PROPERTIES OF THE SUGAR BEET TOPS DURING THE HARVEST

V. M. Bulgakov[1], V. V. Adamchuk[2], L. Nozdrovicky[3], M. Boris[4], Y. I. Ihnatiev[5]

[1]*National University of Life and Environmental Sciences of Ukraine*
[2]*National Scientific Centre "Institute of Agricultural Engineering and Electrification" NAASU*
[3]*Slovak University of Agriculture in Nitra, Slovak Republic*
[4]*Podolsky State Agricultural and Technical University of Ukraine*
[5]*Tavria State Agrotechnological University of Ukraine*

Abstract
All methods of sugar beet tops separation from the roots are based on the difference in the placement tops and root crops relative to the soil surface and their relative placement. Separation of tops residues after cutting is based on the various strength of sugar beet heads and leaves. The aim of the study is to determine the optimal method of mechanical impact on the beet tops in order to improve the quality of its harvest process. To study the form and structure of the sugar beet stalks there was used cuttings used photo-shoot overlaid by coordinate grids. For determine the hardness of various zones was used specially designed hardness tester. Impact action on the root crops head was investigated by a special laboratory facility. As a result of experimental studies there were obtained a new data characterizing the structure, shape and strength of the various zones of the root crops head and leaves with the aim to study the possibilities of effective mechanical destruction of leaves and subsequent separation of them from the head.

Key words: sugar beet, sugar beet tops, structure and properties, harvesting, hardness.

INTRODUCTION

Among the urgent scientific and production task belongs the development of the new high effective working mechanisms for the separation of the sugar beet leaves from the sugar beet root allowing to decrease the losses of the sugar containing part of the sugar beet root and increase the forward speed of the sugar beet topper. The process of the sugar beet topping is focused on the separation of sugar beet top from the sugar beet root. All this process is effected by the different properties of the sugar beet tops and sugar beet roots material. When analysing the current level of the development of technological process and used machines, it is possible to define the following ways of the sugar beet topping: cutting of the leaves with the sensing or without sensing with the additional cleaning of the root tops after the topping and separation of the leaves by using of the dynamic action with the help of the defoliators - rotors with the elastic working elements. All types of the sugar beet topping manners are based on the differences in the location of the sugar beet leaves and sugar beet roots in relation to the soil surface and their joint distribution. Separation of the sugar beet leaves residues after the cut by using of the dynamic action of the cleaning elements on the sugar beet root head is based on the different firmness of the sugar beet root head and leaves. Therefore, it is very important to study such properties of the sugar beet leaves and sugar beet heads, which allow to separate them.

Agro-physical characteristics of the sugar beet crop stands and mechanical-technological properties sugar beet roots and top leaves very studied by VASILENKO (1984); POGORELYJ L. AND TATJANKO (2004); BULGAKOV (2005); ZUEV (1971); VOVK (1936); KHELEMENDIK (1996); MARTINENKO (1997); TOPOROVSKIJ (1988); POGORELIJ M. (2001).

The height of the sugar beet root heads above the soil surface can be considered as a very significant indicator effecting the separation of the leaves from root head. It is the top of the head located above the soil surface which is used for orientation of the sensing mechanism of the sugar beet toppers. According to the distribution of the height values of the sugar beet root heads it is possible to determine the location of the sugar-containing matter in relation to the soil surface and subsequently to determine the height of the sensing-less topping. Based on the research results obtained by POGORELIJ L., TATJANKO (2004) AND TOPOROVSKIJ (1988) it can be stated that the distribution of the heads of sugar beet roots relative to the surface of the soil is described in most cases by the normal law, only in rare cases by lognormal law and Erlang law. The results of the study of morphological structures of roots of sugar beet are presented in scientific papers. POGORELIJ L., TATJANKO (2004); ZUEV (1971) in their research has obtained the values of size and weight characteristics of roots and leaves of the sugar beet. They had obtained also the correlation relations between the diameter of the sugar beet root and height of the root top over the soil surface. The research of the physical and mechanical properties of the sugar beet roots and leaves is presented in the scientific papers BULGAKOV (2005); POGORELIJ L., TATJANKO (2004) and there are evident the variability of the mechanical and technological characteristics, such as: bulk density, specific resistivity coefficient, specific cutting resistivity. MARTINENKO (1997) investigated the characteristics of tensile strength, compression strength and bending strength. It was found that the hardness of the sugar beet leaves and roots, in relation to the depth of penetration of the conical indenter, is different in 2 – 3 times. Anyway, there are not mentioned the zones where the hardness of the sugar beet leaves and roots were measured. The research provided by POGORELIJ M. (2001) had confirmed that the values of hardness of the heads of sugar beet root significantly vary in different points of measuring. The strength of the top the sugar beet root head is lower when compared with other zones. Investigation of the other physical properties, during the process of the leaves separation, and also study of the given process is presented in the scientific papers VISKHOM (1970); KHELEMENDIK (1996); CARENCO ET AL. (2000); ROLLER (2010); MERKES (2001), KOPF (2010). Based on the results obtained it can be stated, that due to the biological specifics of the plants, strength properties in different zones of the sugar beet root and leaves can significantly vary. It is important to provide additional comparative research: to analyze a mechanical structure of the sugar beet root heads and leaves, to compare the strength in different zones of the heads and leaves stalks. It is also very important to formulate conclusions regarding potential possibilities of the separation sugar beet tops by dynamic interactions.

