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QUALITY OF FRUIT CHERRY, PEACH AND PLUM CULTIVATED UNDER DIFERENT WATER AND FERTILIZATION REGIMES

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Abstract

In 2003–2005, a two-factors field experiment was set up on sandy soil of low useful water retention. The aim of the study has been to determine the effect of irrigation and mineral fertilization on the quality of some species of stone fruit trees. The treatments were designed by the split-plot method in 7 replications with cherry, 5 replications with peach, and 4 replications with plum trees. Swards between the trees and herbicide fallows in the rows of trees were maintained. Two factors were considered: subcrown irrigation and mineral fertilization. The mineral fertilization comprised the following variants: 0 NPK –no fertilization, 1 NPK – 130 kg NPK ha^{-1}, 2 NPK – 260 kg NPK ha^{-1} for cherry and plum trees, and 0 NPK –no fertilization, 1 NPK – 150 kg NPK ha^{-1}, 2 NPK – 300 kg NPK ha^{-1} for peach. Irrigation and fertilization differentiated concentrations of macro- and micronutrients in fruits of cherry, peach and plum trees. Irrigation resulted in a higher content of sugars and vitamin C in the dry matter of peaches and a lower concentration of sugars in cherries. A higher dose of mineral fertilizers depressed the dry matter content in fruit of plum trees and the concentration of sugars in the fresh matter of cherries.

Key words: irrigation, fertilization, mineral compounds, sugar, vitamin C, acidity.

JAKOŚĆ OWOCÓW WIŚNI, BRZOSKWINI I ŚLIWY UPRAWIANYCH W ZRÓŻNICOWANYCH WARUNKACH WODNYCH I NAWOZOWYCH

Abstrakt

Doświadczenia polowe przeprowadzono na glebie lekkiej o małej retencji wody użytecznej. Badano wpływ nawadniania i nawożenia NPK na jakość owoców wiśni, brzoskwini

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i śliwy. Wszystkie doświadczenia założono metodą losowanych podbloków w układzie zależnym (ang. split-plot), w 7 powtórzeniach w doświadczeniu z wiśnią Łutówka, 5 – z brzoskwinią Redhaven i 4 – w doświadczeniu ze śliwą Cacanska Rana. Czynnikiem badanym było nawadnianie podkoronowe oraz nawożenie mineralne. W uprawie wiśni i śliwy zastosowano następujące dawki: 0 NPK – bez nawożenia, 1 NPK – 130 kg NPK ha^{-1} (40+30+60), 2 NPK – 260 kg NPK ha^{-1} (80+60+120). W uprawie brzoskwini: 0 NPK – bez nawożenia, 1 NPK – 150 kg NPK ha^{-1} (40+30+60), 2 NPK – 300 kg NPK ha^{-1} (80+60+120). Nawadnianie i nawożenie mineralne różnicowało zawartość makro- i mikroskładników oraz azotanów w owocach wiśni, brzoskwini i śliwy. Zastosowane nawadnianie wpłynęło istotnie na zawartość cukrów i witaminy C w suchej masie brzoskwini oraz koncentrację cukrów w owocach wiśni. Wysoka dawka nawozów przyczyniła się do zmniejszenia się istotnie zawartości suchej masy w owocach śliwy oraz koncentracji cukrów ogółem w świeżej masie owoców wiśni.

Słowa kluczowe: nawadnianie, nawożenie, składniki mineralne, cukier, witamina C, kwasowość.

INTRODUCTION

The quantity and biological quality of fruit tree yields depend on both irrigation and fertilization (Rzekanowski, Rolbiecki 1996, Ostrowska, Ochmian 2003, Podsiadło et al. 2005, Intrigliolo, Castel 2006). Production of large quantities of fruit is not the key point. It is more important to maintain high quality of fruit along with its abundant yield (Morgaś, Szymczak 2007). Concentrations of mineral components in orchard plants are very important for both agrotechnology and human nutrition. Their inadequate levels or disproportionate ratios often cause a reduction in yields and a decrease in their quality (Koszański et al. 2006). The aim of the present study has been to determine the effect of subcrown irrigation and mineral fertilization on the amount of some macro- and micronutrients as well as the amount of nitrates, sugars, vitamin C and acidity of cherry, peach and plum fruits.

