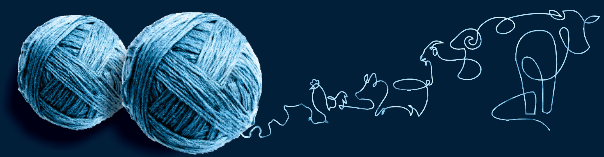
12th
INTERNATIONAL
SYMPOSIUM

MODERN TRENDS IN LIVESTOCK PRODUCTION



PROCEEDINGS

9 -11 October 2019, Belgrade, Serbia

Institute for Animal Husbandry
Belgrade - Zemun, SERBIA

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Circulation 150 copies.

The publication of this Proceedings is sponsored by the Ministry of Education and Science of the Republic of Serbia.
The Proceedings is printed by the Institute for Animal Husbandry, Belgrade, 2019

ISBN 978-86-82431-76-3

Proceedings of the 12th International Symposium
Modern Trends in Livestock Production
October 9-11, 2019

CROPPING SYSTEMS AFFECT PHOTOSYNTHETIC PIGMENTS AND GRAIN YIELD IN MAIZE

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Original scientific paper

Abstract: Maize is still widely growing in monoculture, due to its domination in sowing structure. Nevertheless, rotation, as cropping system has many advantages in regard to monoculture, revealing through better crop growth and yielding. The aim of this experiment was to evaluate different cropping systems, which include maize monoculture (M), maize-winter wheat-soybean (MWS) and maize-soybean-winter wheat (MSW) rotations, with different weed control measures: full and half of herbicide doses, weed removal by hoeing and control – without weed removal, on dry mass (DM), concentration of chlorophyll *a*, chlorophyll *b* and carotenoids in aboveground maize biomass, as well as grain yield during three seasons. Obtained results referred that DM accumulation in above ground biomass highly correlated with carotenoids concentration in maize leaves and that full dose of herbicides is an important strategy for greater DM accumulation. MSW is the most promising cropping system to achieve high grain yield of maize, what is possible tied to low variations in all three photosynthetic pigments, indicating that this system enables better conditions for assimilation and crop growth. Higher values of chlorophyll *a*, as found in treatment with weed removal, are important for maize productivity. What is more, carotenoids role is emphasized again, having primary role in chlorophyll *a* protection against oxidative stress, thus contributing to optimal assimilation and increased grain yielding potential.

Key words: grain yield, maize, crop rotation, monoculture, photosynthetic pigments, dry mass.

Introduction

Maize is still growing in monoculture in Serbia, due to its domination in sowing structure. Nevertheless, rotation, as cropping system has many advantages, when compared to monoculture, revealing through better crop growth and yielding. Predominantly two-crop rotation (winter wheat-maize) is present in sowing structure in Serbia and it is followed by three-crop rotation (winter wheat-maize-soybean). It is well known that maize rotation with other crops could decrease number of pathogens, pests and weeds, maintain or increase soil fertility, enabling better conditions for maize growth and development *(Dolijanović et al., 2006; Stranger and Lauer, 2008; Riedell et al., 2009)*. *Simić et al. (2016)* pointed out that three-crop rotation, such as maize-soybean-wheat, significantly reduced biomass of perennial and annual weeds, particularly when it is combined with standard herbicide application. This type of rotation, together with maize-wheat rotation was also positively reflected on grain yield increase. *Brankov et al. (2017)* likewise stated that herbicides expressed full effect in weed control in maize-wheat rotation and pointed that meteorological factors are very important for expression of herbicide and rotation effectiveness. Rotation provides optimal conditions for crop growth, increasing its competitiveness over weeds for resources such as light, water and nutrients *(Simić and Stefanović, 2007)*. With such improved growing conditions it is able to apply lower amounts of herbicides in order to achieve high yields (*Simić et al., 2012).* Extended rotations that include maize and forage crops could reduce nitrogen inputs, together with increase in maize grain yield, giving them importance as more sustainable cropping systems over short-term rotations *(Stranger and Lauer 2008)*. After 26 years of investigations, savings in agronomic inputs could be accomplished up to 30% whe4n grain and silage maize were grown in rotation with different crops, together with increase of yield stability *(Borrelli et al., 2014)*.