Main aim of the research was to determine the optimal way of the mechanical action on the sugar beet leaves in order to increase the quality of its separation from the root crops.

MATERIALS AND METHODS

During our research our attention was focused on the structure, shape and strength of the different zones on the sugar beet root head and leaves with the aim to study the possibilities of the mechanical destruction of the leaves and their subsequent separation from the root head. The spatial structure of the leaves stalks was investigated by imposing on them cross-sections of the grid (Fig. 1) and the definition of geometric cross-section dimensions and its area. Combining on a certain distance all the sections there have been derived 3D model of a single stalk, which allowed to determine by calculation its mass-centering characteristic.

Studies of spatial distribution on the root head of the individual leaves stalks and the geometric shape of the head itself was carried out by the photos at different times of the growing season (Fig. 6). Impact resistance and stress resistance were determined by application of mechanical shock and stress (Fig. 5).

The experiment was based on laboratory device in order to determine the effect of the convexity of the head of root crops on the process of purification from the leaves residues. To do this, on a place of the root there was consolidated a cylindrical wooden model by setting the cylinder axis parallel to the axis of rotation of the rotor. With multiple camera there was filmed the action of the blade rubber on the model.

It was determined the hardness of the head of root crop in different areas of the placing of green leaves and hardness of the leaves stalks at the surface and in the inner part at different distances from the head. The hardness of the inner part was determined in a direction perpendicular to the cross-sectional plane.

Before hardness measurement of root crop head the stalks were removed a knife prior to disappearance of borders between their bases. Hardness characteristic in this case was considered as an amount of deformation of the spring hardness tester in millimetres at which the indenter penetration occurred into the body of the leaves or head of root. The spring rate was regulated by its previous compression. In order to compare the hardness of the leaves and head of root the pre-compression of the spring was the same in both cases.

RESULTS AND DISCUSSION

Stalks of the leaves significantly change the shape of their cross-section, depending on a distance from the top of the head of root (Fig. 1). Especially intensive there is changed shape in the distance of 0 – 20 mm from the surface of the head, it turns sharply from the vane segment to hexagon shape, one corner of which is directed into the apex section. The biologists use to call such cross-sectional shape of the stalk as a dissected. The cross section of the stalk in the form of a hexagon form further retained throughout a leaf lamina. This form of leaf stalk gives it the rigidity to maintain a massive leaf.

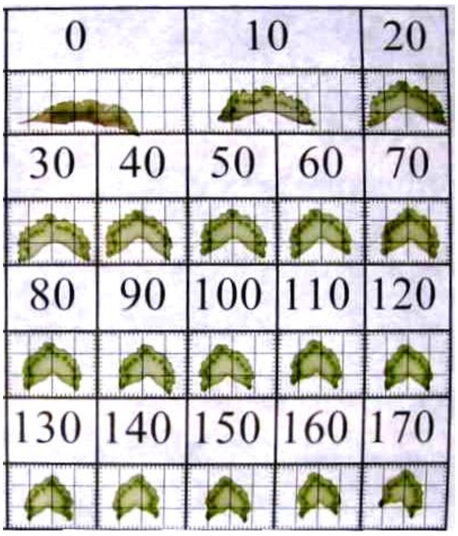

Fig. 1. – The shape of the cross section of the sugar beet leaf stalk

During research we have focused our attention to the area of the cross section of the different leaf stalks from the top part, centre part and down part of the root head (Fig. 2).

