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INVESTIGATIONS ON DETERMINATION OF NUTRITIONAL STATUS OF PEAR TREES ACCORDING TO A NEW INDEX - DEVIATION FROM OPTIMUM PERCENTAGE (DOP)

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ABSTRACT. This experiment was conducted in a private orchard (Kosar) in district of Shahriar of Alborz province (Iran), during 2012-2013, to determine the effects of B and Zn applied on flowers at full bloom stage on leaf macro and micronutrient contents at 90 days after full bloom (DAFB) of three pear cultivars (Spadona and Duchesse and a pear cultivar from Iranian national collection, named as Daregazi). The deviation from the optimum percentage (DOP) index of macro and micronutrients for two studied years was used to evaluate the nutritional status: optimal (DOP = 0), deficiency (DOP < 0) or excess (DOP > 0). The ΣDOP for two studied years is obtained by adding the values of DOP index irrespective of sign. The larger the ΣDOP, the greater is the intensity of imbalances among nutrients. In general, a DOP value close to the optimum level (DOP = 0) were observed in treated studied pear cultivars with B and Zn applied on flowers at full bloom stage compared with the control trees (without any application of boron and zinc). The DOP_{macro} and DOP_{micro} were, respectively, positive and negative for all of studied pear cultivars regardless of treatments. According to £DOP index (during 2012-2013), the combination of both products (borax+zinc sulfate treatments) at full bloom stage applied on flowers of three pear cultivars (Spadona, Duchesse and Daregazi) showed better balanced nutritional values than the rest of treatments.

Key words: DOP index; Pear cultivars; Nutritional status; Boron; Zinc.

INTRODUCTION

The pear belongs to the *Rosaceae* family and *Pomoideae* subfamily and it is the most important pome fruit tree in world after apple. According to recent statistics the area of pear culture in Iran consists of 14,502 hectares with production of about 145,123 tonnes (FAOSTAT, 2011). This average production is low and also, in these areas, one of the main limiting factors for pear production is alkaline soils with

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deficiency of organic matter and inadequate major nutrients availability.

Plenty of researchers have attempted to increase the productivity and quality of pear fruit crops. The use of mineral elements in this respects were cited on pear fruit using boron (Gobara, 1998; Taher and Hassan, 2005); boron and calcium (Abd El-Megeed *et al.*, 2007); boron and zinc (Canesin *et al.*, 2010); gibberellins (Deckers and Schoofs, 2002); bioregulator, combined applications auxin, cytokinin and gibberellin (Lafer, 2008); amino acids and polyamines (Franco-Mora *et al.,* 2005); growth regulators, nutrients and amino acids (Stino *et al.,* 2011) were also tried.

From the point of leaf nutrient status, a number of methods are available for diagnostic interpretation of foliar data (e.g. i). Concentrations and ratios such as Evolutive Nutrient Balance (ENB), Diagnosis and Recommendation Integrated System (DRIS), Deviation from Optimum Percentage (DOP and ΣDOP index) and others (Montañés *et al.,* 1993; Sanz, 1999; Zarrouk *et al.*, 2005). The deviation from optimum percentage (DOP) is an alternative method to the traditional diagnosis and recommendation integrated system (DRIS), which is capable of accurately defining the quantity and quality of each nutrient in plants (Montañés *et al.,* 1993). Besides, it provides the general nutritional status of all macro and micronutrients through the sum of DOP indexes (_DOP_{macro} and _DOP_{micro}).

Determining the effects of single B and Zn products as well as the combination of both products (borax+zinc sulfate) applied on flowers at full bloom stage on leaf macro and micronutrient contents at 90 days after full bloom (DAFB) of three pear cultivars (Spadona and Duchesse and a pear cultivar from Iranian national collection, named as Daregazi) were the scope of the present investigation.

MATERIAL AND METHOD

The experiment was conducted in the period of 2012 to 2013, in a private orchard (Kosar) in district of Shahriar of Alborz province (Iran). The mature pear cultivars (Spadona, Duchesse and Daregazi), grafted on *Pyrus communis* seedlings, planted at a spacing of 4×2m. The results of the soil chemical analysis are presented in *Table 1*. The climate was semi-arid, with an average annual precipitation of 250 mm, with annual average temperature of 32.3°C, and annual average relative humidity of 45.4% (synoptic meteorological stations of Iran, 2013). The studied pear cultivars were sprayed with borax (1%, 2%, 3%), zinc sulfate (1%, 2%, 3%) and borax+zinc sulfate (1% B+1% Zn, 1% B+2%Zn, 1% B+3%Zn, 2%B+1%Zn, 2% B+2%Zn, 2% B+3%Zn, 3%B+1%Zn, 3%B+2%Zn, 3%B+3%Zn) at full bloom stage. Date of full bloom in the first year of experiment was on 30th of March 2012 and for the second year of experiment on 24th of March 2013**.** The following parameters were evaluated:

Table 1 - DOP and ΣDOP index determined from leaf macronutrient contents at 90 DAFB, yield and initial fruit set in Spadona cultivar as affected by B and Zn applied on flowers at full bloom stage during two years experimental trials (2012-2013)

