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Effect of Desiccant Application on Pre-Harvest Humidity of Medium-Early Hybrid LG 3258 Corn in Western Forest-Steppe Conditions

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Abstract. The high pre-harvest humidity of corn grain leads to seed injury and considerably increases the cost of growing technology. The purpose of the study is to establish the effectiveness of using desiccants to reduce the pre-harvest moisture content of grain and determine whether the desiccation of corn crops affects the yield. The following methods were used to achieve this purpose: field – to establish the effect of desiccation on corn yield, laboratory – to determine the moisture content in grain, statistical – for mathematical processing of experiment results. A field experiment that examined the timing of desiccation and the norms of desiccant use involving Roundup Max and Reglon Super preparations was conducted. Hybrid corn – LG 3258, FAO 250, medium-early. According to the results of the study, the use of desiccants reduced the pre-harvest moisture content of corn grain in all variants of the experiment. Weather conditions had a considerable impact on the decrease in grain humidity. Thus, in 2018 and 2019, the desiccation decreased the pre-harvest moisture content of grain by 6.4-8.0%, and in 2020 – by 4.0-5.3% with the treatment of corn plants in the black dot phase with Roundup Max at a rate of 3.2 l/ha. The use of Reglon Super in the phase of the appearance of a black dot resulted in a decrease in humidity by 5.2-7.8%, depending on the rate of consumption of the drug and the year of study. The treatment with Roundup Max 10 days after the black dot appeared decreased the humidity by 4.0-7.5%, depending on the consumption rate and the year of study. The use of Reglon Super reduced pre-harvest humidity by 4.0-6.5%, depending on the rate of the drug and the year of the study. Treatment of plants in the 40% grain moisture phase was the most effective, which contributed to the formation of 20.1% humidity when using Roundup Max at a rate of 3.2 l/ha. Desiccant treatment of corn crops did not affect the yield in any of the variants of the experiment. According to the results of the study, corn desiccation is an effective technological technique that reduces the pre-harvest moisture content of grain by 4.0-8.0%, depending on the drug, its rate, and weather conditions. The lowest harvesting humidity – 20.1% was obtained in the variant of treating corn with a grain humidity of 40% with Roundup Max at a rate of 3.2 l/ha. The economic assessment showed that the highest net profit was obtained in the Roundup Max 2.4 l/ha treatment option in the black dot phase – UAH 47,491/ha, the profitability level is 165%

Keywords: corn, harvesting humidity, desiccation, pre-harvest drying, yield

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INTRODUCTION

Corn ranks second in terms of gross grain harvest and structure of sown areas. This is a highly productive crop with a wide range of applications, which conditions its demand. During 1990-2020, there had been a tendency in Ukraine to increase the sown area of corn and, accordingly, the gross harvest, according to which Ukraine ranks 6th in the world [1]. Corn cultivation has an essential economic role, as Ukraine ranks third/fourth in the world in terms of supply volumes [2].

An important element of corn cultivation technology is harvesting. It is conducted at a grain humidity of no more than 25-30%. The high moisture content of the grain increases the risk of injury and the level of loss. According to S.V. Krasnienkov et al [3; 4] with the shift of harvesting dates from early to late, the number of dead plants increased from 0.1 to 9.1% and drooping – by 6.8-67.1%, depending on the hybrid. The delay in harvesting dates led to an increase in disease damage by 9.3-23.8%, in particular Fusarium wilt – by 7.9-14.5%, Aspergillosis – 9.0-13.5%, etc. The humidity of corn grain was the lowest when harvesting at optimal times (14.5-19.3%), compared to the early ones (14.4-23.3%), and the delay in harvesting times contributed to an increase in grain moisture (16.3-20.8%).

