EFFECTS OF DIFFERENT PLANTING SYSTEMS ON SOME PRODUCTIVE AND QUALITY TRAITS OF RICE

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Abstract
The traditional planting system of rice in the Republic of Macedonia is wet direct seeding (hand broadcasting of seeds into pre-standing water in the fields). In this paper, the effects of different planting methods of rice (wet seeding as well as dry seeding by using seed drills) on productivity and quality of rice are presented. Field trials were set up at the Experimental Station of the Institute of Agriculture – Skopje, locality Mishjak, Kocani region, with two varieties (San Andrea and Onice) included. The following planting systems were explored: 1. wet direct seeding, with seeding rate of 250 kg seeds per ha (control); 2. dry seeding, 150 kg seeds per ha; 3. dry seeding, 200 kg seeds per ha. During the harvesting, the number of tillers per m^2, biological yield, paddy rice yield, head rice yield and white rice yield were analyzed. The highest number of tillers per m^2 (San Andrea 383.00 and Onice 731.33) and the highest average paddy yield (San Andrea 11,780.00 kg ha^{-1} and Onice 10,113.33 kg ha^{-1}) were achieved in the control. The highest biological yield in Onice (21,493.33 kg ha^{-1}) was found in the control, while in San Andrea (20,650.00 kg ha^{-1}) in the treatment dry seeding, 150 kg seeds per ha. For the head rice yield, the highest percentage was determined in the control (San Andrea, 54.57%) and in the treatment dry seeding, 150 kg seeds per ha (Onice, 66.72 %). Both varieties (San Andrea with 6,428.35 kg ha^{-1} and Onice with 6,143.83 kg ha^{-1}) reached the highest white rice yield in the control. In general, in the treatment dry seeding with 200 kg seeds per ha, the higher values of number of tillers per m^2, paddy yield and white rice yield were assessed, compared to the treatment dry seeding with 150 kg seeds per ha, in both varieties.

Keywords: variety, seeding rate, tillers, yield, paddy rice, head rice yield.

Introduction

The rice production region in Republic of Macedonia is located along the Bregalnica river, mainly in the eastern part of the country, with 90 % of the area located in the territory of Kochani Valley. Average production area of 4,926.36 ha, average paddy yield of 4,692.67 kg ha^{-1} and 23,145.12 t average yearly production of paddy for the 1939- 2014 period have been reported (Andreevska and Andov 2015). The area under rice varies depending on the quantity of accumulated water in the irrigation system used for rice production. The rice crop is grown in flooded paddy fields with constant water bed during the whole vegetation, from seeding to a month before harvest, when the water supply is suspended in order to drain and prepare the rice fields for harvest. During vegetation, the fields are drained only on specific occasions, such as during herbicide application and fertilization. So far, the standard (traditional) seeding method in our country is wet seeding by broadcast (hand dispersal in water bed with seed presoaked in water for 24 hours). This production operation is tedious because it is performed in water and needs large labor force, thus increasing the production costs. The broadcast is often done with poor quality, because of the lack of trained workers. This results in variable and inadequate crop density, leading to low yields. The aim of this study was to examine the possibility of mechanized seeding of the rice crop in dry conditions with a seeding machine. Two sowing rates (seeding material per area) were studied- 150 kg/ha and 200

kg/ha, compared to the traditional seeding way (broadcast in water bed) in two introduced Italian rice varieties (*San Andrea* and *Onice*.).

Material and methods

The field trial was set up in the experimental station of the Institute of Agriculture Skopje (Rice Research Unit in Kochani), in Mishjak area in Kochani. The following three variants were studied in two rice varieties (*San Andrea* and *Onice*) and two sowing rates:

1. mechanical seeding in dry conditions, sowing rate 150 kg ha^{-1};
2. mechanical seeding in dry conditions, sowing rate 200 kg ha^{-1} and
3. traditional seeding method, sowing rate 250 kg ha^{-1} (control).

Kochani Valley, where the trial site is located, belongs to the temperate continental-sub-mediterranean region of the Republic of Macedonia (Filipovski et al. 1996).

In Table 1, the chemical characteristics of the soils from the studied localities are presented. According to some previous surveys (Petkovski et al. 1997), the soil type in the locality where the field trial was set up is alluvial. The pH of the soil is slight acid in water solution (Filipovski, 1984) while in N KCl solution is acid (Ubavić et al. 2001). According to the used Al method, the easily available Phosphorus was at high level, while the easily available Potassium is at medium level (Džamić et al.1996).

