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Effect of Foliar Application of Micronutrients on the Yield and Quality of Sweet Orange (*Citrus sinensis* L.)

M. Tariq, M. Sharif, Z. Shah and R. Khan
Department of Soil and Environmental Sciences, NWFP Agricultural University, Peshawar, Pakistan

Abstract: An experiment was designed to study the effect of foliar application of micronutrients on the yield, quality and leaf composition of sweet orange, Blood red variety at *Shabazgari*, Mardan. The experiment was laid out in a randomized complete block design in 2^3 factorial arrangement. Zinc, manganese and boron were applied as foliar spray at the rate of 0.4, 0.2 and 0.04 kg ha^{-1}, respectively in the presence of 1.56 kg N ha^{-1} as urea and 0.4 kg surfactance ha^{-1} (as wetting agent) in 400 L of water. The maximum fruit yield was obtained, when 0.4 kg Zn ha^{-1} and 0.2 kg Mn ha^{-1} was sprayed along with 1.56 kg N ha^{-1} and 0.4 kg surfactance ha^{-1} in 400 L of water. The minimum % peel was obtained with B alone and minimum % rag with Zn + Mn, maximum fruit size with Zn + B and maximum fruit volume with Zn + Mn. Similarly, % juice in sweet oranges was increased significantly by B alone, reducing sugar by Mn alone and vitamin C contents by Zn + B through foliar spray, suggested that each micronutrient had different role on the quality of citrus fruit. Foliar spray of Zn, Mn and B along with urea significantly increased the concentration of Zn and Mn in citrus leaves, while the concentration of B was not affected with foliar spray, perhaps due to dilution within the citrus tissues. Therefore, it is suggested that either Zn+Mn or Zn+B may be applied as foliar spray in combination with urea and surfactance for getting the maximum yield and improved quality of citrus fruit under prevailing conditions.

Key words: Fruit yield, fruit quality, micronutrients, interaction, foliar spray, citrus

INTRODUCTION

Citrus (*Citrus sinensis* L.) is one of the important fruit crop of the world, occupied third position among the sub-tropical fruits. It has a great nutritional role in our daily food requirements, being a rich source of vitamin C (Gregory, 1993). Citrus is grown in different areas of NWFP including Peshawar, Mardan, Hazara, Dera Ismail Khan, Dir, Swat and Malakand Area. Indigenous nutritional survey, soil and leaf analysis and visual symptoms of various citrus orchards indicated certain micronutrient deficiencies, specifically Zn, Mn and B (Rehman, 1990; Khattak, 1991) and due to these deficiencies some healthy orchards are turning into unproductive plantation with poor quality fruit. Citrus is a nutrient loving plant, but growers of this region are not using micronutrient fertilizers (Personnel communication with the citrus growers), which causes serious nutritional disorders in citrus (Catara, 1987). Moreover, soils of this region are mostly calcareous in nature and alkaline in reaction and these conditions are not favorable to micronutrients availability (Zekri and Obreza, 2003). Similarly, Embleton *et al.* (1973) also reported that Zn applied to alkaline soils is usually adsorbed or precipitated on the surface and does not move readily to the root zone. However, soil application of micronutrients is therefore not very effective to recover these deficiencies in calcareous and alkaline soils. Further, citrus is deep rooted crop so micronutrients application to soil may be of little value. The alternative way is to supply micronutrient fertilizers through foliar spray. Chiu and Chang (1986) reported that foliar spray of boric acid was more effective than soil application in curing B deficiency in citrus. Similarly, Mann *et al.* (1985) found that micronutrients (Zn, Cu, Fe and Mn) spray on the leaves of sweet oranges increased the concentration of the respective nutrient in the leaves. Perveen and Rehman (2000) also concluded that foliar spray of Zn, Mn and B corrected the deficiency symptoms and increased the citrus fruit yield. Keeping in view the unfavorable physico-chemical conditions of our soils, it becomes necessary to supply micronutrients in balanced amount through foliar spray and to raise citrus production. Therefore, the present experiment was designed to study the effect of micronutrients on the yield, quality and leaf composition of sweet oranges in the vicinity of Mardan area.

