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# VARIABILITY OF MAIZE LINES IN ABILITY TO USE NITROGEN

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## Abstract

Nitrogen is an important macro-nutrient that influences various physiological processes in plants. Nevertheless, nitrogen could be loosed from the soil by leaching and evaporation. Thus, low nitrogen inputs are required together with a strategy to improve its utilization by crops. Maize genotypes exhibit various susceptibility to low soil nitrogen. From that reason, variability in the reaction of 32 maize lines to growing in conditions with optimal (fertilization with urea), and with low nitrogen (without fertilization) was examined during 2017 and 2018. All other growing measures and fertilization with other elements was applied in the same manner on the whole experimental plot. 2017 was a drier season, with higher average temperatures, particularly during anthesis and grain filling period.

High variability among genotypes and seasons was present. The values of maize grain yield and 1000 grain weight were slightly higher in treatment with nitrogen application. Some lines under the low nitrogen conditions reached even higher grain yields (efficacy of yielding was 139.7% and 156.7%, for 2017 and 2018) than in conditions with optimal nitrogen in the soil, such as L1, L2, L5, L10, L11, L13, L15, L23 and L31, declaring them as genotypes with high nitrogen using efficiency. However, these lines achieved moderate yields (in both treatments and years) in regard to other lines. Among tested lines, L1 and L23 had higher grain yields in both fertilization treatments indicating them as prominent for further research, i.e. breeding of maize hybrids with better nitrogen usage from the soil, even in the conditions with low nitrogen.


***Key words**:* Maize lines, Nitrogen using efficiency, Grain yield, 1000 grain weight.

## Introduction

Nitrogen is an important macro-nutrient that influences various physiological processes in plants, thus affecting yielding potential. Nitrogen is a very mobile element in soil, prone to leaching and evaporation. From that reason, nitrogen deficiency is a worldwide problem in crop production. Zhou and Butterbach-Bahl (2014) unfold that in maize production, about 15% of N applied from fertilizers is leached in the nitrate form worldwide and that suboptimal fertilization rates to a certain extent, which corresponds to 90% of maximum maize could reduce leaching to a minimum. This fact was supported by the results of Kresovic et al. (2010), who obtained that irrigation, i.e. high soil moisture corresponds positively to increased grain yields of maize, but also with greater nitrogen mobility over a soil profile depth. What is more, precipitation amount and especially precipitation distribution is one of the most important environmental factors that affect grain yield and efficiency of durum wheat to use nitrogen. The regular amount, with 80% of total rainfall occurred from sowing to heading could tempt to

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reduce the amount of applied N, without a reduction in grain yield (Ierna et al., 2015). N uptake by crops is dependable not only on environmental conditions and timing of N application but also on N form, whereas urea is the most efficient N form, when compared to ammonium sulphate (AS) and particularly, calcium-ammonium nitrate (CAN) (Abbasi et al., 2013). Based on previous, low nitrogen inputs are required together with a strategy to improve its utilization by crops. One of the important strategies includes a selection of genotypes particularly adapted to low soil N.

According to Chen et al. (2013) breeding of high-yielding and nutrient-efficient genotypes is the most important strategy that can resolve food security, resource scarcity and environmental pollution, at the same time. The positive and linear connection between fertilizer N input and crop N uptake, and accordingly yield increase, is well known. In regard that 40–68% of applied fertilizer could be recycled by the crops, the great difference among them is present (Yan et al., 2014). Historically, contemporary wheat cultivars have lower N requirements, when compared to the older ones (the 1950s) owing to the reduced N concentrations in straw and grain (Hou et al., 2012).

