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Development of Basic Elements of the Technology of Primary Seed Production of Different Mustard Types under Conditions of the Southern Steppe of Ukraine

Oleksandr ZHUYKOV[1], Sergiy LAVRENKO[1], Olena PETROVA[2], Tetiana KACHANOVA[2], Tetiana MANUSHKINA[2]

Kherson State Agrarian University, Kherson, 23 Stritenska Street, 73006, Ukraine[1]
Mykolayiv National Agrarian University, Mykolaiv, 9 Heorhii Honhadze Street, 54020, Ukraine[2]

ABSTRACT— The paper presents experimental results concerning cultivation of different mustard types under conditions of the Southern Steppe of Ukraine and the effect of growing techniques on the indexes of seed quality. The research made it possible to establish that using the seeds of the 4th generation for sowing, in comparison to the elite seeds, causes a decrease in the level of the seed productivity by 50.5% and that of oil content – by 12.5%, winter-hardiness of winter Sarepta mustard falls by 59.5%. In order to obtain filled seeds, it is necessary to sow mustard seeds with a traditional row method with the row spacing of 15 cm. To obtain high-quality seeds it is necessary to apply one-stage combine harvesting with further obligatory primary seed cleaning to remove impurities, not later than 4 hours after harvesting. Optimum basis moisture of mustard seeds is 8%. Basis moisture can be raised to 12% for the seeds of winter Sarepta mustard, whose shelf life does not exceed 60 days, moisture should be decreased to 8%, in case of creating backup funds of the crop. The shelf life that allows the seeds of white and black Sarepta mustard to retain their seeding standards is three years provided that they are stored in stacks of not more than five sacks.

KEYWORDS: germination energy, laboratory germination, mustard, quality, productivity

1. INTRODUCTION

In the structure of production costs of modern technologies of growing agricultural crops, the cost of high-quality seeding material yields only to the costs spent on purchasing fuels, mineral fertilizers and agro-chemicals. Taking it into account, we can understand the attempts of some agricultural producers to save money neglecting these expenditures, since, in their opinion, probable problems caused by sowing low-quality seeds are deferred and less evident in comparison to other obligatory elements of the technology. However, as the results of the scientists' research and the practice of advanced farms prove, low levels of productivity of most field crops because of low-quality seeding material can entirely reduce a positive effect of applying the most progressive and efficient elements of technology [4], [8], [12], [15]. However, currently it is impossible to ignore the other aspect of this problem, when the cost of seeds turns from an economically reasonable category into a speculative one. In most cases it happens in those situations when there is a middleman on the way from the originator to the end consumer (or even a few middlemen) – therefore an average commodity producer cannot afford to buy original seeds. Therefore, currently the attempt of most agricultural producers to deal with their own primary seed production on the basis of original seeding material is objective and logical, since, in terms of high-quality seed production, most agribusiness entities can follow the technologies. In order to determine basic elements of the technology of primary seed production of mustard types to implement it on the farms of the Steppe zone, we conducted research aimed at examining its biological and technological aspects. According to the data collected by many scientists, the total level of seed productivity of any crop, including mustard, is mainly caused by the following factors: environmental (abiotic and biotic) conditions of an agro- climatic zone, elements of a cultivation technology and genetically specified crop potential [1], [2], [8], [9], [20]. Thus, the use of seeding material of high generations in a production process is a certain guarantee of maximum productive potential of mustard that should be realized in actual production conditions. Nowadays most entities of agricultural activities in Ukraine give priority to the provision of agro-technology with mineral fertilizers, fuels, pesticides, and machines in the issue of supplying resources for the process of crop production, and the problem of high-quality seeding material is often solved last of all [3], [5], [13], [14], [23]. Using unoriginal seeds, lacking necessary seeding standards, often – of low generations and neglecting the principles of variety- and crop-rotation are characteristic of most farms and individual famers. In an absolute majority of crops, the use of seeds of low generations for sowing causes the following negative manifestations: a decrease in the tolerance of a plant organism to the influence of abiotic and biotic factors of agrocenosis, deterioration of main economically valuable properties (first of all, of seed oil content and resistance to lodging and shedding) and, consequently, a reduced level of the crop seed productivity.

2. Materials and methods

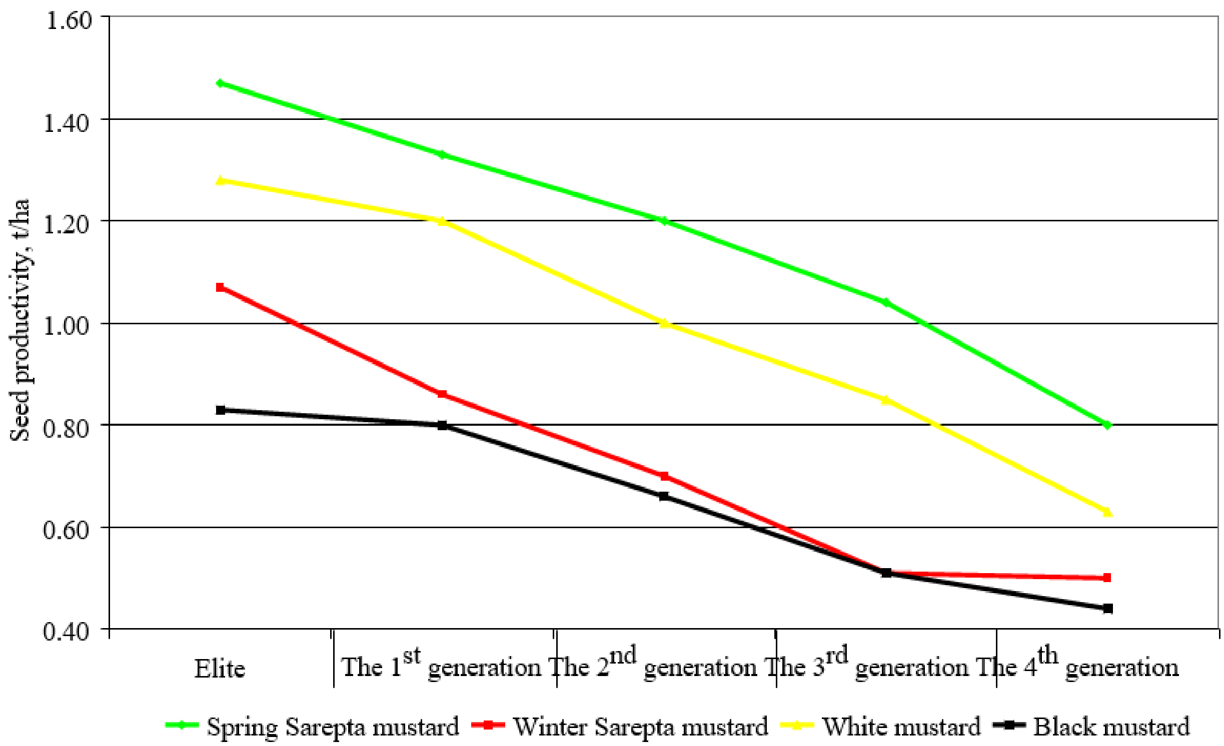
The research was carried out on the experimental fields of Kherson State Agrarian University (Ukraine, the southern part of Kherson region). The experimental plots are located at the 46°69′33 Nw. 33°48′62″ Ed., the average height above sea level is 39 m. The soil of the experimental plot is dark chestnut, medium loam, residual-alkaline. The total humus content is 1.97%, the total nitrogen content is 0.18%, phosphorous content is 0.34%, pH of salt extract is 7.4. The following factors and their variants were included in the research scheme:

Factor A – mustard types: spring Sarepta mustard (*Brassica juncea*), winter Sarepta mustard (*Brassica juncea*), white (*Sinapis* alba) and black mustard (*Brassica nigra*);
Factor B – seed generations: elite, the 1st generation, the 2nd generation, the 3rd generation and the 4th generation.

The field experiment was done with the method of split randomized blocks. The research was accompanied by phonological, biometric, structural and laboratory observations in accordance with generally accepted methods [21]. The cultivation methods in the research corresponded to the field crops in the Southern Steppe of Ukraine and were applied on a high agro-technological level [21], [22]. Winter wheat was a pre-crop of mustard in the experiment. After harvesting the pre-crop, the stubble was disked 14-16 cm deep for spring mustards (Sarepta, white and black). In two weeks the soil was ploughed 22-24 cm deep. In spring, at the time of physical soil maturity, harrowing was carried out followed by pre- sowing cultivation of 3-4 cm. Mustard seeds were sown in the 3rd decade of March at the rate of 2.5 million germinated seeds per hectare. For winter mustard – disking was carried out to the depth of 14-16 cm after harvesting the pre-crop followed by direct sowing of the crop in the 3rd decade of August. The following nutrition scheme was used in the experiments. Nitrogen fertilizers at the rate of N_{30} were applied for pre-sowing cultivation; $N_{15}P_{15}K_{15}$ – at the time of sowing; nitrogen fertilizers at the rate of N_{30} with a liquid complex mineral fertilizer (LCMF) “Hileia – Khrestitsvit” containing chelate complex of macro-, meso- and micro-elements – N, P, K, S, Mn, B, Mo, Zn, Co at the stage of budding – the beginning of flowering. Integrated protection of mustard plants included pre-sowing seed treatment with the preparation based on clothianidin, 300 g/l; fluopicolide, 120 g/l; fluoxastrobin, 90 g/l; at the stage of a leaf rosette, the crops were treated to control weeds with the preparation based on fenoxaprop-P-ethyl, 110 g/l; at the stage of budding the crops were treated with the preparation based on alpha-cypermethrin, 100 g/l to protect them from weeds. The grain yield was calculated by means of harvesting from the total experimental plot. After harvest, the seed yield was converted to basic humidity. The experimental data were processed by the standard procedure of ANOVA within MS Excel software. The significance of the differences was proved for the reliability level of 95% (LSD_{05}). The weather conditions in the years of the research (2016-2020) thoroughly reflected the meteorological characteristic of the Southern Steppe of Ukraine that made it possible to obtain reliable experimental data, draw conclusions and offer recommendations for agricultural production in the given conditions.

3. Results and discussions

The obtained data prove that as there was a decline in the seed generation from the elite generation to the 4th generation, the productivity of the graded seeds of spring Sarepta mustard fell from 1.47 to 0.80 t/ha (by 45.6%), that of winter Sarepta mustard – from 1.07 to 0.50 t/ha (by 53.3%), that of white mustard – from 1.28 to 0.63 t/ha (by 50.1%) and that of black mustard – from 0.83 to 0.44 t/ha (by 47.0%) (Figure 1). The main reasons of this negative phenomenon are thought to be a considerable decrease in the crop tolerance towards the complex of unfavorable abiotic and biotic factors of the environment in agrophytocenosis and resistance to seed shedding.



Note: LSD_{05} for Factor A – 0.20, Factor B – 0.15, the interaction of Factors AB – 0.27 t/ha.

Fig. 1 Mustard seed productivity depending on the seed generation (the average for 2016-2020)

The use of elite seeds of mustard for sowing in the course of four years without renovation reduced oil content from 38.6% to 35.1% in the variant of spring Sarepta mustard, from 38.2% to 35.5% in the variant of winter Sarepta mustard, from 27.8% to 24.4% in the variant of white mustard and from 34.3% to 30.2% in the variant of black mustard (Figure 2). Heterogeneous character of the genetic structure of winter mustard population being a varietal population consisting of individual plants of spring, transitional and winter variety types, caused a reduction in winter- hardiness of the crop (the percentage of plants that regenerated spring vegetation in terms of plant density at the time of the cease of autumn vegetation) because of a decline in the seed generation (Figure 3). A decline in the number of winter Sarepta mustard plants, that regenerated spring vegetation per unit area after winter anabiosis without renovation of the seed generation (from 55.2 – when using elite seeds to 34.6% – when using the seeds of the 4th generation) is explained by an increase in the share of the plants of transitional and spring types in the genetic structure of the varietal population and a simultaneous reduction in the share of the plants of a winter type. Moreover, an allelic gene responsible for a winter type of development is recessive. This process is especially intensive when the seeds of the 2nd and later generations are used for sowing.

