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The effect of seed size and seeding depth on the components of maize yield structure

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Abstract

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The paper describes characteristics of grain maize hybrids by the components of the yield structure depending on the seed size and seeding depth. The dynamics of changes in the examined parameters is determined while changing 1000-kernel weight and increasing seeding depth from 4 to 11 cm. The effect of environmental conditions on the kernel row number and kernel number per row has been determined. Dependence of the kernel row number and kernel number per row on the seeding depth and seed size is examined. The growth of genetic control of the kernel row number depending on the particular hybrid is outlined in comparison with the studied elements of the technology. Application of seeds having large linear size and an optimum seeding depth of 4-7 cm allows us to increase kernel number per row. Dependence of the change in the kernel row number on the seeding depth and seed size, which indicates a high genetic nature of determination of this trait, was established. Kernel number per row increased when decreasing the seeding depth and its greatest value was achieved under the depth of 4 cm. Application of the medium and large seeds increased the value of kernel number per row by 0.2-2.1 kernels compared to small seeds. It is established that sowing of medium and large seeds at the depth of 4-7 cm ensures optimal value of the investigated components of the yield structure of maize hybrids.

Keywords: maize hybrids; yield components; kernel number; 1000-kernel weight; seeding depth; seed size

Introduction

Seed size and seeding depth are the most important components of the crop cultivation technology with the precise seeding rate, including grain maize. Availability of good, compatible and even sprouts as well as plant density and the values of components of the yield structure, which let estimate biological productivity of the crop, depend on them (Palamarchuk et al., 2010; Mazur et al., 2017).

Maize grain yield is closely associated with kernel number at harvest (Andrade et al., 1999). Kernel number per row in maize is a significant trait in determining yield components and it has great significance to study its genetic mechanism (Wu et al., 2017). Kernel row number in maize is also one of the most important yield components and a significant breeding target (Liu et al., 2015).

One of the ways to improve the quality of maize seeds is to calibrate or divide them into fractions according to their size (length, thickness, width) (Yizhyk, 2000; Palamarchuk et al., 2010; Tyshchenko et al., 2011). Selected seeds are a part of precise agrotechnology, since the cost of maize seed grain makes up 5-20% depending on the hybrid, while the increase that can be provided by a properly selected hybrid and high quality seeds can account for 20-80% (Palamarchuk et al., 2010; Kyrpa, 2011; Kyrpa, 2013a, 2013b; Mazur et al., 2017).

The beginning of plant growth, under the absence of the root system, occurs only due to the use of nutrients in the endosperm, which are decomposed by enzymes to simple forms and in the liquid phase through the corymb enter the embryo for the development of the primary root system and germinal stalk (Fadeev, 2014).

The use of large fraction of maize seed is the most positive component for increasing seed yield (Palamarchuk et al., 2010; Fadeev, 2014; Fadeev, 2016; Mazur et al., 2017). Large seed has large germ and much more nutrients, therefore, it provides good and even sprouts, since the primary (germinal) roots and the first leaf are formed, in practice, only due to the nutrients of maize seed (Mazur et al., 2017; Fadeev, 2014).

When kernels from the upper and lower parts of the ear are used for seeding, it ensures development of plants that provide the yield, which is 10-20% lower than the yield obtained when seeding kernels from the middle part of the ear (Fadeev, 2014; Makrushyn, 1994). Maize grain having proper kernel geometry has a higher quality compared to very large or small kernel. Kyrpa and Skotar (2008) note that large and medium maize seed fractions have similar seeding and yield traits, while small seeds lead to significant quality loss.

Seeding depth and evenness of seed placement have a great influence on the compatibility of sprouts, their completeness as well as plant growth and development and maize productivity. Uneven placement of plants in a row enhances competitive relationships for the factors of life, causes decrease in the yield and deterioration of its quality (Tyshchenko et al., 2011; Mazur et al., 2017). Both very shallow and deep seeding negatively affect crop germination, completeness and evenness of sprouts, intensity of maize plant growth in the initial period of vegetation (Yizhyk, 2000; Palamarchuk et al., 2010). Because of deep seeding, young sprouts have to spend excessive amount of plastic substances to overcome a top layer of soil, which makes them become depleted. In addition, the deeper the seeds are sown, the more sprouts contact on their way with pathogenic microorganisms and pests, therefore they are more affected by them, especially in soils with heavy mechanical composition (Palamarchuk et al., 2010; Fedorenko, 2011; Vykhvatniuk, 2012).