At the head of the root, the cross-sectional area of the external (outer) stalks is maximal. They do not set on other stalks. Biologically it leads to an increase of the sectional area and stiffness which is needed to hold the leaf blade. Sectional area of the base of the central rows is close to the outer cross-sectional area of the outer stalks. Much less is the area at the base of the internal (upper) stalks.

If the cross-sectional area of the stalks in the external and middle rows has the maximum value at the base and it is reducing to the direction of leaf blade, the section of the internal cuttings at a distance 0 – 20 mm from the ground is increasing and then decreases. According to the mechanical structure, the surface layer of the stalk is characterized by a large concentration of fibro-vascular tissues and it is strong enough (Fig. 3).

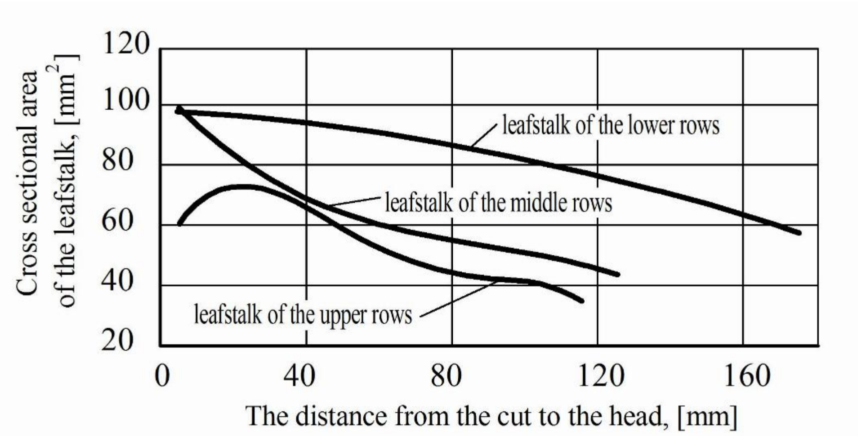

Fig. 2. – Effect of the distance from the root head cutting on the cross section area of the leaf stalk

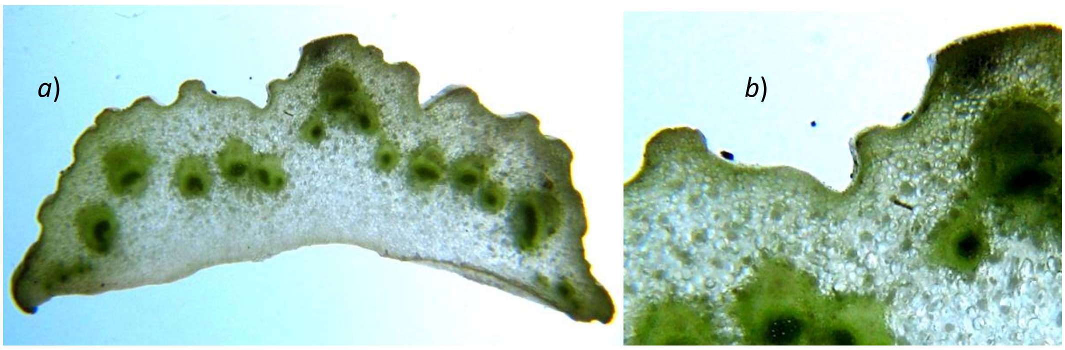

Fig. 3. – Cross-section of the leaf stalk and its mechanical structure

The inner layer is less durable, since the concentration of the mechanical tissues is much less. Thus, the stalk from the point of mechanical structure is anisotropic composite variable cross-section body, it can be characterized by different elastic modules in the longitudinal and transverse directions. At high turgor of the plant (the high osmotic pressure in the cells) significantly, it increases the stress state of the mechanical stiffness of the tissues and the strength of the stalk is necessary to keep the leaf blade. It is well-known that sheaf of sugar beet leaves has a form of cone, rosette and semi-rosette, Fig. 4.

Fig. 4. – The shape of the leaves sheaf at the base and typical stalks disruption

The form of the leaves on top of the root is largely dependent on a turgor, maturation period, fertilizing regime, and plants density on a field. Segment shape of the stalk at the surface of the head creates the preconditions for tight placement of stalks, creating a sufficiently dense and durable package that is difficult to completely destroy during a short-term effect of the cleaner of the heads of the sugar beet roots.

