Sowing and fertilization strategies to improve maize productivity

Violeta Mandić[1]*, Zorica Bijelić[1], Vesna Krnjaja[1], Aleksandar Simić [2], Milena Simić [3], Milan Brankov[3], Snežana Đorđević[4]

[1] Institute for Animal Husbandry, Department of Feed Science, 11080 Belgrade, Serbia
[2] Belgrade University, Faculty of Agriculture, Department of Crop and Vegetable Science, 11080 Belgrade, Serbia
[3]Maize Research Institute, Zemun Polje, 11080 Belgrade, Serbia
[4] Agrounik doo, Research and Development Centre, 11000 Belgrade, Serbia

* Corresponding author: E-mail: violeta_randjelovic@yahoo.com

Keywords: *maize, nitrogen fertilizer, sowing date, qualitative parameters, yield components.*

Abstract

Field experiment was conducted to examine the impacts of two sowing dates (8 April - first date of sowing and 21 April - second date of sowing) and four nitrogen rates (0, 60, 120 and 180 kg ha^{-1}) on the productivity of maize hybrid 'ZP 434' in the Pannonian region of Serbia during 2016 and 2017 seasons. The dry period during late vegetative development and grain filling stage in 2017 decreased ear traits, grain yield, starch and oil contents, nitrogen agronomic (NAE) and nitrogen use efficiency (NUE). The highest number of grains per ear, starch and oil contents, starch and oil yields and lower rainfall use efficiency (RUE) and protein content were obtained from the early sowing date. The ear traits, grain yield, RUE, protein content, oil content and yield of starch, protein and oil significantly increased while NAE, NUE and starch content significantly decreased with increasing nitrogen rate. The results indicated a significant inverse correlation between starch and protein contents, which prevents the improvement of these two parameters simultaneously. Thus, timely sowing and nitrogen input should be used as long term management strategies for increasing maize yield and grain quality.

Introduction

Maize is used as food for humans, as feed for animals and as source of raw material for many agro-based industries. It is grown in 174 countries in the world on about 186 million hectares (FAO 2018). In Serbia, production of maize grain in 2018 was 6,964,770 t grown on 901,753 ha, yielding 7.7 t ha^{-1} (Statistical Yearbook of the Republic of Serbia 2019). The maize is important natural renewable raw material in the sustainable animal feed production in many countries in the world. Thus, about 80% of the Serbian maize production is used for animal feed while 20% for human consumption and in industrial processing (Mandić et al., 2015). In this context improving grain yield and quality parameters can contribute to the stability of the productivity and profitability of farms. In order to increase maize grain yield and qualitative parameters, it is necessary to improve crop and soil management practices. Each maize hybrid has an optimum sowing date for growth and development. Beiragi et al. (2011) observed that delaying sowing reduces physiological maturity, number leaves per plant, number grain per row, ear length, 300-grain weight, ear cob percentage and grain yield of 18 maize hybrids. Tsimba et al. (2013) have concluded that delay in sowing results in reduction in number of the grain per ear, grain weight per ear and grain yield. Koca and Canavar (2014) explained that delay in sowing reduces 1000-grain weight, grain number per ear, ear length, grain yield, protein and oil contents of grain and increases starch content of grain. Coulter et al. (2010) have demonstrated that early dates of sowing (between 21 April and 6 May) in Southwestern Minnesota result in high grain maize yield compared to later date of sowing (until 30 May) when yield was only 80% of the maximum.

Grain yield and qualitative traits of grain also depend on climatic conditions and nitrogen rate given that these factors affect the yield and synthesis of protein, starch and oil in grain. Generally, the nitrogen is the most limiting nutrient for maize grain production and changes starch and protein ratio in grain. Many researchers show that nitrogen application increases grain yield and yield components and changes qualitative traits and other maize parameters. Thus, Delibaltova et al. (2014) have reported that number of rows per ear, number of grains per row, number of grains per ear, ear length, ear weight, grain weight per ear, 1000-grain weight and grain yield of maize crop increase with increasing nitrogen rate from 120 to 240 kg N ha^{-1}. Hammad et al. (2011) have found the highest number of the grain per ear, 1000-grain weight, grain yield and nitrogen use efficiency at 250 kg N ha^{-1}, while grain protein content at 300 kg N ha^{-1}. Khaliq et al. (2009) have found maximum number of grains per m^2, 1000-grain weight and grain yield in treatment with 300 kg N ha^{-1}. Khan et al. (2011) reported that the highest number of the grain per row, number of grain per ear, 1000-grain weight, grain yield and grain protein content was recorded at 300 kg N ha^{-1}. Khayatnezhad et al. (2010) have found that the ear weight, number of rows per ear and grain yield significantly increase with increase in nitrogen rate from 0 up to 150 kg N ha^{-1}. Likewise, Marković et al. (2017) find that the yield components (length, grain weight per ear, number of the grain per ear and 1000-grain weight) significantly increase with increase in nitrogen rate from 0 up to 200 kg N ha^{-1}. However, maize fertilization conducted with nitrogen amount over the optimal level results in reduction of yield and nitrogen losses, leading to negative economic and environmental consequences (Ashraf et al., 2016).

