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FRUIT-BEARING POTENTIAL MODELING OF THE FLORICANE RASPBERRY CV. WILLAMETTE

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Abstract

During the 3-year period (2014-2016) modeling of the fruit-bearing potential of the cultivar, Willamette was conducted with the aim of defining the optimal load of the mixed buds per meter of the hedgerow. Modeling was conducted by a reduction in the fruit-bearing potential of 160 mixed buds, corresponding to a load of canes in the ordinary production practice. The fruit-bearing potential was reduced to 120 (medium potential) and 90 buds (low potential). Lower intensity reduction in a number of mixed buds per meter of hedgerow and selection of quality buds enables an increase in yield for 31.7%. Reduction in a number of mixed buds for about 50% in comparison to ordinary production practice led to a 14.6% decrease in total yield, during the three-year period. The increase in the number of buds per meter of hedgerow to a certain number may affect the increase and continuity of the yield. An increase in fruit-bearing potential outside of the range of the optimum determined by this research (120 mixed buds) may prove counterproductive and lead to a decrease in yield.

Key words*: hedgerow, cane, mixed bud, fruit, yield, quality.*

INTRODUCTION

Raspberry production plays an important role in both agricultural production and rural development in Bosnia and Herzegovina. Frozen raspberry export for the period 2014-2018. had a share from 52.0 to 66.6% in the total value of the fruit and vegetables exports from Bosnia and Herzegovina (Zivotic et al., 2018). New varieties (Sava, 2013) and growing technology (Asanica, 2019) are of crucial importance for efficiency in the raspberry production. Floricane type cultivar Willamette dominates in the countries' raspberry production with share 80% of the total production. Willamete is high-yield characteristics cultivar, resistant to the most significant raspberry diseases and pests and suitable for cultivation in the different local agro ecological conditions (Velickovic et al., 2004; Stanisavljevic et al., 2004; Kempler et al., 2005; Eyduran et al., 2006; Kulina et al., 2012; Fotiric-Aksic et al., 2012; Milivojevic et al., 2012; Poledica et al., 2012; Alibabic et al., 2018). Willamette is cultivated in hedgerow system, patented in Serbia during 1970s (Glisic et al., 2009; Leposavic et al., 2013). Lack of knowledge considering growth biology and development of the floricane raspberry cultivars (Micic et al., 2015) and desire to realize maximal yields often result in an application of the inadequate pomotechnical treatments in commercial plantations. To achieve high yields, producers often leave the maximal number of year-old shoots for fruiting in the next season. Large number of aboveground shoots in one season influences extremely dense plant set per meter of hedgerow, thus resulting in formation of a large number of small fruit. A large number of canes

in the fruiting phase (two-years-old) result in negative competition with the formation of new year-old shoots for the next season. In such conditions shoots cannot reach desired height and diameter which certainly affects the number of mixed buds and the stage of their differentiation. The aim of this research was to define optimal number of mixed buds and density of aboveground shoots for the cultivar Willamette by modeling the fruit-bearing potential through difference in number of mixed buds per meter of hedgerow.

MATERIALS AND METHODS

The experiment was conducted in the commercial orchard owned in the village Borkovac, municipality Bratunac (eastern Bosnia and Herzegovina) during the period 2014-2016. The orchard is situated at plateau of the local river, at the altitude of 216 m (Lat: 44°11'9.37" N; Long: 19°18'29.62" E). The orchard was established in 2008. The spacing was 0.25 m in row and 2 m between rows. The orchard was planted exclusively with cultivar Willamette. Training system was vertical trellis - hedgerow growing system with two wires placed at 120 cm and 180 cm above the ground. Modeling of the fruit-bearing potential was done by reduction in number of mixed buds per meter of hedgerow in comparison to the ordinary production practice. The control was a load of 160 mixed buds per meter of hedgerow i.e. the density of 8 canes per meter of hedgerow, each with 20 mixed buds (8 × 20), corresponding to the load of canes in the ordinary production practice – indicated k_{160} in the tables. Treatments of the reduction of the fruit-bearing potential were done by reduction in number of canes per meter of hedgerow and by the reduction in number of buds per cane. Two different treatments were applied: reduction to 120 mixed buds per meter of hedgerow by retaining 8 canes with 15 buds per each cane - 8 × 15 (treatment 1 - medium fruit-bearing potential, indicated as t_{120}); reduction to 90 buds per meter of hedgerow by retaining 6 canes with 15 buds per each cane (treatment 2 - low fruit-bearing potential, indicated as t_{90}). Primary sampling unit was 1 meter of hedgerow. Each treatment was laid out in a randomized block design in 5 replications (total of 15 meters of hedgerow) at different positions in the orchard. Number of fruiting laterals and number of fruits per meter of hedgerow, percentage of activated buds (%), number of fruiting laterals per cane, fruit weight, fruit length, fruit width, fruit shape index, yield per cane and yield per unit area were determined. The statistical analysis was performed using Statgraphics Centurion. Obtained results were subjected to analysis of variance (ANOVA) according to a factorial design, where the sources of variation were year and treatment, and their interaction. Comparison of means was performed by the Duncan test ($\alpha = 0.05$). The results are presented as the mean value ± standard error of mean (SEM).