MATERIAL AND METHODS

In 2003-2005, three two-factor field experiments were set up at the Agricultural Experimental Station in Lipnik near Stargard Szczeciński. The field experiments were carried out on soil classified as a good rye complex soil and, in respect of soil cultivation, as light soil of small useful water retention. The experiments were designed with the method of random subblocks in a dependent system of split-plots, in seven replications with cv. Łutówka cherry, five with cv. Redhaven peach and four with cv. Cacanska Rana plum trees. The trees were planted in the following spacing: cherry trees – 4 x 2 m, peach trees – 3.5 x 3 m, plum trees – 4.5 x 4 m. Swards between the trees and herbicide fallows in the rows of trees were maintained.

The first experimental factor consisted of subcrown irrigation, minisprinkling: without irrigation; irrigated plots. Mineral fertilization made up the second factor. The following fertilizer doses were applied in the cultivation of cherry and plum trees: no fertilization, 1 NPK – 130 kg NPK ha^{-1} (40+30+60), 2 NPK – 260 kg NPK ha^{-1} (80+60+120); in the cultivation of peach trees: no fertilization, 1 NPK – 150 kg NPK ha^{-1} (40+30+60), 2 NPK – 300 kg NPK ha^{-1} (80+60+120). Nitrogen fertilizers were applied in early spring, before the vegetation started, whereas phosphorous and potassium fertilizers were introduced according to agronomic recommendations. Irrigation was applied according to the indications of a tensiometer at the water potential of soil 0.01 MPa. For the irrigation, a subcrown system was used, in which water was distributed through Hadar mini-sprinklers. One mini-sprinkler was set for each tree. Water doses supplied under the tested stone fruit trees varied in individual periods of vegetation from 0.22 to 0.68 m^3 $tree^{-1}$ (21.7 to 61.3 mm ha^{-1}), depending on monthly precipitation totals in each year. The following chemical elements were determined annually: nitrogen – with Kiejdahl's method, potassium and calcium – with the photometric method, phosphorus – with colorimetric method; magnesium, iron and zinc – with atomic absorption spectrometry (AAS), nitrates – potentiometrically, sugar – with Luff-Schoorl's method, acidity – potentiometrically, and vitamin C – by spectrometry. The results were processed statistically using the analysis of variance for multiannual experiments on treatments means from individual experiments with reconstruction errors. The significance of differences was assessed at $LSD_{0.05}$ by Tukey's test. Analysis of correlation for the features which were significantly differentiated by the interaction of experimental factors was also carried out.

RESULTS AND DISCUSSION

Production of high quality of fruit relies on good agronomic technology, protecting the fruit – bearing plants and providing them with required nutrients and water. Water deficits during the period of intensive growth of shoots and fruit has negative effect on both quantity and quality of yields. Apart from a large volume of yield, it is also important to obtain yields of good biological value, which determines the usefulness of fruit for consumption and processing (Krawiec 2000, Lipecki 2001). Research on the influence of irrigation on the content of macro- and micronutrients in fruit of trees shows it has differentiated effect on the quality of fruit. Increased, decreased or unchanged An increase and a decrease or no changes concentration of nutrients in the fruit growing on irrigated trees have been observed (Podsiadło et al. 2009). The results of our own research show a decrease in the concentration of nitrogen in fruits of all three kinds of fruit trees but it

was only in peaches that the drop was significant drop (4%). On the irrigated plots, lower concentrations of nitrates in fruits of cherry and plum trees, magnesium in cherries, iron and zinc in cherries, zinc in peaches and iron in plums were also observed (Table 1). Calcium is a nutrient which greatly affects the quality of fruit. Its deficiency causes cracking of cherries and plums. Irrigation rose the calcium concentration in fruits of cherry trees but lowered it in fruits of peach and plum trees. In our earlier study (PODSIADŁO et al. 2009), it was shown that irrigation did not cause any change

Table 1

Content of mineral compounds in the dry matter of cherry, peach and plum fruit (means for 2003-2005)

