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INFLUENCE OF CHICORY PLANTS DENSITY ON SIZE-MASS ROOT PARAMETERS

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Abstract. The article reflects the influence of the density of chicory plants on the size and mass parameters of chicory roots in the conditions of the Right-Bank Forest-Steppe of Ukraine. It has been established that, on average, over three years, the optimum plant density on chernozem podzolic coarse-medium-loamy is 140-150 thousand units / ha, which provides a yield of chicory roots of 44.7 t / ha and a collection of inulin of 6.36 t / ha. The decrease or increase in plant density from the optimum causes a significant decrease in yield. So, the lowest yield (34.8 t / ha) was obtained for plant densities – 90 thousand units / ha. The increase in plant standing density to 200-225 thousand units / ha ensured a decrease in root yield to 36.9-39.5 t / ha and a decrease in inulin collection from a unit area – to 5.27-5.63 t / ha. For mechanized harvesting, the most suitable were chicory varieties with cone-shaped roots, evenly placed on the field with intervals between plants of 10-20 cm.

Key words: *Cichorium intybus*; Plant density; Nutrition area; Crop yield; Root size.

INTRODUCTION

One of the effective and acting factors that regulate the use of moisture, light, and the intensity of the assimilation process and crop formation is the number of plants per unit area. The relationship between productivity and plant standing density manifests itself in different ways depending on soil and climatic conditions, biological characteristics of hybrids and agricultural technology. Therefore, the plant density is an important element of the technology for growing various crops. With an optimal determination of the number of plants per unit area, the maximum productivity can be achieved while maintaining high-quality indicators (Veretennikov, V., Tolorai, T. R. 1996)

V.M. Stelmakh (1994), O.V. Tkach, A.V. Ovcharkuk (2017) argue that the distribution parameters of chicory plants in rows (distance between plants, their deviations from the conditional arbor of the rows, the placement of root heads relative to the soil surface) are significantly affected by the uniform distribution of seeds during sowing, which, first of all, depends on the sowing rates, as well as on the dimensional parameters of seeds, laboratory and field germination, the depth of planting, the natural "loss" of plants during the growing season, the final plant density at the beginning of harvesting.

Studies to determine the agrophysical parameters of roots depending on the shape and size of the nutritional area of the plants (in the form of a square: 15x15.25x25.30x30 and 45x45 cm) show that, with an increase in the square nutritional area, the parameters of chicory roots increase in size and weight, namely: root diameter "dK" by 1.3 times, length - 1.36 times, root weight "RK" - 2.3 times, and root yield per unit area (ha), on the contrary, decreases by 4.0 times due to the decrease of plant density by 9.0 times, that is, an increase in the area of nutrition for each plant, as a rule, is associated with a decrease in plant density per unit area, and, consequently, a decrease in the yield of chicory (Humentyk, M.Ya. 2003; Kurilo, V.L. et al. 2012; Zuev, N.N. et al. 2001).

The distance between plants in rows and their distribution on the area also significantly affect the agrophysical parameters of chicory and, accordingly, its productivity. Uneven placement of plants in rows leads to an increase in substandard chicory roots (with a diameter of less than 3 cm or weighing less than 100 g), the number of which varies from 5.3 to 12.7% for different plant densities. With the increase in plant density, the number of chicory roots weighing from 100 to 200 g significantly increases (Yatsenko, A.A. 2000; Tkach, O.V., Kurilo, V.L. et al. 2013).

According to Ya. Yatsenko (2003), at a plant density of 90 thousand pcs. / ha the share of roots weighing 100-200 g is 10.5%, and at 225 thousand pcs. / ha- 40%, which is 3, 8 times more.

Therefore, when choosing the optimal plant density, it should be taken into account under what conditions the size of the roots fractions, which must correspond to the norms of the corresponding marketability, are formed better, and to determine the degree of influence of the planting density, plant placement on the area and the size parameters of the plants on the yield and quality of chicory roots.