Corresponding Author: M. Tariq, Department of Soil and Environmental Sciences, NWFP Agricultural University, Peshawar, Pakistan

MATERIALS AND METHODS

Experimental design and fertilizers: A field experiment was carried out on 15 years old sweet orange, Blood red variety, orchard at *Shahbazgari* Mardan, showing leaf deficiency symptoms of Zn, Mn and B. The trees were selected having uniform canopy and properly tagged. A basal dose of 150 kg N ha^{-1} (1.7 kg urea $tree^{-1}$), 100 kg P_2O_5 ha^{-1} (3 kg single super phosphate $tree^{-1}$) and 100 kg K_2O ha^{-1} (1 kg sulphate of potash $tree^{-1}$) were applied under the canopy of each tree leaving 60 cm area around the tree and then irrigated. The nutrients were applied at the rate of 0.4 kg Zn, 0.2 kg Mn and 0.04 B kg ha^{-1} as $ZnSO_4.7H_2O$, $MnSO_4.3.H_2O$ and H_3BO_3 in 400 L of water in the presence of 1.56 kg N ha^{-1} and 0.4 kg surfactance ha^{-1} (as wetting agent), 3 times at interval of 15 days, when the new spring leaves were not fully developed. Detail of the micronutrients doses and their combinations are given in Table 1. The experiment was laid out in randomized complete block design with 2^3 factorial arrangement and each treatment was replicated 3 times. Before incorporation of nutrients in soil, composite soil samples were collected at the depth of 0-45 and 45-90 cm from four different crossing points of four trees in the orchard for the determination of various physico-chemical characteristics of the experimental soil. Physico-chemical characteristics of citrus orchard of *Shahbazgari*, soil showed that the experimental soil was silt loam in texture, alkaline in reaction, moderately calcareous and non-saline in nature, deficient in organic matter and micronutrients such as Zn, Mn and B. The values of DTPA-extractable micronutrients were compared with the reported literature (Lindsay and Norvell, 1978) and found that Zn and Mn were deficient, Cu and Fe were adequate, while HWS-B was also deficient (Sillanpaa, 1982) in the experimental soil. Similarly leaf samples were collected from the desired treatments before foliar spray for the determination of native micronutrient contents.

Table 1: Detail of micronutrients treatments and their combination used as foliar spray for sweet orange

Treatments	Zn	Mn	B
	------------- kg ha^{-1} in 400 L of water -----------		
Zn_0 Mn_0 B_0	-	-	-
Zn_1 Mn_0 B_0	0.40	-	-
Zn_0 Mn_1 B_0	-	0.20	-
Zn_0 Mn_0 B_1	-	-	0.04
Zn_1 Mn_1 B_0	0.40	0.20	-
Zn_1 Mn_0 B_1	0.40	-	0.04
Zn_0 Mn_1 B_1	-	0.20	0.04
Zn_1 Mn_1 B_1	0.40	0.20	0.04

The subscript 0 indicate no spray of an element on trees, while subscript 1 indicate foliar spray of 0.4 kg Zn, 0.2 kg Mn and 0.04 kg B ha^{-1} in 100 L of water along with 1.56 kg N ha^{-1} and 0.4 kg surf ha^{-1} (wetting agent)

Quality analysis: The chemical quality of fruit such as brix, % juice, vitamin C, juice pH, acidity, reducing and non-reducing sugar were determined according to the methods of AOAC (1990). Brix was determine with a handheld temperature-compensating refractometer, fruit juice extracted by orange extractor and volume was measured by a cylinder, vitamin C was determined by ascorbic acid reduces oxidation-reduction indicator dye, 2, 6-dichloroindophenol to colorless solution method, juice pH was measured by pH meter, reducing and non reducing sugars were determined by polarimetric method before and after inversion with invertase, acidity by titration of a 25 mL aliquot of juice using 0.25 N NaOH to a end point of pH on an auto-titrator. While, physical quality parameters like fruit size measured by vernier caliper and fruit volume by water displacement method and % peel and rag were calculated according to the randomly selected 8 fruit weight formula (Maurer and Taylor, 1999).

