EFFICIENCY OF MECHANIZED COMB TECHNOLOGY OF SOIL TREATMENT PREPARATION FOR SOWING SUGAR BEETS

Viktor Tesliuk[1], Viktor Baranovsky[2], Vasyl Lukach[3], Mykola Ikalchyk[3], Anatoly Kushnirenko[3], Vasyl Kulyk[3]
[1]National University of Life and Environmental Sciences of Ukraine, Ukraine;
[2]Ternopil Ivan Puluj National Technical University, Ukraine;
[3]Separated Subdivision of the National University of Life and Environmental Sciences of Ukraine "Nizhin Agrotechnical Institute", Ukraine
vtesluk@ukr.net , baranovskyvm@ukr.net, vslukach@ukr.net, m.ikalchyk@gmail.com, dekan.msg@gmail.com, shanovnyy@ukr.net

Abstract. Mechanized technology of spring tillage, which is used in farms of Ukraine for sowing sugar beets on moist and heavy soils, provides multiple passes of pre-sowing machines due to significant winter soil moisture, leading to significant compaction of its surface layers. This reduces the yield of root crops, increases the economic costs of their production and the emergence of environmental negative consequences. The aim of the work is to increase the yield and reduce the economic costs of the process of sowing sugar beets by developing advanced technology of pre-sowing soil preparation with the division of operations on autumn ridge formation and spring pruning of their tops followed by sowing seeds in the formed ridges. The results of the experimental research of the offered technology of preparation of soil are shown and indicators of efficiency of its application in comparison with control are defined. It is established that minimization of spring pre-sowing tillage allows sowing seeds at an earlier date with sufficient uniformity of seed sowing depth in the ridge (square depth of deviation – up to 2.3%), which leads to increased growing season and increasing vegetative productivity of plants or root yield. The maximum final yield of root crops in areas sown by the advanced technology was 4.909 tons per hectare, which is approximately 16% more than the yield (4.241 tons/hectare) of the control area. The obtained results confirm the positive efficiency of the proposed technology of pre-sowing tillage for sowing beets on soils heavy in mechanical composition.

Keywords: spring tillage, cultivator, ridges, sowing depth, yield.

Introduction

Analysis of technologies and technological operations of growing crops, including sugar beets, in order to optimize the technological costs of conservation and better improvement of agricultural land, biological systems of agriculture, taking into account soil and climatic characteristics and zonal systems of crop production require constant time and resources [1].

The results of a long term study have shown that sugar beet plants are characterized by high requirements for basic and pre-sowing tillage. The negative impact of its increased density, which is a result of repeated passes of running systems of machine-tractor units of pre-sowing tillage, especially heavy in mechanical composition, which is most favorable for growing sugar beets, was especially noted [2].

Taking into account the analysis of technological requirements for growing sugar beets, a significant role belongs to integration and implementation of effective zonal technological operations and technical support of tillage. A significant role in addition to agro-technical and technological requirements is played by economic indicators, which are significant costs under the conditions of traditional technology [3].

It has been scientifically proven that the main indicators to be achieved by pre-sowing tillage are creation of a compacted fine-grained soil surface 4-5 cm deep (there should be 80-90% of lumps with a fraction of 0.1-1.0 cm, and no lumps over 3 cm). With such requirements for pre-sowing cultivation it is necessary to achieve leveling of the field surface, when there are no 2 cm combs. It is established that the soil density should be in the range of 1.1 to 1.3 $g \cdot cm^{-3}$. Ensuring such indicators determines optimal condition and ratio of air and moisture content of the soil, which is a prerequisite for friendly germination of plant seeds and favourable plant development during the growing season [4; 5].

Analysis of zonal technologies of sugar beet root production showed that technological process involves implementation of successive operations of continuous application of mineral and organic fertilizers, basic and spring pre-sowing tillage, sowing seeds, caring for plants that ensure root

development and sugar accumulation. It is known that the main tillage for sowing and growing sugar beets is performed in two main ways – improved or semi-steam.