Injured seeds have reduced germination, viability, they are worse stored, and prone to pathogens. Corn is most susceptible to injury among cereals. Therefore, it is optimal to harvest it at a grain humidity of 12-22% [5-7]. The pre-harvest humidity of corn is considerably influenced by the ripeness group, weather conditions, and individual characteristics of the hybrid such as the type of grain, the thickness and consistency of the rod, and the density of seed laying, the number of wrappers, their thickness and density, the slope of the cobs after physiological ripeness. According to V. Palamarchuk and O. Kovalenko [8] foliar fertilisation increased pre-harvest moisture of corn by 0.47-5.47% compared to the control. The lowest possible pre-harvest humidity of grain would reduce the cost of drying the grain at which the reduction of 1% moisture consumes 1.6-3.4 kg of fuel, which is especially true with today's increase in fuel prices [9].

It was established that the average daily moisture transfer rate is 0.8-1.2% at a grain humidity of 35-40%, 0.5-0.7% at 30-35%, and 0.3-0.4% at a grain humidity of 25-30% under favourable weather conditions. Cool, humid weather considerably hinders the moisture transfer of grain [10-12]. The use of desiccants can ensure uniform ripening of grain and the ability to harvest in a short time, which prepares the field for subsequent crops. An additional advantage of desiccation is weed control and reduced grain drying costs. This technological technique is widely used on such crops as soy, rapeseed, sunflower [13-15].

For desiccation, preparations based on diquat, glyphosate, and glufosinate ammonium are mainly used, which have different mechanisms of action. It is important to choose the right desiccation time. The use of desiccants before the onset of the physiological ripeness of grain can negatively affect the yield. In hybrids of corn of the early-maturing and medium-maturing groups, an indicator of the onset of physiological ripeness is the development of a "black dot" at the place of attachment of the seed, which indicates that the accumulation of plastic substances is completed. In hybrids of the mid-late group, the signal for desiccation is the drying of 2-3 upper leaves.

Very few studies have been conducted on the use of desiccants on corn. In China, the use of diquat reduced the moisture content of corn grains by 2.01-2.44% [16]. In the conditions of the Russian Federation, the use of desiccants 2 weeks before harvesting decreased the moisture content of corn grain by 3.1-5.6%. Desiccation did not affect the level of corn yield [17; 18]. According to the study by E. Ivanova [19], desiccation at a grain humidity of 40% contributed to a decrease in pre-harvest humidity by 4-5%. According to US researchers, the use of sodium chlorate accelerated the possibility of harvesting corn for 1-3 weeks [20].

However, the conducted studies do not consider the group of ripeness of the hybrid, the terms and rates of the drug use. Climatic conditions also considerably affect the pre-harvest humidity of corn, so it is important to examine the effectiveness of using desiccants in the conditions of the western forest-steppe of Ukraine. Desiccation of corn crops can be an effective measure to reduce the pre-harvest moisture content of grain and have economic feasibility, especially in modern economic conditions, when the cost of drying grain is a major part of the total cost of growing technology; thus, this issue requires detailed investigation.

The purpose of the study is to determine the effectiveness of using desiccants to reduce the pre-harvest humidity of LG 3258 hybrid corn in the conditions of the Western Forest-Steppe.

MATERIALS AND METHODS

Field research was conducted in the Research and Production Centre "Podillia" of Podilskyi State Agrarian Technical University during 2018-2020. The soil of the experimental site is typical chernozem, characterised by the following agrochemical indicators: humus content – 3.27%, easily hydrolysed nitrogen (according to Kornfield) – 116 mg/kg of soil, mobile phosphorus compounds (according to Chirikov) – 95 mg/kg of soil, potassium – 87 mg/kg of soil, pH – 6.5.

The cultivation technology is typical for the region. Its predecessor is winter cereals. After collecting the predecessor, disking was performed at 10-12 cm. Plowing was conducted at 26-28 cm in November. Mineral fertilisers were applied under fallow plowing according to the variants of the experiment. Potassium chloride (potassium content – 60%) was used from potash fertilisers, and ammophos (phosphorus content – 52%) was used

from phosphorous fertilisers. Nitrogen fertilisers were applied in the spring. The fertiliser rate is $N_{120}P_{60}K_{100.}$ In the spring, moisture was closed, pre-sowing cultivation and nitrogen fertilisers were applied, of which 50% of the rate was urea (46% nitrogen) and 50% ammonium nitrate (34.4% nitrogen).

