REGULATED DEFICIT DRIP IRRIGATION AND WATER USE EFFICIENCY OF A RASPBERRY (*RUBUS IDAEUS L.*) PRIMOCANE-FRUITING CULTIVAR

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ABSTRACT

Experimental was carried out during 2002-2004 on 400 m^2 raspberry plantation of the primocane-fruiting "Lyulin" variety. Seven irrigation treatments were studied in four replications under relatively high temperatures and low air humidity. During the main phenophases – 1) intensive growth; 2) blossom; and 3) fruiting; water was applied in amounts equalled to 100%, 75% and 50% of ET_c respectively. Fertilizers were applied through the irrigation system, the fertilization rate being equal for all treatments. The annual yield, averaged over the three experimental years, was in the range 10010—14720 kg/ha. Compared to the control (100% ET_c), yield was significantly lower only in the most severe variants V2-50 and V3-50. For the experimental period, the average mass of one fruit was 2.5—2.7 g. Only in V3-50 fruit diminished significantly. Raspberry fruit was largest at first harvestings of each season, 3.0—3.4 g. Regulated Deficit Irrigation (RDI) suppressed significantly the growth only in variants V2-50 and V3-50. In most variants, water use efficiency (WUE) was about 2.0 kg/m^3. V3-50 resulted in slight increase in WUE – 2.1 kg/m^3, while in V2-50 WUE was only 1.7 kg/m^3. Hence, with "Lyulin" cultivar, application rates can be reduced by 75% without negative impact on yield and fruit quality. Because of the frequent rainfalls in the spring, during the phase of intensive growth irrigation may be even reduced to 50% ET_c.

Keywords: RDI, WUE, drip irrigation, raspberry, primocane-fruiting cultivar

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Experimental work was carried out in the period 2002-2004 in 400 m2 raspberry plantation of the primocane-fruiting "Lyulin" variety. Seven irrigation treatments were studied in four replications under relatively high temperatures and low air humidity. During the main phenophases – 1) intensive growth; 2) blossom; and 3) fruiting – water was applied in amounts equaling to 100 %, 75 % and 50 % of ETc respectively. Fertilizers were applied through the irrigation system, the fertilization rate being equal for all treatments. The annual yield, averaged over the three experimental years, was in the range 10010—14720 kg/ha. Compared to the control (100% ETc), yield was significantly lower only in the most severe variants V2-50 and V3-50. For the experimental period, the average mass of one fruit was 2.5—2.7 g. Only in V3-50 fruit diminished significantly. Raspberry fruit was largest at first harvestings of each season, 3.0—3.4 g. Regulated Deficit Irrigation (RDI) suppressed significantly the growth only in variants V2-50 and V3-50. In most variants, water use efficiency (WUE) was about 2.0 kg/m3. V3-50 resulted in slight increase in WUE – 2.1 kg/m3, while in V2-50 WUE was only 1.7 kg/m3. Hence, with "Lyulin" cultivar, application rates can be reduced by 75 % without negative impact on yield and fruit quality. Because of the frequent rainfalls in the spring, in the phase of intensive growth the reduction may be even by 50 %.

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INTRODUCTION

There is an increasing interest in the raspberry crop in Bulgaria because of the good international market conditions and the quick pay back of investments. The occupied areas increase steadily, expanding to regions without traditions in raspberry production. However, the growing of raspberry in lowlands would not be successful without irrigation, because of the frequent periods of drought occurring during the summer (Pritts and Handley, 1991; Rolbiecki, 2002). For that purpose, most suitable are the systems for microirrigation and fertigation. Growth and yield of fruit crops may be optimized through Regulated Deficit

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Irrigation (RDI), when the maximum annual application rate is decreased on behalf of moderate levels of water stress in plants (Goodwin and Boland, 2002). In Bulgaria, however, the technology for growing of raspberry was developed for the mountain and hilly conditions of raspberry natural habitat (Boicheva et al., 1998). Even for these conditions, the information about water and nutrient regime of raspberry crop is scarce (Ivanov, 1988). Moreover, there is no research done on irrigation of primocane-fruiting raspberry varieties at all.