Spasojević et al. (2014) declared advantage of three-crop rotation which also included maize, soybean and wheat over maize monoculture with lower weed infestation, increased values of leaf area index, chlorophyll content, decreased free energy and carotenoids level, thus reflecting on increased grain yield. Similar results were obtained in maize-wheat rotation, when after three and five experimental years weed biomass was significantly decreased by rotation (averagely by 33.73%), as well as herbicide application, with negligible differences between recommended and half of recommended dose of herbicide. Parameters of maize competitiveness have been changed regarding to the herbicide level and they were greater in maize continuous cropping than in the maize-wheat rotation *(Simić et al., 2016)*. Decrease in maize competitiveness could result from stress pressure, and it is associated with loss of or reduced synthesis of photosynthetic pigments, declined light harvesting and generation of reducing powers, having as a consequence reduction in dry matter accumulation, biomass and grain yield *(Jaleel et al., 2009)*. Rationally cropped maize, i.e. applying of all necessary measures, primary rotation results in increased maize productivity, not only grain, but better dry matter accumulation with grater biomass (*Nevens and Reheul, 2001*).

The aim of this experiment was to evaluate different cropping systems, which include maize monoculture, maize-winter wheat-soybean and maize-soybean-winter wheat rotations, with different weed control measures - full and half of herbicide doses, weed removal by hoeing and control – without weed removal, regarding dry mass production, concentration of chlorophyll *a*, chlorophyll *b* and carotenoids of aboveground maize biomass, as well as grain yield during three seasons.

Material and Methods

The study was initiated in Maize Research Institute "Zemun Polje" in Serbia, with the aim to evaluate the effects of different cropping systems on maize growth and grain yield. The soil type at the experimental field was slightly calcareous chernozem with 53% sand, 30% silt, 17% clay; 3.3% of organic matter content and moderate drainage. The pH is 6.9 and soil structure is silty clay loam.

The following factors were evaluated: 1. maize cropping system - continuous cropping (M), maize-soybean-winter wheat (MSW) and maize-winter wheat-soybean (MWS) rotation; 2. weed control - herbicide mixture for complete control of broadleaf and grass weed species were applied at the recommended dose (H); half of recommended dose (1/2H); control, without weed removal and herbicide application (C); weed free, where weeds were removed by hoeing (WF).

Hybrid ZP606 was sown at the middle of April in 2012, 2015 and 2018. The standard technology of maize production was applied. Farmyard manure was applied in the autumn of previous year, in regard to growing season M and MSW system, while in MWS rotation farmyard manure was not applied. Additionally, mineral fertilizers were applied in the autumn and during early phases of maize development in the spring. The amounts of mineral fertilizers were determined by the soil analysis.

Every year, at the end of the pollination period and beginning of grain filling, when plants are completely developed, dry biomass of above-ground parts from three plants per elementary plot was measured. At the same time, cob leaves were sampled for analysis of photosynthetic pigments concentration: carotenoids, chlorophyll *a* and chlorophyll *b*, by the method of *Sarić et al. (1990)*. Grain yields were analysed at the end of the growing season. The maize grain yield was measured from two inner rows of each subplot and calculated to 14 % of moisture. The experimental data were statistically processed by analysis of the variance (ANOVA) and analysed by the LSD-test (5%), as well as correlation (Pearson correlation) and Principal Component Analysis (PCA) performed by SPSS 15.0 for Windows Evaluation version.

Meteorological conditions. Experimental years were relatively similar in precipitation level and monthly average temperature. The year 2012 was characterised with the lowest precipitation level (216.1 mm) and the highest average temperature (21.1 °C) compared to 2015 and 2018 (Table 1). 2012 and 2015 were also characterised with the unequal precipitation distribution, with only 4.8 and 7.2 mm amount in August of 2012 and July of 2015, signifying drought during grain filling period.