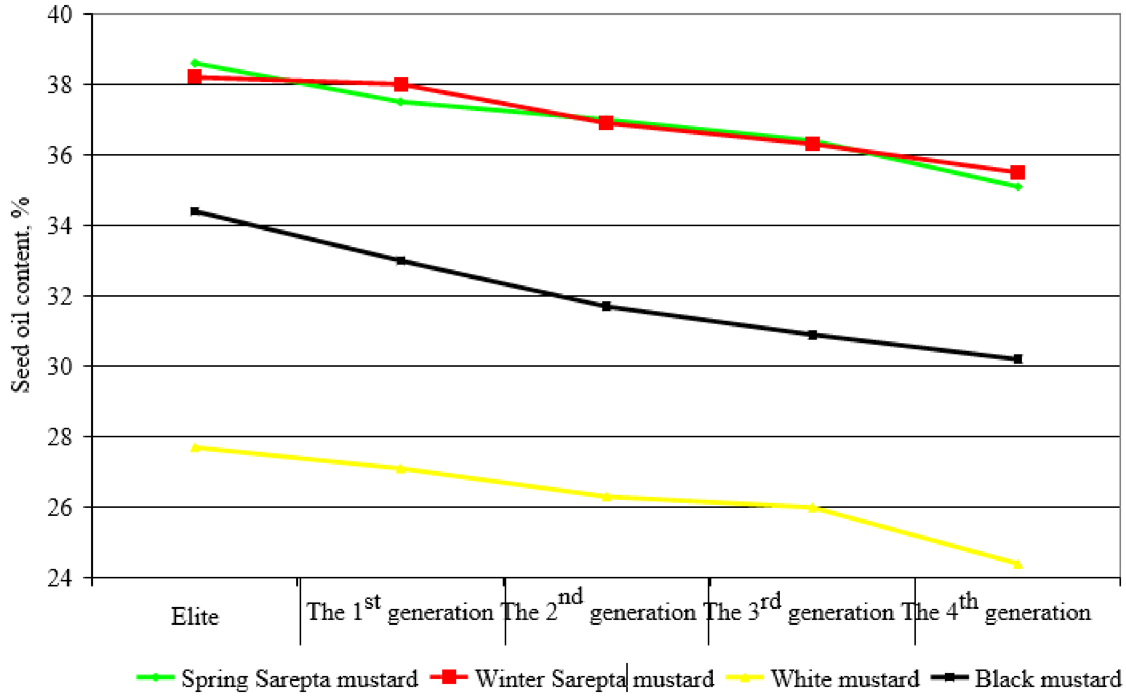


Fig. 2 The dynamics of fatty oil content in mustard seeds depending on the seed generation (the average for 2016-2020)

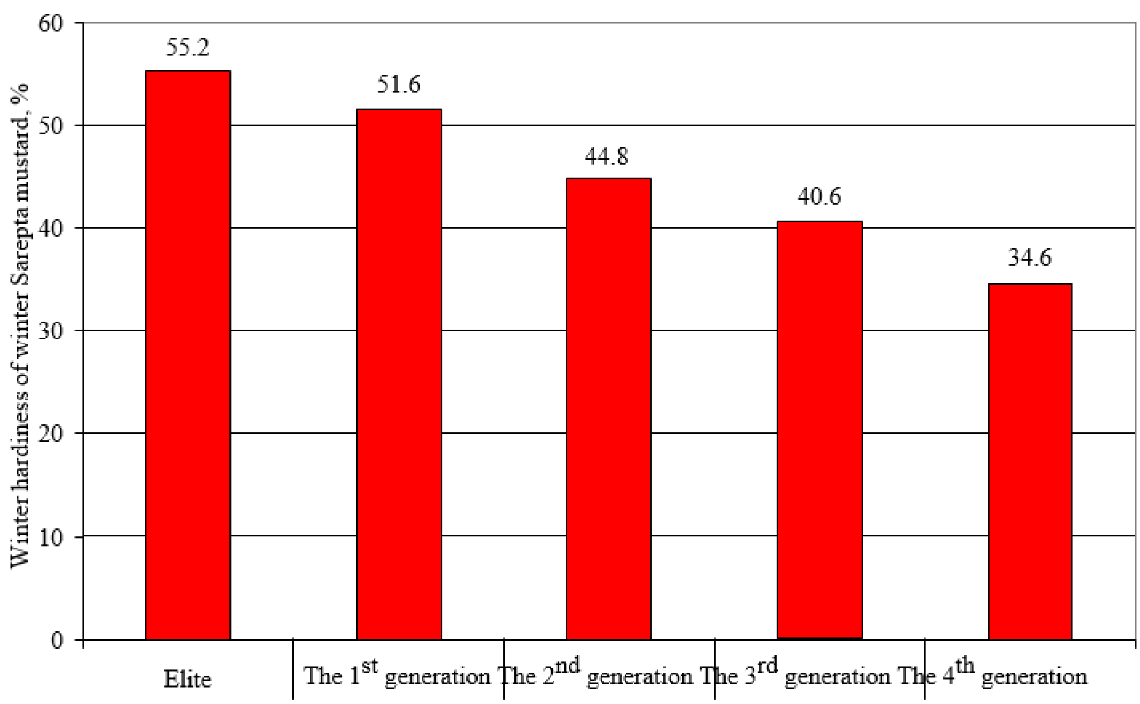


Fig. 3 Winter-hardiness of winter Sarepta mustard agrocenosis depending on the seed generation, % (the average for 2016-2020)

All the technological operations, comprising the technology of primary seed production of the crop, should be oriented towards maintaining maximum values of the weight of 1000 seeds, germination energy and laboratory germination [7], [9]. The broadcast method of sowing forms the crop nutrition area close to a hypothetical circle, but we consider it ineffective at this time because of the following positions: firstly, on the farms there is a lack of machines capable of ensuring even seeding per unit area by their technical parameters – usual mineral fertilizer broadcasters are characterized by uneven seeding up to 75%. Secondly, it is necessary to solve the problem of covering mustard seeds with soil when using the broadcast sowing method that is mainly carried out by means of light toothed harrows that do not allow ensuring even depth of covering the seeds with soil and do not create a seedbed, therefore the sprouts are scarce, and the level of the seed productivity is much lower than with other sowing methods. We registered comparatively high values of the weight of 1000 seeds because of low plant density: 3.4 g – in the variant of spring Sarepta mustard; 3.5 g – in the variant of winter Sarepta mustard; 5.0 g – in the variant of white mustard and 3.2 g – in the variant of black mustard (Table 1).