Due to the fact that maize has the highest yield potential, in regards to other cereals, it removes great N amounts from the soil, requiring high N inputs, which contribute to environmental pollution in the form of soil degradation, eutrophication and volatilization. Hojka (2000) and Hojka et al. (2000) indicated that grain yield of maize lines increased significantly with increased nitrogen rate, but line from earlier maturity group (FAO 300) had the highest outtake of nitrogen, together with phosphorus and potassium. It is important to rationally and jointly use fertilizers in the right doses at the right time, as a part of integrated agronomic management (Noor, 2017). The same author underlined the importance of knowledge about assimilatory pathways during source-sink translocation, through modification of proteome and transcriptome, thus to improve nitrogen using efficiency (NUE) in maize. NUE and yield potential expressions in maize are the traits that are very closely related (Al-Naggar et al., 2011). NUE is a complex trait and it requires research and testing of genetic diversity between various germplasm sources. It also includes research on root morphology and length, since lines with better root development have a greater ability for N assimilation, particularly in low N condition (Abdel-Ghani et al., 2013). Garnett et al. (2015) defined transcripts for $NO^{-}_{3}$ and $NH^{+}_{4}$ transporter genes in the root tissue that could serve as sources of genotype's ability to uphold biomass in maize grown under low N, while Wu et al. (2011) estimated broad-sense heritability and connection between grain yield, ear kernel number, kernel weight, plant height, and chlorophyll content, also in low N condition. Due to the genotypic differences in maize ability to grow and achieve yield in conditions of low and high N (NUE), Chen et al. (2013) classified genotypes into four groups: efficient-efficient (EE) have high yield under both low and high N inputs; high-N efficient (HNE) have high yield only under high N input; low-N efficient (LNE) maintain high yield only under low N input, and nonefficient-nonefficient (NNE) with low yield under neither low nor high N inputs.

Maize genotypes exhibit various susceptibility to low soil nitrogen, which was followed by the different response in growth and yielding potential. From that reason, variability in the reaction of 32 maize lines to growing in conditions with optimal (fertilization with urea), and with low nitrogen (without fertilization) was examined.

## Material and Methods

The research was conducted in Zemun Polje, on a slightly calcareous chernozem soil type, during the vegetative seasons of 2017 and 2018, in dry-land conditions, with pH 7.17 and N level of 166 kg ha$^{-1}$ in 2017 and 153 kg ha$^{-1}$ in 2018. Seeds of various 32 maize lines (L1 – L32) were sown at the second half of April, accordingly to the randomized complete block design (RCBD), in three replications, with an elementary plot of 1.75 $m^2$, including two rows of 2.5 lengths with 70 cm inter-row distance and 25 cm between plants in the row. Before sowing, start fertilization was applied by incorporation of 200 kg N $ha^{-1}$ (in the form of urea – 46% N) (N treatment), while the control remained without fertilization (Ø treatment). Preceding crop was winter wheat in both seasons. After its removal, deep ploughing was performed together with the incorporation of 150 kg $ha^{-1}$ MAP (mono ammonium phosphate). In the spring, seedbed preparation was accomplished, before sowing, with urea incorporation (only at N treatment). During vegetation herbicides were applied: in 2017 as pre-emergence - Dual Gold (s-metolachlor) 1,4 l/ha + Terbis (terbuthylazine) 1,5l/ha and as post-emergence - Callisto () 0,25 l/ha + Motivell (nikosulfuron) 1 l/ha, while in 2018 as pre-emergence Dual Gold (s-metolahlor) 1,4 l/ha + Terbis (terbutilazin) 1,5l/ha and as post-emergence Laudis (tembotrion) 2 l/ha were applied.

After harvesting, grain yield was measured and calculated to 14 % of moisture, together with determination of 1000 grain weight. The difference between maize grown with (N) and without N fertilization (Ø) was presented for grain yield, as coefficient of efficiency (CE = Ø×100/N) and for 1000 grains weight, as percentage of grain mass increase (GMI) in favour of maize grown without N fertilization.

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

*Meteorological conditions*: Lower average air temperature and precipitation level were present in 2017 (19.8 °C and 284 mm, respectively) when compared to 2018 (with 21.1 °C and 357 mm, respectively), (Figure 1). When compared to 2018, the higher average temperatures were present particularly during anthesis and grain filling period, during July and August of 2017, for about 1.7 and 1.9 °C respectively, as well as lower precipitation level, for 35.2 and 20.3 mm, respectively.