Table 1. Average monthly temperature and precipitation sum during seasons of 2012, 2015 and 2018

Year	April	May	June	July	August	September	October	Mean/∑
	Temperature, °C							
2012	14.4	17.9	24.6	27.1	26.2	22.1	15.4	21.1
2015	12.9	19.1	22.1	26.4	25.7	20.2	12.4	19.8
2018	18	21.7	22.7	23.6	25.7	19.8	15.9	21.0
	Precipitation, mm							
2012	56.2	58.5	14.8	19.8	4.8	20.7	41.3	216.1
2015	19.7	97.8	31.1	7.2	56	73.6	65.1	350.5
2018	24.6	39	150.1	61.9	44	16.9	20.8	357.3

Results and Discussion

The significant variations in maize grain yield were obtained by the influence of all of the sources of variation and their interaction, while variations in concentration of carotenoids, chlorophyll *a* and *b* were mainly present under the influence of year and interactions of all examined factors (Table 2). Based on the average from all three years, the highest average grain yield was obtained in MSW cropping system (Figure 1). Also, 1/2H experimental variant was characterised by the significantly higher grain yields in all three cropping systems, with the highest value achieved in MSW-1/2H combination. WF systems had similar grain yield values, while M had the poorest results, as expected, particularly in C variant. Similarly, *Borrelli et al. (2014)* established that the grain yield gradually increased in rotation while the yield of maize grown in monoculture decreased slightly over 26 year period.

Table 2. Analysis of variance ($LSD_{0.05}$ values) for the grain yield, concentrations of carotenoids chlorophyll b and chlorophyll a in maize leaves, under the influence of different cropping system, herbicide treatment and year

Source of variation	df	Grain yield	Carotenoids	Chlorophyll *b*	Chlorophyll *a*
		($t\ ha^{-1}$)	($\mu g\ g^{-1}$ DM)		
Replicate	3	$LSD_{0.05}$			
Cropping system (CS)	2	2.033*	4.202	2.821	8.236
Herbicide treatment (H)	3	1.975*	4.338	3.416	8.815
Year (Y)	2	1.709*	1.492*	2.074*	3.511*
CS × H	11	1.552*	1.351*	1.880*	3.054*
CS × Y	8	1.468*	1.408*	1.746*	2.725*
H X Y	11	1.552*	1.351*	1.880*	3.054*
CS × H ×Y	35	1.184*	0.454*	0.349*	0.427*
Coefficient of variation (%)		1.05	0.15	0.91	1.36
Average		6.90	4.107	4.419	9.545
Min		2.660	0.381	0.801	0.535
Max		10.048	12.562	14.413	27.161

*Significant at 5% probability level; df: degrees of freedom; LSD: least significant difference.

In both three-crop rotations the highest DM concentration was present in H experimental variant (Figure 1), indicating importance of herbicides, as weed suppressants for productivity, i.e. dry matter accumulation in maize biomass, what is also supported by *Khan et al. (2012)*, who achieved the highest maize productivity on plots treated with herbicides. This statement was also supported with the highest DM values obtained in WF variant in M cropping system. This means that only in fields with proper weed control, maize plants are able to accumulate higher DM and eventually realise their full photosynthetic, as well as production potential. There were also present high fluctuations in DM concentration in M system, when compared to both rotation systems, confirming *Nevens and Reheul (2001)* statement that only rationally cropped maize, with applied rotations has increased DM in biomass.

