

PRODUCTIVITY PER LEAF AREA IN SOME INTRODUCED STRAWBERRY VARIETIES IN THE SKOPJE REGION

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Abstract

The study presents the results of the investigation on productivity per leaf area of fifteen strawberry varieties: Idea, Camarosa, Belrubi, Evita, Honeoye, Tethis, Chandler, Onda, Miranda, Paros, Elsanta, Eris, Madeleine, Favette and Marmolada, as well as two standard varieties: Pocahontas and Senga Sengana. The experimental orchard was performed on open field in the Institute of Agriculture – Skopje, on black polyethylene foil in form of double file set on banks and at the distance of 40x30cm between the plants, irrigated by control drip irrigation system. The study has been conducted on fruit number, fruitage and yield of soluble solid matter per unit of leaf area. Also, the effective leaf area for production of 100 number of fruits, for 1 kg of fruitage and for 100 g yield of soluble solid matter in fruits of each variety were examined. The investigated parameters related to productivity per unit of leaf area are ranged from 54,0 at Miranda to 125,1 at Pocahontas for number of fruits, from 0,49 kg/m² in Favette and Elsanta, to 0,96 kg/m² in Honeoye for fruitage and from 41,2 g/m² in Elsanta, to 92,9 g/m² in Pocahontas for the yield of soluble solid matter in fruits. Leaf area of 1,37 m² is effective for 100 number of fruits production, as well as 1,47 m² for 1kg of fruitage and 1,75 m² for production of 100 g soluble dry matter fruits-yield. The productivity per leaf area of the investigated varieties is less dependent on the influence of leaf area per plant and fruit mass, but it is more dependent of the influence of number of fruits per plant, fruitage per plant and yield of soluble solid matter per plant. The values of correlation coefficient between productive parameters per plant and effective leaf area parameters are with similar strength, but they are with an opposite dependency in relation to the corresponding correlations with productive parameters per leaf area.

Keywords: Number of fruits, fruitage, soluble solid matter, effective leaf area, productivity parameters.

Introduction

The fruit production is highly dependent on leaf area and its physiological activity (Ристевски и сop.1994). The number of fruits in a unit of leaf area is an important indicator for determining the leaf productivity (Bulatović 1970), (Blagojević, 1983), (Поповски, 2008). The yield is in direct correlation with plant leaf area, brightness and health of the leaves (Bulatović 1970), (Blagojević, 1983), (Walsh, 1992), (Кипријановски, 2001) (Поповски, 2008). The leaves that are in the peripheral parts of the plant which are exposed in direct sunlight have a 3 to 5 times more intense assimilation compared to the other leaves which are present in the interior of the plant (Sarić i sar., 1989). The photosynthesis in interior leaves even drops under compensation point. Having in mind the relevance of the leaf area for gaining big and quality yields in fruit production, it is of high importance to pay attention to the plant density and the system for shaping and forming the canopy in order to achieve optimal and highly illuminated leaf area (Ристевски и сop., 1994). Also, the specifically applied agro-technical measurements on the various varieties have the high influence on the leaves activity (Blagojević, 1983). Productivity per leaf area oscillates among strawberry varieties cultivated on different climatic and soil conditions (Dénes, 1997). Considering the mentioned facts, the aim of this paper is to examine the productivity on the unit of leaf area related to number of

fruits, fruitage and yield of soluble solid matter with 17 strawberry varieties cultivated in Skopje region.

