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CROPPING SYSTEM AND FERTILIZATION REGIME AS FACTORS OF MAIZE GRAIN QUALITY

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Abstract: Maize cropping systems include continuous cropping (monoculture), which is one of the widespread systems in Serbia and in the world, as well as rotations which include rotation of crops of different species, enabling better control of diseases, pests and weeds, as well as better utilization of water and nutrients from soil, having as a consequence increased yields. When leguminous crop is prior to maize in rotations, the maize grain yields are much higher than in rotations when some other crops are prior to maize. The aim of experiment was to evaluate different cropping systems (maize monoculture (MM), maize-winter wheat rotation (M-W), maize-field pea rotation (M-P) and maize-field pea-winter wheat rotation (M-P-W)) and four fertilization regimes (control - without fertilization, $N_{80}P_{60}K_{40}$, $N_{120}P_{90}K_{60}$ and $N_{160}P_{120}K_{80}$) on maize grain yield and grain quality (protein and oil content) during two meteorologically opposite years (2014 and 2015). The growing season and its interaction with cropping system and fertilization regime were the main factors that influenced significant variations in maize grain yield, protein and oil content. A double lower yield, slightly lower oil content and about 1/3 higher protein content were obtained in dry 2015, in relation to 2014, as a season with high precipitation level and lower average temperature. Rotation with higher crop number included (M-P-W rotation) expressed the highest impact on maize yield increase, together with protein and oil content in grain, particularly during stressful 2015. Similar trend was observed in two crop rotation, where legume crop is prior to maize. What is more, increased fertilization level was positively reflected on yielding potential and protein content increase, but it decreased oil content in grain. Poorer growth conditions, present in maize monoculture revealed lower grain yield and protein content, with greater oil content, particularly in treatment without fertilizer application.

Key words: fertilization, grain yield, maize, oil content, protein content, rotation

Introduction

Continuous cropping (monoculture) is one of the widespread systems of maize growing in Serbia and in the world. It has many disadvantages, reflecting through increased infection by diseases and pests, weed spreading, etc. (*Kovačević, 2003)*. On the other hand, cropping systems which include rotation of crops of different species, when they are properly applied, enables better control of diseases, pests and weeds, as well as better utilization of water and nutrients from soil, having as a consequence increased yields *(Kovačević et al., 2008)*.

Combination of grain crops, cereals, forages and legumes in sequences includes different crop densities, application of various tillage practices, fertilizers, herbicides, etc. changing soil physical and chemical properties and microbiota, maintaining fertility to some extent. *Govaerts et al. (2007)* also indicated that cropping systems that include rotation of different crops, zero tillage and crop residue retention contributes to increased soil microorganisms biomass, activity and diversity, when compared to continuous cropping. Combination of these systems meliorates conditions for development of antagonists and predators, thus increasing ecological stability. *Karlen et al. (2006)* depicted that extended rotations that include three year of forage crops in sequences established the highest soil quality index, suggesting that conservation programs which include more diverse and extended crop rotations are connected to increased soil quality, grain yields and so, increased profit. When leguminous crop is prior to maize in rotations which include increased number of different crops, the maize grain yields are much higher than in rotations when some other crops are prior to maize (*Berzsenyi et al., 2000*). This is of particular importance, since legume crop enriches soil with fixed N, increase mineralization and nutrient absorption, leading as a consequence to the yield increase, especially in cases when fertilizers are not applied in maize crop (*Horst and Härdter, 1994*). *Yusuf et al. (2009)* separated effect of N added by fixation of previous legume crop and "other effect of rotation" and calculated that in maize grain yield that increased up to 1.2-1.3 fold, effect of fixed N ranged from 124 to 279 kg ha^{-1} while rotation effects ranged between 193 and 513 kg ha^{-1}.

Some researchers also have underlined importance of increased N uptake of maize included in rotation with other crops, particularly during anthesis, was positively reflected on protein status in maize grain (*Montemurro et al., 2006)*. *Saha et al. (2008)* applied increased NPK levels in maize-wheat rotation system and achieved higher maize grain yield and protein level when compared to maize monoculture, what means that rotation enables better nutrient utilization by maize crop. What is more, when leguminous crop like soybean is preceding crop to sorghum, sorghum grain yield and quality was raised, reflecting through increased nitrogen level and grain hardness *(Mady Kaye et al., 2007)*.

