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DEVELOPMENT OF A MACHINERY COMPLEX FOR SUGAR BEET PRODUCTION WITH COMBINED ROW SPACING

The article presents results of development of cultivation and harvesting method for sugar beet with combined row spacing as well as machinery for its implementation.
Keywords: *sugar beet; growing space; interrow width; yield; production technology; machinery complex*

Introduction. The main challenges in sugar beet production remain increasing productivity, improving technological characteristics of crop, reducing labour costs and resources. One of the leading factors is obtaining a scientific-based stand plant density, including that by optimizing growing space, with choosing rational scheme of planting that can provide an increase in yield of 35-40 %, which was proved in the last century by academician V.I. Edelstein.

Analysis of recent researches and publications. Currently, a world used practice is sowing sugar beet (SB) with interrow width 35 to 90 cm or more, depending on climatic conditions and other different factors, mainly on machinery being used. In Germany, Holland and Belgium, row spacing is of 40; 41; 45 and 51 cm; in France of 38; 42 and 45 cm; Poland, Romania, Czech Republic of 43cm; England of 50 and 53 cm; Italy of 40 and 50 cm [1].

The most common in the USA, through the use of complex advanced machinery VIK of "Amiti Technologi", became 56 cm row spacing (90% of the total area), however their width varies widely (45 to 90 cm). The most common method of sugar beet planting in Japan is seedling method with interrow width of 50-60 cm.

As we know, in Ukraine, according to the Unification of Machinery for Sugar Beet Production in the countries of the Council for Mutual Economic Assistance (CMEA), width of interrows makes up 45 cm. At the same time, it was proved with theoretical and field experiments by physiologists G.I. Hnatiuk, K. A. Makovetskyi, V.A. Biurysiuk, V.V. Zakharov et al. As well as recent studies by A.F. Nikitin, A.V. Kuryndin, P.N. Renhach et al. (All-Russian Institute for Sugar Beet and Sugar) [1, 2] that rational configuration of growing space for beet is a square of 30 × 30 cm (ideally a circle), corresponding to the area of biologically-based growing space (about 900 cm^2) that is why crop spacing in the 30-ies, when sugar beet were grown and picked by hand, had a width of 30 and 36 cm. These interrows served as both main and technology ones. In the middle of the XX century in connection with the introduction of mechanization in the production of SB due to obvious reasons, technological interrow space width of 45 cm appeared, which served also as main. The consequence of this “expansion” from 30 to 45 cm was the “thickening” of plants in rows in order to obtain an optimal stand density (about 110,000 pcs./ha or 5 pcs. per 1m in a row) in the field that guarantied high yield. This in turn led to the decline from square area and elongation perpendicular to row axis and, consequently, to a decrease in yield.

Both in the past and at present, the return to wide row spacing of 30 cm is entirely impossible to carry out sowing, tending, and harvesting. Also in this case there are problems of passing machinery between rows. However, an alternative is technology with combined width of interrow space.

The goal of the research was to find a method of sugar beet sowing under the scheme, which efficiently combines main (30 cm) and technological (45 cm) spacing based on optimal growing space for each plant as well as the development of complex machines for sowing seeds, tending crops, picking tops and root at the combined width of the rows.

Materials and methods. Laboratory and field tests were performed using a set of experimental models of machines made based on serial: 1) Sowing machine ССТ-12 В; 2) cultivator УСМК-5, 4Б; 3) top-picking machine БМ-6Б; 4) cleaner head root ОГД-6; 5) digger КС-6Б-05. Statistical analysis of experimental data was performed according to conventional methods [3].

Results. Switching to low seed rate of monoseed varieties when grown with width row of 45 cm entails a risk of insufficient stand density with even distribution of plants. This is primarily due to a significant variation in field germination of seeds in different soil and climatic conditions.

Theoretical studies showed that to lower thickness of seedlings narrow aisles could be exercised. They have a number of obvious advantages: a) the extension of lines per hectare will yield the required number of plants at sowing at the final stand density; b) early closing of the leaves in rows will contribute to plant growth and reduction in weediness; c) creates an opportunity to evenly place the plants in the area due to compensation gaps in adjacent lines at bigger their total number [2, 4].

The point of the alternative technology for SB production [5, 6] is the alternation of main and technological interrow space in coverage of working unit according to the scheme:

$$B = (nm + M)i, \qquad (1)$$

Where B – coverage width of sowing unit, m;

n – number of main interrows in the block;

m – width of main interrows = 0.3 m;

M – width of technological between row space = 0.45 m;

i – number of blocks (nm + M), combined in the coverage.