Plant analysis: Leaf samples were collected before and after foliar spray from the non-fruit bearing terminals (90 to 180 cm above the ground) then washed, oven dried, ground and extracted with wet acid digestion method and analyzed for elemental content of Zn and Mn by Atomic Absorption Spectrophotometer, model-2380 (Jones and Case, 1990). While, B was extracted by dry ashing technique and determined by Spectrophotometer, model-601, after color development procedure of curcumin oxalic acid (Jackson, 1973).

Statistical analysis: All the data collected during field and laboratory investigation were statistically analyzed using analysis of variance technique and the treatment differences were evaluated by Duncan's Multiple Range-test of significance (Steel *et al*., 1997).

RESULTS AND DISCUSSION

Micronutrients concentration in citrus leaves before foliar spray: Leaf samples were collected from the desired treatments before foliar spray for the determination of native micronutrient contents. Results showed that the native concentration of micronutrients such as Zn, Cu, Fe, Mn and B before foliar spray were found 17.06, 12.56, 347.84, 31.54 and 28.43 $\mu g\ g^{-1}$, respectively (Table 2). These concentrations were compared with the reported literature (Embleton *et al*., 1973) and found that Zn and B were low, Cu and Mn optimum and Fe was found in excess in sweet orange leaves, which suggested that there was a need of foliar spray of micronutrients on such citrus orchard.

Table 2: Native concentration of Zn, Mn and B ($\mu g\ g^{-1}$) in citrus leaves before foliar application of micronutrients

Treatments	Zn	Cu	Fe	Mn	B
$Zn_0\ Mn_0\ B_0$	17.59	14.94	342.00	16.84	28.72
$Zn_1\ Mn_0\ B_0$	14.80	12.64	341.67	20.64	29.00
$Zn_0\ Mn_1\ B_0$	17.70	11.40	331.34	49.07	27.44
$Zn_0\ Mn_0\ B_1$	16.50	15.34	365.34	32.06	25.14
$Zn_1\ Mn_1\ B_0$	12.40	12.34	365.34	33.97	28.40
$Zn_1\ Mn_0\ B_1$	14.47	11.87	353.67	30.94	29.49
$Zn_0\ Mn_1\ B_1$	18.50	9.60	326.34	33.37	29.22
$Zn_1\ Mn_1\ B_1$	19.70	12.34	352.00	35.44	29.97
Means	17.06	12.56	347.84	31.54	28.43
SD±	2.03	1.58	21.33	5.38	1.92

Table 3: Effect of foliar application of micronutrients on the yield and physical quality of sweet orange fruit

Treatments	Yield (kg tree^{-1})	Increase (%)	8 fruit wt. (kg)	Peel (%)	Rag (%)	Size (cm)	Volume (mL)
$Zn_0\ Mn_0\ B_0$	63.00c	------	1.09bc	37.57a	6.05ab	6.06c	105.84ab
$Zn_1\ Mn_0\ B_0$	79.33b	25.92	1.18bc	34.50ab	6.13ab	6.39b	113.00ab
$Zn_0\ Mn_1\ B_0$	89.00ab	41.97	1.11bc	33.67b	5.01bc	6.28b	115.50ab
$Zn_0\ Mn_0\ B_1$	64.00c	1.59	1.13bc	26.88b	6.78a	6.42b	121.30ab
$Zn_1\ Mn_1\ B_0$	123.3a	95.70	1.15bc	34.71ab	4.54c	6.65a	140.50a
$Zn_1\ Mn_0\ B_1$	115.3a	83.02	1.08bc	33.86b	5.64abc	6.75a	128.30ab
$Zn_0\ Mn_1\ B_1$	103.0ab	65.56	1.19bc	33.74b	5.84ab	6.65a	119.60ab
$Zn_1\ Mn_1\ B_1$	75.00bc	19.05	1.28a	33.40ab	5.80abc	6.41b	104.20b
Zn	**		*	NS	NS	*	NS
Mn	**		**	NS	**	NS	NS
B	NS		NS	**	**	*	NS
Zn × Mn	*		NS	NS	NS	**	NS
Zn × B	NS		NS	**	NS	**	*
Mn × B	NS		*	**	NS	**	NS
Zn × Mn × B	*		*	**	NS	**	NS