Table 1 – part I

Treatments	Leave B (ppm)		Leave Mg (%)		Leave K (%)		Leave N (%)		Leave Zn (ppm)		Leave Fe (ppm)		Leave P (%)		Leave Ca (%)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Control	29.55	29.52	-71.07	296.11	95.1	131.95	15.62	56.19	-10.85	-33.33	-21.1	76.4	343.22	53	-60.67	3964.22
1%Zn	126.98	152.39	-2.32	-38.54	61.31	80.79	0.26	57.37	38.73	-12.8	-9.54	33.56	194.35	99.09	-67.16	3964.22
2%Zn	22.52	194.83	-59.32	19.04	29.96	63.02	-20.07	13.89	18.91	-2.64	-19.3	80.58	109.13	74.48	-72.05	4488.48
3%Zn	77.92	156.28	-34.9	68.68	-33.08	112.6	-15.71	19.8	33.78	15.44	-43.97	57.87	186.78	95.26	-54.49	4552.28
1%B	107.61	259.14	-8.25	72.46	-19.5	-5.81	-26.4	-24.93	73.4	52.6	4.92	116.13	506	334.78	-69.51	4544.46
2%B	-8.18	26.66	2.75	93.18	27.39	49.05	21.18	23.6	23.87	9	-20.15	64.49	232.17	117.39	-67.07	4333.99
3%B	-3.43	67.06	114.68	303.64	-51.06	-42.73	53.33	56.4	167.55	135.44	-9.07	87.33	-8.96	-13.04	-64.58	4327.07
1%Zn1%B	79.46	77.14	-3.89	89.57	-54.78	62.68	-31.68	18.03	48.74	0.06	-30	46.93	356.3	75.17	-64.62	4082.58
1%Zn2%B	-11.29	83.32	20.11	56.86	-6.31	58	-14.29	-0.46	240.21	-3.9	-7.07	28.36	400.96	42.48	-63.51	4091.82
1%Zn3%B	12.33	97.25	-25.79	254.32	-7.55	57.6	24.09	4.68	385.45	-30.3	-31.08	32.74	344.87	92.17	-64.58	3608.27
2%Zn1%B	39.68	92.09	21.46	11.143	-22.93	63.1125	56.02	16.15	-0.3	0.38	-25.91	30.58	-12.57	57.65	-69.42	3945.74
2%Zn2%B	7.15	164.27	-28.39	127.43	30.42	27.74	0.72	9.96	21.47	6.05	-19.61	41.2	169.917	33.78	-68.52	4310.94
2%Zn3%B	-62.99	213.86	-56.96	93.5	-5.175	40.56	29.55	80	-10.88	6.37	22.64	37.56	38.48	77.83	-68.05	3503.76
3%Zn1%B	92.83	185.24	-21.46	168	-25.42	67.55	-20.75	-7.72	53.91	-21.88	-19.53	44.84	382.13	84.04	-60.67	3836.62
3%Zn2%B	21.47	86.9	-46.93	181.04	40.56	38.19	34.41	12.67	-20.65	-20.56	-17.86	38.8	211.61	83.13	-73.78	3772.82
3%Zn3%B	27.49	152.13	-64.61	267.32	3.81	39.22	-13.99	3.83	490.91	-29.29	-31.6	29.38	267.91	53.09	-53.91	3695.16

Leaf composition standards for pear cultivar trees, based on mid-shoot leaves sampled at 90 DAFB (Bergmann, 1992). Sign (−) indicates lower content than optimum, while sign (+) indicates higher content than optimum.

Table 1 – part II

Treatments	Leave Mn (ppm)		Leave Mo (ppm)		Leave Cu (ppm)		£DOP index	Initial fruit set (%)	Yield (kg/tree)
	2012	2013	2012	2013	2012	2013		2012+2013	
Control	-51.16	-6.21	15.62	56.19	22.35	22.32	811.81 cb	4.18d	6.78e
1%Zn	-55.416	-6.21	0.26	57.37	114.37	138.37	713.29 fcegd	6.75cd	19.05be
2%Zn	-46.64	5.89	-20.07	13.89	15.71	178.46	656.33 fegd	10.39bcd	32.14bdec
3%Zn	-46.95	7.36	-15.71	19.8	68.04	142.04	770.81 cebd	5.14cd	10.17e
1%B	-53.79	7.18	-26.4	-24.93	96.07	239.2	1138.30 a	10.3bcd	25.19bec
2%B	-55.89	2.32	21.18	23.6	-13.28	50.03	628.77 fg	10.12bcd	25bec
3%B	-55.96	2.16	53.328833	56.4	-8.8	124.25	781.11 cbd	10.05bcd	23.4bec
1%Zn1%B	-53.66	-3.48	-31.69	18.03	69.49	67.3	723.08 fcegd	14.52ba	39.19bdac
1%Zn2%B	-60.01	-3.27	-14.29	-0.46	-16.22	73.14	639.56 feg	17.34a	42.31badc
1%Zn3%B	-54.6	-14.43	24.09	4.68	6.1	22	730.37 fcegd	17.1a	63.57a
2%Zn1%B	-64.33	-6.64	56.017	16.15	31.92	52.19	495.26 h	8.29bcd	21.23bec
2%Zn2%B	-51.25	1.79	0.72	9.96	1.2	149.58	594.87 hg	11.1bc	25.85bec
2%Zn3%B	-59.31	-16.84	29.55	80	-65.05	196.42	709.94 fcegd	9.17bcd	24.37bec
3%Zn1%B	-50.35	-9.15	-20.75	-7.72	82.12	169.39	877.91 b	18.03a	53.6b2a
3%Zn2%B	-45.28	-10.63	34.41	12.67	14.72	76.51	643.09 feg	4.18d	24.23bec
3%Zn3%B	-57.4	-12.42	-13.99	3.83	20.4	138.12	755.63 fcebd	6.75cd	46.63bac

