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Productivity of corn hybrids in relation to the seeding rate

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Abstract. Potential yield of corn hybrids with a different FAO number is limited by not only rainfall amount, average soil and air temperature throughout vegetation period, but also directly depends on plant density. The study and practical application of special agricultural techniques allows us to limit and mitigate the negative impact of these factors on the productivity of maize, depending on the indicators under study and the soil and climatic resources of the cultivation zone. Therefore, the study of the influence of the seeding rate on the growth and development of corn plants remains relevant. The results presented make it possible to choose optimal seeding rates for corn hybrids of early and middle groups of ripeness (FAO 180-280). Overcrowding from 61,000 to 93,000 seeds ha^{-1} leads to increase in interstage period 'sprouting–wax ripeness' of Rodnik 179SV hybrid for 4 days, of MAS 12R and AMELIOR hybrids–for 2 days, and of MAS 30K hybrid – for 3 days. Hybrids Rodnik 179SV and AMELIOR reached maximum height – 217 cm and 214 cm respectively – at seeding rate of 73,000 seeds ha^{-1}, while hybrids MAS 12R and MAS 30K grew up to their 213 cm and 223 cm respectively at seeding rate of 77,000 seeds ha^{-1}. Decrease in seeding rate to less than 73,000 seeds ha^{-1} and, contrary to it, overcrowding of seeds of more than 77,000 seeds ha^{-1} leads to decrease in corn hybrid plant height. Agronomically, the most efficient for maximizing early ripe Rodnik 179SV and MAS 12R hybrids yields (6.39 and 6.73 t ha^{-1}) and middle-early ripe AMELIOR hybrid yield (6.81 t ha^{-1}) was the seeding rate of 73,000 seeds ha^{-1}, while the highest yield of middle MAS 30K hybrid (7.21 t ha^{-1}) was at the seeding rate of 77,000 seeds ha^{-1}.

Key words: seeding rate, early ripeness, density, yield.

INTRODUCTION

Total corn yield over the world has risen in recent years, and it is assumed that its growth and absolute productivity level are in close relation to soil-climatic and macroeconomic conditions, as well as to intensity of plant growing and bio-technological progress (Hasenclever, 2000; Spiekers, 2000; Free, 2001; Heinrich, 2001; Zellner, 2004).

Corn hybrids productivity is conditioned by quantitative parameters determining its habitus, such as plant height,leaf coverage, area of leaf surface etc. These parameters' value determines the reaction of plants to changes in growing conditions. Growth and development of corn plants depend on a number of factors, primarily on existing meteo-conditions, biological properties of the hybrids and the agrotechnology applied (Jager, 2004; Spaar et al., 2009).

Studies of a number of Russian and foreign scientists give no unanimous opinion on optimal seeding rate for corn hybrids of different ripeness groups. Thus, Dorffi & Borzeny (1996) claim that optimal plants quantity per ha depends on humidification conditions of a certain year: 80,000 plants ha^{-1} in years enough humidified, 30,000 plants ha^{-1} – in droughts. Russian researchers Popov et al. (1991) claim that medium ripening hybrids form maximal yield at 50,000 plants ha^{-1}. Yakhtanigova & Topalova (2008) claim that optimal density for each hybrid is determined basing on individual parameters. Thus, the studies of Belozerny 1 MV and Kavkaz 307 MV hybrids have shown the optimal density of 60,000 plants ha^{-1}, while those of Nika 353 MV were 50,000 plants ha^{-1}. As Potapov et al. (2016) suggest, formation of optimal density of corn seedlings is not only conditioned by available humidity and nutrient reserves, but also by architectonics and drought resistance of a hybrid itself. For medium ripening hybrids, increase in plant density of more than 65,000 plants ha^{-1} results in the increase in yield, but not more than 85,000 plants ha^{-1}. The optimum for such hybrids is 75,000 plants ha^{-1}. Such scientists as Kravchenko (2010), Filin & Mikhin (2014), Zubkova & Sozin (2016) claim that the plant degree of density optimum depends on soil-climatic zones of cultivation.