Mean values followed by similar letter(s) do not differ significantly from one another; *, ** = Indicate significant at ($p<0.05$) and ($p<0.01$), respectively; NS = Non Significant

Fruit yield: Results showed that foliar application of Zn and Mn alone or in combination with each other significantly increased the fruit yield of sweet oranges compared with the control treatment (Table 3). The maximum fruit yield of 123.3 kg tree^{-1} was obtained from the treatment receiving Zn + Mn followed by 115.3 kg tree^{-1} from Zn + B, 103.0 kg tree^{-1} from Mn + B and 89.0 kg tree^{-1} from Mn alone treatment, but the yield differences among such treatments were statistically at par with each other, indicating foliar sprays of micronutrients were effective in increasing the fruit yield over control (tree without foliar spray). Similar results were reported by Leyden (1983); Perveen and Rehman (2000). It was also observed that Zn + Mn caused 95.70% increase in yield over control. The corresponding increases were 83.02% by Zn + B, 65.56% by Mn + B and 41.97% by Mn alone treatment. Perhaps these increases in fruit yield were due to the significant increase in leaf Zn and Mn concentrations, which in turn induced more flowering and minimize fruit let drop in sweet orange trees. Because, it was reported that fruit let drop decreased as leaf Zn and Mn content increased (Garcia *et al.*, 1984). On the other hand, B alone treatment did not significantly increase the fruit yield of sweet oranges, but in combination with Zn and Mn the fruit yield considerably increased, perhaps due to positive interactions among these micronutrients. Because the interactions between Zn × Mn and Zn × Mn × B were found statistically significant. These results are in line with the previous work of Perveen and Rehman (2000) who reported that B alone spray could not give satisfactory yield, but yield was increased when it was applied in combination with Zn and Mn.

Fruit quality: Results of the physical quality of citrus fruit indicate that the % peel in sweet oranges was significantly reduced by B alone, Mn alone, Mn + B and Zn + B treatments compared with the control treatment (Table 3). These results are in line with the previous work of El-Shazly and Hennawy (1983). The % rage was affected significantly only in Zn + Mn treatment comparing with control. The size of fruit was however, significantly increased by all micronutrient treatments of which the maximum size of 67.75 cm was attained from Zn + B treatment. The interactions between micronutrients with respect to size were found statistically significant. The volume of fruit was however, not affected significantly by any of the micronutrients treatment. The overall results regarding physical quality of citrus fruit indicate that B significantly decreased the % peel and rag and improved the size of citrus fruit.

The foliar spray of micronutrients showed variable effects on the chemical quality of sweet oranges juice (Table 4). The brix, juice pH, acidity and the level of non-reducing sugar were not affected significantly by any of

Table 4: Effect of foliar application of micronutrients on the chemical quality of sweet orange fruit

Treatments	Brix	Juice (%)	Juice pH	Acidity (%)	Reducing sugar	Non reducing sugar	Vitamin C mg/100 mL
Zn_0 Mn_0 B_0	10.80	51.10b	3.66	0.68	4.68b	2.84	42.77b
Zn_1 Mn_0 B_0	11.87	59.28ab	3.61	0.72	4.85b	2.94	51.49a
Zn_0 Mn_1 B_0	11.23	58.29ab	3.64	0.69	5.84a	3.04	48.88ab
Zn_0 Mn_0 B_1	11.22	62.59a	3.65	0.64	4.68b	2.64	48.21ab
Zn_1 Mn_1 B_0	11.10	55.59ab	3.64	0.77	4.40b	2.84	50.29a
Zn_1 Mn_0 B_1	11.57	56.03ab	3.58	0.62	4.40b	2.78	52.36a
Zn_0 Mn_1 B_1	11.37	58.79ab	3.66	0.66	4.71b	2.62	47.02ab
Zn_1 Mn_1 B_1	11.57	54.81ab	3.71	0.64	4.57b	2.67	48.95ab
Zn	NS	NS	NS	NS	*	NS	**
Mn	NS	NS	NS	NS	NS	NS	NS
B	NS	**	NS	NS	**	NS	NS
Zn × Mn	NS	*	NS	NS	*	NS	NS
Zn × B	NS	*	NS	NS	NS	NS	NS
Mn × B	NS	*	NS	NS	*	NS	NS
Zn × Mn × B	NS	*	NS	NS	NS	NS	NS