Material and methods

The experimental orchard was performed on open field in the Institute of Agriculture –Skopje on black polyethylene foil in form of double file set on banks and at the distance of 40x30cm between the plants, irrigated by control drip irrigation system. It was established in the second half of September 2011, with a frigo virus-free planting material. The analysis was performed during 2012–2014. The soil was homogeneous, alluvial, possessing a good water-air regime, suitable for strawberry growing. The agrochemical composition of the soil consisted of 0,93-2,05% hummus, 9,32-10,38mg/100g N, 14,3-21,1mg/100g P₂O₅, 10,06-22,2 mg/100g K₂O, 6,49-7,25% CaCO₃, pH 7,93-8,19 in H₂O and 7,4-7,63 in KCl. The soil has been ameliorative fertilised with mineral fertiliser and organic fertiliser from California worms. According to data for meteorological parameters from the Hydrometeorological Station Petrovec, the climate of the Skopje Region featured warm dry summers and foggy cold winters. Productivity per leaf area was observed on 15 strawberry varieties: Idea, Camarosa, Belrubi, Evita, Honeoye, Tethis, Onda, Chandler, Miranda, Paros, Elsanta, Eris, Madeleine, Favette and Marmolada, as well as two standard varieties: Pocahontas and Senga Sengana. Varieties production is presented per unit of leaf area by analyzing the following parameters: number of fruits per leaf area (NF/LA), fruitage per leaf area (F/LA) (kg/m²) and yield of soluble solid matter per leaf area (YSSM/LA) (g/m²). Also, the production of varieties is presented through the effective leaf area for production of 100 numbers of fruits (ELA100NF) (m²), effective leaf area for 1kg fruitage (ELA1kgF) (m²) and effective leaf area for 100 g of soluble solid matter (ELA100gYSSM) (m²). The values of the parameters are obtained by calculating the data for leaf area per plant (LA/P) (cm²) and productive parameters: fruit mass (FM) (g); number of fruits per plant (NF/P), fruitage per plant (F/P) (g) and yield of soluble solid matter per plant (YSSM/P) (g). Analyses of variance were performed for statistical analysis of the results. The results were processed using LSD-test to prove the statistical significance of the differences between the varieties, with a significance levels of 0,05 and 0,01. The interconnectedness of certain properties is expressed with correlation analysis by determining the correlation coefficient (R). The strength of the correlation between the properties is determined according to the classification of Chebyshev (cit. by Hajčevska, 2002).

Results and discussion

The leaf area and productive parameters per plant of the investigated strawberry varieties are presented in Table 1. LA/P is ranged from 3051 cm² at Chandler to 5497 cm² at Miranda, while the average is 4530 cm². The FM has an average value of 10,3 g, ranges from 6,4 g at the control Senga Sengana to 12,8 at Onda. The Pocahontas control is characterized by the highest NF/P, F/P and YSSM/P. The lowest fruitage has Elsanta. Besides having the smallest leaf area, Chandler has the lowest values for NF/P (19,9) and for YSSM/P (13,0 g). NF/P for all varieties is in average of 35,10, while the F/P is 314,15g and YSSM/P is 27,0 g respectively. Our results are several times higher than the results obtained by Bulatović (1970) in the region of Belgrade, where the values for investigated parameter is ranged between 641 do 1402 cm² per plant. The average NF/LA for all varieties in the examined period is 78,8 (Table 2). The standard variety Pocahontas produces the highest amount of fruits (125,1 fruits/m²), followed by Honeoye and second standard Senga Sengana. The lowest amount of fruits is noticed at Miranda (54,0 fruits/m²). It is noticed that the varieties with larger fruits (Table 1) are characterized by smaller NF/LA (Table 2). From an annual point of view, the highest average NF/LA is present in 2014 (135,3) i.e. in the year with the highest fruitage per plant. On the other hand, the smallest average of NF/LA is present in 2012 (9,1), when the total fruitage was at its lowest. The medium strong negative correlation between the NF/LA and the FM was determined (R= -0,569) (Table 5). The medium positive correlation between the NF/LA and F/P and with YSSM/P was determined (R= 0,524 and R= 0,516).

area is Honeoye (224,0) followed by control Pocahontas and Evita, in 2014. The lowest number was noticed at Favette. Кипријановски (2001), analyzed this property in Pocahontas and Red Gauntlet varieties in the region of Skopje. He identified an average of 136,2 NF/LA for Pocahontas. This value varies between 83,4 and 207,2 NF/LA in the duration of the study, which are a bit higher compared to the results present in our paper. For the Red Gauntlet variety, he identified an average of 126,9 NF/LA that varies from 75,6 up to 183,9 fruits. Statistical high significant differences were determined for the average values of NF/LA between the Pocahontas and Marmolada, Camarosa, Madeleine, Favette, Miranda and Belrubi. Significant differences were determined between Pocahontas and Paros, Chandler, Onda and Elsanta. Another set of significant differences were found between Honey and Chandler, Onda, Elsanta, Camarosa, Marmolada, Madeleine, Belrubi, Favett and Miranda, as well as between Senga Sengana and Favette and Miranda varieties. According to annual data, high significant differences between the average values of this parameter for all investigated years were found. The effective leaf area for production of the unit yield depends on the genotype and it presents the photosynthetic potential of the variety, i.e. the leaf efficiency for synthesis of organic matter. The ELA100NF of the investigated strawberry varieties, amounts to an average of 1,37 m² (Table 2). The varieties with lower values for this parameter are more productive. Therefore the Pocahontas variety with the lowest value for this parameter (0,8 m²) produces the highest NF/LA (125,1), while Miranda which has the highest value for ELA100NF (1,85 m²) produces the lowest NF/LA (54,0). The values for these two properties are inversely proportional. Together with the abundance of the variety, they have practical significance in determining the planting distance, the breeding system and the yield estimation for strawberry production. The LA/P has small dependence on the ELA100NF (R= 0,450). The data for F/LA are presented in Table 3. The average values for all examined varieties during the study period is 0,71 kg/m². The highest yield is identified for Honeoye the Tethis (0,96 and 0,94 kg/m²), followed by the standard variety Pocahontas (0,93 kg/m²), statistically different from more varieties. The lowest fruitage is mentioned at Elsanta and Favette (0,49 kg/m²), statistically different from Paros, Evita, Chandler and Idea. The standard Senga Sengana is characterized with an average fruitage of 0,60 kg/m² leaf area, which is significantly lower than Honeoye, Tethis, Pocahontas and Idea. From an annual point of view, the highest average for F/LA is noticed in 2014, while and the smallest in 2012.