Hybrid LG 3258 (FAO 250), mid-early, originator company – Limagrain. The total area of the experimental plot is 40 m^2, and the accounting area is 32 m^2. Sowing took place in the third decade of April with a Monosem NG Plus 8 seeder, focusing on temperature indicators. Row spacing is 70 cm wide and seed embedding depth is 6 cm. The seeding rate is 90 thousand seed/ha. The stocking density was 80,000 plants/ha. Hybrid LG 3258 (FAO 250), medium-early, originator – Limagrain Europe. Seeds of category F1 comply with DSTU 2240-93 [21] and are treated by the manufacturer with the following active ingredients: clothianidin + thiram + fludioxonil + metalaxyl M.

Weed protection included the application of herbicides Primextra TZ Gold SC (S-Metolachlor – 312.5 g/l + Terbuthylazine – 187.5 g/l) – 4.0 l/ha before germination and Maister (foramsulfuron 300 g/kg + Iodosulfuron 20 g/kg + Isoxadifen-ethyl 300 g/kg) – 0.15 kg/ha in the phase of 5 leaves. Pest protection – Rimon Fast (novaluron, 50 g/l + bifenthrin, 50 g/l) – 0.5 l/ha in the ejection phase.

Spraying of plants was conducted when a "black dot" appeared – a dark layer at the seed attachment point, and 10 days after the black dot using a satchel sprayer. Roundup Max (450 g/l of glyphosate in acid equivalent) was used to treat plants at a rate of 2.4 l/ha and 3.2 l/ha, Reglon Super (150 g/l of diquat ion) at a rate of 2.0 and 3.0 l/ha. Harvesting, crop accounting, and humidity determination were conducted using a Haldrup C-85 combine. The economic efficiency of the cultivation technology was established using the calculation method.

Climatic conditions during 2018-2020 differed from the long-term average values (Table 1). The average annual temperature in 2018 was higher by 2.3°C, and in 2019 and 2020 – by 2.9°C from the long-term average temperature. Precipitation was also higher than the long-term average. Notably, the nature of precipitation distribution was uneven – dry periods were replaced by heavy downpours.

***Table 1**. Distribution of precipitation and air temperature over the years under study*

Year	Months												Amount for the year
	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	
Precipitation distribution, mm													
L.A.*	27	27	27	48	66	84	85	68	50	40	38	32	592
2018	23	34	62	16	31	113	118	23	21	31	33	59	564
2019	43	23	19	49	139	198	47	26	11	14	21	28	617
2020	14	36	27	20	70	155	39	31	120	62	10	36	620
Average monthly temperatures, °C													
L.A.*	-5.3	-3.8	1.1	7.8	14.4	17.2	19.2	18.5	14.2	8.7	2.2	-2.5	7.6
2018	-1.2	-2.8	-0.2	13.9	17.8	19.7	20.3	21.6	16.1	11.0	2.2	-1.6	9.7
2019	-3.4	1.7	5.5	10.1	15.1	21.8	19.8	21.1	16.0	10.1	6.8	1.7	10.5
2020	-0.3	2.3	5.5	9.3	12.7	20.0	20.0	21.4	17.0	12.7	4.3	1.4	10.5