Shallow seeding in the wet soil ensures the best temperature conditions for seed germination and much of the nutrients of the endosperm are used to accelerate the growth and development of maize sprouts in the early spring period (Piven, 2003; Palamarchuk et al., 2010). Consequently, there are different opinions about the feasibility of using seeds of different fractions and the seeding depth, which requires further research and is highly relevant.

The purpose of the paper is to identify the peculiarities of forming agro-tectonics for the formation of grain productivity of maize hybrids depending on the seeding depth and seed size, to determine the effect of abiotic factors and factors studied on the basic components of the yield structure.

Materials and Methods

The research was conducted at Vinnytsia National Agrarian University at the research farm PE "Kordelivske", village Kordelivka, Kalinivsky region, Vinnytsia oblast, during 2014-2016. The experiments determined the components of the yield structure of maize hybrids depending on the seeding depth (4.7 and 11 cm) and seed size (S – small seed, M – medium seed, L – large seed). Seeding was conducted by the updated seeder SUPN-8 at the seeding rate of 75 thousand seeds per hectare. The seeding depth was 4-5 cm.

The record area of sites for hybrids was 10.5 m^2. Replication in the experiments for hybrids was 3-4 times. The sites were located by the method of randomized blocks. The records of maize yield from the record area were taken in accordance with Volkodav technique of the state variety testing of agricultural crops (grain crops, cereals and grain-legume crops) (Vovkodav, 2001) and the technique developed for maize (Lebid et al., 2008). Biological yield of maize was determined by the formula (Avramenko et al., 2011):

$$Yb = W * N: 1{,}000{,}000 \text{ (t/ha)},$$

where W is weight of kernels per ha of productive ear and N is number of productive ears per ha, units.

Physical and mechanical traits of grain, such as humidity, linear sizes, 1000-kernel weight and specific weight of kernels were determined according to generally accepted techniques (Kazakov, 1987; SSTU, 2002). The sum of linear kernel sizes was determined by the calculation method.

Results and Discussion

Reserves of nutrients in the endosperm of maize grains and large germs allow them to germinate from the depth of 10 cm or more and to remain viable for a long time while staying in dry soil. Results of conducted researches have established the effect of seed size and seeding depth on the kernel row number (Table 1).

The kernel row number in the group of early maize hybrids did not depend on the seeding depth, and an increase in the seed size provided growth of this trait. Thus, in particular, on average over three years of research, when sowing small seeds at the depth of 4 cm, the kernel row number in hybrid DKS 2960 was within 14.6, when sowing medium seeds – 15.4, and when sowing large seeds – 14.7. When the seeding depth was 7 cm, the kernel row number was 14.8, 15.1 and 15.0, and when increasing the seeding depth to 11 cm, it was 14.7, 15.2 and 15.0. A similar situation was observed in hybrid DKS 2971.

To a greater extent, characteristics of formation of kernel rows are affected by climatic conditions. Thus, in particular, favorable conditions for moisture supply in 2014 and 2016 contributed to the increase in the kernel row number on average by 0.1-3.3, compared to a more drought year of 2015.

In the mid-early hybrid group, there was observed a general increase in the kernel row number compared to the early group. Thus, in particular, on average over three years, hybrid DKS 3472 had 15.8 kernel rows under shallow seeding at the depth of 4 and 7 cm, 15.7 at the depth of 11 cm; 16.1 – when sowing medium and large seeds at the depth of 4 cm, 16.3 at the depth of 7 cm, and 15.9 at the depth of 11 cm; 15.7 – when sowing seeds of a large fraction at the depth of 4 cm, 15.8 at the depth of 7 cm, and 16.0 at the depth of 11 cm.

Mid-early hybrid DKS 3795 had 14.7 kernel rows when sowing small seeds at the depth of 4 cm, 14.6 at the depth of 7 cm, and 14.3 at the depth of 11 cm; 14.5 – when sowing medium seeds at the depth of 4 cm, 15.0 at the depth of 7 cm, and 14.8 at the depth of 11 cm. When sowing large seeds at the depth of 4, 7 and 11 cm the kernel row number was 14.7, respectively.