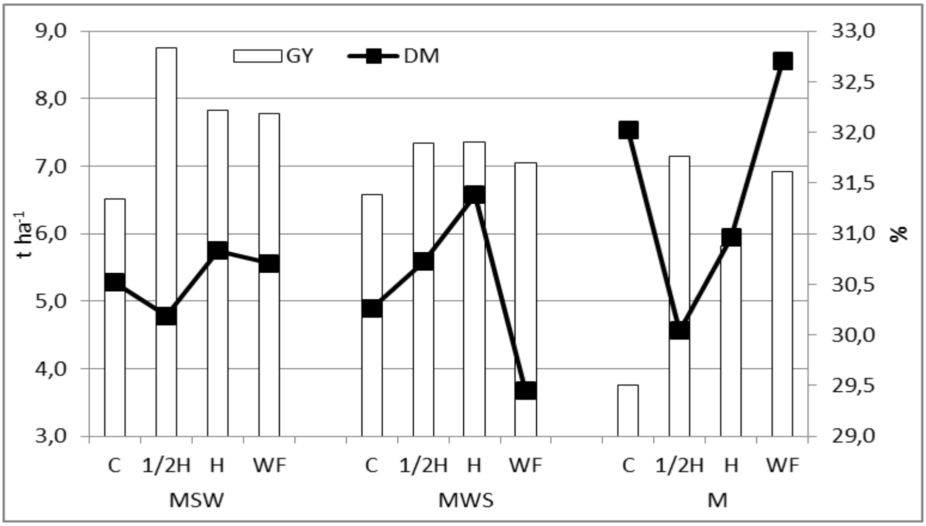

Figure 1. Average grain yield (GY) and dry mass of above-ground biomass (DM) of maize grown in different cropping systems (MSW – maize-soybean-winter wheat rotation; MWS – maize-winter wheat-soybean rotation; M – maize monoculture; C- control; 1/2H – half dose of applied herbicide; H – full dose of applied herbicide; WF – weed free)

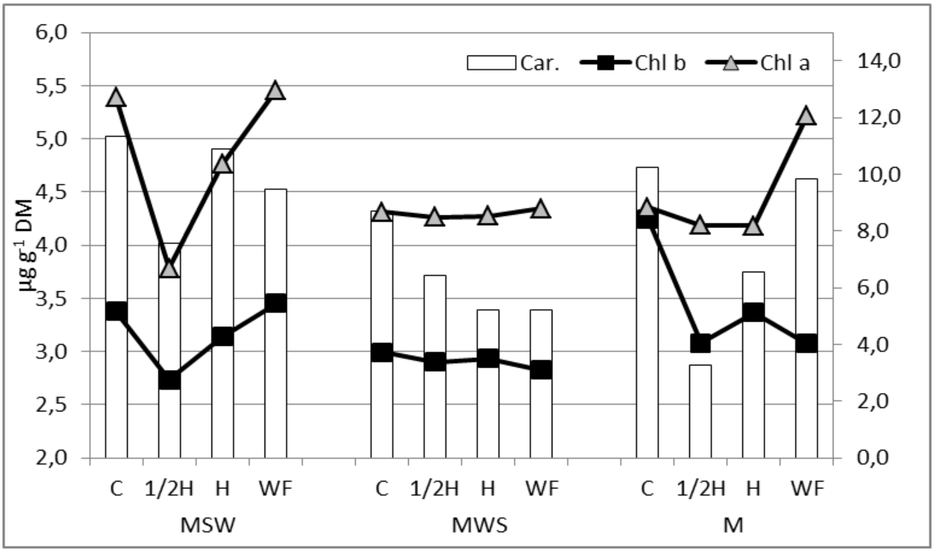

Figure 2. Average concentrations of carotenoids (Car.), chlorophyll *b* (Chl b) and chlorophyll *a* (Chl a) in leaves of maize grown in different cropping systems (MSW – maize-soybean-winter wheat rotation; MWS – maize-winter wheat-soybean rotation; M – maize monoculture; C-control; 1/2H – half dose of applied herbicide; H – full dose of applied herbicide; WF – weed free)