Under conditions of Central Chernozem Region of Russia (CCR) unstable humidification, the influence of corn hybrid seeding rate and degree of density on yield of modern hybrids of various groups of ripeness has not been investigated to the full. Hence, the objective of the study presented is a scientific grounding of optimal seeding rate of various ripeness group corn hybrids grown under conditions of unstable humidification.

MATERIALS AND METHODS

The field experience was laid during 2013–2015 on the fields of SP by the head of the farm Kotov V.V. Bobrovsky district of the Voronezh region (N50.513678 E40.014524), according to a two-factor scheme:

Factor A – hybrids (MAS 12R, AMELIOR, MAS 30K and Rodnik 179SV (control));

Factor B – seeding rate (61,000; 67,000; 73,000; 77,000; 83,000; 87,000 and 93,000 seeds ha^{-1}).

4 hybrids were used in the experiment:

1. Rodnik 179SV is a short-season (FAO 180) three-linear maize hybrid, created jointly by breeders of the Voronezh Experimental Station VNIK and LLC Innovation and Production Agrofirm 'Selection'. The plants are 240–260 cm tall, untillered, folious. The ear is 70–75 cm high, slightly cone-shaped, weighing 110–140 grams and 20–25 cm long. The grain is semi-toothed, yellow. The mass of 1,000 grains is 260–290 g. The grain row number on the cob is 14–16. The threshing yield of the grain is 80–82%. The recommended plant density per hectare per grain for Bogar is 60,000 plants ha^{-1}, for irrigation it is 75,000 plants ha^{-1}. If fertilizers are not applied, the density should be decreased by 5,000–10,000 plants ha^{-1}depending on the soil fertility and moisture.

2. MAS 12R is a short-season (FAO 180) hybrid, it has been produced by the MAS Seeds company, flint, cold-resistant, intended for early sowing. Rapid growth and early development. Plants are 250–265 cm tall, untillered, folious. The ear is 70–75 cm high, slightly cone-shaped, weighing 110–140 grams and 20–25 cm long. The grain is semi-

toothed, yellow. The mass of 1,000 grains is 260–280 g The grain row number on the cob is 14–16. The recommended seeding rate is 58,000–62,000 seeds ha^{-1}.

3. AMELIOR is a middle-early hybrid (FAO 240), produced by the company MAS Seeds; it is flint and dent-like, has a high yield potential for grain, is environmentally plastic and drought-resistant. The grain is semi-toothed, yellow. The mass of 1,000 grains is 300–310 g. The grain row number on the cob is 14–16. The recommended plant density per ha^{-1} is 75,000–85,000 and (under the conditions of sufficient moistening) or 70,000–75,000 (under the conditions of unstable moistening).

4. MAS 30K – is a mid-season hybrid (FAO 280), produced by the company MAS Seeds; it is dent-like and has a good moisture-yielding ability due to its semi-toothed grains. The grain is semi-toothed, yellow. The mass of 1,000 grains is 320–340 g. The grain row number on the cob is 14–16. The recommended plant density per ha^{-1} is 70,000–80,000 (under the conditions of sufficient moistening) or 70,000–75,000 (under the conditions of unstable moistening).

Soils of the experimental plot are the ones of ordinary chernozem, medium loamy. Humus content in plowing layer is 4.3%, pH–5.6. The degree of soil saturation with bases is 88.9%. The content of mobile phosphorus is 73 and exchangeable potassium–103 mg kg^{-1} of soil (Chirikov, 1956).

The total area of the plot – 157 m^2, accounting–120 m^2.The experiment was laid by the method of split plots with their randomized placement inside repetitions. The experiment repetition is 4-fold. Corn's preceding crop had been winter wheat. The technology of corn cultivation in the experiment is as follows:

– plowing (John Deere 8310R + Lemken Euro Diamant) to a depth of 25–27 cm;

– cultivation (John Deere 8310R +Lemken Korund9) to a depth of 8–10 cm;

– fertilization (in the fall – anhydrous ammonia at the rate of 0.1 t ha^{-1} (82 kg AI ha^{-1}), in spring - ammophos of 75 kg ha^{-1} (39 kg AI ha^{-1}) in physical mass at sowing and Rexolin microfertilizer 0.15 kg ha^{-1}(0.22 kg AI ha^{-1}) – for top dressing;

– sowing (MTZ-1221 + Gaspardo (8 lines), planting dates – III third of April – I third of May;

– pesticide treatment (by Titus Plus herbicide – 0.387 kg ha^{-1} (dicamba 609 g kg^{-1} + rimsulfuron 32.5 g kg^{-1}), Rogor-S insecticide – 1 L ha^{-1} (dimetoat 400 g L^{-1});

– gathering (Acros 580) in lines, with recalculation on 14% humidity and 100% purity.