Treatment		N	P	K	Ca	Mg	Fe	Zn	$N\text{-}NO_3^-$
		(g kg^{-1} d.m.)					(mg kg^{-1} d.m.)		
Cherry									
Irrigation	O	11.5	2.25	12.8	0.65	0.90	130.0	9.50	98.3
	W	11.3	2.36	13.4	0.70	0.61	117.8	8.44	74.9
Fertilization	0 NPK	11.2	2.14	12.5	0.72	0.77	141.7	9.08	91.6
	1 NPK	11.2	2.37	13.3	0.56	0.66	106.7	10.5	66.6
	2 NPK	11.9	2.41	13.5	0.74	0.84	123.3	7.33	101.8
$NIR_{0.05}$	O	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	W	n.s.	n.s.	n.s.	n.s.	n.s.	18.0	n.s.	n.s.
Peach									
Irrigation	O	9.20	2.12	12.0	1.42	0.76	87.7	14.1	18.4
	W	8.84	2.19	12.7	1.26	0.77	88.9	12.9	18.4
Fertilization	0 NPK	8.79	2.08	12.5	1.41	0.77	93.3	13.7	17.9
	1 NPK	8.97	2.32	12.7	1.51	0.79	91.7	12.8	18.8
	2 NPK	9.29	2.08	11.8	1.11	0.74	80.0	14.0	18.7
$NIR_{0.05}$	O	0.33	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	W	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
Plum									
Irrigation	O	9.29	1.87	11.7	0.61	0.61	103.3	6.33	67.0
	W	9.13	2.01	12.0	0.51	0.61	78.9	6.94	60.8
Fertilization	0 NPK	8.76	1.95	11.5	0.55	0.60	101.7	6.92	62.8
	1 NPK	9.45	1.93	12.2	0.48	0.61	88.3	6.83	61.8
	2 NPK	9.43	1.93	11.9	0.65	0.62	83.3	6.17	67.2
$LSD_{0.05}$	O	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.
	W	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.	n.s.

n.s. – not significant

in the amount of calcium in cherries. The present results of analyses of fruits have demonstrated that the complementary irrigation differentiated the content of sugars, vitamin C and acids (Tables 2-4). Significant effects of this treatment, such as an increased content of sugars (by 5%) in the dry matter of peach and vitamin C (by 43%) in the fresh matter of peach and a decrease in the concentration of sugars in the dry matter of cherry (by 3%) were also observed. The results reported by RZEKANOWSKI, ROLBIECKI (1996) show a decrease in the level of dry matter and in the content of vitamin C in the fruit of irrigated apple trees. These authors noticed that irrigation also depressed the content of sugars in cv. Spartan apple tree fruits but caused no significant differences in this respect in apples grown on other apple trees.

Table 2

Content of dry matter, sugar, vitamin C and acidity in cherry fruit (means from 2003-2005)

Treatment		Dry matter (g 100 g^{-1} f.m.)	Sugar (% f.m.)	Sugar (% d.m.)	Vitamin C (mg 100 g^{-1} f.m.)	Acidity (g 100 g^{-1} f.m.)
Irrigation	O	0.13	7.64	58.9	4.58	1.12
	W	0.13	7.34	57.0	4.51	1.16
Fertilization	0 NPK	0.13	7.76	57.6	4.44	1.19
	2 NPK	0.12	7.22	58.3	4.64	1.09
$LSD_{0.05}$	O	n.s.	n.s.	0.19	n.s.	n.s.
	W	n.s.	0.05	n.s.	n.s.	n.s.

n.s. – not significant

Table 3

Content of dry matter, sugar, vitamin C and acidity in peach fruit (mean from 2003-2005)

Treatment		Dry matter (g 100 g^{-1} f.m.)	Sugar (% f.m.)	Sugar (% d.m.)	Vitamin C (mg 100 g^{-1} f.m.)	Acidity (g 100 g^{-1} f.m.)
Irrigation	O	0.12	7.14	59.3	4.21	0.46
	W	0.12	7.51	62.4	6.00	0.49
Fertilization	0 NPK	0.12	7.20	61.1	4.94	0.49
	2 NPK	0.13	7.45	60.6	5.27	0.45
$LSD_{0.05}$	O	n.s.	n.s.	0.31	0.18	n.s.
	W	n.s.	n.s.	n.s.	n.s.	n.s.

n.s. – not significant

Mineral fertilization, applied in this experiment, caused an increase in the content of nitrogen in the fruits of all the kinds of trees, potassium and phosphorus in fruit of cherry trees and potassium in fruit of plum trees (Table 1). Concentration of phosphorus in fruits of peach and plum trees, affected by fertilizing, ranged within an approximately same level in all the

Table 4

Content of dry matter, sugar, vitamin C and acidity in plum fruit (means from 2003-2005)

Treatment		Dry matter (g 100 g^{-1} f.m.)	Sugar (% f.m.)	Sugar (% d.m.)	Vitamin C (mg 100 g^{-1} f.m.)	Acidity (g 100 g^{-1} f.m.)
Irrigation	O	0.15	7.33	49.8	1.06	1.39
	W	0.13	6.49	48.6	1.37	1.40
Fertilization	0 NPK	0.15	7.29	49.8	1.20	1.37
	2 NPK	0.13	6.53	48.6	1.23	1.42
$LSD_{0.05}$	O	n.s.	n.s.	n.s.	n.s.	n.s.
	W	0.02	n.s.	n.s.	n.s.	n.s.

