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HARVEST TIME EFFECT ON QUANTITATIVE AND QUALITATIVE PARAMETERS OF FORAGE MAIZE

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ABSTRACT

Maize silage is source of palatable and high-energy forage for ruminants. Therefore, production of high quality forage maize represents an essential strategy for stable production of milk and meat on livestock farms. This study examined the effect of harvest date (early dent, at half milk line, at three quarters milk line and black layer) on the quantitative and qualitative parameters of whole maize plant under contrasting climatic conditions in the Srem - Serbia. A 2 × 4 factorial (two years and the four cutting times) randomized blocks design was used, with three replications. The plant height, stem diameter, number of leaves per plant, forage yield, dry matter yield and dry matter content were higher in 2014 probably due to favorable weather conditions. With the delay of the harvest the forage yield, crude protein content, acid detergent fiber (ADF) and neutral detergent fiber (NDF) decreased, and dry matter yield, dry matter content and ear percentage increased. Sufficiently high dry matter content and ear percentage were achieved at the third harvest. However, the delay of harvested time reduces the quality parameters of the biomass, but this loss in the entire plant is moderated by grain filling.

Keywords: *maize, harvest time, forage yield, forage quality*.

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INTRODUCTION

Whole-plant maize silage is the important component in the diet of ruminants because of the high energy content and good ensiling characteristics (Khan *et al*., 2015) and excellent palatability which is attractive to animals (Khaing *et al*., 2015). The climatic conditions, hybrid type and origin, plant density, planting date, bio-fertilizers, organic and chemical fertilizers and plant stage at harvest are important forage and silage quality determining factors (Moshaver *et al*., 2016; Guyader *et al*. 2018). The optimum harvest time of maize for forage yield, quality, and proper ensiling is when the whole plant has 30-40% of dry matter, and grain milk line from ½ to ¾ (Wiersma *et al*., 1993). The silage harvested early has higher loss of nutritive value due to reduced starch accumulation in the grains and low energy concentration (Neylon and Kung, 2003). On the other hand, silage harvested late has lower nutritional value due to reduced starch and fiber digestion. Delayed harvest results in drying of plants to levels inadequate for suitable ensiling (Marsalis *et al*., 2009). Mandić *et al*. (2018) found that the dry matter content significantly increased, while forage yield, crude protein content, ADF and NDF significantly decreased when harvest was delayed. Similarly, Souza Filho *et al*. (2011) reported that advancing maturity during the grain-filling period increased dry matter content and decreased NDF in maize forage. However, maize forage yield and quality do not just depend on controllable management practices (planting density, N, P and K fertilization rates, harvesting time and harvesting height), but also uncontrollable environmental factors such as drought and heat stresses (Ferreira *et al*., 2015). These environmental stresses during the reproductive stages significantly reduce yield and nutritional value of maize whole-plant (Ferreira *et al*., 2016), and thus cause large economic loss. Also, the plant height, stem diameter and forage yield of maize are significantly reduced under drought and heat stresses (Mohammed and Mohammed, 2019). Drought delays development of the maize plant increases the leaf/stem ratio and reduces the cell wall concentration (Brown, 2017).

The objectives of this study were to evaluate the effects of climatic conditions and four harvest times during grain filling stage on quantitative and qualitative characteristics of whole plant maize.

MATERIALS AND METHODS

Experimental details and treatments: The field experiments were conducted in the southwest region of Vojvodina (Serbia), in the Srem District (location: 45° 01′ N and 19° 33′ E) during 2013 and 2014. The site soil was chernozem. In both research years, immediately after winter wheat harvest (preceding crop), it was done shallow plowing was at a depth of 8-12cm. The deep plowing was carried at the end of October (autumn) at a depth of 30-35 cm. Maize hybrid NS 6043 (FAO maturity group 600) was tested. In both years, the sowing date was April 13. The plant population was 59.000 plant ha^{-1}. Sub-plot area was 2.8 m × 6 m (4 rows, 70 cm inter-row spacing). The plot was set up in a randomized complete blocks design in three replications. The NPK 10:30:20 fertilizer was applied in autumn at a rate of 300 kg ha^{-1}. KAN (27% N) was applied in May at the V6-V7 stages at a rate of 334 kg ha^{-1}. A standard cultivation practice was applied.

The experiments were conducted in rain-fed conditions. The lower monthly total rainfall (275.9 mm) and higher monthly average temperature (19.1 ºC) were recorded in 2013 compared to 2014 (429.0 mm and 18.3 ºC, respectively), Table 1.

The chernozem was the following characteristics: pH in H_2O = 7.12, $CaCO_3$ = 16.45%, total N = 0.18%, organic matter = 3.64%, P = 7.5 mg 100 g^{-1} and K = 17.4 mg 100 g^{-1}.

