Research Article

Effect of Zinc and Boron using Different Application Methods on Yield of Citrus (Sweet Orange) in Calcareous Soils

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Abstract | This study was conducted to assess the effect of Zn and B and their methods of application on the yield and yield attributes of citrus (*Citrus Sinensis*) orchards established on calcareous soils at three farmers fields in Dubandai and Palai area of District Malakand of Khyber Pakhtunkhwa, Pakistan during 2009-2010. A randomized complete block experiment with split plot arrangement was used. Methods of application (Soil and Foliar) were assigned to main plots while micronutrients (Zn @2.5 kg ha^{-1}, B @ 2.5 kg ha^{-1} and Zn plus B) were kept in subplots. The results showed that Zn, B and Zn + B and their methods of application significantly affected the yield attributes of citrus in both years. The combined application of Zn and B increased flower (12118), fruit set (8.3%), fruit retained (59.42 %), and fruit yield (14.34 t ha^{-1}) relative to control. June fruit drop was reduced by 28.82 % by Zn alone. In methods foliar spray significantly improved fruit retained (46.24%) and fruit yield (12.4 t ha^{-1}) relative to soil applications. The fruit retained and yield were also significantly increased by 10.41% and 15.93% respectively, while June drop was reduced by 33.75% during 2nd year of the experiment compared to the 1st year. Results further revealed that Treatments x Years, Methods x Sites and Years x Methods x Treatments interaction significantly affected June drop while Years x Methods and Methods x Treatments significantly affected fruit retain and fruit yield of citrus fruit. It can be concluded that foliar spray of micronutrients improves yield and yield attributes of citrus and is recommended for the citrus industry of Pakistan.

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Introduction

Pakistan is the 10th largest citrus producer in the world with an annual production of 2.29 million tons spread over an area of 193212 hectares of the country (Naseer, 2010). As such citrus production is play an important role in the macro and micro-economic development, particularly in poverty alleviation in mountainous and marginal farming areas. This production is, however, hindered by the inherently low fertility of the soils, mostly calcareous in nature and elevated inputs costs pose an impending vulnerability to the increasing yields and quality of citrus fruit (Ghafoor et al., 2008; Sajid et al., 2010). This needs concurrent increase in yield and quality fruit together with sustainable utilization of resources and minimizing input costs is developing as a foremost assignment for researchers in Pakistan (Anjum et al., 2011).

Most of the citrus orchards in Malakand Division are deficient both in macronutrients as well as in micronutrients (Sharif et al., 1998). Among micronutrients, the deficiency of Mn, Zn and B are more common in citrus orchards (Shah et al., 2012). Khattak (1995) in his study reported that more than 50 % of the cultivated areas of Khyber Pakhtunkhwa are deficient in Zn and B. Progressive decline in soil fertility and poor nutrient use efficiency, coupled with high pH and calcareous nature of soils, is obstructing the citrus productivity and fruit quality in Pakistan (Shah et al., 2012). Regardless of soil types, the application of nutrients amendments and its application method enhance citrus yield and quality (Sajid et al., 2012).

Zn is one of the essential nutrients required for normal growth, metabolism, enzymes and hormones activation of plants (Ranja and Das, 2003; Aboutalebi and Hassanzadeh, 2013). Zinc is low in calcareous soils and in the plant grown on such soils and consequently in animal and humans nourishing on such soils (Cakmak, 2006). The deficiency of Zn in citrus orchards established on calcareous soil are common due to the higher pH (pH >8.0) of calcareous soils (Srinivasara et al., 2008). Another important micronutrient limiting citrus yield is boron. Boron is a distinctive nonmetal micronutrient, taken up by plants as an uncharged molecule from soil (Miwa and Fujiwara, 2010). The roles of B in plants primarily include; sugar transport, cell wall synthesis, lignification, carbohydrate metabolism, ribose nucleic acid metabolism, indole acetic acid metabolism, and phenol metabolism (Parr and Loughman, 1983; Welch, 1995; Ahmad et al., 2009). The deficiency of B is more extensive in world (Blevins and Lukaszewski, 1998) as in Pakistan (Khattak et al., 1995), compared to other micronutrients. Its management is defying, as the margin between the optimal and low B application range is narrow and application rates can differ from one soil to another (Gupta, 1993; Marschner, 1995).