***Note**: * – long-term averages*

RESULTS AND DISCUSSION

The harvesting moisture content of corn grain depended on the climatic conditions of the studied year. September 2020 was characterised by an excess of the long-term average precipitation rate, which affected the humidity of corn grain, which was 29.2%. On average, over the years under study on the control variant, the pre-harvest moisture content of corn grain was 27.7% (Table 2). The introduction of desiccants at a grain humidity of 40% contributed to the greatest decrease in the harvesting humidity of corn. When using Roundup Max at a rate of 2.4 l/ha, the humidity was 20.6%, which is 7.1% less than the control. When the drug rate was increased to 3.2 l/ha, the humidity decreased to 20.1%, which is 7.6% less than the control. The use of Reglon Super at a rate of 2.0 l/ha reduced the moisture content of corn grain to 20.8%, which is 6.9 less than the control. When 3.2 l/ha of Reglon Super was applied, the moisture content was 20.4%, which is 7.3% less than the control. Spraying plants in the black dot phase and 10 days after the black dot was slightly less effective. Treatment of corn with Roundup Max 2.4 l/ha reduced the humidity of corn grain to 21.2%, and with an increase in the rate to 3.2 l/ha – 20.9%. When Reglon was applied at the rate of 2.0 l/ha in the black dot phase, the grain moisture was 21.3%, and when applying 3.0 l/ha – 21.0%, which is 6.4 and 6.7% less than the control. The smallest decrease in grain moisture was obtained in the option of applying desiccants 10 days after the black dot.

***Table 2**. Harvesting humidity of corn depending on the use of desiccants, %*

Application period	Drug	2018	2019	2020	Average	± to control, %
	1. Control	26.4	27.5	29.2	27.7	–
40% grain moisture	2. Roundup Max 2.4 l/ha	19.1	19.5	23.2	20.6	-7.1
	3. Roundup Max 3.2 l/ha	18.3	19.0	23.1	20.1	-7.6
	4. Reglon 2.0 l/ha	19.1	19.8	23.4	20.8	-6.9
	5. Reglon 3.0 l/ha	18.8	19.1	23.2	20.4	-7.3
Black dot	6. Roundup Max 2.4 l/ha	19.2	20.0	24.4	21.2	-6.5
	7. Roundup Max 3.2 l/ha	19.2	19.5	23.9	20.9	-6.8
	8. Reglon 2.0 l/ha	19.3	20.5	24.2	21.3	-6.4
	9. Reglon 3.0 l/ha	18.6	20.2	24.0	21.0	-6.7
10 days after the black dot	10. Roundup Max 2.4 l/ha	19.5	20.9	25.2	21.9	-5.8
	11. Roundup Max 3.2 l/ha	18.9	20.7	25.0	21.5	-6.2
	12. Reglon 2.0 l/ha	20.0	21.1	25.2	22.1	-5.6
	13. Reglon 3.0 l/ha	19.9	20.3	25.0	21.7	-6.0

Thus, when using Roundup Max 2.4 l/ha, humidity was 21.9%, and when applying 3.0 l/ha – 21.5%, which is 5.8 and 6.2% less than the control. The introduction of Reglon Super at a rate of 2.0 l/ha reduced the moisture content to 22.1%, and at a rate of 3.0 l/ha – 21.7%, which is less than the control by 5.6 and 6.0%. The use of desiccants in the cultivation of corn dries the vegetative mass of the plant, which promotes faster physical evaporation of moisture in the grain, which is more intense at higher temperatures. Similar data are observed in a number of studies by Chinese and Russian researchers, in which the decrease in moisture content in corn grain was 2.01-5.6% [17-20].

According to the results of the study, the effect of desiccation depends to a greater extent on the timing of application of the drug (Table 3). In the variants of using desiccants at a corn grain humidity of 40%, grain losses in the amount of 0.17-0.35 t/ha of grain were observed, depending on the drug, rate, and year of the study. When using Roundup Max at a grain humidity of 40%, the average yield was 10.67 t/ha, which is 0.22 t/ha less than the control option – 10.89 t/ha. An increase in the rate of the drug to 3.2 l/ha contributed to an increase in losses by 0.25 t/ha, the yield was 10.63 t/ha (Fig. 1). Corn treatment with Reglon at a rate of 2.0 l/ha reduced the yield to 10.61 t/ha, which is 0.28 t/ha less than the control, and the use of 3.0 l/ha decreased the yield to 10.58 t/ha, which is 0.30 t/ha less than the control. Desiccation at a grain moisture content of 40% reduces the grain yield of corn by stopping photosynthesis, synthesis, and metabolism, artificially accelerating the end of the growing season.

