of variance (ANOVA) (Steel et al. 1997) using Duncan's Multiple Range Test (Duncan 1955) for their significance.

RESULTS

Pre-treatment soil and leaf analysis showed that Zn was deficient in the soil and plant tissue while B was deficient in soil but surprisingly optimum in plant tissues. Other micronutrients were found in optimum range in both soil and plants (Table 1).

Effect of soil and foliar application of Zn and B on number of fruits plant^{-1}

Boron through foliar application @ 60 ppm produced significantly ($p \leq 0.05$) good results in terms of number of fruits (416 plant^{-1}) in 2008-2009 while in the next two consecutive years (2010-2011), soil application of B @ 15 g plant^{-1} showed its superiority over foliar spray of the same nutrient as well as to other treatment applications (Table 2). In case of Zn, there was no significant ($p \leq 0.05$) difference observed between soil and foliar application during the 1st and 2nd year of experiment. However, Zn through foliar spray found better during the last year (2010-2011) compared to soil application of Zn. Numbers of fruits plant^{-1} were significantly increased when both the micronutrients (Zn + B) were applied simultaneously through soil application as compared to their foliar spray throughout the study period.

Effect of soil and foliar application of Z and B on fruit yield

Among all treatments, soil and foliar application of B to Feutrell's Early increased the fruit yield significantly ($p \leq 0.05$) during 2008-2009 (Table 3). However, response of foliar spray of B was found inconsistent compared to soil application and significant ($p \leq 0.05$) positive response of B through soil application was observed throughout the experimental period. Foliar spray of Zn significantly ($p \leq 0.05$) produced higher fruit yield in 2nd year of study. Integrated application of Zn and B through soil increased the fruit yield significantly ($p \leq 0.05$) as compared to foliar spray during 2009-2011.

A significant ($p \leq 0.05$) increase in fruit weight 115.06 g plant^{-1} in 2008-2009 was recorded in T3 where B @ 15 g plant^{-1} was applied through soil as compared to other treatments (Table 4), while a non-significant ($p \leq 0.05$) difference was observed in 2009-2010 among the treatments. During 2010-2011, soil and foliar application of Zn showed no significant difference to each other while B through soil application increased the fruit weight significantly as compared to foliar spray. Furthermore, Zn + B either through soil or foliar remained significantly equal to each other but found less effective as compared to single application of both Zn and B.

Effect of Zn and B on fruit quality

Results of the physical and chemical quality characteristics of the fruit indicated that percentage of TSS was not significantly ($p \leq 0.05$) affected with the application of Zn and B during 2008-2010 but during last year Zn alone through foliar while B and Zn + B through soil significantly increased the percentage of TSS of Feutrell's Early than control and other treatments (Table 3).

Juice percentage remained unaffected with all treatments in 1st year of the experiment while after 2nd year a significant difference was observed between control and other treatments (Table 4). During 2010, Zn + B through soil, Zn either through soil or foliar spray while B only through foliar spray improved juice % significantly compared with other treatments. During last year (2011), Zn again through foliar spray as well as with soil application while B only with foliar spray significantly increased the juice percentage. A significant ($p \leq 0.05$) difference was also observed with Zn + B when applied through soil as compared to its foliar spray.

Table 1 Pre-sowing soil and leaf analysis of Feutrell's Early

Soil analysis											
Soil depth (cm)	EC (dS m^{-1})	pH	OM (%)	Soil available nutrients (mg kg^{-1})							Texture
				P	K	Zn	Cu	Fe	Mn	B	
0-15	1.65	8.2	0.87	6.8	160	0.84	1.72	2.94	5.95	0.35	loam
15-30	1.72	8.1	0.57	5.3	135	0.62	1.46	1.90	4.70	0.30	loam

Leaf analysis						
P	K	Zn	Cu	Fe	Mn	B
(%)		(mg kg^{-1})				
0.13	1.25	18.6	45.0	54.20	48.3	165.6

Table 2 Effect of soil and foliar application of zinc and boron on number of fruits and fruit yield of Feutrell's Early

Treatments	Number of fruits $tree^{-1}$ $year^{-1}$			Fruit yield (kg $tree^{-1}$ $year^{-1}$)		
	2009	2010	2011	2009	2010	2011
Control	331 c	601 b	577 d	33.35 b	64.46 c	61.75 d
Zn Soil	334 c	645 b	603 cd	32.55 b	74.40 bc	70.4 bc
B Soil	349 bc	833 a	710 a	40.14 a	90.04 a	83.93 a
Zn + B Soil	377 b	782 a	650 b	35.65 b	81.84 ab	71.89 bc
Zn Foliar	338 c	644 b	630 bc	34.97 b	76.33 abc	76.20 b
B Foliar	416 a	677 b	609 cd	42.51 a	83.78 ab	66.78 cd
Zn + B Foliar	344 c	641 b	610 cd	34.0 b	69.54 bc	66.57 cd
LSDP ≤0.05	29.72	93.42	38.61	4.19	14.5	6.76

