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EFFECTS OF FERTILIZATION AND ROW SPACING ON GRAIN SORGHUM YIELD GROWN IN SOUTH-EASTERN ROMANIA

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Abstract

The paper presents the results of a research conducted during 2014-2016 with the purpose of identifying the optimal interaction of technological factors for the cultivation of grain sorghum (sowing distance x fertilization level), in order to optimize the yield of crops grown in South-East Romania. The research was carried on a soil chromic luvisol using ten fertilization levels and two sowing distances between rows. Results show that both sowing distance and fertilization had a statistically significant influence on sorghum's grain yield. The most favourable combination of technological factors, which ensured a maximum yield of 9.22 t/ha, was represented by sowing sorghum at the distance of 70 cm between rows and using a fertilization level N_{120} P_{60} K_{60}. Compared to the sowing distance of 50 cm between rows, the sowing distance of 70 cm between rows generated yield increases between 0.21 t/ha and 0.48 t/ha.

***Key words**: Sorghum bicolor L .(Moench), mineral fertilization, sowing distance, rainfall, yield.*

INTRODUCTION

Although grain sorghum crop is well adapted to different environmental conditions, the need to optimize its yield is still a challenge. Sorghum grows in areas with rainfall below 450 mm/year (Aleminew, 2015), thus the specialized literature (Sarca et al., 2004; Staggenborg et al., 2008) recommends being cultivated in restrictive climatic and soil conditions. Research analyzing grain sorghum suitability to the conditions in South-East Romania (Pintilie et al., 1970; Matthew, 2011; Oprea et al., 2016) highlight yield levels that support crop's cultivation opportunity in this region. However the variability of climatic conditions in the area and the tendency of aridity (Marin et al., 2016) affect yield's stability, given that water scarcity is, nevertheless, a limiting factor for sorghum crop in terms of using nutrients obtained through fertilization (Lemaire, 1996). Moreover, in low rainfall conditions plants' density is a factor that requires attention in terms of yield optimization (Stanggenborg, 1999; Fromme, 2012; Fernandez, 2012). In this context, the objective of the research is to identify cultivating factors interaction that ensures an optimum yield level in correlation to the climatic conditions of South-Eastern Romania.

MATERIALS AND METHODS

The research was conducted during 2014-2016 on a chromic luvisol at the Didactic and Experimental Farm Moara Domnească of USAMV Bucharest (44°30' latitude, 26°13' longitude). Weather conditions of the area are characterized by a yearly rainfall amount of 556.1 mm and an annual average temperature of 10.5°C.

Analysis of weather parameters (temperature and rainfall) during plants vegetative period, reflect some variability as compared with the normal values (Table 1). The average temperature during the growing season of sorghum plants has provided a number of useful thermal units (t>6°C) of 1923°C, higher than the hybrid requires (1850°C). Analyzing rainfall, their average volume in the months May to August was 38.3 mm (14.3%) lower than the normal value of the area, but showed a different distribution.

Thus, after sowing (May), at flowering and grain filling period (July) rainfall records were 5.2% and 75.0% lower than the multiannual values. In the vegetative growth stage (June) and near physiological maturity (August), the average rainfall recorded in 2014-2016 were by 9.9% and 7.9% higher than the normal values.

Table 1. Climatic conditions during sorghum plant's vegetative period at Moara Domnească, Ilfov

Months of the vegetative period	Temperature (°C)		Rainfall (mm)	
	Average 2014-2016	Normal	Average 2014-2016	Normal
May	17.9	16.5	64.2	67.7
June	21.1	20.2	94.9	86.3
July	24.1	22.1	15.8	63.1
August	23.8	21.1	54.5	50.5
Avg./Sum May–August	21.7	20.0	229.3	267.6

The biological material used was the hybrid Alize (provided by Euralis), a hybrid recorded in the official catalogue of varieties of crop plants in Romania since 2014. Alize is a grain sorghum hybrid (FAO 380-400) highly tolerant to drought.

The experimental design was built using the split plot method in four replications. The main factor investigated was fertilization, as active substance, with ten levels: a_1 - $N_0P_0K_0$ (Control), a_2 - $N_{60}P_0K_0$, a_3 - $N_{90}P_0K_0$, a_4 - $N_{120}P_0K_0$, a_5 - $N_{90}P_{60}K_0$, a_6 - $N_{90}P_{60}K_0$+foliar fertilization (H), a_7 - $N_{90}P_{60}K_{60}$, a_8 - $N_{90}P_{60}K_{60}$ + foliar fertilization (H), a_9 - $N_{120}P_{60}K_0$, a_{10} - $N_{120}P_{60}K_{60}$.

Factor B, with two graduations, was the sowing distance between rows: b_1 - 70 cm, b_2 - 50 cm.

