IMPROVEMENT OF EQUIPMENT FOR BASIC TILLAGE AND SOWING AS INITIAL STAGE OF HARVEST FORECASTING

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ВДОСКОНАЛЕННЯ ТЕХНІКИ ДЛЯ ОСНОВНОГО ОБРОБІТКУ ҐРУНТУ ТА ПОСІВУ – ПОЧАТКОВИЙ ЕТАП ПРОГРАМУВАННЯ ВРОЖАЮ

Asst.Ph.D. Stud. Eng. Vasylkovska K.V., Lect.Ph.D.Eng. Leshchenko S.M.,
Lect.Ph.D.Eng. Vasylkovskyi O.M., Lect. Ph.D. Eng. Petrenko D.I.
Kirovohrad National Technical University / Ukraine;
Tel: +380667103625; E-mail: vasilkovskakv@ukr.net

Keywords: *harvest forecasting, chisel tillage, soil deformers, precision seeding, pneumatic and mechanical seeding*

ABSTRACT

The article presents the key tendencies of improving machines for subsoil basic tillage and sowing machines in order to implement resource-saving cultivation technologies and the basics of harvest forecasting. The suggested design of the combined chisel deep tiller with additional deformers and twin toothed rollers enable achieving better quality indicators of tillage while cultivating heavy soil. The new pneumatic and mechanical sowing device with peripheral layout of cells on the seeding disk and passive device for taking out excess seeds by centering method was developed. The new sowing device assures even distribution of seeds on the feeding area. The article presents key results of the research and recommendations for application of the suggested machines.

РЕЗЮМЕ

В статті наведені основні тенденції вдосконалення машин для безполицевого основного обробітку ґрунту та посівних машин з метою запровадження технологій ресурсозберігаючого землеробства і реалізації основ програмування врожаю. Запропонована конструкція комбінованого чизельного глибокорозпушувача із додатковими деформаторами та спареними зубчастими котками, використання якого дозволяє досягти покращених показників якості обробки під час роботи на важких ґрунтах. Для інтенсифікації посівних операцій розроблено новий пневмомеханічний висівний апарат з периферійним розташуванням комірок на висівному диску та пасивним пристроєм для видалення зайвого насіння відцентровим способом, що дозволяє забезпечити рівномірний розподіл насіння за площею живлення. В роботі представлені основні результати досліджень та рекомендації що до використання запропонованих машин.

INTRODUCTION

The basis of effective achievement of technologies of agricultural production is the forecasting of harvest which is based on the system of reclamation of productivity and soil protective technologies. Another important factor is the quality of seeds preparation, resource saving mechanization and production automation including effective plant protection from diseases, pests and weeds.

It is well-known that fertility is the ability of soil to feed plants with necessary quantity of nutrients, water, warmth and air (*Horunzhenko V.E., 1996*).Today we face constant lack of fertility which is the result of intensive cultivation, growing monocultures that exhaust soil and pollute the environment in Ukraine. Another important aspect is the decrease of organic stuff in the cultivated layer and systematic application of erosion-dangerous agricultural machines (*Horunzhenko V.E., 1996*). Therefore, the search for new technologies and ways of mechanization to preserve the fertility and decrease resource losses, preservation of the environment and growing ecologically safe products are the guarantee of rich harvests and welfare of the country.

Harvest forecasting is one of the important and prospective trends in production technologies particularly tilled crops that make possible to use material, labour and energy resources rationally to get maximum production with high quality (*Moroz N.V., 2011*). Today there are separate trends of harvest forecasting that help analyzing and assessing the quality of growing of tilled crops but the trends can only partially assist in the provision of quality and fertility of crop production (*Osadchij S.I., 2014*). Complete implementation of harvest forecasting technology into the real economic conditions is constrained by a

range of problems which have to be solved complexly. One of the key problems is the choice of the tools for soil cultivation that provide the realization of the technologies of soil protection and resource saving agriculture including precision seeding as even distribution of seeds on the feeding area guarantees good harvest in future.