Comparison of means of different treatments in different years. LSD: Least Significant Difference Test with P ≤ 0.05. (Control: No Zn and No B, Zn Soil: Zn @ 50 g $plant^{-1}$ through soil application, B Soil: B @ 15 g $plant^{-1}$ through soil application, Zn + B Soil: Zn + B @ 50 + 15 g $plant^{-1}$ through soil application, Zn Foliar: Zn @ 1000 ppm through foliar application, B Foliar: B @ 60 ppm through foliar application, Zn + B Foliar: Zn + B @ 1000 ppm + 60 ppm through foliar application)

Table 3 Effect of soil and foliar application of zinc and boron on fruit weight, total soluble solid (TSS) and juice content of Feutrell's Early

Treatments	Fruit weight (gram)			TSS (%)			Juice content (%)		
	2009	2010	2011	2009	2010	2011	2009	2010	2011
Control	100.71bc	108.56	107.07c	9.5	9.17	9.0 d	38.19	40.48c	41.27c
Zn Soil	97.26bc	115.13	116.7ab	9.0	8.83	9.42 b	39.7	44.78ab	44.23ab
B Soil	115.06a	107.8	118.33ab	9.5	9.50	9.63 a	39.46	40.70c	42.23bc
Zn + B Soil	94.53c	104.93	110.67bc	9.3	9.17	9.62 a	38.64	45.97a	42.3bc
Zn Foliar	103.59b	118.23	120.93a	9.7	9.67	9.62 a	38.6	43.37abc	44.87a
B Foliar	102.05b	110.17	109.77bc	9.1	8.67	9.16 c	38.7	43.22abc	44.57a
Zn + B Foliar	99.01bc	108.37 ns	109.10bc	9.7 ns	9.17ns	9.18 c	40.87ns	41.67bc	42.07c
LSD P ≤0.05	7.42	12.53	9.5	0.977	0.82	0.135	4.1	3.19	2.0

Comparison of means of different treatments in different years. LSD: Least Significant Difference Test with P ≤ 0.05. (Control: No Zn and No B, Zn Soil: Zn @ 50 g $plant^{-1}$ through soil application, B Soil: B @ 15 g $plant^{-1}$ through soil application, Zn + B Soil: Zn + B @ 50 + 15 g $plant^{-1}$ through soil application, Zn Foliar: Zn @ 1000 ppm through foliar application, B Foliar: B @ 60 ppm through foliar application, Zn + B Foliar: Zn + B @ 1000 ppm + 60 ppm through foliar application).

Table 4 Analysis of variance (ANOVA) of three consecutive years (2009-2011)

Source of variation	**DF**	**2009**		**2010**		**2011**	
		F	**P**	**F**	**P**	**F**	**P**
Fruit numbers	6.0	10.15	0.0004**	3.96	0.0204*	4.89	0.0095*
Juice percentage	6.0	0.47	0.82^{NS}	1.70	0.2041^{NS}	30.37	0.0000**
Peel weight	6.0	2.01	0.1423^{NS}	7.85	0.0013**	11.72	0.0002**
Rag weight	6.0	1.33	0.31^{NS}	1.12	0.4085^{NS}	2.42	0.0905^{NS}
TSS	6.0	0.78	0.60^{NS}	1.22	0.3624^{NS}	0.71	0.6469^{NS}
Fruit weight	6.0	7.51	0.0016**	1.37	0.3016^{NS}	3.00	0.0499^{*}
Fruit yield	6.0	7.52	0.0016**	3.46	0.0320^{*}	11.02	0.0003**

*Significant @ alpha 0.05; **Highly significant @ alpha 0.05; NS: Non-significant