The precursory crop was winter wheat (*Triticum aestivum* L.). Land preparation was ploughed at 20 cm. The day before sowing seedbed preparation was carried out at a depth of 5-6 cm. Sowing dates fluctuated under the influence of climatic conditions between April 24 and May 2, and harvesting was conducted between September 1 and 15. The average density was 18 harvestable plants/m^2 at 70 cm between rows and 21 harvestable plants/m^2 at 50 cm between rows. Fertilization was carried out at seedbed preparation and during vegetation. Two foliar fertilization treatments were applied using commercial product Hortifor 30-20-10 in a dose of 2.5 kg/ha. Pre-emergence weed control was performed using *S-metolachlor* 960 g/l (commercial product Dual Gold, 1.5 l/ha) while for post-emergent weed control was carried out using a treatment with 344 g/l *2.4 D* + 120 g/l *dicamba* (commercial product Dicopur Top, 1 l/ha) and the application of mechanical hoeing. Pest control *(Tanymecus dilacotillis)* was carried out using *thiacloprid* 480 g/l (Calypso, dose at 150 ml/ha).

To determine the influence of technological factors on yield the analysis of variance was used and the relationship between factors was determined based on the correlation and regression analysis.

RESULTS AND DISCUSSIONS

Sowing distance influence on grain yield

Analyzing the influence of the sowing distance on the average grain yield of the period 2014-2016, the data presented in Table 2, indicate that sown at a distance of 70 cm between rows records an higher yield compared to the 50 cm sowing distance, the differences being statistically assured ($p<0.05$). Only for the complex fertilization $N_{120}P_{60}K_{60}$ the yield difference between the two sowing distances was not statistically significant, with a value of 0.21 t/ha, the yield was higher at the sowing distance of 70 cm between rows.

Research on the influence of the sowing distance on grain sorghum yield is inconsistent and often conflicting, influenced by experimental conditions. Thus, similar to the results presented in this paper, Fernandez et al. (2012) highlighted that grain sorghum grown in strips (30 cm) generated higher yields in favourable rainfall conditions, than sorghum grown in the conventional system (9.5 cm between rows), but in the absence of rainfall the differences are not significant. In dry zones, reducing the distance between rows conserves soil's water reserves up to the vegetative stages of reproductive growth of grain filling, which positively influences yield (Bandaru et al., 2006). Staggenborg (1999) shows that in years with high rainfall, the yield obtained for narrow rows is higher than that obtained for conventional sowing distances. Fromme (2012) also reported an enhanced efficiency in economic terms for growing sorghum at 51 cm between rows, even though in terms of yield research findings do not reveal significant differences.

Also, results obtained by Buah and Mwinkaara (2009) show that plant density had no significant influence on yield, whereas nitrogen fertilization caused a linear increase of the yield.

Table 2. Sowing distance influence on grain yield (t/ha), average 2014 – 2016

Variants	Grain yield (GY t/ha) 70 cm		50 cm		Significance
	GY (t/ha)	Diff. (t/ha)	GY (t/ha)	Diff. (t/ha)	
$N_0 P_0K_0$	5.75	Ct	5.32	-0.43	$p < 0.01^{oo}$
$N_{60} P_0K_0$	6.97	Ct	6.55	-0.42	$p < 0.01^{oo}$
$N_{90}P_0K_0$	7.62	Ct	7.18	-0.44	$p < 0.01^{oo}$
$N_{120} P_0K_0$	8.27	Ct	7.90	-0.37	$p < 0.05^{o}$
$N_{90} P_{60} K_0$	8.00	Ct	7.66	-0.34	$p < 0.05^{o}$
$N_{90}P_{60} K_0$+H	8.13	Ct	7.74	-0.39	$p < 0.05^{o}$
$N_{90}P_{60}K_{60}$	8.33	Ct	8.00	-0.33	$p < 0.05^{o}$
$N_{90}P_{60}K_{60}$+H	8.58	Ct	8.10	-0.48	$p < 0.01^{oo}$
$N_{120} P_{60} K_0$	8.89	Ct	8.55	-0.34	$p < 0.05^{o}$
$N_{120} P_{60} K_{60}$	9.22	Ct	9.01	-0.21	ns
Avg. variants	7.98	Ct	7.60	-0.37	$p < 0.05^{o}$

LSD 5% = 0.29 t/ha; LSD 1% = 0.40 t/ha; LSD 0.1% = 0.57 t/ha

GY = grain yield at STAS (14%), ns = not significant

Grain yield under different fertilization rates Fertilization has a favourable effect on grain sorghum yield, for both the sowing distances of 70 and 50 cm between rows (Table 3). Under the influence of fertilization, grain yield recorded increases, highly significant in statistical terms ($p < 0.001$) for all levels of fertilization (Table 3). Similarly, Matei (2011) obtained the highest grain yield for sorghum cultivars fertilized N_{160} P_{80} K_{80} at distance of 70 cm between rows.

