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SEED PRODUCTIVITY OF CARROT (*DAUCUS CAROTA* L.) BY DIRECT SOWING METHOD OF GROWING OF CULTIVATION IN IRRIGATED CONDITIONS OF SOUTHERN UKRAINE

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Problem statement. Carrot (*Daucus carota* L.), one of the most important root crops of the *Apiaceae* family, is cultivated worldwide. This root crop is widely used due to its richness in carotenoids, anthocyanins, dietary fiber, vitamins and other nutrients. The area occupied by this crop in the world is increasing every year, as the need for its consumption in fresh and processed form is growing. Breeders have created many varieties and hybrids that are characterized by high yield, improved uniformity, market value and resistance to diseases and pests, competitiveness against weeds, high product quality. For highly efficient cultivation of vegetables, the use of high-quality seed material is of paramount importance. The main goal of seed production is the propagation and introduction into production of new, highly productive varieties and hybrids of vegetable crops.

Analysis of recent research and publications. Carrot seeds are grown in two ways: by transplanting and without transplanting the mother root crops. In the transplanting method, the mother root crops are planted in early spring after winter storage and autumn selection. In the second year, a seed plant is formed from the mother root crop. The technology of growing seeds consists of three stages: growing mother root crops, storing mother material, and growing seed plants. This method is also called “root to seed” [1]. The yield and quality of mother root crops largely depend on the choice of plant density. Depending on the growing conditions, the density ranges from 400 thousand pcs./ha to 1.0 million pcs./ha [2, 3]. Growing conditions have a significant impact on the productivity of seed plants. The size of the mother root crop affects the growth, development of plants, seed productivity, and seed quality [4]. According to Ilyas et al. Larger root crops (mother plants) form more branched seed plants [5]. As the area of carrot seed plants feeding decreases, the architecture of the seed bush changes. As a result, the yield per plant decreases, but increases per unit area [6]. By increasing the density of small-sized root crops, it is possible to obtain a 22% higher seed yield compared to medium-sized mother plants [7]. Depending on the growing conditions, the seed yield ranges from 0.4 to 2 t/ha, from one plant – 6.3-10.6 g [8, 9].

In the no-seedling method, the mother plants of the summer sowing periods are not harvested, but left for the winter in the field. In the second year, the mother plants enter the generative phase – they form flowering shoots, bloom and set seeds [10]. American scientists call this method “seed to seed” [11]. The method of growing by direct sowing of seeds at the end of summer for root crops (sugar beets, fodder beets, table carrots) is used in regions with a short, relatively warm winter period. Growing seeds in the no-seedling method in the conditions of the southern part of Ukraine has a number of advantages: weather and climatic conditions are favorable for the successful overwintering of mother plants; there is no need for winter storage and planting of mother plants, which significantly reduces the overall costs of growing seeds; plants use spring moisture reserves better and flower-bearing shoots grow earlier. However, in some years, significant freezing of mother plants is possible. Damage and death of mother

plants can be caused by severe frosts in snowless winters, sharp temperature fluctuations, stagnation of water on the soil surface (soaking), ice crusts, etc. Often, death occurs from the combined action of several factors [12].

To conduct seed production of table carrots using the no-till method, it is necessary to specify the cultivation parameters taking into account soil and climatic factors in each specific zone in order to avoid negative consequences or to minimize their impact using technological methods of cultivation. One of the main elements of the technology of no-till cultivation is the choice of the time for sowing carrot seeds [13]. Seed yield, to a large extent, depends on the phase of development of root crops at the end of the autumn vegetation and overwintering of plants [14]. Weather conditions of the growing season significantly affect the passage of all phases of growth and development of carrot seed plants. Low air temperatures in April and May and sufficient moisture reserves in the soil contribute to the formation of large seed bushes [15].

Along with climatic conditions, De Resende at al., and LingJuan at al., indicate that plant density significantly affects the formation of seed productivity of carrot plants [16, 17]. Increasing the density of seed plants to 200,000 pcs./ha significantly increases yield without significant deterioration of seed quality [18]. On the other hand, the best quality of carrot seeds was obtained with the largest area of feeding of seed plants [19].

Studies by Mengistu et al. have established a direct positive correlation between seed yield per hectare and the number of inflorescences per plant (r2=0.58), umbel diameter (r2=0.78), and seed yield per umbel (r2=0.89) [2]. The main mass of the seed yield is formed by the inflorescences of the central and first orders. Scientists point to the different quality of seeds collected from inflorescences of different orders. The highest germination percentage (78%) and the mass of 1000 seeds (1.91 g) were characterized by seeds from the central inflorescence. The germination of seeds formed in inflorescences of higher orders decreased by 6% [20]. Seeds from shoots of the first orders give, with subsequent sowing, a higher marketable yield than seeds from inflorescences of higher orders [21]. Under favorable weather conditions and compliance with the elements of technology, the no-sowing method allows for high yields of high-quality carrot seeds. The seeds' compliance with varietal characteristics is 96-98% [22]. This method is used once for growing certified seeds, which are used to obtain marketable products.