The aim of this experiment was to evaluate different cropping systems, which include maize monoculture, maize-winter wheat rotation, maize-field pea rotation and maize-field pea-winter wheat rotation and three fertilization regimes, with different NPK levels on maize grain yield and grain quality (protein and oil content) during two opposite years in meteorological factors.

Material and Methods

Experiment was settled up in Maize Research Institute "Zemun Polje" during 2014 and 2015 growth seasons, with the aim to evaluate effects of different cropping systems (rotations) and fertilization regimes on maize grain yield and grain quality reflected through protein and oil content during two opposite seasons. Experiment included four cropping systems: maize monoculture (MM), two year rotations: maize-winter wheat rotation (M-W), maize-field pea rotation (M-P) and three year rotation: maize-field pea-winter wheat rotation (M-P-W) and four fertilization regimes: control - without fertilization (F1), $N_{80}P_{60}K_{40}$ (F2), $N_{120}P_{90}K_{60}$ (F3) and $N_{160}P_{120}K_{80}$ (F4). The relation between nutrients is 1:0.75:0.50 for maize fertilization and winter wheat, while field pea was fertilized with half of the N dose applied for maize and wheat, with exception of control, without fertilizer added. Fertilizers were applied at the end of October in 2013 and 2014, while sowing was performed during first half of April, dependently on meteorological conditions. All standard protection measures were applied.

After harvesting, grain yield was measured and calculated with 14% of moisture. The content of protein and oil was determined on infrared analyser (Infraneo, Chopin Technologies, France).

The experimental data were statistically processed by analysis of the variance (ANOVA) using Microsoft Excel and analysed by the LSD-test (5 %) and correlation (Pearson correlation).

Meteorological conditions. Two experimental years of 2014 and 2015 were opposite in precipitation level and monthly average temperature. The year 2014 was characterised with the double higher precipitation level (709.1 mm) compared to 2015, with 350.5 mm (Table 1).

Table 1. Average monthly temperature and precipitation sum during seasons of 2014 and 2015

Year	April	May	June	July	August	September	October	M/∑
	Temperature, °C							
2014	13.7	17.4	21.1	23.2	22.6	18	14.1	18.6
2015	12.9	19.1	22.1	26.4	25.7	20.2	12.4	19.8
	Precipitation, mm							
2014	84.8	192.5	71.2	187.4	41	75.6	56.6	709.1
2015	19.7	97.8	31.1	7.2	56	73.6	65.1	350.5

In 2015, precipitation were unequally distributed with the lowest value in July, of only 7.2 mm. This season was also characterised with higher average temperature (19.8 °C) and higher temperature during July, August and September for 3.2 °C, 3.1 °C and 2.2 °C respectively, compared to the same months in 2014. This means that drought was present during flowering and grain filling period of 2015 season.

Results and Discussion

The significant variations in maize grain yield were obtained by the influence of growing season (year), and interactions year x cropping system, year x fertilization regime, cropping system x fertilization regime and year x cropping system x fertilization regime, while single factors, like cropping system and fertilization regime were insignificant for yield variability (Table 1). Such situation could be closely tied to precipitation level, as well as drought present during 2015, when grain yield almost for half was lower than in 2014. Irrespective to insignificant influence of cropping system, the lowest yield was obtained in maize monoculture, what is averagely about 1.58 t ha^{-1} lower than in maize-field pea rotation. Three crop rotation system showed advantage during stressful 2015, with grain yield of 6.60 t ha^{-1}, what is 2.26 t ha^{-1} higher in comparison to monoculture, while in 2014, as a season with high precipitation level, the highest grain yield was achieved in maize-field pea rotation, with 12.03 t ha^{-1}, what is 1.44 t ha^{-1} higher than in monoculture. This means that in maize monoculture higher grain yield losses (in regard to rotation systems) are present during dry season, in relation to season with higher precipitation level *(Berzsenyi et al., 2000)*. The same authors indicated that increase in species number included in rotation reflects positively on maize grain yield, particularly when leguminous crop is prior to maize. Legume, as previous crop to maize in rotation has positive effect on grain yield increase and nutrient absorption. Legume crop increases soil N content by fixation, as well as mineralization, thus increasing yield in unfertilized filed *(Horst and Härdter, 1994)*, like F1 is in this experiment, what is particularly present during 2014. *Yusuf et al. (2009)* calculated separately the effect of N fixed by leguminous preceding crop, as well as rotation effect on maize yield and they obtained that increase in maize grain yield by 1.2-1.3 folds was supported by 124 to 279 kg ha^{-1} with fixed N and almost double by rotation effect, meaning that rotation with legume crop is complex and it has much more importance to yielding potential of maize than fertilization alone.