In order to implement the basics of harvest forecasting it is important to go through certain stages. The first step towards harvest forecasting is to choose moistness conservative, soil protective and energy saving cultivation. The second step is to prepare seeds for sowing and the third step is to assure equal distribution of seeds on the feeding area while sowing (*Vasylkovska K., 2013*; *Vasylkovska K.V., 2013; Vasylkovska K.V., 2014*).

To improve seed germination the qualitative cultivation should be done which helps to keep moistness due to destruction of soil and stimulating effective development of the plant root system because of the qualitative soil loosening of the cultivated layer.

Saving and restoring soil fertility is necessarily accompanied by a deep loosening of soil which minimizes the number of further tillage operations and provides conditions for humus accumulation (*Leshchenko S., 2014*). It should be noted that the application of traditional tools for basic tillage does not allow intensifying all factors that ensure effective increase and reproduction of fertility. Certain types of mechanical cultivation such as traditional mouldboard and disk ploughing, cultivation and rototilling can lead to intense biological destruction and compaction of soil, and it loses its structure. Taking into account the necessity of basic tillage in the conditions of high moistness as well as in dry conditions especially in the areas with possible erosions, the traditional methods of basic tillage cannot be used and the effective alternative method is subsoil tillage in the form of deep loosening (*Vetokhin V.I., 2008*; *Leshchenko S.M., 2013; Salo V.M., 2014*).

It is known that sowing should be done in certain agricultural periods. They influence the conditions of plant sprouting (even sprouting) and its further development. It is also connected with moistness and temperature of the upper soil layer. If the agricultural period of sowing is assured then there will be better sprouting.

Even sowing and even distribution of seeds assure not only good germination but also good harvest in future. Moreover, while increasing the evenness of seeds distribution on the feeding area we decrease the amount of weeds in the field.

Therefore, the issue of improvement of technical appliances for basic tillage and sowing can become the initial stage in harvest forecasting and practical solving of this task will enable increasing the competitiveness of crop products and implement the basics for soil protective and energy saving cultivation.

MATERIAL AND METHOD

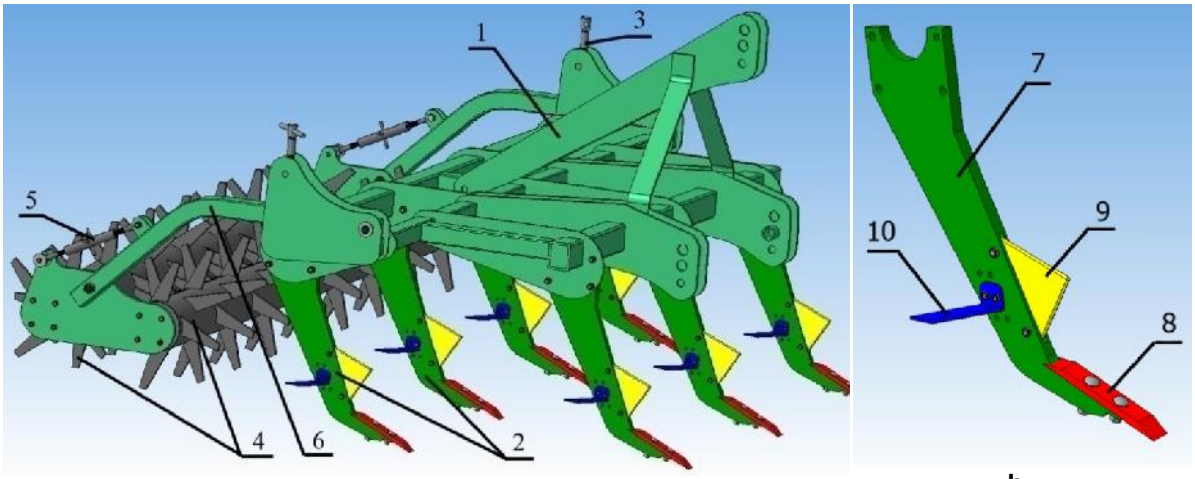
The basis of minimal soil cultivation is a subsurface deep loosening which can be done with the help of chisel deep tiller *(Leshchenko S., 2014; Vetokhin V.I., 2008; Leshchenko S.M., 2013)*. Chiseling allows increasing the tilling width of the machine compared to ploughing and to decrease fuel losses for basic tillage (40-50%), destruct compacted subsoil layer. But there are some disadvantages in this operation including incomplete cutting of weeds, impossibility to achieve solid furrow sole after tillage, low level of incorporation of residues into the soil, weed seeds and fertilizers, creation of big clods on the surface of the field.