Present article is focused on the possibilities for regulation of raspberry growth and yielding through dosing and timing of water stress. It is aimed to establishing of eventual phases of drought tolerance during vegetation as well as critical periods of increased vulnerability to water deficit, which to be used for developing of a resource-saving technology for Regulated Deficit Irrigation. Presented results are part of a larger project on integrated approaches for growing of raspberry under micro-irrigation and fertigation carried out at the Fruit Growing Institute in Plovdiv since 2000 (Koumanov, 2003; Koumanov, 2004; Koumanov et al., 2005; Rankova and Koumanov, 2004).

MATERIAL AND METHODS

The experimental work was carried out in a 400 m^2 raspberry plantation of the primocane-fruiting "Lyulin" variety. Plantation was established in the autumn of 1998 with distance between rows 2.30 m and 0.50 m plant spacing in the rows. Drip irrigation system was installed in the spring of 2000 with one lateral per row and 0.30 m dripper spacing along the laterals. Dripper discharge was 2.4 L h^{-1} (8 L h^{-1} m^{-1}). Seven variants of irrigation regimes, replicated four times, were investigated during the main phenophases – F1) intensive growth, F2) blossom, and F3) fruiting – the water applications being regulated as follows: Vc-100 – 100% of the crop evapotranspiration (ET_c), control; V1-75 – 75% ET_c in F1; V1-50 – 50% ET_c in F1; V2-75 – 75% ET_c in F2; V2-50 – 50% ET_c in F2; V3-75 – 75% ET_c in F3; V3-50 – 50% ET_c in F3. Crop evapotranspiration was calculated upon the readings of Class A evaporation pan. The pan coefficient, K_p = 0.80, and the values of the crop coefficient K_c were estimated according to the FAO methodology (Allen et al., 1998). The coefficient of reduction was accepted Kr = 1 for crop canopy shadowing above 60 %, after Fereres et al. (1982). According to the probability (p) of rainfalls (P) during the vegetation period, year 2002 was wet (P = 527 mm; p = 1%), 2003 dry (P = 197 mm; p = 80%), and 2004 average (P = 242 mm; p = 66%), which proved the obtained results representative. Maximum temperatures varied from 30°C to 35°C, the average daily temperatures in the same period being about 25°C. In 2003, the temperatures remained permanently high in a period of three months – Jun to August – which might probably reduce the photosynthetic activity (Fernandez and Pritts, 1994) resulting, in turn, in decreasing of the yield. The number of water applications was 50 in 2002 realized from 9 May till 21 September, 65 in 2003 from 7 May till 6 October, and 71 in 2004 from 13 April till 8 October. Fertilization was the same for all treatments and the fertilization rates were estimated on the basis of leaf analysis. Fertilizers were of "Kristalon" series of YARA. Fertilizers, and other agro-chemicals when necessary, were added to the irrigation water through a dosing pump DI 150 of DOSATRON INTERNATIONAL. Yield was estimated by replications and variants. Raspberry fruit was harvested 29 times in year 2002, 27 times in 2003, and 23 times in 2004. Differences in the integral yield between the variants were evaluated for each harvesting using dispersion analysis. The same was done for the

average mass of one fruit, which was obtained as weighed average for 13 harvestings in year 2002, 20 in 2003, and 15 in 2004, after weighing of 100 random fruits in each replication. Water use efficiency (WUE_{ET}) and irrigation water efficiency (WUE_M) were obtained as ratios of the yield and the annual evapotranspiration (ET) and the yield and the annual application rate (M), respectively.