Table 1. Chemical characteristics of the soil from the trial site

Depth (cm)	$CaCO_3$ %	pH		Easily available Phosphorus and Potassium (mg/100 g soil)	
		H_2O	N KCl	P_2O_5	K_2O
0 – 30	-	5.6	4.7	18.87	19.80

At the end of vegetation, during harvest, average samples (rice sheaf from 1 m^2 crop area) were taken in each replication, on the basis of which the number of productive tillers/ m^2, biological yield (straw + paddy), and paddy rice yield were determined. The hygroscopic moisture of paddy rice (in time of harvest) and the milling fractions were determined under the laboratory conditions. Milling fractions (head rice yield, brokens, total milled rice, chalky grains, rice bran and hull) were assessed by milling average sample of 100 g paddy of each replication on laboratory milling machine during 1.40 min. The white rice yield was determined on the basis of the obtained paddy rice and head rice yield data. The average value for each sub-variant was calculated from the data of the replications. Results were analyzed by two-way ANOVA and LSD test at 0.05 and 0.01 probability level.

Results and discussion

The results for the number of productive tillers m^{-2} are shown in Table 2. There was significant difference in number of tillers between the three seeding variants in both varieties. The highest average number of productive tillers was achieved in the control-traditional seeding method (*San Andrea*-383.00*, Onice*-731.33). This is understandable as the control had the highest seeding rate of 250 kg ha^{-1}. In the variants with mechanical seeding, the results were lower. Accordingly, in variant No. 1 where the lowest rate was applied (150 kg ha^{-1}) the lowest number of productive tillers m^{-2} was produced (*San Andrea*-270.33, *Onice*-395.50). Aside from the seeding method, the results significantly differed on varietal level, as *Onice* produced significantly higher number of tillers compared to *San Andrea*. The highest average biological yield in *Onice* (straw + paddy) was achieved in the control (21,493.33 kg ha^{-1}, Table 3), while the lowest in variant No. 1 (17,225.00 kg ha^{-1}). Statistically significant differences were found between variant No. 1 and the control ($P \leq 0.01$) and variant No. 1 and variant No. 2 ($P \leq 0.05$). The highest average biological yield in *San Andrea* was determined in variant No 1. (20,650.00 kg ha^{-1}**)**, while the lowest in variant No. 2 (18,545.00 kg ha^{-1}**)**. Significant difference was found only between variant No.1 and No. 2 ($P \leq 0.05$).

Table 2. Number of productive tillers m^{-2}

Variant	Variety		Average
	San Andrea	*Onice*	
No. 1 (150 kg ha^{-1})	270.33	395.50	332.92
No. 2 (200 kg ha^{-1})	329.00	463.17	396.09
Control	383.00	731.33	557.17
Average	327.44	530.00	428.72

Statistical analysis					
Source	F test sign.	LSD test- pairwise comparisons on varietal level		*San Andrea*	*Onice*
Seeding	P ≤0.01	44.97 ($LSD_{0.05}$) 63.96 ($LSD_{0.01}$)	Var. No. 1 Control	-112.67 **	- 335.83**
			Var. No. 2	-58.67*	-67.67**
Variety	P ≤0.01		Var. No. 2 Control	-54.00*	- 268.16**
			Var. No. 1	58.67*	67.67**
Seeding x variety	P ≤0.01		Control Var. No. 1	112.67**	335.83**
			Var. No. 2	54.00*	268.16**
		* significant difference at 0.05 level of probability ** sign. difference at 0.01 level of probability			

Table 3. Biological yield (kg ha^{-1})

Variant	Variety		Average
	San Andrea	*Onice*	
No. 1 (150 kg ha^{-1})	20,650.00	17,225.00	18,937.5
No. 2 (200 kg ha^{-1})	18,545.00	19,805.00	19,175.00
Control	20,300.00	21,493.33	20,300.00
Average	19,831.67	18,515.00	19,173.33

Statistical analysis					
Source	F test sign.	LSD test- pairwise comparisons on varietal level		*San Andrea*	*Onice*
Seeding	P ≤0.05	2,040.49 ($LSD_{0.05}$) 2,902.30 ($LSD_{0.01}$)	Var. No. 1 Control	350.00 ns	- 4,268.33**
			Var. No. 2	2,105.00*	- 2,580.00 *
Variety	P >0.05 (n.s.)		Var. No. 2 Control	-1,755.00 ns	- 1,688.33 ns
			Var. No. 1	-2,105.00*	2,580.00*
Seeding x variety	P ≤0.01		Control Var. No. 1	- 350,00 ns	4,268.33**
			Var. No. 2	1,755.00 ns	1,688.33 ns
		* significant difference at 0.05 level of probability; ** significant difference at 0.01 level of probability; ns- not significant;			