In the group of mid hybrids, the kernel row number was the highest compared with the early and mid-early hybrids. Thus, on average over three years, when sowing small seeds of hybrid DK 315 at the depth of 4 cm, the kernel row number was 16.1, at the depth of 7 cm – 15.5, and at the depth of 11 cm – 15.9. When sowing medium seeds at the depth of 4 cm, the kernel row number was 15.4, at the depth of 7 cm – 16.0, and at the depth of 11 cm – 16.2. In that case, there was observed a certain increase in the kernel row number when increasing the seeding depth for medium seeds from 4 to 11 cm. When sowing large seeds at the depth of 4 cm, the kernel row number was 16.1, at the depth of 7 cm – 15.8, and at the depth of 11 cm – 15.6. When sowing large seeds there was observed a decrease in the kernel row number under the increase in the seeding depth from 4 to 11 cm.

When seeding small seeds of hybrid DKS 4082 at the depth of 4 cm, the kernel row number was 15.9, at the depth of 7 cm – 16.3, and at the depth of 11 cm – 16.2. When sowing medium seeds at the depth of 4 cm the kernel row number was 16.3, at the depth of 7 cm – 16.7, and at the depth of

Table 1
Kernel row number in maize hybrids depending on the seeding depth and seed size, rows (over 2014-2016 ± Sr)

№	Hybrid name	Seed fraction	Seeding depth											
			4 cm				7 cm				11 cm			
			2014	2015	2016	average	2014	2015	2016	average	2014	2015	2016	average
			Early hybrids											
1.	DKS 2960	S (187 g)	14.9	14.0	14.8	14.6±0.5	14.7	13.6	16.0	14.8±1.2	13.9	14.2	16.1	14.7±1.2
		M (238 g)	16.7	13.6	16.0	15.4±1.6	16.1	13.7	15.6	15.1±1.3	15.6	14.2	15.9	15.2±0.9
		L (277 g)	15.8	12.8	15.4	14.7±1.6	16.5	13.2	15.2	15.0±1.7	15.6	14.3	15.2	15.0±0.7
2.	DKS 2971	S (194 g)	12.9	12.5	13.2	12.9±0.4	13.1	12.5	13.2	12.9±0.4	12.7	12.7	13.2	12.9±0.3
		M (256 g)	13.4	13.1	13.2	13.2±0.2	13.7	12.9	12.8	13.1±0.5	13.4	12.7	13.6	13.2±0.5
		L (279 g)	13.7	12.6	13.0	13.1±0.6	13.8	12.6	14.4	13.6±0.9	13.6	12.9	14.4	13.6±0.8
			Mid-early hybrids											
3.	DKS 3472	S (249 g)	15.9	15.6	16.0	15.8±0.2	16.0	15.8	15.6	15.8±0.2	16.0	15.5	15.7	15.7±0.3
		M (326 g)	16.1	16.5	15.6	16.1±0.5	16.5	16.0	16.4	16.3±0.3	15.6	16.8	15.3	15.9±0.8
		L (385 g)	15.6	16.0	15.4	15.7±0.3	15.9	16.3	15.2	15.8±0.6	16.2	16.2	15.5	16.0±0.4
4.	DKS 3795	S (166 g)	14.6	14.8	14.8	14.7±0.1	14.3	14.4	15.2	14.6±0.5	14.1	13.8	15.0	14.3±0.6
		M (207 g)	14.5	14.0	14.9	14.5±0.5	14.7	15.4	14.8	15.0±0.4	14.5	15.1	14.8	14.8±0.3
		L (287 g)	14.3	14.6	15.2	14.7±0.5	14.7	14.4	14.9	14.7±0.3	14.9	14.7	14.6	14.7±0.2
			Mid hybrids											
5.	DK 315	S (223 g)	15.4	16.9	16.1	16.1±0.8	15.3	15.4	15.9	15.5±0.3	15.6	16.2	16.0	15.9±0.3
		M (294 g)	15.6	15.2	15.4	15.4±0.2	15.4	16.3	16.4	16.0±0.5	16.3	16.0	16.4	16.2±0.2
		L (327 g)	15.8	16.6	15.8	16.1±0.5	16.1	15.4	16.0	15.8±0.4	15.7	15.4	15.8	15.6±0.3
6.	DKS 4082	S (172 g)	16.3	15.4	16.0	15.9±0.6	16.0	16.1	16.8	16.3±0.4	16.3	16.2	16.0	16.2±0.2
		M (227 g)	16.5	16.5	16.0	16.3±0.3	16.5	16.0	17.6	16.7±0.8	16.8	16.4	17.2	16.8±0.4
		L (278 g)	16.4	16.3	17.0	16.6±0.4	17.0	16.0	17.0	16.7±0.6	16.6	16.0	16.7	16.4±0.4

Note: S – small seed fraction, M – medium seed fraction, L – large seed fraction

11 cm – 16.8. But when sowing large seeds at the depth of 4 cm the kernel row number was 16.6, at the depth of 7 cm – 16.7, and at the depth of 11 cm – 16.4.