Sowing beets to a preset plant density is carried out in accordance with established schemes in which growing space of each plant is assumed to be a rectangle with side ratio k = 0.9-1.2, which can be determined by following formula:

$$k = \frac{l_p}{m} = \frac{10\,000(n+1)^2}{c(nm+M)^2}, \qquad (2)$$

where: k – side ratio of the rectangle;

l_p – side of the rectangle equal to the sum of two semi-intervals relative to neighbouring plants in a row or interval between plants m (Fig. 1);

c – stand density, thousand of pcs./ha.

For example, when p = 100,000 pcs./ha; n = 3; m = 0.3 and M = 0.45 according to formula (2) k = 0.9, i.e. the ratio of the rectangle area of growing space is close to the side ratio of the square.

Such spacing, when growing space for each plant shape is close to a square provides better productivity of sugar beet at guaranteed stand density of 100-110 thousand pcs. due to an increase in the number of linear meters of rows in the area of 1 hectare 1.33 times as much or by 33-34% as compared with 45 cm rows.

But the main advantage of such a combination of main interrows m with the required number of technological interrows M, which is 1.5 times wider than main ones, is provision of machine tending and harvesting crops of SB.

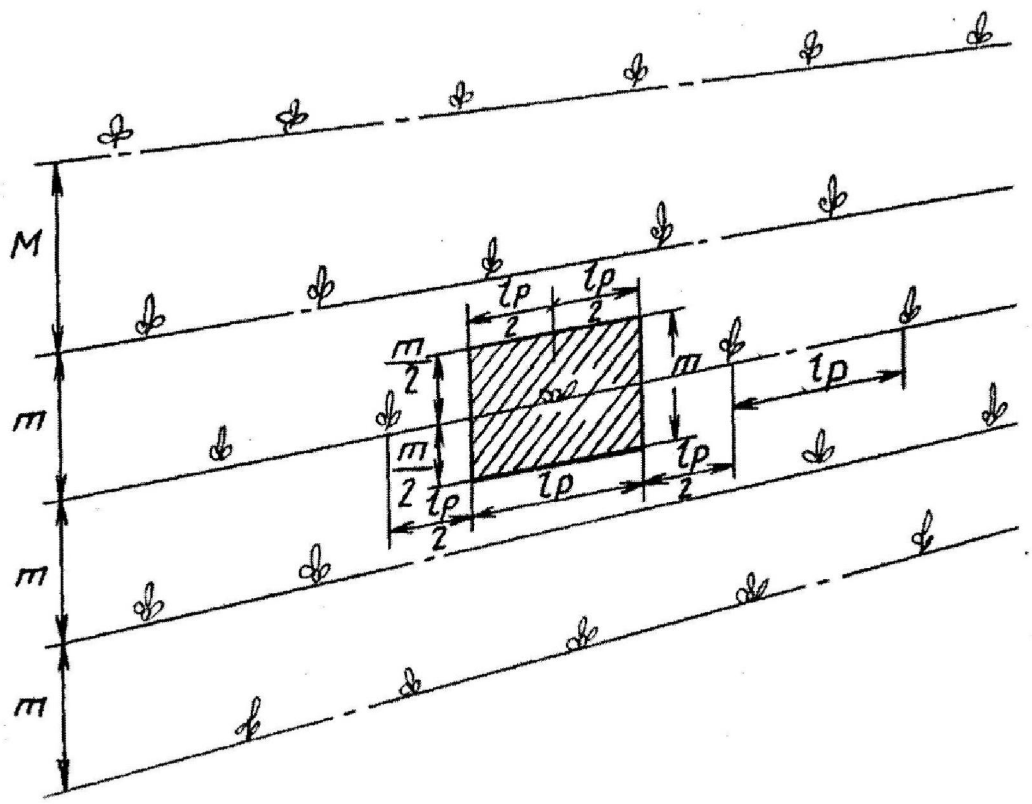

Fig. 1. To determination of a plant growing space

According to formula (2), which takes into account the configuration of growing space, we performed calculations on choosing the layout of plants under combined width of the rows. The results are summarized in Table 1.

