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WEEDINESS AND GRAIN YIELD OF SPECIALTY MAIZE HYBRIDS CULTIVATED WITH THE APPLICATION OF ECOLOGICAL FERTILISERS

Milena Simić[1]*, Vesna Dragičević[1], Milan Brankov[1],
Jelena Vančetović[1], Milomir Filipović[1], Jelena Srdić[1]

Summary

Maize hybrids (*Zea mays* L.) with specific traits, such as those with red pericarp, high-protein flints or white kernel hybrids, have increased utility value as they contain some vitamins and minerals beneficial to human and animal nutrition. Furthermore, their cultivation with the application of specific fertilisers could further increase the grain quality through increased participation of macro- and micro-elements that are lacking in the diet.

Agronomic biofortification encompasses the application of different production technology that enables better absorption and effective accumulation of essential elements such as iron, zinc, manganese, copper in the edible parts of cultivated plants. On the other hand, fertilisation influences the weed infestation levels and especially the presence of nitrophilic weed species in maize crop. The fertiliser application changes the balance in competition between crops and weeds, not only for nutrients but also for other resources.

The effects of different fertilisers were compared within developmental research in the field of ecological agriculture to point up the advantages of microbiological and organic fertilisers, since these fertilisers can contribute to higher yields, but unlike mineral fertilisers, they positively affect the soil and agro-ecosystem. The studies were carried out to determine to what extent agronomic biofortification contributed to the increase of yielding potential and grain quality of maize genotypes with specific traits, as well as how it affected the occurrence and distribution of weeds.

The red kernel maize hybrid ZP5048C, high-protein flint maize hybrid ZP737 and white kernel maize hybrid ZP552b, were grown in variants with mineral fertiliser urea, microbiological fertiliser Team Micorriza Plus and organic fertiliser Fertor, that contained essential elements necessary for the nutrition of cultivated plants. No fertiliser was applied to the control treatment.

The fertilisation mainly contributed to the increase of weed mass in comparison with the non-fertilised control variant in extremely dry 2017. The highest weed mass was recorded in the hybrid ZP737 in the variant with organic fertiliser, while the lowest weed mass was recorded in all hybrids when microbiological fertiliser had been applied. The highest, i.e. lowest grain yield was recorded in the hybrid ZP5048C (5.83 t ha^{-1}), i.e. ZP737 (3.36 t ha^{-1}), respectively. The protein content was increased at the highest extent in the kernel of ZP737 hybrid after the application of urea, while oil and starch contents were the highest in the grain of white kernel hybrid ZP552b treated with microbiological fertiliser.

Due to the specificities and importance of meteorological conditions, the studies will be continued during the next few seasons.

Key words: maize, hybrid, fertilisation, weeds, grain yield

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[1] Simić M, Dragičević V, Brankov M, Vančetović J, Filipović M, Srdić J, Maize Research Institute Zemun Polje, Slobodana Bajića 1, Zemun - Belgrade, Serbia

*e-mail: smilena@mrizp.rs

Introduction

Production of raw materials for quality nutrition is based on sustainable cropping principals. In ecological and sustainable cropping systems great attention is paid on application and utilization of nutrients in order to have their efficient and targeted utilization and simultaneously to preserve agroecosystem. Therefore, maize is more often produced after legumes (Videnović et al., 2013a; Osei-Bonsu and Asibuo, 2013), with cover crops (Mahama et al., 2016; Janošević et al., 2017), and balanced application of mineral and organic fertilizers (Simić et al., 2016a).

Different measures which enable better absorption and increased accumulation of essential macro and microelements, such as nitrogen, phosphorous, potassium, iron, zinc, manganese, copper, etc. in eatable plant parts are called biofortification. Agronomic biofortification presents a complex of measures, by which targeted implementation of certain nutrients during cultivation is performed. This leads to the increase of important elements content in grain and produces better quality raw material (Dragičević et al., 2013; Dragičević et al., 2015a; Simić et al., 2017). Moreover, unavoidable part of the biofortification is the promotion of factors that increase absorption of micronutrients, while eliminating factors that interrupt it (Dragičević i sar., 2015b). Certain bio- and organic fertilizers could increase the level of β-carotene, and decrease the level of phytate in maize grain, by elevating essential micronutrients accessibility.