MATERIALS AND METHODS

The studies were conducted on the experimental field of the Khmelnytskyi State Agricultural Experimental Station of the Institute of Feed and Agriculture of the Podillia of the National Academy of Agricultural Sciences of Ukraine during 2012-2016. It is located in the north-eastern part of the Khmelnytskyi region within the Starokonstiantynivskyi district.

The soil of the experimental field is podzolized chernozem coarse-sawn-medium loamy on loess-like loams. The humus content (according to Tyurin's) in the 0-3 cm layer is 2.8-3.6 %. The content of nitrogen compounds that are easily hydrolyzed (according to Kornfield) is 9.0-11.6 mg per 100 g of soil, mobile phosphorus (according to Chirikov) 6.0-8.5 mg per 100 g of soil and exchange potassium (according to Chirikov) – 6.9-10.0 mg per 100 g of soil.

The length of the roots after digging out from soil was measured using a ruler with an accuracy of 1.0 mm. The mass of the roots, after cleaning from the tops and the soil, was weighed on an electronic balance with an accuracy of 0.1 g.

The number of measurements for all indicators (root weight mk, technical length lk, root diameter dk, weight mk and length *lk* tops of leaves) in five times repeated was at least N =100.

At the beginning of harvesting chicory roots in areas with different densities, plants with a nutrition area that was provided for by the research methodology were selected. Based on the obtained indicators, theoretical yield indicators were calculated and compared with experimental ones.

RESULTS AND DISCUSSION

According to the results of plant density analysis, yield, inulin content and the ratio of fractions according to the size of roots, corresponding to the requirements of commercial products for mechanized drying of chicory raw materials at processing plants, the optimal plant density in the row and the area was determined (table 1).

Table 1. *The yield of chicory roots depending on the density of plants at the beginning of harvesting, t /ha (average for 2012-2016)*

Indicator	Plant density, thousand /ha					
	90	115	140	175	200	225
Sp , см	25,0	19,4	15,9	12,8	11,1	9,8
n, шт. /м	4,0	5,2	6,3	7,8	9,0	10,3
Vsp, %	78,6	51,3	51,7	62,2	65,1	68,0
Area of supply, cm²	1125,0	873,0	715,5	576,0	499,5	441,0
Yield, t /ha	34,8	42,5	44,7	42,6	39,5	36,9
± ut to 140 thousand /ha, HIP05=2,3	-9,9	-2,2	0	-2,3	-5,4	-8
The content of inulin in the roots,% on dry matter	15,1	14,7	14,1	13,9	13,7	13,4
± up to 140 thousand /ha, HIP_{05}=0,4	1,0	0,6	0,0	-0,2	-0,4	-0,7
Inulin collection, t /ha	5,12	6,01	6,36	6,05	5,63	5,27

Note: Sp and Vsp are the average distance and the coefficient of variation of the distance between plants, respectively; n is the number of plants per 1.0 m line.

So, with an average plant density of 140 thousand pcs. / ha (with fluctuations in the range of 120-160 thousand / ha, that is, with 5-8 plants per 1 meter line with a distance between plants within 19-13cm), a root yield in the range of 43.5-45.8 t / ha and an inulin yield in the range of 6.05-6.46 t / ha can be obtained. The lowest yield (35.9 t / ha) was obtained by us with the distance between plants of 25 cm (4 plants per 1 meter row) and the plant density of 88.9 thousand pieces / ha. That is, the decrease in plant standing density ensured an increase in the nutrition area of one plant to 1125.0 cm², which ultimately affected the yield. The plant density increase to 200-225 thousand units / ha also ensured a decrease in the yield of roots to 37.8-40.4 t / ha. As it can be seen from the table, a plant density higher than 200 thousand pcs. / ha affects the inulin content in roots, namely, we obtained 133.4-13.7% on dry matter, and ultimately affected the collection of inulin per unit area (5.07-5.53 t / ha).

