Nitrogen Fertilization Effect on Biomass Yield of Six Different *Sorghum bicolor* Varieties

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Abstract. Sorghum belongs to the *Poaceae* family and it is used for its high biomass production. A field experiment was conducted using a factorial split-plot design with three replicates and twenty-four plots per replication. The main factor was the different varieties (V_1: Buffalo grain, V_2: Elite, V_3: Big Kahuna, V_4: 25K1009, V_5: 4264 and V_6: 5D61) and the sub-factor the different nitrogen fertilization levels (N_1: 0, N_2: 80, N_3: 160 and N_4: 240 kg ha-1, using urinary ammonia 40-0-0). In the case of fresh biomass weight, the variety "25K1009" produced the higher yield, followed by "Big Kahuna" and "Elite" with 66.9, 65.27 and 63.03 t ha^{-1} respectively, which are statistically significantly higher compared to the yield produced from the other three varieties. The same was also found in the case of the dry biomass weight. The increase in the fresh biomass weight was higher between the higher n-application (160 and 240 kg N ha^{-1}) reaching the 9 t ha^{-1}.

Keywords: Sorghum; biomass; yield; nitrogen.

1 Introduction

The mechanization of agriculture led to the intensification of agriculture and the over-exploitation of land. This practice has resulted in a reduction in soil fertility and a consequent increase of the cultivation cost and the reckless overuse of fertilizers. Various suitable systems are used for soil remediation or maintenance of soil's fertility as well as the increase of productivity, such as crop rotation with legumes, inoculated crops, co-crops, green or organic fertilizers, etc. (Ball et al., 2005). It has been reported that corn - soybean rotation can increase corn yield up to 5-30% (Marburger et al., 2015; Stanger & Lauer 2008). Crop rotation along with fallow and green manure are the oldest and most substantial agricultural practices. The change of crops with the system of crop rotation or the intermediate cultivation helps to reduce harmful enemies that appear in the monoculture system such as insects, diseases and weeds (Castellazi et al., 2008; Pantoja et al., 2015). These cultivation practices affect the nitrogen cycle in soil, and they consist the major source of

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nitrogen enrichment by binding the atmospheric N and making it available for successive crops (Powlson et al., 1987; Biederbeck et al., 1996; Lucker et al., 2010). Through these practices it is succeeded a better pest management, an enrichment of the soil microbial community and a protection of the soil erosion (Chamberlain et al., 2020). Cultivation of legumes can improve nitrogen levels in the soil and increases the yield of the following crops (Wang et al., 2017; Peralta et al., 2018).

Sorghum belongs to the *Poaceae* family and it is one of the most significant cereals used for its high biomass production, as animal feed in the semi-arid, tropical regions due to its ability to grow at high temperatures and dry conditions in areas where no other crops can be grown (Morris 2006; McCary et al., 2020). Globally, sorghum is one of the top cereal crops, ranking fifth in cereals after maize, wheat, rice and barley, with 57.6 million tons of annual production worldwide in 2017 (FAO). *Sorghum* is known for its excellent adaptability, which enables it to grow in a wide variety of climates. It is drought tolerant, heat resistant and can grow at high altitudes, in alkaline and barren soils, due to the fact that it has a well-developed root system with a high root-to-leaf ratio (Rooney & Waniska, 2000). Today, there are many varieties and hybrids as it is a multi-purpose plant. The yield of sorghum in Greece depends on the cultivated variety, the sowing season, the irrigation, the fertilization as well as the soil and climatic conditions of each area. The production potential of sorghum ranges from 20-40 tons per hectare per dry weight, which means 100-120 tons per hectare of fresh weight per year.

It is reported that sorghum is a crop with high biomass yield due to its C4 photosynthesis efficient (Zegada-Lizarazu et al., 2012; Wortmann et al., 2010; Xu et al., 2018), a crop with a high soil-climatic adaptability (Teetor et al., 2011) and a crop of high nitrogen and water use efficiency with a short life cycle (Stone et al., 2001; Farré and Faci, 2006; Ananda et al., 2011).

Legumes plants such as previous cultivation can improve sorghum yields by helping farmers, especially in the poorer parts of the world (Bagayoko et al., 2000; Bado et al., 2006). All types of legumes and especially peas significantly increased the yield of the following cereal crop compared with cereals that had grown in a monoculture system. In the case of sorghum that grow as monoculture the reached grain yield was about 1.08 (t ha^{-1}) while when sorghum was grown after legume cultivation, it was reached a yield of 1.18 (t ha^{-1}) (Franke et al., 2018). Experiments conducted by Bado et al., (2011) that lasted 4 years shown that compared to monoculture, rotation sorghum with pea can increase sorghum yield from 50% to 300%. It has been observed that legumes as a previous crop enrich the soil with available nitrogen for the following sorghum cultivation, resulting in an increased yield of 20-30% (Giller et al., 1995).