In the process of research, phenological observations were carried out on ten marked plants of each plot in four repetitions. The following phases of maize development were noted: the beginning and the full sprouting, the beginning and the full panicle emergence, the beginning and the full flowering of the cobs (filaments emergence), the milky, milky-wax state of the grain, the waxy ripeness, the complete ripeness. The onset of each phase was noted at its development stage: the beginning (in 15% of the plants), complete (in 75% of the plants). The standing density was determined by counting plants from 14.3 m.p. (10 m^2) in quadruplicate from each experimental plot; the field germination was determined in the phase of full germination. The plant height was measured in each phase of the growing season on 10 plants from each experimental plot. The mathematical processing of the research results was performed by B.A. Dospekhov's (1985) variance analysis method on a personal computer.

Weather conditions during the field studies for 2013–2015 had deviations from the average annual data on the main indicators. The best weather conditions for the growth and development of maize developed in 2013, the amount of precipitation during the growing season was 395.4 mm or 118% of the average annual rate. High temperatures and lack of moisture in the interphase period 'inflorescence emerge – flowering' in terms of 2014 and 2015 were the most critical to corn plants. In total, during the growing season in 2014, 191.4 mm of precipitation fell, which is 57% of the average annual norm, and in 2015 – 246.6 mm or 74% of the average annual norm.

RESULTS AND DISCUSSION

Duration of vegetation period is an important biological indicator that allows differentiating all hybrids by their earliness of ripening. To characterize the vegetation period duration of corn, two interstage periods are distinguished: sprouting–flowering and flowering–wax ripening. The duration of vegetation period of hybrids under study has been different in different years and mostly depended on the indicator of earliness of ripening. Thus, on average for three years of research, the following hybrids with FAO 180 were the most ripening: MAS 12R (102 days) und Rodnik 179SV (104 days). AMELIOR (FAO 240) hybrid vegetation period made up 113 days. MAS 30K (FAO 280) hybrid proved to be the most late ripening, with vegttion period of 122 days (Table 1).

It should be noted that the seeding rate had a slight effect on the vegetation period of all studied hybrids. There is a tendency to the increase of the vegetation period with increasing of seeding rate, especially in such early ripening hybrids as Rodnik 179SV and MAS 12R.

Table 1. Duration of vegetation period of corn hybrids at different seeding rates

Seeding rate, seeds ha^{-1}	Vegetation period (range/average), days			
	Rodnik 179CB FAO 180	MAS 12R FAO 180	AMELIOR FAO 240	MAS 30K FAO 280
61,000	99 – 105 / 102	95 – 104 / 100	109 – 115 / 112	117 – 122 / 120
67,000	101 – 104 / 102	99 – 104 / 101	110 – 115 / 112	118 – 124 / 120
73,000	102 – 105 / 104	98 – 103 / 100	110 – 118 / 114	120 – 125 / 123
77,000	102 – 104 / 103	97 – 101 / 99	109 – 118 / 113	121 – 125 / 123
83,000	102 – 106 / 104	101 – 103 / 102	113 – 116 / 114	119 – 124 / 121
87,000	104 – 108 / 106	101 – 105 / 103	113 – 115 / 114	122 – 124 / 123
93,000	105 – 107 / 106	100 – 106 / 103	112 – 116 / 114	122 – 124 / 123
Average by factor A	**104**	**102**	**113**	**122**

Increase in seeding rate from 61,000 to 93,000 seeds ha^{-1} had no significant influence on duration of 'sowing–sprouting' interstage period in all hybrids under study and made up 18–19 days(Table 2).