Table 1

Selection of the combination of row spacing as affected by the side ratio of rectangle k of growing space (100,000 pcs./ha)

Variants	Parameters of the formula	Numerator $(n+1)^2$	Denominator $10(nm+M)^2$	$k=\frac{(n+1)^2}{10(nm+M)^2}=$ = 0.9 – 1.2	m/ha
I	n =3 m = 0.3м M = 0.45м	16	18.225	0.9	29630
II	n =5 m =0.3м M = 0.45м	36	38.025	0.95	30770
III	n =5 m = 0.3м M = 0.6м	36	44.1	0.82	28571
IV	n =3 m =0.3м M =0.6м	16	22.5	0.77	26667
V	n =3 m = 0.3м M = 0.7м	16	25.6	0.63	25000
VI	n =3 m = 0.3м M = 0.8м	16	28.9	0.55	23530

The table shows that variant I and II with a combination of 3-5 main rows spacing m = 0.3 m with technological rows M = 45 cm increase the length of rows in each hectare under optimal planting density by 7.5-8.5 thousand meters, as compared with the 45 cm interrow space and increases growing space per plant with shape close to square (k = 0.9-0.95), which in general, provides a significant increase in productivity of sugar beet.

To verify the efficiency of the proposed alternative technology we performed tests on the area of 50 ha in a collective farm "Peremoha" in Dubno district of Rivne region.

Sowing SB was carried out with specially altered serial domestic sowing unit CCT-12B according to layout (Fig. 2) with 16-row sowing machine in the unit with the tractor T-70C (Fig. 3).

Loosening between rows, while tending crops, was carried out with altered16-rows cultivator УСМК – 5.4Б in the unit with T-70C (Fig. 4).

Estimation of biological yield was carried out immediately prior to harvesting by relevant methods of sampling and statistical analysis of the data [3] showed reliable increase in root yield of 42-58 kg/ha (depending on the planting density of 90-105 thousand/ha) against the control background (technology with interrow space of 45 cm) yield of 4.80-4.96 t/ha.

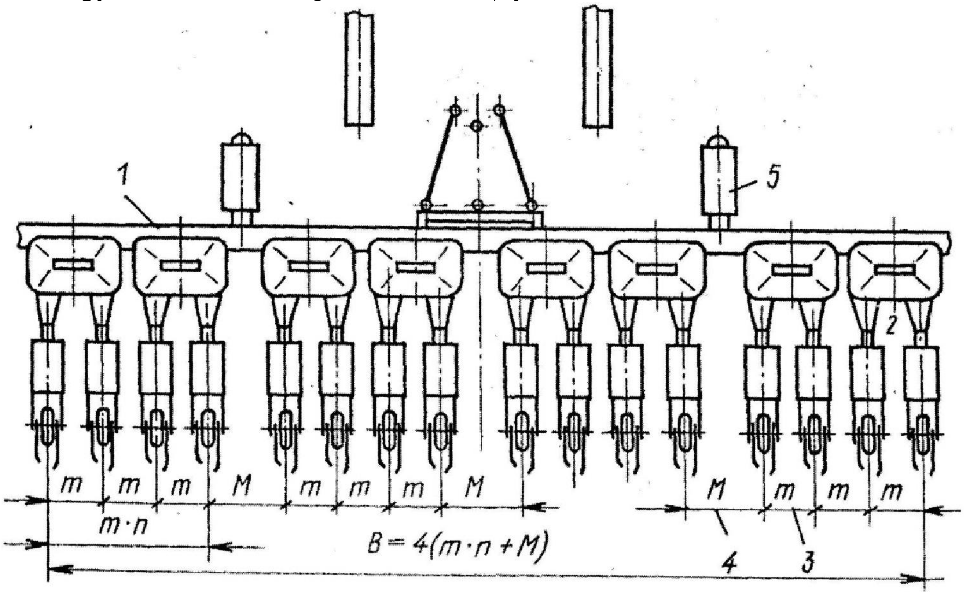

Fig. 2. Layout of the sowing sections on the sowing machine:
1 - main frame; 2 - sowing section; 3 - the main space between rows (30cm), 4 - technological space between rows (45cm); 5 - resistance-driving wheel