Table 1. The effect of a sowing method on the weight of 1000 seeds of different mustard types, g (the average for 2016-2020)

Mustard type	Sowing method			
	Broadcast	Narrow-row (7.5 cm)	Row (15 cm)	Wide-row (45 cm)
Spring Sarepta mustard	3.4	3.1	3.4	3.1
Winter Sarepta mustard	3.5	3.3	3.6	3.0
White mustard	5.0	4.3	5.1	4.2
Black mustard	3.2	3.0	3.3	2.8

According to the results of our research, we can draw a conclusion that the sowing method that does not yield to the broadcast method by the index of the weight of 1000 seeds ensuring optimum plant density in agrocenosis is a traditional row sowing method with the row spacing of 15 cm. It is explained by more optimal geometry of the nutrition area of an individual plant, correspondingly, by the provision with life factors – the average index of the weight of 1000 seeds for the years of the research was 3.4 g in spring Sarepta mustard; 3.6 g – in winter Sarepta mustard; 5.1 g in white mustard and 3.3 g – in black mustard. The narrow-row method of sowing mustard (with the row spacing of 7.5 cm) and the wide-row method (with the row spacing of 45 cm) appeared to be less efficient by the effect on the weight of 1000 seeds. The average weight of 1000 seeds of the 1st variant among the mustard types was: spring Sarepta mustard – 3.1 g; winter Sarepta mustard – 3.3 g; white mustard – 4.3 g and black mustard – 3.0 g. When the wide-row sowing method was used, these indexes were the following: 3.1 g; 3.0 g; 4.2 g and 2.8 g respectively. According to the research results of many scientists, direct application of mineral fertilizers at the time of maximum consumption of certain elements of mineral nutrition by plants is much more efficient than background application of mineral fertilizers, firstly, in terms of the effect of this agricultural technique on the formation of quantity and quality indexes of a generative part of the yield (including the index of the weight of 1000 seeds) [18], [19], [17]. This problem can be solved under certain production conditions by means of foliar feeding of mustard plants with liquid complex mineral fertilizers containing chelate compounds of macro-, meso- and micro-elements [16], [17], [24]. Foliar feeding of the mustard plants proved to be especially efficient, in terms of an increase in the seed weight at the transition to the stage of a green pod that coincides with the stage of ontogenesis characterized by a maximum average daily increase in linear size and weight indexes of a generative part of the crop yield. The results of the experiment show that foliar feeding with the liquid mineral fertilizer "Hileia – Khrestotsvit" at the stage of "green pod" is considered to be especially efficient for all the mustard types – a substantial increase has been registered in this variant. In comparison to the control variant, the average value of the weight of 1000 seeds of spring Sarepta mustard increased by 0.2 g (from 3.5 to 3.7), that of winter Sarepta mustard – by 0.2 g (from 3.6 to 3.8), white mustard – by 0.1 g (from 4.8 to 4.9) and black mustard – by 0.3 (from 3.3 to 3.6) (Table 2). We have established that the neglect of chemical treatment aimed at protection of a generative part of plants (flowers, fruits and seeds) from pests reduces the weight of 1000 seeds of all the mustard types.

Table 2. The effect of foliar feeding of different mustard types with the LCMF "Hileia – Khrestotsvit" on the weight of 1000 seeds, g (the average for 2016-2020)

Mustard type	Feeding method			
	Without feeding – control	One-time feeding at the stage of budding	One-time feeding at the stage of "green pod"	Double feeding (budding + "green pod")
Spring Sarepta mustard	3.5	3.6	3.7	3.7
Winter Sarepta mustard	3.6	3.7	3.8	3.7
White mustard	4.8	4.8	4.9	5.0
Black mustard	3.3	3.5	3.6	3.6

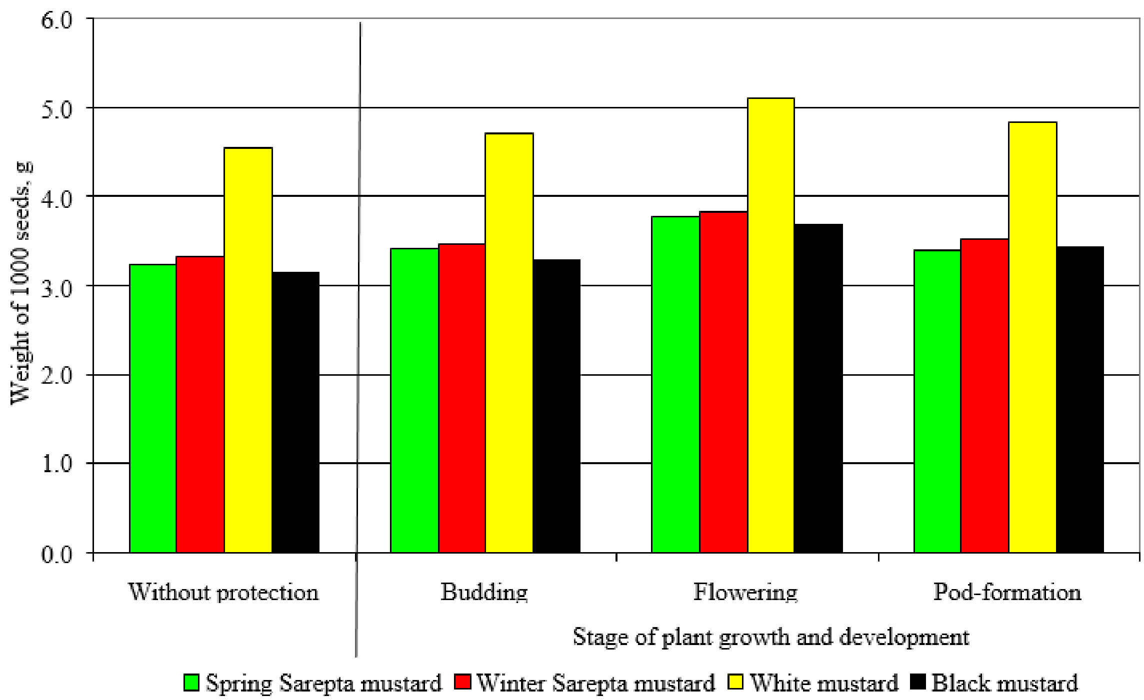


Fig. 4 The effect of the time of chemical treatment of mustard crops with the preparation Biskaiia® from pests of generative plant parts on the weight of 1000 seeds, g (the average for 2016-2020)

