UDC 004.925.8

THE EFFECT OF BEET SEEDER DESIGN ON THE ACCURACY OF SEED PLACEMENT ALONG THE ROW

Mykola Volokha,[1] doctor of Technical Sciences
vol54@i.ua, ORCID: 0000-0002-0112-7324
Saveliy Kukharets,[2] doctor of Technical Sciences
info@vdu.lt, ORCID: 0000-0002-5129-8746
Sergiy Zalevskiy[1], candidate of Technical Sciences
zalsergkpi@gmail.com, ORCID:0000-0002-7411-1462
Margarita Lazarchuk,[1] graduate studen
mlazarchuk@ukr.net, ORCID: 0000-0001-6192-6825
Mykhailo Luka,[1] student ISZZI
luka07.xxx@gmail.com
[1] National Technical University of Ukraine
"Igor Sikorsky Kyiv Polytechnic Institute" (Ukraine, Kyiv)
[2] Vytautas Magnus University (Lithuania, Kaunas)

Abstract. *The precision of seed placement along the row, as well as the depth of seed placement in the soil, are important agronomic parameters that vary depending on the biology of the crop and the specific soil and microclimatic conditions prevailing in the field. Clearly, uniform seed distribution in the furrow optimizes the root zone of each plant and increases yield by reducing competition between neighboring plants. At the same time, there is currently insufficient information on how the design of the seeder's seeding mechanism affects the size and uniformity of seed spacing along the row.*

In this article, we present the results of comparative field trials of the "Multicorn" (Germany), SU-12 "Orizon," UPS-12 (Ukraine), and the mechanical SST-12V (Elvorti plant) to determine the effect of seeding rate and seeder operating speed on the coefficient of variation in seed placement.

Keywords*: seeding mechanism, operating speed, seeding rate, uniformity, coefficient of variation, response surface, two-dimensional cross-section*

Statement of the problem. The main criteria for sugar beet (SB) yield during the pre-sowing soil preparation stage are the creation of favorable conditions to ensure maximum field germination of the seeds, and during the sowing stage - the precision of seed placement along the row and the depth at which they are planted in the soil.

Ensuring uniform seed placement is a key indicator for evaluating a seeder's performance, as it directly affects yield and intra-species competition. Precise, uniform seed placement not only maximizes the space available to each individual plant but also inhibits weed growth by preventing gaps from forming. It is precisely to meet these requirements that seeders designed for wheat or corn were developed [1].

Modern mechanized technologies for growing sugar beets involve sowing seeds at the target density to achieve 5.5–6.0 evenly spaced seedlings per linear meter. In this context, it is crucial to correctly determine the seeding rate, taking into account factors such as seed quality (laboratory germination rate, uniformity, and germination energy must be at least 95%), the presence of pests and diseases, the level of weed infestation in the field, and others. Under such limiting conditions, when seedlings emerge, the coefficient of variation of the intervals between them along the row (Vcx), as a measure of their uniformity, will obviously be lower relative to the coefficient of variation of the placement of sown seeds (Vн) [2].

Various systems for monitoring sowing parameters are known; however, in our view, one of the most important is the assessment based on the variation in the distance between seeds. In particular, E. Aliiev and P. Bezverkhniy, through field experiments and numerical modeling of the pea seeding process using a John Deere 90 Series precision air seeder, established that a smaller seed spacing value (< 0.029 m) explains the occurrence of "doubles," while a larger value (> 0.059 m) explains the occurrence of "gaps" [3].

Analysis of recent research. While in the early 2000s, a test bench with adhesive tape was used to determine the distance between seeds - a method that minimizes factors such as seed bounce and rolling by applying lubricant to the tape [4] - today, in the context of monitoring the uniformity of this parameter, modern sensor technologies have emerged, encompassing optical, electromagnetic, and piezoelectric systems based on computer vision [5]. The well-known method of manually digging up sown seeds although labor-intensive, ensures the reliability of the data obtained.