Application of fertilizers is always closely associated with cropping system, yielding potential, needs and traits of soils and crops (Dragičević et al., 2017). Growing popularity of organic principals in crop production points to the increasing need for the introduction of various organic fertilizers, primarily in vegetable, but also in field crops production (Filipović et al., 2012). Different forms and types of fertilizers are available today and they differ by the origin – organic, microbiological, and mineral; by formulation – liquid, solid, granulated, with aminoacids, slow-acting; by the method and time of appliance – soil, foliar, start, basic. Besides that, fertilizing contributes to better crop growth and development and therefore better yielding. Application of fertilizers is an important cropping practice that significantly influences the level of weediness in crops (Simić et al., 2012). Moreover, when applying higher dosages of nitrogen fertilizers, which are essential in maximizing maize yielding potential, especially abundance of nitrophylic species is increased.

Biological and organic fertilizers, as well as biological agents, contribute the better integration of fertilizers, as the cropping practice. Microbiological fertilizers also have an ecological dimension (Mahmoud, 2001). Bio-fertilizers contain microorganisms which assist in nitrogen assimilation, phosphorous solubility and crop growth (Hedge et al., 1999). Thus, fertilization should be a component of integrated cropping system practices (Walker and Buchanan 1982; Simić, 2016), which are applied in order to reduce weediness. In such systems it could be an efficient component when applied in appropriate amounts, formulations, date and place of application – in a row, between rows, broadcasting application (Simić et al., 2016b). Date of fertilization which is adjusted to crops rather than weeds needs greatly influences at the competitive balance between maize and major weeds (Evans et al., 2003). Nutrient content in the soil has also a significant impact on the presence and prevalence of weed species (Lehoczky et al., 2014; Kamuti et al., 2015).

Weeds among other factors could significantly reduce maize yield (Abouziena et al., 2015). According to Lehoczky et al. (2013), in early developmental stages, weeding competition could reduce maize biomass up to 64%. Maize yield is also influenced by water and nutrient supply (Berzsenyi et al., 2011; Várallyay, 2011). As weeds use water and nutrients, on surfaces with their prevalence, the nitrogen content is lower due to the presence of weeds and thus its availability to maize in a part of growing period is decreased (Lindquist et al., 2007).

The effects of different fertilisers were compared within developmental research in the field of ecological agriculture to point up the advantages of microbiological and organic fertilisers, since these fertilisers can contribute to higher yields, but unlike mineral fertilisers, they positively affect the soil and agro-ecosystem. The studies were carried out to determine to what extent agronomic biofortification contributed to the increase of yielding potential and grain quality of maize genotypes with specific traits, as well as how it affected the occurrence and distribution of weeds.

Material and methods

This research was conducted in the experimental field of the Maize Research Institute Zemun Polje, in the vicinity of Belgrade, Serbia (44°52'N 20°20'E) under rainfed conditions in 2017. Zemun Polje is located in a semiarid region with good environment performances for maize growing. The 10-year average precipitation sum during maize growing season (Apr. - Sept.), was 320.2 mm (data provided by the Institute Meteorological Station) and in some years the irrigation was required. The average air temperature during the same period amounted to 20.6 ˚C. The soil was slightly calcareous chernozem with 47 % clay and silt and 53 % sand. The 0–30-cm layer had 3.3 % organic matter, 0.21 % total N, 1.9 % organic C, 14 and 31 mg per 100 g of soil available P and extractable K, respectively, 9.7 % total $CaCO_3$, and pH 7.8.

Red pericarp hybrid ZP5048C, high protein flint hybrid ZP737 and white kernel ZP552b are produced with the application of mineral fertilizer Urea, microbiological fertilizer Team Micorriza Plus, and organic fertilizer Fertor, all containing necessary elements for crop nutrition.The control treatment without fertilization was also included in the experiment.