Figure 4 presents the results of the effect of the time of chemical protection of the crop from the above-mentioned phytophagans on the weight of 1000 seeds. The plants were treated with the insecticide preparation Biskaiia® (thialcloprid, 240 g/l) at the rate of 0.3 l/ha that allowed chemical treatment of the crop during the period of mass pollination of the crop plants by honey bees because there are no components with evident repellent characteristics in its composition. We have established that the use of this agricultural practice allowed increasing the weight of 1000 seeds of spring Sarepta mustard – by 0.29 g or 9.0%, that of winter Sarepta mustard – by 0.27 g or 8.1%, that of white mustard – by 0.33 g or 7.3% and that of black mustard – by 0.32 g or 10.1% in comparison to the control. The stage of flowering appeared to be the time of treatment that ensured a maximum increase in the index value under study in all the mustard types where the weight of 1000 seeds of mustard on the average for the years of the research was – 3.8 g in spring Sarepta mustard; 3.8 g in winter Sarepta mustard; 5.1 g – in white mustard and 3.7 g in black mustard. In most cases the mustard seeds in the pods of a central inflorescence and side fruit-bearing branches mature at the same time, however, in some years (the following years of the research: 2016, 2019, 2020) there was a lag in the seed maturation of the central tassel and side fruit-bearing branches (it was especially visible in agrophytocenosis of winter Sarepta mustard) on some farms of the northern areas in the Steppe zone caused by atmospheric precipitation in the last quarter of the vegetation period. Therefore, there was a necessity to carry out artificial acceleration of the outflow of organic substances into seeds by means of desiccation of the crops. According to the results of our research, the application of the above-mentioned agricultural practice to the crops had a negative effect on the weight of 1000 seeds. Artificial acceleration of the outflow and redistribution of organic substances in generative and vegetative plant parts substantially reduced its value in the variants of all the mustard types in comparison to the control (without desiccation): the average decrease over the years of the research was 0.2 g (from 3.5 g to 3.2 g) in spring Sarepta mustard, 0.2 g (from 3.7 g to 3.5 g) in winter Sarepta mustard, 0.2 g (from 4.8 g to 4.6 g) in white mustard and 0.2 g (from 3.4 g to 3.2 g) in black mustard (Figure 5).

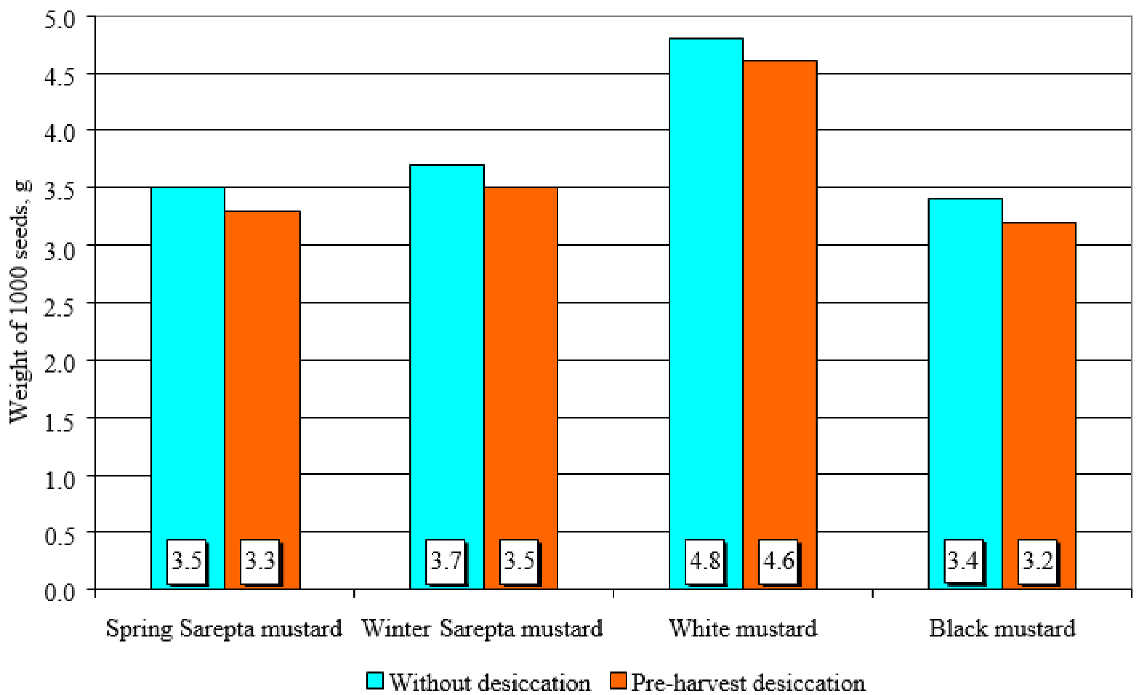


Fig. 5 The effect of pre-harvest desiccation on the weight of 1000 seeds of mustard (the average for 2016-2020)

A great number of scientists examining the problem of obtaining steady and guaranteed yields of oil brassicaceae crops, focus on considering a two-stage harvesting method as an alternative one, especially in case of some organizational difficulties or those related to the environment and climate at the crop gathering time that do not allow high-quality combine harvesting of these crops [5], [11]. However, according to our data, over the years of the research a two-stage method of combine harvesting did not ensure a substantial increase in the weight of 1000 seeds in any of the mustard types under study, and, vice versa, it was inferior to a direct one-stage method. On the average, over the years of the research, the value of the weight of 1000 seeds was 3.6 g with a one-stage method of harvesting and 3.3 g with a two-stage method (a decrease by 0.3 g) in the variant of spring Sarepta mustard; 3.7 g and 3.5 g (0.2 g) in the variant of winter Sarepta mustard; 5.2 g and 4.7 g (0.5 g) in the variant of white mustard; 3.1 g and 3.4 g (0.3 g) in the variant of black mustard respectively. A substantial difference in the values of this index with a one-stage and two-stage combine harvesting of the crops is explained by an accelerated outflow of organic substances in the mowed swaths from the tissues of vegetative parts into pods and seeds, that against the background of a strict hydro-thermal coefficient characteristic of that season of the year leads to accelerated seed maturation, its underdevelopment and weakness (Table 3).