The aim of the study. Determine the actual spacing between sugar beet seeds sown using the field excavation method, and evaluate the effect of the operating speed of different types of seeders and the seeding rate on seed distribution uniformity.

The main part. Comparative field studies were conducted at the L. Pogorily Ukrainian Research Institute. The following main results were obtained.

<u>Regression models of seedling distribution uniformity</u>

Both imported pneumatic seeders (such as the German "Multicorn") and domestically produced models (such as the SU-12, manufactured by the "Orizon" plant in Smila, Cherkasy Oblast), ensure more uniform seedling placement along the row than the best domestic seeder, the SST-12V, with mechanical seeding units [2].

The advantages of pneumatic seeders are more pronounced when sowing coated seeds (Fig. 1a) and are also evident when sowing encrusted seeds (Fig. 1b). The coefficient of variation in seed placement in the soil, averaged over several years, after the passage of pneumatic seeders when sowing coated seeds at a rate of 8-10 seeds/m is 49.1%, and for the SST-12V seeder - 69.2%; when sowing with coated seeds, the figures are 56.7% and 81.4%, respectively.

As the seeder's speed and seeding rate increase, the uniformity of seed placement in the soil along the length of the row deteriorates, and the relationshipsbetween the coefficient of variation in seedling emergence are as follows:

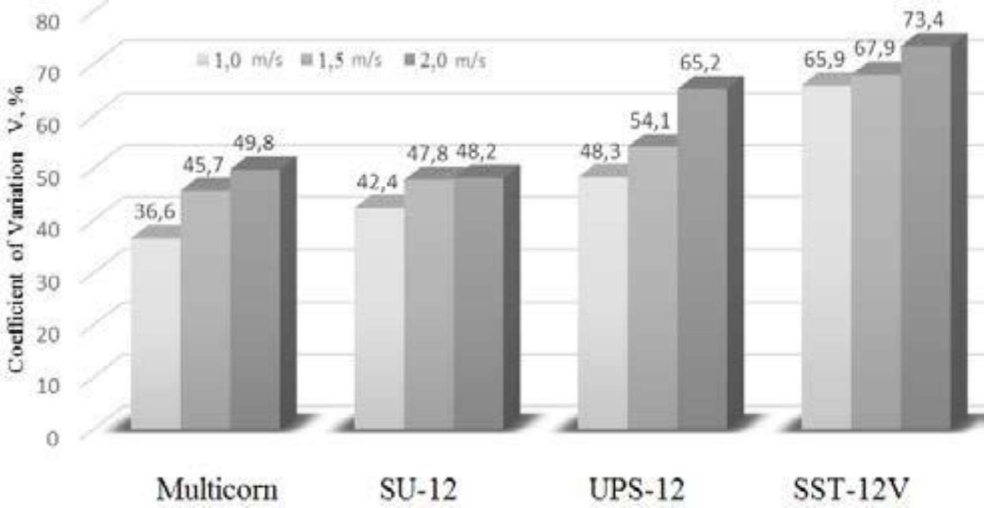
$$V_{cx} = a + a_1 Y + a_2\, YN + a_3/Y,$$

or: $V_{cx} = 41{,}82Y + 0{,}89YN + 63{,}87/Y - 92{,}5$, % (coated, 3.5 - 4.5 mm granules);