***Table 3**. Corn yield depending on the use of desiccants, t/ha*

Application period	Drug	2018	2019	2020	Average	± to control	
						t/ha	%
	1. Control	10.55	11.33	10.78	10.89	–	–
40% grain moisture	2. Roundup Max 2.4 l/ha	10.27	11.16	10.58	10.67	-0.22	-2.0
	3. Roundup Max 3.2 l/ha	10.24	11.12	10.54	10.63	-0.25	-2.3
	4. Reglon 2.0 l/ha	10.22	11.08	10.52	10.61	-0.28	-2.6
	5. Reglon 3.0 l/ha	10.20	11.05	10.50	10.58	-0.30	-2.8
Black dot	6. Roundup Max 2.4 l/ha	10.54	11.32	10.77	10.88	-0.01	-0.1
	7. Roundup Max 3.2 l/ha	10.54	11.32	10.76	10.87	-0.01	-0.1
	8. Reglon 2.0 l/ha	10.53	11.31	10.76	10.87	-0.02	-0.2
	9. Reglon 3.0 l/ha	10.53	11.32	10.76	10.87	-0.02	-0.2

Table 3, Continued

Application period	Drug	2018	2019	2020	Average	± to control	
						t/ha	%
10 days after the black dot	10. Roundup Max 2.4 l/ha	10.55	11.32	10.79	10.89	0.00	0.0
	11. Roundup Max 3.2 l/ha	10.54	11.34	10.79	10.89	0.00	0.0
	12. Reglon 2.0 l/ha	10.54	11.33	10.77	10.88	-0.01	-0.1
	13. Reglon 3.0 l/ha	10.56	11.32	10.78	10.89	0.00	0.0
$HIP_{0,5}$ t/ha	2018	A = 0.10; B = 0.11; AB = 0.11					
	2019	A = 0.15; B = 0.12; AB = 0.12					
	2020	A = 0.12; B = 0.10; AB = 0.10					

Spraying plants in the black dot phase and 10 days after the black dot had little effect on yield (Fig. 1) since the development of a dark layer at the site of seed attachment means that by this time the process of accumulation of assimilates is completed. The desiccation during this period decreased yield by 0-0.02 t/ha of corn grain, which is not statistically proven.