Table 2. Duration of interstage periods of corn hybrids at different seeding rates

Seeding rate, seeds ha^{-1}	Interstage periods, days											
	Rodnik 179SV FAO 180			MAS 12R FAO 180			AMELIOR FAO 240			MAS 30K FAO 280		
	sowing – sprouting	sprouting – flowering	sprouting - wax ripeness	sowing – sprouting	sprouting – flowering	sprouting - wax ripeness	sowing – sprouting	sprouting – flowering	sprouting - wax ripeness	sowing – sprouting	sprouting – flowering	sprouting - wax ripeness
61,000	18	50	94	17	51	93	18	64	104	18	65	112
67,000	18	53	94	18	50	93	18	64	104	18	64	112
73,000	18	52	96	17	53	93	18	63	106	19	65	114
77,000	18	53	95	17	52	92	18	64	105	19	65	114
83,000	18	53	96	18	53	94	18	65	106	18	66	113
87,000	18	53	98	18	53	95	18	64	106	19	66	114
93,000	18	54	98	18	53	95	18	65	106	19	65	114
r (yield correlation)			-0.51			-0.79			0.03			-0.18

Differencies in development of corn hybrid plants in relation to a seeding rate started to show by the stage of flowering. By the beginning of flowering of corn plants the overcrowding of seeds of such early ripening hydrids as Rodnik 179SV and MAS 12R lead to the increase in 'sprouting–flowering' interstage period up to 2–4 days, which was not observed in medium ripening (AMELIOR) and late ripening (MAS 30K) hybrids.

To the phase of wax ripeness with an increase in the seeding rate per 1 ha for all hybrids, one can note the tendency of increase in the 'sprouting–wax ripeness' interstage period. Thus, Rodnik 179SV hybrid's interstage period increased by 4 days, that of MAS 12R and AMELIOR hybrids did by 2 days,while medium ripening MAS 30K hybrid's interstage period increased up to 3 days.

At the initial stages of development, corn plants grow slowly. Within the first half of vegetation, in 12–15 days after sprouting, the highest average daily plant growth gain under favourable conditions can only reach 1.0–2.5 cm. 10 days before ear formation corn plant growth gain reaches its maximum values, that is up to 5–10 cm a day. After the flowering stage, corn plant linear growth stops.

For three years of study, the height of corn plants in the beginning of ear formation stage, in relation to seeding rate, made up 81–104 cm. MAS 12R hybrid plants grew higher – 104 cm at the seeding rate of 73,000 seeds ha^{-1}, AMELIOR hybrids were somewhat lower–95 cm at the seeding rate of 83,000 seeds ha^{-1}. Medium ripening MAS 30K hybrid grew up to its maximum of 93 cm at the seeding rate of 87,000 seeds ha^{-1} (Table 3).

Table 3. Corn hybrid plants' height by vegetation stages at different seeding rates

Seeding rate, seeds ha^{-1}	Corn hybrid plants' height by vegetation stages, cm											
	Rodnik 179SV FAO 180			MAS 12R FAO 180			AMELIOR FAO 240			MAS 30K FAO 280		
	ear formation	flowering	ripening	ear formation	flowering	ripening	ear formation	flowering	ripening	ear formation	flowering	ripening
61,000	84	196	208	101	188	194	92	202	205	91	202	210
67,000	85	188	203	98	196	203	92	200	203	87	206	209
73,000	86	202	217	104	198	205	94	210	214	88	207	216
77,000	86	198	210	97	206	213	92	206	210	92	215	223
83,000	85	201	215	99	204	210	95	207	210	86	212	221
87,000	81	197	202	98	201	203	91	199	202	93	207	211
93,000	81	196	201	94	193	199	89	198	201	91	199	209
r (yield correlation)			0.36			0.54			0.95			0.65

MAS 30K hybrid plant had the biggest height (215 cm) by the beginning of flowering stage in a variant with the seeding rate of 77,000 seeds ha^{-1}. The lowest at this stage were MAS 12R hybrid plants, that is, 193 cm at the seeding rate of 93,000 seeds ha^{-1}.