Micronutrients application in citrus orchards is commonly done through soil broadcasting and foliar spray. In conditions where it is poorly supplied from the soil, the foliar spray improves micronutrient content in plant tissue and citrus fruit yield (Sajid et al., 2012; Srivastava et al., 2009; Karim et al., 1996). However, soil application of micronutrient also improved yield and quality of the citrus (Kazi et al., 2012), but this may need to apply larger quantities of fertilizer, especially to calcareous soils (Singh and Chaudhri, 1997). Although micronutrients can be fertilized through any of the above stated methods, foliage sprays have been considered as more responsive in increasing yield and improving quality of the produce. But as it is laborious and costly; taking into consideration the poor socio-economic status of the farmers, the wider adoption of foliar application method is not practiced (Johnson, 2006).

The ultimate inspiration behind this study was to determine the usefulness of micronutrients and its application methods to improve the citrus fruit yield and yield attributes of long established citrus orchards on calcareous soils and to develop strategies for micronutrients availability under such prevailing conditions in Malakand Division. The prevailing soil conditions, climate change scenario, global rise in temperatures, erratic rainfall patterns are aggravating the production stress issues in citrus orchards which can be managed by addressing nutrient deficiencies. The main objective of the study was to evaluate the effect of micronutrients (Zn and B) and their methods of application on the yield and yield attributes of sweet orange in Malakand Division and to develop strategy for increasing micronutrients availability in calcareous soil.

Materials and Methods

Site characteristics

Three citrus orchards of different farmers were selected in Dubandai and Palai area, some 30 km toward East of main Dargai city of District Malakand Khyber Pakhtunkhwa Pakistan (located between 34°35′N 71°57′E and 34.583°N 71.95°E) during 2009 and 2010. The study area is considered to be the export quality sweet orange producing area in Pakistan. The selected orchards were about 15 years old and had evident deficiencies of Zn and B in some plants. Soil samples (0-15 cm) were collected from each orchard, just before the establishment of experiment, for site characterization. At each site several core samples were randomly collected and then samples of the same orchards were composited, thus having one composite sample for each orchard. The collected soil samples were first broken down and passed through 2 mm sieve.

Soil physicochemical properties

All the composite soil samples were analyzed for selected physicochemical properties (Table 1). The bulk density of the soils was determined by core sampling method of Black (1965) while electrical conductivity (ECe) was determined by the method of Black

(1965). Soil pH was determined in saturation paste extract as described by McClean (1982), Soil texture was determined by hydro-meter method devised by Koehler (1984). Lime content was determined by acid neutralization method as described by Richard (1954). Organic matter was analyzed by Walkley-Black method as described by Nelson and Sommers (1982). Mineral N in soil sample was determined in soil extract by the procedure as described by Mulvaney (1996). Extractable P, K, Zn were determined in AB-DTPA extract by the method of Soltanpour and Schwab (1977). Moreover, for P determination, the extract was analyzed on spectro-photometer, K on flame-photometer and micronutrients were determined on atomic-absorption-spectro-photometer. The soil available B was determination by dilute acid method of Bingham (1982).

Table 1: *Important soil properties of the citrus orchards used for the experiment.*

Soil physical properties↕	Unit	Value at the depth of (0-15cm)		
Sites ↔		Duban-dai-1	Duban-dai-2	Palai
Sand	%	43	47	47
Silt	%	38	35	31
Clay	%	19	18	22
Soil Texture Class	-	Sandy loam	Sandy loam	Sandy clay loam
Soil Bulk Density	g cm^{-3}	1.48	1.47	1.44
Soil chemical properties				
pH	-	8.2	8.1	8.1
EC	d Sm^{-1}	0.31	0.29	0.34
Lime	%	11.85	12.54	12.83
Organic Matter	%	0.92	0.85	0.96
Soil Total Mineral N	mg kg^{-1}	57	49	61
ABDTPA Extractable K	mg kg^{-1}	133	104	147
ABDTPA Extractable P	mg kg^{-1}	5.28	3.42	2.85
ABDTPA Extractable Zn	mg kg^{-1}	0.68	0.56	0.38
ABDTPA Extractable B	mg kg^{-1}	0.16	0.18	0.21

Climatic conditions

Malakand District has peculiar valleys with fertile sandy loamy textured soils, hemmed in by mountains. The weather of valley remain moderate in winter and pleasant in summer with an annual rainfall of 600 to 650 mm. The higher temperature in the area is recorded mostly in the month of June (41.50 ^{0}C). The mean maximum (37.5°C) and minimum 25°C temperature are recorded in summer that runs from May through September. The mean minimum (≤ 4°C) and maximum (22.4°C) temperature are recorded in winter that prevails from December through February. On the average, rainfall is higher in winter than that of summer season. The maximum winter rainfall usually occurs in February and March, while the maximum summer rainfall occurs in August (Metrological Station, Pakistan Forest Institute, Peshawar Pakistan).