Table 1. Meteorological data in 2013 and 2014.

Year	Month					Σ / x̄
	April	May	June	July	August	
				Rainfall, mm		
2013	31.9	119.0	62.0	44.7	18.3	275.9
2014	74.2	187.0	37.2	74.9	55.7	429.0
	Temperature, ºC					
2013	13.0	17.4	20.0	22.1	22.9	19.1
2014	12.8	16.1	20.3	21.5	20.6	18.3

Data collection: To determine the plant height, stem diameter and number of leaves per plant, it was ten plants per subplot were measured. These plants were manually cut and divided into stem, leaf and ear to determine their percentage/share in forage. Forage yield was determined by harvesting of two center rows at different times from each subplot using a forage combine harvester. Forage yield was converted into kg ha^{-1}. Four harvest dates during the grain-filling stages were tested by collecting forage on August 12 (early dent), August 19 (1/2 milkline), August 26 (3/4 milkline) and September 2 (no milkline). Forage mass of 1 kg from each subplot was dried at 105 °C to a constant weight to determine dry matter concentration. Dry matter yield was calculated by multiplying the forage yield by the % dry matter content. Crude protein content was determined by the method of Kjeldahl (AOAC, 1990), while the acid detergent fibre (ADF) and neutral detergent fibre (NDF) by the method of Van Soest *et al*. (1991).

Statistical Analysis: The two-way analysis of variance (ANOVA) was used in the analysis of experimental data (plant height, stem diameter, number of leaves per plant, percentage participation of ear, stem, and leaf, forage yield, dry matter yield, dry matter content, crude protein, ADF and NDF), using STATISTICA program (version 10; StatSoft, Tulsa, Oklahoma, USA) as a randomized complete block design with 3 replicates. The Tukey test was used for the comparison of mean values at the level of $p \leq 0.05$.

RESULTS AND DISCUSSION

The plant height, stem diameter, number of leaves per plant, forage yield, dry matter yield and dry matter content were significantly affected by years (Tables 2 and 3).

Values of these parameters were higher in the second year compared to first year. In general, the optimum weather conditions (better distribution and high amount of rainfall and low temperature) throughout the growing period of maize in 2014 had a positive effect on plant height, stem diameter, number of leaves per plant, forage and dry matter yields and dry matter content. In 2013, the higher average monthly temperature and lower monthly total rainfall have been observed from July to harvest, that is, during flowering and grain filling stages which led to lower forage yield. Under unfavorable weather conditions, cell division and cell size are reduced which causes the reduction in plant growth. The hybrid had early stover senescence and therefore lower radiation uptake and biomass accumulation. The temperature and rainfall during the growing period of maize are emerging as a major constraint in realizing high forage productivity and quality (Mandić *et al*., 2018; Saiyad and Kumar, 2018). The percentages of stem and leaf in whole-plant forage yield did not differ among the years, although plant height, stem diameter and the number of leaves per plant were significantly higher in 2014 compared to 2013. Also, the percentage of the ear, crude protein content, ADF and NDF in maize forage did not differ among the years. Percentage of ear in the whole plant of forage was lower than 35% which means that production of maize is not on a profitable basis according to Gaafar *et al*. (2018).

Table 2. Agronomic performance response of maize hybrid to year and harvest time.

Factor	Plant height (cm)	Stem diameter (cm)	Number of leaves per plant	Percentage (%)		
				Stem	Leaf	Ear
Year (Y)						
2013	263.9^{b}	2.32^{b}	14.4^{b}	49.2	28.4	22.4
2014	271.7^{a}	2.48^{a}	15.0^{a}	51.0	27.2	21.8
F test	**	**	**	ns	ns	ns
Harvest time(HT)						
Early dent	267.9	2.39	14.5	51.8	28.9	19.4^{b}
1/2 milkline	267.7	2.42	14.8	50.9	26.3	22.8^{ab}
3/4 milkline	267.9	2.44	14.6	48.3	27.2	24.5^{a}
No milkline	267.7	2.35	14.8	49.4	28.7	21.9^{ab}
F test	Ns	Ns	ns	ns	ns	*
Interactions						
Y × HT	*	Ns	ns	ns	ns	ns
M	267.8	2.40	14.7	50.1	27.8	22.1

Means not followed by the same letter within column are significantly different according to Tukey test ($p \leq 0.05$); *, ** - Significant at the 0.05 and 0.01 probability levels, respectively; ns - non-significant.

Table 3. Forage yield (FY), dry matter yield (DMY), dry matter content (DMC), crude protein (CP), acid detergent fibre (ADF) and neutral detergent fibre (NDF) responses of maize hybrid to year and harvest time.