Opposite to productivity parameters (grain yield and DM concentration), concentration of photosynthetic pigments at the beginning of grain filling period had mainly the highest values in MSW three-field rotation (Figure 2). Nevertheless, relatively low variations in all three photosynthetic pigments was present in MWS cropping system, indicating that this system enables better conditions for plant growth and assimilation, irrespective to weed control measures. *Ennin and Clegg (2001)* also achieved higher productivity and chlorophyll content in maize grown after soybean, due to the higher N residues provided by soybean. Average concentration of carotenoids tent to be higher in control, evidencing about presence of stressful conditions, due to higher weed infestation *(Simić and Stefanović, 2007; Simić et al., 2012)*. Carotenoids serve as an important protectors not only of photosynthetic apparatus against stress, but also of different plant tissues against free radicals produced in stressful conditions *(Jaleel et al., 2009)*. This could be the reason of the significantly higher and positive correlation between carotenoids concentration and dry mass content (Table 3). When applied treatments for weed control were considered, the highest chlorophyll a concentrations was observable at WF treatment, in all three cropping systems, while the highest chlorophyll *b* concentration was present in control. Such situation indicates that optimal conditions for crop growth and increased potential for assimilation was enabled by weed removal with hoeing. However, increased overshadow and competitiveness between crop plants and weeds were present in control, similarly by results obtained on maize grown with different spatial arrangement *(Simić et al., 2012)*. This was supported by significant and negative correlation between chlorophyll *b* concentration and grain yield, as well as significant and positive correlation between chlorophyll *b* and dry mass, evidencing that crop plants tend to accumulate greater dry biomass in conditions of overshadow (competitiveness) the rather than to translocate assimilative into grain, lowering yield potential *(Sarabi et al., 2011)*.

Table 3. Correlation between grain yield and above-ground dry biomass content and concentrations of carotenoids, chlorophyll *b* and *a* in maize leaves

	Grain yield (t ha^{-1})	Dry mass (%)
Carotenoids	-0.206	0.429*
Chlorophyll *b*	-0.818*	0.471*
Chlorophyll *a*	-0.005	0.320*

Pearson correlation coefficients at the level of significance of 0.05*

Principal component analysis revealed that PC1 and PC2 participated with 53.3% and 25.8% in total variability, respectively. Grain yield and chlorophyll *b* mainly contributed to PC1, while carotenoids and chlorophyll *a* mainly contributed to PC2. According to data present in Figure 3, H, C and WF treatments from MSW cropping system mainly induced variability in carotenoids and chlorophyll *a* concentration, while dry mass and chlorophyll *b* varied mainly in monoculture control (M-C). MWS cropping system (C, 1/2H, H and WF treatments), as well as MSW in combination with 1/2H largely contributed to the variation in grain yield, but in lesser extent. All that could indicate that high chlorophyll *b* concentrations are connected to lower yielding potential, as it was previously supposed, while carotenoids have primary role in chlorophyll *a* protection against oxidative stress, thus contributing to optimal assimilation and increased grain yielding potential (*Jaleel et al., 2009*).