RESULTS AND DISCUSSION

Data for the total evapotranspiration and the annual application rate are given in Table 1 by variants, by years, and as total for the three years of investigation. The maximum value of the daily evapotranspiration ($ET_{max.d}$) for 2002 was 5 mm day^{-1}, calculated for the third decade of June and the second one of July. In 2003, $ET_{max.d}$ reached 6.6 mm day^{-1} in the first decade of July, with values of about 5 mm day^{-1} persisting for a 50-day period from June till August. This confirms again the dry character of year 2003. In 2004, the $ET_{max.d}$ exceeded 5 mm day^{-1} only in the first decade of July (5.4 mm day^{-1}). In the control variant, the estimated crop water use of raspberry plantation for 2002-2004 was from 548 mm to 694 mm, which is well below the 750 mm reported by now for Bulgaria. Because of the limited volume of soil wetting and the frequent water applications, the used portion of the rainfalls was not high and varied from 26 % to 59 %, the average for 2002-2004 value being 28 %.

Table 1. Total evapotranspiration ET (mm) and annual application rates M (mm)

Variant	2002		2003		2004		Total for the period	
	ET	M	ET	M	ET	M	ET	M
Vc-100	548	546	694	675	672	655	1914	1876
V1-75	520	395	639	641	635	590	1794	1626
V1-50	492	367	583	586	599	554	1674	1507
V2-75	520	339	656	530	638	517	1814	1386
V2-50	493	367	619	603	605	556	1717	1526
V3-75	513	340	630	566	598	523	1741	1429
V3-50	476	360	566	577	523	516	1565	1453

Table 2. Yield and average mass of one fruit

Variant	2002		2003		2004		Total for the period	
	Yield	Mass	Yield	Mass	Yield	Mass	Yield	Mass
	kg/ha	g	kg/ha	g	kg/ha	g	kg/ha	g
Vc-100	14176	2.87	12527	2.26	12988	2.73	39691	2.62
V1-75	13300	2.81	12341	2.33	9912***	2.61*	35553*	2.58
V1-50	16429	2.98	13888	2.41	12616*	2.78	42933*	2.72
V2-75	12586	2.95	12897	2.36	12040	2.75	37523	2.69
V2-50	11525*	2.89	9041***	2.27	8435***	2.72	29001***	2.63
V3-75	13629	2.83	14085	2.34	13252	2.75	40966	2.64
V3-50	12493	2.75**	10018***	2.07***	10860***	2.6**	33371***	2.47***

Note: * P 0.05; ** P 0.01; *** P 0.001

The yield and the average mass of one fruit are presented by years and variants in Table 2. In most variants, the yield is high, exceeding significantly the maximum value of 11000 kg ha-1 reported for "Lyulin" variety under irrigation (Boicheva et al., 1998). The yield for 2002 could be even higher but rain-storms spoiled the production of two harvestings in the beginning of August. Frequent and heavy rains along the vegetation attenuated the differences between the investigated variants of regulated water deficit. In that year, only the yield reduction in variant V1-75 was proven significant as far as the decreased water supply in this variant coincided with a period of relatively less rainfalls. In the driest 2003 and the average 2004, the yield decreased significantly only in the variants with severest reduction of the application rates V2-50 and V3-50. In 2004, significant yield reduction was found also in variant V1-75 but, apparently, it is not due to decreased water supply because, for the same phenophase, the yield in the more restricted variant V1-50 exceeded that in the control. It is subject of further investigations to find out the factors determining such a decrease in V1-75. Values of the averaged over the three-year period yield confirm the already established for each year fact that significant reduction of the yield, compared to the control, occurs only in the variants with 50 % reduction of the application rates V2-50 and V3-50. Averaged over the period 2002-2004, only the yield in variant V1-50 was higher than that in the control Vc-100. For the period 2002-2004, the average mass of one fruit was 2.5—2.7 g. Only the maximum application rate reduction in variant V3-50 caused a proven size reduction of the raspberry fruit. In 2004, the average mass of one fruit was significantly lower in variant V1-75 but, as it was already discussed, it was not probably due to the application rate reduction. In all experimental years, there was tendency to diminishing of fruit with the progress of vegetation period. Raspberry fruit was largest at first harvestings of each season, when the average mass reached up to 3.0—3.4 g. Despite of the drier lowland climate, the fruit mass in all investigated variants remained much larger than 1.3—1.9 g, reported for most of primocane-fruiting raspberry varieties (Pritts and Handley, 1991). Hence, fruit remained with pretty good market quality even under RDI treatments. Differences between the investigated variants in fruit chemical composition and leaf mineral composition did not outline any trend and could be rather characterized as incidental.