The present study was planned to find optimal sowing date and N rate to improve grain yield and qualitative parameters of maize, considering the hypothesis that the efficiency of applied N changes across diverse environment conditions.

Materials and Methods

Experimental trials and treatments

The experimental plots and trials were conducted at the experimental field of Institute for Animal Husbandry in Zemun (44°84' N, 20°40' E; 88 m a.s.l) in the Pannonian region of Southwest Vojvodina province (Serbia) during the 2016 and 2017 growing seasons. The dent maize hybrid 'ZP 434' (FAO 400 maturity group) was tested at two sowing dates (8 April - first date of sowing and 21 April - second date of sowing) and four nitrogen rates (0, 60, 120 and 180 kg ha^{-1}) were applied.

Plot size was 16.8 m^2. Preceding crop was winter wheat. Plant density was 69.000 plants ha^{-1}. The standard agricultural practices were applied. Fertilizer ammonium nitrate - NH_4NO_3 with 34.4% N produced in "Kuibyshev Azot", Togliatti (Russia) was applied at the five-leaf (V5) to six-leaf (V6) stage at a rate 0, 174.4, 348.8 and 523.3 kg ha^{-1}, respectively.

Soil properties and climatic conditions

The soil was a chernozem (IUSS Working Group WRB, 2014) with the following parameters: C_aCO_3 – 1.41%, pH in KCl – 7.8, humus – 5.17%, total N – 0.258%, phosphorus – 19.08 mg $100g^{-1}$ of soil and potassium – 17.0 mg $100g^{-1}$ of soil.

The rainfall during growing season April-September in 2016 was higher by 140.1 mm while mean monthly temperature was lower by 1.2°C than in 2017 (282.6 mm and 21.0 °C, respectively) (Figure 1). According to Walter and Lieth (1967) climate diagram, in 2016 dry period was short in July at the flowering stage. On the contrary, in 2017 dry period was long and lasted from second half of June to the first half of September (stem elongation stage, flowering stage and grain filling stage). Essentially, rainfall amounts and distribution were more suitable for plant growth in 2016.

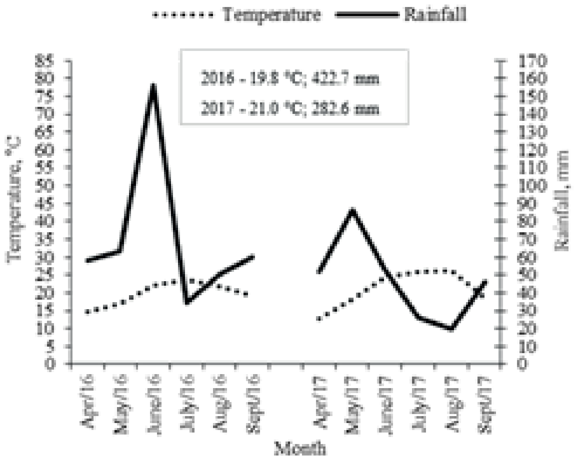

Fig. 1 - Climate diagram of the study site (Zemun 44°84' N, 20°40' E; 88 m a.s.l in the Pannonian region - Serbia) according to Walter and Lieth (1967).

Data collection, qualitative parameters and efficiency traits

In both years, harvesting was done manually during early October. The central two rows from each plot were used to determine grain yield. Grain yield was calculated on a 14% moisture basis. The ear length, number of the grain per ear, weight of grain per ear, 1000-grain weight and qualitative parameters of maize grain were analyzed from ten plants from each sub plot.

Protein, starch and oil content in grain were determined by near-infrared reflectance spectroscopy using NIR Infratec 1241 Grain analyzer (Foss Tecator, Sweden). The starch yield was calculated according to formula: grain yield × starch content, protein yield by formula: grain yield × protein content and oil yield by formula: grain yield × oil content.

Rainfall use efficiency (RUE) is based on the proportionality between grain yield and total seasonal rainfall (Gwenzi et al., 2008), nitrogen use efficiency (NUE) between grain yield and N applied (Moll et al., 1982) and nitrogen agronomic efficiency (NAE) calculated by formula: (grain yield at N treatment - grain yield at zero N)/applied N at N treatment) (Delogu et al., 1998).

Statistical analysis

The trial was set up according to randomized block design with four replications. Statistical analysis of the experimental data included ANOVA and correlation using STATISTICA (version 10; StatSoft, Tulsa, Oklahoma, USA) at significance levels P≤0.05 and P≤0.01. Tukey's test was used to differentiate the significance of treatment means at level P≤0.05. Pearson correlation coefficient was conducted to determine the correlation between studied parameters.