So, the following factors determine the yield of chicory roots: soil fertility, predecessors, soil tillage

system, forms and rates of mineral fertilizers, growing technology and a system of machines for its implementation, timing and quality of operations, plant density and their distribution in rows. The maximum yield can be obtained with the optimal density of evenly distributed plants in the area. A decrease or increase in plant density from the optimum causes a significant decrease in yield.

Since the uniform distribution of plants in the row is one of the main factors in increasing the yield of chicory, we conducted studies to investigate the agrophysical parameters of chicory roots.

Besides, the technological processes development for growing chicory is based on the study of the agrophysical and physicomechanical properties of roots. Their peculiarity is the presence of several external and internal signs, which significantly change during the growth and development of plants. They depend on the variety, the applied crop care technology, soil and weather conditions, and the growing zone.

According to the results of the established studies (table 2), the diameter of the root depends on the distance between the plants in the row. So, the lowest value of this indicator was noted in the variant with a distance of 0-10 cm – 54.2 mm, and the highest value – 75.2 mm in the variant with a distance between plants of 40-50 cm. An important agrophysical indicator is root length. The maximum size of chicory roots was obtained in the variant with a distance between plants of 40-50 cm – 263.1 mm; a slightly shorter length was in the variant with the interval between chicory plants of 30-40 cm, namely 252.3 mm.

Table 2. *Agrophysical parameters and yield of chicory roots depending on the distance between plants in rows (row spacing - 3*30+45 cm) (Average for 2012-2016)*

Indicators	Distance between plants (S), cm				
	0…10	10…20	20…30	30…40	40…50
Root weight Rk, g	304	361	412	446	493
The diameter of roots *dk, mm*	54,2	60,3	62,4	64,5	75,2
Length of roots *lk, mm*	221,3	233,2	245,4	252,3	263,1
Average power area *Sm*, *см*^{2}	225	675	1125	1575	2025
The aspect ratio of rectangle, *k*	0,21	0,43	0,66	0,88	1,00
Theoretical plant density C, thousand / ha	341,8	192,5	115,6	82,5	64,2
Root yields B = C xPk, t / ha	103,9	69,5	47,6	36,8	31,6

We also found that the mass of the root is directly proportional to its diameter and length, and the diameter affects the marketability of roots. When harvesting, chicory roots with a diameter of more than 20 mm are considered standard. Their separation into standard and non-standard fractions is best done using the sorting point PSK-6, which not only divides the roots by size, but cleans them of impurities and damaged roots.

It should be noted that increasing the distance between plants in a row, although it affects the mass of chicory root, however, the number of plants per unit area decreases and their agrophysical parameters change, which ultimately affects the yield and marketability. So, for mechanized harvesting, the most suitable are chicory varieties with a conical root shape. The varieties Umansky-95, Umanskyi 97 and Umansky-99 most fully meet these criteria. They provided root yields at the level of 53.8 t / ha, with plant density –148.1 thousand pcs. / ha, and with intervals between plants of 10-20 cm.

CONCLUSIONS

Thus, as a result of the studies, it was found that in the conditions of the Right-Bank Forest-Steppe of Ukraine on the chernozem podzolized coarse-medium loamy on average for 3 years the optimal plant density is 140-150 thousand / ha, which provides a yield of chicory roots of 45.8 t / ha and a yield of inulin of 6.46 t / ha. For mechanized harvesting, chicory varieties with cone-shaped roots were found to be most suitable. They were evenly distributed over the field with intervals between plants of 10-20 cm.

It should also be noted that serial root-harvesting machines cannot efficiently and cost-effectively harvest through a considerable length of the productive part of chicory roots 18-27 cm. The problem of mechanized harvesting of chicory roots is urgent and chicory varieties with a conical root shape turned out to be the most similar in shape to sugar beets, for this, beet-harvesting machines should be used to dig them out after a slight conversion.

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