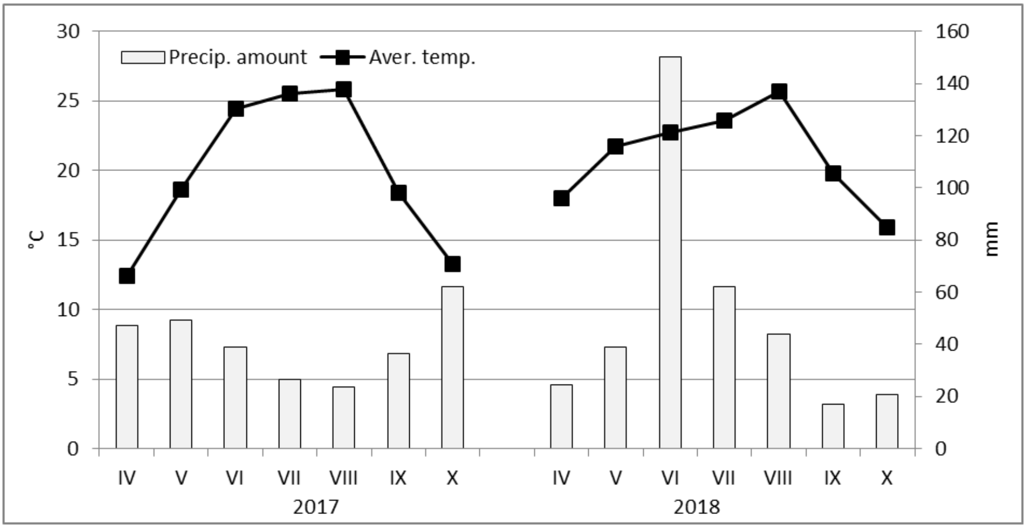



*Figure 1. Average monthly air temperature and precipitation sum during vegetative seasons of 2017. and 2018.*
*Grafikon 1. Prosečne mesečne temperature vazduha i suma padavina za vegetativne sezone 2017. i 2018. godine*

## Results and Discussion

High variability between tested genotypes across conditions was present. Analysis of variance indicates that genotype, year, as well as their interaction with other factors (year and treatment) is the source of significant variations in grain yield and 1000 grains weight (Table 1). Irrespective to insignificant difference between

Ø and N treatment, genotype × N level expressed significant variation of grain yield and 1000 grains weight, similarly to the results obtained by Al-Naggar et al. (2011) who find that genotype is the main source of expression of the yielding potential, as well as nitrogen using efficiency and that these traits are closely related. Hojka et al. (2000) also confirmed that genotype and its interaction with fertilization (nitrogen) rate are the main source of variation in grain yield of maize lines.

*Table 1. Analysis of variance for grain yield and 1000 grains weight for variability induced by year, treatment and genotype*
*Tabela 1. Analiza varijanse za varijabilnost prinosa zrna i mase 1000 semena, uzrokovana godinom, tretmanom i genotipom*

| Source of variation | | Year | Treatment | Line | Y x T | Y x L | T x L | Y x T x L |
|---|---|---|---|---|---|---|---|---|
| Grain yield | F | 75.59 | 1.40 | 11.16 | 25.83 | 17.61 | 5.29 | 8.41 |
| | p | 0.00 | 0.24 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | LSD | 1.48* | 1.61 | 1.18* | 1.48* | 0.83* | 1.22* | 0.85* |
| 1000 grains weight | F | 44.42 | 0.35 | 9.02 | 14.88 | 7.87 | 4.50 | 3.88 |
| | p | 0.00 | 0.56 | 0.00 | 0.00 | 0.00 | 0.00 | 0.00 |
| | LSD | 103.30* | 108.80 | 83.75* | 103.50* | 74.47* | 85.68* | 76.96* |

*Significant at 5% probability level

As it was expected, the values of maize grain yield and 1000 grains weight of the majority of tested lines were slightly higher in the treatment with nitrogen fertilization (Figure 2 and Figure 3). It is also evident that values of grain yield were lower in 2017, when compared to 2018. In similar, Mansouri-Far et al. (2010) and Kresovic et al. (2012) obtained better maize performance in years with higher precipitation amount, as well as under irrigation, underlining that grain weight is particularly sensitive to water shortage. They also find higher water amounts reflects positive on improved N uptake. Besides, in 2017, variability among genotypes and difference between N and Ø treatments in grain yield was greater, while difference between N and Ø treatments in 1000 grains weight was lesser, than in 2018. Beleteet al. (2018) underlined that interaction between genotype, year and their interaction significantly affected nitrogen concentrations in grain and straw of durum wheat, as well as agronomic efficiency, agro-physiological efficiency and apparent recovery efficiency. They also showed that with increase of N fertilization rate decreased wheat efficiency parameters, indicating positive connection between low N inputs and its better usage. Ierna et al. (2015) also exhibited that meteorological factors, presumably precipitation amount runs grain yield and N use efficiency of durum wheat and that optimal rainfall amount and distribution brings upon improved N usage by more efficient genotypes, even at low N inputs.