Results and discussion

Maize material choice

The hybrid ZP 434 used in the present study is a medium early hybrid which is grown in Serbia and is very popular for Serbian farmers, firstly because of its remarkable phenotypic plasticity. It is tolerant to higher plant densities and to poor environmental conditions, such as drought. Thus, due to the present trend in climate change, the popularity of this hybrid on market is rising; it represents about 15-20% of Serbian maize sowing choice. At the same time, it is one of the most important export hybrids, especially in the surrounding countries. The hybrid ZP 434 is characterized by excellent early growth and rapid release of water from the grains. Thus, fast maturation and early harvesting time could be convenient maize traits useful to release the soil for the intercropping farming system.

Effect of climatic conditions on studied parameters

Significantly lower ear length (20.8 cm), number of grain per ear (579.7), weight of grain per ear (125.0 g), 1000-grain weight (272.2 g), grain yield (8425.4 kg ha^{-1}), NAE (10.4 kg grain increase kg N applied^{-1}) and NUE (65.8 kg grain kg fertilizer N^{-1}) were recorded in 2017 than in 2016 (21.2 cm, 604.5, 177.3 g, 326 g, 12117.7 kg ha^{-1}, 24.5 kg grain increase kg N applied^{-1} and 97.9 kg grain kg fertilizer N^{-1}, respectively), as reported in Table 1. The lower values of ear traits and grain yield could be explained by unfavorable 2017 weather conditions during tasseling, silking and pollination stage (July) when the size of the ear and number of potential grains per row are determined. Dry stress at this time reduced the number of grains per row resulting in shorter ears and less grains per ear and yield potential.

Table 1 - Year, sowing date and nitrogen rate effects on ear traits, grain yield, rain use efficiency, nitrogen agronomic efficiency and nitrogen use efficiency

Factor[2]/	EL1/	NGE	WGE	TGW	GY	RUE	NAE	NUE
Year (Y)								
2016	21.2^a	604.5^a	177.3a	326.0^a	12117.7^a	28.7^b	24.5^a	97.9^a
2017	20.8^b	579.7^b	125.0^b	272.2^b	8425.4^b	29.8^a	10.4^b	65.8^b
F test (Y)	**	**	**	**	**	*	**	**
Sowing date (SD)								
First date	21.0	603.9^a	153.2	305.9	10426.9	30.2^a	17.7	83.5
Second date	21.0	580.2^b	149.1	292.2	10116.2	28.3^b	17.2	80.2
F test (SD)	ns	**	ns	ns	ns	**	ns	ns
N rate, kg ha^{-1} (N)								
0	20.1^b	548.4^b	124.6^c	259.0^b	8427.1^c	24.2^c	0^d	0^d
60	21.1^a	595.9^a	151.9^b	298.5^a	10359.6^b	29.4^b	32.2^a	172.7^a
120	21.4^a	609.7^a	163.0^a	315.4^a	11108.4^a	31.5^a	22.3^b	92.6b
180	21.5^a	614.4^a	165.2^a	323.3^a	11191.2^a	31.9^a	15.4^b	62.2^c
F test (N)	**	**	**	**	**	**	**	**
Y × SD	**	ns	**	**	**	**	**	**
Y × N	ns	ns	**	ns	**	ns	**	**
SD × N	ns	ns	ns	**	ns	ns	ns	ns
Y × SD × N	**	ns	**	**	**	**	ns	**

[1] Ear length - EL (cm), number of grain per ear - NGE, weight of grain per ear - WGE (g), 1000 grain weight - TGW (g), grain yield - GY (kg ha^{-1}), rain use efficiency - RUE (kg ha^{-1} mm^{-1}), nitrogen agronomic efficiency - NAE (kg grain increase kg N applied^{-1}), nitrogen use efficiency -NUE (kg grain kg fertilizer N^{-1}).

[2] Distinct letters in the row indicate significant differences according to Tukey's test (P ≤ 0.05), ** - significant at 1% level of probability, ns – non-significant.

These ear traits are highly correlated with grain yield because of their direct positive contribution to grain yield (r = 0.50** and r = 0.55**, respectively), (Table 3). Lauer (2012) concluded that rainfall stress during flowering and pollination stages reduces grain yield of maize from 3 to 8% for each day of stress. Also, Yue et al. (2018) found that water stress at these physiological stages reduced number grains per row, number row per ear and grain yield of different maize hybrids. Maize has little capacity to compensate the reduced number of grains by increasing seed size; resulting in a permanent loss of yield. Further, in August 2017 the water stress during grain filling stage substantially shortened grain filling period and reduced grain weight per ear and 1000-grain weight, and hence grain yield. Grain yield resulted strongly positively correlated with these traits (r = 0.97** and r = 0.79**, respectively, Table 3). In general, the drought stress after flowering decreases translocation of assimilates to the grains which results in low grain weight. It should be noted that during both years favorable weather conditions for germination and emergence of maize were recorded. Rainfall Use Efficiency (RUE) is an important parameter for maize stable production in Serbia because maize crop is not irrigated. Usually, RUE values are higher in unfavorable years, indicating the better use of rainfall by plants in dry season. Thus, RUE was higher in 2017 (29.8 kg ha^{-1} mm^{-1}) compared to 2016 (28.7 kg ha^{-1} mm^{-1}). Amount of rainfall (282.6 mm) and distribution were a limiting factor during growing season in 2017 compared to 2016 (422.7 mm) and values of Nitrogen Agronomic Efficiency (NAE) and Nitrogen Use Efficiency (NUE) were significantly lower during 2017 than 2016 (Table 1). Therefore, NAE and NUE depend on the water availability. Our results showed that NAE and NUE were in positive correlation with RUE (r = 0.34** and r = 0.41**, respectively, Table 3). Rainfall and its distribution during maize growing season influence the effect of nitrogen application. Marković et al. (2017) stated that NUE increases with nitrogen rate in extreme wet growing seasons and decreases with N rate in dry summer growing season.

