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Influence of Sowing Periods and Seeding Rates on Yield of Grain Sorghum Hybrids under Regional Climatic Transformations

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Abstract: Field experiments were carried out on dark chestnut middle loamy slightly alkalinized soils in the non-irrigated conditions of the southern steppe of Ukraine in 2013-2015. The three-factor experiment: Factor A-grain sorghum hybrids: Sontsedar, Prime, Burggo, Sprint W, Dash E and Targga. Factor B-seeding rate, thousand pcs/ha: 100, 140, 180 and 220. Factor C-sowing time: early (when soil temperature at the depth of seeding is 8-10°C), which on average during the years of research coincided in time with the first decade of May; late-when soil temperature is 14-16°C or the third decade of May. In all cases, the early sowing show persistently higher yield of hybrid crops compared to late sowing. The early term of sowing grain sorghum hybrids provided average yield of certified seeds at 4,9 t/ha, which is 1.82 times higher than late sowing, the average yield of which was 2.69 t/ha. Significant variation in yield was observed with different seeding rates. The highest average yield was observed at the sowing rate 140 thousand pcs/ha followed by 180 and 220 thousand pcs/ha .

Keywords: Grain sorghum, Climate change, Sowing term, Seeding rate, Growth stimulants, Yield

Modern climate transformation currently affecting agrocenosis of all agricultural backgrounds of Ukraine, make producers frequently review the concepts and practical approaches to the formation of the range of crops in rotations that are able to provide stable and cost-effective yields in more rigid conditions of the value of the hydrothermal coefficient (Adamenko 2003, Yeshchenko et al 2004). Under the current conditions of agrarian production in Ukraine, the prospect of fulfilling the agrobiological and production potential of sorghum cultivars, their introduction, production, processing, and consumption become of paramount importance. Under the conditions of a strong hydrothermal coefficient peculiar both to the growing zone (South and South-East) and recently to almost all agrarian zones in the country, it can form stable and economically feasible harvests with quality indicators that allow its multi-vector use. Recently, the grain becomes associated not only with food or fodder, but also with a significant source of raw materials for the production of bioethanol (Bun 2009, Hryhorenko 2011, Storozhyk 2011). However, the most important argument for more intensive involvement of the mentioned crop in the Southern steppe agrocenoses is its extremely high ecological plasticity, which is capable of being an alternative to other spring crops (barley, corn, sunflower, etc.) in unfavourable conditions according to the value of the hydrothermal coefficient of the agroseason (Vlasov VH 2005, Hurskyj 2002, Dranischev et al 2008).

Under the influence of climate change, sorghum is gaining in popularity in Ukraine. Though this grain used to be referred to as a source of herbage needed to meet the needs of livestock, grain producers are currently interested in it as well. A positive tendency in the cultivation of sorghum is also observed worldwide. Sorghum is particularly valuable because of its ability to tolerate long periods of drought and high air temperatures without significant reduction in grain productivity, effectively use atmospheric precipitation in the second half of the summer, restore growth after a long period without water and produce rather high yields, which allows it to grow in arid zones, such as the south of Ukraine The late spring crops, grain sorghum has almost no alternative if the producer desires to get economic benefit from an arable hectare.

MATERIAL AND METHODS

Field experiments were carried out on dark chestnut middle loamy slightly alkalinized soils in the non-irrigated conditions of the southern steppe of Ukraine in 2013-2015. The three-factor field experiment was based on the method of randomized split plot design with four replication. The sown area of the plots was 56.0 sq. m; and the record area was 33.6 sq. m. The number of variants in experiment was 48 with 192 total of experimental plots. The factor A - grain sorghum hybrids: Sontsedar, Prime, Burggo, Sprint W, Dash E and Targga; factor B - seeding rate, thousand pcs/ha: 100,

140, 180, and 220; factor C - sowing time: early, average and late when soil temperature at the depth of seeding is 8-10°C mention date for 2 years and when soil temperature is 14-16°C or the third decade of May. The sampling of soil and plants and analysis were carried out only with methodological guidelines and state Standards of Ukraine. Crop monitoring and recording were conducted according to Dospiekhov's methodology (Dospekhov 1979) and recommendations for conducting field experiments (Ostapov 1985). During the growing season, the biometric measurements were recorded in the main phases of crop development, plant height, leaf surface and herbage yield. Phenological observations were conducted on permanently allocated sites in two non-adjoining repetitions. The beginning of the phase is believed to be its onset in 10 per cent of plant, and the full phase in 75 per cent of plants.