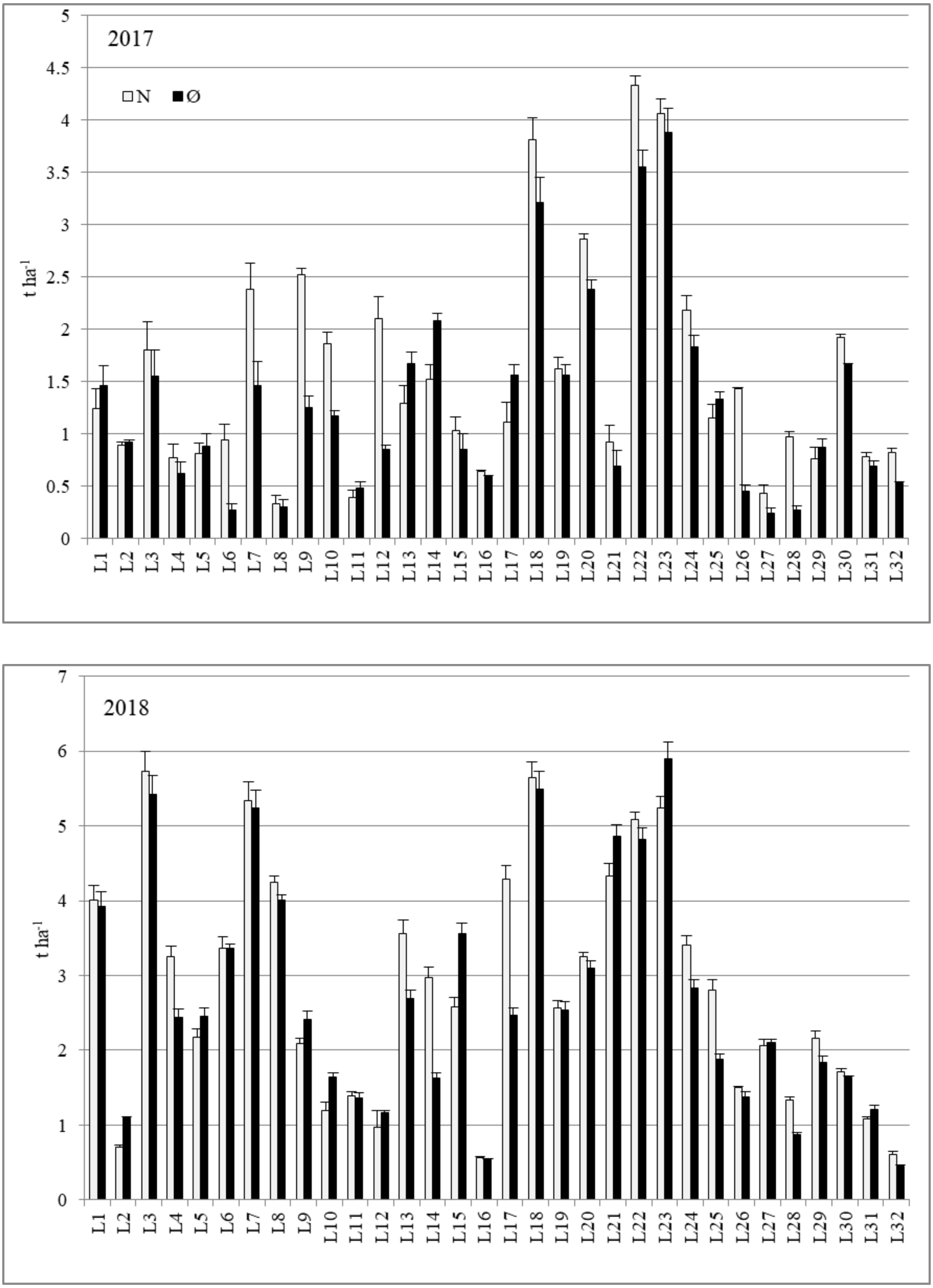
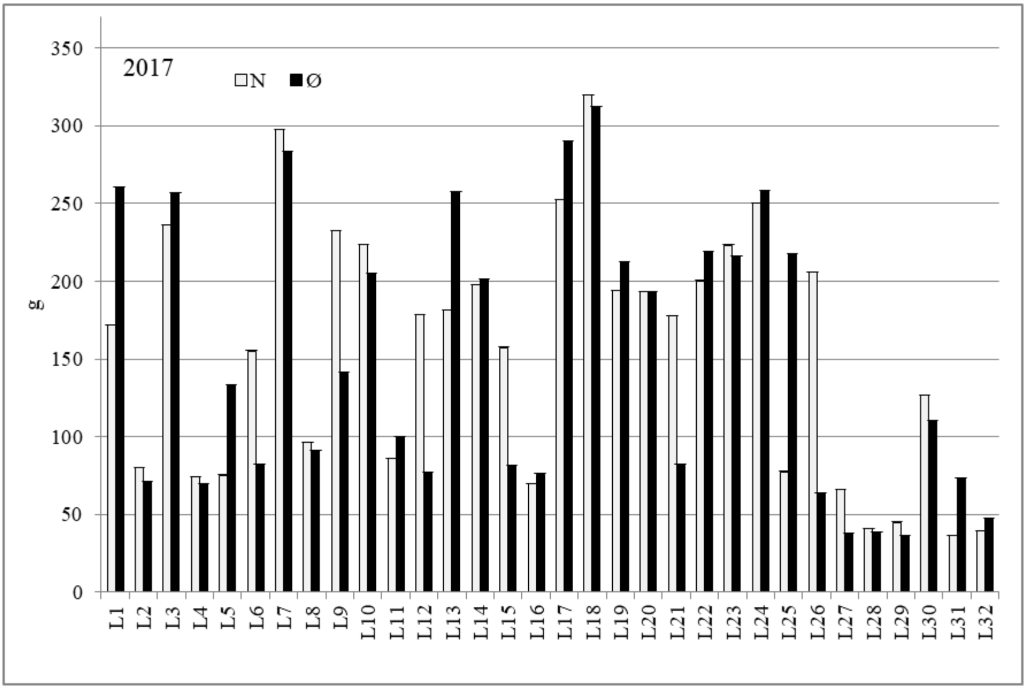