The research highlighted that starch content, protein content, oil content, starch yield, protein yield and oil yield were significantly affected by year (Table 2). These parameters, except protein content were significantly higher in 2016 compared to 2017. It could be supposed that in the present experimental trials the lower

Table 2 - Year, sowing date and nitrogen rate effects on starch, protein and oil contents and starch, protein and oil yields.

Factor[2]/	SC1/	PC	OC	SY	PY	OY
Year (Y)						
2016	70.96^{a}	9.30^{b}	4.13^{a}	8578.3^{a}	1138.4^{a}	500.4^{a}
2017	67.10^{b}	11.08^{a}	3.35^{b}	5662.4^{b}	926.6^{b}	284.6^{b}
F test (Y)	**	**	**	**	**	**
Sowing date (SD)						
First date	69.64^{a}	9.77^{b}	3.88^{a}	7263.4^{a}	1019.9	407.4^{a}
Second date	68.42^{b}	10.61^{a}	3.60^{b}	6977.3^{b}	1045.1	377.6^{b}
F test (SD)	**	**	**	**	ns	**
N rate, kg ha^{-1} (N)						
0	69.78^{a}	9.82^{c}	3.70^{b}	5916.1^{c}	809.0^{c}	316.5^{c}
60	68.91^{b}	10.21^{b}	3.75^{a}	7173.3^{b}	1039.8^{b}	398.3^{b}
120	68.78^{bc}	10.38^{a}	3.74^{a}	7677.4^{a}	1133.1^{a}	426.4^{a}
180	68.66^{c}	10.37^{a}	3.78^{a}	7714.7^{a}	1148.3^{a}	428.8^{a}
F test (N)	**	**	**	**	**	**
Y × SD	**	**	**	**	**	**
Y × N	**	**	**	**	**	**
SD × N	**	**	**	ns	ns	ns
Y × SD × N	**	**	**	**	**	**

[1] Starch content - SC (%), protein content - PC (%), oil content - OC (%), starch yield - SY (kg ha^{-1}), protein yield - PY (kg ha^{-1}), oil yield - OY (kg ha^{-1}).

[2] Distinct letters in the row indicate significant differences according to Tukey's test (P ≤ 0.05), ** - significant at 1% level of probability, ns – non-significant.

temperature and higher amount of rainfall in 2016 during grain filling stage favored synthesis of starch and oil and decreased synthesis of amino acids, determining the inverse relationship of the last mentioned parameters. Protein content showed very strong negative correlation with starch content (r = -0.97**) and oil content (r = -0.89**), (Table 3). Similarly, Randjelovic et al. (2011), Iqbal et al. (2014) and Khan (2016) also reported higher grain protein content due to limited rainfall availability. In literature is reported that hybrids with the highest starch content have the lowest protein content in grain which indicates inverse relationship between these traits (Dudley et al., 2004; Wassom et al., 2008; Ignjatovic-Micic et al., 2014). Starch yield, protein yield and oil yield were significantly higher in 2016 than during 2017, the same trend grain yield resulted higher the mentioned parameters have very strong positive correlation with grain yield. Similarly, Barutçular et al. (2016) reported that reduction in grain yield under stressful condition resulted in in protein and oil yield decline.

Effect of sowing time on studied parameters

Delay of sowing from 8 April to 21 April significantly reduced the number of grains per ear (580.2), RUE (28.3 kg ha^{-1} mm^{-1}), starch content (68.42%), oil content (3.60%), starch yield (6977.3 kg ha^{-1}) and oil yield (377.6 kg ha^{-1}) and significantly increased protein content (10.61%). The delayed sowing caused that maize plants were exposed to more water stress during the growing season, especially during grain filling stage in 2017. This situation induced as consequence increase protein content, as percentage, in maize grain. Accordingly, the sowing date changed grain quality. Buriro et al. (2015) explain that delay of sowing of different maize hybrids, outside of the optimum date, reduces number of ears per plant, ear length, number of grains per ear, grain yield, protein, starch and oil content in the grain. Liaqat et al. (2018) point that the delay in sowing decreases days to tasseling, silking and maturity, plant height, ear height, ear length, number of the row per ear, number of the grain per ear, 1000 - grain weight, biomass and grain yield.