Leaf composition standards for pear cultivar trees, based on mid-shoot leaves sampled at 90 DAFB (Bergmann, 1992). Sign (−) indicates lower content than optimum, while sign (+) indicates higher content than optimum.

Soil analysis = surface soil (0-45 cm), variables [total neutralizing value %, pH, total N %, available K use (me L^{-1}), available P (me L^{-1}), silt %, sand %, clay %, organic matter %]. Soil at the beginning of experiment of studied pear cultivars were determined according to Walkley and Black (1934), Drouineau (1942), Isaac and Kerber (1971) and Olsen and Sommers (1982).

Yield (kg/tree): when fruits reached maturity stage according to El-Azzouri *et al.,* 1975. Number of fruits born on each tree were counted and multiplied with the average fruit weight for that tree.

The DOP and ΣDOP index: leaf macro and micronutrient contents at 90 days after full bloom (DAFB) and deviation from optimum percentage; DOP and £DOP index were estimated for the diagnosis of the leaf mineral status of the trees (Montañés *et al.*, 1991). The DOP index was calculated from the leaf analysis in July of 2012 and 2013 by the following mathematical expression:

$$DOP = \frac{C \times 100}{C_{ref}} - 100,$$

where C is the nutrient content in the sample to be studied, and C_{ref} is the major nutrient content considered as optimum, both values given on a dry matter basis. The C_{ref} was taken from optimum values, proposed by Bergmann (1992) for nutrients. The ΣDOP for two studied years is obtained by adding the values of DOP index irrespective of sign. The larger the ΣDOP, the greater is the intensity of imbalances among nutrients.

The experiment was conducted in a Randomized Complete Block Design with three replicates. The statistical evaluation was done by using analysis of variance (ANOVA). This paper would use SAS statistic computer system to calculate the surveyed data and means were evaluated using Duncan's multiple range test at $p = 0.05$. The relationships between studied parameters were evaluated by Pearson's correlation coefficients at $p \leq 0.05$.The final data results are means of analysis over the two years.

RESULTS

Analysis of the soil was done at 0-45 cm depth. According to this analysis the soil was a silt loam with: 0.9% organic matter (Walkley and Black, 1934), 11.87% active lime (Drouineau, 1942) and a pH in water of 7.46. The soil had 12.51 mg P kg^{-1} (Olsen and Sommers, 1982) and 335.14 mg K kg^{-1} (Isaac and Kerber, 1971). The climate of research region was semi-arid, with an average annual precipitation of 250 mm, with annual average temperature of 32.3°C, and annual average relative humidity of 45.4% (synoptic meteorological stations of Iran, 2013). The deviation from the optimum percentage (DOP) index of macro and micronutrients at 90 days after full bloom (DAFB) from three studied pear cultivars (Spadona, Duchesse and Daregazi), which were grown in a private orchard (Kosar) in district of Shahriar of Alborz province (Iran), during two years experimental trials (2012-2013), were used to evaluate the nutritional status: optimal (DOP = 0), deficiency (DOP < 0) or excess (DOP > 0). The ΣDOP for two studied years is obtained by adding the values of DOP index irrespective of sign. The larger the ΣDOP, the greater is the intensity of imbalances among nutrients. Also the relationship

between ΣDOP index with leaf nutrient contents at 90 DAFB, yield and initial fruit set of the studied pear cultivars was studied. In general, a DOP value closer to the optimum level (DOP = 0) were observed in treated studied pear cultivars with B and Zn applied on flowers at full bloom stage compared with the control trees (without any application of boron and zinc). The DOP_{macro} and DOP_{micro} were, respectively, positive and negative for all of studied pear cultivars. The other following observations by cultivar were recorded during the course of experimentation.