Consequently, the kernel row number is a trait which is mainly determined by the genetic features of a particular hybrid and does not depend on the seeding depth. But it can increase in hybrids grown from the medium and large seeds in comparison with the small ones. It is also necessary to note the dependence of formation of the kernel row number on the moisture supply, thus in the years of sufficient moisture supply, the kernel row number increases, while in the years of moisture deficiency (2015), on the contrary, decreases, in the same maize hybrids.

Characteristics of hybrids by kernel number per row depending on the seed size and seeding depth are presented in Table 2.

Data presented in Table 2 show that the hybrids studied differ in kernel number per row. On average over three years, hybrid DKS 2960 had 37.7 kernels per row when seeded at the depth of 4 cm, 36.9 – at the depth of 7 cm, and 35.9 – at the depth of 11 cm. When sowing medium seeds at the depth of 4 cm kernel number per row was 38.2, at the depth of 7 cm – 37.6, and at the depth of 11 cm – 38.6. When sowing large seeds at the depth of 4 cm kernel number per row was 39.1, at the depth of 7 cm – 38.6, and at the depth of 11 cm – 38.7. Another early hybrid DKS 2971 had similar traits.

In the mid hybrid group, kernel number per row in hybrid DKS 3472 ranged within 36.1-41.3, in hybrid DKS 3795 – 36.0-40.5. On average over three years of research, when sowing small seeds of hybrid DKS 3472 at the depth of 4 cm kernel number per row was 37.7, at the depth of 7 cm – 37.6, and at the depth of 11 cm – 37.7. When medium seeds of this hybrid were sown at the depth of 4 cm kernel number per row was 38.5, at the depth of 7 cm – 38.3, and at the depth of 11 cm – 38.7. When sowing large seeds at the depth of 4 cm kernel number per row was 38.5, at the depth of 7 cm – 38.6, and at the depth of 11 cm – 38.5. The seeding depth, seed size and kernel number per row in mid-early hybrid DKS 3795 were the same as in hybrid DKS 3472. In the group of mid-early hybrids, kernel number per row ranged within 37.4-43.6.

Describing the dependence of the seeding depth, seed size and the kernel row number in hybrid DK 315, it should be noted that when sowing its small seeds at the depth of 4

Table 2
Kernel number per row in maize hybrids depending on the seeding depth and seed size, kernels (over 2014-2016 ± Sr)