Methods and materials of research. The research was conducted on the experimental field of the Institute of Irrigated Agriculture of the NAAS in 2018-2021. The soil of the experimental plot is dark chestnut, slightly saline, medium loam. Experimental scheme: factor A – sowing time: 1) the first decade of August, 2) the second decade of August; 3) the third decade of August. Factor B – plant density: 1) 150 thousand pcs./ha, 2) 200 thousand pcs./ha, 3) 250 thousand pcs./ha. The first vegetative irrigation was carried out immediately after sowing, the following were prescribed when the moisture content of the soil layer 0-30 cm decreased to 70% RH. Irrigation in the experimental plots began immediately after sowing. During the autumn vegetation of the mother plants, 3-6 irrigations were carried out, the irrigation rate was 100–160 m^3ha^{-1}. At the beginning of the spring-summer vegetation of plants, watering began in 2019 – June 10, in 2020 – May 10, in 2021 – May 15. In total, 8-12 waterings were carried out during the vegetation period. Seed sowing qualities were determined by indicators: weight of 1000 pcs. seeds, germination energy (determined on the 6th day of germination in Petri dishes in a thermostat at t 25) and seed germination (determined on the 12th day).

Research results. According to scientists, in different climatic zones, from 11-14% to 45-73% overwinter [15]. The decisive factor in the overwintering of root crops is the soil temperature at the depth of the growth point (the top of the root crop) and the duration of low temperatures [23]. Our studies have established that in the conditions of southern Ukraine, mother plants well tolerated winter conditions in all years of research. Accounting for the state of overwintering of mother plants showed that when sowing in the first decade of August, 50.4–61.4% of plants survived after winter (Fig.1).

On average over the years of research, the best survival after winter (59.7%) was noted for sowing in the second decade of August. The number of plants that overwintered well during the first sowing period was 57.1%, during the third – 54.3%. At a density of 150 thousand pcs./ha, 55.4% of plants survived, at a density of 200 thousand pcs./ha, an increase in their number by 1.5% was observed, at 250 thousand pcs./ha – by 3.4% more than during the first sowing period. In the phase of mass regrowth of flowering stems, the actual plant density was recorded, which was 69.4-139.3 thousand pcs./ha depending on the sowing period and the density of seed plants (Fig. 2).

When sowing in the first decade of August, the actual density of plants in the field was on average 107 thousand pcs./ha, which is 6.0% more than when sowing in the third decade of August. During the second sowing period, the density of seed plants in the spring was on average 110 thousand pcs./ha, which is 9.0% more than during the latest sowing period.

We conducted an analysis of biometric measurements of carrot plants in the mass flowering phase, which showed that the height of seed plants was the greatest during the early sowing period. Thus, on average over the years of research, plants formed from mother plants sown in the first decade of August had a height of the central flowering shoot of 111.1–116.4 cm, in the second decade of August – 101.8–105.9 cm, in the third decade of August – 97.0–101.8 cm. The diameter of the central inflorescence (umbrella) was, respectively, 10.6; 10.1; 9.9 cm. Plant density has a smaller effect on the formation of the carrot seed bush. The height of the seed bush at the maximum plant density was 4.7 cm higher than at a density of 150 thousand pcs./ha (103.3 cm). The diameter of the inflorescence did not decrease significantly.

According to scientists, the productivity of carrot seed plants largely depends on growing conditions, and in the no-till method varies from 190 to 1264 kg/ha [13].

Analysis of plant seed productivity data in our experiment showed that the yield of carrot seeds when sown in 2019 was 422–561 kg/ha, in 2020 – 384–624 kg/ha, in 2021 – 417–604 kg/ha, depending on growing conditions (Table 1).