Field experiment

Three citrus orchards (13-15 years old) at the farmers' field were selected for the experiment. In each orchard 48 trees with almost same size and vigor were selected for the study. The experiment was arranged in randomized complete block design with split plot arrangements. Methods of micronutrient application (soil and foliar application) were kept in main plots and micronutrients treatments in subplots, whereas each treatment was replicated three time. Crystal structure zinc sulphate ($ZnSO_4.7H_2O$) containing 23 % Zn was used as a source for zinc, and boric acid powder (H_3BO_3) containing 11 % B was used as a source of boron. All the treatments were applied for two consecutive years. In case of soil application, the applied dose of micronutrients Zn and B (9 g $tree^{-1}$), calculated on per tree basis in view of 275 trees ha^{-1}, was mixed with carrier material (soil) and was applied under the canopy of each tree. Full dose of micronutrients was applied to soil, before the current year fresh growth, along with basal dose of urea (N), single supper phosphate (SSP) and sulphate of potash (K) at the rate of 1:1:1 kg $tree^{-1}$. All the P, K, Zn and B and half dose of N were applied in last week of January while the remaining half N was applied in 2nd week of May in both year (2009-2010).

In case of foliar spray, micronutrients dose (9 g $tree^{-1}$ of each Zn and B) calculated on per tree basis was divided into three equal parts and sprayed at three different growth stages of fruit development, viz. before flower initiation, after fruit set when it attained berry size, and 45 days after second spray in both years. The micronutrients (Zn and B) treatments used were as follows:

Treatment 1: Control
Treatment 2: Zn application alone (2.5 kg ha^{-1})
Treatment 3: B application alone (2.5 kg ha^{-1})

Treatment 4: Zn + B application in combination (2.5+2.5 kg ha^{-1})

The solution for foliar spray was prepared by dissolving 13 g $ZnSO_4$ for Zn treatment and 27 g of H_3BO_3 for B i.e. one third of the quantity calculated per tree per session and the same dose of both for the combination treatment of Zn and B in 6 L of water, for each treatment separately, just before the foliar spray. Surfactant required as adjuvant for wetting spreading and adhering of the nutrient to leaf surface by lowering the surface tension between the liquid and leaf surface was also used at rate of 1% (Stevens, 1994). Before solution preparation, the amount of water required to wet the whole tree was determined by spraying five average size trees with water till run-off of the leaves, and then water quantity was estimated by averaging the values. The average water quantity required was 6.0 L $tree^{-1}$. In both years, NPK basal dose was also applied to soils of each treatment receiving Zn and B as a foliage spray. Both methods and treatments were randomly allotted to each replication at each site. Two trees were kept in each treatment. For data collection, total number of branches $tree^{-1}$ were counted and 4 branches on each tree were selected at equal elevation from ground surface and labelled. Data on number of flower, fruit set, June drop, fruit retained and final yield of fruit were recorded for consecutive years (2009 and 2010) on selected and labelled branches.

Procedure for data recording

The selected and labelled shoots in all four directions of each tree were used for recording observations on No. of flower, fruit set, June drop, fruit retained and yield parameters for two consecutive years. The number of flowers on selected shoots were counted, on 5^{th} and 7^{th} April of 2009 and 2010 respectively. The counted numbers of flowers were then converted to total number of flowers per $tree^{-1}$ by multiplying it to the already counted total number of shoots per tree of each treatment. The percent fruits set was determined by counting the set fruit when it was of berry size on selected shoots on 10^{th} and 13^{th} May of 2009 and 2010 and then converted to total number of fruit set as did for the data of number of flowers per tree. Similar procedure to No. flower per tree was also adopted for fruit set established from the same flowers of current year. The % fruit set was estimated as follow:

$$\text{Percent fruit set} = \frac{\text{Number of fruit sets}}{\text{Number of flowers}} \times 100$$

After collecting the fruit set data, the number of fruit retained on the same tagged shoots was determined in late June (30^{th} and 26^{th} June), of the same years, to calculate the fruit drop data. The June drop (%) was calculated using the fruit set and number of fruits dropped in June with the following formula:

$$\text{Percent June drop} = \frac{(\text{Fruit set} - \text{fruit retained till June})}{\text{Fruit set}} \times 100$$

The fruit retained data was recorded when the fruit reached its physiological maturity stage. Number of mature fruit per tree were counted in each treatment on 25^{th} and 21^{st} September during 2009-2010 and expressed as % fruit retained of the fruit set in June. The final yield was recorded on 15^{th} and 10^{th} November 2009 and 2010 at time of picking, the fruits weight per tree was recorded for each treatment by weighing the entire fruit of each tree with help of filed electronic balance and was expressed as fruit yield (t ha^{-1}).