Use of improved method is recommended in the climatic zone of unstable and semi-steam -with sufficient moisture. The basic of the operation of tillage and use flat-cut deep plowing is recommended, and on uneven surfaces with soils capable of floating additional leveling of the field surface is needed [6; 7].

Use of traditional soil preparation technology implies that during spring pre-sowing tillage soil is loosened with toothed harrows with subsequent alignment with loop harrows in the unit with toothed harrows, and the zone of sufficient moisture requires additional deep loosening with cultivators for continuous tillage. It is necessary to use it on heavy soils prone to floating, as well as in places where after the main cultivation the field surface is not brought to the required leveling. In the traditional technological process of spring pre-sowing soil preparation, cultivation to the depth of seed excavation is final, and in case of excessively loose soil, rolling is necessary.

This number of spring passes of machine-tractor units in the field leads to excessive soil compaction, which is especially harmful for heavy floating. Analysis of the distribution of energy costs of tillage in preparation for cultivation of sugar beets found out that 50-80% of total resources for main and pre-sowing tillage is consumed.

In addition, application of pesticides and fertilizers leads to excessive material and financial costs and negative impact on the environment. Therefore, according to the costs, taking into account the cost of energy and material resources, traditional technologies are not characterized as energy-saving and environmentally friendly.

In addition, in spring there is a lot of work, and it is quite difficult to carry out a set of necessary spring operations that require timely delivery.

The main way to optimize production of sugar beets, reduce the cost of material and financial resources is to rationalize tillage. Estimation and realization of the forecasted project of regularity of influence of cultivator design parameters on power costs of the process of soil cultivation was investigated during field tests [3; 5].

The proposed requirements [4-8] developed a mathematical model of a soil tillage unit that establishes the existing functional relationship of soil properties, geometric parameters of the working body, depth of cultivation, speed of movement and width of capture unit. Subsequently, the effect of changing the depth of cultivation and the speed of movement of the tillage unit on the cost of the required power was established.

However, the developed mathematical models for predicting traction resistance did not sufficiently take into account the existing complex interactions between the working body and the soil of complex tillage units.

The evaluation of the quality of sowing of sugar beet in field conditions was also considered, where the variability of rows in a row and depth of sowing were evaluated, depending on the soil condition. It is established that the exact drills with internal filling of the collecting holes allowed to obtain higher quality of sowing [9], and the placement of seeds in the soil profile (depth/sowing) depends on the soil and climatic conditions, preparation of the seminal type [10; 11].

Analysis of literature and patent sources shows that the prospects of mechanized technology and development of technical means for its implementation in sugar beets cultivation in the direction of increasing yields and reducing energy consumption can be seen in the comb method of soil preparation. However, in Ukraine there are no specialized machines and working bodies for wide testing and introduction into production [1].

The aim of the research is to increase the efficiency of sugar beet root crops on mechanically heavy soils by minimizing pre-sowing cultivation in spring with postponement of the operation to autumn.

Materials and methods

To study the theoretical prerequisites of the proposed technological operations of pre-sowing tillage with the division of operations of the depth of seed excavation and yields of sugar beet roots for autumn and spring periods a program of experimental research and technical support for them was developed.

Laboratory field research and testing of the proposed technology was conducted in the research and production association "Elita", Volyn region using experimental planning methods and statistical processing of experimental data using appropriate software products (Microsoft Excel, Statistica).

According to the research program, physical and mechanical characteristics of the soil were made; uniformity of comb formation and degree of shrinkage during winter to spring, formation of soil crust, thickness of the cut layer of the tops of the combs, agrophysical indicators of the quality of sugar beet seeds were researched. Agronomic indicators of crop condition, dynamics of plant growth and development, sugar beet yield were studied.

Field experiments are laid out according to the scheme of one-factor experiment with the following options.

1. Control. Traditional technology of growing sugar beet roots for the zone.
2. Experimental, which provided local tape application of dry mineral fertilizers, followed by the formation of combs in the autumn.
3. Experimental, which provided continuous application of dry mineral fertilizers, followed by the main tillage and formation of combs in the autumn.