To the ripening stage, the differences in the height of all hybrid plants in relation to seeding rate became smaller. Thus, maximal difference in heights of MAS 30K and AMELIOR plant hybrids in relation to seeding rate made up 13 cm, or 6.1%.

In our experiments, the tendency has been observed of the increase in corn plant height with the increase in FAO. Thus, plant height at the ripening stage in MAS 12R hybrid with FAO 180 amounted, in relation to seeding rate, to 193–213 cm, in AMELIOR hybrid with FAO 240–to 201 – 2014 cm, and in MAS 30K with FAO 280–to 209–223 cm. The height of AMELIOR hybrid plants with seeding density of 77,000 and 83,000 seeds ha^{-1} at the ripening stage was the same and made up 210 cm. The same insignificantly did the plants height change at seeding rates of 61,000 and 67,000 seeds ha^{-1}. MAS 30K hybrid has displayed the same tendency. It should also be noted that Rodnik 179SV and AMELIOR hybrid plants at the seeding rate of 61,000 seeds ha^{-1} grew 4–7 cm higher than at the seeding rate of 93,000 seeds ha^{-1}. In medium ripening MAS 30K hybrid with FAO 280, this tendency has had little manifestation.

MAS 12R and MAS 30K hybrid plants showed top growth results at the seeding rate of 77,000 of germinable seeds ha^{-1}. Reducing seeding rate to less than 77,000 seeds ha^{-1} and, contrary to it, overcrowding of seeds to more than 77,000 seeds ha^{-1} leads to decrease in corn hybrid plants height. Thus, Rodnik 179SV and AMELIOR hybrid plants grew the highest (217 cm and 214 cm respectively) at the seeding rate of 73,000 seeds ha^{-1}, while MAS 12R and MAS 30K hybrids reached their 213 cm and 223 cm respectively at the seeding rate of 77,000 seeds ha^{-1}.

For the three years of research, germinating ability of seeds in all corn hybrids under study has been decreasing with increase in seeding rates. Of all the hybrids, MAS 12R responded most significantly to a change in seeding rate, displaying the change in field germinating capacity from 94.3% to 87.2%. MAS 30K hybrid showed the smallest change in field germinating capacity (92.3% to 87.2%) in relation to increase in quantity of seeds sown per 1 ha (Table 4).

Table 4. Plant density and germinating ability of corn seeds at the sprouting stage at different seeding rates

Seeding rate, seeds ha^{-1}	Rodnik 179SV FAO 180		MAS 12R FAO 180		AMELIOR FAO 240		MAS 30K FAO 280	
	density, thous ha^{-1}	germinating capacity,%	density, thous ha^{-1}	germinating capacity,%	density, thous ha^{-1}	germinating capacity,%	density, thous ha^{-1}	germinating capacity,%
61,000	56.0	91.7	57.5	94.3	56.9	93.3	56.3	92.3
67,000	61.1	91.1	62.2	92.8	61.7	92.1	60.4	90.1
73,000	66.1	90.5	67.6	92.6	66.8	91.5	64.5	88.3
77,000	69.7	90.5	71.2	92.5	69.7	90.6	67.8	88.0
83,000	74.1	89.3	73.6	88.7	74.2	89.4	72.8	87.8
87,000	75.5	86.7	76.8	88.3	76.0	87.3	76.2	87.6
93,000	79.7	85.7	81.1	87.2	81.0	87.1	81.1	87.2

At the sprouting stage, the best germinating capacity (94.3%) and plant density (57,500 plants ha^{-1}) were displayed by MAS 12R hybrid at the seeding rate of 61,000 seeds ha^{-1}. The worst germinating capacity (85.7%) and plant density (79,700 plants ha^{-1}) were displayed by Rodnik 179SV hybrid at the seeding rate of 93,000 seeds ha^{-1}.

In 2013–2015, the capacity of sprouts for gathering in relation to seeding rates was from 95.0 to 84.6%. AMELIOR hybrid plants showed better capacity for gathering, while MAS 12R hybrid plants deteriorated more than others (Table 5).