Spadona

The combination of both products (borax+zinc sulfate treatments) at full bloom stage applied on flowers of Spadona cultivar showed significantly better balanced nutritional values, yield and initial fruit set than the rest of treatments. So the results showed that treatment of 2% Zn1% B at full bloom stage applied on flowers of Spadona tended to have a DOP_{Zn} (-0.30 for 2012 and+0.38 for 2013) and DOP_{Mg} (+11.14 for 2013) closer to the optimum level (DOP = 0) than the rest of treatments. Also £DOP index (during 2012-2013) with treatment of 2% Zn1% B at full bloom stage applied on flowers tended to have significantly better balanced nutritional values than the rest of treatments (£DOP=495.26) than the rest of treatments. The average of DOP_B, DOP_{Mg}, DOP_K (except of 1 and 3% B treatments), DOP_N (except of 1% B and 1% Zn+2% B treatments), DOP_{Fe}, DOP_P (except of 3% B treatment), DOP_{Ca} and DOP_{Cu} were positive in 2013 as compared to 2012 regardless of treatments. The average yield plant (63.57 kg/tree) and initial fruit set (19.62%) were the highest with treatment of 1% Zn+3% B for yield plant and with 3% Zn+3% B for initial fruit set compared with the other treatments for 2012 and 2013. For Spadona, statistically positive significant correlation between £DOP index and leaf nutrient contents at 90 DAFB (leaf-Mg,-B,-Zn,-Fe,-Ca,-Cu) and between initial fruit set with leaf-Mg and with leaf-B were found (*Tabs. 1 and 2*).

Duchesse

The combination of both products (borax+zinc sulfate treatments) at full bloom stage applied on flowers of Duchesse cultivar showed significantly better balanced nutritional values, yield and initial fruit set than the rest of treatments. Also the results showed that all of the trees of Duchesse treated with combination of both products (borax+zinc sulfate treatments) at full bloom stage applied on flowers tended to have a level of $DOP_{nutrient}$ closer to the optimum level (DOP = 0) than the rest of treatments, except of DOP_{Zn} (for 2012), DOP_P (for 2012), DOP_{Ca} (for 2013), DOP_{Mn} (for 2013) and DOP_{Mo} (2013). £DOP index (during 2012-2013) with treatment of 1% Zn1% B at full bloom stage applied on flowers tended to have

significantly better balanced nutritional values than the rest of treatments (£DOP=512.97) than the rest of treatments. The average yield plant (34.59 kg/tree) and initial fruit set (11.59%) were the highest with treatment of 2% Zn+3%B, compared with the other treatments for 2012 and 2013. For Duchesse, statistically positive significant correlation between £DOP index and leaf nutrient contents at 90 DAFB (leaf-Mg, -Mn, -P,-Fe,-Ca,-Cu) and negative significant correlation between £DOP index and initial fruit set were found (*Tabs. 3 and 4*).

Daregazi

The combination of both products (borax+zinc sulfate treatments) at full bloom stage applied on flowers of Daregazi cultivar showed significantly better balanced nutritional values, yield and initial fruit set than the rest of treatments. Also the results showed that all of the trees of Daregazi treated with combination of both products (borax+zinc sulfate treatments) at full bloom stage applied on flowers tended to have a level of $DOP_{nutrient}$ closer to the optimum level (DOP = 0) than the rest of treatments, except of DOP_B (for 2012 and 2013), DOP_P (for 2012), DOP_{Mg} (for 2013), DOP_{Fe} (for 2013), DOP_p (for 2012), DOP_{ca} (for 2012), DOP_{Mn} (for 2012) and DOP_{Mo} (for 2012). £DOP index (during 2012-2013) with treatment of 1% Zn,1% B, 2% Zn, 3% B, 3% Zn,1% B, and 3% Zn, 3% B and also 1% B at full bloom stage applied on flowers tended to have significantly better balanced nutritional values than the rest of treatments (£DOP between 550.59 - 626.65) than the rest of treatments. The average yield plant (84.58 kg/tree) and initial fruit set (19.02%) were the highest with treatment of 3% Zn+2% B for yield plant and 3% Zn1% B for initial fruit set compared with the other treatments for 2012 and 2013. For Daregazi, statistically positive significant correlation between £DOP index and leaf nutrient contents at 90 DAFB (leaf-B,-Mn,-Cu,-C) were found (*Tabs. 5 and 6*).

DISCUSSION

Single B [borax (1%, 2%, 3%)], Zn [zinc sulfate (1%, 2%, 3%)] products as well as the combination of both products {borax+zinc sulfate (1%B+1%Zn, 1%B+2%Zn, 1%B+3%Zn, 2%B+1%Zn, 2%B+2%Zn, 2%B+3%Zn, 3%B+1%Zn, 3%B+2%Zn, 3%B+3%Zn)} at full bloom stage applied on flowers of three pear cultivars (Spadona, Duchesse and Daregazi), which were grown in a private orchard (Kosar) in district of Shahriar of Alborz province (Iran), during 2012-2013 , because these different products resulted in fruit set, yield and better balanced nutritional values of pear cultivar (Taher and Hassan 2005).