Table 3. The effect of a method of combine harvesting of mustard on the weight of 1000 seeds, g (the average for 2016-2020)

Mustard type	Method of combine harvesting	
	One-stage	Two-stage
Spring Sarepta mustard	3.6	3.3
Winter Sarepta mustard	3.7	3.5
White mustard	5.2	4.7
Black mustard	3.4	3.1

The experimental research proves the advantages of a one-stage method of combine harvesting in comparison to a two-stage method for all the mustard types – an increase in the weight of 1000 seeds was 9.7% in spring Sarepta mustard, 6.6% – in winter Sarepta mustard, 9.1% – in white mustard and 12.1% – in black mustard. Taking into consideration a substantial negative effect of a two-stage method of harvesting mustard on the weight of 1000 seeds, considerable production inputs, organizational complexity and a lack of the necessary number of pick-up attachments on the farms in the research area, we consider this method to have no prospects. According to the results of our research, application of such an agricultural practice as pre-harvest desiccation that is quite reasonable for commodity crops to accelerate the outflow of organic substances into seeds in case of unfavorable weather conditions at the final stages of plant growth and development, is not appropriate for the crops grown for seeds because of a negative effect on basic seeding characteristics (Table 4).

Table 4. The impact of pre-harvest desiccation of mustard with the preparation Hlifohan® on seeding characteristics (the average for 2016-2020)

Mustard types	Laboratory germination, %		Germination energy, %	
	Without desiccation	Pre-harvest desiccation	Without desiccation	Pre-harvest desiccation
Spring Sarepta mustard	95.1	92.2	94.5	90.3
Winter Sarepta mustard	94.4	92.0	93.1	88.5
White mustard	96.3	90.0	92.9	85.9
Black mustard	93.4	91.7	90.7	82.7

On the average for the years of the research, pre-harvest desiccation of the crops grown for seeds caused substantially lower indexes of laboratory germination of the seeds of spring Sarepta mustard – from 95. % on the control plot to 92.2% on the treated plots, those of winter Sarepta mustard – from 94.4% to 92.0%, those of white mustard – from 96.3% to 90.0% and those of black Sarepta mustard – from 93.4% to 91.7% respectively. Similar changes were traced in the indexes of seed germination energy. The laboratory research showed a decrease in this index in the variant of spring Sarepta mustard – from 94.5% to 90.3%, that of winter Sarepta mustard – from 93.1% to 88.5%, that of white mustard – from 92.9% to 85.9% and that of black mustard – from 90.7% to 82.7%. According to the results of our research, green impurities (fragments of vegetating weeds and green parts of the crop, immature seeds) are especially dangerous in the context of the effect on the seeding standards of mustard seeds, that when combined with a high caloric value of mustard seeds, create favorable conditions for self-warming of the plant mass in the clamp, and result in worse seeding characteristics because of temperature coagulation of protein compounds in the seeds. As the results of the laboratory and field research show, the temperature in the interior part of the clamp did not exceed 30.5ºC provided that uncleaned seeds of Sarepta mustard underwent efficient primary cleaning to remove green impurities. In the control heap with the seeds, not cleaned off grain and non-grain impurities, the dynamics of temperature was characterized by a sharp increase reaching 62-63°C at the 7th hour of the observation that is a threshold value marking the beginning of coagulation of some protein substances (Figure 6).

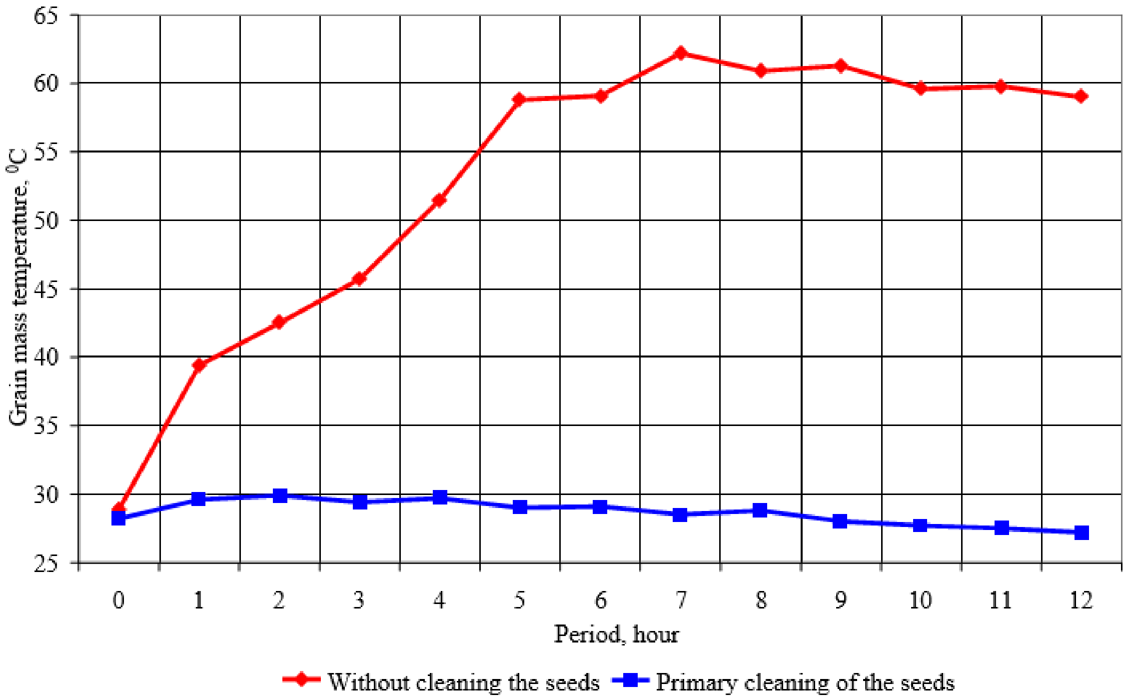


Fig. 6 Temperature dynamics of mustard seeds in the clamp (the average for 2016-2020)

The above-mentioned data prove that without primary cleaning of mustard seeds during the first 4-5 hours after harvesting its temperature increases to critical points when organic substances in seeds start disintegrating, and consequently, the main seeding characteristics become worse – first of all, laboratory germination and germination energy. The optimum time for primary cleaning of mustard seeds aimed at preventing deterioration of the seeding characteristics of mustard seeds because of self-warming inside the clamp, is the first 4 hours after harvesting for all the mustard types. On the average for the years of the research, during this time interval, the temperature dynamics, according to our research results, did not reach the intensity that could considerably worsen the main seeding characteristics of Sarepta (spring and winter), white and black mustard (Table 5).