The crop density was determined twice per vegetation in fixed areas, which were isolated after the sprouting. The first count was carried out in the phase of full sprouts, the second – before harvesting. According to the first record, the field germination of the seeds was determined and the density was formed according to the experimental scheme. According to the second record, the preservation of the plants during the growing season was determined. The yield was estimated on whole plot basis with combine using the Sampo-130 plot combine. The results of measurements, determinations, and yield counts were subjected to dispersion analysis and statistical processing using computer technology and methodological recommendations for conducting field experiments.

Table 1. Yield of grain sorghum hybrids for different sowing times and seeding rates, t/ha (average for 2013-2015)

Hybrid (factor A)	Seeding rate, thousand pcs/ha (factor B)			
	100	140	180	220
8-10 ºC (factor C)				
Sontsedar	5.64	6.54	4.88	4.79
Prime	3,20	4.54	4.62	3.83
Burggo	4.38	5.50	5.00	4.29
Sprint W	2.96	2.93	3.16	3.49
Dash E	4.55	6.23	6.69	5.26
Targga	3.83	4.98	5.60	4.58
14-16 ºC				
Sontsedar	2.67	2,18	2.29	2.0 5
Prime	1.75	2.43	1.70	1.60
Burggo	1.93	2.39	1.94	2.28
Sprint W	1.43	1.39	1.25	1.45
Dash E	3.29	3.52	3.96	3.96
Targga	2.59	2.61	3,20	2.64
Least significant difference $_{05}$, t/ha	A		0.18-0.39	
	B		0.20-0.57	
	C		0.21-0.52	
	AB		0.32-0.74	
	AC		0.44-0.63	
	BC		0.48-0.77	
	ABC		0.62-1.07	

RESULTS AND DISCUSSION

The yield of grain sorghum, obtained at the early seeding, was on average 2.29 t/ha or 49.3 per cent higher than at the late sowing, which indicates the advantage of seeding the crop in the early period due to more optimal conditions for plant growth and development, and in the first place because of improving water availability for agrophytocenosis (Table 1). Seeding the crop when the soil temperature at the depth of seeding is 8-10ºC, the hybrid Sontsedar gave the maximum grain yield (6.54 t/ha) for the seeding rate of 140 thousand pcs/ha, and the average yield according to the variant of seeding rate amounted to 5.46 t/ha.

The maximum yield of the hybrid Prime was 180 thousand pcs/ha and amounted to 4.62 t/ha with an average yield of 4.05 t/ha. In the areas where the Burggo hybrid was grown, the best plant density was 140 thousand pcs/ha, which resulted in the production of 5.50 t/ha of standard seeds with an average yield of 4.79 t/ha. Hybrid Sprint W is characterized by maximum grain yield of 3.49 t/ha when seeding in the early period with the density of 220 thousand pcs/ha, and at the seeding rate factor the average yield is 3.14 t/ha. The Dash E hybrid is characterized by a significantly higher level of grain productivity: given the variant of increasing density up to 180 thousand pcs/ha on average, over the years of research, we received 5.68 t/ha of grains, which, as well as its average yield by factor B at the level 5.68 t/ha, is the highest index among the studied hybrids. The grain yield analysis of the Targga hybrid, seeded in the early term, has shown that the optimal amount of plants per hectare is also 180 thousand pcs/ha, which resulted in the yield of 5.60 tons of standard grain from this area. On average, this hybrid demonstrated the productivity of 4.75 t/ha by the factor of crop density.

By the index of plasticity, that is, the ability to minimally change the grain productivity with the decrease or increase in the agrocenosis density, the Dash E hybrid, whose average yield by seeding rate (5.68 t/ha) is 0.22 t/ha or 3.9 per cent higher than similar parameters of Sontsedar hybrid; 1.63 t/ha or 28.7 per cent - Prime hybrid; 0.89 t/ha or 15.7 per cent - Burggo hybrid; 2.54 t/ha or 44.7 per cent - Sprint W hybrid, and 0.93 t/ha or 16.4 per cent - Targga hybrid. A similar nature