RESULTS AND DISCUSSIONS

Applied treatments had a statistically highly significant influence on the average percentage of activated mixed buds, number of fruiting laterals and number of fruits per meter of hedgerow (Table 1). In the control treatment, there was 15 to 20% less activated buds compared to t_1 and t_2, while less significant difference was observed between t_1 and t_2. Reduction in number of mixed buds per meter of hedgerow, during all three years of research induced statistically higher number of fruiting laterals of the control canes compared to canes with reduced bud number. Slightly larger number of fruiting laterals was observed within the control canes, even though in some seasons (2015 and to some extent 2014) the difference was not statistically significant. Number of fruits per meter of hedgerow was significantly higher in the seasons 2014 and 2015, compared to the season 2016.

Analysis of the number of fruits implies significant differences between applied treatments. Highest number of fruits per cane was recorded for the treatment $t_{2\text{-}120}$. The research demonstrated that the control canes bearing the highest number of mixed buds, in absolute quantity, also developing the highest number of fruiting laterals compared to treatments where the number of mixed buds was reduced. However, for the control canes, in average 15 to 20% of the retained buds never were activated and did not produce fruiting laterals.

Table 1. The influence of year and treatment on percentage of activated buds (%), the number of fruiting laterals per meter of hedgerow, the number of fruits per meter of hedgerow, the number of fruiting laterals per cane and number of fruits per cane

	2014	2015	2016
	$\overline{X}$ ± SEM		
	percentage of activated buds (%)		
$t_{1\text{-}90}$	90.6^{a} ± 1.47	95.5^{a} ± 1.22	100.0^{a} ± 0.0
$t_{2\text{-}120}$	97.3^{a} ± 1.33	95.3^{a} ± 1.19	98.8^{a} ± 0.82
$k_{\text{-}160}$	79.6^{b} ± 2.99	80.9^{b} ± 2.73	81.6^{b} ± 2.78
average	89.2 ± 2.23	90.6 ± 2.08	93.5 ± 2.42
	number of fruiting laterals (m^{-1})		
$t_{1\text{-}90}$	81.6^{c} ± 1.33	86.0^{b} ± 1.09	90.0^{c} ± 0.00
$t_{2\text{-}120}$	116.8^{b} ± 1.59	114.4^{a} ± 1.44	118.6^{b} ± 0.98
$k_{\text{-}160}$	135.2^{a} ± 9.57	122.4^{a} ± 5.19	145.8^{a} ± 9.60
average	111.2 ± 1.06	107.6 ± 4.5	112.3 ± 6.78
	number of fruits (m^{-1})		
$t_{1\text{-}90}$	1206.6^{b} ± 73.41	1219.0^{b} ± 52.27	1067.6^{c} ± 59.43
$t_{2\text{-}120}$	1724.8^{a} ± 72.30	1717.8^{a} ± 79.40	1658.0^{a} ± 113.66
$k_{\text{-}160}$	1570.0^{a} ± 130.84	1629.8^{a} ± 97.27	1336.8^{b} ± 61.81
average	1500.5 ± 77.53	1522.2 ± 71.68	1354.1 ± 78.04
	number of fruiting laterals per cane		
$t_{1\text{-}90}$	13.6	14.3	15.0
$t_{2\text{-}120}$	14.6	14.3	14.8
$k_{\text{-}160}$	16.9	15.3	18.2
average	15.0	14.6	16.0
	number of fruits per cane		
$t_{1\text{-}90}$	201.1	203.2	177.9
$t_{2\text{-}120}$	215.6	214.7	207.3
$k_{\text{-}160}$	196.3	203.7	167.1
average	204.3	207.2	184.1