When removing from the head, due to the peculiarities of leaves shapes, the sprout becomes less dense and therefore easily destroyed. Under the influence of gravity force of the leaves the stalk is in the initial state of stress and due high turgor of the plant it becomes fragile and easily destroyed by minor efforts.

External stalks can be easily cracked almost at their base, and internal once at a distance of 10-20 mm from the head, due to the dense placing the stalks in the sprout (Fig. 4).

Often under the influence of the working body on the sprout tops, towards the centre of the root, it occurs quite effective shock damping by internal stalks. In this, outer stalks close to the base are destroyed, and subsequently, when approaching the centre of the sprout passes there occurs the combing only of the upper part (Fig. 5). Due to the conical structure of the root, with the approach to the centre, the length of the destruction and splitting of the stalks into the fibres, is reduced.

On the side of the root head, located opposite to the direction of rotation of the rotor shaft, stalks are not sufficiently destroyed, necessitating the use of two treatment counter-rotating shafts. Root crops with the small head height above ground or in which heads are placed below a soil surface are especially badly cleaned.

Fig. 5. **–** The view of the head of a sugar beet root with low extend from the soil after cleaning

The shape of the head of root varies during the growing season from spherically flattened at the beginning of the growing season to the spherical at the beginning of autumn and convex cone-shaped at the end of the growing season for the period of harvesting of the crops (Fig. 6). The development of this form of the head depends upon the biological characteristics of crop - the head of the sugar beet root can be considered as a modified stem.

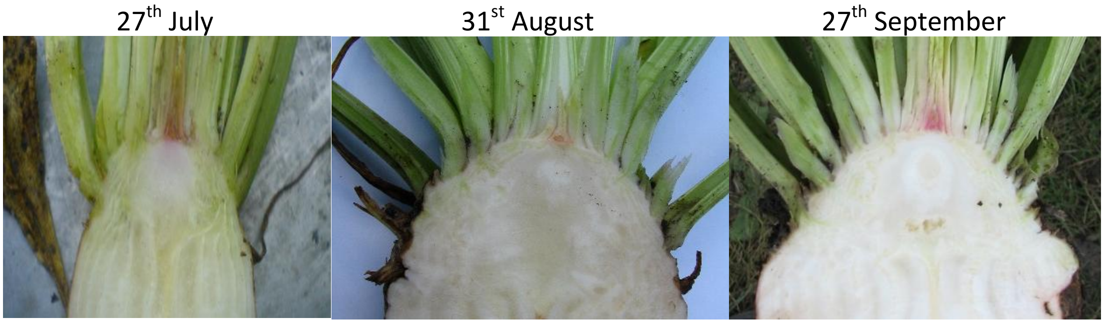

Fig. 6. – The shapes of the heads of sugar beet root during growing season (beginning, middle, end of the growing season)

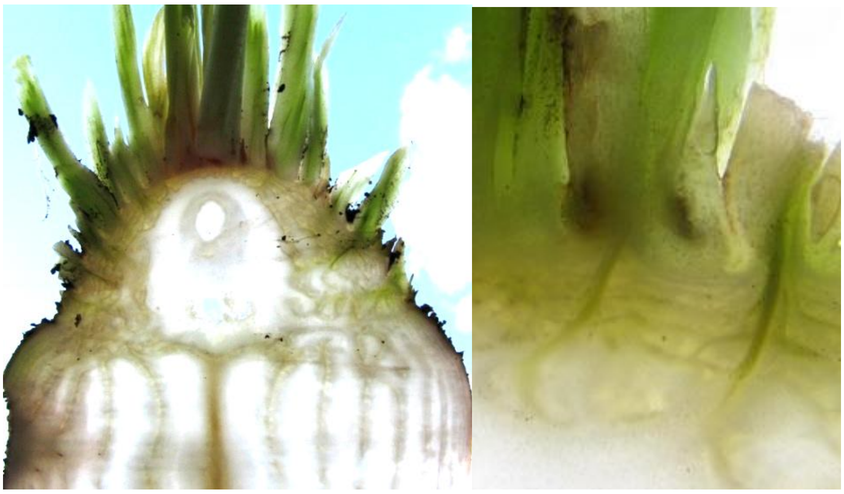

Fig. 7. – The morphological structure of the head of the sugar beet root

Individual heads may have a nearly spherical shape, flattened conical. However, their number in the total number of roots is small.