Mean values followed by similar letter(s) do not differ significantly from one another; *, ** = Indicate significant at ($p<0.05$) and ($p<0.01$), respectively; NS = Non Significant

the micronutrient spray. Mann *et al.* (1985) also reported that micronutrients spray had no significant effect on the quality of citrus fruit. Other quality parameters such as % juice, reducing sugar and vitamin C were significantly affected by one or more micronutrients. The application of B alone significantly increased the % juice compared with the control treatment. The % juice was 62.59 in the B and 51.10 in the control treatment. However, the % juice in other micronutrient treatments was at par with that in the control treatment. Similarly, the level of reducing sugar in orange juice was increased significantly only by the application of Mn alone spray. The vitamin C content of juice was significantly increased by the application of Zn alone, Zn + Mn or Zn + Mn + B treatments compared with the control treatment. Rehman (1992) also reported increase in vitamin C content of citrus fruit due to foliar application of these micronutrients. Although vitamin C content of juice in Mn alone, B alone, Mn + B or Zn + Mn + B treatments were higher than that in the control treatment, but the differences were found statistically non significant. These results demonstrated that % juice in sweet oranges was increased significantly by B alone, reducing sugar by Mn alone and vitamin C contents by Zn alone, Zn + Mn or Zn + B through foliar application, suggesting that each nutrient had different role on the quality of sweet oranges.

Micronutrients concentration in citrus leaves after foliar spray: Results show that the foliar spray of Zn significantly increased the Zn concentration in citrus leaves (Table 5). A highest Zn concentration of 87.33 $\mu g\ g^{-1}$ was obtained in the treatment in which the Zn was applied alone. Similar increase in the Zn concentration of citrus leaves were found by Nanaya *et al.* (1985). Results also show that the applied Zn decreased the concentrations of both Mn and B in

Table 5: Effect foliar application of micronutrients on the concentration of Zn, Mn and B in sweet orange leaves

Treatments	Zn	Mn	B
	----------------------	$\mu g\ g^{-1}$	----------------------
Zn_0 Mn_0 B_0	30.73c	34.77bc	23.80b
Zn_1 Mn_0 B_0	87.33a	16.67d	19.92bc
Zn_0 Mn_1 B_0	14.90d	85.87a	22.90bc
Zn_0 Mn_0 B_1	24.37c	28.47c	23.93b
Zn_1 Mn_1 B_0	69.30b	56.83ab	17.65c
Zn_1 Mn_0 B_1	86.87a	27.90c	22.78bc
Zn_0 Mn_1 B_1	30.87c	53.60ab	30.07a
Zn_1 Mn_1 B_1	79.30ab	48.57b	24.28b
Zn	**	NS	NS
Mn	NS	**	NS
B	NS	NS	**
Zn × Mn	**	NS	NS
Zn × B	NS	NS	NS
Mn × B	NS	NS	**
Zn × Mn × B	NS	NS	**

Mean values followed by similar letter(s) do not differ significantly from one another; *, ** = Indicate significant at ($p<0.05$) and ($p<0.01$), respectively; NS = Non Significant

citrus leaves, perhaps due to interaction among these micronutrients. Because the statistical analysis indicate that Zn and Mn interaction is significant, while Zn and B interaction did not attain the statistical significance. However, results suggested that Mn in Zn spray significantly reduced the Zn concentration in citrus leaves. On the other hand, Zn concentration was significantly increased compared to the control when B was included in spray mixture with Zn.