Experimental, which provided continuous application of dry mineral fertilizers with subsequent basic tillage, formation of combs with seals and formation of inter-comb gap. Analysis of agricultural techniques of tillage, taking into account the shortcomings of traditional technologies for growing broad-leaved crops on soils heavy in mechanical composition, gave us the direction of development, research and testing to implement a method of sugar beet production, which will optimize tillage and reduces material and financial costs.

The novelty of the proposed technology is division of operations into autumn and spring periods.

In the autumn, against the background of main and surface tillage on the surface of the field cultivator 2 (Fig. 1a) equipped with working bodies comb formers 6 forms combs with a row spacing of 450 mm (Fig. 1b).

The cultivator is aggregated by the tractor 1 with an interwheel base of 1350 mm.

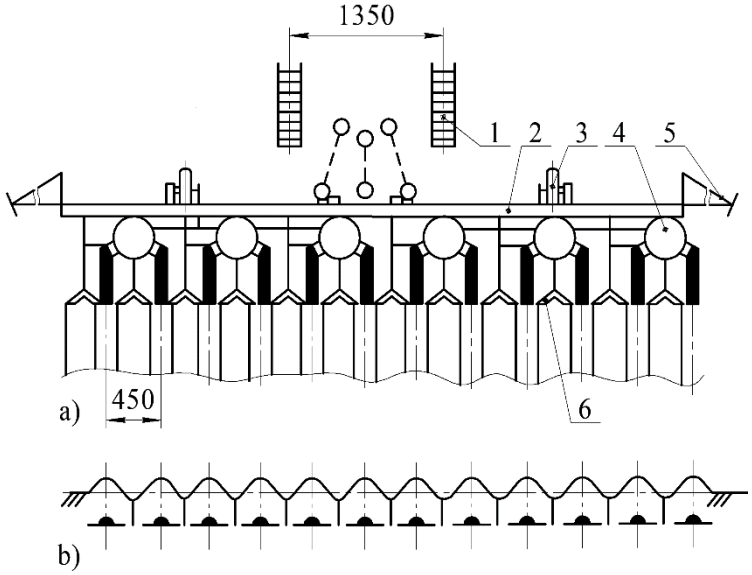

Fig. 1. **Autumn application of fertilizers with formation of combs:** a – completion of the comb-forming unit; b – ridge surface of the field; 1 – energy tool; 2 – cultivator-comb-former; 3 – cultivator support wheels; 4 – devices for applying fertilizers; 5 – markers; 6 – working bodies of comb formers

Preliminarily under the combs in the area of rows, it is recommended to apply mineral fertilizers with the help of installed fertilizer spreaders 4. Orientation of the movement of the cultivator-comb-forming occurs by means of the established markers. The formed profiled surface of the field remains for winter.

The profiled surface of the field after the passage of the unit is shown in Fig. 2.

Spring pre-sowing tillage, involves cutting the tops of combs 30 ... 40 mm high,and is performed by a machine unit consisting of a tractor 1 (Fig. 3a) and a row cultivator 2, followed by sowing seeds with a precision seeder (Fig. 3c) in the area of cut vertices of the comb (Fig. 3b).