№	Hybrid name	Seed fraction	Seeding depth											
			4 cm				7 cm				11 cm			
			2014	2015	2016	average	2014	2015	2016	average	2014	2015	2016	average
			Early hybrids											
1.	DKS 2960	S (187 g)	36.0	37.4	39.8	37.7±1.9	35.4	37.8	37.6	36.9±1.3	36.5	37.1	34.2	35.9±1.5
		M (238 g)	37.3	37.1	40.1	38.2±1.7	36.7	37.8	38.2	37.6±0.8	36.7	40.7	38.4	38.6±2.0
		L (277 g)	37.9	38.6	40.9	39.1±1.6	38.0	37.4	40.4	38.6±1.6	36.4	37.6	42.0	38.7±3.0
2.	DKS 2971	S (194 g)	40.6	42.1	42.1	41.6±0.9	39.6	41.0	41.2	40.6±0.9	40.4	41.2	39.6	40.4±0.8
		M (256 g)	40.9	41.7	42.9	41.8±1.0	39.8	41.5	44.6	42.0±2.4	40.4	42.1	42.2	41.6±1.0
		L (279 g)	41.0	42.5	43.3	42.3±1.2	40.5	41.9	40.6	41.0±0.8	41.3	42.1	38.8	40.7±1.7
			Mid-early hybrids											
3.	DKS 3472	S (249 g)	36.1	37.0	40.1	37.7±2.1	35.8	37.6	39.4	37.6±1.8	35.9	38.1	39.0	37.7±1.6
		M (326 g)	36.9	38.0	40.5	38.5±1.9	36.6	38.8	39.6	38.3±1.6	38.1	37.3	40.6	38.7±1.7
		L (385 g)	37.4	36.9	41.3	38.5±2.4	36.6	38.4	40.9	38.6±2.2	37.4	37.6	40.6	38.5±1.8
4.	DKS 3795	S (166 g)	38.2	37.0	37.3	37.5±0.6	38.1	38.1	36.4	37.5±1.0	38.5	38.0	36.5	37.7±1.0
		M (207 g)	40.0	39.9	37.7	39.2±1.3	39.0	37.6	36.0	37.5±1.5	40.5	38.1	37.0	38.5±1.8
		L (287 g)	39.7	38.2	38.9	38.9±0.8	38.7	38.1	37.6	38.1±0.6	38.6	38.2	37.6	38.1±0.5
			Mid hybrids											
5.	DK 315	S (223 g)	38.7	37.4	39.1	38.4±0.9	39.3	39.7	39.2	39.4±0.3	39.8	37.8	39.4	39.0±1.1
		M (294 g)	39.8	41.0	43.0	41.3±1.6	40.2	40.2	39.9	40.1±0.2	41.2	40.7	40.2	40.7±0.5
		L (327 g)	40.0	41.1	41.9	41.0±1.0	40.1	42.2	41.0	41.1±1.1	40.5	40.9	42.4	41.3±1.0
6.	DKS 4082	S (172 g)	40.0	43.5	42.5	42.0±1.8	39.9	40.3	40.2	40.1±0.2	40.0	42.3	40.4	40.9±1.2
		M (227 g)	40.1	41.3	42.6	41.3±1.3	43.6	41.7	41.4	42.2±1.2	43.9	42.9	42.3	43.0±0.8
		L (278 g)	42.1	42.2	42.4	42.2±0.2	42.8	41.7	41.9	42.1±0.6	43.2	42.2	43.4	42.9±0.6

Note: M – small seed fraction, S – medium seed fraction, V – large seed fraction

cm, on average over three years of research, kernel number per row was 38.4, at the depth 7 cm – 39.4, and at the depth of 11 cm – 39.0. Kernel number per row was 41.3 when sowing medium seeds at the depth of 4 cm, 40.1 – at the depth of 7 cm, and 40.7 – at the depth of 11 cm. Kernel number per row was 41.0 when sowing large seeds at the depth of 4, 41.1 – at the depth of 7 cm, and 41.3 – at the depth of 11 cm.

When sowing small seeds of hybrid DKS 4082 at the depth of 4 cm, kernel number per row was 42.0, at the depth of 7 cm – 40.1, and at the depth of 11 cm – 40.9. When sowing medium seeds at the depth of 4 cm, kernel number per row was 41.3, at the depth of 7 cm – 42.2, and at the depth of 11 cm – 43.0, while sowing of large seeds at the depth of 4 cm provided 42.2 kernels per row, at the depth of 7 cm – 42.1, at the depth of 11 cm – 42.9.

Consequently, application of seeds of different sizes affects kernel number per row. As a rule, medium and large seeds increase kernel number per row, while the change in the seeding depth has a different effect on the kernel number per row.

Characteristics of 1000-kernel weight depending on the seed size and seeding depth are presented Table 3. 1000-kernel weight in the group of early hybrids ranged within 219.2-264.3 g. On average over three years, 1000-kernel weight of hybrid DKS 2960 amounted to 234.4 g when sowing small seeds at the depth of 4 cm, 236.7 g – at the depth of 7 cm, and 227.5 g – at the depth of 11 cm. When sowing medium seeds at the depth of 4 cm, 1000-kernel weight amounted to 240.3 g, at the depth of 7 cm – 249.3 g, and at the depth 11 cm – 238.1 g. Large seeds sown at the depth of 4 cm provided 1000-kernel weight of 248.3 g, when sown at the depth of 7 cm – 244.6 g, and at the depth of 11 cm – 248.9 g.

1000-kernel weight of hybrid DKS 2971 amounted to 241.8 g when sowing small seeds at the seeding depth of 4 cm, 241.9 g – at the depth of 7 cm, and 227.2 g – the depth of 11 cm. When sowing medium seeds at the depth of 4 cm, 1000-kernel weight was 249.9 g, at the depth of 7 cm – 250.6 g, and at the depth of 11 cm – 248.6 g. Sowing of large fraction at the depth of 4 cm provided 1000-kernel weight of 254.8 g, at the depth of 7 cm – 251.1 g, and at the depth of 11 cm – 250.9 g.