Table 2. Maize grain yield (t ha^{-1}) influenced by the different cropping system and fertilization regime

	2014					2015				
	MM	M-W	M-P	M-P-W	Aver.	MM	M-W	M-P	M-P-W	M.
F1	5.57	7.53	10.43	8.82	8.09	3.39	4.71	5.79	6.25	5.03
F2	10.54	12.93	12.69	11.79	11.99	4.29	4.76	6.57	6.31	5.48
F3	13.09	13.63	12.89	11.94	12.89	5.04	6.12	5.84	6.96	5.99
F4	13.16	13.23	12.10	11.63	12.53	4.62	4.91	5.97	6.89	5.60
M.	10.59	11.83	12.03	11.05	11.37	4.34	5.13	6.04	6.60	5.53
Year average						LSD 0.05				
F1	4.48	6.12	8.11	7.54	6.56	Year	1.873	Y x F	1.299	
F2	7.42	8.85	9.63	9.05	8.74	Fert.	3.388	Y x CS	1.762	
F3	9.07	9.88	9.37	9.45	9.44	Crop. Sys.	3.469	F x CS	3.439	
F4	8.89	9.07	9.04	9.26	9.06	Y x CS x F		0.82		
M.	7.46	8.48	9.04	8.82	8.45					

MM - maize monoculture; M-W - maize-wheat rotation; M-P - maize-field pea rotation, M-P-W - maize-field pea-wheat rotation; F1 - without fertilization; F2 -$N_{80}P_{60}K_{40;}$ F3 - $N_{120}P_{90}K_{60}$ and F4 - $N_{160}P_{120}K_{80}$

Increased fertilizer inputs are also important for maize yielding potential. The highest grain yield was obtained in F3 treatment in both years (12.89 t ha^{-1} in 2014 and 5.99 t ha^{-1} in 2015) (Table 2). When interactions of all three examined factors are considered, the differences between seasons emphasized that in 2014 the highest grain yield was achieved in combination of M-W with F3 fertilization regime (13.63 t ha^{-1}), while in 2015 the yield reached 6.96 t ha^{-1} in combination M-P-W rotation and also F3 fertilization regime. *Berzsenyi et al. (2000)* also achieved the higher grain yields with increased NPK fertilizer inputs, particularly in two year rotations.

Similarly to grain yield, the significant variations in protein content (Figure 1) and oil content (Figure 2) were obtained by the influence of year, interactions year x cropping system, year x fertilization regime, cropping system x fertilization regime and year x cropping system x fertilization regime, while factors as a cropping system and fertilization regime were insignificant for protein and oil variability. *Kaye et al. (2007)* likewise found that grain yield and N content in sorghum grain was significantly affected by interaction of cropping system and fertilization, increasing yield and grain quality by increased fertilizer supply and rotation with soybean, which adittionaly contributed to increased N level. The drought presence in 2015 affected not grain yield, but grain quality, too, increasing

protein content and decreasing oil content in all applied treatments, when compared to 2014 (in average for about 1.97% and 0.27%, respectively).