Statistical analysis

The data recorded on different parameters were subjected to Analysis of Variance (ANOVA) technique (Steel and Torri, 1980) to observe the differences between the treatment as well as their interactions. For the purpose a randomized complete block design with split plot arrangements was used. In case where the differences were significant, the means were further assessed for differences through Least Significant Difference (LSD) test. For all the data arrangements and statistical computations MS excel of Microsoft Office and SPSS software were used.

Results and Discussion

The experiment was conducted to explain the effect of micronutrients (Zn and B) application on yield and yield attributes of citrus fruit at three farmers' fields established on calcareous soils in Dubandai and Palai area of Malakand District during 2009-2010. During this experiment, the effect of rate and methods of micro nutrient application was assessed for two consecutive years. The results obtained on various yield and quality parameters of citrus fruit are presented as follows.

Number of flowers $tree^{-1}$

Data regarding number of flowers $tree^{-1}$ as affected by rates and methods of micronutrients (Zn and B) application at all the three sites are presented in Table 2. Statistical perusal of the data revealed that micronutrients, methods of application and years as source of variation were found significant in improving number of flowers tree^{-1} ($P < 0.05$). The effect of sites and all the interactions effects were found insignificant for total number of flowers tree^{-1}. The application of Zn and B in integration produced more flowers (12118) in citrus than sole application of Zn or B. Foliar application of Zn and B produced more flowers (10101) tree^{-1} than soil application method. Likewise, number of flower were higher (10612) in the 2nd year as compared with the findings of 1st year. Although, no significant change was noted due to sites however; higher number of flowers tree^{-1} were observed at Palai (10284 tree^{-1}) followed by Dubandi-2 with 9397 flowers tree^{-1}. All the interaction; Years × Sites (Y×S), Years x Methods (Y×S), Sites x Methods (S×M), Years x Treatments (Y×T), Sites × Treatments (S×T), Methods × Treatments (M×T), Years × Sites × Methods (Y×S×M), Years × Sites × Treatments (Y×S×T), Years × Methods × Treatments (Y×M×T), Sites × Methods × Treatments (S×M×T), Years × Sites × Method × Treatments (Y×S×M×T), were recorded insignificant (Table 2).

Fruit set (%)

The effect of rates and methods of micronutrients application on % fruit set of citrus at different sites (Dubandi-1, Dubandi-2 and Palai) are shown in Table 2. According to statistical analysis of the data, the effects of micronutrients and years of application were significant at $P < 0.05$ and $P < 0.001$, respectively, while the effect of sites and methods remained insignificant. All interactions for % fruit set were found non-significant. The combined application of B and Zn resulted in significantly higher fruit set (8.30%) than all the other treatments. The fruit set was higher with foliar application (7.61%) than with soil application (7.19%).

June fruit drop (%)

Data regarding June drop, which is actual fruit drop from fruit set till June, are reported in Table 2. Statistical analysis of the data revealed that treatments (micronutrients), sites and years induced significant changes in June drop of citrus. June drop was higher in control plots (43.8%) as compared to treated plots, however, difference among treated plot was found insignificant yet lower fruit drop was found in Zn alone treatment (34.50%). June drop was lower (32.76%) in second year as compared to first year of the experiment. Likewise, June drop was significantly lower (32.93%) at Palai followed by Dubandi-1 and Dubandi-2 locations. Results on the interaction analysis revealed that S×M, Y×T, Y×S×T and Y×M×T were found significant in reducing fruit drop. It was recorded that foliar application overall reduced June drop but at Palai and Dubandai 1 sites it significantly reduced June drop relative to the soil

Table 2: *Number of flower, fruit set and June fruit drop of citrus as affected by micronutrients their methods of application at different sites.*