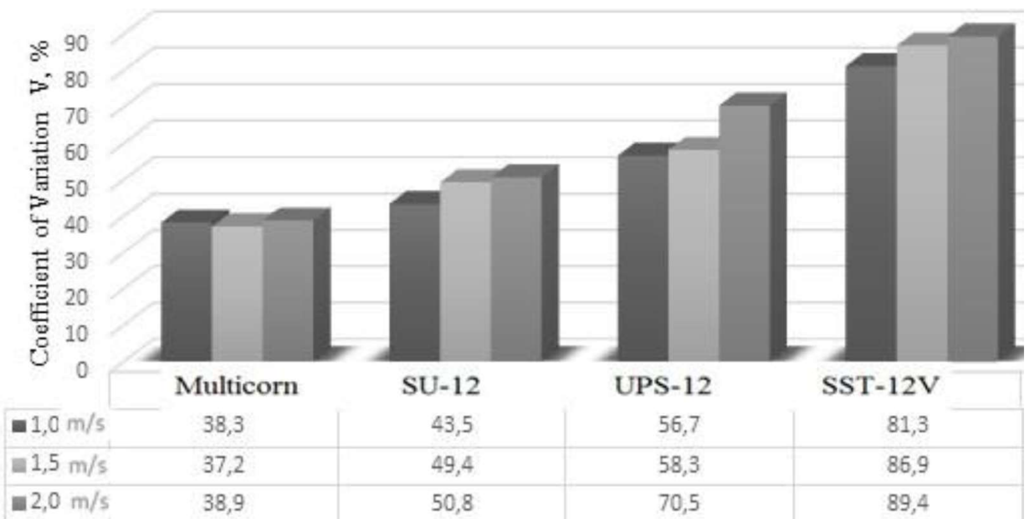
$V_{cx} = 41{,}69Y + 0{,}90YN + 63{,}45/Y - 94{,}1$, % (coated, 4,5–5,5 mm);

$V_{cx} = 41{,}20Y + 0{,}91YN + 63{,}02/Y - 87{,}2$, % (inlaid, 3,5–4,5 mm);

$V_{cx} = 41{,}30Y + 0{,}90YN + 63{,}04/Y - 88{,}3$, % (inlaid, 4,5–5,5 mm).



a)



b)

Figure 1. Effect of seeder speed on the coefficient of variation in seedling distribution at a seeding rate of 8–10 seeds/m for coated (a) and encrusted (b) seeds of the 4.5–5.5 mm fraction

Model field research

Studies of the uniformity of spacing between sown seeds (as measured by the coefficient of variation) were conducted in model field experiments of the type 2^3, where 3 is the number of key operational and technological factors: x_1 – the speed of the seeding unit (Y, m/s); x_2 – seed rate (N, seeds/m); x_3 – average spacing between seeds (S, cm).

The calculation of the regression coefficients resulted in a second-order mathematical model:

$$y = 0{,}0164 + 0{,}283x_1 - 0{,}324x_2 - 0{,}0876x_3 - 0{,}1946x_1x_2 - 0{,}4125x_1x_3 + 0{,}1648x_2x_3 + 0{,}3061x_1^2 - 0{,}0845x_2^2 + 0{,}0624x_3^2$$

The model's adequacy was tested using Fisher's criterion at a significance level of a=0,05 при ступенях свободи v1=18-3=16; v2=3-1=3. $F_{table.}(16;3)=8.66$:

($F_1 \le F_{табл.}$), y not multicollinear with the others.

($F_2 \le F_{табл.}$), x_1 not multicollinear with the others.

($F_3 \le F_{табл.}$), x_2 not multicollinear with the others.

($F_4 \le F_{табл.}$), x_3 not multicollinear with the others.

Since the calculated Fisher's criterion is less than $F_{table.}$, then the resulting mathematical model can be considered adequate.

<u>Visualization of research results</u>

To use this model as a calculation formula, it has been decoded:

$$\hat{y} = 0,0055 + 0,566Y - 0,162N + 0,0195S - 0,1946YN + 0,1833YS -$$
$$0,0183NS + 1,2244Y^2 - 0,0211N^2 + 0,003S^2$$