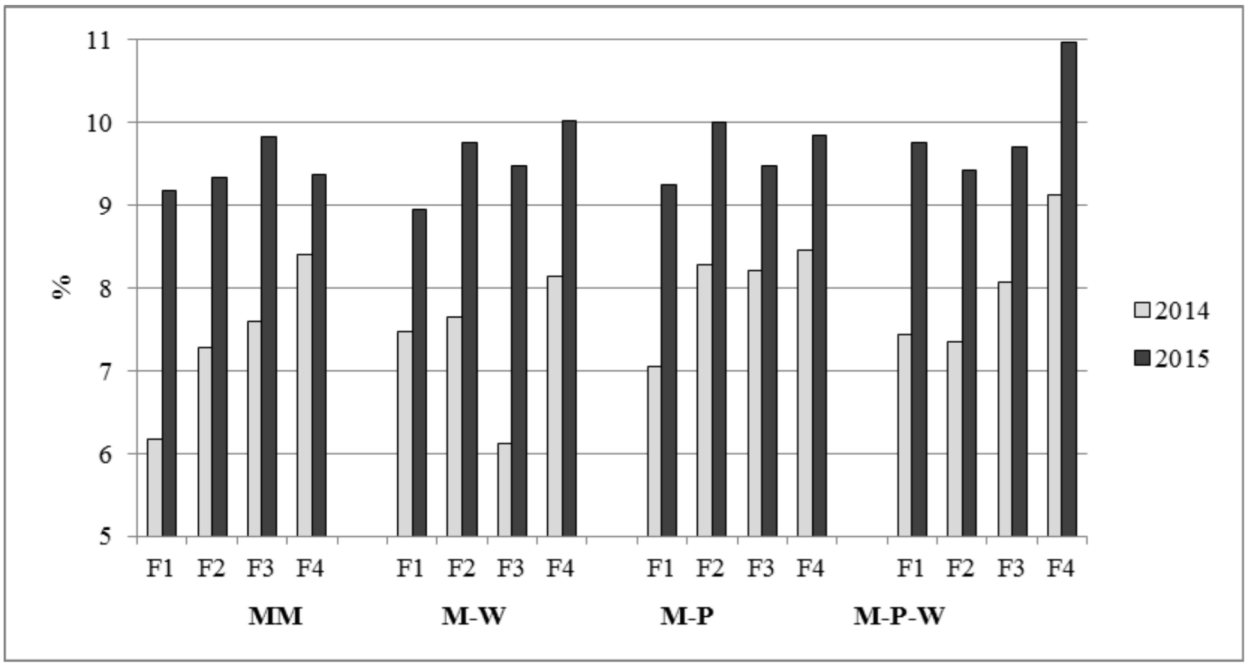

Figure 1. Protein content in maize grain influenced by different cropping system (MM - maize monoculture, M-W – maize-wheat rotation, M-P – maize-field pea rotation, M-P-W – maize-field pea-wheat rotation) and fertilization regime (F1 - without fertilization, F2 -$N_{80}P_{60}K_{40}$, F3 - $N_{120}P_{90}K_{60}$, F4 - $N_{160}P_{120}K_{80}$); LSD 0,05 for year=0.716; fertilization regime 1.179; cropping system 1.225; Y x F = 0.60; Y x CS = 0.697; F x CS = 1.238; Y x CS x F = 0.433)