Table 3. Fertilization influence on grain yield (GY t/ha) of sorghum sown at 70 cm and 50 cm between rows (Moara Domnească, average 2014-2016)

Variants	Grain yield (GY) 70 cm		50 cm	
	GY (t/ha)	Diff. (t/ha)	GY (t/ha)	Diff. (t/ha)
$N_0 P_0K_0$	5.75	Ct^{ns}	5.32	Ct^{ns}
$N_{60} P_0K_0$	6.97	1.22^{***}	6.55	1.23^{***}
$N_{90}P_0K_0$	7.62	1.87^{***}	7.18	1.86^{***}
$N_{120} P_0K_0$	8.27	2.52^{***}	7.90	2.58^{***}
$N_{90} P_{60} K_0$	8.00	2.25^{***}	7.66	2.34^{***}
$N_{90}P_{60} K_0$+H	8.13	2.39^{***}	7.74	2.42^{***}
$N_{90}P_{60}K_{60}$	8.33	2.58^{***}	8.00	2.68^{***}
$N_{90}P_{60}K_{60}$+H	8.58	2.83^{***}	8.10	2.78^{***}
$N_{120} P_{60} K_0$	8.89	3.15^{***}	8.55	3.23^{***}
$N_{120} P_{60} K_{60}$	9.22	3.47^{***}	9.01	3.69^{***}
Avg. variants	7.98	2.23^{***}	7.60	2.28^{***}
	LSD 5% = 0.43 t/ha; LSD 1% = 0.58 t/ha; LSD 0.1% =0.77t/ha		LSD 5% = 0.36 t/ha; LSD 1% = 0.48 t/ha; LSD 0.1% = 0.64 t/ha	

ns = not significant; *** = p<0.001; ** = p<0.01; * = p < 0.05

Munteanu (2011, 2012) also points out the influence of fertilization on the grain yield of sorghum grown on a brown soil, the highest yield being obtained when fertilizing with $N_{240}P_{80}K_{80}$. In the field conditions of the research area the use of mineral nutrients applied to the sorghum crop was slightly higher at a distance of 50 cm between rows (Table 4). Although the production obtained at 50 cm sowing distance is lower than the one recorded for the 70 cm sowing distance, yield increase brought by a unit of fertilizer at 50 cm sowing distance reflects a better use of fertilizers in conditions of increased competition between plants. The achieved growth is influenced mainly by significant distinct differences in yield between the two distances obtained for control. The efficiency of nitrogen use increases with the growth of the rate of fertilization both for 70 cm and 50 cm sowing distances (Table 3), from 20.33 kg grain/kg N and 20.50 kg grain/kg N (for the fertilization level $N_{60}P_0K_0$) to 21.00 kg grain/kg N and 21.50 kg grain/kg N (for the fertilization level $N_{120}P_0K_0$). Regarding phosphorus and potassium, there is a higher efficiency of their capitalization when used in combination with 120 kg N/ha. Research carried out by the Buah and Mwinkaara (2009), show that the efficiency of using mineral fertilizing elements (nitrogen) decreases with increasing dose of active substance and is not influenced by crop's density.

Table 4. Grain yield increase (kg) per kg of fertilizer active substance (GYI/kg a.s.), 2014-2016, for sorghum sown at 70 cm and 50 cm between rows

Fertilizer doses	70 cm				50 cm			
	GY (t/ha)	GYI/kg a.s.			GY (t/ha)	GYI/kg a.s		
		N	P	K		N	P	K
$N_0 P_0K_0$	5.75	-	-	-	5.32	-	-	-
$N_{60} P_0K_0$	6.97	20.33	-	-	6.55	20.50	-	-
$N_{90}P_0K_0$	7.62	20.78	-	-	7.18	20.67	-	-
$N_{120} P_0K_0$	8.27	21.00	-	-	7.90	21.50	-	-
Average	**7.15**	**20.70**	**-**	**-**	**6.74**	**20.89**	**-**	**-**
$N_{90} P_{60} K_0$	8.00	-	6.33	-	7.66	-	8.00	-
$N_{120} P_{60} K_0$	8.89	-	10.33	-	8.55	-	10.83	-
Average	**8.45**	**-**	**8.33**	**-**	**8.11**	**-**	**9.42**	**-**
$N_{90}P_{60}K_{60}$	8.33	-	-	5.50	8.00	-	-	5.67
$N_{120} P_{60} K_{60}$	9.22	-	-	5.50	9.01	-	-	7.67
Average	**8.78**	**-**	**-**	**5.50**	**8.51**	**-**	**-**	**6.67**

GYI/a.s. – grain yield increase per kg of fertilizer active substance (a.s)

CONCLUSIONS

Analyzing the results obtained in the three years of research, we see that yield is significantly influenced by both levels of fertilization and sowing distance between rows. At a distance of 70 cm between rows fertilization ensured an yield increase between 21.2% ($N_{60}P_0K_0$) and 60.4% ($N_{60}P_{60}K_{60}$), while at 50 cm between rows the same fertilization levels led to increases from 23.1% to 63.9%, compared to control (unfertilized variant). The yield obtained at a distance of 50 cm between rows was between 92.5% ($N_0P_0K_0$) and 97.7% ($N_{120}P_{60}K_{60}$) of the output value recorded at 70 cm sowing distance. Based on the results obtained, given the soil and climatic conditions in South-Eastern Romania, it is recommended for grain sorghum to be cultivated at the distance of 70 cm between rows, with a level of fertilization of $N_{120}P_{60}K_{60}$.

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