Similarly, foliar spray of Mn on citrus leaves significantly increased the concentration of Mn in citrus leaves (Table 5). A highest concentration of 85.87 μg Mn g^{-1} was obtained in the treatment where Mn was applied alone. Moreover, Mn application decreased the Zn concentration, while the concentration of B was unaffected. Razeto *et al.* (1988) reported that the increase in Mn concentration in orange leaves was greater when applied singly than in combination with Zn. Furthermore, when Mn was applied in combination with Zn and B a non-significant interaction was found among these micronutrients. The reverse trend occurred in the case of B (Table 5). Boron concentration in citrus leaves was not considerably increased as it was expected, when B was applied alone or in combination with Zn. The reason is that boron was transferred to fruit, so this may be used in correcting the deficiency symptoms. However, a highest concentration of 30.07 μg B g^{-1} was obtained when it was applied in combination with Mn, because the interaction effect between Mn and B suggested that the concentration of B in citrus leaves was significantly increased from 21.86-27.18 μg g^{-1} as compared to the control when Mn and B were sprayed in mixture. Leon *et al.* (1983) also found that high B concentration was associated with increased Mn and Zn in lemon leaves.

The overall effect of the micronutrients spray on citrus leaves showed that foliar application of Zn alone and in combination with Mn and B completely eliminated the yellow interveinal blotches contrasting with a green background, produced a lush green color in leaves, increased the size of the leaves and eliminated rosettes. Similarly, foliar application of Mn gave dark green and shiny color to the leaves. Foliar application of B had no apparent effect on citrus leaves, but increased the fruit size soften the peel and decreased the peel thickness. The number of smaller fruits were less in those treatments where B was applied alone or in combination with other micronutrients, compared to the control. Similarly, Shorrocks (1984) reported that a deficiency of boron suspected on the basis of leaf symptoms should be confirmed by fruit symptoms.

CONCLUSIONS

The following conclusions were drawn from the present study.

The maximum fruit yield was obtained, when 0.4 kg Zn ha^{-1} and 0.2 kg Mn ha^{-1} was sprayed along with 1.56 kg N ha^{-1} and 0.4 kg surfactance ha^{-1} in 400 L of water.

The minimum % peel was obtained with B alone and minimum % rag with Zn + Mn, maximum fruit size with Zn + B and maximum fruit volume with Zn + Mn. Similarly, % juice in sweet oranges was increased significantly by B alone, reducing sugar by Mn alone and vitamin C contents by Zn + B through foliar spray, suggested that each micronutrient had different role on the quality of citrus fruit.

Foliar spray of Zn, Mn and B along with urea significantly increased the concentration of Zn and Mn in citrus leaves, while the concentration of B was not affected with foliar spray, perhaps due to dilution within the citrus tissues.

REFERENCES

AOAC, 1990. Association of Official Analytical Chemists. Official Methods of Analysis. 15th Edn., Washington, D.C.

Catara, A., 1987. Compendium of citrus diseases and disorder in Pakistan. Results of a preliminary survey. Agrotec SPA, Rome project for research and development in the cultivation of fruit, vegetables and olives. PARC, Islamabad, pp: 14-15.

Chiu, T.S. and S.S. Chang, 1986. Diagnosis and correction of boron deficiency in the citrus orchard of Taiwan. Soil and Fertilizer in Taiwan, 1986, pp: 33-44.

El-Shazly, S.A. and M.H. Hennawy, 1983. Effect of foliar application of manganese on leaf mineral content, yield and fruit quality of Naval orange trees grown in sandy soil. Ann. Agric. Sci. Egypt. 1985, 23: 1805-1815.

Embleton, T.W., W.W. Jones, C.K. Labanauskas and W. Reuther, 1973. Leaf analysis as a diagnostic tool and guide to fertilization. In: The citrus industry. University of California, Division of Agricultural Sciences, USA., pp: 83-210.