Fig. 3. 16-rows sowing unit aggregated with tractor T-70C

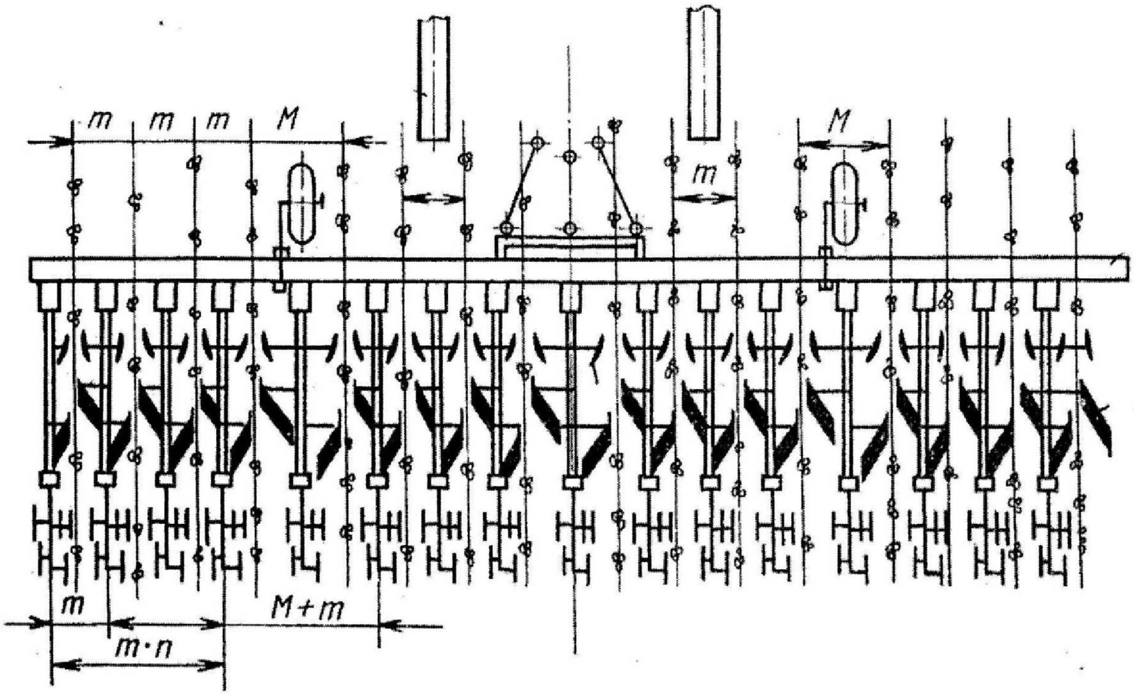

Fig . 4. Layot of working units on the frame of the cultivator for loosening space between rows

Harvesting roots grown with combined width row spacing was carried out with altered at Ternopil combine factory 6-8 row serial unit into 8 row experimental one (Fig. 5, 6): top-picking machine was made based on БМ-6Б; cleaner - on ОГД-6; digger on КС-6Б-05 (Fig. 7).