The results for the paddy rice yield at 14 % grain moisture are presented in Table 4. Significant difference in results on both seeding and varietal level were obtained. The highest average was obtained in the control (traditional seeding way)- 10,946.67 kg ha^{-1}, (*San Andrea*- 11,780.00 kg ha^{-1}, *Onice*-10,113.33 kg ha^{-1}). The control had the highest seeding rate of 250 kg ha^{-1} and the highest crop density. In variant No. 2- mechanical seeding with 200 kg ha^{-1} rate the average yield dropped for 1,526.67 kg ha^{-1}. In variant No. 1, lowering the rate to 150 kg ha^{-1} resulted in additional yield drop of 375.00 kg ha^{-1} and a total of 1,901.67 kg ha^{-1} compared to the control. This variant had the lowest yield- 9,045.00 kg ha^{-1} average (*San Andrea*-9,385.00 kg ha^{-1}, *Onice*-8,705.00 kg ha^{-1}). Significant difference was found between the control and variant No.1 ($P \leq 0.05$). On varietal level, *San Andrea* gave higher average paddy yield (10,313.33 kg ha^{-1}) compared to *Onice* (9,301.11 kg ha^{-1}) at 0.05 level of probability ($P \leq 0.05$).

Table 4. Paddy rice yield at 14 % grain moisture (kg ha^{-1})

Variant	Variety		Average
	San Andrea	*Onice*	
No. 1 (150 kg ha^{-1})	9,385.00	8,705.00	9,045.00
No. 2 (200 kg ha^{-1})	9,755.00	9,085.00	9,420.00
Control	11,780.00	10,113.33	10,946.67
Average	10,313.33	9,301.11	9,807.22

Statistical analysis				
Source	F test sign.	LSD test- pairwise comparisons		
Seeding	P ≤ 0.01	1,608.76 ($LSD_{0.05}$) 2,288.22 ($LSD_{0.01}$)	Var. No. 1 Control Var. No. 2	-1,901,67 * -375.00
Variety	P ≤0.05		Var. No. 2 Control Var. No. 1	-1,526,67 375.00
Seeding x variety	P>0.05 n.s.		Control Var. No. 1 Var. No. 2	1,901,67* 1,526.67
		* significant difference at 0.05 level of probability; ** sign. difference at 0.01 level of probability; ns- non significant;		

The results for the milling fractions, including the head rice yield are shown in Table 5 and Table 6. In *Onice,* the highest head rice yield was obtained in variant No. 1 (66.72%). Similar results were found in variant No. 2 (66.67 %). Both variants with mechanical seeding resulted in statistically higher head rice yield compared to the control (P ≤ 0.01). The lowest value was determined in the standard seeding variant (the control)- 60.75 %. In *San Andrea*, the mechanical seeding resulted in lower head rice yield compared to the control, where the highest value was obtained (54.57 %). The lowest head rice yield was found in variant No. 1 (47.87 %). Significant differences were obtained between the control and variant No. 1 (P ≤ 0.01) and variant No. 1 and variant No. 2 (P ≤ 0.05). *Onice* variety showed higher head rice yield (64.71 % average) compared to San *Andrea* (51.43%), regardless of the seeding technique, with significant difference at both level of probability (0.05 and 0.01). The seeding significantly affected the white rice yield. The highest white rice yield was determined in the control (6,286.09 kg ha^{-1} average, *San Andrea*- 6428.35 kg ha^{-1} and *Onice*- 6,143.83 kg ha^{-1}). The seeding variant No. 1 and No.2 where lower seeding rate was applied produced lower white rice yield. The lowest yield was obtained in variant No.1 (5,150.29 kg ha^{-1} average, *San Andrea*-4,492.60 kg ha^{-1}, *Onice*-5,807.98 kg ha^{-1}, Table 7). Significant differences were found between the control and variant No. 1 (P ≤ 0.05). On varietal level, *Onice* variety produced significantly higher (P ≤ 0.05) white rice yield (6,002.93 kg ha^{-1}) compared to *San Andrea* (5,326.31 kg ha^{-1}). In the rice producing conditions of Republic of Macedonia, the effect of sowing method was previously studied by Andov et al. (2011) on variety *San Andrea*. During 2009 and 2010, three sowing methods were investigated: manual seed broadcasting onto watered soil (standard method of sowing), manual seed broadcasting onto dry soil surface and sowing with seed drills on dry soil. The highest average number of tillers m^{-2} (428), the highest average biological yield (16,860.00 kg ha^{-1}), and paddy rice yield (7,612.00 kg ha^{-1}) were obtained when sowing by seeding machine on dry soil. According to Basnayake et al. 2006, the increase in seeding rate from 50 kg ha^{-1} to 200 kg ha^{-1} in conditions when the rice crop was affected by weed increased the grain yield in both broadcast and row seeded rice for 26% and 29% respectively. The reason for the increase in yield was the increased plant density, which resulted in decline in weed competition thereby contributing to the higher grain yield. Similar results were reported by Ahmed at al. 2014, who studied the effect of seeding rates (20, 40, 60, 80 and 100 kg ha^{-1}) and weed infestation (partially-weedy and weed-free conditions) in dry seeded rice. Under weed-free conditions, higher crop yields were obtained at the seeding rate of 40 kg ha^{-1} and thereafter, yield decreased slightly beyond 40 kg seed ha^{-1}. Under partially-weedy conditions the increase in seeding rate from 20 to 100 kg/ha resulted in increased yield by 30 to 33%, while weed biomass decreased by 41–60% at 35 days after sowing and 54–56% at crop anthesis. The authors