The aim of this study was to determine the most suitable variety of sorghum and the most effective nitrogen fertilization dose to improve the production of biomass in a field where the previous crop was the pea for silage production.

2 Materials and Methods

A field experiment was conducted in a clayey soil with an alkaline reaction in both the surface and sub-surface soil horizon. It is particularly fertile with a percentage of organic matter of 2.91% at a depth of 0-30 cm and 1.86% at 30-60 cm.

A factorial split-plot design was used with three replicates (blocks) and twenty-four plots per replication. The main factor was the different varieties (V_1: Buffalo grain, V_2: Elite, V_3: Big Kahuna, V_4: 25K1009, V_5: 4264 and V_6: 5D61, six varieties in total) and the sub-factor the different nitrogen fertilization levels (N_1: 0, N_2: 80, N_3: 160 and N_4: 240 kg ha^{-1}, using urinary ammonia 40-0-0) with three replicates. The occupied area of each plot was 42 m^2 (6 m wide and 7 m long).

Initially, in the fall, pea was sown (11/21/2018, Olympus variety) with a quantity of 140 kg ha^{-1} of seeds. Pea biomass harvest took place on 5/29/2019, and thereafter the field was cultivated for the sowing of the six varieties of sorghum. Sorghum sowing took place on 5/6/2019, Plant distance was 50 cm between the lines (for the first three varieties V: 1-3) and 75 cm between the lines (for the rest V:4-6) while the plant distance on the line was 8 cm, for all varieties, according to the established correct practice (and the characteristics of the varieties). The surface nitrogen-fertilization was carried out on 20/7/2019. Control of broadleaf weeds took place using a chemical herbicide after sorghum germination, while no approved formulation was found for the herbaceous plant, as a result of the weed *Sorghum halepense*, which belongs to the same genus. Therefore, *Sorghum halepense* was controlled manually.

The final harvest took place on October 25, where 1 m^2 cut from the inner area of each plot in order to minimize the boarder effect. The plants were weighed at once and afterwards two representative plants were selected for further laboratory analysis.

Complete weather data were recorded by an automated meteorological station, which was installed next to the experimental field.

Finally, the analysis of variance (ANOVA) within sample timings for all measured and derived data was conducted using the statistical package GenStat (7th Edition). The $LSD_{0.05}$ was used as the test criterion for assessing differences between means (Steel and Torrie, 1982) of the main and/or interaction effects.

3 Results and Discussion

3.1 Climatic data

The experimental area is characterized by a typical Mediterranean climate. During summer months the average recorded air temperature was 25.8^{o}C, which decreased by 4^{o}C in September (Fig. 1).

The recorded precipitation for the summer months was only 46 mm of which 60% occurred in July. In September there was recorded a precipitation of 21 mm (Fig. 1), making the growing year very dry and adverse. Due to the significant rainfall (28 mm) that recorded in the second ten days of July, there was accompanied a significant drop in temperature.

Sorghum base growing temperature is 13°C (*Ferraris* and *Charles-Edwards*, 1986), while the favor temperature growth range is 20-30°C, which was consistently reached by June and maintained until end of September.

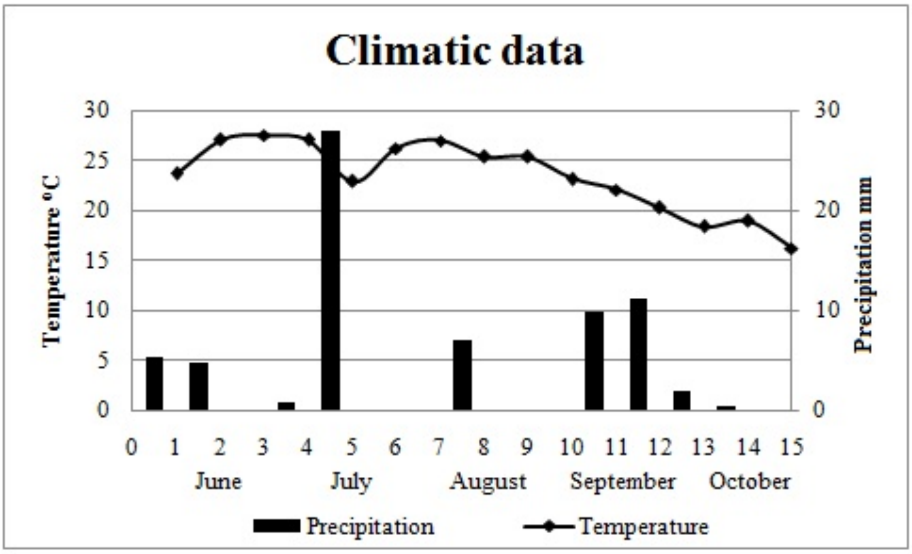

Fig. 1. Average air temperature and precipitation occurred during sorghum cultivation.