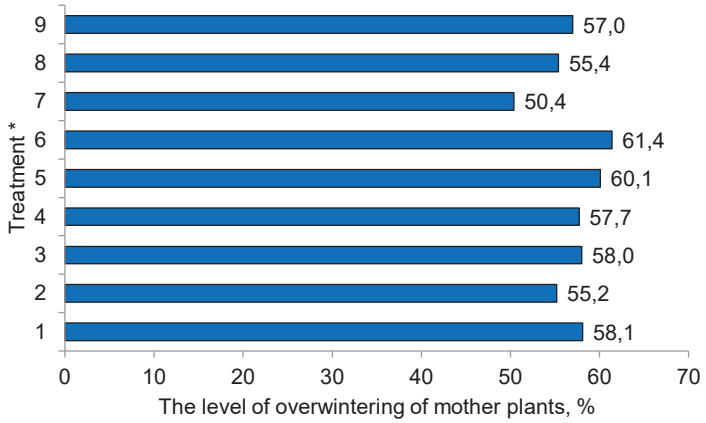

Figure 1. The level of overwintering of mother plants of carrot, 2019-2021

Treatment 1 – *sowing at first decade of August, density 150 thus. ha^{-1};* **2 –** *sowing at first decade of August, density 200 thus. ha^{-1};* **3** *– sowing at first decade of August, density 150 thous.ha^{-1};* **4** *– sowing at second decade of August, density 150 thous.ha^{-1};* **5** *– sowing at second decade of August, density 200 thus. ha^{-1};* **6** *– sowing at second decade of August, density 250 thus. ha^{-1};* **7 –** *sowing at third decade of August, density 150 thous.ha^{-1};* **8** *– sowing at third decade of August, density 200 thus. ha^{-1};* **9** *– sowing at third decade of August, density 200 thus. ha^{-1}*

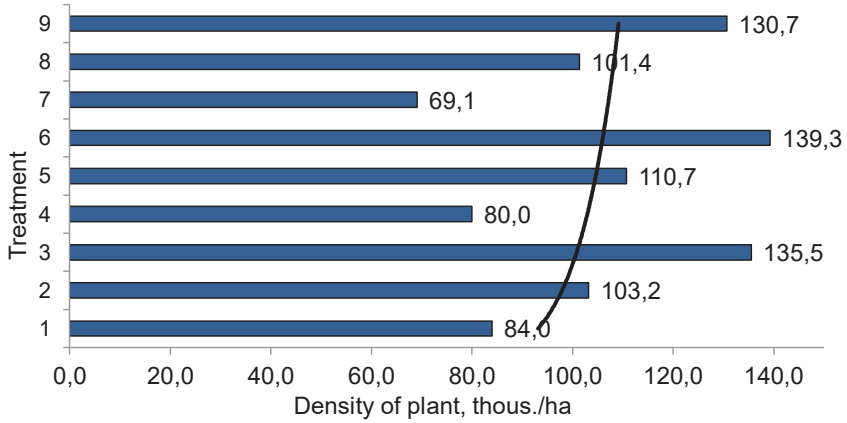

Figure 2. The density of carrot seed plants in the phase of mass stemming (average of 2019-2021)

Table 1

Productivity of carrots in fallow trees by time of sowing and density of seed plants

Variant	Time of sowing	Plant density, thus. ha^{-1}	Seed yield by years of research, t ha^{-1}			
			2019	2020	2021	2019-2021
1	The first decade of August	150	509	469	503	494
2		200	542	538	551	544
3		250	561	624	604	596
4	The second decade of August	150	471	472	483	475
5		200	498	586	551	545
6		250	524	596	566	562
7	The third decade of August	150	422	384	417	408
8		200	465	471	482	473
9		250	489	514	510	504
LSD_{05} main effects on factor A			24,2	17,1	19,3	
LSD_{05} main effects on factor B			19,1	10,0	11,5	

The sowing date and plant density are crucial for successful seed production of root crops using the no-till method. The highest density of carrot plants after winter (64.9–73.8 thousand pcs./ha) was reported for sowing in the first decade of August, and the plant density in autumn was 600 thousand pcs./ha. This technology results in the formation of more developed seed heads, which provide a seed yield of 440 kg/ha, which is 193% more than with the traditional seedling method. On the other hand, the yield from one plant using the seedling method (root to seed) is reported to be higher compared to no-till cultivation. High yields can only be obtained with optimal plant density after wintering [22].

Our research also confirms that the sowing date and plant density significantly affect the yield of carrot seeds. The highest seed productivity was characterized by plants of the early sowing date. On average, over the years of research, when sowing in the first decade of August, the seed yield is 545 kg/ha, in the second decade of August – 527 kg/ha, in the third decade of August – 462 kg/ha. The increase in yield during early sowing is 18 kg/ha (3.4%) compared to the second term and 83 kg/ha (18.0%) compared to the third term. At a plant density of 250 thousand pcs./ha, the seed yield is 554 kg/ha, which is 34 kg/ha (6.5%) more than at a density of 200 thousand pcs./ha and 95 kg/ha (20.8%) more than at 150 thousand pcs./ha. The highest seed yield (596 kg/ha) was obtained at the first sowing date and a seed plant density of 250 thousand pcs./ha.