Table 2 - Correlation coefficient between ΣDOP index, leaf nutrient contents at 90 DAFB, yield and initial fruit set in Spadona cultivar as affected by B and Zn applied on flowers at full bloom stage during two years experimental trials (2012-2013)

	Leave B (ppm)	Leave Mg (%)	Leave K (%)	Leave N (%)	Leave Zn (ppm)	Leave Fe (ppm)	Leave P (%)	Leave Ca (%)	Leave Mn (ppm)	Leave Mo (ppm)	Leave Cu (ppm)	£DOP index	Initial fruit set (%)	Yield (kg/tree)
Leave B (ppm)	1													
Leave Mg (%)	.282	1												
Leave K (%)	.245	.188	1											
Leave N (%)	-.090	.295	.232	1										
Leave Zn (ppm)	-.304	-.240	-.44*	-.150	1									
Leave Fe (ppm)	.58**	.63**	.385*	.244	-.340	1								
Leave P (%)	-.08	-.50**	-.289	-.604**	.393*	-.399*	1							
Leave Ca (%)	.47**	.290	.58**	.378*	-.238	.532**	-.420*	1						
Leave Mn (ppm)	-.23	-.55**	-.215	-.400*	.091	-.403*	.447*	-.45*	1					
Leave Mo (ppm)	-.09	.295	.232	1.000**	-.150	.244	-.6**	.378*	-.400*	1				
Leave Cu (ppm)	.98**	.354*	.187	-.045	-.274	.616**	-.10	.444*	-.217	-.045	1			
£DOP index	.69**	.52**	.245	.115	-.019	.916**	-.21	.50**	-.325	.115	.735**	1		
Initial fruit set (%)	.38*	.47**	.180	-.143	-.252	.218	-.28	.162	-.534**	-.143	.355*	.176	1	
Yield (kg/tree)	-.04	.210	-.162	-.292	.076	-.229	.014	-.281	-.195	-.292	-.052	-.21	.701**	1

N=32 **Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

Table 3 - DOP and ΣDOP index determined from leaf macronutrient contents at 90 DAFB, yield and initial fruit set in Duchesse cultivar as affected by B and Zn applied on flowers at full bloom stage during two years experimental trials (2012-2013)

Table 3 – part I

Treatments	Leave B (ppm)		Leave Mg (%)		Leave K (%)		Leave N (%)		Leave Zn (ppm)		Leave Fe (ppm)		Leave P (%)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Control	35.62	226.51	109.93	246.43	41.98	-28.88	10.65	7.26	13.96	7.02	-37.48	71.2	247.61	37.96
1%Zn	-43.11	248.09	-8.25	122.29	2.59	45.54	-11.29	18.81	-0.51	-19.73	-5.47	42.15	-0.35	53.52
2%Zn	30.86	128.18	34.96	111.64	-55.42	33.19	21.52	-1.59	58.53	-8.34	18.29	51.24	18.39	81.26
3%Zn	36.76	83.55	-32.11	-29.46	-39.52	13.14	-12.77	-6.01	-0.61	-15.2	-25.39	64.34	111.44	48.13
1%B	55.67	169.31	-32.54	26.86	-46.1	20.78	10.54	12.75	22.21	7.55	-4.25	97.24	304.78	204.35
2%B	24.86	116.01	17.43	120.79	-19.39	47.48	33.07	35.73	58.22	39.24	-12.55	80.15	280.48	160.87
3%B	-94.57	-6.06	34.96	153.71	-64.35	2.53	5.81	7.92	58.55	39.52	1.5	109.09	318.78	247.82
1%Zn1%B	40.4	142.89	-29.82	93.5	-19.8	6.92	-7.8	4.48	-20.69	-5.83	-5.7	47.58	-4.96	32.35
1%Zn2%B	61.04	163.43	29.68	-25.5	-12.69	25.94	-12.15	3.83	59.92	-9.58	-11.39	28.54	209.96	78.39
1%Zn3%B	103.57	44.43	40.25	115.61	-54.41	34.49	33.07	-4.16	-20.85	-20.69	7.09	75.2	237	57.13
2%Zn1%B	41.6	169.2	-8.25	60.82	23.31	48.88	19.7	1.98	43.69	-15.9	-0.84	25.52	366.39	57.09
2%Zn2%B	27.91	184.37	31.36	49.5	-37.47	43.06	27.5	-8.72	58.45	-6.33	2.96	71.09	152.7	86.26
2%Zn3%B	-21.28	120.07	2.54	85.64	-24.16	-0.18	-27.5	16.1	39.17	-0.61	3.458	54.07	418.48	47.22
3%Zn1%B	67.74	169.52	-50.04	64.75	-70.13	66.22	-16.06	1.98	35.65	-26.67	-18.08	56.04	424.61	56.22
3%Zn2%B	59.2	10.43	-47.43	184.96	-1.93	-3.15	23.26	-15.71	35.42	4.05	1.22	113.16	282.17	86.91
3%Zn3%B	18.51	131.28	8.07	68.68	-50	58.29	-43.23	18.81	38.97	-21.55	13.25	238.07	216.65	54.74

Leaf composition standards for pear cultivar trees, based on mid-shoot leaves sampled at 90 DAFB (Bergmann, 1992). Sign (−) indicates lower content than optimum, while sign (+) indicates higher content than optimum.