3.2 Biomass Yield

Table 1 shows the fresh and dry yield of the tested sorghum varieties at harvest. In the case of fresh biomass weight the variety "25K1009" produced the higher yield, followed by "Big Kahuna" and "Elite" with 66.9, 65.27 and 63.03 t ha^{-1} respectively, which are statistically significantly higher compared to the yield produced from the other three varieties.

The increase in nitrogen fertilization produced significant higher fresh biomass yield. Biomass production followed the principle that the higher the nitrogen fertilization, the higher the production was (Table 1). The same was also found in the case of the dry biomass weight. The increase in the fresh biomass weight was higher between the higher n-application (160 and 240 kg N ha^{-1}) reaching the 9 t ha^{-1}.

Regarding the interactions of the factors, the highest yield in fresh and dry weight was achieved in the variety "25K1009" for the higher n-fertilization level (240 kg N ha^{-1}; Table 1).

The measured yields of the tested varieties were lower than expected (Mrvova et al, 2018), which may be due to the delayed establishment of the sorghum as a result of the existence in the field of the previous pea cultivation as an intermediate crop. Furthermore, the lower yield may be due to the competition of the cultivation with a weed of the same genus (*Sorghum halepense*), for which an attempt was made to reduce the population manually since there are no herbicides that would not affect the cultivation.

Table 1. Fresh and dry biomass yield of the tested varieties as affected by the different N-fertilization levels (0, 80, 160, and 240 kg N ha-1).

			Fresh Biomass	Dry Biomass
			t ha^{-1}	
Varieties	**Buffalo Grain**		35.58	9.07
	Elite		63.03	14.69
	Big Kahuna		65.27	11.53
	25K1009		66.90	16.15
	4264		45.36	10.96
	5D61		38.54	10.56
LSD.05			***5.265***	***1.991***
N-fertilization	**0**		44.52	10.81
	80		48.80	11.82
	160		53.64	12.01
	240		62.83	13.98
LSD.05			***4.439***	***1.275***
Interaction (Varieties X N-fertilization)	**Buffalo Grain**	**0**	32.40	8.84
		80	33.17	8.86
		160	36.63	8.76
		240	40.13	9.81
	Elite	**0**	60.30	15.43
		80	60.90	13.99
		160	62.17	14.18
		240	68.77	15.15
	Big Kahuna	**0**	54.40	9.79
		80	57.23	10.61
		160	66.90	11.67
		240	82.53	14.04
	25K1009	**0**	53.00	13.05
		80	62.85	16.51
		160	68.62	15.63
		240	83.12	19.44
	4264	**0**	32.25	7.83
		80	42.05	10.16
		160	48.05	11.58
		240	59.10	14.25
	5D61	**0**	34.80	9.89
		80	36.58	10.91
		160	39.47	10.23
		240	43.32	11.20
LSD.05			***ns***	***ns***
CV (%)			***12.5***	***15.5***

The produced biomass yield is higher than the reported yield (Buxton et al., 1999; Regassa and Wortmann, 2014; Wannasek et al., 2017). The dry biomass of the unfertilized treatments in the current study is higher compared to the reported yield of 23 t ha^{-1} (Pannacci and Bartolini, 2018). The dry yield of all tested varieties had been significant affected by nitrogen fertilization which has been reported in previous studies (Ayoub et al., 2003; Pholsen and Sornsungnoen, 2004; Pholsen and Suksri, 2007).

4 Conclusions

Six sorghum varieties were grown in 2019 to determine the effect of N fertilization of the most productive variety when grown after pea into a rotational system. Regardless of the delayed sowing of sorghum, the variety with the highest biomass production (66.9 t ha^{-1}) was the "25K1009", recorded to the treatment of the highest N-fertilization level (240 kg N ha^{-1}). Based on the above results, it could be concluded that the higher the nitrogen application is, the higher the sorghum biomass (fresh and dry) yield is produced. Furthermore, a legume—cereal system could be introduced into cultivating systems as a second nitrogen supplier to subsequent crops.

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