Garcia, A., N.E. Haydar and C. Ferrer, 1984. Influence of Zn and Mn on the physiological behavior and yields of Valencia oranges. Center Agricola (1982). Institute Superior Agricola Ciego de Avila, Cuba, 10: 57-58.

Gregory, J.F., 1993. Ascorbic acid bioavailability in foods and supplements. Nutr. Rev., 51: 301-303.

Jackson, M.L., 1973. Soil Chemical Analysis. Prentice Hall of India, New Delhi, pp: 498.

Jones, J.B.Jr. and V.W. Case, 1990. Sampling, Handling and Analyzing Plant Tissue Sample. In: Soil Testing and Plant Analysis. Westermann, R.L. (Ed.), 3rd Edn., 1990. Soil Sci. Soc. Am. Book Series No. 3, Madison, WI., pp: 389-427.

Khattak, J.K., 1991. Micronutrients in NWFP Agriculture. BARD, PARC, Islamabad, Pakistan.

Leon, A., A. Torrecillas, F. Amor-Del and M.R. Monllor, 1983. Criteria for the diagnosis of excess boron in lemon trees. Anales de Edafologia y Agrobiologia, 42: 807-817.

Leyden, R.F., 1983. Nutrition of Young Star Ruby Grapefruit. J. Rio-Grande Valley Hortic. Soc., 36: 67-71.

Lindsay, W.L. and W.A. Norvell, 1978. Development of DTPA soil test for zinc, iron, manganese and copper. Soil Sci. Soc. Am. J., 42: 421-428.

Mann, M.S., J.S. Josan, G.S. Chohan and V.K. Vij, 1985. Effect of foliar application of micronutrients on leaf composition, fruit yield and quality of sweet orange (*Citrus sinensis* L.) cv. Blood red. Indian. J. Hortic., 42: 45-49.

Maurer, M.A. and K.C. Taylor, 1999. Effect of foliar boron sprays on yield and fruit quality of naval oranges. http://ag.arizona.edu/pubs/crops/az1138. (Accessed on 15th October, 2006).

Nanaya, K.A., K. Anjaneyulu and C.S. Kotur, 1985. Effect of foliar application of Zn, Mn, Cu and Mg on growth parameters, chlorosis and interrelationships of micronutrient in leaf tissue of Coorg mandarin. Prog. Hortic., 17: 309-614.

Perveen, S. and H. Rehman, 2000. Effect of foliar application of zinc, manganese and boron in combination with urea on the yield of sweet orange. Pak. J. Agric. Res., 16: 135-141.

Razeto, M.B., M.J. Longueria, Z.S. Rojas and M.G. Reginato, 1988. Correction of manganese and zinc deficiencies in orange. Agricultura Tecnica, 48: 347-352.

Rehman, H., 1990. Survey of the fruit plants for nutrient-elements content and planning of fertilizer research programme. Annual Report, Directorate of Soil and Plant Nutrition. Agric. Res. Inst. Tarnab, Peshawar.

Rehman, W., 1992. Effect of foliar application of micronutrients in combination with urea on the yield and fruit quality of sweet orange. M.Sc. (Hon's) Thesis, Department of Soil Science, NWFP Agricultural University, Peshawar.

Shorrocks, V.M., 1984. Boron Deficiency its Prevention and Cure. Borax Holdings Limited, Borax House, Carlisle Place, London SW1P 1HT, England.

Sillanpaa, M., 1982. Micronutrient and Nutrient Status of Soil. A global study, FAO Soil Bulletin. No. 48: Rome.

Steel, R.G.D., J.H. Torrie and D.A. Dickey, 1997. Principles and Procedures of Statistics. A Biometrical Approach. 3rd Edn., McGraw Hill Companies, Inc. New York, USA.

Zekri, M. and T.A. Obereza, 2003. Micronutrient deficiencies in citrus: Iron, zinc and manganese. Document SL 204, a fact sheet of the Soil and Water Science Department, Florida, Cooperative Extension Service, Institute of Food and agricultural Services, University of Florida, USA. http://edis.ifas.ufl.edu. (Accessed on 15th October, 2006).