Years	Flower count	Fruit Set (%)	June Drop (%)
First Year	8524	6.35	42.55
Second Year	10612	8.45	32.76
LSD	1072.4	0.79	4.0
Sites			
Dubandi-1	9024	7.96	38.94 a
Dubandi-2	9397	6.82	41.10 a
Palai	10284	7.41	32.93 b
LSD	ns	ns	4.93
Methods			
Soil	9035	7.19	39.55
Foliar	10101	7.61	35.77
LSD	1005.0	ns	ns
Treatments			
Control	7133 c	6.96 b	43.8 a
Zinc	8236 c	7.16 b	34.5 b
Boron	10787 b	7.18 b	35.1 b
Zinc + Boron	12118 a	8.30 a	37.2 b
LSD	1250.7	0.84	**3.77**
Interactions	**Significance level**		
Years×Sites	ns	ns	ns
Years×Methods	ns	ns	ns
Sites×Methods	ns	ns	*
Years ×Treatments	ns	ns	**
Sites×Treatments	ns	ns	ns
Methods×Treatments	ns	ns	ns
Years×Sites×Methods	ns	ns	ns
Years×Sites×Treatments	ns	ns	*
Years×Methods×Treatments	ns	ns	*
Sites×Methods×Treatments	ns	ns	ns
Years×Sites×Method×Treatments	ns	ns	ns

*Means for same parameter followed by changed alphabet (s) are statistically different at 5, 1 or 0.1% level of probability (P); ns = non significant; *,**,*** = Significant at 5, 1 and 0.1% level of probability respectively.*

application (Figure 1). Likewise, sole B and sole Zn application significantly reduced June drop during the 2nd year relative to the 1st year of experiment (Figure 2). Furthermore, combined application of Zn and B, through foliage spray, significantly reduced fruit drop during the 1st year of experiment, while sole B application was significant during 2nd year relative to soil application method (Figure 3). Moreover, the response of citrus orchards, at different sites, to micronutrient was significant in different years. The sole Zn application reduced fruit drop at Palai in both the year of experiment relative to control treatment at all the sites. The effect of micronutrient at different sites was more profound in the 2nd year compared to the 1st year. Sole application of Zn and B significantly reduced the fruit drop at Palai site compared to Dubandai 1 and Dubandai 2 sites as well as the control treatments in 2nd year of experiment (Figure 4).

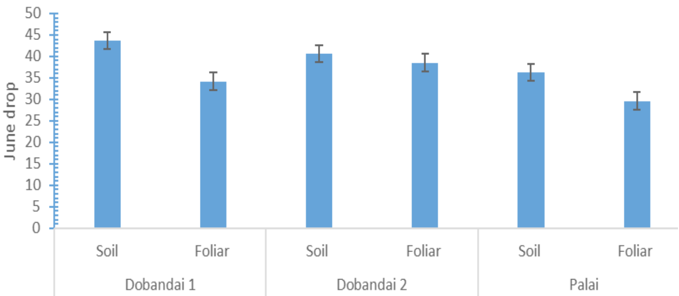

Figure 1: *Interactive effect of methods of micronutrients application on June drop (%) of citrus fruit at different sites.*

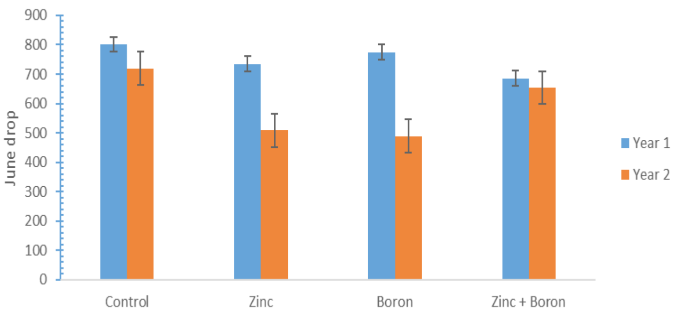

Figure 2: *Interactive effect of micronutrients and year on June drop (%) of sweet orange fruits.*

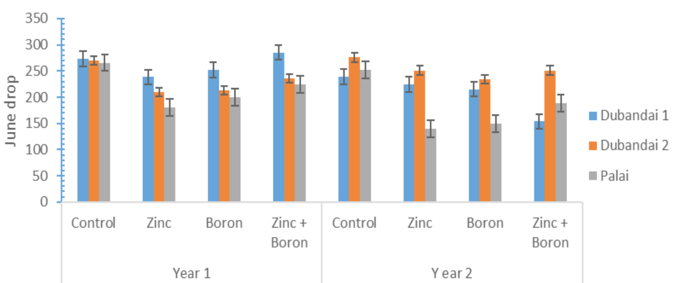

Figure 3: *Interactive effect of micronutrients their methods of application and years on June drop (%) sweet orange fruit.*

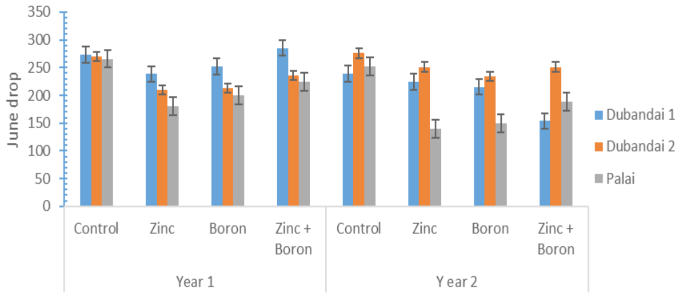

Figure 4: *Interactive effect of years, sites and treatments on June drop of sweet orange fruit.*