1000-kernel weight of mid-early hybrids ranged within 222.1-294.4 g. 1000-kernel weight of hybrid DKS 3472 amounted to 249.7 g when sowing small seeds at the depth

Table 3
1000-kernel weight of maize hybrids depending on the seeding depth and seed size, g (over 2014-2016 ± Sr)

№	Hybrids name	Seed fraction	Seeding depth											
			4 cm				7 cm				11 cm			
			2014	2015	2016	average	2014	2015	2016	average	2014	2015	2016	average
			Early hybrids											
1.	DKS 2960	S (187 g)	236.6	227.3	239.4	234.4±6.3	253.6	236.3	220.2	236.7±16.7	239.0	224.4	219.2	227.5±10.3
		M (238 g)	250.2	238.4	232.3	240.3±9.1	260.0	247.7	240.2	249.3±10.0	257.4	226.0	230.8	238.1±16.9
		L (277 g)	255.0	244.3	245.6	248.3±5.8	233.5	255.8	244.6	244.6±11.1	259.9	244.6	242.1	248.9±9.7
2.	DKS 2971	S (194 g)	238.2	227.5	259.7	241.8±16.4	230.9	235.3	259.4	241.9±15.4	225.9	220.1	235.6	227.2±7.8
		M (256 g)	249.6	245.7	254.4	249.9±4.4	248.3	243.7	259.8	250.6±8.3	257.5	240.3	247.9	248.6±8.6
		L (279 g)	255.8	244.2	264.3	254.8±10.1	252.6	244.5	256.2	251.1±6.0	256.5	238.9	257.2	250.9±10.4
			Mid-early hybrids											
3.	DKS 3472	S (249 g)	240.1	230.7	288.6	253.1±31.1	244.3	221.9	282.9	249.7±30.9	235.3	222.1	271.1	242.8±25.4
		M (326 g)	255.4	240.0	294.4	263.3±28.0	250.7	238.8	281.6	257.0±22.1	256.8	238.6	292.2	262.5±27.3
		L (385 g)	259.2	249.8	292.9	267.3±22.7	262.9	243.6	289.6	265.4±23.1	253.0	239.7	285.4	259.4±23.5
4.	DKS 3795	S (166 g)	247.0	236.6	274.1	252.6±19.4	244.5	241.2	262.3	249.3±11.4	241.9	240.7	246.4	243.0±3.0
		M (207 g)	256.1	266.5	288.8	270.5±16.7	259.5	237.5	278.5	258.5±20.5	254.1	246.8	272.2	257.7±13.1
		L (287 g)	266.0	265.4	280.3	270.6±8.4	266.4	245.5	286.7	266.2±20.6	262.2	253.7	296.2	270.7±22.5
			Mid hybrids											
5.	DK 315	S (223 g)	254.9	234.9	280.0	256.6±22.6	256.3	241.5	274.9	257.6±16.7	242.6	228.7	261.4	244.2±16.4
		M (294 g)	263.0	254.7	271.4	263.0±8.4	272.7	245.1	276.5	264.8±17.1	255.1	243.3	272.9	257.1±14.9
		L (327 g)	263.5	242.1	277.5	261.0±17.8	273.3	254.4	281.4	269.7±13.9	262.8	257.9	278.2	266.3±10.6
6.	DKS 4082	S (172 g)	231.6	229.1	250.0	236.9±11.4	232.7	232.9	249.1	238.2±9.4	226.5	208.8	250.7	228.7±21.0
		M (227 g)	236.9	233.0	274.9	248.3±23.1	239.8	243.6	265.1	249.5±13.7	242.4	227.3	263.8	244.5±18.3
		L (278 g)	235.6	232.8	253.5	240.6±11.2	236.8	242.0	268.7	249.2±17.1	243.7	238.5	262.8	248.3±12.8

Note: M – small seed fraction, S – medium seed fraction, V – large seed fraction

of 4 cm, 253.1 g when sowing at the depth of 7 cm, and 242.8 g when sowing at the depth of 11 cm. When sowing medium seed fraction at the depth of 4 cm, 1000-kernel weight was 263.3 g, while the increase in the seeding depth up to 7 cm provided 1000-kernel weight of 257.0 g, and the seeding depth of 11 cm provided 1000-kernel weight of 262.5 g. Large seed sown at the depth of 4 cm provided 1000-kernel weight of 267.3 g, at the depth of 7 cm – 265.4 g and at the depth of 11 cm – 259.4 g.