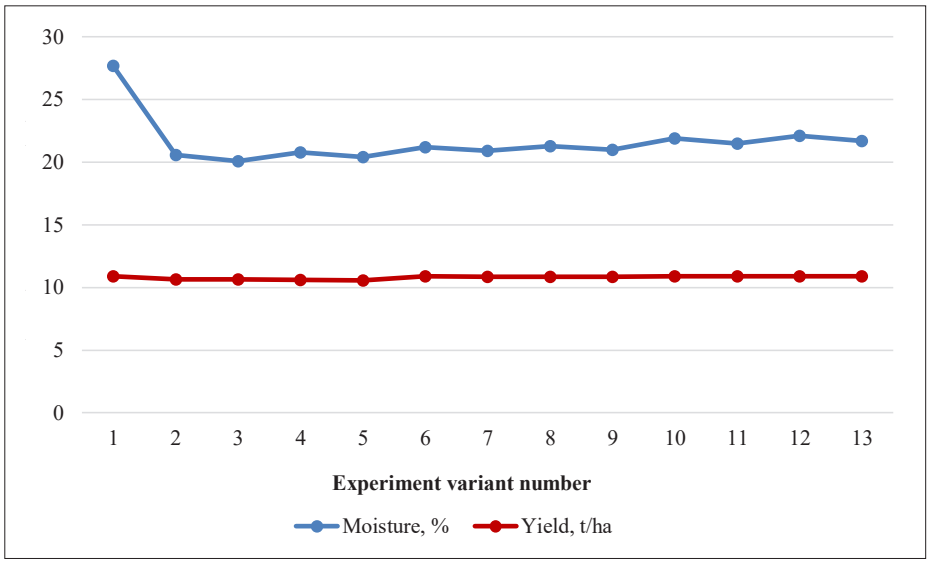

***Figure 1**. Dynamics of moisture and yield of corn under the use of desiccants*

Data on the impact of desiccation on the yield level vary. According to studies by E. Alcantara and D. Wyse [22], the use of glyphosate did not affect yields and had little effect on reducing humidity in high humidity conditions. Other studies also indicate a slight effect on yield. According to A. Volkov, L. Prokhorova and M. Sivandaev, desiccation in the phase of full ripeness of corn reduced the yield by 0.05-0.09 t/ha, depending on the drug and the year under study [23]. L. Zhao et al. [24] report that the effect of glyphosate on yield depends on the hybrid. The study established that the treatment of corn with glyphosate slightly reduces the yield and does not affect the quality indicators.

For a comprehensive assessment of the studied elements of corn cultivation technology, economic efficiency indicators were calculated (Table 4).

***Table 4**. Economic efficiency of using desiccants in corn cultivation, 2018-2020*

	Option	Yield, t/ha	Cost of products with 1 ha, UAH	Expenses per 1 ha, UAH	Prime cost of 1 tonne, UAH	Conditionally net profit from 1 ha, UAH	Profitability level, %
	1. Control	10.89	76230	31571	2899	44659	141
40% grain moisture	2. Roundup Max 2.4 l/ha	10.67	74690	28340	2656	46350	164
	3. Roundup Max 3.2 l/ha	10.63	74410	28215	2654	46195	164
	4. Reglon Super 2.0 l/ha	10.61	74270	28404	2677	45866	161
	5. Reglon Super 3.0 l/ha	10.58	74060	28403	2685	45657	161

Table 4, Continued

	Option	Yield, t/ha	Cost of products with 1 ha, UAH	Expenses per 1 ha, UAH	Prime cost of 1 tonne, UAH	Conditionally net profit from 1 ha, UAH	Profitability level, %
Black dot	6. Roundup Max 2.4 l/ha	10.89	76160	28739	2639	47491	165
	7. Roundup Max 3.2 l/ha	10.88	76090	28727	2640	47433	165
	8. Reglon Super 2.0 l/ha	10.87	76090	28765	2646	47325	165
	9. Reglon Super 3.0 l/ha	10.87	76090	28822	2651	47269	164
10 days after b.d.	10. Roundup Max 2.4 l/ha	10.89	76230	29121	2674	47109	162
	11. Roundup Max 3.2 l/ha	10.89	76160	29057	2668	47173	162
	12. Reglon Super 2.0 l/ha	10.88	76160	29203	2684	46957	161
	13. Reglon Super 3.0 l/ha	10.88	76160	29206	2684	46954	161

Additional spraying and desiccation are cost-effective compared to control. According to Table 4, production costs per 1 ha decreased by 2365-3356 UAH, respectively, the prime cost of 1 t/ha decreased by 214-259 UAH due to the reduction of grain drying costs. Desiccation allows getting 998-2832 UAH/ha more of conditionally net profit.

The smallest increase in net profit was in the options of applying desiccants at 40% humidity of corn grain due to a decrease in yield. The greatest increase in conditional net profit was obtained with the use of desiccants in the black dot phase, where treatments have little effect on yield and reduce humidity by 6.5-6.8%, and the economic efficiency is almost the same regardless of the drug and the rate of its application.