Table 3. Fruitage (kg/m²) and effective leaf area for 1 kg of fruit production (m²)

No.	Variety	Fruitage per leaf area (kg/m ²)				Effective leaf area for 1kg of fruits (m ²)
		2012	2013	2014	Average	
1	Idea	0,37	0,64	1,52	0,85	1,18
2	Camarosa	0,01	0,58	1,33	0,64	1,57
3	Belrubi	0,11	0,24	1,70	0,68	1,46
4	Evita	0,06	0,64	1,61	0,77	1,30
5	Honeoye	0,05	0,66	2,16	0,96	1,05
6	Tethis	0,33	0,54	1,97	0,94	1,06
7	Chandler	0,54	0,17	1,71	0,81	1,24
8	Onda	0,15	0,41	1,50	0,69	1,46
9	Pocahontas	0,09	0,90	1,79	0,93	1,08
10	Senga Sengana	0,04	0,83	0,93	0,60	1,67
11	Miranda	0,05	0,52	1,10	0,56	1,80
12	Paros	0,05	0,71	1,47	0,75	1,34
13	Elsanta	0,02	0,66	0,79	0,49	2,04
14	Eris	0,05	0,89	1,13	0,69	1,45
15	Madalene	0,00	0,89	1,10	0,66	1,51
16	Favette	0,19	0,62	0,67	0,49	2,03
17	Marmolada	0,17	0,62	0,94	0,58	1,74
	AVERAGE	0,14	0,62	1,38	0,71	1,47

LSD 0.05=0,15

LSD 0.05=0,24

LSD 0.05=0,49

LSD 0.01=0,21

LSD 0.01=0,35

LSD 0.01=0,73

The F/LA ranges between 0,01kg/m² at Camarosa to 0,54 kg/m² at Chandler, in 2012. Standard Pocahontas had the highest fruitage in 2013, followed by Eris, Madeleine and second standard Senga Sengana. The other 13 varieties had the lower fruitage then Senga Sengana (from 0,71 at Paros to 0,17 at Chandler). In 2014, the highest values was present at Honeoye (2,16 kg/m²), followed by Tethis and standard Pocahontas. Senga Sengana is characterized by almost equal values for fruitage (0,93 kg/m²), as 2014. The smallest F/LA in 2014 was noticed at Favette, and with Elsanta they are the only two varieties with smaller fruitage than standard Senga Sengana. According to annual data, high significant differences between the average values of this parameter for all investigated years were found. In two different locations in Hungary which differ in climate and soil, Dénes (1997) examined numerous strawberry varieties. The F/LA differed a lot and varied from 1,19 kg/m² for Elvira variety to 2,0 kg/m² for Elsanta variety. Senga sengana had yield of 1,74 kg/m² in environment with moderate continental climate. The Melsada variety had exhibited the lowest yield (0,74 kg/m²) while the highest yield was with the Tago variety (3,06 kg/m²). The quoted values are significantly higher than the values in our examinations. Kiprijanovski (2001), while investigated this parameter at Pocahontas variety, indicated the F/LA of 1,01kg/m², ranged from 0,67 to 1,56 kg/m² during the examined period, similar in our data. According to Благојевиќ (1998), the average F/LA for 10 strawberry varieties range from 2,98 kg/m² per leaf area at Sequoia to 5,29 kg/m² for Red Gauntlet. These are higher values compared with our research. Also, the fruitages of Senga Sengana was in average of 3,17 kg/m², (range from 2,19 to 4,24 kg/m²), while it was 3,29 kg/m² for Belrubi (from 2,71 to 3,98 kg/m²) leaf area.