If we analyse the photo of the cross section of the head, it can be seen that the area of green leaves has a fibrous structure and relatively smoothly penetrates into the head (Fig. 7). Analyzing the morphological structure of the head, it is possible to conclude that perhaps there is a small difference in the strength of the stalks and heads in zone of their delineation. Due to the convex shape of the head of root the cleaning is very poor on the opposite side to the direction of rotation of the rotor cleaner.

On a trace of the action of the blade on the model it is clearly visible the spot on the part of the surface from the side of the rotation of the rotor. It is the evidence of the impossibility of the application of effective efforts to the head from the opposite side of the rotor rotation. In addition, this type of contact area indicates the absence of an effective working body sliding across the head and confirms that the normal load is applied to the head of sugar beet root.

The results of the determination of a hardness of the different zones of the head of the sugar beet root are shown on Fig. 8.

Hardness of the heads was measured both on the surface of the head in different zones, and in layers of these zones up to a depth of 15 mm. Maximum hardness of the head was measured in the area of green leaves in the layer at a depth of 5 – 10 mm, minimum hardness on top of the head in a layer of 0 – 5 mm.

Hardness zone of the sleeping cells was less than the hardness of the zone of green leaves, but the difference is negligible. The hardness of the top of head differs significantly from the other zones of hardness at a depth of 0 – 10 mm, and in a smaller extent – at a depth of 10 – 15 mm.

The hardness of the surface of the cuttings on the base is almost equal to the hardness of the top of head, and is 20 – 30% different from the hardness of the surface areas of green leaves and sleeping cells. However, at the depth 20 – 30 mm from the surface of the head, the hardness of the stalk surface is almost halved. With an increase of up to 30 – 40 mm distance from the surface, the hardness of the stalk head of root decreases and then increases. The hardness of the inner part of the stalks is significantly smaller than the hardness of all zones of the root head. During laboratory research of the process of separation of leaves residues it was observed a light separation of the sugar beet leaves at a distance of 20 – 30 mm from the surface of the sugar beet root. It is very difficult to separate, and sometimes not at all to separate the leaves at a distance of less than 10 mm. These quality indicators are easily explained by a slight difference in the hardness of leaves and root.

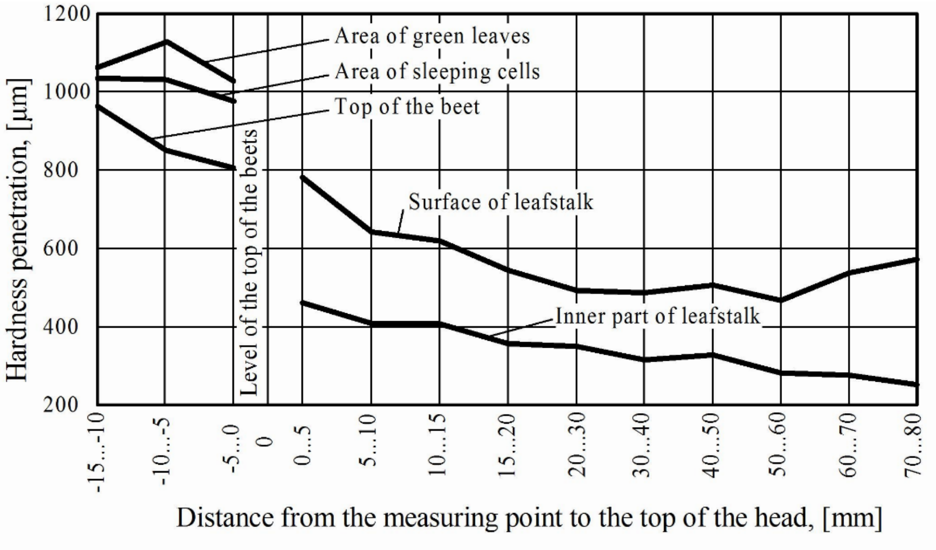

Fig. 8. – Hardness of the stalks and zones on the head of the sugar beet root

CONCLUSIONS

1. Results of the conducted research of physical-mechanical and agrophysical properties of the head and leaves of the sugar beet root allowed to receive their new properties which can be used for definition of an optimum way of mechanical impact on a sugar beet tops for improvement of its separation quality.