Table 3: *Fruit retain and yield of citrus fruit as affected by micronutrients their methods of application at different sites.*

Years	**Fruit retained (%)**	**Yield (t ha^{-1})**
First Year	49.27	9.93
Second Year	53.88	11.80
LSD	4.5	1.8
Sites		
Dubandi-1	49.04	11.03
Dubandi-2	50.25	9.812
Palai	55.43	11.76
LSD	Ns	ns
Methods		
Soil	49.86	9.333
Foliar	53.29	12.40
LSD	2.7	1.5
Treatments		
Control	42.30 c	7.66 c
Zinc	51.13 b	11.19 b
Boron	54.23 b	10.27 b
Zinc + Boron	58.64 a	14.34 a
LSD	3.70	1.20
Interactions	**Significance level**	
Years×Sites	ns	ns
Years×Methods	ns	ns
Sites×Methods	**	ns
Years × Treatments	ns	ns
Sites × Treatments	ns	ns
Methods × Treatments	ns	**
Years × Sites × Methods	ns	ns
Years × Sites × Treatments	ns	ns
Years × Methods × Treatments	ns	ns
Sites × Methods × Treatments	ns	ns
Years × Sites × Method × Treatments	ns	ns

*Means for same parameter followed by changed alphabet (s) are statistically different at 5, 1 or 0.1% level of probability (P); ns = non significant; *,**,*** = Significant at 5, 1 and 0.1% level of probability respectively.*

Number of fruit retained (%)

The effect of micronutrients (B and Zn) and their application methods at three different sites of citrus on % fruit retained till harvesting time are shown in Table 3. Results revealed that micronutrient, application methods and years significantly improved the fruit retention in citrus. Among the treatments, higher number of fruits (58.64%) were retained when Zn and B were applied in combination compared to solo application of Zn (51.13%) and B (54.23%), which however, were both significantly better than control treatment. The investigation further revealed that significantly higher (53.29%) fruit retained was observed with foliar application compared to the soil application method (49.86%). Though insignificant higher (55.43) fruit were retained at Palai site compare to Dubandai-1 and Dubandai-2. Moreover, fruit retention was higher (53.88%) in the 2nd year of the experiment compared to first year (49.27%). The analysis of the data indicated that the interactive effect of S×M was found significant in improving fruit retention. It was observed that foliar application of micronutrients improved the number of fruit retained at Palai site compared to the soil application methods at all the sites (Figure 5).

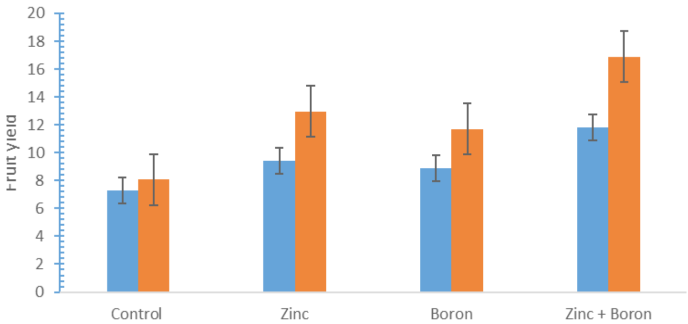

Figure 5: *Interactive effect of micronutrients application methods and sites on fruit retain (%) till harvest of citrus.*

Fruit yield (t ha^{-1})

Fruit yield is the central component of citrus production industries. The effects of micronutrients application on yield of citrus fruits at all the three sites are shown in Table 3. Statistical analysis of the data indicated that citrus fruit yield was significantly influenced with micronutrients treatments, methods of application and years, however the effect of sites was reported insignificant. The effect of all the interactions were also found insignificant except for the M×T interactions which was found significant (Figure 6). The results on the effect of treatment revealed that combined application of Zn and B produced higher (14.34 t ha^{-1}) yield of citrus fruit compared with sole application of Zn (11.19 t ha^{-1}) and B (10.27 t ha^{-1}). The yield obtained with micronutrients treatment was significantly greater as compared with control (7.66 ton ha^{-1}). Likewise, the variation due to methods of application indicates that fruit yield obtained with foliar application was significantly greater (12.40 t ha^{-1}) than soil application of micronutrients (9.33 t ha^{-1}). The results on effect of years revealed that fruit yield of sweet orange was higher (11.80 t ha^{-1}) in 2nd year relative to 9.93 t ha^{-1} obtained during 1st year of study. The interaction analysis of the data showed that combine application of Zn and B through foliar spray produced significantly greater fruit compared to the soil application method (Figure 6).