A similar formation of 1000-kernel weight depending on the seeding depth and the weight of seed fraction was observed in the mid maize hybrid DKS 3795. Comparison of 1000-kernel weight in the mid and early hybrids reveals its growth in the group with a longer vegetation period. 1000-kernel weight of mid maize hybrids ranged from 208.8 to 281.4 g. Thus, on average over three years, 1000-kernel weight of hybrid DK 315 amounted to 256.6 g when sowing small seeds at the depth of 4 cm, 257.6 g when sowing at the depth of 7 cm, and 244.2 g when sowing at the depth of 11 cm. Medium fraction provided 1000-kernel weight of 263.0 g under the seeding depth of 4 cm, 264.8 g under the seeding depth of 7 cm, and 257.1 g under the seeding depth of 11 cm. Large seed fraction provided 1000-kernel weight of 261.0 g when seeded at the depth of 4 cm, 269.7 g – at the depth of 7 cm, and 266, 3 g – at the depth of 11 cm.

On average over three years of research, 1000-kernel weight of hybrid DKS 4082 amounted to 236.9 g when sowing small seeds at the depth of 4 cm, 238.2 g – at the depth of 7 cm, and 228.7 g – at the depth of 11 cm. Medium fraction sown at the depth of 4 cm provided 1000-kernel weight of 248.3 g, while its sowing at the depth of 7 cm provided 1000-kernel weight of 263.8 g, and sowing at the depth of 11 cm provides 1000-kernel weight of 244.5 g. Large seeds sown at the depth of 4 cm provided 1,000-kernel weight of 240.6 g, at the depth of 7 cm – 249.2 g, and at the depth of 11 cm – 248.3 g.

Consequently, the highest value of 1000-kernel weight is obtained when seeding at the depth of 4-7 cm, while the increase in the seeding depth up to 11 cm negatively affects 1000-kernel weight in the studied maize hybrids.

The largest value of 1000-kernel weight is formed when the seeding depth is 4 and 7 cm, while the increase in the seeding depth up to 11 cm usually leads to reduction

Table 4
Yield of maize hybrids depending on the seeding depth and seed size, t/ha (over 2014-2016 ± Sr)

№	Hybrid name	Seed fraction	Seeding depth											
			4 cm				7 cm				11 cm			
			2014	2015	2016	average	2014	2015	2016	average	2014	2015	2016	average
			Early hybrids											
1.	DKS 2960	S (187 g)	7.61	7.14	8.46	7.74±0.67	7.92	7.29	7.95	7.72±0.37	7.28	7.08	7.24	7.20±0.11
		M (238 g)	9.35	7.21	8.94	8.50±1.14	9.21	7.70	8.59	8.50±0.76	8.83	7.83	8.46	8.37±0.51
		L (277 g)	9.15	7.23	9.28	8.55±1.15	8.79	7.58	9.01	8.46±0.77	8.86	7.88	9.27	8.67±0.71
2.	DKS 2971	S (194 g)	7.48	7.18	8.66	7.77±0.78	7.18	7.24	8.46	7.63±0.72	6.95	6.91	7.39	7.08±0.27
		M (256 g)	8.20	8.05	8.64	8.30±0.31	8.12	7.82	8.90	8.28±0.56	8.36	7.70	8.54	8.20±0.44
		L (279 g)	8.62	7.85	8.93	8.47±0.56	8.46	7.74	8.99	8.40±0.63	8.63	7.78	8.62	8.34±0.49
			Mid-early hybrids											
3.	DKS 3472	S (249 g)	8.27	7.99	11.11	9.12±1.73	8.40	7.91	10.43	8.91±1.34	8.11	7.84	9.96	8.64±1.15
		M (326 g)	9.10	9.02	11.16	9.76±1.21	9.07	8.88	10.97	9.64±1.16	9.16	8.96	10.89	9.67±1.06
		L (385 g)	9.07	8.84	11.18	9.70±1.29	9.17	9.14	10.80	9.70±0.95	9.20	8.75	10.78	9.58±1.07
4.	DKS 3795	S (166 g)	8.27	7.76	9.08	8.37±0.67	7.99	7.94	8.71	8.21±0.43	7.88	7.57	8.09	7.85±0.26
		M (207 g)	8.91	8.93	9.73	9.19±0.47	8.93	8.24	8.90	8.69±0.39	8.95	8.51	8.94	8.80±0.25
		L (287 g)	9.06	8.87	9.94	9.29±0.57	9.09	8.08	9.64	8.94±0.79	9.05	8.55	9.76	9.12±0.61
			Mid hybrids											
5.	DK 315	S (223 g)	9.10	8.91	10.58	9.53±0.91	9.23	8.86	10.28	9.46±0.74	9.04	8.39	9.89	9.11±0.75
		M (294 g)	9.80	9.51	10.78	10.03±0.67	10.13	9.61	10.86	10.20±0.63	10.28	9.51	10.80	10.20±0.65
		L (327 g)	9.99	9.91	11.02	10.31±0.62	10.57	9.91	11.08	10.52±0.59	10.02	9.73	11.18	10.31±0.77
6.	DKS 4082	S (172 g)	9.06	9.21	10.20	9.49±0.61	8.90	9.06	10.09	9.35±0.65	8.86	8.57	9.72	9.05±0.60
		M (227 g)	9.41	9.52	11.24	10.06±1.03	10.35	9.75	11.59	10.56±0.94	10.73	9.60	11.52	10.62±0.97
		L (278 g)	9.76	9.61	10.96	10.11±0.74	10.33	9.68	11.48	10.50±0.91	10.49	9.66	11.43	10.53±0.89

