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SEED SPACING AND DEPTH IN WINTER RYE SOWING
RAZMAK I DUBINA SETVE SEMENA OZIME RAŽI

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SUMMARY

Proper seed distribution over area and depth is the essential condition that provides later uniform plants distribution over the vegetation space. Paper presents statistical analysis of two drills accuracy results in winter rye sowing. Experiment was done in north Kosovo, during rye sowing with two mechanical seed drills, OLT Gama and IMT 634.23. Besides the comparative analysis of the sowing results achieved by these two drills, in the paper is tested and verified the applicability of Gaussian function for analytical description of longitudinal, transverse and depth distribution of winter rye seed at the experimental plot.

Key words: rye sowing, seed drill, Gaussian function, fitting, descriptive statistics.

1. INTRODUCTION

High quality sowing, i.e. proper longitudinal, transverse and depth seed distribution at the agricultural parcel represents the main postulate for providing the uniform plants distribution over the whole vegetation space applied in crop production. Uniform feeding and seed distribution depends on design properties of seed metering apparatus and seedbed preparation. Successful introduction of precision sowing in the precision agriculture is hardly possible without application of appropriate sowing units with simultaneous accounting for the specific properties of used seed (Auernhammer, 2004; Wiesenhoff and Koller, 2004). Evaluation of drill working quality should be performed through analysis of the level of accomplishing the specific demands related to desired sowing norm and uniform seed distribution (Marković et al, 2007). Seed drills are equipped with metering (sowing) devices for every row or central metering apparatus that distributes seed to all drill's depositors. In comparison to individual metering, central metering apparatus has higher values of non-uniformity coefficient over seed depositors and higher values of variation coefficient (i.e. more expressed non-uniformity) of longitudinal and transverse seed distribution over the plot (Malinović et al, 2001; 2003; Mehandžić et al, 2006, Barać et al, 2015). Modern seed drills are equipped with monitoring systems that control most of their working parameters. Sensors enable easy collecting the various spatial and temporal data, thus representing the important elements of precision agricultural production (Radičević et al, 2009). Unfortunately, modern agricultural technique is generally expensive and often demands complex maintenance procedures. Consequently, inappropriate machines having classic (outdated) designs are still used, especially in the undeveloped regions and countries in transition. Measurement of the seed depths, longitudinal (intra-row) and transverse (inter-row) seed distances provides experimental data that enables formulation of appropriate fitting functions, which analytically describe various statistical parameters of seed distribution over an area and depth of the experimental field (Tomantschger et al, 2013). This kind of information, related to seed spatial distribution, also characterises working accuracy of tested seed drills.Therefore, the primary goal of present work was to determine the sowing accuracy of two types of mechanical drills, using statistical approach to analyse and describe achieved results.

2. MATERIAL AND METHOD

Experiments were conducted at redish-brown soil on flysch within the agro-ecological conditions of north Kosovo (43° 06′ 14" N, 20° 48′ 10" E), in the second half of October in 2013 and 2014. Soil conditions are illustrated in figure 1. Moisture content was 25 % and 29 %, respectively. Data related to the soil texture are given in table 1.

Tabela 1. Soil texture of district cambisoil*
*Tabela 1. Mehanički sastav distričnog kambisola**

Depth - *Dubina* (cm)	Sand - *Pesak* (%)	Silt - *Prah* (%)	Clay - *Glina* (%)	Textural class - *Teksturna klasa*
0-10	22.3	67.3	10.4	Silt loam - *Praškasta ilovača*
10-20	20.5	65.7	13.8	Silt loam - *Praškasta ilovača*
20-30	18.9	65.8	15.3	Silt loam - *Praškasta ilovača*
30-40	15.7	69.2	15.1	Silt loam - *Praškasta ilovača*

*Remark: USDA classification; sand, particle diameters 2.00-0.05 mm; silt, particle diameters 0.05-0.002 mm; clay, particle diameters < 0.002 mm (Baize, 1993)
*Napomena: USDA klasifikacija; pesak, čestice prečnika 2.00-0.05 mm; prah, čestice prečnika 0.05–0.002 mm; glina, čestice < 0.002 mm (Baize, 1993)