$^{a, b, c}$ means followed by different letter within the particular year are significantly different (Duncan, α=0.05)

The number of fruiting laterals per cane was in the range from 13.6 to 18.2. These results are in accordance with the other research (Poledica et al., 2012), where the number of fruiting laterals was in the range of 11.2 to 18.6 depending on the applied treatments and in the range from 7.4 to 23.4 (Fotiric-Aksic et al., 2012). It should be noted that the number of fruiting laterals, during this research, was very uniform for the $t_{2\text{-}120}$, and with significant differences among $t_{1\text{-}90}$ and $k_{\text{-}160}$. The number of fruits per meter of hedgerow was significantly influenced by applied treatments. This confirms the assertion that the number of developed fruiting laterals per cane does not necessarily imply large number of fruits. It could be said that projected – moderate reduction in number of mixed buds per meter of hedgerow ($t_{2\text{-}120}$) provides good balance between vegetative and generative growth, as well as continuity of high fruit number. The reduction of higher intensity ($t_{1\text{-}90}$) decreases fruit-bearing potential. High fruit-bearing potential ($k_{\text{-}160}$) may support the occurrence of extremely high yields in one season, resulting in extremely low yields in the next season. The analysis of the number of fruiting laterals and fruits per cane implies the validity of moderate reduction of mixed buds per cane. Control canes had higher number of fruiting laterals compared to canes in treatments $t_{1\text{-}90}$ and $t_{2\text{-}120}$. Taking into account that the control canes had an average of 30% more retained buds per cane observed difference in number of fruiting laterals is negligible, except for the season 2016 when it was only slightly expressed. The number of fruits per cane was both, the highest and most constant through the seasons for the treatment with moderate reduction of the fruit-bearing potential ($t_{2\text{-}120}$). Slightly lower number of fruits per cane (161.3) was determined in research conducted in Serbia (Milivojevic et al., 2012). Significant variations of the number of fruits in relation to applied treatment in a range from 147.0 to 218.0 and 128.5 to 226.1 were observed by other authors as well (Glisic et al., 2009; Poledica et al., 2012; Alibabic et al., 2018). Yield per cane and per unit area is to

a large degree specific to the variety of the raspberry, because it depends on the number of fruits and on average fruit weight as well.

The largest fruit size, regardless of the year of research (Table 2), was recorded for the treatment $t_{2\text{-}120}$.

Table 2. Values of the average fruit weight (g), fruit length (mm), fruit width (mm) and fruit shape index

	Fruit weight (g)	Fruit length (mm)	Fruit width (mm)	Fruit shape index (length/width)
Year (Y)	***	***	***	*
Treatment (T)	***	***	***	ns
Y×T	***	***	*	*
Year		$\overline{X} \pm$ SD		
2014	$5.0^{a} \pm 0.15$	$23.9^{b} \pm 0.31$	$22.3^{b} \pm 0.30$	$1.07^{a} \pm 0.006$
2015	$4.7^{b} \pm 0.08$	$25.2^{a} \pm 0.21$	$24.2^{a} \pm 0.28$	$1.05^{b} \pm 0.009$
2016	$3.4^{c} \pm 0.04$	$20.7^{c} \pm 0.15$	$19.5^{c} \pm 0.11$	$1.07^{a} \pm 0.007$
Treatment				
$t_{1\text{-}90}$	$4.3^{b} \pm 0.12$	$22.8^{b} \pm 0.33$	$21.9^{b} \pm 0.32$	$1.05^{b} \pm 0.0074$
$t_{2\text{-}120}$	$4.4^{a} \pm 0.15$	$23.5^{a} \pm 0.35$	$22.0^{a} \pm 0.38$	$1.06^{ab} \pm 0.0088$
$k_{\text{-}160}$	$4.0^{c} \pm 0.10$	$22.9^{b} \pm 0.28$	$21.4^{b} \pm 0.28$	$1.07^{a} \pm 0.0065$

$^{a, b, c}$means followed by different letter within the particular year are significantly different (Duncan, α=0.05)