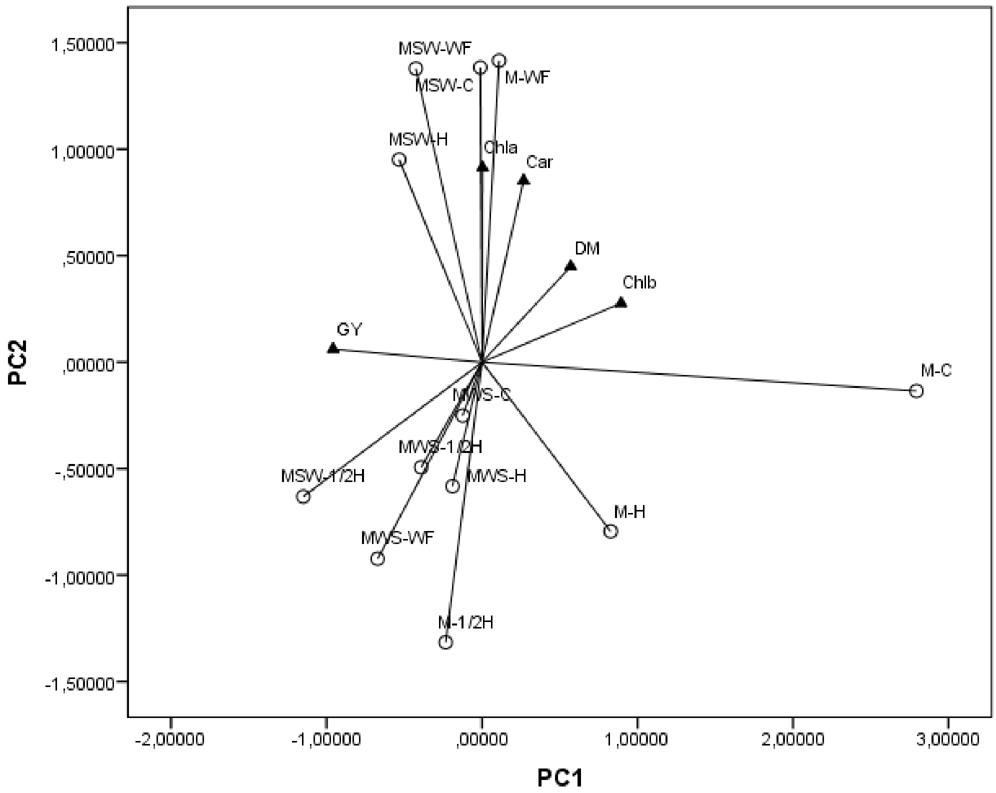

Figure 3. Principal Component Analysis for grain yield (GY), dry mass (DW), carotenoids (Car), chlorophyll b (Chl b) and chlorophyll a (Chl a) concentrations in leaves of maize grown in different cropping systems (MSW – maize-soybean-winter wheat rotation; MWS – maize-winter wheat-soybean rotation; M – maize monoculture; C- control; 1/2H – half dose of applied herbicide; H – full dose of applied herbicide; WF – weed free)

Conclusion

Obtained results referred that dry mass accumulation in above ground biomass depends on carotenoids concentration in maize leaves and that full dose of herbicides (H treatment) is an important strategy for greater DM accumulation. MSW is the most promising cropping system to achieve high grain yield of maize, what could be also tied to low variations in all three photosynthetic pigments, indicating that this system enables better conditions for plant growth and assimilation. Higher values of chlorophyll *a*, as found in WF treatment, are important for maize productivity. What is more, carotenoids role is emphasized again, having primary role in chlorophyll *a* protection against oxidative stress, thus contributing to optimal assimilation and increased grain yielding potential.

Kako sistemi gajenja utiču na fotosintetske pigmente i prinos zrna kukuruza

Vesna Dragičević, Milena Simić, Branka Kresović, Milan Brankov

Rezime

Najšire rasprostranjen način gajenja kukuruza je monokultura zahvaljujući njegovoj dominantnosti u setvenoj strukturi. Međutim, plodored ima brojne prednosti u odnosu na monokulturu koje se ogledaju u boljem rastu i prinosu useva. Cilj eksperimenta je da se uporede različiti sistemi gajenja koji uključuju monokulturu kukuruza (M), kao i rotacije kukuruz-ozima pšenica-soja (MWS) i kukuruz-soja-ozima pšenica (MSW), u kombinaciji sa različitim merama kontrole zakorovljenosti: puna i polovina doze herbicida, uklanjanje korova okopavanjem i kontrola – bez kontrole zakorovljenosti, na suvu masu (DM), koncentraciju hlorofila *a* i *b* i karotenoida u nadzemnoj biomasi kukuruza, kao i prinos zrna, na kraju vegetacije tokom tri sezone. Dobijeni rezultati ukazuju da akumulacija suve mase nadzemnih delova u visokom stepenu korelira sa promenama koncentracije karotenoida u listovima kukuruza i da je puna doza herbicida važna strategijacza veće nakupljanje suve mase. MSW se pokazao kao najperspektivniji sistem za povećanje prinosa zrna kukuruza, što je najverovatnije povezano sa smanjenjem u variranu fotosintetskih pigmenata, što upućuje da upravo ovaj sistem gajenja omogućava bolje uslove za asimilaciju i rast useva. Povećanje vrednosti hlorofila *a*, posebno u tretmanu gde su korovi ručno uklanjani su vrlo važne za produktivnost kukuruza. Važna uloga karotenoida je iznova istaknuta, preko zaštite hlorofila *a* od oksidativnog stresa, što doprinosi optimalnoj asimilaciji i povećanju potencijala rodnosti kukuruza.

Ključne reči: prinos zrna, kukuruz, plodored, monokultura, fotosintetički pigmenti, suva masa

Acknowledgment

Research was financed by the Ministry of Science and Technological Development, Republic of Serbia, project TR 31037.

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