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Original scientific paper

EFFECT OF NATURAL AMORPHOUS SILICA - MULTIMINERAL FERTILIZER FLORAL MICROSIL ON SOME MORPHOLOGICAL AND YIELD COMPONENTS IN RICE (*ORYZA SATIVA* L.)

Trajche Dimitrovski[1*], Danica Andreevska[1], Dobre Andov[1], Emilija Simeonovska[1], Ljube Lozanovski[2]

*e-mail: dimitrovskitrajche@gmail.com

[1]Institute of Agriculture, University Ss. Cyril and Methodius, Skopje, Republic of Macedonia
[2]Učilišten Centar "Krste P. Misirkov", Demir Hisar, Republic of Macedonia

The effect of natural multimineral fertilizer Floral microsil (FM) (50 % bio-available amorphous SiO_2 + macronutrients and trace elements) was investigated on some morphological and productive properties in rice at the environmental conditions of Republic of Macedonia, on cultivar San Andrea. Two treatments were studied: control (standard fertilization) with 450 kg/ha complex mineral fertilizers NPK (16:16:16) as basic fertilizer + two splits with Urea 46 % N (200 + 100 kg/ha), and FM treatment: 20 kg/ha FM before sowing, seed treatment with 20 kg/ha FM + three splits of FM + Urea (30 + 100; 20 + 60 and 20 + 60 kg/ha respectively). The field trials were set up in Zade design during 2014 and 2015. Results were analyzed with ANOVA and LSD test.

The FM treatment significantly affected plant and stem height (2014), producing shorter plant (103.02 cm) and stem (87.47 cm) compared to the control (111.81 cm and 95.91 cm). Significantly lower biological (20958.34 kg/ha) and straw yield (10769.67 kg/ha) were determined in the FM treatment compared to the control (24852.00 kg/ha and 15101.34 kg/ha). The FM treatment significantly increased the 1000 grains weight (39.97 g against 38.28 g control average). The paddy and white rice yield (9839.99 kg/ha; 5856.75 kg/ha) in FM treatment were statistically on par with the control (9368.60 kg/ha and 5907.91 kg/ha), as well as the panicle length, number of productive and non-productive tillers per m^2, the head rice yield (whole grains and broken grains) and the hectoliter weight.

The application of FM significantly increased the nitrogen use efficiency estimated thru the partial factor productivity (97.24 kg paddy rice/kg N and 57.88 kg white rice/kg N), as compared to the control average (44.61 kg paddy rice/kg N and 28.14 kg white rice/kg N). Therefore, paddy and white rice yield statistically on par with the standard fertilization were produced with a lower amount of applied nitrogen fertilizer. These findings are of ecological significance for the rice production in the Republic of Macedonia.

Key words: fertilizer; morphological; partial factor productivity; productive; rice; silica

INTRODUCTION

High and stable yield along with good crop quality is of main importance for farmers in plant agriculture, including rice production. The implementation of adequate fertilization that allows balanced crop nutrition with the required nutrients is essential in achieving high yield and quality products in rice production. The optimal nutritional balance in rice for production of 1 t of paddy is achieved by uptake of around 14.7 kg N, 2.6 kg P and 14.5 kg K [1], or 14.8 kg N, 3.8 kg P and 15.0 kg K [2].

The improvement of rice production technology in the Republic of Macedonia is a continuous process. As fertilization is an important part of rice production, over the years different types of fertilizers and fertilization techniques have been investigated. This process is ongoing, depending on the availability of new fertilizers. A number of studies have shown that basic rice fertilization before sowing with nitrogen or NPK fertilizers is necessary for obtaining good yield results [3–7]. The study of foliar application with NPK fertilizers with trace elements - Kristalon™ Special [8] and Lactofol O [9]

[#]Dedicated to academician Gjorgji Filipovski on the occasion of his 100th birthday showed a positive effect of this type of fertilizers on rice yield. Calcium-based foliar fertilizers Megagreen and Herbagreen generally showed no significant effect in rice production [10, 11].