Urea contains 46% of nitrogen while TEAM MYCORRHIZAE PLUS is mycorrhizae inoculum in a powder form with pH=6 and 56% of organic matter. The fertilizer contains *Glomus intraradices* (150 spores/g) *Glomus mosseae,* (150 spores/g) and bacteria from rhizosphere (300 spores/g). It enhances supplying of crops with nutrients and increases resistance to biotic and abiotic stress. Moreover, mycorrhiza contributes to the higher soil fertility. FERTOR is organic fertilizer in the pellet form. It is manufactured from 100% hen's manure, with the supplement of another plant organic material, which enhances its nutritional value. Beside basic elements – N 4.5%, P_2O_5 2.7%, K_2O 2.3%, CaO 9.3%, and MgO 1.1%, it contains microelements (Fe, Mn, B, Zn, Cu). Fertilizers were applied according to recommendations, before sowing – by the end of April and beginning of May, as followed: Urea 200 kg/ha, Fertor 2500 kg/ha. Team Micorriza Plus was applied on the soil as water solution in concentration 50 g of fertilizer per 10 L of water.

After the standard soil management hybrids were sown on 9th May 2017. Sowing was performed manually by Split-plot design with four replications at 70 cm between rows and 22 cm in-row distance between plants. The elementary plot contained six rows of a hybrid in each replication with the size of 21 m^2. After sowing and prior to emerging, herbicides S-metalachlor+terbuthylazin+glyphosate was applied as a tank mixture, according to labels and across the whole trial as a standard technology in maize cultivation but because of dry conditions their full effect was missed. Fertilizers were applied according to recommendations, before sowing – by the end of April and beginning of May, as followed: Urea 200 kg ha^{-1}, Fertor 2500 kg ha^{-1}. Team Micorriza Plus was applied on the soil as water solution in concentration 50 g of fertilizer per 10 l L of water.

Weediness was estimated by the square meter method, four weeks after maize emergence, on 21st June 2017. The number of species and individuals, as well as weed mass per m^2 was determined. At full maturity, the trial was manually harvested, and yield was measured and calculated to 14% grain moisture. Protein, oil and starch content from yellow and white kernel hybrids were analysed at NIR apparatus (Infraneo, Chopin, France). Obtained data were processed by ANOVA, and differences between means were tested by LSD at 0.05 probability level.

Meteorological conditions

Meteorological conditions in 2017 were dry and unfavourable for maize production. At the beginning of vegetation (April-May) there was abundant precipitation, and the period of extreme drought appeared later on (June-September). A major deficiency of precipitation in June, July, and especially August, coincided with a period of intense growth and development, and the greatest water requirements, which significantly affected maize grain yield and quality.

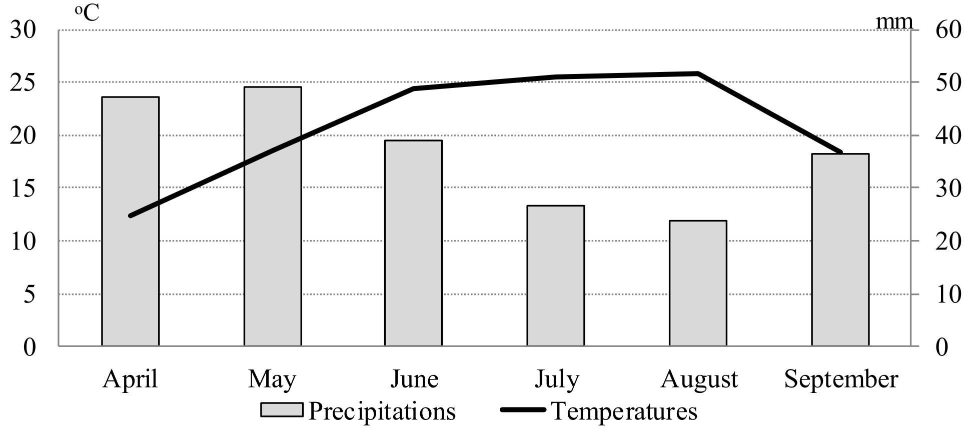

Figure 1. Meteorological data for the maize growing period in 2017. in Zemun Polje
Grafikon 1. Meteorološki uslovi u toku vegetacionog perioda 2017. godine u Zemun Polju

Results and discussion

Obtained data showed that in extremely dry 2017, there were significant differences concerning the level of weediness, and slightly lower differences in maize grain yield of observed genotypes in dependence of applied fertilizer.