According to the results of the correlation analysis, a direct relationship was found between seed yield and factors influencing the formation of plant productivity. In 2021, a mathematical model was calculated that characterizes the dependence of plant seed productivity on sowing dates (sum of active temperatures over 10°C during the growing season) and plant density, and is expressed by the regression equation: $Y = 1.07–0.021x^1+ 0.034x^2$, where Y– seed yield, t/ha; x^1 – sum of active temperatures during the growing season, thousand°C; x^2 – plant density, thousand pcs./ha. This model shows that sowing dates and plant density significantly affect plant seed productivity. During the third sowing date, the yield significantly decreases compared to the first date. A strong direct functional correlation dependence was established between the average seed yield over the years of research and plant density: the correlation coefficient for different sowing dates is r=0.94-0.99, R=0.88-0.98.

Seed quality is a set of indicators that include the sowing and yield qualities of the grown seeds. Carrot seeds obtained from the central inflorescence have a greater mass of 1000 pcs. seeds and germination compared to seeds from umbrellas of higher orders. Therefore, an increase in plant density contributes to an increase in the number of less branched seed plants of the 1st and 2nd types of branching and leads to a decrease in the number of inflorescences of higher orders. Under such conditions, the largest seed yield with better biological properties is formed. In experiments with a no-sowing method, the seed germination energy was 62–72%, germination – 76–80%. Field inspection of the obtained seeds showed that the varietal purity of seeds in subsequent generations was at the level of 97% [22].

In our studies, the sowing date did not have a significant effect on the sowing quality of seeds (Table 2).

The weight of 1000 pcs. seeds on average over the years of research was 0.82–0.90 g, germination energy – 63–66%, laboratory germination – 77–84%. The germination energy of seeds grown during sowing in the first decade of August was 1.3% higher compared to the third term (63.7%). During sowing in the first decade of August, seed germination was 4.3% higher compared to the third term of sowing (78.7%). At a plant density of 150 thousand pcs./ha, an increase in germination energy by 1.7%, seed germination – by 2.7% compared to a density of 250 thousand pcs./ha is observed. Inspection of crops was carried out. The conformity of the variety in all parameters (typicality) of the obtained seeds in the offspring was within 96.0–99.0%. In the reference version, where plants were grown by the seedling method, where autumn and spring selection of mother plants were carried out, during which the mother root crops typical of the Yaskrava variety were selected, it was 100.0%. The varietal purity of seeds for the first sowing period was 97.0%, for the second – 97.7%, for the third – 97.0%. The varietal purity of seeds for growing seed plants with different densities was 97.0–97.3%. The

Table 2

Seed quality of carrot by different time of sowing and density of seed plants, (average of 2019-2021)

Variant	Time of sowing	Plant density, thus. ha^{-1}	Seed quality		
			weight 1000 pcs. seed, g	vigour index, %	germination capacity, %
1	The first decade of August	150	0,90	66	84
2		200	0,87	64	84
3		250	0,85	65	81
4	The second decade of August	150	0,88	66	82
5		200	0,87	63	81
6		250	0,86	64	80
7	The third decade of August	150	0,85	65	80
8		200	0,84	63	79
9		250	0,82	63	77
LSD_{05} main effects on factor A			0,3	3,3	3,1
LSD_{05} main effects on factor B			0,1	2,3	2,4

varietal purity indicators are higher than the minimum permissible level (95%), which meets the requirements for certified carrot seeds.

Thus, the use of the seedling-free method makes it possible to obtain seeds with high sowing qualities.

Conclusions. In the conditions of southern Ukraine, when growing carrot seeds without transplanting, the optimal sowing time is the first or second decade of August. Seed yield increases significantly compared to sowing in the third decade of August. Increasing plant density from 150 to 250 thousand pcs./ha reduces the yield per plant, but increases the yield per unit area by 21.3%. Correlations between plant density and seed yield were established. Seed sowing qualities did not depend on the sowing time and the density of seed plants. Varietal purity (typicality) of the obtained seeds was 96.0–99.0%.