*Figure 2. Variations in grain yield of 32 maize lines grown with N fertilization (N) and without it (Ø) during 2017 and 2018 (results are present as mean ± standard deviation)*

*Grafikon 2. Variranje prinosa zrna 32 linije kukuruza gajene u uslovima đubrenja azotom (N) i bez N (Ø), tokom 2017. i 2018. godine (prosečne vrednosti ± standardna devijacija)*



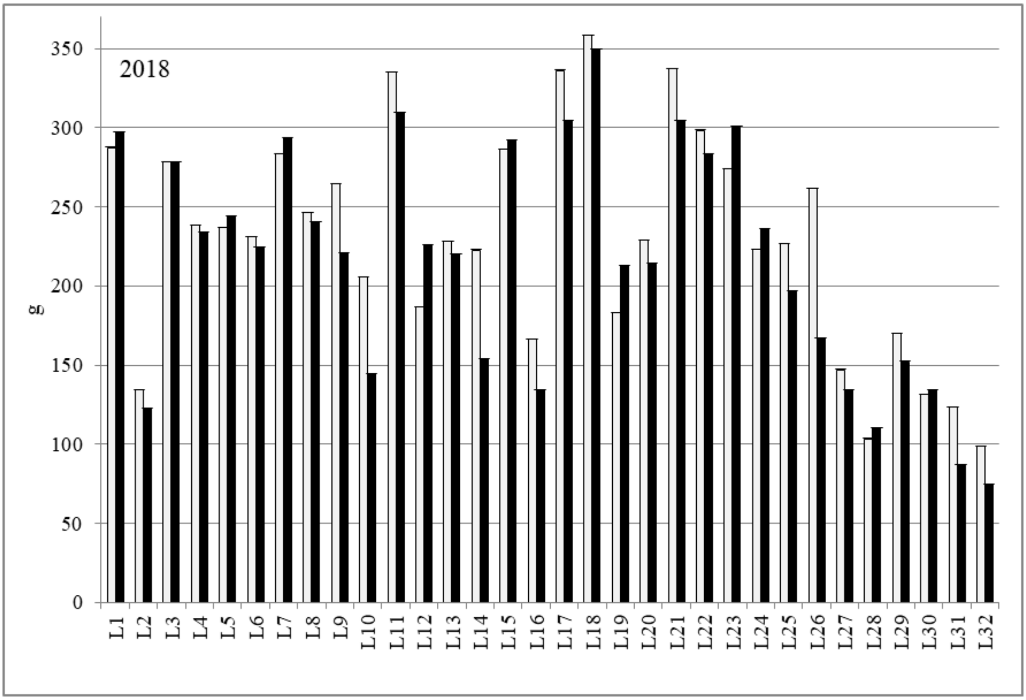




*Figure 3. Variations in 1000 grains weight of 32 maize lines grown with N fertilization (N) and without it (Ø) during 2017 and 2018 (results are present as mean ± standard deviation)*