At the experimental plot at Zemun Polje, prevalent were annual weed species *Chenopodium album*, *C. hybridum*, *Amaranthus hybridus* and *Solanum nigrum*, and perennials *Sorghum halepense* and *Convolvulus arvensis.* Moreover, those are prevalent weed species in weed associations, most often present in maize in Central Serbia that is characterized for intensive production cropping systems (Stefanović et al., 2011). Concerning meteorological conditions in 2017, obtained data indicate differences in weediness of hybrids, depending on the applied fertilizer. Previous studies, also revealed that on the plots well supplied with nutrients, prevalent were nitrophylic species such as *Chenopodium album* (Kamuti et al., 2015). A composition of weed association is also determined by soil water presence given, that water influences nutrient availability (Lehoczky et al., 2014).

The highest number of weed individuals is noticed in hybrid ZP737 (3.40 individuals per m^2) with the treatment of organic fertilizer (Figure 2). Lowest number of weed individuals was found at plots treated with microbiological fertilizers (1.03, 1.76, and 1.64 in hybrids ZP5048C, ZP737, and ZP552b, respectively). In the treatment with mineral fertilizer Urea, the number of weed individuals in all hybrids was almost the same as in control. This shows that mineral nitrogen fertilizer did not show good efficiency in dry 2017. Under conditions of limited availability of ecological factors, such as water, weeds are more competitive than crops (Simić et al., 2017).

In hybrid ZP737, also the highest weeds mass was established, after the application of organic fertilizer (47.59 g m^{-1}), and significantly lower in all other hybrids at treatment with

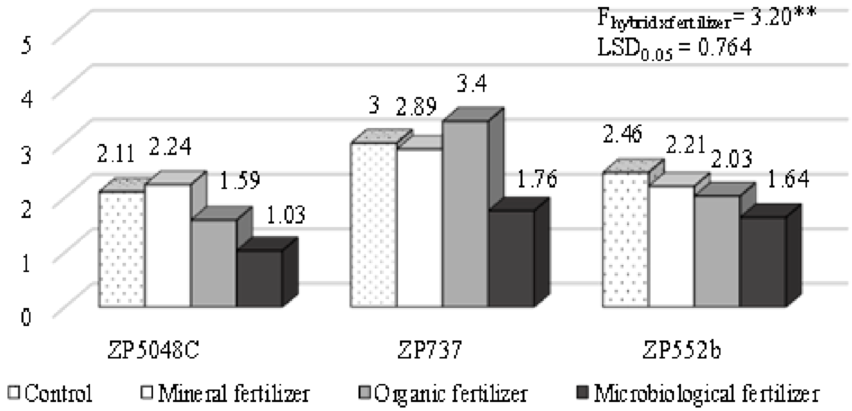

Figure 2. The effect of fertilization on the presence of weed plants (No m[-2]) in investigated hybrids
Grafikon 2. Uticaj đubriva na broj jedinki korova (br m[-2]) u ispitivanim hibridima

microbiological fertilizer. It seems that microbiological fertilizer did not express its full effect under drought conditions, considering that the number of individuals was also the lowest at this treatment. Application of mineral and organic fertilizer, mostly contributed to the increase of weed mass, in comparison to the control, and especially in hybrids ZP5048C and ZP737 (Figure 3). In previous, similar study (Oljača et al., 2017), fresh and dry weed weight was significantly higher in treatments with microbiological fertilizer Uniker in favourable 2014, as well as in dry 2015, followed by treatments with organic fertilizer. Agroecological conditions and amounts of precipitation, i.e. soil water supply, significantly influence the floristic composition and the level of weediness (Várallyay, 2011), thereafter in previous studies speciality maize weed infestations was higher in dry 2015 (Oljača et al., 2017).