The standard rice production technology in the Republic of Macedonia includes basic crop fertilization and supplemental fertilization. The largest amount of the fertilizer in the field (around 2/3 of N, and completely P and K) is applied with the basic fertilization prior to seeding, usually with application of 400 to 600 kg/ha complex mineral fertilizers (NPK: 15-15-15, 16-16-16, 17-17-17, 20-13-15). The rest amount of N is applied with the supplemental fertilization (second split application) during vegetation in the tillering stage by using 150 to 250 kg/ha nitrogen fertilizers such as urea, ammonium nitrate or CAN [12, 13]. Fertilizers containing other nutrients, including silica and other trace elements are not used, as N, P, K, S and Zn are the nutrients generally considered critical for the rice crop [14–18].

The aim of this study was to evaluate the effect of Floral microsil fertilizer (50 % SiO_2 + macronutrients and trace elements) on some important morphological and yield properties in rice. Although silicon is not considered an essential element for rice nutrition, it has a positive effect on s the rice plant as it supports healthy growth and development [1, 19–21]. A number of studies point to the positive effect of silica fertilizers in rice production, such as resistance to lodging, increased uptake of nutrients (N, P, K), increased yield components, yield and resistance to diseases [22–31].

Other elements present in Floral microsil, such as calcium, magnesium, iron, boron, copper and manganese are not considered critical for the growth and yield of the rice crop, as their deficit in irrigated paddy fields is generally considered a rare case [32–37]. The essential elements for rice present in the fertilizer are potassium, sulfur and phosphorus.

The results obtained from this study are important in understanding the effect of silica from silica-based fertilizers on the rice crop in the environmental conditions of the Republic of Macedonia.

MATERIAL AND METHOD

Material

Floral microsil (FM) is a natural multimineral fertilizer. By chemical composition, FM contains: silica (Si) – the main component of the fertilizer, as amorphous SiO_2 50 %, aluminum (Al) 18.9 %, potassium (K) 7.8 %, magnesium (Mg) 4.2 %, calcium (Ca) 3.6 %, iron (Fe) 3.2 %, sulfur (S) 2 %, sodium (Na) 1.2 %, titanium (Ti) 0.5 %, phosphorus (P) 0.1 %, strontium (Sr) 0.1 %, barium (Ba) 969 ppm, fluorine (F) 500 ppm, copper (Cu) 327 ppm, vanadium (V) 156 ppm, zirconium (Zr) 144 ppm, manganese (Mn) 119 ppm, zinc (Zn) 78 ppm, cerium (Ce) 68 ppm, rubidium (Rb) 42 ppm, chlorine (Cl) 40 ppm, nickel (Ni) 30 ppm, gallium Ga 17 ppm, lithium (Li) 17 ppm, boron (B) 15 ppm and molybdenum (Mo) 13 ppm. In water, the amorphous silica forms a colloid solution of monosilicic acid H_4SiO_4 or $Si(OH)_4$ which is bioavailable to the plant roots. A concentration of 1400 ppm monosilicic acid is present in 2.5 g of fertilizer dissolved in 1 l water. This fertilizer is not available on the market, as it is still in the phase of evaluation. Cultivar San Andrea was used in this experiment.

Method

The field trials were set up in Zade design (trial with plot arrangement in long stripes developed by Adolf Zade) during 2014 and 2015, under typical rice producing conditions of the Republic of Macedonia. Two treatments of Floral microsil (FM) treatment and control were studied. The size of each application was 1000 m^2. The standard rice production technology was applied in both treatments. The only difference between the treatments was the fertilization. The overview of the types and quantities of applied fertilizers in each treatments and time of application, along with the quantity of applied nutrients from fertilizers is shown in Table 1.

At the end of vegetation, prior to harvest, the plant height, stem height and panicle length were measured in field conditions on a total of 30 plants in each treatment (10 random plants per replication). Prior to harvest, average sample (bundle of whole plants – above ground biomass from 1 m^2 crop area) was taken from each replication in order to assess the number of productive and non-productive tillers (sterile tillers, unripe panicles and weedy rice panicles) per m^2, the biological yield (straw + paddy), straw yield and paddy rice yield. In laboratory conditions were determined the hygroscopic grain moisture at harvest, the 1000 grains weight and hectoliter weight of paddy rice, and the head rice yield. In order to determine the head rice yield, paddy rice samples of 100 g from each replication were milled on a laboratory milling machine during 1.40 min. The white rice yield was estimated on the basis of obtained paddy rice yield and head rice results. Results were analyzed by ANOVA and LSD test at 0.05 and 0.01 levels of probability.