The importance of meteorological factors was underlined, particularly during anthesis and grain filling period, thus proper sowing time could enable avoidance of drought during this critical period. Recently present meteorological changes brought upon dry spring seasons and severe droughts during July and August grain filling period (2012, 2015 and 2017). On the other hand, early sowing dates (end of March - beginning of April) could provide damages that could be induced by frost and delayed germination and start growth. For instance, Gaile (2012) has tested sowing in four different times with 10 days interval and concluded that the grain yield was significantly influenced by the sowing date. Maize grain yield increase is very important because hybrids with genetic potential of 10-15 t ha^{-1} have been grown over 40 years in Serbia but average yields are considerably low (5.5-6.0 t ha^{-1}) and uncertain over years. The maize grain yield is affected by the several factors: growing conditions differ in our country; in Eastern Serbia drought is often present during the growing season; the irrigation, which diminishes negative effects of drought, is applied at only 3% of the maize production area; not all types of soils are appropriate for intensive production - it is estimated, that only 1/3 of the total maize production has been carried out on favourable soils; economic power of producers is weak, so the application of mineral fertilizers is insufficient; machinery is outdated, which is a significant obstacle in cropping technology; fragmentation of arable farms is still characteristic for agricultural production in Serbia, so a high end economic yields cannot be achieved (Videnović et al., 2013; Filipović et al. 2013; Simić et al., 2018).

Effect of nitrogen rate on studied parameters

Ear traits and grain yield were significantly affected by nitrogen rate. This study clearly showed that nitrogen treatments had achieved an overall greater grain yield as compared to control by increasing the ear length, number grain per ear, weight of grain per ear and 1000-grain weight. Nitrogen is key nutrient for stimulation of many physiological processes in plant. Thus, nitrogen promotes the grain-filling, a crucial stage of grain yield formation in maize (Iqbal et al., 2014). Accordingly, N increased grain weight and yield. However, there are no significant differences among rates of 120 and 180 kg N ha^{-1}, hence it may be concluded that rate of 120 kg N ha^{-1} is acceptable and reasonable because of a substantial utilization of N by plants during their growing period. Further increasing N fertilizer application rates would not be economically justified. Therefore, efficiency of medium tested nitrogen dose in maize cropping systems is related to a low cost that is connected with lower waste and lower environmental impact. Many studies have found that the higher grain yield was directly related to the higher ear length, number grain per ear, weight of grain per ear and 1000-grain weight (Iqbal et al., 2014; Ahmad et al., 2018). Kablan et al. (2017) have concluded that maize response to fertilizer N was higher for early planting combined with wet conditions than late planting combined with dry conditions.

All rates of nitrogen applied in this research significantly increased RUE and reduced the NAE and NUE compared to control. An improved RUE is highly recommended, given that it is necessary to best use the small amount of rainfall. Rainfall is the biggest limiting factor in the maize production. Therefore, to maximize production we must seek to maximize the available rainfall. Our results showed that the nitrogen input can be improved by rain use efficiency, especially the application of 120 kg N ha^{-1}. The highest N loss was at 180 kg N ha^{-1} treatment where the lowest values of NAE (15.4 kg grain increase kg N applied^{-1}) and NUE (62.2 kg grain kg fertilizer N^{-1}) were determined. Therefore, the studied hybrid uses available N most efficiently and had greater relocation of plant N to grain yield at 120 kg N ha^{-1}. Generally, too much available N in soil is susceptible to loss through volatilization, denitrification, leaching, and runoff (Ju and Zhang 2017). The decline in maize yield per unit of applied N indicates higher economic cost with severe negative possible impacts on the environment. Hartmann et al. (2015) and Shi et al. (2016) studies also showed that NUE declines with the increase of N rates. Increasing nitrogen fertilization rate from 60 to 180 kg ha^{-1} a decrease in starch content and an increase in protein content were observed in this research. Similar results have been obtained by Holou and Kindomihou (2011) and Iqbal et al. (2014). In addition, Khan (2016) found that starch content in maize grain is reduced with increasing nitrogen fertilization level, while Amanullah and Shah (2009) found that protein content increases with increasing nitrogen fertilization level. Generally, it can be concluded that the nitrogen fertilizer reduced the synthesis of starch and favored the synthesis of protein. The expression of genes related to nitrogen metabolism in maize grown under organic and inorganic nitrogen supplies is reported by Guo et al. (2015). Therefore, nutritive value of maize grain can be altered by the nitrogen fertilizer inputs. N from fertilizer is the important nitrogen source for the biosynthesis of amino acids and the expression of proteins. The high protein content in maize grain provides adequate feed for ruminant animals therefore, so, increasing protein content in grains is significant from the point of view of animal nutrition. On the other hand, maize grain is a very good raw material for bioethanol production due to its high starch content. Our results showed that nitrogen fertilizer significantly increased the oil content compared to control. However, Holou and Kindomihou (2011) did not find variation in the oil content between nitrogen rates, but observed that the nitrogen fertilization increased the oil yield of maize grain. On the other hand, Kaplan et al. (2017) found that application of nitrogen fertilizer significantly reduces the oil content. Generally, the nitrogen is the most limiting nutrient for maize grain yield and changes of starch and protein ratio in grain. Nitrogen fertilization was positive reflected on the starch, protein and oil content, in parallel to the increase of the grain yield