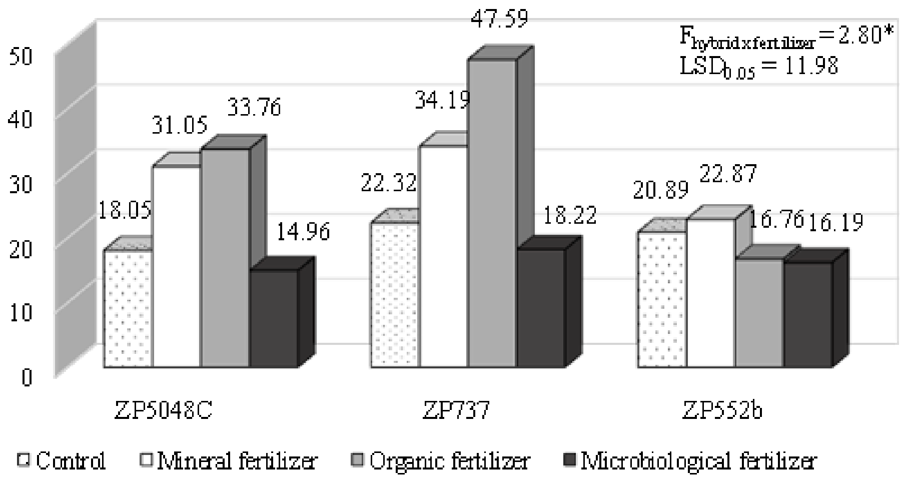

Figure 3. The effect of fertilization on the weed mass (g m[-2]) in investigated hybrids
Grafikon 3. Uticaj đubriva na svežu masu korova (g m[-2]) u ispitivanim hibridima

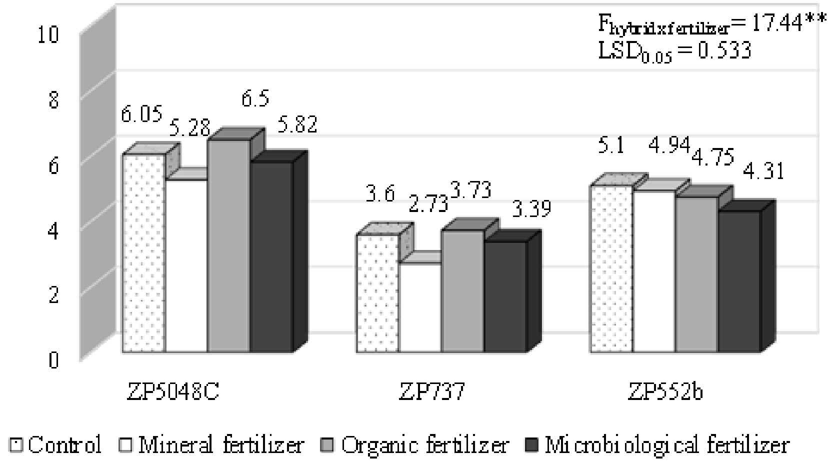

Figure 4. Grain yield (t ha^{-1}) of specialty maize hybrids depending on the applied fertilizer
Grafikon 4. Prinos hibrida (t ha^{-1}) specifičnih svojstava u zavisnosti od primene đubriva