To construct a two-dimensional cross-section of the response surface that characterizes the coefficient of variation as a function of x_2 , x_3 , the values were substituted into the model equation $x_1 = 0$, after obtaining the equation in canonical form:

$$\hat{y} = 0,055 - 0,162x_2 + 0,0195x_3 - 0,0183x_2x_3 + 0,0211x_2^2 + 0,0013x_3^2$$

$$\begin{cases} \dfrac{\partial \hat{y}}{\partial x_2} = -0,162 - 0,0183x_3 + 0,0422x_2 = 0 \\ \dfrac{\partial \hat{y}}{\partial x_3} = 0,0195 - 0,0183x_2 + 0,0026x_3 = 0 \end{cases};$$

$$x_2 = 3,4554,\ x_3 = 16,8206$$

$$Y_s = 0,055 - 0,5598 + 0,328 - 1,0636 + 0,2519 + 0,3678 = -0,6207.$$

$$Y + 0,6207 = 3,4554X_2^2 + 16,8206X_3^2$$

The rotation angle of the new coordinate axes at the center of the response surface for this case:

$$\text{ctg}2\alpha = \frac{0,0211 - 0,0013}{-0,0183} = -1,0819; \alpha = 68°$$

Using the canonical equation and the Maple 11 software, a response surface with a two-dimensional cross-section was plotted (Fig. 2*a*).

Similarly, the equation in canonical form is obtained

$$Y + 0,0386 = -0,099X_1^2 - 0,2237X_3^2$$

$$Y + 0,2665 = 0,1167X_1^2 + 4,3769X_2^2$$

and the charts shown in Fig. 2(*b*) and 2(*c*) have been performed.

The plot illustrating the combined effect of the interaction between factors x_1 and x_2 in the region of the extremum (seeding unit operating speed Y = 1.2 - 1.4 m/s, seed rate N = 7 - 8 p/m) shows an extreme value of the coefficient of variation at a speed of 1.35

m/s and a seed rate of 7.4 p/m (Fig. 2, *c*).