Table 5. Mustard seeding characteristics depending on the time of primary cleaning (the average for 2016-2020)

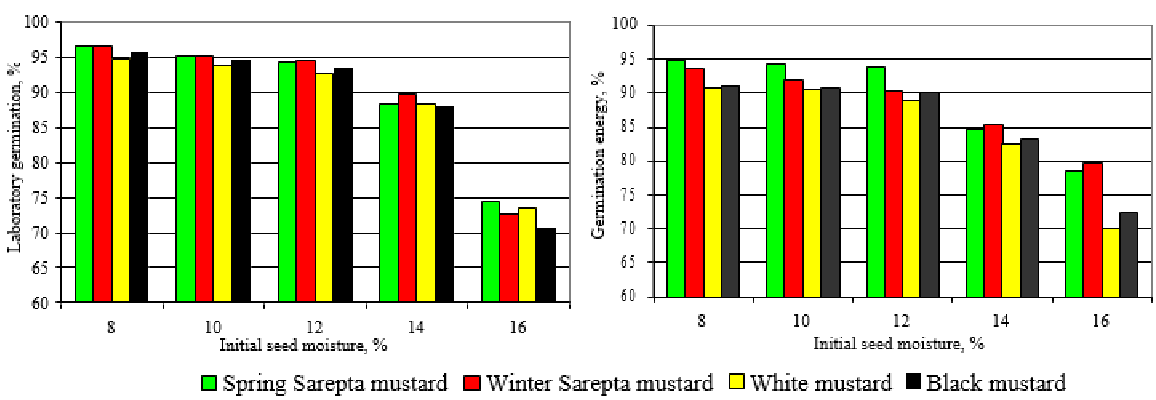
Duration of the period "harvesting – primary cleaning", hours	Laboratory germination, %				Germination energy, %			
	Spring Sarepta mustard	Winter Sarepta mustard	White mustard	Black mustard	Spring Sarepta mustard	Winter Sarepta mustard	White mustard	Black mustard
0-2	96.9	95.1	96.2	94.4	92.6	91.1	95.5	89.7
2-4	97.1	94,4	93,2	87.7	90.7	90.2	94.3	86.8
4-6	93.0	82.7	87.4	80.4	77,7	80.0	80.7	74.9
6-8	85.3	66.3	68.3	70.0	70.1	72.2	72.2	70.0
8-10	66.2	61.0	60.6	63.7	62.4	57.0	65.7	52.2
10-12	62.2	60.7	60.1	59.8	52.0	50.5	65.5	44.7

An absolute majority of researchers emphasize in their studies that, irrespective of the crop, the largest seed fraction is the most appropriate in terms of seeding characteristics that ensures earlier and simultaneous germination, more dynamic initial stages of ontogenesis and, consequently, a higher level of the integrated tolerance towards abiotic and biotic factors of the environment due to the maximum content of organic substances, under equal conditions of warmth and moisture supply at the time of sowing [5], [6], [10]. According to the results of our research, after double cleaning of mustard seeds, additional cleaning and grading with the machine Petkus K-218 "Selektra", the index of laboratory germination of mustard seeds did not depend on the seed fraction size both in individual years of the laboratory research and on the average for the years of the research (Table 6).

Table 6. Dependence of the seeding characteristics of mustard seeds on the fraction size (the average for 2016-2020)

Mustard types	Fraction by the index of the weight of 1000 seeds, g	Laboratory germination, %	Germination energy, %
Spring Sarepta mustard	Small (<2.8)	94.9	88.7
	Medium (2.8-3.3)	94.2	90.4
	Large (>3.3)	95.2	94.0
Winter Sarepta mustard	Small (<3.0)	96.0	86.0
	Medium (3.0-3.5)	95.4	88.9
	Large (>3.5)	95.3	92.7
White mustard	Small (<4.6)	96.6	90.5
	Medium (4.6-5.0)	96.5	91.1
	Large (>5.0)	96.5	93.2
Black mustard	Small (<2.5)	94.7	88.0
	Medium (2.5-3.0)	95.0	89.2
	Large (>3.0)	95.5	89.9

Germination energy directly depended on the seed fraction that is explained by a comparatively larger supply of organic substances responsible for activation of growth processes at the initial stages of the crop ontogenesis (Table 6). Carrying out the laboratory research in order to determine optimum regimes of a short-term (for winter Sarepta mustard) and long-term warehouse storage of mustard seeds, we analyzed the dependence of the main seeding characteristics of the crops on the basis moisture of the batch prepared for warehouse storage (Figure 7).



Note: The indexes for winter Sarepta mustard were calculated at the time of the 60-day period of storage, and at the time of the 180-day period – for the rest of the types.

Fig. 7 Seeding characteristics of mustard seeds depending on basis moisture (the average for 2016-2020)

The research results allow drawing a conclusion that, in case of warehouse storage of the mustard seeds for the 60-day period (as in case of winter Sarepta mustard, for which the time gap between harvesting of the previous year and sowing is 40-50 days), the seed basis moisture must not exceed 12%, and, in case of storing the seeds of the other mustard types or the backup funds of the seeds, the seed moisture content must be 8%, and the seeds of white mustard, due to the less fatty oil content in them, do not lose their seeding standards if the humidity of the storage area is 10%. In the scientific literature there are data on the possibility of a long-time storage of mustard seeds without considerable deterioration of their quality under favorable conditions in terms of temperature indexes and values of relative humidity of the air in the storage area. Retaining germination characteristics and germination energy in the course of time is explained by ethereal oil content in the crop seeds, that has bactericidal and fungicidal properties, especially those resisting mycelial fungi [5], [23]. We conducted laboratory research examining the effect of the duration of storage time of the seeds on the index of their laboratory germination and germination energy in order to determine the time limits of storing backup funds of the crop seeds in the warehouse. We established that laboratory germination and germination energy of mustard seeds reach their maximum values in 6-12 months after harvesting that is explained by physiological processes that continue occurring in the seeds – first of all, by the transition of labile forms of organic substances into reserve substances. Under standard conditions of storage (it mainly concerns temperature regime and relative humidity of the air in the warehouse), mustard seeds do not lose their seeding standards in terms of laboratory germination in the course of 4 years, germination energy – in the course of 3 years (according to our data, this period proved to be less by a year in black mustard) (Figure 8).