*Grafikon 3. Variranje mase 1000 semena, 32 linije kukuruza gajene u uslovima đubrenja azotom (N) i bez N (Ø), tokom 2017. i 2018. godine (prosečne vrednosti ± standardna devijacija)*

Some lines under the low N conditions (Ø) exhibited even higher grain yields, such as L1, L2, L5, L10, L11, L13, L15, L23 and L31, than in conditions with optimal soil N, having increased CE values (Figure 4), and declaring them as genotypes with increased nitrogen using efficiency. However, majority of noted lines achieved low to moderate yields (in both treatments and years) in regard to other lines (Figure 2). Hojka et al. (2000) highlighted that increased fertilization rates, especially of nitrogen reflected positive on grain yield increase, while nitrogen outtake is presumable genotype trait. Among tested lines, L1, and L23 had relatively higher grain yields indicating them as prominent for further research, i.e. breeding of maize hybrids with better nitrogen usage from soil, even in the conditions with low nitrogen. The higher GMI values were obtained by L1, L3, L5, L7, L11, L13, L17, L19, L22, L23, L24, L287, L31 and particularly L25 ((GMI ≥ 100%; Figure 4), emphasizing L5, and L25 as a genotypes which are especially able to have greater grains when they were grown on low N, i.e. without N fertilization. Wu et al. (2011) ascertained positive connection between grain weight and other grain yield parameters with N agronomic efficiency, when maize lines were grown on low N. Furthermore, according to Akmal et al. (2010) maize genotypes with better crop growth rate and leaf area profile have also better ability for assimilates uptake, including nitrogen, having as a consequence increased grain yield and grain weight.

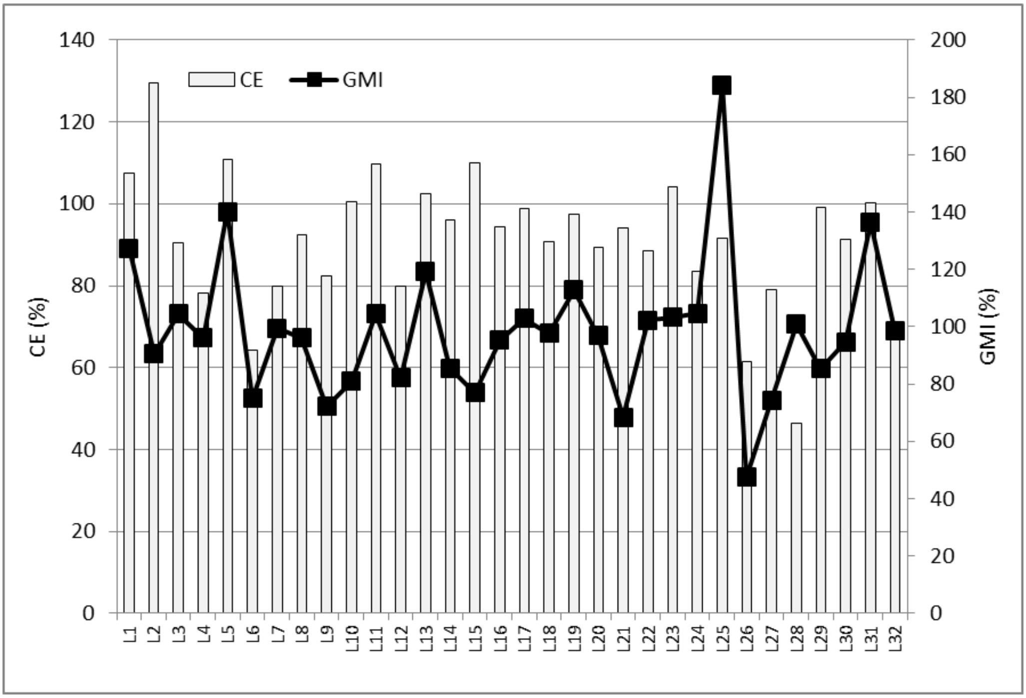



*Figure 4. Coefficient of efficiency (CE) and percentage of grain mass increase (GMI) of 32 maize lines (average of 2017 and 2018)*