The partial factor productivity from applied nitrogen was calculated according to Cassman *et al.* [38], as a ratio of the grain yield to the applied N:

PFP = Y/N_r, where Y is grain yield (kg/ha) and N_r is the amount of applied N (kg /ha). Partial factor productivity was calculated for both paddy and white rice yield per 1 kg nitrogen from applied fertilizers.

The effect of FM fertilizer was studied on Italian rice cultivar San Andrea, which was at the period of the trial the most prevalent variety in cultivation in the Republic of Macedonia. This cultivar is a line from the cultivar Rizzoto, with a plant height of 107 to 116 cm, vegetation length of 150 to 160 day, head rice yield of 61 to 66.5 %, 1000 paddy grains weight of 35 to 37 g, and paddy yield of 6480 to 8710 kg/ha [39, 40].

Table 1. Quantities and time of application of the used fertilizers in the study

Control (standard rice production technology)		
Time of application	Fertilizer type and quantity (kg/ha)	Nutrients kg/ha
Basic: before sowing	NPK 16:16:16 (450)	72 (N); 72 (P); 72 (K)
1st split: active tillering	Urea 46 N (200)	92 (N)
2nd split: end of tillering	Urea 46 N (100)	46 (N)
Total quantity of applied fertilizers: 750 kg/ha (450 NPK + 300 Urea 46 N) Total active nutrients from fertilizers: 210 (N) + 72 (P) + 72 (K)		
Floral treatment		
Time of application	Fertilizer type and quantity kg/ha	Nutrients kg/ha
Before sawing	FM (20)	10 (Si); 1.56 (K); 0.4 (S); 0.02 (P)+ trace elements
Seed treatment	FM (20)	10 (Si); 1.56 (K); 0.4 (S); 0.02 (P)+ trace elements
1st split: early tillering	FM + Urea 46 N (30 + 100)	15 (Si); 2.34 (K); 0.6 (S); 0.03 (P); trace elements + 46 (N)
2nd split: active tillering	FM + Urea 46 N (20 + 60)	10 (Si); 1.56 (K); 0.4 (S); 0.02 (P); trace elements + 27.6 (N)
3rd split: end of tillering	FM + Urea 46 N (20 + 60)	10 (Si); 1.56 (K); 0.4 (S); 0.02 (P); trace elements + 27.6 (N)
Total quantity of applied fertilizers: 330 kg/ha (220 Urea 46 N + 110 FM) Total active nutrients from fertilizers: 101.2 (N) + 55 (Si) + 8.58 (K)+ 2.2 (S)+ 0.11 (P) + trace elements		

Weather and soil conditions

The field trials were set up in the Rice experimental station of the Institute of Agriculture Skopje, in the Sredorek area of Kochani. The trial site is located within the main rice-producing region that belongs to the temperate continental submediterranean region of the Republic of Macedonia [41] and represents typical rice producing conditions of the country. The temperatures and precipitation sums during rice vegetation in the trial years 2014 and 2015, along with long-term average data for the 1998–2013 period are presented in Table 2 (data obtained from the meteorological station at the Institute of Agriculture Skopje – Rice research station in Kochani).

From previous surveys [42] the soil in the Sredorek area where the field trial was set up is classified as alluvial. pH (reaction) of the soil solution has been determined with a glass electrode in water suspension and in 1MKCI suspension [43]. The content of $CaCO_3$ was determined using Scheiblers calcimeter [43]. Easily available forms of P_2O_5 and K_2O were determinate by the Al method [44]. The major soil characteristics are given in Table 3.