concluded that increasing seeding rates in dry seeded rice can suppress weed growth and reduce grain yield losses from weed competition.

Table 5. Milling fractions (whole grains, broken grains, total milled rice, chalky grains, bran and hulls) obtained in the studied seeding variants and varieties [%]

Variety	Whole grains %	Broken grains %	Total milled rice %	chalky grains %	Bran %	Hulls %
150 kg ha^{-1}						
San Andrea	47.87	15.30	63.17	0.33	10.70	25.80
Onice	66.72	4.00	70.72	0.98	6.57	21.73
200 kg ha^{-1}						
San Andrea	51.85	12.58	64.43	0.27	10.50	24.80
Onice	66,67	3.90	70.57	1,04	6.57	21.82
Control						
San Andrea	54.57	10.80	65.37	0,63	10.50	23.50
Onice	60.75	10.00	70.75	7.00	0.35	21.90

Table 6. The effect of the method and the seeding rate on head rice yield in the examined rice varieties [%]

Variant	Variety		Average
	San Andrea	*Onice*	
No. 1 (150 kg ha^{-1})	47.87	66.72	**57.30**
No. 2 (200 kg ha^{-1})	51.85	66.67	**59.26**
Control	54.57	60.75	**57.66**
Average	**51.43**	**64.71**	**58.07**

Statistical analysis

Source	F test sign.	LSD test- pairwise comparisons on varietal level		*San Andrea*	*Onice*
Seeding	P > 0.05 ns	3.41 ($LSD_{0.05}$) 4.86 ($LSD_{0.01}$)	Var. No. 1 Control Var. No. 2	-6.70 ** -3.98*	5.97** 0.05ns
Variety	P ≤ 0.01		Var. No. 2 Control Var. No. 1	-2.72 ns 3.98*	5.92** -0.05 ns
Seeding x variety	P ≤ 0.01		Control Var. No. 1 Var. No. 2	6.70** 2.72 ns	-5.97** -5.92**
		* significant difference at 0.05 level of probability; ** sign. difference at 0.01 level of probability; ns- non significant;			

Table 7. White rice yield (kg ha^{-1})

Variant	Variety		Average
	San Andrea	*Onice*	
No. 1 (150 kg ha^{-1})	4,492.60	5,807.98	5,150.29
No. 2 (200 kg ha^{-1})	5,057.97	6,056.97	5,557.47
Control	6,428.35	6,143.83	6,286.09
Average	5,326.31	6,002.93	5,664.62

Statistical analysis

Source	F test sign.	LSD test- pairwise comparisons		
Seeding	P ≤ 0.05	985.98 ($LSD_{0.05}$) 1402.41 ($LSD_{0.01}$)	Var. No. 1 Control Var. No. 2	-1135.80 * - 407.18 ns
Variety	P ≤ 0.05		Var. No. 2 Control Var. No. 1	-728.62 ns 407.18 ns
Seeding x variety	P > 0.05 not sign.		Control Var. No. 1 Var. No. 2	1135.80* 728.62 ns
		* significant difference at 0.05 level of probability; ** sign. difference at 0.01 level of probability; ns- non significant;		

Conclusions

The seeding methods significantly affected the examined productive parameters in rice. The control, where the standard seeding method was applied (hand broadcasting in water bed and highest seeding rate of 250 kg ha^{-1}) resulted in the highest crop density, the highest paddy rice yield and the highest white rice yield. The lowest values were obtained in the mechanical seeding variant No.1, where the lowest seeding rate of 150 kg ha^{-1} was applied. On the basis of the obtained results it may be argued that the difference in results stem from the different seeding rate, rather than the method used for seeding (mechanical dry seeding versus traditional seeding in water bed).

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