Table 4. Yield of soluble solid matter (g/m²) and effective leaf area for 100 g of solid matter production (m²)

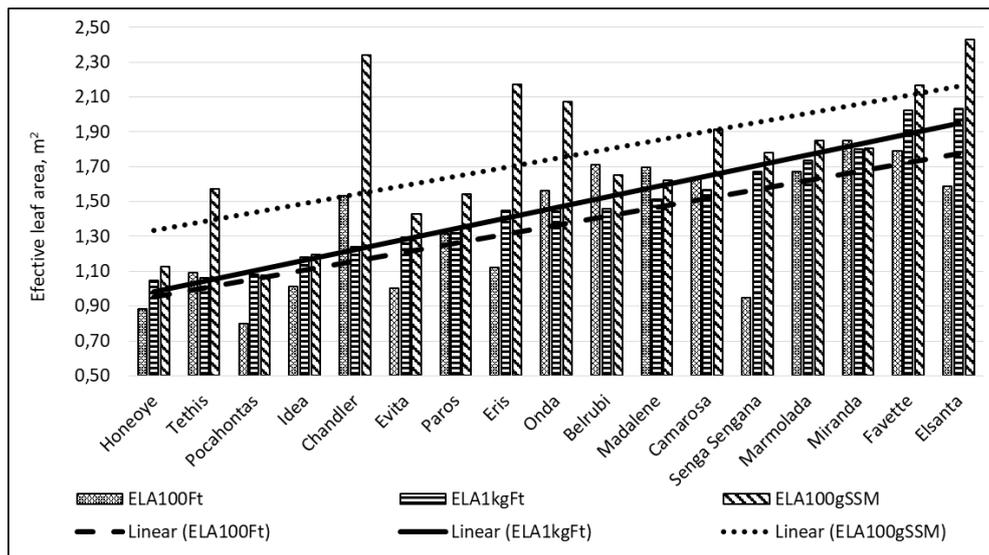
No.	Variety	Yield of soluble solid matter (g/m ²)				Effective leaf area for 100g of solid matter production (m ²)
		2012	2013	2014	Average	
1	Idea	35,8	61,0	154,1	83,6	1,20
2	Camarosa	0,8	45,7	110,2	52,2	1,91
3	Belrubi	9,6	23,0	149,2	60,6	1,65
4	Evita	5,7	54,4	150,1	70,1	1,43
5	Honeoye	5,2	63,0	197,6	88,6	1,13
6	Tethis	22,8	31,9	136,3	63,7	1,57
7	Chandler	22,9	26,3	78,9	42,7	2,34
8	Onda	10,2	28,2	106,2	48,2	2,07
9	Pocahontas	8,6	89,0	181,1	92,9	1,08
10	Senga Sengana	3,6	76,6	88,2	56,1	1,78
11	Miranda	4,8	52,1	109,1	55,3	1,81
12	Paros	4,9	60,7	129,0	64,9	1,54
13	Elsanta	2,0	55,2	66,3	41,2	2,43
14	Eris	3,0	59,9	75,1	46,0	2,17
15	Madalene	0,0	81,4	103,6	61,7	1,62
16	Favette	17,9	57,0	63,6	46,2	2,17
17	Marmolada	16,4	60,1	85,8	54,1	1,85
	AVERAGE	10,9	54,4	116,7	60,5	1,75
		LSD 0.05=19,99		LSD 0.05=42,23		LSD 0.05= 1,22
		LSD 0.01=2,74		LSD 0.01=56,77		LSD 0.01= 1,64

The medium strong negative correlation between the F/LA and LA/P was determinate. Its values are increased with the increase in the NF/P and Frg/P. Fruit mass has an very small negative influence on F/LA (Table 5). The average ELA1kgF is 1,47 m². The values range from 1,05 m² at Honeoye to 2,04 m² at Elsanta. The F/LA and ELA1kgF are inversely proportional parameters. Physiological activity and productivity of the plants can be expressed accurately from a net-mass i.e. through the production of YSSM/LA (Walsh, 1992). The data for YSSM/LA are presented in Table 4. The average yield for investigation period is 60,5 g/m². The highest average for YSSM/LA for the study period is the standard Pocahontas (92,9 g/m²), which is statistically significantly higher than the average of

Onda, Favette, Eris, Chandler and Elsanta. It is followed by Honeoye (88,6 g/m²) and Idea (83,6 g/m²).