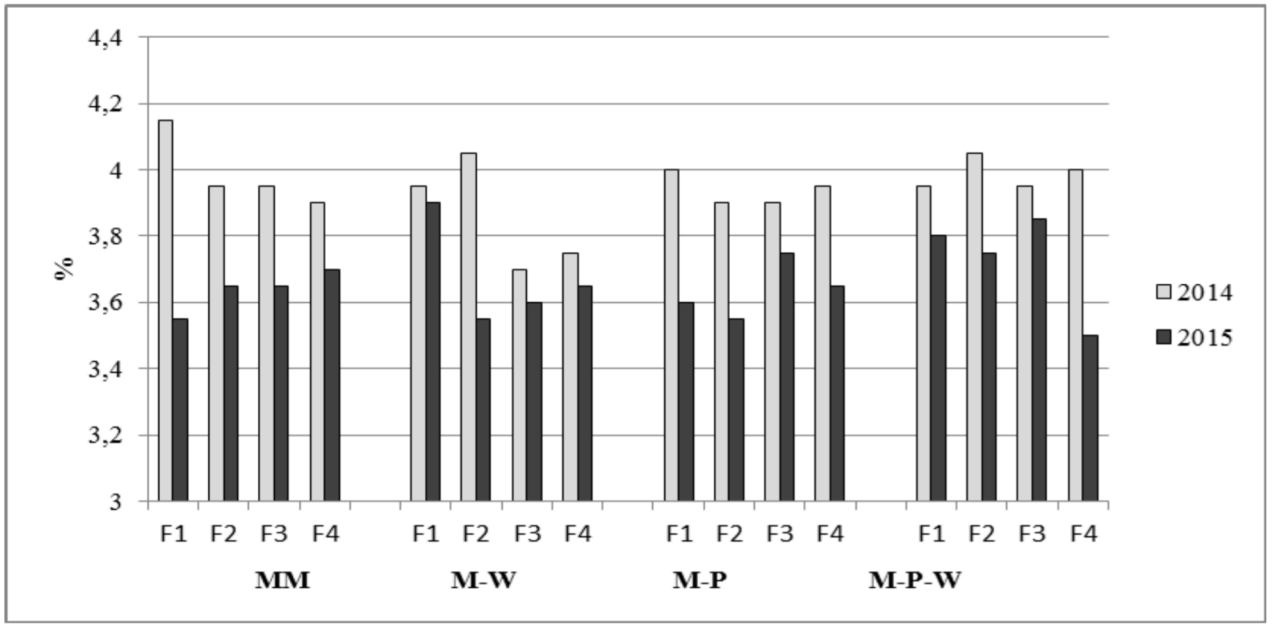

Figure 2. Oil content in maize grain influenced by different cropping system (MM - maize monoculture, M-W – maize-wheat rotation, M-P – maize-field pea rotation, M-P-W – maize-field

pea-wheat rotation) and fertilization regime (F1 - without fertilization, F2 -$N_{80}P_{60}K_{40}$, F3 - $N_{120}P_{90}K_{60}$, F4 - $N_{160}P_{120}K_{80}$); LSD 0,05 for year = 0.142; fertilization regime 0.199; cropping system 0.199; Y x F = 0.139; Y x CS = 0.142; F x CS = 0.210; Y x CS x F = 0.125)

Cropping system is important measure to increase maize grain quality, by increasing protein and oil content, which had the highest values in three crop, M-P-W rotation (on average 8.98% and 3.86%, respectively). Fertilization regime was correspondingly reflected on protein and oil content, with inverse results. This means that the highest average protein content was in F4 fertilization regime, while the highest oil content was in F1 fertilization regime. Contrary, the lowest protein content was in F1 and oil content in F4, denoting that increased NPK (mineral fertilizer) amounts are important for increased protein level in maize grain, but also it is negatively reflecting on oil synthesis, decreasing its content. *Montemurro et al. (2006)* indicated that increased amounts of soil N are important for increased N uptake, particularly after anthesis, thus positively reflecting on grain yield and grain N status (protein level). *Saha et al. (2008)* also confirmed that NPK mineral fertilizers, when applied in higher amounts reflect positive on maize grain protein level and grain yield in maize-wheat rotation system. The highest protein content in 2014 and 2015 was achieved in M-P-W x F4 treatment combination with values of 9.12% and 10.97%, respectively, while the highest oil content was achieved in 2014 in MM x F1 treatment combination and in 2015 in M-W x F1 combination. This means that the conditions provided by three year rotation and high fertilizer amounts enables increased protein synthesis, while the poorer conditions, with lower nutrient levels, such as monoculture and maize-wheat rotation, without fertilizer inputs are better basis for increased oil synthesis. This is opposed to results of *Rastija et al. (2006)* who obtained increased grain yield and oil content in soybean fertilized with ameliorative NPK fertilization.

The interdependence between fertilization regime and examined parameters obtained that increase in amount of applied fertilizer was significantly and positive followed mainly by the grain yield and in some lesser extent by the protein content, while correlation with oil content was also significant, but negative. Grain yield positively correlated with protein content and negative with oil content, too. *Montemurro et al. (2006)* and *Saha et al. (2008)* confirmed that increased fertilization positively affects yield and protein content in maize grain.