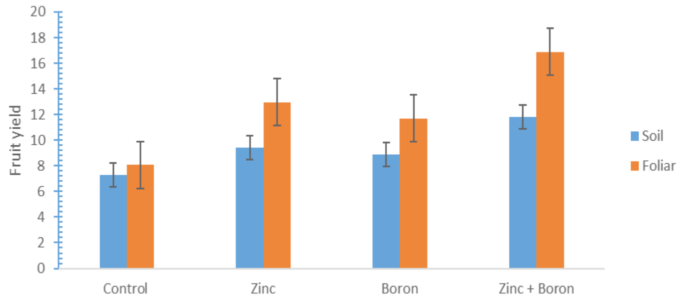

Figure 6: *Interactive effect of micronutrients application methods and treatments on fruit yield of citrus (t ha^{-1}).*

Micronutrients deficiencies could be responsible for declining yield of citrus fruit in northern Khyber Pakhtunkhwa where citrus orchards are mostly established on calcareous soils. The results of the experiment showed that application of both Zn and B significantly increased yield and yield attributes of citrus in Dubandai and Palai areas of Malakand Division. The increase in yield was more when Zn and B were applied together compared with the sole application of Zn and B. The integrated application of Zn and B increased total number of flowers tree^{-1} by 19.66 and 27.49 % over sole application of Zn and B respectively, while the increase was profound in comparison with control (41.14%). However, June fruit drop was at par in all the micronutrient treatments compared with the higher fruit drop in control, probably showing the fruit retention occurred due to the increased fruit set after the micronutrients application. The combined application increased the retention of fruit set by 8.26 % over sole application of Zn, 5.37% over sole application of B and 8.2% over control. All the micronutrient treatments increased the final yield (t ha^{-1}) of sweet orange, but a significantly higher yield of 46.58% relative to control, was recorded with the combined application of Zn and B. However, it has been hypothesized that the long-term effects of micronutrients availability due to continuous application can increase soil nutrients bank which intensifies over time (Zane et al., 2002) and can lead to greater nutrient retention in rhizosphere soil and boost yield attributes and ultimately the crops yield. Ashraf et al. (2012) in their study also reported that micronutrients application can be responsible for short-term increases in fruits yield of citrus. Possible explanation for increase in number of flowers and fruit retention with Zn and B application could be attributed to the fact that Zn is an essential element required by plants for different metabolic process and play vital part in enzyme activation and biosynthesis of specific growth hormones (Ranja and Das, 2003). Similarly, B is also involved in metabolism and translocation of carbohydrate, hormonal activities and pollen tube elongation. It also enhances flower initiation, fruit production, N absorption, growth of plants and indirectly influences fruit set (Cakmak and Romheld, 1997; Simmons, 1998; Anonymous, 2007). Contrarily, declines in citrus yield in B deficient soils could result from impaired reproductive development during the flowering and fruiting cycle (Dell and Huang, 1997). Comparable responses to our findings were also reported by Sajid et al. (2010) and Tariq et al. (2007).

In methods of micronutrients application, foliar spray resulted in promoting the number of flowers tree^{-1} by 11.77%, fruit set by 5.91%, fruit retention by 9.03%, total yield by 24.72% and reduced June fruit drop by 5.58%. The better performance of foliar application of micronutrients relative to soil application could be due to the fact that these soils are mostly calcareous with sandy loam texture, therefore, in soil application method, in addition to leaching, the micronutrients become unavailable to plant due to the higher adsorption and strong buffering capacity of these soils (Khattak, 2010; Shah et al., 2012). Whereas, in foliar application micronutrients are directly applied to plants foliage which are readily available for uptake (Hafeez and Haq, 2006). The results are also in agreement with those of Sajid et al., 2010 and Ashraf et al., 2012, who also reported that foliar use of Zn in citrus orchards improved the growth and physiological characteristics of the trees which resulted in higher yield of citrus fruit. Several investigations showed that Zn and B are essential elements for the normal growth and metabolism of plants that play important role in the biosynthesis of enzymes, growth hormones, nucleic acids, enzyme activation, translocation of carbohydrate in the plant, pollen tube development, flower initiation, fruit development, and improvement in plant growth (Simmons, 1998; Anonymous, 2007; Ranja and Das, 2003; Zekri, 2002). Several scientist (Hafeez and Haq, 2006; Perveen and Rehman, 2000; Razzaq et al., 2013) are of the view that the yield and quality of citrus were improved by the foliar application of micronutrients on calcareous soils. Foliar B applications has also been observed to promote flowering, fruit set, and yield in a variety of perennial tree crops (Nyomora et al., 1999; Stephenson and Gallagher, 1987). Faisal et al. (2008) concluded in their study that the foliar spray of Zn and B may be applied in order to control physiological disorder and increase the production at micronutrient deficient soils.