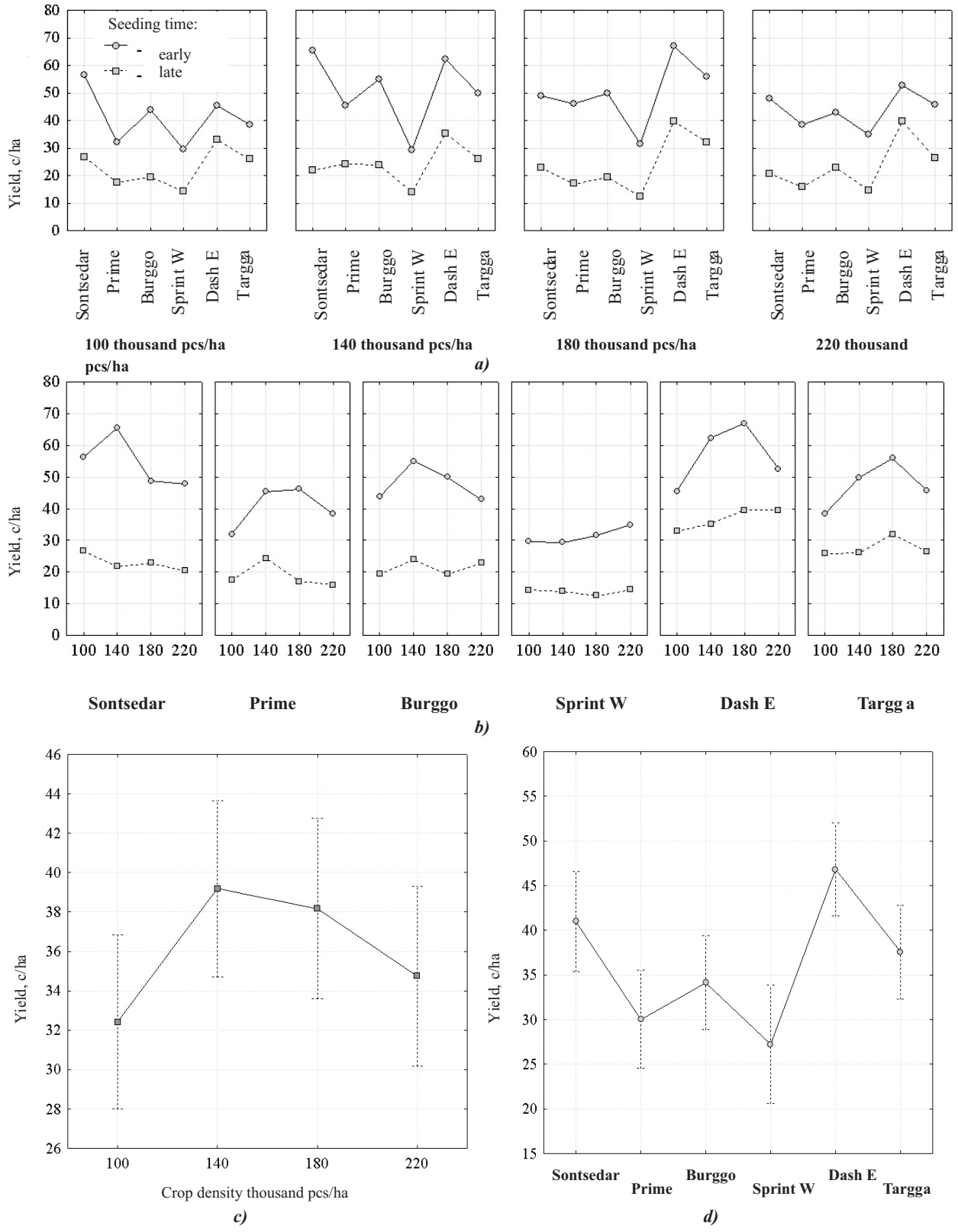

Fig. 1. Formation of the yield of the hybrid composition of grain sorghum depending on the seeding rate and sowing dates for 2013-2015: a) distribution by crop density, thousand pcs/ha; b) distribution by hybrid composition; c) average yield and confidence interval (0.95), depending on the grain seeding rate; d) average yield and confidence interval (0.95) depending on the hybrid composition

of the dependencies was recorded by analyzing yield productivity of sorghum hybrids, sown with different density in the late period. Thus, seeding the crop when the temperature of the soil at the depth of seeding reaches 14-16ºC, Sontsedar hybrid produced the maximum grain yield 2.67 t/ha at the seeding rate of 100 thousand pcs/ha, and the average yield per variant of seeding rate is 2.30 t/ha.

Prime hybrid, seeded in the same time period, produced the maximum grain yield at the rate of 140 thousand pcs/ha. An average of 2.43 t/ha of standard grain was obtained with average yield of 1.87 t/ha. The maximum grain yield of the Burggo hybrid was recorded by us when increasing density of the crop to the mark of 140 thousand pcs/ha - 2.39 tons of grain was received from each ha, while the average value at such factor B is 2.14 t/ha. In early seeding period, Sprint W hybrid was the least productive. Its maximum yield at the level of 1.43-1.45 t/ha was formed at the same time by the variants of the minimum and maximum crop density. On average, according to the given factor, the hybrid provided 1.38 t/ha of grain. At the same time, the hybrid Dash E has formed the maximum grain yield at late seeding time as well, confirming not only high adaptive properties, but also a significant level of environmental and productive plasticity. The maximum yield level was obtained from experimental plots, where the density was formed at the level of 180-220 thousand pcs/ha - 3.96 t/ha, and on average by the factor of seeding rate - 3.68 t/ha.Targga hybrid is significantly inferior to others according to the indicated parameters: the maximum grain yield of the plant of this hybrid, which is 3.20 t/ha, was formed at the seeding rate of 180 thousand pcs/ha. The average yield, when increasing seeding rates from 100 to 220 thousand pcs/ha, is 2.76 t/ha.