Table 3 - DOP and ΣDOP index determined from leaf macronutrient contents at 90 DAFB, yield and initial fruit set in Duchesse cultivar as affected by B and Zn applied on flowers at full bloom stage during two years experimental trials (2012-2013)

Table 3 – part II

Treatments	Leave Ca (%)		Leave Mn (ppm)		Leave Mo (ppm)		Leave Cu (ppm)		£DOP index	Initial fruit set (%)	Yield (kg/tree)
	2012	2013	2012	2013	2012	2013	2012	2013		2012+2013	
Control	-64.4	-17.55	1.477	-1.69	10.649	7.26	28.08	208.37	840.33bac	3.754f	8.59f
1%Zn	-66.93	-54.49	-6.45	-0.43	-11.29	18.81	-46.27	228.74	655.16de	6.0880dce	18.53ced
2%Zn	-70.8	-26.53	-1.19	-6.53	21.52	-1.59	23.59	115.50	595.24de	6.44dc	13.41ef
3%Zn	-67.02	-39.25	13.83	0.94	-12.77	-6.01	29.16	73.35	507.27e	6.10dce	17.43ced
1%B	-45.47	-23.11	32.15	29.51	10.54	12.75	47.02	154.35	816.09bac	6.72dc	19.76cebd
2%B	-55.55	-37.33	-9.98	-11.78	33.07	35.73	17.92	104.01	728.7bdc	5.9343de	14.10ef
3%B	-70.8	-58.83	20.88	18.47	5.81	7.93	-88.88	-77.67	906.09a	5.13dfe	13.87ef
1%Zn1%B	-74.22	-51.91	-8.02	0.16	-7.8	4.48	32.6	129.39	512.97e	9.12b	25.05cb
1%Zn2%B	-66.93	-37.95	-15.29	-4.63	-12.15	3.83	52.1	148.79	634.95de	5.37de	23.92
1%Zn3%B	-61.93	-51.91	2.55	-1.79	33.07	-4.16	92.26	36.41	694.99cc	5.17dfe	15.94efd
2%Zn1%B	-79.82	-47.6	20.26	-9.26	19.7	1.98	33.73	154.24	714.77bdc	4.79fe	20.21cbed
2%Zn2%B	-62.17	-44.09	-5.65	3.33	27.5	-8.72	20.8	168.57	643.53de	6.40dc	24.87cb
2%Zn3%B	-59.42	-48.45	5.85	7.25	-2750	16.1	-25.65	107.85	728.18bdc	11.52a	34.59a
3%Zn1%B	-55.5	-45.47	13.84	-8.28	-16.06	1.978	58.42	154.55	854.79ba	5.35de	13.53ef
3%Zn2%B	-67.15	-41.82	-10.94	-9.58	23.26	-15.71	50.35	4.30	684.31dc	12.08a	22.47cbd
3%Zn3%B	-58.13	-54.89	-0.23	-9.26	-43.23	18.81	11.93	118.43	754.73bdac	7.59c	27.08b

Leaf composition standards for pear cultivar trees, based on mid-shoot leaves sampled at 90 DAFB (Bergmann, 1992). Sign (−) indicates lower content than optimum, while sign (+) indicates higher content than optimum.

Table 4 - Correlation coefficient between ΣDOP index, leaf nutrient contents at 90 DAFB, yield and initial fruit set in Duchesse cultivar as affected by B and Zn applied on flowers at full bloom stage during two years experimental trials (2012-2013)

	Leave B (ppm)	Leave Mg (%)	Leave K (%)	Leave N (%)	Leave Zn (ppm)	Leave Fe (ppm)	Leave P (%)	Leave Ca (%)	Leave Mn (ppm)	Leave Mo (ppm)	Leave Cu (ppm)	£DOP index	Yield (kg/tree)	Initial fruit set (%)
Leave B (ppm)	1													
Leave Mg (%)	.325	1												
Leave K (%)	.529**	.329	1											
Leave N (%)	.234	.156	.164	1										
Leave Zn (ppm)	-.57**	-.176	-.53**	.107	1									
Leave Fe (ppm)	.368*	.505**	.499**	.119	-.377*	1								
Leave P (%)	-.435*	-.341	-.408*	-.002	.630**	-.384*	1							
Leave Ca (%)	.634**	.460**	.335	.002	-.369*	.478**	-.291	1						
Leave Mn (ppm)	-.169	-.206	-.328	-.023	.165	-.110	.481**	-.013	1					
Leave Mo (ppm)	.234	.156	.164	1.000**	.107	.119	-.002	.002	-.023	1				
Leave Cu (ppm)	.989**	.272	.504**	.221	-.57**	.316	-.436*	.618**	-.197	.221	1			
£DOP index	.337	.382*	.034	.184	.094	.322	.451**	.345	.368*	.184	.291	1		
Yield (kg/tree)	.159	.013	.140	.067	-.147	.420*	-.189	-.010	-.033	.067	.161	-.067	1	
Initial fruit set (%)	-.49**	-.262	-.50**	-.108	.232	-.223	.107	-.436*	.043	-.108	-.441*	-.353*	.472**	1

N=32 **Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

Table 5 - DOP and ΣDOP index determined from leaf macronutrient contents at 90 DAFB, yield and initial fruit set in Daregazi cultivar as affected by B and Zn applied on flowers at full bloom stage during two years experimental trials (2012-2013)