Inferences related to the interaction between factors

Interaction year × sowing date was not significant only for number grain per ear. Interaction year × nitrogen rate was highly significant (P≤0.01) for weight of grain per ear, grain yield, NAE, NUE, qualitative parameters and yields of starch, protein and oil. Interaction sowing date × nitrogen rate was highly significant (P≤0.01) for 1000 grain weight and qualitative parameters. Interaction year × sowing date × nitrogen rate was not significant for number grain per ear and NAE. Maize response to the interactive effect of year × sowing date, year × nitrogen rate, sowing date × nitrogen rate and year × sowing date × SD × N suggests effective N management practices for sustainable maize production.

Correlation between parameters

Results reported in Table 3 show that the grain yield was very strongly positively correlated with starch, protein and oil yields, weight grain per ear and 1000-grain weight. Also, grain yield was positively significantly correlated with other evaluated parameters, except protein content. De Carvalho et al. (2012) and Mastrodomenico et al. (2018) stated that NUE was highly correlated with grain yield under low and high N conditions. Khayatnezhad et al. (2010), Marković et al. (2017) and Yue et al. (2018) found that the grain yield was highly correlated with ear length, ear weight, number of the grains per ear and grain weight. The negative correlations between grain yield and protein content, protein content and oil content and protein and starch contents, make it difficult to improve these traits simultaneously. The high negative correlation between starch and protein contents was also present. Also Seebauer et al. (2010) and Randjelovic et al. (2011) found negative correlation between starch and protein content. Additionally, a study of Abou-Deif et al. (2012) demonstrated negative correlations between protein and oil contents.

Conclusions

In 2017, the second experimental season, unsuitable weather conditions during the late vegetative and grain filling stages caused the reduction in ear traits, grain yield, NUE, NAE, starch content and oil content. Our findings suggest that delayed time of sowing could reduce the starch and oil contents and increases protein content in grain. Differences for grain qualitative traits among different planting dates could depend on different climatic conditions, especially high temperature

Table 3 - Correlation matrix (Pearson) between studied parameters

	EL[1]/	NGE	WGE	TGW	GY	RUE	NAE	NUE	SC	PC	OC	SY	PY
NGE	0.72**												
WGE	0.50**	0.51**											
TGW	0.54**	0.39**	0.74**										
GY	0.50**	0.55**	0.97**	0.79**									
RUE	0.47*	0.39**	0.53**	0.65**	0.56**								
NAE	0.55**	0.62**	0.55**	0.40**	0.59**	0.34**							
NUE	0.39**	0.44**	0.49**	0.39**	0.50**	0.41**	0.79**						
SC	-0.09^{ns}	-0.04^{ns}	0.53**	0.32**	0.53**	-0.19^{ns}	0.14^{ns}	0.06^{ns}					
PC	0.12^{ns}	0.10^{ns}	-0.51**	-0.37**	-0.51**	0.11^{ns}	-0.09^{ns}	-0.07^{ns}	-0.97**				
OC	0.13^{ns}	0.12^{ns}	0.76**	0.55**	0.76**	0.08^{ns}	0.31*	0.28*	0.86**	-0.89**			
SY	0.46**	0.52**	0.97**	0.77**	1.00**	0.50**	0.58**	0.47**	0.60**	-0.58**	0.80**		
PY	0.65**	0.67**	0.89**	0.76**	0.93**	0.73**	0.64**	0.54**	0.19^{ns}	-0.16^{ns}	0.48**	0.89**	
OY	0.42**	0.47**	0.96**	0.74**	0.98**	0.42**	0.56**	0.47**	0.65**	-0.63**	0.87**	0.99**	0.84**

[1]Ear length - EL, number of grain per ear - NGE, weight grain per ear - WGE, 1000-grain weight - TGW, grain yield - GY, rain use efficiency - RUE, nitrogen agronomic efficiency - NAE, nitrogen use efficiency - NUE, starch content - SC, protein content - PC, oil content - OC, starch yield - SY, protein yield - PY, oil yield - OY.

and low rainfall during maize plant life cycle. The insufficient N supply reduced ear traits and grain yield while NAE and NUE increased. The highest N rate exhibited no significant effects on NAE and NUE, determining on the other side highest N loss and lowest NUE. Higher supply of N caused a reduced starch and oil content and increased protein content in maize grain. Taking into account the need for high quality, grain yield and resource use efficiency, the first sowing date and 120 kg N ha^{-1} would lead to an optimal balance between maize yield and sustainable resource use efficiency.

Acknowledgements

The research was supported by the Ministry of Education, Science and Technological Development of Republic of Serbia No 451-03-68/2020-14. Special thanks and gratitude to students of Faculty of Agriculture and Technical School Zmaj from Belgrade and their professors for limitless help.