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Кокойко В.В., Марченко Т.Ю., Косенко Н.П., Книш В.І., Шабля О.С., Дробіт О.С. Насіннєва продуктивність моркви (*Daucus carota* L.) за безвисадкового способу вирощування насіння в зрошуваних умовах півдня України

Мета – дослідити вплив елементів технології на врожайність та якість насіння моркви (*Daucus carota* L.) за безвисадкового способу вирощування в зрошуваних умовах півдня України. **Методи та матеріали досліджень:** польовий, візуальний, математико-статистичний, розрахунково-порівняльний. **Результати.** У статті наведено результати досліджень безвисадкового способу вирощування насіння моркви в зрошуваних умовах півдня України. Представлено дані перезимівлі маточних рослин сорту моркви Яскрава, біометричні параметри насіннєвих рослин, урожайність насіння. Залежно від умов вирощування досліджені якісні показники насіння. Найбільша густота після зимового періоду

формується за сівби у першій декаді серпня – відсоток перезимівлі – 59,7%. Залежно від строків сівби та густоти рослин восени фактична густота насіннєвих рослин на час збирання врожаю становила 69,4-139,3 тис./га. Найбільшу врожайність (596 кг/га) сформували насіннєві рослини, отримані від сівби у першій декаді серпня і густоти маточних рослин восени 250 тис./га. Найбільший вплив на формування продуктивності чинила густота рослин. Різниця між рівнями врожайності за густоти 150 та 250 тис/га була 20,8%. Маса 1000 шт. насінин в середньому за роки досліджень становила 0,82–0,90 г, енергія проростання – 63–66%, лабораторна схожість – 77–84%. Енергія проростання насіння, що було вирощено за сівби у першій декаді серпня була на 1,3% більшою порівняно з третім строком (63,7%). За сівби у першій декаді серпня схожість насіння була на 4,3% більшою порівняно з третім строком сівби (78,7%). За густоти рослин 150 тис. шт./га спостерігається збільшення енергії проростання на 1,7%, схожості насіння – на 2,7% порівняно з густотою 250 тис. шт./га. В умовах півдня України за безвисадкового способу вирощування насіння моркви оптимальним строком сівби є перша-друга декади серпня. Встановлено кореляційні зв'язки між густотою рослин та врожайністю насіння. Посівні якості насіння не залежали від строку сівби і густоти насіннєвих рослин. Сортова чистота (типовість) отриманого насіння була 96,0–99,0%. Наші дослідження показали, що в умовах півдня України можливо вирощувати високоякісне сертифіковане насіння моркви.

Ключові слова: морква (*Daucus carota* L.), спосіб вирощування насіння, строки сівби, густота рослин, врожайність, якість насіння.

Kokoiko V.V., Marchenko T.Yu., Kosenko N.P., Knysh V.I., Shablia O.S., Drobit O.S. Seed productivity of carrot (*Daucus carota* L.) by direct sowing method of growing of cultivation in irrigated conditions of southern Ukraine

The aim is to investigate the influence of technology elements on the yield and quality of carrot seeds (*Daucus carota* L.) under the no-till method of cultivation in irrigated conditions of southern Ukraine. **Research methods and materials**: field, visual, mathematical-statistical, computational-comparative. **Results.** The article presents the results of research on the no-till method of growing carrot seeds in irrigated conditions in southern Ukraine. Data on the overwintering of mother plants of the carrot variety Yaskrava, biometric parameters of seed plants, and seed yield are presented. Depending on the growing conditions, qualitative indicators of seeds were studied. The highest density after the winter period is formed when sowing in the first decade of August – the percentage of overwintering is 59.7%. Depending on the sowing dates and plant density in autumn, the actual density of seed plants at the time of harvesting was 69.4-139.3 thousand/ha. The highest yield (596 kg/ha) was formed by seed plants obtained from sowing in the first decade of August and a density of mother plants in autumn of 250 thousand/ha. The greatest influence on the formation of productivity was exerted by plant density. The difference between the yield levels at densities of 150 and 250 thousand/ha was 20.8%. The weight of 1000 pcs. seeds on average over the years of research was 0.82–0.90 g, germination energy – 63–66%, laboratory germination – 77–84%. The germination energy of seeds grown during sowing in the first decade of August was 1.3% higher compared to the third term (63.7%). When sowing in the first decade of August, seed germination was 4.3% higher compared to the third term of sowing (78.7%). At a plant density of 150 thousand pcs./ha, an increase in germination energy by 1.7%, seed germination – by 2.7% compared to a density of 250 thousand pcs./ha is observed. In the conditions of southern Ukraine, when growing carrot seeds without transplanting, the optimal sowing time is the first or second decade of August. Correlations between plant density and seed yield have been established. Seed quality did not depend on the sowing time and density of seed plants. Varietal purity (typicality) of the obtained seeds was 96.0–99.0%. Our studies have shown that in the conditions of southern Ukraine it is possible to grow high-quality certified carrot seeds.

Key words: carrot (*Daucus carota* L.), seed growing method, sowing time, plant density, yield, seed quality.