Table 5 – part I

Treatments	Leave B (ppm)		Leave Mg (%)		Leave K (%)		Leave N (%)		Leave Zn (ppm)		Leave Fe (ppm)		Leave P (ppm)	
	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013	2012	2013
Control	122.86	22.86	-31.07	263.39	-31.39	31.69	-32.47	20.52	53.6	-12.57	-12.378	127.5	174.35	82.246
1%Zn	201.72	101.72	-2.46	122.29	-82.05	48.57	22.91	-10.43	127.91	-3.93	-22.54	78.292	387.52	30.98
2%Zn	189.98	89.98	34.96	102.89	-90.01	38.24	-20.07	12.67	118.12	-11.583	-20.076	23.96	183.78	46.74
3%Zn	202.8	102.8	-64.61	102.59	43.29	9.18	-48.46	-4.75	100.99	-10.75	-31.28	69.85	285.52	60.25
1%B	219.62	119.62	-5.93	76.84	-19.77	-17.36	13.53	15.8	43.69	26.45	-15.3	74.48	-20.3	-56.52
2%B	391.77	291.77	-0.143	87.73	-32.7	-30.68	-21.12	-19.55	98.18	74.4	-20.02	64.76	151.3	117.39
3%B	313.48	213.48	-47.42	-1.13	-82.98	-82.47	-18.42	-16.79	48.69	30.85	-20.01	64.78	294.22	-84.23
1%Zn1%B	249.68	149.68	-0.21	60.8	-50.51	20.59	18.87	23.5	68.46	2.72	-18.92	76.27	189.87	92.37
1%Zn2%B	187.92	87.92	-32.54	102.59	-64.9	-20.84	-20.27	0.13	43.69	1.17	-12.36	103.21	112.3	36.22
1%Zn3%B	191.34	91.34	71.46	-82.6	-26.22	-13.71	3.02	-43.75	88.28	14.75	-10.09	64.5	301.43	44.19
2%Zn1%B	132.36	32.36	-13.93	213.73	-91.26	-1.32	-36.05	27.79	80.91	-5.93	-15.83	49.83	395.65	82.81
2%Zn2%B	194.01	94.01	17.71	181.02	-61.29	65.17	-20.33	-26.4	108.48	29.31	-20.03	71.28	169.57	51.77
2%Zn3%B	198.54	98.54	-32.54	229.03	-57	0.81	-6.87	-5.01	9.06	3.37	-0.98	75.11	-32.09	18.77
3%Zn1%B	187.57	87.57	7.61	64.75	-59.13	11.44	-9.05	46.87	72.49	-2.61	-23.79	81.64	167.96	57.25
3%Zn2%B	205.48	105.48	1.29	168.01	-50.78	-16.89	-21.12	-22.97	45.33	-8.82	-17.76	104.63	246.78	35.5
3%Zn3%B	172.55	72.55	-1.54	196.78	-12.3	-13.13	21.52	6.4	68.46455	-8.82	-6.32	100.04	142.74	40.37

Leaf composition standards for pear cultivar trees, based on mid-shoot leaves sampled at 90 DAFB (Bergmann, 1992). Sign (−) indicates lower content than optimum, while sign (+) indicates higher content than optimum.

Table 5 – part II

Treatments	Leave Ca (%)		Leave Mn (ppm)		Leave Mo (ppm)		Leave Cu (ppm)		£DOP index	Yield (kg/tree)	Initial fruit set (%)
	2012	2013	2012	2013	2012	2013	2012	2013		2012+2013	
Control	-59.6	-30.222	-12.57	-6.21	-32.47	20.53	32.22	16.03	654.52ed	6.86e	3.70f
1%Zn	-55.25	-46.7553	11.45	3.16	22.91	-10.43	22.35	90.52	791.48bdc	58.49bc	14.81b
2%Zn	-72.09	-57.0667	23.92	-5.61	-20.07	12.67	-63.2	79.42	686.99edc	33.54ecd	6.30fe
3%Zn	-59.6	-28.2667	2.01	-7.68	-48.46	-4.75	-9.3	91.53	654.14ed	24.53ed	9.66ced
1%B	-65.8	-51.778	-16.51	-18.18	13.53	15.8	-11.86	107.42	550.59e	67.05ba	11.79cbd
2%B	-47.65	-26.1787	30	27.4	-21.12	-19.55	65.38	270.01	947.96a	46.43bcd	10.09ced
3%B	-55.55	-37.3333	44.74	41.85	-18.42	-16.79	71.14	196.07	863.25ba	34.27cd	8.45ed
1%Zn1%B	-60.45	-22.7113	1.02	-4.63	18.87	23.5	5.24	135.81	626.65e	66.36ba	13.59cb
1%Zn2%B	-56.93	-44.0887	33.51	7.58	-20.277	0.129	86.71	77.48	673.56ed	41.43bcd	6.06fe
1%Zn3%B	-65.78	20.53333	-2.89	9.37	3.02	-43.75	-29.01	80.71	656.11ed	25.27ed	7.01fe
2%Zn1%B	-60.67	-44.178	-15.25	-18.2	-36.05	27.79	103.09	25.01	837.21bac	38.38cd	7.93fed
2%Zn2%B	-59.95	-46.7553	27.19	-15.36	-20.33	-26.4	1.61	83.24	649.01ed	45.02bcd	10.0ced
2%Zn3%B	-53.55	-47.5553	-13.18	-3.01	-6.87	-5	4.76	87.51	587.67e	32.80ecd	6.87fe
3%Zn1%B	-59.55	-24	4.58	-16.84	-9.05	46.87	-7.23	77.15	554.24e	54.15bc	19.02a
3%Zn2%B	-55.33	-54.4	-22.93	-6.21	-21.13	-22.97	0.56	94.06	693.81edc	84.58a	12.61cbd
3%Zn3%B	-53.2	-51.9113	-15.42	-10.59	21.51	6.4	-30.28	62.97	587.82e	30.84ecd	8.96ced