Fig. 2. **General view of combs on the soil surface**

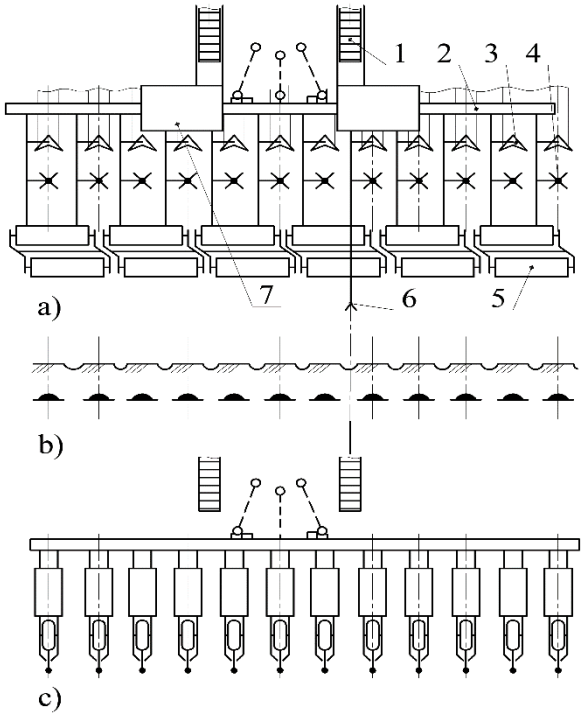

Fig. 3. **Scheme:** a – of cutting the tops of the combs; b – cross section of cut combs; c –sowing in cut combs; 1 – energy tool; 2 – row cultivator; 3 – working bodies of the cultivator; 4 – mounted sprayer; 5 – pond rotor; 6 – tracer; 7 – sprayer capacities

The cultivator is completed with working bodies of arrow type with dumpers and a sprayer 7 with sprinkler 4 and pipelines for presowing tape application of herbicides and excavation by rod rotors 5. The cultivator is equipped with a tracer 6, which forms a trail for the sowing unit (Fig. 3a).

The advantages of the combs formed in the autumn are intensive accumulation of moisture, accelerated spring maturation of the soil in the comb area, which facilitates sowing at an earlier date without carrying out other operations.

The main task of spring tillage is the most complete preservation of moisture accumulated during winter-autumn period and creation of favorable conditions for free penetration of precipitation into the soil and their maintaining.

Moreover, the task of spring tillage includes creation of aligned, loose, fine-grained layer of soil to wrap the seeds to the desired depth, to provide the conditions for quick and friendly germination and weed control.

Results and discussion

According to the requirements set for spring pre-sowing tillage, it is necessary to provide optimal conditions for sowing and seed germination as well as promoting further growth and development of sugar beets. Pre-sowing tillage should follow agrotechnical demands for uniformity of the seeding rate and depth for digging, which were studied by us. The results of accounting for the depth of seed excavation are given (Table 1).

Evaluation of the significance of the difference between average sample data of the depth of seed excavation was conducted according to the criteria "*t*", Student [12]. According to the results of mathematical data processing it is established that:

$$t_{exp.\ 1:2} = 3.4;\ t_{exp.\ 1:4} = 6.8;\ t_{exp.\ 2:4} = 0.6;$$

$$t_{exp.\ 1:3} = 4.5;\ t_{exp.\ 2:3} = 0.76;\ t_{exp.\ 3:4} = 1.46.$$

The tabular value of this criterion for the general sample $N = 100$ (number of degrees of freedom) will be $t_{mab.} = 1.97$.

Table 1

Depth of seed excavation according to different variants of pre-sowing seed treatment

Variant	Number of measurements *N*	Arithmetic mean $\bar{x}$, cm	Standard deviation σ, cm	Coefficient of variation *V*, %	Expected value *m*, cm	Average error *P*, %	Pearson's matching criterion χ^2
1 (Control)	70	3.42	0.73	22.2	0.07	2.5	6.6
2	70	2.81	0.77	24.9	0.07	2.8	2.3
3	70	2.92	0.79	22.0	0.08	3.1	4.14
4	70	2.75	0.79	18.1	0.08	2.7	4.13

Comparison of the experimental values of Student's criterion with theoretical shows that a significant difference in the depth of seed excavation is observed between control options, that is traditional pre-sowing tillage and suggested way. It is a result of deep spring loosening and uneven pre-sowing tillage. Further vegetation and care for the development of sugar beet plants on the research variants till the harvesting period was conducted in the same way.

The main indicator that characterizes productivity of sugar beet cultivation is the yield.

The results of the experimental data as for the yield are given in Table 2.

Table 2

Yield of sugar beets depending on ways of pre-sowing tillage

Variant	Average yield, t·ha^{-1}	Standard deviation σ, t·ha^{-1}	Coefficient of variation *V*, %	Expected value *m*, t·ha^{-1}	Average error *P*, %
1 (Control)	4.241	0.216	5.2	0.108	2.6
2	4.909	0.235	4.77	0.117	2.3
3	4.687	0.199	4.25	0.99	2.4
4	4.811	0.206	4.31	0.103	2.4

The significance of the difference between the compared options was tested by the Student's criterion "*t*". As a result of calculations of the experimental data it was determined:

$$t_{exp.\ 1:2} = 4.3;\ t_{exp.\ 1:4} = 3.9;\ t_{exp.\ 2:4} = 0.56;$$
$$t_{exp.\ 1:3} = 3.2;\ t_{exp.\ 2:3} = 1.38;\ t_{exp.\ 3:4} = 0.90.$$

As a result of the experimental research a significant difference in the obtained yield of sugar beet cultivation was established.