DISCUSSION

It was found that Zn and B both either through soil or foliar application (alone or in combination) increased the fruit yield attributes including number of fruits plant^{-1}, fruit yield and fruit weight as well as improved the fruit quality as compared to control. Number of fruits, fruit yield and fruit weight were improved by sole application of B through foliar only during 1st year due to quick response of foliar as compared to soil but after that soil application was remained superior as compared to foliar as well as to other treatments. These results were in line with the findings of Rajaie et al. (2009) who reported that the yield of Kinnow mandarin was significantly affected by foliar application of B. The study reflected that after 1st year, B through soil application produced higher yield i.e. fruit yield and number of fruits plant^{-1} as compared to its foliar application during the remaining years of study. The similar results were also produced by Quaggio et al. (2003) who found a significant ($p \leq 0.05$) response to soil B application in two years compared to the conventional spray treatment which did not improve yield and fruit quality. Zhang et al. (2015) also reported after three years of study that soil application of B increased the yield of Satsuma mandarin while Zn improved only fruit quality. In this study, Zn also increased the fruit weight regardless of soil and foliar method while B only through soil. This increased in yield attributes may be due to the involvement of B in different plant's functions like hormonal activities, transportation of energy and pollen tube elongation etc. While, Zn is also contributory factor of various enzymes and phytohormonal activities, leading to marked improvement in vegetative growth of plants and fruit (Srivastava and Singh 2003). These functions are indirectly linked with maintaining the health of tree and thus reduced post-harvest fruit drops. On the other hand, some scientists reported that B alone did not significantly increased the fruit yield of sweat oranges, but in combination with Zn and Mn, the fruit yield considerably increased due to positive interaction among these micronutrients (Perveen and Rehman 2000). Sourour (2000) and Ahmed et al. (2012) conducted an experiment with Valencia orange for two successive years and concluded that there was a significant and gradual increase in fruit yield, number of fruits tree^{-1}, fruit weight and fruit size with increasing Zn foliar application. El-Baz (2003) reported that highest yield of Balady mandarin trees was obtained by Zn (250 ppm) due to increase in both number of fruits tree^{-1} and fruit weight. The Zn and Mn alone caused an increase in yield by 49.79 and 30.87%, respectively over control (Rehman and Haq 2006). Likewise, Bahadur et al. (1998) studied the effect of foliar and soil application of Zinc sulfate on Zn uptake, tree size, yield and fruit quality of mango. They concluded that there was non-significant ($p < 0.05$) increase in yield, fruit size and weight, pulp or stone weight with any treatment of zinc sulfate. Total soluble solids in the fruit was significantly higher (18.6%) with the treatment of soil application of zinc sulfate (0.5 kg tree^{-1}) as compared to all other treatments of zinc sulfate and the control. Acid and sugar contents of the fruit were not significantly ($p \leq 0.05$) affected by the foliar or soil application of zinc sulfate. Foliar application of B to sweet oranges increased the yield by 5.82% as compared to trees not sprayed with B (Khurshid et al. 2008). Ullah et al. (2012) also reported that that the yield of Kinnow mandarin was significantly ($p \leq 0.05$) affected by foliar application of B.

In case of fruit quality characteristics, Zn increased the juice percentage prominently through soil as well as foliar spray while B only by foliar application. The similar conclusion was also depicted by Khan et al. (2012) who found that the tree height, leaf size, fruit weight, juice weight percentage, soluble solids contents (SSC) and titratable acidity (TA) were significantly ($p \leq 0.05$) increased with application of 0.3% boric acid + 0.5% zinc sulfate at the fruit set stage. This study indicated that both Zn and B were involved positively in improving fruit's internal quality by increasing juice percentage than the peel weight of the fruit. The findings were also according the study of Tariq et al. (2007) who found that percent peel was significantly ($p \leq 0.05$) decreased with B application alone, Mn + B and Zn + B treatments compared with control. It was also concluded form this study that foliar application of Zn improved the TSS over soil while soil with B and Zn + B found better as compared to foliar application.

Boron application through spray significantly ($p \leq 0.05$) increased TSS, titratable acidity ratio, ascorbic acid and total sugars (Rajaie et al. 2009). It was also observed from this study that juice contents in the Feutrell's Early were ranged from 30.78 to 44.87%. The application of micronutrients along with NPK might improve tree heath which could be the main reason for an increase in the juice contents. The results obtained in the present study confirmed the findings of Gosh and Basra (2000). The peel and rag weight were remained unaffected by the application of Zn and B.

CONCLUSION

The present study explored the relatively better method of Zn and B application to get higher yields and fruit quality of Feutrell's Early. It was concluded that both Zn and B were effective through soil as well as foliar application in producing better yield of Feutrell's Early. Soil application of B while foliar application of Zn performed better to affect yield and fruit quality. Furthermore, the separate application of both Zn and B was more effective as compared to their combined application. Therefore, it is recommended that farmers should use Zn and B separately in citrus orchards for obtaining optimum production and good quality fruit.

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