Chisel deep tillers produced in Ukraine and in the former Soviet countries are not much different from their foreign analogues but the quality of working elements and the material used for their production shorten the terms of exploitation. Taking into consideration scientific research in the sphere of technologies of subsoil tillage the Department of Kirovohrad National Technical University under the supervision of Professor Vasyl Salo designed the construction of the universal combined chisel adapted to the real soil and climatic conditions of Ukraine (Fig.1a).

The main working elements of the designed machine are chisel plough which consists of stem 7, spike 8, tooth for breaking clods 9 and the wings 10 (Fig. 1b). The additional working element is a twin toothed roller 4 (Fig.1a) which has the mode of tillage depth regulation as well as it breaks big clods, incorporates and mixes plant residues into lower layers at the depth of 15-20 cm. Depending on working conditions of the twin toothed roller, it is possible to adjust the chisel tilling depth and the intensity of mixing and crushing of residues after tillage.

While loosening of soil with chisel plough the spike 8 cuts solid soil, tooth 9 crushes clods intensively and takes them away from stem 7 and the wings 10 cut weeds and additionally crush the soil and depending on their adjustment can even the furrow bottom.

In its turn, the precision seeding is provided with dispensing element of the seed drills. Since the beginning of the twentieth century there have been made searches for constructions implying single-grain sowing. One of the first pneumatic and mechanical sowing machines was a seed drill with drum-digital dispenser designed in the USA in 1904 *(Patent US of America №773205, 1904)*. By their design, the pneumatic and mechanical appliances may be of disk or drum type, and by the way of their application they are divided into vacuum and extreme pressure devices.



a **b**

Fig. 1 – Combined chisel deep tiller

a – general view of deep tiller ; b – 3D model of chisel plough
1 – frame; 2 – chisel plough; 3 – screw mechanism of adjustment of tillage depth; 4 – toothed rollers;
5 – screw mechanism of roller adjustment; 6 – roller frame; 7 – stem; 8 – spike; 9 – tooth; 10 – wing

Sowing machines that are used in mass production have insufficient dispensing capacity caused by limited seed disk rotary velocity and random uncontrolled redistribution of spacing between seeds in the furrow because of the high relative velocity of the seeds *(Horunzhenko V.E., 1996; Sysolin P.V., 2001; Vasylkovska K,. 2013)*. To increase the efficiency of seeding precision of cultivated crops the Department of Agricultural Engineering of Kirovohrad National Technical University designed and manufactured a prototype of the new pneumatic and mechanical disk for sowing device *(Vasylkovska K., 2013; Vasylkovska K.V., 2013; Vasylkovska K.V., 2014)* (Fig. 2).

The main feature of the new sowing device is the application of sowing disk 1 with peripheral layout of cells 2. Behind the cells there are blades 3 on the inner surface of the disk for enforced seizure of seeds by the disk 9 in the chamber and their further transportation to the release spot.

To remove excess seeds from the cells of seeding disk 1 at the top of the cylindrical surface of the body there is a passive cavity-shaped device 7, that gets excess seeds and separate them from the disk transporting the seeds back to the filling zone. In the lower part of the housing surface there is seeding hole 6 which provides free release of the seeds to the furrow.

The design of the pneumatic and mechanical disk sowing device due to the enforced seizure of seeds by blades 3 ensures the reliability of the process of filling the cells of the sowing disk and increases the efficiency of removal of excess of seeds with the help of passive device 7. It makes reliable the process of releasing seeds from the cells in the sowing area. This ensures an even distribution of seeds in the furrow through the stabilization of the dispensing process and releasing seeds from the sowing disk.