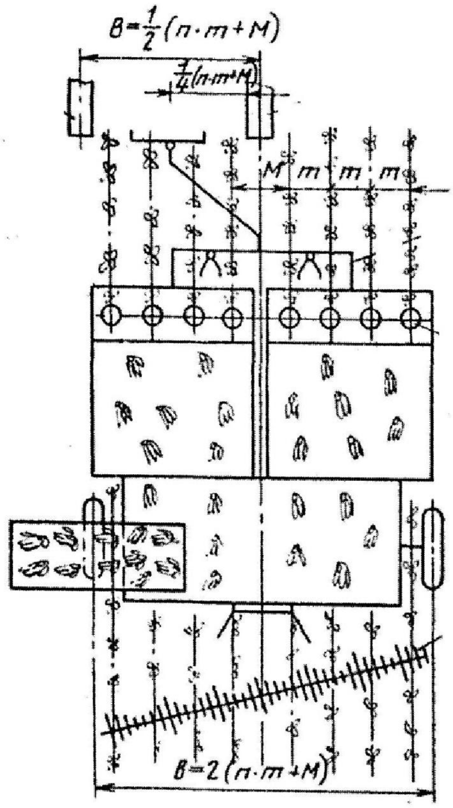

Fig. 5. Layout of top-picking machine

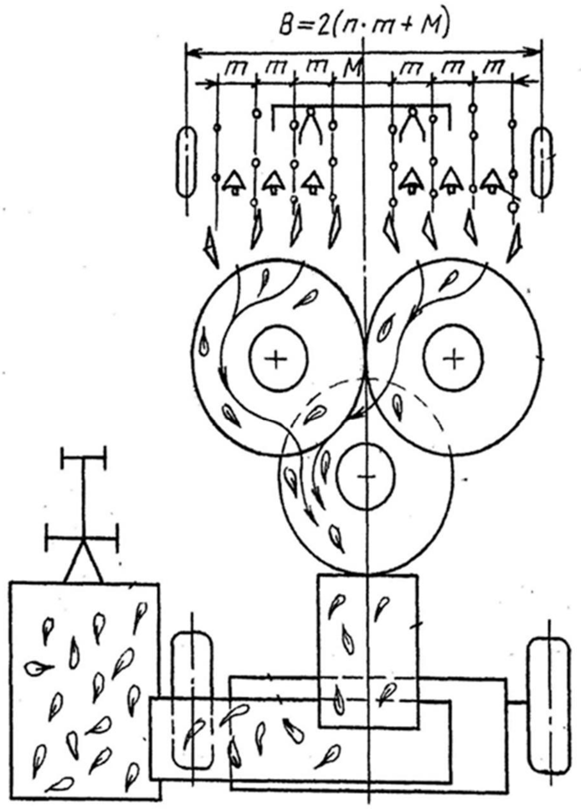

Fig. 6. Layot of digger

Each of two sections of top-picking machine consisted of four cutting units for without-tracing cutting tops with three rectangular saber blades assembled at an angle of 120° to each other. This machine was aggregated with a tractor T-70C in the left lateral displacement relative to the central axis of the machine for 675 mm (half the width of the tractor track), which allows the tractor to move left track on the harvested field. The height of the blades relative to the surface of the field was regulated by bearer-copying wheel in such a way that waste mass of roots while cutting tops would not exceed 0.5-1.0 %. The speed of the unit was up to 5.3 km/h.

Two-oval top-cleaner was altered from hinged ОГД-6 into pull-type one with a bearer-copying wheel that spontaneously directed along spaces between rows of roots. Cleaner was aggregated with tractor T-70C.

To alterate digger КС-6Б-05 into 8-row we made a front axle beam for track width of 2.7 m. Digging working units of machine were made in the form of spherical disks in conjunction with arrow-headed under-digging claws. Roots were cleaned from the ground and plant residues with the aid of three bar stock turbines with a vertical axis of rotation (Fig. 8). To ensure the lateral resistance, frame was fixed with braces. The machine was reliable in operation on light and medium soils.

Fig. 7. Experimental set of 8-rows digger: self-propelled digger; pull-type post-cleaner of tops

In general, the experiments have shown that the use of complex of altered machines is capable to harvest SB with a combined width between rows under sufficient quality of top picking, post-cleaning and digging (Fig. 9).

Fig. 8. Digging-cleaning working units of the "under-digging claw - spherical disc - turbine (cleaner)" type

However, to introduce this technology widely it is necessary to develop a new, of less metal content complex of harvesting machines, especially diggers that are still self-propelled and weight more than 10,000 kg, because they were developed by the analogues of too complex and powerful bunker combines of leading Western-European firms that have been dominating sugar beet fields in Ukraine over the last 10-15 years. The production test carried out in the average farm in Rivne region using the altered serial beet machinery of both domestic (digger ССТ-12Б, post-cleaner ОГД-6, top-picking БМ-6Б and digger КС-6Б-05), and now foreign (cultivator УСМК – 5.4Б (Russia) tractor Т-70С (Moldova) production has proved that a goal of developing new machines should be reducing their energy intensity and metal content i.e., developing machines and tools of pull and mounted type.

Fig. 9. Alterated digger in a work

Conclusions. Developed and tested was a new (Patent of Ukraine No. 5132) alternative technology of sowing and growing sugar beet combining main (30 cm) and technological (45 cm) spaces between the rows in one coverage of 16-rows sowing unit and cultivator for interrow hoeing as well as 8-row units for separate collection tops and roots. An advantage of proposed method of production is a possibility of forming optimal stand density (100,000- 110,000 pcs./ha) along with rational spacing on the surface of field and growing space of each plant close to optimal, that allows obtaining additional root yield of 5-6 t/ha with more even weight distribution and higher (by 0.4-0.6%) sugar content.

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Анотація

Волоха М.П., Балан В.М.

Розробка технологічного комплексу машин для виробництва цукрових буряків з комбінованою шириною міжрядь

Наведено результати досліджень по розробці способу вирощування і збирання цукрових буряків з комбінованими міжряддями і комплексу машин для його реалізації

Ключові слова: *цукрові буряки, площа живлення, ширина міжряддя, урожайність, технологія виробництва, комплекс машин*

Аннотация

Волоха Н.П., Балан В.Н.

Разработка технологического комплекса машин для производства сахарной свеклы с комбинированной шириной междурядий

Приведены результаты исследований по разработке способа выращивания и уборки сахарной свеклы с комбинированными междурядьями и комплекса машин для его реализации.

Ключевые слова: *сахарная свекла, площадь питания, ширина междурядья, урожайность, технология производства, комплекс машин*