Fig.1. Soil conditions at experimental plot
Sl.1. Zemljišni uslovi na oglednom polju

The weather was fairly similar during both experiments (2013 and 2014). Average values of temperature were stable, 15^0C and 18^0C, and of relative air humidity were 83% and 87%, respectively. Test sowing was performed with IMT 634.23 and OLT Gama drills, under working velocities of 5.5 km h^{-1} (2013) and 6 km h^{-1} (2014). Samples were collected within 4 series per each of two analyzed years, giving 8 experimental series in total. Acquired experimental data are then statistically processed. Basic technical parameters of tested seed drills are presented in table 2.

Table 2. Technical data of investigated seed drills
Tabela 2. Tehničke karakteristike ispitivanih sejalica

Parameters *Parametri*		Type of seed drill *Tip sejalice*	
		OLT Gama	IMT 634.23
Number of rows - *Broj redova*	(-)	14	23
Working width - *Radni zahvat*	(cm)	175	276
Total mass (empty) - Težina (prazna sejalica)	(kg)	280	501
Seed hopper volume - Zapremina sanduka	(l)	120	390
Required power - Potrebna snaga	(kW)	20	26
Max. working speed -Maksimalna radna brzina	(km h^{-1})	15	15

Following the common practice at north Kosovo, the self-refined rye seed variety of "Raša" was used for sowing. Seed characteristics are given in table 3. Low germination of such kind of seed, as well as an inappropriately prepared soil, demanded increasing the seeding norm to 200 kg ha^{-1}. The previous crop was silage corn. Seed drills were coupled with tractor having power of 29.0 kW (44.2 HP).

Table 3. Characteristic of seeding material
Tabela 3. Karakteristike semenskog materijala

Parameters - *Parametri*	Values - *Vrednosti*
Bulk-density – *Nasipna gustina*	722 kg/m^3
1000 seeds mass – *Masa 1000 zrna*	40 g
Whole grain – *Celo zrno*	94.60 %
Damaged grain – *Oštećeno zrno*	0.90 %
Broken grain – *Polomljeno zrno*	1.20 %
Broking of the grain – *Nalomljeno zrno*	1.10 %
Baldly grain – *Šturo zrno*	1.20 %
Other impurities – *Ostale primese*	0.50 %

Preset inter-raw distance was 13 cm, intra-raw seed distance was set to 5 cm and sowing depth was between 3.5 cm and 4 cm (3.75 cm in average). The seeding accuracy evaluation assumed comparison between the real positions of seed deposition with respect to the appropriate preset values. Longitudinal and lateral distributions of the rye seed, as well as the sowing depth, were determined after germination. Longitudinal and transverse distances were directly measured between young rye plants having 2-3 leaves. Sowing depths were estimated following Heege (1993). Soil subsidence was also taken into account.

3. RESULTS AND DISCUSSION

Results of analysis of experimental data are graphically illustrated in figures 2-5, given below. Figure 2 illustrates average distributions of rye seed over area and depth in winter sowing with seed drills OLT Gama and IMT 634.23 in 2013 and 2014.