Fruits of the largest size, with the largest fruit length and width, were recorded for the treatment $t_{2\text{-}120}$, during all years of research. Research done in Serbia (Milivojevic et al., 2012) determined slightly lower values of the fruit weight (2.9 g in average) which is in accordance with the other researchers (Alibabic et al., 2018). There are some findings (Kempler et al., 2005) stated the fruit weight was ranging from 3.2 to 3.7 g, with the ascertainment that growing conditions and applied treatments significantly affect fruit characteristics. Higher values of fruit weight (3.3-3.4 g) were recorded in the traditional raspberry growing area in Serbia (Velickovic et al., 2004). Previous data about fruit weight within the same region in which this research was conducted in Bosnia and Herzegovina (Kulina et al., 2012) determined the average fruit weight of 3.51 g. Very large fruits with average fruit weight of 4.72 g were observed by some other researchers (Stanisavljevic et al., 2004; Poledica et al., 2012). Results obtained on fruit length and width are in accordance with the results obtained by other authors (Milivojevic et al., 2012; Alibabic et al., 2018). Most authors agree that fruit shape index for the cultivar Willamette is slightly larger than 1, which is in accordance with the results obtained in this research. Tendency of linear decrease in yield was observed for applied treatments during all three years of research, while the control treatment showed uneven variations (Table 3).

Table 3. The influence of year and treatment on average yield

	Average yield per cane (g)			Average and total yield (t) per unit area (1 ha)				Difference in yield for t_1 and t_2 compared to control (%)
	2014	2015	2016	2014	2015	2016	Total	
$t_{1\text{-}90}$	1102.0	918.3	599.6	21.2	17.6	11.5	50.3	- 14.6
$t_{2\text{-}120}$	1263.4	1062.9	702.6	32.3	27.2	17.9	77.5	+ 31.6
$k_{\text{-}160}$	790.9	951.4	558.1	20.3	24.4	14.3	58.9	0.0

Yield per meter of hedgerow was highest for the treatment $t_{2\text{-}120}$ in all seasons. Exceptionally high yields in 2014 and 2015 were conditioned not only by the large number of fruits, but by large fruit size as well. Number of fruits per cane and average fruit weight were used to calculate yield per cane. Highest average yield per cane was recorded for the treatment $t_{2\text{-}120}$ during all years of research, while the lowest yield was recorded for the control treatment in 2014 and for the treatment $t_{1\text{-}90}$ in 2015. Raspberry average yield in available literature is most often under the real value of raspberry fruit-bearing potential. In the research conducted in Turkey (Eyduran et al., 2006) was recorded very low yields per cane (96.0 g)

which could be explained by unfavourable climatic conditions and/or the lack of adequate pomotechnical and agrotechnical treatments. Researchers from Serbia recorded significantly higher yields (Leposavic et al., 2013) as well as in Bosnia and Herzegovina (Kulina et al., 2012) where determined the average yield of 20100.0 kg/ha. Achieved yields within this research suggest that the optimal modeling of the fruit-bearing potential could provide for profitable, and in certain conditions extremely profitable yields. Lower intensity of the reduction in number of mixed buds per meter of hedgerow $t_{2\text{-}120}$ and selection of quality buds enables increase in yield for 31.7%. This is important, considering the attitude of most of the producers and some of the experts that increase in number of mixed buds per meter of hedgerow (via increase in retained canes and buds they bear) necessarily leads to increase in yield. Reduction in number of mixed buds for about 50.0% ($t_{2\text{-}120}$) in comparison to ordinary production practice led to decrease in total yield for 14.6%, during the three-year period. The abovementioned imposes the necessity of additional analysis of the production in conditions of the reduced fruit-bearing potential by the ease of application of standard pomotechnical and agrotechnical procedures in orchards with lower vegetative mass. Could the decrease in yield of 14.6% be compensated by more efficient pesticide application, less necessity for manual labor during dormancy, more cost effective agrotechnical procedures (fertilization and pesticide application) and picking? These are questions that should be additionally answered in the next period, so the more complete assessment of the efficacy of this treatment could be provided.

CONCLUSIONS

Obtained results clearly demonstrate that the increase in number of buds per meter of hedgerow to a certain number may affect increase and continuity of the yield. Increase in fruit-bearing potential outside of the range of the optimum determined by this research (120 mixed buds per meter of hedgerow) may prove counterproductive and lead to decrease in yield. This occurs as a result of the creation of unfavorable, competitive relations between one and two-year aboveground shoots. Large number of mixed buds per meter of hedgerow is not a guarantee of high yield. Increase in number of canes per meter of hedgerow implies increase in application of the agrotechnical procedures, namely fertilization as well as manual labor during pruning and picking and more difficult (less efficient) application of pesticides. Such procedures have to be taken into consideration as to achieve the objective evaluation of the applied treatments of the reduction of the fruit-bearing potential and its impact on the cultivation of the Willamette variety in local production.

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