Factor	FY (kg ha^{-1})	DMY (kg ha^{-1})	DMC (%)	CP (%)	ADF (%)	NDF (%)
Year (Y)						
2013	60072^{b}	18637^{b}	32.50^{b}	7.71^{b}	24.12	49.40
2014	65415^{a}	20960^{a}	33.19^{a}	8.01^{a}	25.07	51.27
F test	**	**	**	ns	ns	ns
Harvest time (HT)						
Early dent	73971^{a}	16644^{d}	22.50^{d}	9.15^{a}	28.63^{a}	58.63^{a}
1/2 milkline	70092^{b}	20220^{c}	28.70^{c}	7.85^{b}	24.78^{b}	50.62^{b}
3/4 milkline	58463^{c}	20470^{b}	35.00^{b}	7.92^{b}	24.58^{b}	50.33^{b}
No milkline	48448^{d}	21860^{a}	45.17^{a}	6.51^{c}	20.38^{c}	41.75^{c}
F test	**	**	**	**	**	**
Interactions						
Y × HT	**	**	**	**	**	**
M	62744	19799	32.84	7.86	24.59	50.33

Means not followed by the same letter within column are significantly different according to Tukey test ($p \leq 0.05$); ** - significant at the 0.01 probability level; ns - non-significant.

The ear percentage, forage yield, dry matter yield, dry matter content, crude protein content, ADF and NDF were significantly affected by harvest time. With the delay in harvesting, forage yield, crude protein content, ADF and NDF decreased and ear percentage, dry matter yield and dry matter content increased. Significantly higher forage yield (73.971 kg ha^{-1}), crude protein content (9.15%), ADF (28.63%) and NDF (58.63%) and significantly lower ear percentage (19.4%), dry matter yield (16.644 kg ha^{-1}) and dry matter content (22.50%) were recorded in the first harvest time (early dent stage) compared to other times of harvest. Similar trend have been reported by Gaile (2008) and Opsi *et al*. (2013) who observed increase ear percentage, dry matter yield and decrease in fresh forage yield, NDF and ADF of maize as maturity advanced. The lowest ear percentage was at the first harvest when the grain was not yet developed. The higher ear share provides better nutritional value of maize forage because the grain contains a higher amount of crude protein and soluble carbohydrates and lower fibre content compared to stem and leaves (Nazli *et al*., 2019). The delay harvest time provides an opportunity to accumulate higher amounts of dry matter, and decreases NDF and ADF due to dilution effect of the increasing amounts of starch (Cone *et al*., 2008). Generally, drying maize grain increased the dry matter content with delaying harvest. Essentially, whole-plant fibre content decreases as the starch content of the grain increases with advancing maturity likely due to the increasing percentage of grain (Andrae *et al*., 2001). These authors find that the maize plant maturity decreases digestibility of dry matter, content of starch, NDF and ADF. In our case, forage has optimum dry matter content for harvesting (35%) at third harvest time. Also, Lee *et al*. (2005) suggested harvesting maize before black layer formation at near 35% dry matter content to obtain high forage yield with optimum nutritive values. At first and second harvesting times, the forage has dry matter content of less than 32% (22.50 % and 28.70%, respectively), the mass was wet and difficult to ensile, and therefore later the silage appears to have high acetic acid content and high nutrient losses caused by runoff. Maize forage has 45.17% of dry matter content at fourth harvesting time. If the dry matter is higher in forage, it will be difficult to compress when packing. In generally, fermentation is restricted in the silage with a high dry matter concentration and digestibility of fibre and starch is low. Weather delays of harvest result in a significant drying of maize plants to levels inadequate for ensiling. Similar, Weiss (2008) also found significantly positive correlation between dry matter content and maturity. Accordingly, dry matter content significantly increased with increasing harvest maturity of maize. The crude protein content of the forage maize was low and ranged from 6.51 to 9.15%. The decrease in protein should be attributed to the greater proportion of grain contains mostly starch in the more mature whole-plant maize. Plant height, stem diameter, number of leaves per plant, stem percentage and leaf percentage are not influenced by the time of harvest. The number of leaves and stem diameter were not significantly different among different harvesting stages because of the vegetative growth completion during silking stage in tandem with the constant plant height.

There were significant effects of interaction between year and harvest time on plant height, forage yield, dry matter yield, dry matter content, crude protein content, ADF and NDF.

Conclusions: It may be concluded that maize silage should be harvested at three-quarter milk stage for proper dry matter content and better quality. However, the climatic conditions influence the agronomic performance of plants, forage yield and dry matter yield.

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