CONCLUSIONS

Roundup Max and Reglon Super both affected the pre-harvest moisture content of corn grains. Weather conditions of the year had a considerable impact on the pre-harvest humidity of grain, compared to the drug and its consumption rate. Desiccation had a positive effect on the pre-harvest moisture content of corn in all variants of the experiment. Desiccant treatments were most effective at a grain moisture content of 40%, the least effective was the treatment 10 days after the onset of the black dot. The lowest grain moisture of 20.1% of corn was obtained when applying Roundup Max at the rate of 3.2 l/ha in the variant of plant treatment at a humidity of 40%. This allows harvesting and preparing the field for subsequent crops in optimal time and reducing the cost of drying grain.

The timing of treatments is found to be important when using chemical dehumidifiers. Desiccation at a corn grain humidity of 40% reduced the yield by 0.17-0.35 t/ha, depending on the drug, its rate, and the year of the study. Spraying in the black dot phase and 10 days after the black dot had little effect on yield – 0-0.02 t/ha less than the control variant. The use of desiccants in corn cultivation technology is cost-effective. The largest net profit was obtained with the Roundup Max 2.4 l/ha treatment option in the black dot phase – UAH 47,491/ha, the profitability level is 165%.

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Вплив застосування десикантів на передзбиральну вологість кукурудзи середньораннього гібриду LG 3258 в умовах Західного Лісостепу

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Анотація. Висока передзбиральна вологість зерна кукурудзи призводить до травматизації насіння та значно збільшує витрати у технології вирощування. Метою досліджень було встановити ефективність застосування десикантів для зниження передзбиральної вологості зерна та визначити чи впливає проведення десикації посівів кукурудзи на врожайність. Для досягнення мети були використані такі методи: польовий – для визначення впливу проведення десикації на врожайність кукурудзи, лабораторний – для визначення вмісту вологи у зерні, статистичний – для математичної обробки результатів досліду. Проведено польовий дослід, у якому були вивчені строки проведення десикації та норми застосування десикантів, з використанням препаратів Раундап Макс і Реглон Супер. Гібрид кукурудзи – ЛГ 3258, ФАО 250, середньоранній. За результатами досліджень встановлено, що застосування десикантів знижувало передзбиральну вологість зерна кукурудзи в усіх варіантах досліду. На зниження вологості зерна вагомий вплив мали погодні умови. Так, у 2018 та 2019 рр. за допомогою десикації передзбиральна вологість зерна знизилася на 6,4–8,0 %, а у 2020 р. – на 4,0–5,3 % при обробці рослин кукурудзи у фазі чорної точки препаратом Раундап Макс у нормі 3,2 л/га. При застосуванні Реглону Супер у фазі появи чорної точки спостерігали зниження вологості на 5,2–7,8 % залежно від норми витрати препарату та року досліджень. У варіантах обробки через 10 днів після чорної точки препаратом Раундап Макс вологість знизилася на 4,0–7,5 % залежно від норми витрати та року досліджень. Використання Реглону Супер знижувало передзбиральну вологість на 4,0–6,5 % в залежності від норми препарату та року досліджень. Обробка рослин у фазі 40 % вологості зерна була найефективнішою, що сприяло формуванню вологості 20,1 % при застосуванні Раундап Макс у нормі 3,2 л/га. Проведення обробки десикантами посівів кукурудзи не мало впливу на врожайність у жодному з варіантів досліду. За отриманими результатами дослідження було встановлено, що проведення десикації кукурудзи є ефективним технологічним прийомом, що дозволяє знизити передзбиральну вологість зерна на 4,0–8,0 % залежно від препарату, його норми та погодних умов. Найнижчу збиральну вологість – 20,1 % отримали у варіанті обробки кукурудзи при вологості зерна 40 % препаратом Раундап Макс в нормі 3,2 л/га. Економічна оцінка показала, що найбільший чистий прибуток отримали у варіанті обробки препаратом Раундап Макс 2,4 л/га у фазі чорної точки – 47491 грн/га, рівень рентабельності становить 165 %

Ключові слова: кукурудза, збиральна вологість, десикація, переджнивне підсушування, врожайність