References

Abou-Deif MH, Mekki BB, Mostafa EAH, Esmail RM, Khattab SAM, 2012. The genetic relationship between proteins, oil and grain yield in some maize hybrids. World J Agric Sci 8:43-50.

Ahmad S, Khan AA, Kamran M, Ahmad I, Aliand S, Fahad S, 2018. Response of maize cultivars to various nitrogen levels. Eu J Exp Biol 8:1-4.

Amanullah K, Shah P, 2009. Timing and rate of nitrogen application influence grain quality and yield in maize planted at high and low densities. J Sci Food Agric 90:21-29.

Ashraf U, Salim MN, Sher A, Sabir SR, Khan A, Pan SG, Tang X, 2016. Maize growth, yield formation and water-nitrogen usage in response to varied irrigation and nitrogen supply under semi-arid climate. Turk J Field Crops 21:87-95.

Barutçular C, Dizlek H, El Sabagh A, Sahin T, El Sabaghand M, Islam MS, 2016. Nutritional quality of maize in response to drought stress during grain-filling stages in Mediterranean climate condition. J Exp Biol Agric Sci 4:644-652.

Beiragi MA, Khorasani SK, Shojaei SH, Dadresan M, Mostafavi K, Golbashy M, 2011. A study on effects of planting dates on growth and yield of 18 corn hybrids (*Zea mays* L.). Am J Exp Agric 1:110-120.

Buriro M, Bhutto T, Gandahi A, Kumbharand I, Shar M, 2015. Effect of sowing dates on growth, yield and grain quality of hybrid maize. J Basic App Sci 11:553-558.

Coulter J, Nafziger ED, Janssen MR, Pedersen P, 2010. Response of Bt and near-isoline corn hybrid to plant density. Agron J 102:103-111.

De Carvalho EV, Afferri FS, Peluzio JM, Dotto MA, Cancellier LL, 2012. Nitrogen use efficiency in corn (*Zea mays* L) genotypes under different conditions of nitrogen and seeding date. Maydica 57:43-48.

Delibaltova V. 2014. Response of maize hybrids to different nitrogen applications under climatic conditions of Plovdiv region. Int J Farming Allied Sci 3:408-412.

Delogu G, Cattivelli L, Pecchioni N, De Falcis D, Maggiore T, Stanca AM, 1998. Uptake and agronomic efficiency of nitrogen in winter barley and winter wheat. Eur J Agron 9:11-20.

Dudley JW, Dijkhuizen A, Paul C, Coates ST, RochefordTR, 2004. Effects of random mating on marker-QTL associations in the cross of the Illinois high protein x Illinois low protein maize strains. Crop Sci 44:1419-1428.

FAO. 2018. FAO statistical yearbook. Food and Agriculture Organization (FAO) of the United Nations, Rome, Italy. Available at http://www.fao.org/docrep/015/i2490e/i2490e00.htm (accessed November 2019).

Filipović M, Srdić J, Simić M, Videnović Ž, Radenović Č, Dumanović Z, Jovanović Ž, 2013. Potential of early maturity flint and dent maize hybrids at higher altitudes. Rom Agric Res 30:117-124.

Guo S, Sun W, Gu R, Zhao B, Yuan L, Mi G, 2015. Expression of genes related to nitrogen metabolism in maize grown under organic and inorganic nitrogen supplies. Soil Sci Plant Nutr 61:275-280.

Gwenzi W, Taru M, Mutema Z, Gotosa J., Mushiri SM, 2008. Tillage system and genotype effects on rainfed maize (*Zea mays* L.) productivity in semi-arid Zimbabwe. Afr J Agric Res 3:101-110.

Hammad HM, Ahmad A, Khaliq T, Farhad W, Mubeen M, 2011. Optimizing rate of nitrogen application for higher yield and quality in maize under semiarid environment. Crop Environ 2:38-41.

Hartmann TE, Yue SC, Schulz R, He XK, Chen XP, Zhang FS, Muller T, 2015. Yield and N use efficiency of a maize-wheat cropping system as affected by different fertilizer management strategies in a farmer's field of the North China Plain. Field Crops Res 174:30-39.

Holou R, Kindomihou V, 2011. Impact of nitrogen fertilization on the oil, protein, starch, and ethanol yield of corn (*Zea mays* L.) grown for biofuel production. J Life Sci 5:1013-1021.

Ignjatovic-Micic D, Kostadinovic M, Bozinovic S, Andjelkovic V, Vancetovic J, 2014. High grain quality accessions within a maize drought tolerant core collection. Sci Agric 71:345-355.

Iqbal S, Khan HZ, Ehsanullah, Zamir MSI, Marral MWR, Javeed HMR, 2014. The effects of nitrogen fertilization strategies on the productivity of maize (*Zea mays* L.) hybrids. Zemdirbyste 101:249-256.

IUSS Working Group WRB. 2014. World reference base for soil resources 2014. International soil classification system for naming soils and creating legends for soil maps. World Soil Resources Reports nr 106. FAO, Rome, Italy.