Grain yield of investigated hybrids was low in dry 2017. Average grain yield for all hybrids was 4.68 t ha^{-1}, which is much lower than yielding potential of these hybrids (Videnović et al., 2013b). This is due to the deficiency of precipitation during crucial maize developmental phases. The highest average grain yield over all treatments had ZP5048C – 5.83 t ha^{-1}, and the lowest ZP737 – 3.36 t ha^{-1}. Average grain yields of all hybrids didn't differ significantly according to fertilizer treatment, as well as control. Application of fertilizers during vegetation in maize, under drought stress is not sometimes most efficient for the crop, so hybrids ZP737 and ZP552b, had slightly higher yields in control than in treatments with fertilizers (Figure 4). Nevertheless, when fertilizer treatments were compared, it is established that the highest average maize grain is achieved with the application of organic fertilizer – 6.50 t ha^{-1}, 3.73 t ha^{-1} and 4.75 t ha^{-1}, respectively. Results of the previous researches, also showed that after organic fertilizer application the highest average grain yield was achieved in red pericarp variety Rumenka, and high protein hybrid (Oljača et al., 2016).

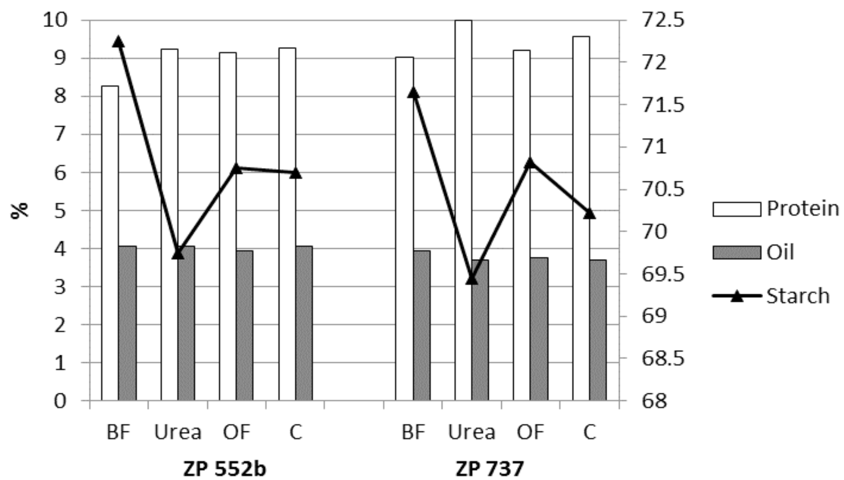

Figure 5. The effects of the application of different fertilizers on protein, oil and starch content in maize grain
Grafikon 5. Uticaj primene različitih tipova đubriva na sadržaj proteina, ulja i skroba u zrnu kukuruza

Beside the weediness and grain yield, application of fertilizers also influenced protein, oil and starch grain content of examined hybrids. The grain of ZP737, on average had higher protein and lower oil content comparing to ZP552b. Treatment with microbiological fertilizer on average produced higher oil and starch content, while higher protein content in maize grain was under Urea treatment. Among all treatments, urea most likely contributed to the grain protein content in ZP737 (Figure 5), while oil and starch content were highest in microbiological fertilizer treatment in ZP552b grain. Moreover, there were no differences in oil content in this hybrid in treatments with urea and microbiological fertilizer. Previous studies showed that extensive maize production conditions, such as monoculture, led to the achievement of lower yield and protein content in grain, and higher oil content, especially on surfaces with no fertilizer application. A significant increase of yield and protein content was noticed by the application of higher dosages of fertilizers, but on the other hand oil content was decreased (Dragičević et al., 2017). Studies of the influence of fertilizers on the maize grain yield and quality, produced under conditions of sustainable and ecological technology, pointed out to the significant contribution of microbiological and mineral fertilizer on the increase of yield and 100 kernel weight in red pericarp variety Rumenka (Simić et al., 2012; Dragičević et al., 2013).

Conclusion

Meteorological conditions, especially precipitation highly influenced effects of applied fertilizers. Application of organic fertilizers increased weed infestation in hybrids of this trial, both concerning number of individuals and fresh mass. Microbiological fertilizer did not increase weed infestation, because under drought conditions it probably did not have full effect.

All hybrids achieved the highest average yields when organic fertilizer was applied. Average grain yield was low due to the drought – 4.68 t ha^{-1}.