In order to confirm the hypothesis about the necessity of harvest forecasting we conducted testing of implementation of new highly efficient working elements for tilling and sowing machines in the system of resource-saving technologies of cultivation of agricultural crops.

Tests of combined chisel -deep tillers were conducted during 2013-2015 in the fields of Kirovohrad region. The conditions of testing corresponded to the average conditions in the region: mechanical soil texture was heavy and with medium loam; soil hardness was 20...35 kg/cm^2 at the depth of 0-10 cm, 35...65 kg/cm^2 at the depth of 10-20 cm, and 60...100 kg/cm^2 at 20-30 cm. Permissible humidity was

limited to soil sticking to the chassis system of the tractor and working elements of the chisel. Technical characteristics of combined chisel deep tillers (Table 1) makes possible to assess their competitiveness in comparison with the best foreign analogues.

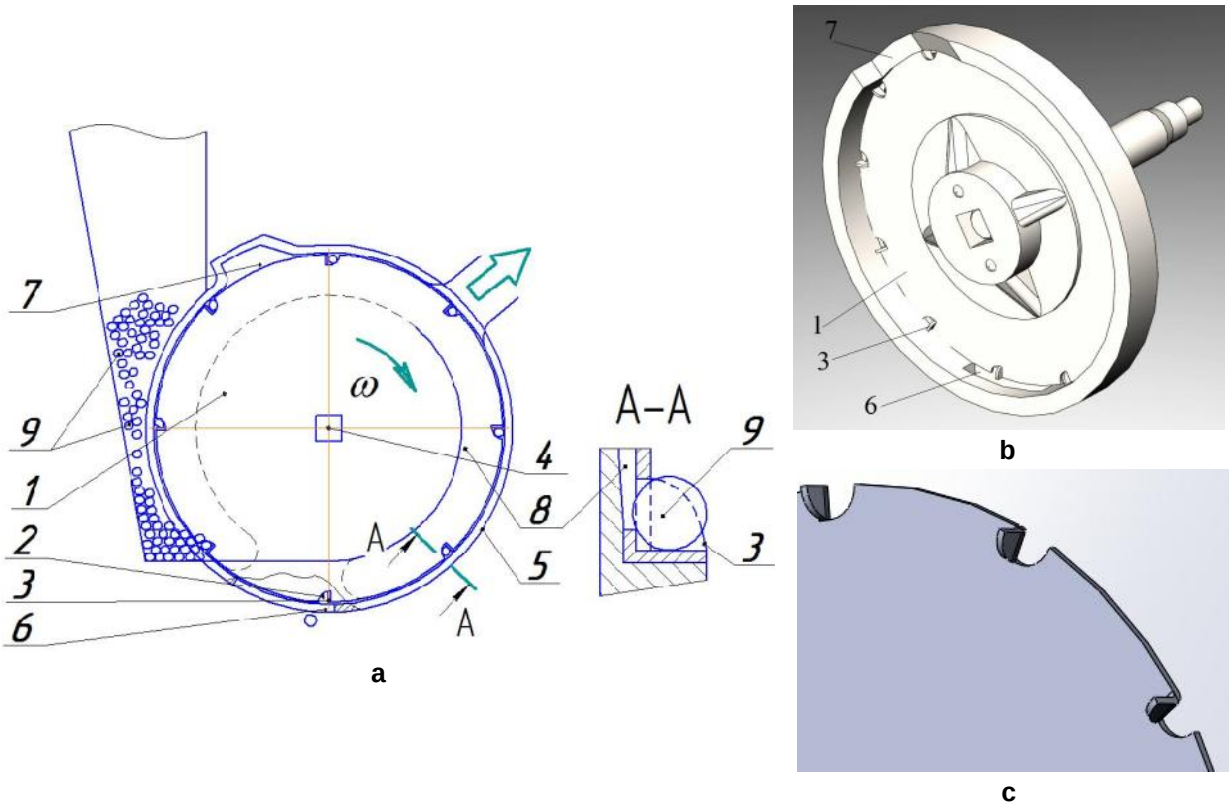


Fig. 2 – Pneumatic and mechanical sowing device
a – scheme; b – 3D model of the sowing device; c – 3D model of the fragment of sowing disk