Though the effect of soil application was not as pronounced as foliar application however, the results of soil application were superior as compared to control. The positive effect of soil application of micronutrients could be attributed to either nutrients saving (residual effect) or improved soil micro-flora (Ayeni et al., 2010). Soil application of Zn and B has the capability to cater the deficiency of these nutrients in the long run and improve soil capability such as ensuring timely availability of these nutrients, which enhance the plant biomass. Furthermore, Zekri and Obreza (2003) reported that choosing appropriate fertilizers and their rates, the grower can drive a crop toward earlier and heavier fruit set. Based on the finding of this research work it can be suggested that the sweet orange orchard in Malakand District should be fertilized with micronutrients in order to overcome the effects of malnutrition. Application of Zn fertilizer to soils is a general strategy to cope with Zn deficiency and to improve leaf Zn content.

The effect of micronutrient, over years, was also positive but insignificant, the total number of flowers were increased in the 2nd than in the 1st year of experiment, but were substantially greater than the control in both years of study. Further, the fruit set and yield (t ha^{-1}) were higher and June drop and fruit retained was lower in second year of experiment. The comparatively lower retention of fruit in the second year of experiment may be attributed to the historic rain and flood that occurred in the 2010. The results of our study obtained from different sites show that the observations recorded at Palai site were markedly better from Dubandi-1 and Dubandi-2. Palai had the maximum numbers of flowers, which may be due to its location which is covered from almost all sides and hence is protected from wind and high temperature damages.

In spite of limited work on the interactive effect Zn and B on each other, some researchers suggest that Zn reduces leaf B content in citrus especially in soils with higher available B content. Swietlik and LaDuke, 1991; and Gunes, 1999 in their studies also reported that an antagonistic relationship existed between Zn and B. The results on number of flowers tree^{-1}, fruit set (%), fruit drop (%) and fruit retain (%) revealed that the Zn application significantly enhanced these attributes especially when used in integration with B and similar results were also reported by Sourour (2000). Due to the involvement of these micronutrients in a number of plant metabolic processes, enhancement in plant growth and yield with their application is apparent. Boron fertilization improve metabolites synthesis that also benefits the fertilization process and subsequent fruit set (Swietlik, 1995). Metabolites are low-molecular-weight organic and inorganic chemicals that are the reactants, intermediates, or products of enzyme-mediated biochemical reactions (Fanos and Atzori, 2012). In disparity, Zekri (2002) reported that inadequate supply of B drastically reduced the fruit set, while squatted sugar and disproportionate fruit drop of orange fruits due to B deficiency are also reported by Ali et al., 1999. In the light of all these investigations it is reasonable to attribute the increase in fruit set to integrated application of Zn and B. Due to the optimum supply of Zn and B, along with other biochemical processes, the rate of carbohydrates production and its translocation increased which ultimately increased the fruit set and reduced the fruit drop (Gupta et al., 1993; Heitholt, 1994). Proper nutrient management can significantly improve the citrus production, soil properties and tree performance (Zaman and Schumann, 2006).

Conclusions and Recommendations

Citrus fruit yield and quality and the extent of bearing life of orchards, established on calcareous soils, can effectively be enhanced by application of Zn and B at the rate of 2.5 kg ha^{-1} each either alone or in combination. Foliar application of micronutrients proved to be more effective than soil application, however soil application also improved fruit yield and quality compared to no micronutrients application. Continued application of micronutrient are needed to combat widespread deficiencies and control the declining status of citrus orchards in Malakand Division.

Novelty Statement

Novelty of this study is to evaluate the effect of micro-nutrients (Zn and B) and their methods of application on the yield and yield attributes of sweet orange in Malakand Division, Khyber Pakhtunkhwa, Pakistan and to develop strategy for increasing micronutrients availability in calcareous soil.

Author's Contribution

Yousaf Noor conceived the idea, conducted the research and collected the data. Zahir Shah was major supervisor who designed the research and edited the final draft. Muhammad Tariq helped in final analysis.

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