*Grafikon 4. Koeficijent efikasnosti (CE) i procenat povećanja mase zrna (GMI) 32 linije kukuruza (prosek 2017. i 2018. godine)*

Chen et al. (2013) gave classification of maize genotypes based on the average yields achieved when they were grown with or without N fertilization into four types, i.e. based on their NUE: efficient-efficient (EE) were efficient under both low and high N inputs, high-N efficient (HNE) under only high N input, low-N efficient (LNE) under only low N input, and nonefficient-nonefficient (NN) under neither low nor high N inputs. Accordingly, genotypes like L18, L22 and L23, had the highest yields obtained in both years and in both treatments and could be defined as EE genotypes; L3, L4, L6, L7, L8, L9, L10, L12, L3, L14, L17, L20, L24, L25, L26 and L30 could belong to HNE group due to the higher yields mainly achieved at N treatment (especially during 2017); L1, L5, L11, L15, L19 L21, L27 and L29 could belong to LNE group, due to the higher yields obtained at Ø treatment, while L2, L16, L28, L31 and L32 could be defined as NN genotypes, owing to the low yields noticed during the both seasons at the both treatments. Lines like L9, L10, L12, achieved higher yields at low N conditions (Ø) in 2018, while L13, L14, L17 and L25 had higher yields at low N in 2017 and they could be partly considered as HNE genotypes.

## Conclusion

Present the high variability among tested maize lines in grain yield and 1000 grains weight, could be a good potential source for examination of high nitrogen using efficiency. Some lines exhibited higher grain yields in conditions of low nitrogen (without fertilization), than under fertilization. Among all tested lines, L1 and L23 achieved higher grain yield in both years, with slight difference in yield when they were grown in non-fertilized and fertilized conditions, characterising them as efficient-efficient genotypes. From this point they could be prominent for further research, i.e. breeding of maize hybrids with better nitrogen usage.

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# VARIJABILNOST LINIJA KUKURUZA ZA ISKORIŠĆAVANJE AZOTA

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**Sažetak**

Azot je važan makro-element koji je uključen u brojne fiziološke procese kod biljaka. Međutim, gubici azota iz zemljišta putem ispiranja i evaporacijom mogu biti veliki, tako da su preporučljivi niži unosi u kombinaciji sa strategijama koje poboljšavaju njegovo usvajanje. Genotipovi kukuruza različito reaguju na nizak nivo azota u zemljištu. Stoga je ispitana varijabilnost u reakciji 32 linije kukuruza na gajenje u uslovima optimalne obezbeđenosti (đubrenje ureom) i niskog nivoa azota (bez đubrenja), tokom 2017. i 2018. godine. Sve ostale mere gajenja i đubrenja sa drugim elementima su primenjene na isti način na celoj eksperimentalnoj površini. 2017. godina je bila sa manje padavina, sa većim prosečnim dnevnim temperaturama, posebno tokom perioda cvetanja i nalivanja zrna kukuruza.

Bila je prisutna visoka varijabilnost između ispitivanih genotipova i sezona. Vrednosti prinosa i mase 1000 zrna su bile nešto niže na delu ogleda bez đubrenja azotom. Na istom delu ogleda su neke linije (L1, L2, L5, L10, L11, L13, L15, L23 i L31) imale čak veći prinos, u odnosu na deo ogleda sa optimalnim nivoom azota u zemljištu (efikasnost prinosa je bila 139.7% i 156.7%, za 2017. i 2018.), karakterišući ih stoga kao vrlo efikasne u smislu iskorišćenja azota. Međutim, navedene linije su ostvarile nešto niže vrednosti prinosa zrna (u oba tretmana i u obe godine) u odnosu na ostale linije. Od svih ispitivanih, L1 i L23 su imale relativno veće prinose u oba tretmana, što ukazuje da bi mogle biti pogodne za dalja istraživanja, tj. u oplemenjivanju hibrida sa boljom efikasnošću iskorišćenja azota čak i u uslovima njegovog niskog sadržaja u zemljištu.

***Ključne reči:*** linije kukuruza, efikasnost iskorišćenja azota, prinos zrna, masa 1000 zrna

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