Table 2. Average temperatures and precipitation sums for 2014 and 2015, along with 1998 – 2013 averages

	Months							Average	
	IV	V	VI	VII	VIII	IX	X	Yearly average	During vegetation
Year	Mean monthly temperatures (ºC)								
2014	12.4	16.8	20.8	23.2	23.8	18.3	13.8	13.8	18.4
2015	11.4	18.9	21.0	26.3	25.5	21.6	13.9	13.9	19.8
AVG 1998- 2013	13.9	18.7	22.8	25.5	25.2	20.0	14.8	14.1	20.1
	Mean monthly maximum temperature (ºC)								
2014	18.0	23.0	28.1	30.9	31.8	25.0	20.7	20.1	25.4
2015	18.3	25.9	28.2	34.1	33.2	28.3	20.2	20.4	26.9
AVG 1998- 2013	19.4	24.1	28.7	31.6	31.6	26.3	20.4	19.5	26.0
	Mean monthly minimum temperature (ºC)								
2014	7.4	10.8	14.0	16.5	16.6	13.4	8.7	8.5	12.5
2015	5.2	12.5	14.1	17.9	17.5	14.8	9.3	7.8	13.0
AVG 1998- 2013	5.8	10.3	13.4	15.2	15.2	10.8	6.8	6.4	11.1
	Monthly precipitation (mm)							Precipitation sum (mm)	
2014	121.0	92.0	116.0	65.0	31.0	89.0	37.0	794.0	551.0
2015	31.0	32.0	62.0	2.0	32.0	59.0	127.0	605.0	345.0
AVG 1998- 2013	39.7	49.1	59.3	27.9	33.0	41.8	58.5	493.9	309.3

Table 3. Some chemical characteristics of the soil in Sredorek area

Soil depth (cm)	$CaCO_3$ (%)	PH		Easy available mg/100 g soil	
		H_2O	N KCl	P_2O_5	K_2O
0 – 20	0	5.60	4.70	23.61	13.30
20 – 40	0	6.00	5.30	7.48	12.95

RESULTS AND DISCUSSION

The results obtained in this study are presented in Tables 4 to 11. FM treatment resulted in lower average plant height (103.02 cm) and stem height (87.47 cm) as compared to the control (Table 4). Similar results were reported by Hekimhan *et al.* [28]. Statistically significant differences were obtained in 2014. On the other hand, the differences in 2015 were non-significant. In the control, the cultivar San Andrea had an average plant height of 111.81 cm and an average stem height of 95.91 cm. This plant height value corresponds to the range of 107 cm to 116 cm reported for this cultivar in the country of origin [39, 40].

Shorter panicle in FM treatment was observed in both years, with significant differences.

The lower values for the plant height, stem height and panicle length in the FM treatment can be attributed to the lower nitrogen rate as compared to the control. Nitrogen level plays an important role in increasing rice plant height [45]. According to Dastan *et al.* [25], while plant height, stem length and panicle length increased by increasing the nitrogen fertilizer, their values decreased by silicon application.

While lodging occurred in the control in both years, resistance to lodging was evident in the FM treatment, as lodging was not observed. These resultsare in accordance with the reported effect of silica on rice resistance to lodging [31]. Silicon is distributed to tissues involved in maintaining rigidity of the plant to prevent lodging, specifically the leaf sheath, the outermost part of the stem and the leaf blade midrib [23]. According to Dastan *et al.* [25], the silicon application increased resistance to lodging because of a decrease in plant height, stem, panicle, 3rd and 4th internodes length, which decreased the bending moment of the 3rd internode. The effect of silica on rice stalk rigidity was greater at lower doses of applied nitrogen [22].

During the tillering stage (monitored at early and active tillering), the rice plants are grown in the FM treatment developed longer roots compared to control, as evident in Figures 1 and 2. These observations are in accordance with Jawahar *et al.* [46], who reported that silica fertilizer (Silixol) significantly increased the root length and volume in rice. Similarly, Adhikari *et al.* [47] reported enhanced length, volume and dry matter weight of root in rice seedlings with the application of silica nanoparticles.