Ju XT, Zhang C, 2017. Nitrogen cycling and environmental impacts in upland agricultural soils in North China: A review. J Integr Agric 16:2848-2862.

Kablan LA, Chabot V, Mailloux A, Bouchard MÈ, Fontaine D, Bruulsema T, 2017. Variability in corn yield response to nitrogen fertilizer in eastern Canada. Agron J 109:2231-2242.

Kaplan M, Kale H, Karaman K, Unlukara A, 2017. Influence of different irrigation and nitrogen levels on crude oil and fatty acid composition of maize (*Zea mays* L.). Grasas Aceites 68:e207.

Khaliq T, Ahmad A, Hussain A, Ali MA, 2009. Maize hybrids response to nitrogen rates at multiple locations in semiarid environment. Pak J Bot 41:207-224.

Khan A, 2016. Maize (*Zea mays* L.) genotypes differ in phenology, seed weight and quality (protein and oil contents) when applied with variable rates and source of nitrogen. J Plant Biochem Physiol 4:164.

Khan HZ, Iqbal S, Iqbal A, Akbar N, Jones DL, 2011. Response of maize (*Zea mays* L.) varieties to different levels of nitrogen. Crop Environ 2:15-19.

Khayatnezhad M, Gholamin R, Jamaati-e-Somarin S, Zabihi-e-Mahmoodabad R, 2010. Correlation coefficient analysis between grain yield and its components in corn (*Zea mays* L.) hybrids. Am-Eu J Agric Environ Sci 9:105-108.

Koca Y, Canavar O, 2014. The effect of sowing date and yield and yield components and seed quality of corn (*Zea mays*. L.). Sci Papers Series A Agron 57: 227-223.

Lauer J, 2012. The effects of drought and poor corn pollination on corn. Field Crops 28:493-495.

Liaqat W, Akmal M, Ali J, 2018. Sowing date effect on production of high yielding maize varieties. Sarhad J Agric 34:102-113.

Mandić V, Krnjaja V, Bijelić Z, Tomić Z, Simić A, Stanojković A, Petričević M, Caro-Petrović V, 2015. The effect of crop density on yield of forage maize. Biotechnol Anim Husb 31:567-575.

Marković M, Josipović M, Šoštarić J, Jambrović A, Brkić A, 2017. Response of maize (*Zea mays* L.)

grain yield and yield components to irrigation and nitrogen fertilization. J Cent Eur Agr 18:55-72.
Mastrodomenico AT, Hendrix CC, Below FE, 2018. Nitrogen use efficiency and the genetic variation of maize expired plant variety protection germplasm. Agriculture 8: doi: 10.3390/agriculture8010003
Moll RH, Kamprath EJ, Jackson WA, 1982. Analysis and interpretation of factors which contribute to efficiency of nitrogen utilization. Agron J 74:562-564.
Randjelovic V, Prodanovic S, Tomic Z, Bijelic Z, Simic A, 2011. Genotype and year effect on grain yield and nutritive values of maize (*Zea mays* L.). J Anim Vet Adv 10:835-840.
Seebauer JR, Singletary GW, Krumpelman PM, Ruffo ML, 2010. Relationship of source and sink in determining kernel composition of maize. J Exp Bot 61:511-519.
Shi DY, Li YH, Zhang JW, Liu P, Zhao B, Dong ST, 2016. Increased plant density and reduced N rate lead to more grain yield and higher resource utilization in summer maize. J Integr Agric 15:2515-2528.
Simić M, Kresović B, Dragičević V, Tolimir M, Brankov M, 2018. Improving cropping technology of maize to reduce the impact of climate changes. Proceedings of the IX International Scientific Agriculture Symposium "Agrosym 2018", Jahorina, October, 3-7, Bosnia and Herzegovina, 631-639.
Statistical Yearbook of the Republic of Serbia, 2019. Republic Institute for Statistics in Belgrade, Belgrade, Serbia.
Tsimba R, Edmeades GO, Millner JP, Kemp PD, 2013. The effect of planting date on maize grain yields and yield components. Field Crops Res 150:135-144.
Videnović Ž, Dumanović Z, Simić M, Srdić J, Babić M, Dragičević V, 2013. Genetic potential and maize production in Serbia. Genetika 45:667-678.
Walter H, Lieth H, 1967. Klimadiagram-Weltatlas. VEB Gustav Fischer Verlag, Jena, Germany.
Wassom JJ, Wong JC, Martinez E, King JJ, DeBaene J, Hotchkiss JR,Mikkilineni V, Bohn MO, Rocheford TR, 2008. QTL associated with maize kernel oil, protein, and starch concentrations; kernel mass; and grain yield in Illinois high oil x B73 backcross-derived lines. Crop Sci 48:243-252.
Yue H, Chen S, Bu J, Wei J, Peng H, Li Y, Li C, Xie J, 2018. Response of main maize varieties to water stress and comprehensive evaluation in Hebei Province IOP Conf. Series: Earth Environ Sci 108:1-7.