1 – sowing disk; 2 – cell; 3 – blade; 4 – drive shaft; 5 – housing; 6 – seeding hole; 7 – passive device (container) for removing excess seeds; 8 – vacuum chamber; 9 – seeds

Table 1

Characteristics of combined chisel deep tillers

Machine-Type	CN-1,5	CN-2,5	CN-3,5	CN-4,5
Productivity, ha/hour	1.2	2.0	2.8	3.6
Working width, m	1.5	2.5	3.5	4.5
Tillage depth, cm	50	50	50	50
Number of working elements, pieces	3	5	7	9
Depth of roller tilling, cm	15	15	15	15
Necessary tractor power, HP	80 - 120	120-180	160-220	250-340
Weight, kg	750	1200	1700	2300

After deep loosening we made performance assessment by the coefficient of soil crushing and evenness of depth tilling. We considered structural elements of soil to be appropriate if they did not exceed the size of 50 mm. Also we conducted the assessment of the impact of speed rate on quality performance. The experiments were repeated five times and the results have average values.

The results of experimental studies to determine the quality indicator of loosening were evaluated at the depth of tilling *h*=32-40 cm. The height of the ridge that is formed between adjacent passages of chisel ploughs on the bottom of the furrow was *h1*=18-20 cm. The maximum speed of the machine was limited by critically possible speed at maximum transmission in specific soil and climatic conditions based on providing the necessary traction which is developed by tractor suspension system without tractor drive wheels slip. The analysis of the results (Fig. 3) shows that the lowest quality of soil crushing is achieved by chisel working without rollers and this figure ranges from 49% to 60%, and the increase of working speed improves quality indicator. Similar result is observed when chisel is used with one roller (operation with

one roller is achieved by changing position of the adjusting screw 5 (Fig. 1)), but the quality indicators of the unit are much higher *k*=55-69%.

Field tests of experimental prototype of pneumatic and mechanical sowing device mounted on the serial seed drill section УПС-12 connected to the tractor MTZ-82 were conducted in fields of agro-industrial Group "Favorit" Ltd (Pidhaitsi of Kirovohrad district, Kirovohrad region) (*Vasylkovska K., 2015; Vasylkovska K., 2015*).

Sowing seeds of sugar beet variety «Yaltushkivskyy ЧС-72» was held on 2 ploughing beds with the area of 0.86 hectares each after ploughing and pre-seeding tillage. The speed of the tractor was 4.26 km/h on the first ploughing bed, and 7.24 km/h on the second bed. Sowing rate of seeds was 10.65 pc./line m. Checking the quality of sugar beet seeding was held on 10 scoring areas with the total length of 40 m.

Sowing seeds of maize variety «Orzhytsa 237 MB» was held on the ploughing bed with area of 0.43 hectares. Sowing rate of seeds was 7 pcs/line m. Sowing seeds of soybean variety «Jubilee» was held on the ploughing area of 0.43 hectares. Sowing rate of seeds was 10 pcs/line m.

Quality control of corn and soybeans sowing was held on 5 scoring areas with the total length of 20 m.

Quality of seeding was estimated by the coefficient of variation [3] of distribution of seeds along the length of the row which shows standard deviation to the arithmetic mean of the plurality and variability is considered to be small if the coefficient of variation is not higher than 10%, the average variability is more than 10% but less than 20%, and significant variability is with the coefficient of variation of 20% (*Voytyuk P., 2005*).