Leaf composition standards for pear cultivar trees, based on mid-shoot leaves sampled at 90 DAFB (Bergmann, 1992). Sign (−) indicates lower content than optimum, while sign (+) indicates higher content than optimum.

Table 6 - Correlation coefficient between ΣDOP index, leaf nutrient contents at 90 DAFB, yield and initial fruit set in Daregazi cultivar as affected by B and Zn applied on flowers at full bloom stage during two years experimental trials (2012-2013)

	Leave B (ppm)	Leave Mg (%)	Leave K (%)	Leave N (%)	Leave Zn (ppm)	Leave Fe (ppm)	Leave P (%)	Leave Ca (%)	Leave Mn (ppm)	Leave Mo (ppm)	Leave Cu (ppm)	£DOP index	Yield (kg/tree)	Initial fruit set (%)
Leave B (ppm)	1													
Leave Mg (%)	.175	1												
Leave K (%)	.100	.536**	1											
Leave N (%)	-.113	.382*	.193	1										
Leave Zn (ppm)	-.341	-.573**	-.548**	-.311	1									
Leave Fe (ppm)	.531**	.737**	.543**	.266	-.785**	1								
Leave P (%)	-.345	-.380*	-.386*	-.218	.705**	-.643**	1							
Leave Ca (%)	.503**	.087	.324	.026	-.5**	.58**	-.34*	1						
Leave Mn (ppm)	.279	-.331	-.472**	-.356*	.394*	-.210	.132	.033	1					
Leave Mo (ppm)	-.113	.382*	.193	1.000**	-.311	.266	-.218	.026	-.356*	1				
Leave Cu (ppm)	1.000**	.175	.100	-.113	-.341	.531**	-.345	.503**	.279	-.113	1			
£DOP index	.579**	.076	-.273	-.268	.273	.095	.393*	.067	.417*	-.268	.579**	1		
Yield (kg/tree)	-.016	-.19	-.27	.139	.144	-.2	-.01	-.25	-.033	.139	-.016	-.06	1	.5**
Initial fruit set (%)	.118	.030	.250	.325	-.14	.119	-.005	.067	-.176	.325	.118	.003	.5**	1

N=32 **Correlation is significant at the 0.01 level (2-tailed). *Correlation is significant at the 0.05 level (2-tailed).

The fruit set, yield in all studied pear cultivars with combination of both products (borax+zinc sulfate) in our experiment was rather higher than the control (without any application of boron and zinc) trees and the other single B and Zn products (Canesin *et al.,* 2010). Furthermore, leaf macro and micronutrient contents at 90 days after full bloom (DAFB) and deviation from optimum percentage (DOP and £DOP) index were estimated for the diagnosis of the leaf mineral status of the trees. The larger the ΣDOP, the greater is the intensity of imbalances among nutrients (Montañés *et al.* 1993). According to £DOP index (for 2012+2013), the combination of both products (borax+zinc sulfate treatments) at full bloom stage applied on flowers of three pear cultivars (Spadona, Duchesse and Daregazi) showed better balanced nutritional values than the rest of treatments.

Previous works, carried out by Jiménez *et al.* (2004) and Zarrouk *et al.* (2005), did not find a significant differences for nutritional balance values, i.e. ΣDOP, among peaches and sweet cherries. The differences between our results could be explained by differences in the cultural practices (application of B and Zn applied on flowers at full bloom stage), as previously reported (Leece and Ende, 1975; Shear, 1975; Shear and Faust, 1980). The negative $DOP_{macro\ and\ micro}$ indicated the tendency of nutrient deficiency in plants. But in this study, The DOP_{macro} and DOP_{micro} were, respectively, positive and negative for all of studied pear cultivars regardless of treatments (*Tabs. 1, 3 and 5).* In our results, negative significant correlation was found between fruit set and £DOP index only for Duchesse cultivar. It can mean that the combination of both products (borax+zinc sulfate) applied on flowers at full bloom stage on leaf macro and micro nutrient contents at 90 days after full bloom (DAFB), specially of Duchesse significantly increased fruit set and a tendency of better balanced of nutritional values.

CONCLUSION

From the above mentioned results, the following conclusion was exhausted from the present study. The combination of both products (borax+zinc sulfate treatments) at full bloom stage applied on flowers of studied pear trees significantly increased yield, fruit set and mad a tendency of better balanced of nutritional values in studied trees.

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