n.s. – not significant

fertilizing combinations (Table 1). These results are partly confirmed by the study on cherry trees conducted by PODSIADŁO et al. (2009), who observed that increasing doses of mineral fertilizers were accompanied by an increasing content of nitrogen and potassium in cherries, whereas the concentration of phosphorus did not change. In the present study, high mineral fertilizing was also found to be favourable to storing nitrates in fruits of all the fruit trees (Table 1). A similar relationship was reported by CHEŁPIŃSKI et al. (2009), who reported an increase in the amount of nitrates in peaches after application of multi-component fertilizers. In this experiment, fertilizing increased the content of calcium and magnesium in fruits of cherry and plum trees but decreased it in peaches. Intensive mineral fertilizing also modified concentration of micronutrients in the fruits, but only in cherries a significant effect of this treatment appeared such as a 13% decrease in iron. Mineral fertilizing had no significant influence on the content of dry matter of cherries and peaches, which ranged within an approximately same level. A high dose of fertilizers decreased significantly the dry matter content in fruit of plum trees (by 3%) and also the concentration of total sugars in the fresh matter of fruit of cherry trees (by 4%). The experiments run by SZWEDO et al. (2000), ŠVAG•DYS, VIŠKELIS (2002) as well as our own studies showed no significant influence of mineral fertilizing on the content of sugars in the dry matter, vitamin C and acidity in fruits of the examined kinds of fruit trees.

Additionally, in the analyzed material, positive, highly significant correlation between the content of potassium and calcium and the concentration of sugars in the fresh matter of fruit of plum trees was observed. Moreover, a highly significant positive relationship between the concentration of nitrogen and the content of sugars in the dry matter of fruit of peach trees was recorded (Table 5). The results are not confirmed by BEN (1997), who noted that the concentration of nitrogen and calcium showed negative correlation with the content of sugars, and the relationship between the content of phosphorus, potassium and magnesium and the concentration of sugars was non-significant.

Table 5

Correlation between concentrations of macronutrients in fruit (x) of cherry, peach and plum trees versus the content of sugar in the fresh and dry matter of cherries, peaches and plums (y)

Specification *Y*	*X*									
	Macronutrient									
Sugar total	N		P		K		Ca		Mg	
Cherry										
in fresh matter	0.13	-0.58	-0.49	-0.93	-0.96	-0.89	0.00	-0.87	0.45	-0.87
	0.43	**0.82***	-0.16	0.53	-0.78	0.19	0.00	0.49	0.66	0.67
Peach										
in fresh matter	-0.24	**0.82**	-0.59	-0.13	0.36	-0.02	-0.21	-0.63	0.78	-0.63
in dry matter	-0.61	0.13	-0.47	0.13	0.70	-0.28	0.45	-0.13	0.13	-0.13
Plum										
in fresh matter	-0.18	-0.72	-0.89	-0.14	-0.63	**0.95**	0.44	**0.98**	-0.84	-0.54
in dry matter	0.22	-0.72	-0.69	0.51	-0.15	0.26	0.47	0.14	-0.82	-0.78

*(figures in bold) significant

CONCLUSIONS

1. Irrigation results in the differentiation of the content of macro- and micronutrients in fruits of cherry, beach and plum trees. In fruit of peach trees, decreased nitrogen content and a lower concentration of nitrates in fruits of cherry and plum trees were observed. Irrigation led to increased content of sugars and vitamin C in the dry matter of fruit of peach trees and decreased concentration of sugars in fruit of cherry trees.

2. Mineral fertilization decreased the content of iron in fruit of cherry trees. In the fertilized treatments, an increase in the concentration of nitrogen was observed in fruits of all the fruit trees. A high dose of fertilizers significantly decreased the content of dry matter in fruit of plum trees and total concentration of sugars in the fresh matter of fruit of cherry trees.

3. The strongest relationships between the content of potassium and calcium and the concentration of sugars in the fresh matter were noticed in fruit of plum trees. A highly significant positive relationship was also observed between the concentration of nitrogen and the content of sugars in the dry matter of cherries. No differences were recorded between the content of nitrogen and the concentration of sugars in the fresh matter of fruit of peach trees.

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