Table 4. Effect of Floral microsil fertilizer on plant height, stem height and panicle length (cm) in rice cultivar San Andrea

Plant height										
	Floral	SD	CV	min	max	Control	SD	CV	min	max
2014	103.97*	6.16	5.94	94	115	118.85	8.57	7.21	105	133
2015	102.07	5.33	5.22	92	111	104.77	4.12	3.93	96	111
Average	**103.02**					**111.81**				
* the result for the Floral microsil treatment significantly differs from the control ($p < 0.05$) LSD (2014): 9.26 ($\alpha_{0.05}$), 21.37 ($\alpha_{0.01}$); LSD (2015): 10.42 ($\alpha_{0.05}$), 24.03 ($\alpha_{0.01}$)										
Stem height										
	Floral	SD	CV	min	max	Control	SD	CV	min	max
2014	87.67*	5.96	6.80	78	99	102.52	8.92	8.70	88	118
2015	87.27	4.83	5.53	79	96	89.30	4.00	4.48	81	97
Average	**87.47**					**95.91**				
* the result for the Floral microsil treatment significantly differs from the control ($p < 0.05$) LSD (2014): 9.81 ($\alpha_{0.05}$), 22.62 ($\alpha_{0.01}$); LSD (2015): 9.82 ($\alpha_{0.05}$), 24.64 ($\alpha_{0.01}$)										
Panicle length										
	Floral	SD	CV	min	max	Control	SD	CV	min	max
2014	16.30	1.65	10.21	13	21	16.33	2.31	14.15	12	23
2015	14.80*	1.32	8.92	13	18	15.47	1.37	8.86	13	18
Average	**15.55**					**15.90**				
* the result for the Floral microsil treatment significantly differs from the control ($p < 0.05$) LSD (2014): 1.32 ($\alpha_{0.05}$), 3.03 ($\alpha_{0.01}$); LSD (2015): 0.63 ($\alpha_{0.05}$), 1.44 ($\alpha_{0.01}$)										

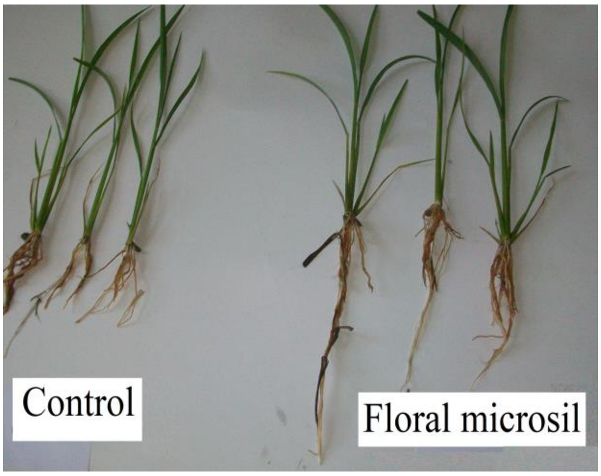

Figure 1. Root development in rice at early tillering stage: Control- plants grown with standard fertilization; Floral microsil- plants grown with Floral microsil fertilizer

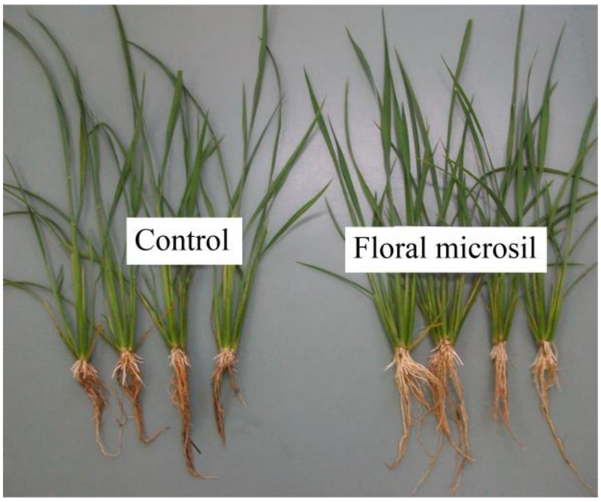

Figure 2. Root development in rice at active tillering: Control- plants grown with standard fertilization; Floral microsil- plants grown with Floral microsil fertilizer

Table 5 presents the results for the number of productive and non-productive tillers per m^2. In the FM treatment, a higher average number of productive and non-productive tillers per m^2 (412.50 and 4.00 accordingly) were produced as compared to the control (381.50 and 1.17 respectively). The differences were non-significant.