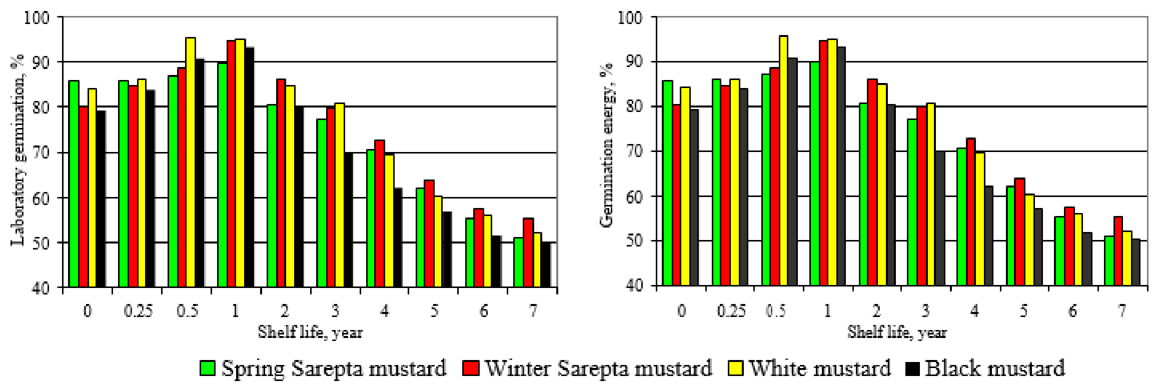


Fig. 8 Dynamics of the main seeding characteristics of mustard seeds depending on the shelf life (the average for 2016-2020)

In order to use the storage area efficiently and determine optimum regimes for storing mustard seeds (including backup funds), we analyzed the effect of the number of sacks in stacks on the degree of seed damage and their seeding standards. Scientists and commodity producers maintain that bulk density of seeds is a precondition of efficient storage of mustard seeds for further sowing, in comparison to other agricultural crops (Figure 9).

We established that the stack height of more than 5 sacks, at the expense of increasing specific pressure on a lower layer of sacks, causes an increase in the amount of damaged seeds of Sarepta mustard in the sacks of a lower layer to 1% and more, that, in its turn, considerably reduces the indexes of laboratory germination and germination energy, decreasing the seeding standards of at least 20% of the seed batch.

4. Conclusions

1. Using the seeds of the 4th generation for sowing, in comparison to the elite seeding material, caused a decrease in the level of the seed productivity by 50.5%, that of oil content – by 12.5%, winter hardiness of

winter Sarepter mustard – by 59.5%.

2. In order to obtain seeds with the maximum index of the weight of 1000 seeds (with maximum indexes of laboratory germination and germination energy), it is necessary to sow mustard seeds with a traditional row method with the row spacing of 15 cm, taking measures of integrated chemical protection of the crop from a complex of phytophagans.

3. Pre-harvest desiccation of the crops is not reasonable because of its negative effect on a number of seeding characteristics. In order to obtain mustard seeds of the best seeding standards it is more appropriate to use a one-stage combine harvesting of the crop with obligatory further primary cleaning of the seeds off impurities, not later than in the 4-hour period after harvesting. After this time microbiological processes in uncleaned seeds result in their self-warming to the temperature causing coagulation of protein substances in the seeds and, consequently, radical deterioration of their seeding characteristics.

4. Optimum basis moisture for mustard seeds meant for a long-term storage is 8%. Basis moisture of winter Sarepta mustard seeds, whose shelf life before sowing is not more than 60 days, can be increased to 12%, in case of creating a backup fund of the crop seeds, basis moisture must be decreased to 8%. The shelf life allowing Sarepta, white and black mustard seeds to retain their seeding standards, is 3 years, provided that they are stored in stacks of not more than 5 sacks.

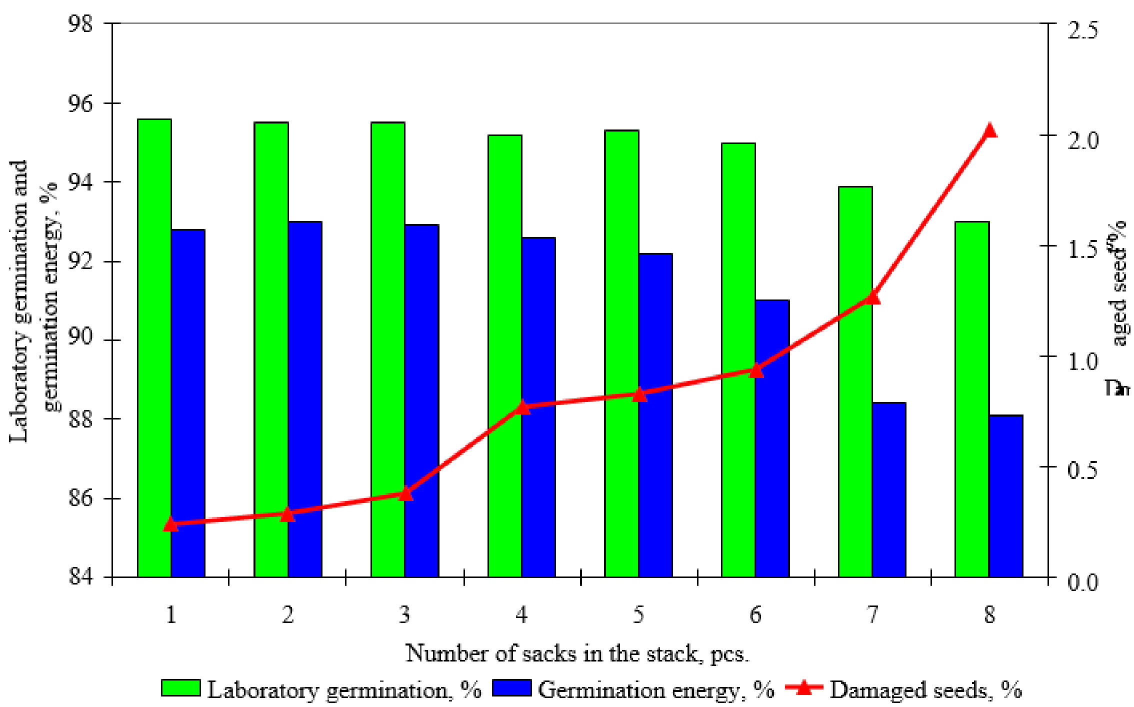


Fig. 9 The effect of a stack height on the seeding characteristics of Sarepta mustard seeds under conditions of warehouse storage (the average for 2016-2020)

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