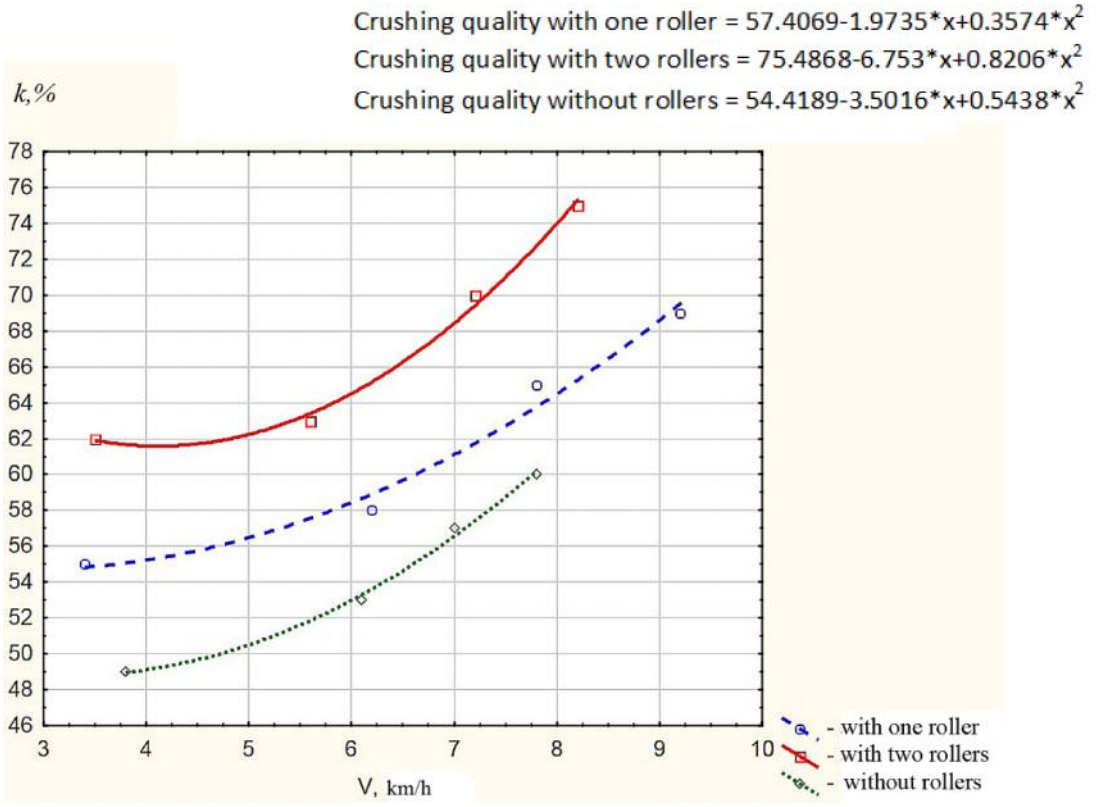


Fig. 3 – Correlation of the quality of soil crushing *k* on the chisel working speed *V* in different modes of operation of the twin toothed roller

RESULTS

After analyzing the results of experimental studies of combined chisel unit which operates in the conditions of heavy and medium loam it is possible to state that the most efficient soil tillage is achieved during chiselling with two rollers at the speed of 7-8 km/h. Quality indicator of crushing soil in these conditions is 70-75% which is higher than the corresponding figures of some foreign machines (for example, under heavy black soil conditions for Artiglio S 250-500 «Gaspardo» *k*=55-60%, Cenius 400/18 «AMAZONE» *k*=58-65% (*Leschenko S., 2014; Leshchenko S., 2015*).

Quality assessment of sowing sugar beets showed the following results (Fig. 4):

- the first ploughing bed showed that coefficient of variation of distribution of sugar beet seeds along the length of the row was 10.3% for the prototype and 14.6% for the serial;

- the second ploughing bed showed that coefficient of variation of distribution of sugar beet seeds along the length of the row was 9.8% for the prototype and 18.4% for the serial.

Quality assessment of sowing maize and soy seeds showed the following results (Fig. 4):

- coefficient of variation of distribution of maize seeds along the length of the row was 11.2% for the prototype and 14.4% for the serial;

- coefficient of variation of distribution of soy seeds along the length of the row was 9.8% for the prototype and 15.9% for the serial.