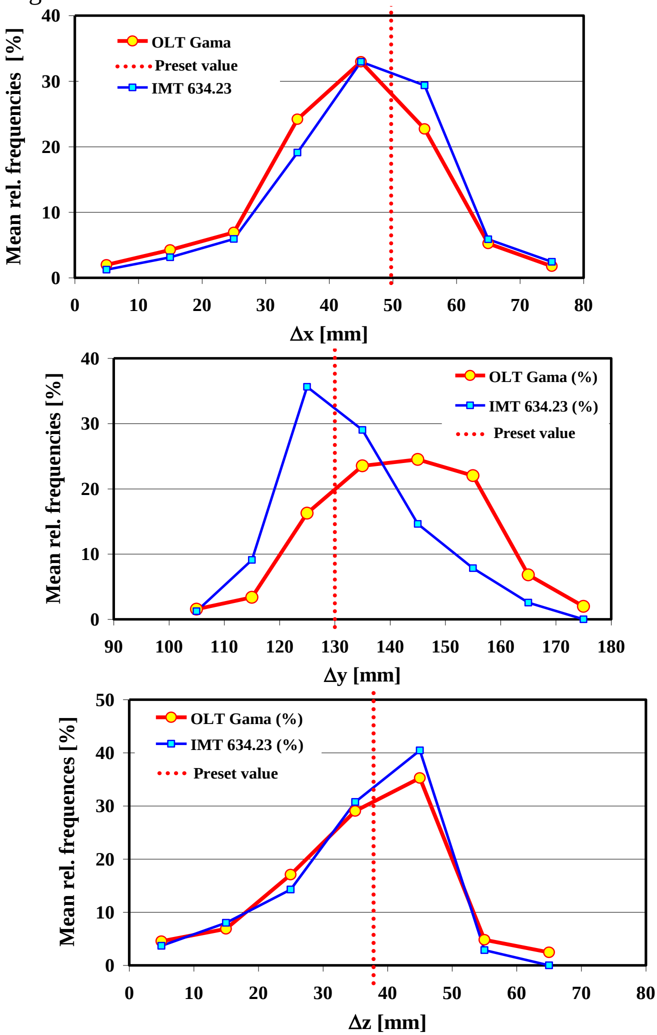

Figure 2 Average distributions of rye seed in winter drilling: (a) longitudinal (Δx); (b) transverse (Δy) and (c) sowing depth (Δz)

Sl. 2 Srednje raspodele semena pri setvi ozime raži: (a) uzdužna (Δx); (b) poprečna (Δy) i (c) dubina setve (Δz)

Presented values are the mean values of 8 experimental series, while preset values of sowing distances and depths are sketched with thick red dotted lines. The figure shows that both drills achieved similar sowing accuracy with respect to longitudinal and depth distribution of the rye seed, although the advantage of IMT 634.23 is evident with respect to OLT Gama.

Figure 3 presents descriptive statistical parameters that characterise the variability of seed distribution over an area and depth of experimental plot for both tested drills: minimum and maximum (fig. 3a), quartiles (Q_1 and Q_3, figure 3b) and the first and last percentile (P10% and P90%, figure 3c).

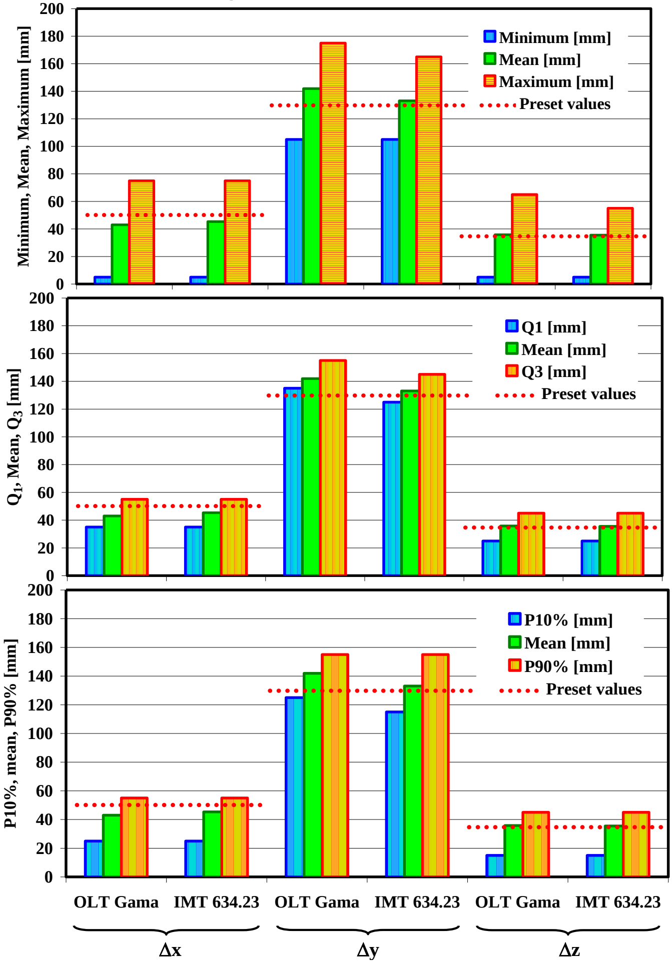

Fig.3 Statistical parameters characterising the variability of rye seed longitudinal (Δx), lateral (Δy) and depth (Δz) distributions after sowing with seed drills OLT Gama and IMT 634.23: (a) minimum and maximum; (b) the first and third quartile and (c) 10% percentile and 90% percentile values