Table 5. Effect on Floral microsil fertilizer on the number of productive and non-productive tillers per m^2 in rice cultivar San Andrea

	No. productive tillers/m^2			**No. non-productive tillers/ m^2**		
	2014	2015	**Average**	2014	2015	**Average**
Floral	420.33	404.66	**412.50**	6.33	1.66	**4.00**
SD	111.38	94.55		4.16	1.91	
Control	430.33	332.66	**381.50**	0.33	2.00	**1.17**
SD	63.34	42.52		0.58	4.00	
Ftest	$p > 0.05$	$p > 0.05$		$p > 0.05$	$p > 0.05$	
$LSD_{0.05}$	224.46	215.16		8.96	8.37	
$LSD_{0.01}$	517.72	394.96		20.66	15.36	

The biological yield (straw + paddy), straw yield and paddy rice yield at 14 % grain moisture are presented in Table 6. The FM treatment resulted in significant differences in the biological and straw yield, while the paddy rice yield was statistically on par with the control values.

In the FM treatment, significantly lower biological and straw yield was produced in both years, with an average of 20958.34 kg/ha and 10769.67 kg/ha accordingly, as compared to the control (biological yield- 24852.00 kg/ha; straw yield 15101.34 kg/ha). The average paddy rice yield at 14 % grain moisture was higher in the FM treatment (9839.99 kg/ha) as compared to the control (9368.60 kg/ha). The differences were non-significant.

The decrease in biological yield in the FM treatment in both years was mainly due to the decrease in straw yield as compared to the control. The significantly lower straw yield can be attributed to the lower N rate applied. According to Pramanik and Bera [45], nitrogen application increased the straw yield significantly with an increase in levels up to 200 kg/ha.

The average hygroscopic grain moisture in paddy rice at harvest ranged from 17.43 % in the FM treatment to 17.92 % in the control (Table 7). Significant differences were found in 2015.

Table 6. Effect of Floral fertilizer on the biological yield (straw + paddy), straw yield and paddy rice yield at 14 % grain moisture in rice cultivar San Andrea (kg/ha)

	Floral	**SD**	**Control**	**SD**	**F test**	**$LSD_{0.05}$**	**$LSD_{0.01}$**
			Biological yield				
2014	20016.67	1164.40	23116.67	236.29	$p \le 0.05$	2602.63	6003.05
2015	21900.00	1195.83	26587.33	1553.16	$p \le 0.05$	2932.49	5382.99
Average	**20958.34**		**24852.00**				
			Straw yield				
2014	9466.67	557.52	12650.00	259.81	$p \le 0.05$	1868.77	4310.37
2015	12072.67	1384.59	17552.67	1437.99	$p \le 0.01$	1084.76	1991.23
Average	**10769.67**		**15101.34**				
			Paddy rice yield at 14 % grain moisture				
2014	10152.30	721.61	10054.87	275.41	$p>0.05$	1961.43	4524.09
2015	9527.67	837.17	8682.33	603.61	$p>0.05$	2263.14	4154.30
Average	**9839.99**		**9368.60**				

Table 7. Effect of Floral fertilizer on hygroscopic grain moisture at harvest in rice cultivar San Andrea (%)

	Floral	**SD**	**Control**	**SD**	**Ftest**	**$LSD_{0.05}$**	**$LSD_{0.01}$**
2014	17.80	0.26	17.93	0.06	$p>0.05$	0.80	1.84
2015	17.05	0.10	17.90	0.08	$p \le 0.01$	0.21	0.38
Average	**17.43**		**17.92**				

The application of FM had a significant effect on the 1000 grains weight, but not on the hectoliter weight (Table 8). Significantly higher 1000 grains weight was obtained in both years in Floral with an average value of 39.97 g, as compared to the control (38.28 g). Significantly increased 1000 grains weight due to silica application was also reported by Hekimhan *et al.* [28], Pati *et al.* [29] and Cuong *et al.* [30].

Significant differences were not determined for the hectoliter weight, which ranged from 51.69 kg/hl in FM to 51.35 kg/hl in the control.