Table 5. Plant density and corn plant capacity for gathering at different seeding rates

Seeding rate, seeds ha^{-1}	Rodnik 179SV FAO 180		MAS 12R FAO 180		AMELIOR FAO 240		MAS 30K FAO 280	
	density, thous ha^{-1}	capacity for gathering, %	density, thous ha^{-1}	capacity for gathering, %	density, thous ha^{-1}	capacity for gathering	density, thous ha^{-1}	capacity for gathering, %
61,000	49.6	88.6	51.3	89.3	52.7	92.5	52.0	92.2
67,000	56.8	93.1	54.0	86.8	56.7	91.9	52.9	87.6
73,000	58.8	89.0	60.0	88.9	62.1	93.0	58.6	90.8
77,000	63.1	90.5	60.3	84.6	64.7	92.7	64.4	95.0
83,000	65.0	87.6	64.2	87.2	66.8	90.1	68.2	93.6
87,000	69.6	92.2	69.8	90.8	68.3	89.9	70.8	92.9
93,000	71.9	90.2	73.6	90.7	72.9	90.0	75.1	92.7

In early ripening Rodnik 179SV hybrid, the best gathering capacity level (93.1%) was at the seeding rate of 67,000 seeds ha^{-1}. In MAS 12R hybrid plant, the capacity was higher (90.7–90.8%) at maximal seeding rates of 87,000 and 93,000 seeds ha^{-1}, medium-early AMELIOR hybrid had the highest percentage of preserved plants (93.0%) at the seeding rate of 73,000 seeds ha^{-1}, while medium ripening MAS 30K hybrid displayed maximum capacity (95.0%) at the seeding rate of 77,000 seeds ha^{-1}.

The highest productivity of Rodnik 179SV (6.39 t ha^{-1}), MAS 12R (6.73 t ha^{-1}) and AMELIOR (6.81 t ha^{-1}) hybrids was at the rate of 73,000 seeds ha^{-1}, while MAS 30K hybrid gave the highest productivity of 7.21 t ha^{-1} at the seeding rate of 77,000 seeds ha^{-1}. The lowest hybrid corn yield was at the seeding rates of 61,000 and 93,000 seeds ha^{-1}. (Table 6).

Table 6. Corn hybrids yield at different seeding rates

Seeding rate, seeds ha^{-1}	Yield, t ha^{-1}							
	Rodnik 179SV FAO 180				MAS 12R FAO 180			
	2013	2014	2015	average (factor B)	2013	2014	2015	average (factor B)
61,000	5.25	5.05	4.94	**5.08**	6.08	5.31	4.83	**5.41**
67,000	7.32	6.45	5.83	**6.53**	8.29	4.66	5.49	**6.15**
73,000	6.23	6.78	6.15	**6.39**	9.49	5.66	5.04	**6.73**
77,000	5.80	6.12	5.94	**5.95**	5.71	6.19	6.93	**6.28**
83,000	6.29	5.34	4.47	**5.37**	6.63	4.94	5.82	**5.80**
87,000	-	5.52	4.93	**5.23**	-	5.05	5.17	**5.11**
93,000	-	4.91	4.76	**4.84**	-	4.47	4.26	**4.37**
average (factor A)	**6.18**	**5.74**	**5,29**		**7.24**	**5.17**	**5.36**	
LSD_{05} (A)	0.71	0.44	0.33		0.71	0.44	0.33	
LSD_{05} (B)	0.63	0.34	0.25		0.63	0.34	0.25	
LSD_{05} (AB)	1.42	0.89	0.67		1.42	0.89	0.67	
Seeding rate, seeds ha^{-1}	AMELIOR FAO 240				MAS 30K FAO 280			
	2013	2014	2015	average (factor B)	2013	2014	2015	average (factor B)
61,000	6.17	4.85	5.19	**5.40**	8.26	6.95	5.41	**6.87**
67,000	6.85	5.34	4.73	**5.64**	7.19	5.89	5.43	**6.17**
73,000	7.87	6.15	6.41	**6.81**	7.91	6.54	6.67	**7.04**
77,000	8.44	5.61	5.95	**6.67**	8.49	7.06	6.08	**7.21**
83,000	7.63	5.15	6.07	**6.28**	8.08	6.85	4.91	**6.61**
87,000	-	4.54	5.21	**4.88**	-	5.54	5.84	**5.69**
93,000	-	4.61	4.94	**4.78**	-	5.14	5.02	**5.08**
average (factor A)	**7.39**	**5.18**	**5.50**		**7.98**	**6.28**	**5.62**	
LSD_{05} (A)	0.71	0.44	0.33		0.71	0.44	0.33	
LSD_{05} (B)	0.63	0.34	0.25		0.63	0.34	0.25	
LSD_{05} (AB)	1.42	0.89	0.67		1.42	0.89	0.67	