Conclusions

As a result of the research, it was determined that an average indicator of the depth of seed excavation on the proposed variant is 2.81 cm when deviating from specified depth by the value of the Pearson criterion $\chi^2 = 2.3$, while in control $\chi^2 = 6.6$. Uneven sowing depth causes unevenness and even lack of seedlings and seed germination which influences the final yield of root crops.

It was found that the final yield of root crops on the research variant 2 was 4.909 $t \cdot ha^{-1}$, at the same time 4.241 $t \cdot ha^{-1}$ on the control, which in comparison is 16 per cent more.

The obtained results confirm the positive efficiency of the proposed technology of pre-sowing tillage for sowing beets on soils heavy in mechanical composition.

References

[1] Барановський В. М., Підгурський М. І., Паньків М. Р., Теслюк В. В., Онищенко В. Б. Основи розробки адаптованих транспортно-технологічних систем коренезбиральних машин (Fundamentals of development of adapted transport-technological systems of root-harvesting machines). Ternopil Ivan Puluj National Technical University, Ternopil: Тернопільський національний технічний університет імені Івана Пулюя, Тернопіль, 2015. 401 p. (In Ukrainian).

[2] Bulgakov V., Nozdrovický L. The experimental research of combine harvesters. Research in Agricultural Engineering, 2016, no. 62, pp. 106-112.

[3] Manuwa S.I., Ademosun O.C. Draught and soil disturbance of model tillage tines under varying soil parameters. Agricultural Engineering International: The CIGR journal, 2007, no. 154, pp. 1-18.

[4] Moeenifar A., Mousavi-Seyedi S.R., Kalantari D. Influence of tillage depth, penetration angle and forward speed on the soil/thin-blade interaction force. Agricultural Engineering International: The CIGR Journal, 2014, vol. 161, pp. 69-74.

[5] Baranovsky V., Skalskiy O. Digging of chicory root crops by a combined digger. Scientific Journal of TNTU (Tern.), 2018, vol. 2(90), pp. 115-123.

[6] Bulgakov V., Ivanovs S., Pascuzzi S., Boris A., Ihnatiev Ye. Mathematical model of the cutting process of the sugar beet leafy tops without a tracer. INMATEH: Agricultural Engineering, 2019, Vol. 59(1), pp. 29-38

[7] Al-Suhaibani A.S., Al-Jnobi A.A., Al-Majhadi Y.N. Tractors and tillage implements performance. In: Proceedings from the Canadian Society for Bio Engineering (CSBE-SCGAB) Annual Conference. Paper No. 06-129. July 16–19, 2006. Edmonton, Alberta.

[8] Ramadhan M.N. Development and performance evaluation of the double tines subsoiler in silty clay soil part1: draft force, disturbed area and specific resistance. Mesopotamia Journal of Agriculture, 2014, vol. 421, pp. 293-313.

[9] Ramadhan M.N. Field study to evaluate the mechanical performance of the double tines longitudinally arranged subsoiler and its effect on some growth characteristics of barley Hordeumvulgare L. [MSc. Thesis.] College of Agriculture, Basrah University, 2011, Iraq.

[10] Páltik J., Nozdrovický L., Findura P., Maga J. Quality of the seed placing in seeding of sugar beet. Res. Agr. Eng., 2005, vol. 51, pp. 33-38.

[11] Uhlíř V., Mareček J., Červinka J. Impact of soil compaction in sowing on development and crops of sugar beet. Res. Agr. Eng., 2006, 52: 11-16.

[12] Granovskiy, V. A. and Siraya, T. N. Metody obrabotki eksperimental'nykh dannykh priizmereniyakh. ENERGOATOMIZDAT, 1990, L.