Table 8. Effect of Floral microsil fertilizer on 1000 grains weight (g) and hectolitre mass of paddy (kg/hl) in rice cultivar San Andrea

	Floral	SD	Control	SD	Ftest	$LSD_{0.05}$	$LSD_{0.01}$
			1000 grains weight				
2014	39.20	1.44	37.33	2.00	$p \leq 0.05$	1.60	3.68
2015	40.73	0.96	39.23	0.50	$p \leq 0.05$	0.92	1.69
Average	**39.97**		**38.28**				
			Hectolitre mass				
2014	51.50	0.50	51.33	0.29	$p > 0.05$	0.72	1.65
2015	51.87	0.48	51.37	0.25	$p > 0.05$	0.65	1.19
Average	**51.69**		**51.35**				

The head rice yield in the FM treatment was statistically on par with the control values. Insignificantly higher values were found in the control for the whole grains (Table 9). The FM had average values for the total milled rice, whole grains and broken grains of 69.32 %, 59.80 % and 9.52 % accordingly as compared to 70.18 %, 63.53 % and 6.65 % in the control.

The head rice yield (whole grains) in both the control and the FM treatment was higher in 2015 as compared to 2014. Accordingly, the broken grains percentage was higher in 2014. This variation of the head rice yield can be explained by the environmental factors that prevailed during the study, as 2014 was a cooler and wetter year during rice vegetation and grain filling period compared to 2015.

Table 9. Effect of fertilizer Floral microsil on the head rice yield in cultivar San Andrea (%)

	Floral	SD	Control	SD	F test	$LSD_{0.05}$	$LSD_{0.01}$
			Whole grains				
2014	53.87	2.40	58.03	2.53	$p > 0.05$	7.25	16.73
2015	65.73	2.37	69.03	0.97	$p > 0.05$	4.77	8.75
Average	**59.80**		**63.53**				
			Broken grains				
2014	12.13	2.76	10.00	1.85	$p > 0.05$	9.82	22.65
2015	6.90	2.17	3.30	0.87	$p > 0.05$	4.52	8.31
Average	**9.52**		**6.65**				
			Total milled rice				
2014	66.00	0.46	68.03	1.27	$p > 0.05$	3.07	7.07
2015	72.63	0.53	72.33	0.29	$p > 0.05$	0.84	1.53
Average	**69.32**		**70.18**				

The results for the white rice yield are shown in Table 10. The white rice yield in FM treatment in both years was statistically in par compared to the yield obtained in the control, with the average yield difference of only -0.87 %. The FM treatment yielded 5856.75 kg/ha average white rice, while the control 5907.91 kg/ha. The results show that the application of FM in combination with a lower amount of nitrogen yielded white rice yield that is statistically on par with the standard fertilization method.

Table 10. Effect of Floral fertilizer on white rice yield in rice cultivar San Andrea

	Floral	SD	Control	SD	F test	$LSD_{0.05}$	$LSD_{0.01}$
2014	5457.70	166.89	5824.64	511.26	p>0.05	1636.51	3774.67
2015	6255.80	508.38	5991.17	339.05	p>0.05	1275.81	2341.92
Average	**5856.75**		**5907.91**				

The partial factor productivity from applied nutrients is a useful measure of nitrogen use efficiency because it provides an integrative index that quantifies total economic output relative to the utilization of all nutrient resources in the system, including indigenous soil nutrients and nutrients from applied inputs [38]. According to Pati *et al.* [29] and Cuong *et al.* [30], Si application significantly increased the uptake of nutrients (N, P, K), and increased the yield and yield components. This was also evident in the trial, as the FM treatment significantly increased the nitrogen use efficiency estimated thru the partial factor productivity from applied nitrogen. In FM treatment average partial productivity of 97.24 kg, paddy rice/kg N and 57.88 kg white rice/kg N was obtained as compared to the control (average values of 44.61 kg paddy rice/kg N and 28.14 kg white rice/kg N). Therefore, a significantly higher quantity of paddy and white rice per 1 kg applied nitrogen was produced in the FM treatment.