Note: M – small seed fraction, S – medium seed fraction, V – large seed fraction

in 1000-kernel weight in the studied hybrids.

In 2015, due to the lack of moisture during kernel formation and filling, there was a sharp decrease in 1000-kernel weight compared with 2014 and 2016, which were more favorable for water supply.

Characteristics of grain yield of the studied maize hybrids depending on the seeding depth and seed size are presented in Table 4. Analysis of data in Table 4 shows that grain yield ranged within 6.95-9.35 t/ha in the group of early hybrids. Thus, on average over three years when sowing small seeds of hybrid DKS 2960 at the depth of 4 cm, its grain yield amounted to 7.74 t/ha, while seeding at the depth of 7 cm provided the yield of 7.72 t/ha, and seeding at the depth of 11 cm provided the yield of 7.2 t/ha. The seeds of medium fraction provided, on average over three years, the yield of 8.5, 8.5 and 8.46 t/ha of grain, respectively, under the seeding depth of 4, 7 and 11 cm. The highest yield of DKS 2960 hybrid was obtained when sowing large seeds, namely 8.55, 8.46 and 8.67 t/ha, respectively, at the depth of 4, 7 and 11 cm.

Grain yield of early hybrid DKS 2971 amounted to 7.77, 7.63 and 7.08 t/ha, respectively, when sowing small seeds at the depth of 4, 7 and 11 cm. Increase in seed size provided the growth of the hybrid yield.

In the group of mid-early hybrids there was observed the growth of crop productivity compared with the early hybrids. Thus, on average over three years, grain yield of hybrid DKS 3472 was 9.12, 8.91 and 8.64 t/ha, respectively, when sowing seeds of small fraction at the depth of 4, 7 and 11 cm. Medium seeds provided the yield of 9.76, 9.64 and 9.67 t/ha, while large seeds provided the yield of 9.7, 9.7 and 9.58 t/ha, respectively, under the seeding depth of 4, 7 and 11 cm. Hybrid DKS 3795 had a similar change of productivity depending on the seeding depth and seed size, like in hybrid DKS 3472.

Representatives of the group of mid hybrids appeared to be the most productive. Thus, on average over three years, grain yield of hybrid DK 315 was 9.53, 9.46 and 9.11 t/ha when sowing seeds of small fraction, 10.03, 10.86 and 10.2 t/ha when sowing medium seed, and 10.31, 10.52 and 10.31 t/ha, when sowing seeds of large fraction at the depth of 4, 7 and 11 cm, respectively.

Grain yield of hybrid DKS 4082 amounted to 9.49 t/ha, 9.35 and 9.05 t/ha when sowing seeds of small fraction, 10.06, 10.56 and 10.62 t/ha when sowing medium seeds, and 10.11, 10.5 and 10.53 t/ha, when sowing seeds of large fraction at the depth of 4, 7 and 11 cm, respectively.

Conclusions

Consequently, grain yield significantly depends on climatic conditions of the year. An increase in the seeding depth for small seeds leads to a decrease in the productivity of maize hybrids, while an increase in the seeding depth for medium and large seeds up to 7-11 cm does not cause a sharp decline in the yield and it especially refers to the group of mid hybrids.

Application of large and medium seeds positively affects the increase in grain yield compared to the small fraction.

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