Table 5. Correlations between examination parameters

Corelations		Productivity parameters per plant					Prouctivity parameters per leaf area			
		LA/P	FM	NF/P	F/P	YSSM/P	YSSM/LA	F/LA	NF/LA	
Productivity parameters per leaf area	NF/LA	-0,355	-0,569	0,820	0,524	0,751	0,711	/	/	
	F/LA	-0,681	-0,260	0,627	0,504	0,740	/	/		
	YSSM/LA	-0,362	-0,353	0,504	0,552	/	/	/		
Effective leaf area parameters	ELA100NF	0,450	0,548	-0,781	-0,586	-0,684	-0,684	-0,723	-0,983	
	ELA1kgF	0,613	0,268	-0,580	-0,567	-0,698	-0,698	-0,979	-0,684	
	ELA100gYSSM	0,292	0,314	-0,569	-0,567	-0,970	-0,970	-0,692	-0,677	



Graph 1. Effective leaf area parameters of the examined varieties.

The average of Honey is statistically significantly higher than Favette, Eris, Chandler and Elsanta, as well as the average of Idea is higher than Elsanta. The values for this parameter are the lowest in 2012, and they are within a wide range of 0,8 g/m² in Camarosa, up to 35,8 g/m² in Idea. The highest values for this parameter were determined in 2014 (116,7 g/m²), range from 63,6 g/m² of Favette to 197,6 g/m² at Honeoye. According to annual data, high significant differences between the average values of this parameter for all investigated years were found. According to Благојевиќ (1998), the average YSSM/LA for 10 strawberry varieties ranges from 0,026 kg/m² at Sequoia, up to 0,046 kg/m² for Red Gauntlet. These are twice lower values compared with our research. Also, the YSSM/LA of Senga Sengana was in average of 0,026 kg/m² (ranged from 0,022 to 0,041 kg/m²), while it was 0,032 kg/m² for Belrubri (ranged from 0,022 to 0,041 kg/m²). The average ELA100gYSSM is 1,75 m². Its values range from 1,08 m² at Pocahontas to 2,43 m² at Elsanta. The YSSM/LA and ELA100gYSSM are inversely proportional parameters. There is a low negative correlation between the YSSM/LA with LA/P and with FM, medium strong positive correlation with a NF/P and with F/P and strong positive correlation with the YSSM/P. The analyzed productive parameters per leaf area (NF/LA, F/LA and YSSM/LA) are interdependent with a medium strong positive correlation (Table 5). The values for correlative coefficients are very similar (from 0,711 to 0,751). Analyzing the dependence of the productive parameters per leaf area on the effective leaf area parameters, it can be noted that there is an medium strong and very strong negative correlation dependence between them. Very strong correlation is expected given that the corresponding data for both groups of parameters are inversely proportional (Table 5). The effective leaf area parameters of the examined varieties are

presented in Graph.1 It is noticed that the varieties with lower ELA100NF values are also characterized by lower values for ELA1kgF and ELA100gYSSM, and vice versa.

Table 6. Correlations between effective leaf area parameters.

ELA100Ft	ELA1kgFt	0,691	ELA100Ft	ELA100gSSM	0,621	ELA1kgFt	ELA100gSSM	0,678
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Through the effective leaf area parameters lines tendencies (Graph 1), a medium strong positive correlation was established between all investigated parameters (Table 6).

Conclusions

The investigated parameters related to productivity per unit of leaf area are ranged from 54,0 at Miranda to 125,1 at Pocahontas for number of fruits, from 0,49 kg/m² in Favette and Elsanta, to 0,96 kg/m² in Honeoye for fruitage and from 41,2 g/m² in Elsanta, to 92,9 g/m² in Pocahontas for the yield of soluble solid matter in fruits. Leaf area of 1,37 m² is effective for 100 number of fruits production (from 0,8 m² at Pocahontas to 1,85 m² at Miranda), as well as 1,47 m² for 1kg of fruitage (from 1,05 m² at Honeoye to 2,04 m² at Elsanta) and 1,75 m² for production of 100 g soluble dry matter fruits-yield (from 1,05 m² at Honeoye to 2,04 m² at Elsanta). The productivity per leaf area of the investigated varieties is less dependent on the influence of LA/P and FM, but it is more dependent of the influence of NF/P, F/P and YSSM/P. A low to medium strong negative correlation between LA/P and FM with all productive parameters per leaf area was determined. While, medium strong to strong positive correlation between NF/P, F/P and YSSM/P with all productive parameters per leaf area was also determined. The values of correlation coefficient between productive parameters per plant and effective leaf area parameters are with similar strength, but they are with an opposite dependency in relation to the corresponding correlations with productive parameters per leaf area. Varieties characterized with higher assimilation activity, i.e. higher photosynthetic capacity, use a smaller leaf surface to produce unit yield. These varieties have lower values for effective leaf area parameters and have more productive leaf surface than the varieties characterized with higher values for these parameters. The varieties with the highest productivity per leaf area are Honeoye, Tethis and control variety Pocahontas. The smallest productivity is noticed at Elsanta, Favette and Miranda.

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