Grain protein content was mostly increased in ZP737 after application of Urea, while oil and starch content were highest under microbiological fertilizer treatment in ZP552b.

Application of organic and microbiological fertilizers could contribute to the achievement of higher, quality maize grain yield of investigated hybrids. Agronomic biofortification affects the appearance of weed species and weediness in maize, and total effects of this cropping practice are highly dependent on meteorological conditions during maize production.

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ZAKOROVLJENOST I PRINOS KUKURUZA SPECIFIČNIH SVOJSTAVA GAJENIH UZ PRIMENU EKOLOŠKIH ĐUBRIVA

Milena Simić, Vesna Dragičević, Milan Brankov,
Jelena Vančetović, Milomir Filipović, Jelena Srdić

Sažetak

Hibridi kukuruza (*Zea mays* L.) specifičnih svojstava, poput onih sa crvenim perikarpom, tvrdunci sa povećanim udelom proteinske komponente ili hibridi belog zrna, imaju povećanu upotrebnu vrednost jer sadrže određene vitamine i minerale korisne za ishranu ljudi i životinja. Njihovim gajenjem, uz primenu određenih đubriva, moguće je dodatno povećati kvalitet zrna unošenjem makro i mikorelemenata koji inače nedostaju u ishrani.

Agronomska biofortifikacija obuhvata različite mere gajenja kojima se omogućava bolja apsorpcija i povećana akumulacija esencijalnih mikroelemenata, kao što su gvožđe, cink, mangan, bakar i dr. u jestivim delovima gajenih biljaka. Primena đubriva značajno utiče i na nivo zakorovljenosti useva, posebno nitrofilnim vrstama korova. Unošenjem đubriva menja se balans u kompeticiji između useva i korova, ne samo za hraniva nego i za ostale resurse. U okviru razvojnih istraživanja iz oblasti ekološke poljoprivrede upoređivani su efekti primene različitih đubriva i ukazane su prednosti mikrobioloških i organskih đubriva. Ova đubriva takođe mogu doprineti većem prinosu, ali za razliku od mineralnih đubriva, pozitivnije utiču na zemljište i agroekosistem.

Data ispitivanja su sprovedena kako bi se utvrdilo u kolikoj meri agronomska biofortifikacija utiče na pojavu i zastupljenost korova i doprinosi povećanju rodnog potencijala i kvaliteta zrna specifičnih genotipova kukuruza.

Hibrid kukuruza crvenog perikarpa ZP5048C, hibrid tvrdunac sa povećanim procentom proteina ZP737 i hibrid belog zrna ZP552b gajeni su uz primenu mineralnog đubriva Urea, mikrobiološkog đubriva Team Micorriza Plus i organskog đubriva Fertor, koja sadrže neophodne elemente za ishranu gajenih biljaka. Na kontrolnoj površini đubrenje nije primenjeno. Rezultati su pokazali da u 2017. godini, koja je bila ekstremno sušna, ima značajnih razlika u nivou zakorovljenosti i nešto manjih razlika u prinosu zrna gajenih genotipova zavisno od vrste primenjenog đubriva. Najveća masa korova utvrđena je kod hibrida ZP737 nakon primene organskog đubriva, dok je najmanja masa korova kod svih hibrida zabeležena nakon primene mikrobiološkog đubriva. Đubrenje je uglavnom doprinelo povećanju mase korova u poređenju sa neđubrenom, kontrolnom varijantom. Najveći prinos zrna je imao ZP5048C (5,83 t ha^{-1}), a najmanji ZP 737 (3,36 t ha^{-1}). Sadržaj proteina najviše je povećan u zrnu hirbida ZP737 nakon primene uree, dok su sadžaj ulja i skroba bili najveći u varijanti sa mikrobiološkim đubrivom u zrnu ZP552b. Zbog specifičnosti i značaja meteoroloških uslova za delovanje đubriva na hibride kukuruza, ispitivanja će se nastaviti.

Ključne reči: kukuruz, hibrid, đubrenje, korovi, prinos zrna

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