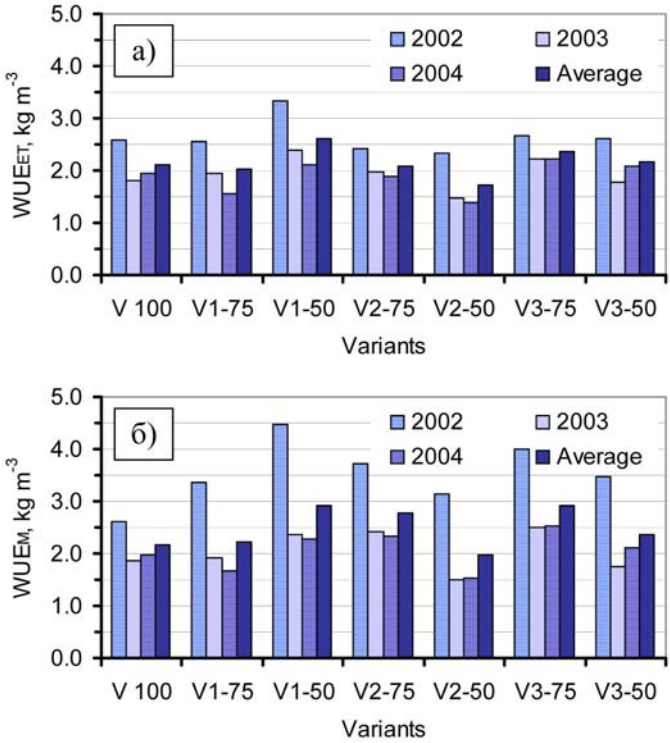

Figure 1. Water use efficiency (WUE_{ET})-a and irrigation water efficiency (WU_M)-a

The water use efficiency of raspberry crop, both WUE_{ET} and WUE_M, is illustrated on Fig. 1 by variants for each experimental year and average for the period 2002-2004. WUEET (Fig. 1a) increased substantially in 2002 because of the higher yield. According to the obtained results, the raspberry plantation used one cubic meter of water to produce 2.0—2.5 kg fruit. RDI increased WUE_M and, according to this criterion, the variants with 50 % reduction of the application rates equaled the control, where one cubic meter of water produced 2.1 kg fruit, Fig. 1b. The irrigation water efficiency was significantly increased under the 25 % reduction of the application rates, where the WUE_M values were about 2.9 kg m-3.

CONCLUSIONS

According to the obtained results, water application rates may compensate only 75 % of ETc for "Lyulin" variety (60% of the evaporation from a Class A pan) without negative impact on the yield and the fruit quality. Moreover, in the phase of intensive growth, application rates can be reduced even by 50 % of ETc (40 % of the evaporation from a Class A pan) because the rainfalls in this period are usually frequent and the water regime of the raspberry plants is more favorable than that corresponding to 50 % of ETc.

In different phenophases, one may realize water savings from 4 % to 17 % without significant reduction of the yield. When the irrigation water is scarce or its price is too high, the annual application rate may be reduced by 8—31 % at a still relatively high levels of the yield and the fruit quality.

ACKNOWLEDGMENTS

This study was carried out with the kind support of the International Atomic Energy Agency, the Fund "Scientific Investigations" at the Bulgarian Ministry of Education and Science – Project CC-14-10, and DOSATRON INTERNATIONAL, Bordeaux, France. We thank "KVS AGRO" – representatives of YARA for Bulgaria, who kindly provided the soluble fertilizers of "Kristalon" series. We express our special thanks to Professor Georgi Stoilov for the consultations and the valuable discussions on fertilization.

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