Table 11. Effect of Floral microsil application on partial factor productivity of applied nitrogen in rice cultivar San Andrea

	Floral	SD	Control	SD	F test	$LSD_{0.05}$	$LSD_{0.01}$
Partial factor productivity from applied nitrogen (paddy rice)							
2014	100.32	7.13	47.88	1.31	$p \leq 0.01$	18.23	42.04
2015	94.15	8.27	41.34	2.87	$p \leq 0.01$	17.56	32.23
Average	**97.24**		**44.61**				
Partial factor productivity from applied nitrogen (white rice)							
2014	53.93	1.65	27.74	2.43	$p \leq 0.01$	9.77	22.53
2015	61.82	5.02	28.53	1.61	$p \leq 0.01$	10.13	18.59
Average	**57.88**		**28.14**				

The application of Floral microsil fertilizer significantly increased the nitrogen use efficiency estimated thru the partial factor productivity. Therefore, paddy and white rice yield statistically on par with the standard fertilization were produced with a lower amount of applied nitrogen fertilizer. These findings are of ecological significance, as they suggest that the application of plant bio-available silica in Macedonian rice production could reduce the use of mineral fertilizers prevalent in the standard fertilization.

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ВЛИЈАНИЕТО НА ПРИРОДНОТО МУЛТИМИНЕРАЛНО ЃУБРИВО СО АМОРФЕН СИЛИЦИУМ FLORAL MICROSIL ВРЗ ОДРЕДЕНИ МОРФОЛОШКИ И ПРИНОСНИ СВОЈСТВА КАЈ ОРИЗОТ (*ORYZA SATIVA* L.)

Трајче Димитровски[1*], Даница Андреевска[1], Добре Андов[1], Емилија Симеоновска[1], Љубе Лозановски[2]

[1] Земјоделски институт – Скопје, Универзитет „Св. Кирил и Методиј“, Скопје, Република Македонија
[2] Училиштен центар „Крсте П. Мисирков“, Демир Хисар, Република Македонија
e-mail: dimitrovskitrajche@gmail.com

Влијанието на природното мултиминерално ѓубриво Floral microsil (FM) (50 % биодостапен аморфен SiO_2 + макронутриенти и елементи во траги) врз некои морфолошки и продуктивни својства на оризот беше испитано во агроеколошките услови на Република Македонија кај сортата San Andrea. Беа испитани две варијанти: контрола (стандарден начин на ѓубрење) со 450 kg NPK (16:16:16) како основно ѓубриво + две прихранувања со Urea 46 % N (200 + 100 kg/ha), и FM варијанта: 20 kg/ha FM пред сеидба, третман на семе со 20 kg/ha FM + три прихранувања со FM + Urea (30 + 100; 20 + 60 и 20 + 60 kg/ha соодветно). Полските опити

беа поставени според Zade-методот во текот на 2014 и 2015 година. Резултатите беа анализирани со ANOVA и LSD-тест.

Третманот со FM значајно влијаеше на висината на растението и стеблото (2014), резултирајќи со пониско растение (103.02 cm) и стебло (87.47 cm) во споредба со контролата (111.81 cm и 95.91 cm). Значително понизок биолошки принос (20958.34 kg/ha) и принос на слама (10769.67 kg/ha) беа добиени кај FM-варијантата во споредба со контролата (24852.00 kg/ha и 15101.34 kg/ha). Третманот со FM значајно ја зголеми масата на 1.000 зрна (39.97 g наспроти 38.28 g просек во контролата). Разликите во приносот на арпа и бел ориз (9839.99 kg/ha; 5856.75 kg/ha) во FM-варијантата беа статистички на исто ниво со контролата (9368.60 kg/ha и 5907.91 kg/ha), како и должината на метличката, бројот на продуктивни и непродуктивни братимки на m^2, рандманот (цели зрна и кршени зрна) и хектолитарската маса.

Апликацијата на FM значајно ја зголеми искористеноста на азотот, одредена преку односот на количината на добиен земјоделски производ (приносот) и количината на употребено ѓубриво на единица површина – partial factor productivity (97.24 kg арпа/kg N и 57.88 kg бел ориз/kg N), во споредба со контролата (44.61 kg арпа/kg N и 28.14 kg бел ориз/kg N). Според тоа, при апликација на ѓубривото Floral microsil во комбинација со помала количина азотно ѓубриво се постигна принос на арпа и бел ориз сличен со стандардниот начин на ѓубрење. Овие резултати се од еколошко значење за оризопроизводството на Република Македонија.

Клучни зборови: ѓубриво; морфолошки; partial factor productivity; продуктивни ориз; силициум