Table 3. Correlation between fertilization regime and examined traits: grain yield, protein content and oil content in maize grain

		Fertilization regime	Grain yield	Protein content
Grain yield	CC*	0.728		
	p**	0.001		
Protein content	CC	0.645	0.552	
	p	0.007	0.027	
Oil content	CC	-0.502	-0.483	-0.191
	p	0.047	0.058	0.479

*CC-correlation coefficient; the significant values at the level of significance of 0.05; **p-error

Conclusion

The significant variations in maize grain yield, protein and oil content were mainly obtained by the influence of growing season, as well as its interaction with cropping system and fertilization regime. That means that almost double lower yield, slightly lower oil content and about 1/3 higher protein content were obtained in dry 2015, in relation to 2014, as a season with high precipitation level and lower average temperature. Rotation with higher crop number included (M-P-W rotation) expressed the highest impact on maize yield increase, together with protein and oil content in grain, particularly during stressful 2015. Similar trend was observed in two crop rotation, where legume crop is prior to maize. What is more, increased fertilization level, mainly F3 and in some extent F4 treatment, were positively reflected on increase in yielding potential and protein content, but in parallel oil content in grain was decreased. Poorer growth conditions, present in maize monoculture revealed lower grain yield and protein content, with greater oil content, particularly in F1 treatment. This means that increased fertilization was followed significantly by yield and protein increase, but negatively by oil content in grain.

Sistemi gajenja i režimi đubrenja kao faktori kvaliteta zrna kukuruza

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Rezime

Sistemi gajenja kukuruza podrazumevaju kontinuirano gajenje (monokulturu), koje je jedan od najrasprostranjenijih sistema gajenja kukuruza u Srbiji i svetu, kao i plodored, koji podrazumeva gajenje useva različitih vrsta, obezbeđujući bolju kontrolu bolesti, štetočina i korova, kao i bolje iskorišćavanje vode i hraniva iz zemljišta, samim tim povećavajući prinose. Kada u plodoredu kukuruzu prethodi leguminoza, prinosi zrna kukuruza su znatno veći, nego u plodoredima gde druge biljne vrste prethode kukuruzu. Cilj eksperimenta je bio da se oceni uticaj različitih sistema gajenja (monokultura kukuruza (MM) i plodoredi kukuruz-ozima pšenica (M-W), kukuruz-jari stočni grašak (M-P) i kukuruz-jari stočni grašak-pšenica (M-P-W) i četiri režima đubrenja (kontrola, $N_{80}P_{60}K_{40}$, $N_{120}P_{90}K_{60}$ i $N_{160}P_{120}K_{80}$) na prinos kukuruza i kvalitet zrna (sadržaj proteina i ulja) tokom dve sezone suprotne po meteorološkim faktorima (2014. i 2015.). Sezona i njena interakcija sa sistemima gajenja i režimima đubrenja su osnovni faktori koji su uticali na variranje prinosa, sadržaj proteina i ulja u zrnu kukuruza. Duplo manji prinos, nešto niži sadržaj ulja i za oko 1/3 veći sadržaj proteina bio dobijen u sušnoj 2015. godini, u odnosu na 2014., kao sezonu sa više padavina i nižim prosečnim temperaturama. Plodored sa većim brojem useva (M-P-W sistem) je pokazao najveći uticaj na povećanje prinosa, sadžaj proteina i ulja, posebno u 2015. godini. Sličan trend je uočen i u plodoredu sa dva useva gde leguminoza prethodi kukuruzu. Takođe, povećan nivo đubriva se pozitivno odrazio na povećanje potencijala rodnosti i sadržaja proteina, ali je paralalno uticao na smanjenje sadržaja ulja u zrnu. Lošiji uslovi gajenja, koji su prisutni u monokulturi uticali su na smanjenje prinosa i sadržaja proteina, uz povećanje sadržaja ulja u zrnu i to posebno u tretmanu bez primene đubriva.

Ključne reči: đubrenje, prinos zrna, kukuruz, sadržaj ulja, sadržaj proteina, plodored

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