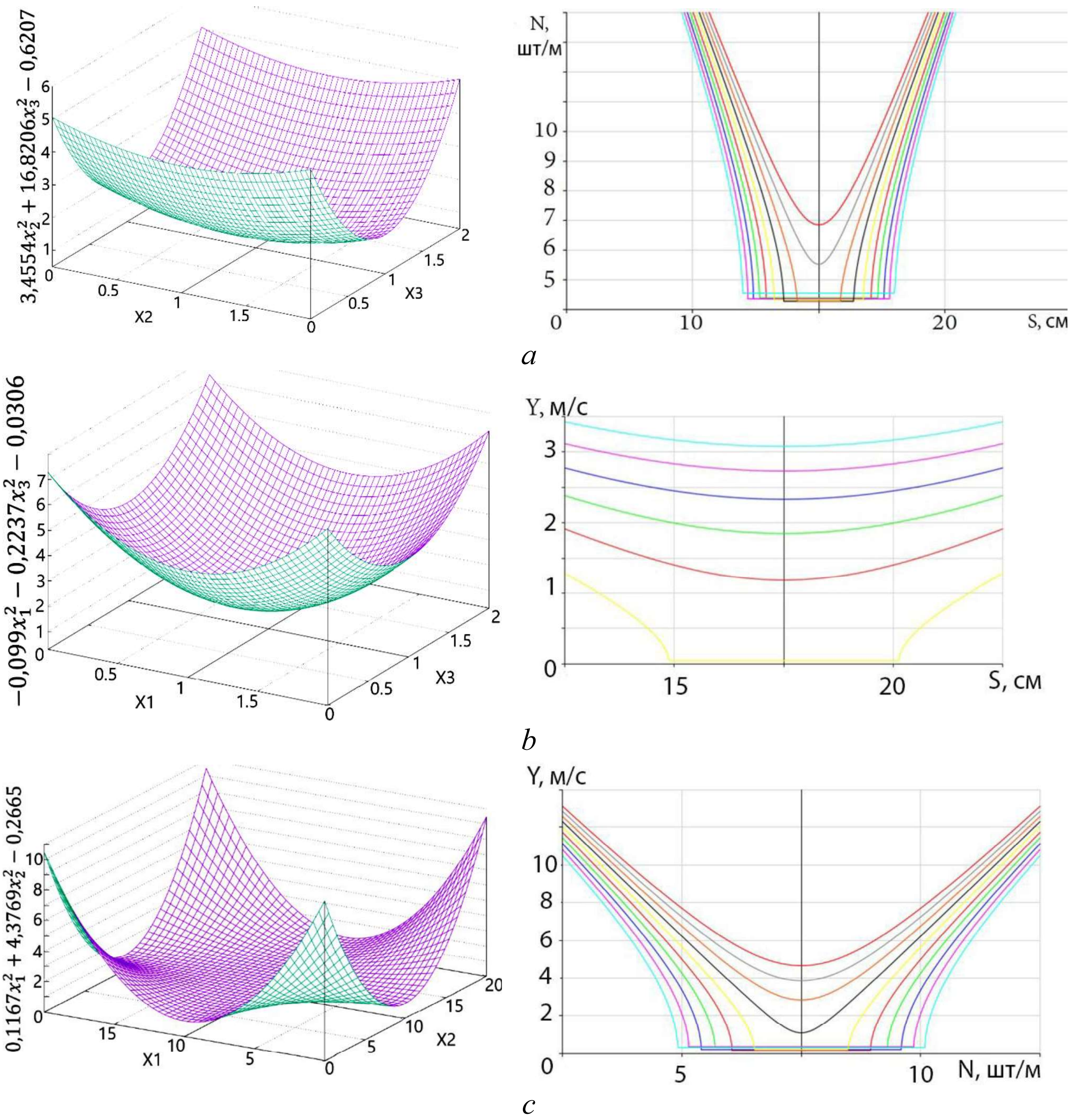


Figure 2. Response surface plots (left) and two-dimensional cross-sections (right) illustrating the coefficient of variation in seed placement for when $x_1 = 0$ (*a*), $x_2 = 0$ (*b*), $x_3 = 0$ (*c*)

Conclusions. It was demonstrated that pneumatic seeders, both foreign and domestic, ensure greater uniformity of seed placement along the row than the best domestic seeder, the SST-12V, equipped with mechanical seeding units.

It has been proven that the coefficient of variation in seed sowing is jointly influenced by the seeder's working speed *Y* and the seeding rate *N*, which in the region of the extremum are equal to 1.35 m/s and 7.4 p/m, respectively.

References

1. Davut Karayel, Eglė Jotautienė, Egidijus Šarauskis, Sebastián Rossi, Ignacio Rubio Scola, Gastón Bourges. (2024). Evaluation of monitoring systems for seeder seed spacing uniformity. Journal of International Scientific Publications: Agriculture & Food 12, 105-116. https://doi.org/10.62991/AF1996556881.
2. Volokha, M. (2018). Research of indexes of placement of seedlings of sugar beet for sowing seeds by mechanical and pneumatic seeders. Machinery & Energetics, 9(3), 153-158. https://doi.org/10.31548/me2018.03.153.
3. Aliiev E., Bezverkhniy P. Є. (2023). Study of the factors of the deterioration of sowing accuracy with pneumatic seeders. Tekhnika, enerhetyka, transport APC, 2 (121), 4-15. https://doi.org/10.37128/2520-6168-2023-2-6. [in Ukrainian].
4. Karayel, D. & Özmerzi, A. (2000). Düşey plakalı hava emişli bir hassas ekim makinasının bazı sebze tohumları için laboratuvar ve tarla koşullarında sıra üzeri tohum dağılım değerlerinin karşılaştırılması. Agricultural Mechanisation National Congress, 1-2 June 2000, Erzurum, Turkey, 153-159.
5. Pradhan, NC, Sahoo, PK, Kushwaha, DK, Mani, I, Srivastava, A, Sagar, A, Kumari, N, Sarkar, SK & Makwana, YA (2021). 'Novel Approach for Development and Evaluation of LiDAR Navigated Electronic Maize Seeding System Using Check Row Quality Index' Sensors, 21, 5934. https://doi.org/10.3390/s21175934.