Dash E hybrid was best in term of index of plasticity and early. The average yield was 3.68 t/h) against 1.38 t/ha or 37.5% in Sontsedar hybrid by followed by; Prime Burggo Sprint and Targga hybrid. The optimal plant density of Dash E hybrid is 180 thousand pcs/ha in both early and late sowing. In the event that the agro-climatic and production conditions allow early sowing of the crop, alternatively, Sontsedar hybrid should be considered, with an optimal plant density of 140 thousand pcs/ha. The yield of early sowing of grain sorghum hybrids was 4.9 1 t/ha, which is 1.82 times more than late sowing, (2.69 1.08 t/ha). Significant heterogeneity in the yield of grain sorghum is observed under different conditions of seeding. The highest average yield was at the seeding rate of 140 thousand pcs/(3.92 t/ha) followed buy 180 and 220 thousand pcs/ha – and the least at 100 thousand pcs/ha – (3.24 t/ha). Dash E hybrid has the best adaptability to the climatic conditions of the southern steppe of Ukraine with average yield of 4.69 t/ha. Sprint W hybrid demonstrated the lowest. A good adaptability was also observed in Sontsedar (4.11 t/ha) and Targga (3.0 t/ha).

Recently, in progressive technologies of production of agricultural crops, attention is being increasingly focused on the problem of the use of biologically active substances in agrophytocenoses - natural and synthetic plant growth stimulators, which, at minimum spending standards, are able to radically change the intensity and vectors of the growth and productive processes of the plant organism . By the targeted use of one or another growth regulating compound, it is possible to improve the complex of adaptive properties of a crop, regulate growth processes and the mechanism of formation and accumulation of spare substances (sugars, fat, protein, etc.) (Nikishenko et al 2009, Samoilenko et al 2009). The problem of the use of plant growth stimulants in the most common crops of Southern agrocenoses is currently on the initial stage of scientific investigation and the question of their use in crops of grain sorghum is almost untouched by the researchers.

In order to objectively study the effectiveness of the

Table 2. Effect of treatment with growth stimulator on yield of grain sorghum hybrids for early sowing (soil temperature – 8-10˚C), t/ha (Average for 2013-2015)

Hybrid (factor A)	Treatment method (factor B)				
	Without treatment - target value	Pure water - background	+ - to target value	0.01% solution of succinic acid	+ - to target value
Sontsedar	4.88	4.95	0.07	5.60	0.72
Prime	4.62	4.71	0.09	5.28	0.66
Burggo	5.00	5.07	0.07	5.75	0.75
Sprint W	3.16	3.25	0.09	3.57	0.41
Dash E	6.69	6.75	0.06	7.51	0.82
Targga	5.60	5.65	0.05	6.34	0.74
Least significant difference $_{05,}$ t/ha	A			0.62-0.91	
	B			0.38-0.64	
	AB			0.88-1.67	

influence of the mentioned growth stimulator on the quantitative and qualitative indicators of the yield of grain sorghum hybrids, due to its minimum input rate (30 – 40 g/ha), additionally introduced the option of background control - treatment with pure water - in our experimental. This measure was aimed at eliminating the distortion of the results by the positive effect of refreshing generative organs (pollen, flowers, inflorescences) with highly dispersed spray of water when spraying plants with a solution of succinic acid on the productivity of the crop. As the results of present study, treatment of grain sorghum plants of early sowing with 0.01% solution of succinic acid during the formation of buds proved highly effective measures aimed at increasing grain crop yield (Table 2). On average, growth stimulator was use, The yield of the grain crop was 5.67 t/ha where growth stimulator was used against 5,06 t/ha, where the plants were treated with clean water and for 4,99 t/ha in check treatment. The use of a growth regulating agents caused a significant positive effect on the yield of grain sorghum and refreshing water had a noticeable effect during the formation of the generative part of the crop.

CONCLUSION

In all of the studied hybrids, the use of 0.01 per cent solution of succinic acid increased the seed yield of the crop compared to the untreated target value. The maximum increase in Sontsedar hybrid by 0.72 t/ha or 12.9 per cent followed by Prime , Burggo and Sprint W . The minimal but positive effect of spraying plants of grain sorghum with pure water is explained by the short-term improvement of the microclimate of the upper tier of agrophytocenois, primarily due to the lowering of the air temperature and the increase of the relative humidity of air during the formation of generative organs of the plant organism when the agroclimatic conditions during the years of conducting researches were characterized by adverse effects of hydrothermal coefficient.

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