2. As a result of the conducted experimental research by determination of hardness of the leaves at the head of the root and hardness of the head in the areas of green leaves and sleeping cells, and also to the hardness of top of head of the sugar beet it is defined that head hardness on 30 - 40% are higher, than root crop hardness.

3. Repeated measurements confirm that the leafstalk considerably changes the form and the cross-sectional area depending on the distance to the head top. Thus in a zone of mechanical separation of leafstalks from a head of the sugar beet root during harvesting it has the greatest cross-sectional area and the most elongated form.

4. The results of multiple measurements cross-sectional area of the upper, middle and lower rows of the stalks allowed to find that the sugar beet stalk is anisotropic composite variable cross-sectional body. It can be characterized by different elastic modules in the longitudinal and transverse directions.

5. The typical form of the sheaf of sugar beet leaves was studied. The shape and morphological structure of the sugar beet head in different periods of vegetation were considered as well.

6. A number of repeated measurements of hardness of stalks and areas of root head enabled to define new dependences of their hardness on the location upon the head of sugar beet root. The received data indicate that the maximum hardness of the head appeared in the area of green leaves in the layer at 5 – 10 mm depth. Minimum hardness was on top of the head in a 0 – 5 mm layer. The hardness of the stalks surface at the base is almost equal to the hardness of the top of head, and is 20 – 30 % different comparing with the hardness of the surface areas of green leaves and sleeping cells.

7. Set of the received physical-mechanical and agrophysical properties of the head and leaves of the sugar beet root allowed to establish that the separation of the sugar beet leaves takes place most easily at a distance of 20 – 30 mm from the surface of the sugar beet root.

REFERENCES

1. BULGAKOV, V.M.: Theory of beet harvesting machinery (In Russian language), Kiev, Ukraine, Izdatelskij centr NAU 2005.
2. CARENKO, O.M. – JACUN, S.S. ET AL.: Mechanical and technological properties of agricultural materials: practicum (In Russian language), Kiev, Ukraine, Agrarnoe obrazovanie 2000.
3. KHELEMENDIK, N.M.: Increasing the mechanical-technological efficiency of labor-intensive processes in the sugar beet production (In Russian language) [Ph.D. thesis.], TPI, Ternopol, Ukraine, 1996, 48 p.
4. MARTINENKO, V.JA.: Machines for harvest the beet tops (In Russian language), Ternopol, Ukraine, Polygrafist 1997.
5. MERKES R.: 50 Jahre Prodaktionstechnik im Zuckerrübenbau in Deutchland. J. Zuckerrübe №4., 2001: 214–217.
6. POGORELIJ, M.L.: Increasing the technological efficiency of machines for harvest beets (In Russian language) [Ph.D. thesis.], NAU, Kiev, Ukraine, 2001, 21 p.
7. POGORELIJ, L.V. – TATJANKO N.V.: Machines for harvest beets: history, design theory, forecast (In Russian language), Kiev, Ukraine, Feniks 2004.
8. ROLLER O.: Entblatten statt Köpfen. J. Zuckerrüben № 2., 2010: 14–15.
9. TOPOROVSKIJ, S.A.: Substantiation process and basic parameters of the working body for cleaning the tops of sugar beet without copying heads of root crops (In Russian language) [Ph.D. thesis.], USKhA, Kiev, USSR, 1988, 19 p.
10. VASILENKO, P.M. – POGORELIJ L.V.: Basics of scientific research (Mechanization of agricultural production) (In Russian language), Kiev, USSR, Vysshaja shkola 1984.
11. VISKHOM.: Physical and mechanical properties of plants, soils and fertilizers: research methods, equipment, specifications (In Russian language), Moscow, USSR, Kolos 1970.
12. VOVK, P.F.: Agrophysical properties of sugar beet roots in connection with the mechanization of harvesting. In: Theory, design and manufacture of agricultural machinery: collection of scientific papers. Tome II (In Russian language). pp. 269-284. Moscow, USSR, Selkhozgiz 1936.
13. ZUEV, N.M.: Research of quality of sugar beet harvesters, depending on the agrophysical properties of sugar beet at different ways of forming of planting of plants (In Russian language) [Ph.D. thesis.], Kharkov, USSR, 1971, 33 p.

Corresponding author:
prof. Volodymyr Bulgakov, DrSc.,National University of Life and Environmental Sciences of Ukraine