The results of testing of sowing device of the suggested design showed that the coefficient of variation of distribution of seeds in the furrow in all cases has little variation (compared with serial type). This fact confirms the hypothesis of stabilization of seeding parameters.

CONCLUSIONS

In summary, we can state that deep loosening by chisel deep tiller is an alternative to the traditional tillage which improves water and air condition of soil, reduces biological destruction of useful soil components, ensures the destruction of compacted subsoil and reduces energy costs for conducting basic cultivation. The design of the universal combined chisel significantly expands the possibilities of its use in various operations of deep loosening with additional possibility to crush clods and incorporate crop residues to a certain depth by the twin roller as well as the traditional chiselling and soil slotting. It was established that the combined chisel of the proposed construction with two toothed rollers has quality index of crushing soil k=68-75% at the speed of the machine V=7-8 km/h.

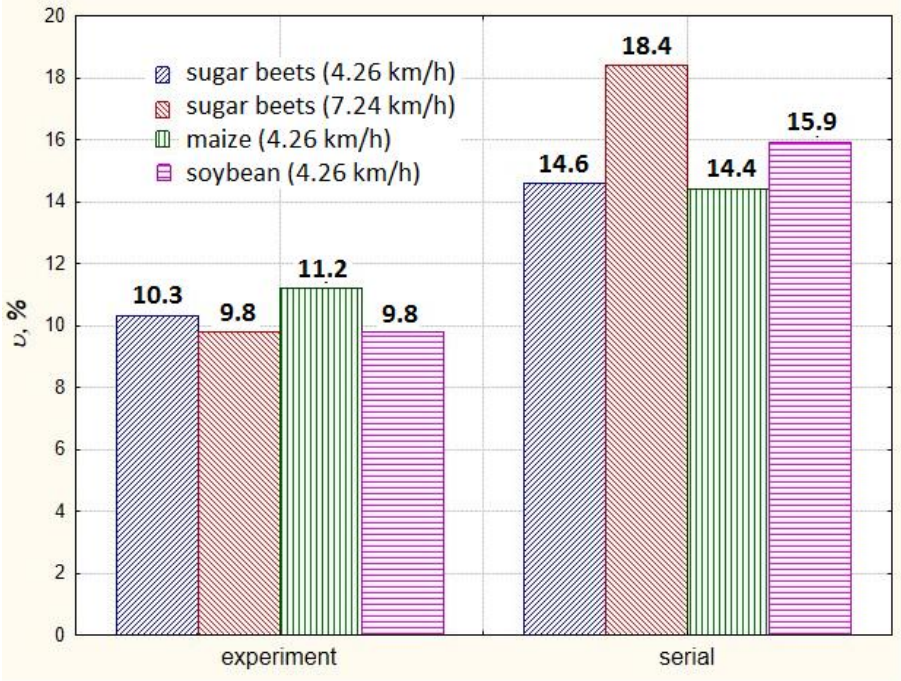


Fig. 4 – Variation of distribution of seeds of the studied cultivated crops in the row for the prototype and serial sowing units

The experimental studies of the pneumatic and mechanical seed drill for precision seeding with new pneumatic seeding device with peripheral layout of cells on the seeding disk and passive device for removing excess seeds by centrifugal method proved a more even distribution of seeds in a row. The application of new pneumatic and mechanical sowing machine allows reducing seed costs while maintaining high quality seed distribution in the line, thus even seed distribution on the feeding area. The coefficient of variation of distribution of sugar beet seeds in the furrow ^{3}=9.8...11.2 at minor variation is possible with the following parameters: dilution in the vacuum chamber aP - from 0.2 to 0.3 kPa (*Vasylkovska K.V., 2016*), the rotary velocity of cells of the seeding disk $V_к$ from 2.0 to 2.5 m/s, and the speed of the sowing unit V_c 1.0 to 2.0 m/s.

Therefore, consistent implementation of the designed devices in the processes of growing crops will practically enable achieving certain basic techniques of harvest forecasting in the system of soil protective and resource saving agriculture.

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