The favorable combination of heat and moisture supply in 2013 contributed to the fullest realization of the productive potential of all the studied hybrids. The average yield of early ripe hybrids Rodnik 179SV and MAS 12R was 6.18 and 7.24 t ha^{-1}, respectively. The maximum yield of the Rodnik 179SV hybrid (7.32 t ha^{-1}) was at a seeding rate of 67,000 seeds ha^{-1}, and MAS 12R (9.49 t ha^{-1}) - at a seeding rate of 73,000 seeds ha^{-1}. An increase in the seeding rate of more than 73,000 units per hectare or a decrease of less than 67,000 units per hectare statistically significantly reduced the yield of maize for these hybrids. In the medium-early AMELIOR hybrid, the average yield was 7.39 t ha^{-1}, the maximum value (8.44 t ha^{-1}) was 77,000 seeds ha^{-1} in the variant with a seeding rate. It should be noted that with a seeding rate of 73,000 seeds ha^{-1}, this hybrid yields did not decrease statistically significantly, within the limits of experimental error. In options with low rates, less than 73,000 seeds ha^{-1}, as well as in thickened crops, more than 77,000 seeds ha^{-1}, the grain yield of this hybrid has significantly decreased. The productivity of the mid-season hybrid MAS 30K averaged 7.98 t ha^{-1}. The maximum yield values were in thickened crops with seeding rates from 73,000 to 83,000 seeds ha^{-1}. In the variant with a seeding rate of 67,000 seeds ha^{-1}, the grain yield was statistically significantly reduced. In less favorable hydrothermal conditions in 2014 and 2015, the grain yield on average in hybrids was lower by 1.01–1.70 t ha^{-1} (16.3–21.3%). For early ripening hybrids, the Rodnik 179SV and MAS 12R, the statistically significant yield increase was on varieties with a sowing of crops from 67,000 to 77,000 seeds ha^{-1} in 2014, from 73,000 to77,000 seeds ha^{-1} in 2015. An increase in the seeding rate from 77,000 to 93,000 seeds ha^{-1} resulted in a decrease in the grain yield of maize, according to the hybrid Springnik 179CB on average by 10.1–14.5%, according to MAS 12R – by 13.5–20.5%. This trend was also on the later ripening hybrids AMELIOR and MAS 30K.

Thus, the highest yield of early ripening Rodnik 179SV and MAS 12R hybrids was obtained at the seeding rate of 73,000 seeds ha^{-1}, of medium-early ripening AMELOR hybrid–also at the seeding rate of 73,000 seeds ha^{-1}, while medium MAS 30K hybrid was the most productive at the seeding rate of 77,000 seeds ha^{-1}.

CONCLUSIONS

Thus, the results of field studies for 2013–2015, showed that in conditions of unstable moistening, the rate of sowing seeds is one of the main factors influencing the formation of optimal plant density and the realization of the potential possibilities of maize hybrids, different groups of ripeness. An increase in the seeding rate from 61,000 to 93,000 seeds ha^{-1} did not contribute to an increase in the yield of maize, on the contrary, the higher or lower this indicator was from the optimum, the lower were the yields. The highest yield of early ripening Rodnik 179SV and MAS 12R hybrids was obtained at the seeding rate of 73,000 seeds ha^{-1}, of medium-early ripening AMELOR hybrid–also at the seeding rate of 73,000 seeds ha^{-1}, while medium MAS 30K hybrid was the most productive at the seeding rate of 77,000 seeds ha^{-1}.

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