Sl. 3 Vrednosti statističkih parametara koji karakterišu varijabilitet uzdužne (Δx), poprečne (Δy) i dubinske (Δz) raspodele semena raži posle sejanja uskorednim sejačicama OLT Gama i IMT 634.23: (a) minimum i maksimum; (b) prvi i treći kvartil i (c) 10% i 90% vrednosti

All these parameters are identical for longitudinal distribution. However, in other two cases, these parameters verify the smaller variability of seeding with IMT drill. More precisely, maximums were closer to the means for lateral and depth distribution of seed drill IMT 634.23. This drill is also superior according the values of Q_1, Q_3, P10% and P90% with respect to preset value (figures 3b,c).

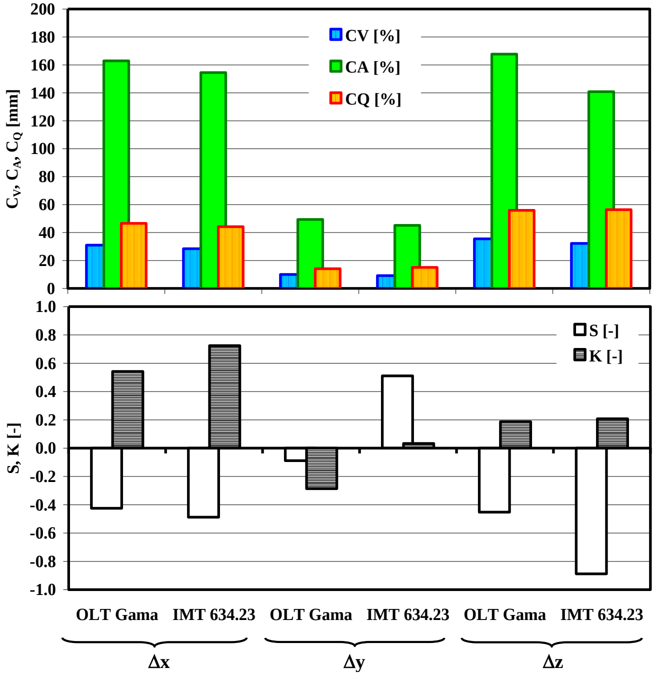

Fig. 4 Basic descriptive statistical parameters of rye seed distributions over an area and depth: (a) dispersion parameters - Variation (C_V), amplitude (C_A) and inter-quartile (C_Q) coefficients and (b) shape parameters – skewness (S) and kurtosis (K) factors

Sl. 4. Osnovni statistički parametri raspodela semena raži po površi i dubini: (a) disperzioni parameteri – koeficijent varijacije (C_V), amplitudni koeficijent (C_A) i inter-quartilni koeficijent (C_Q) i (b) parametri oblika – faktor asimetrije (S) i kurtozis (K)

Figure 4a additionally verifies the superiority of the IMT 634.23 seed drill having more advanced sowing apparatus. Variation (C_V), amplitude (C_A) and inter-quartile (C_Q) coefficients, which characterize experimental data dispersion around the mean, generally took the smaller values for this drill.

Figure 4b shows the so-called distribution shape factors: skewness and kurtosis. In all cases, both parameters are fairly close to zero, indicating that experimental data could follow the normal distribution, analytically described by Gaussian function. This motivated authors of present paper to attempt fitting of the experimental pdfs by Gaussian function.

Consequently, three fitting functions of Gaussian type, related to longitudinal, transverse and depth distribution of rye seed, were formulated. They are presented together with the appropriate experimental data in figures 5a,b,c. These figures verify the applicability of Gaussian function for analytical describing the rye seed distributions in winter drilling with OLT Gama and IMT 634.23 seed drills.

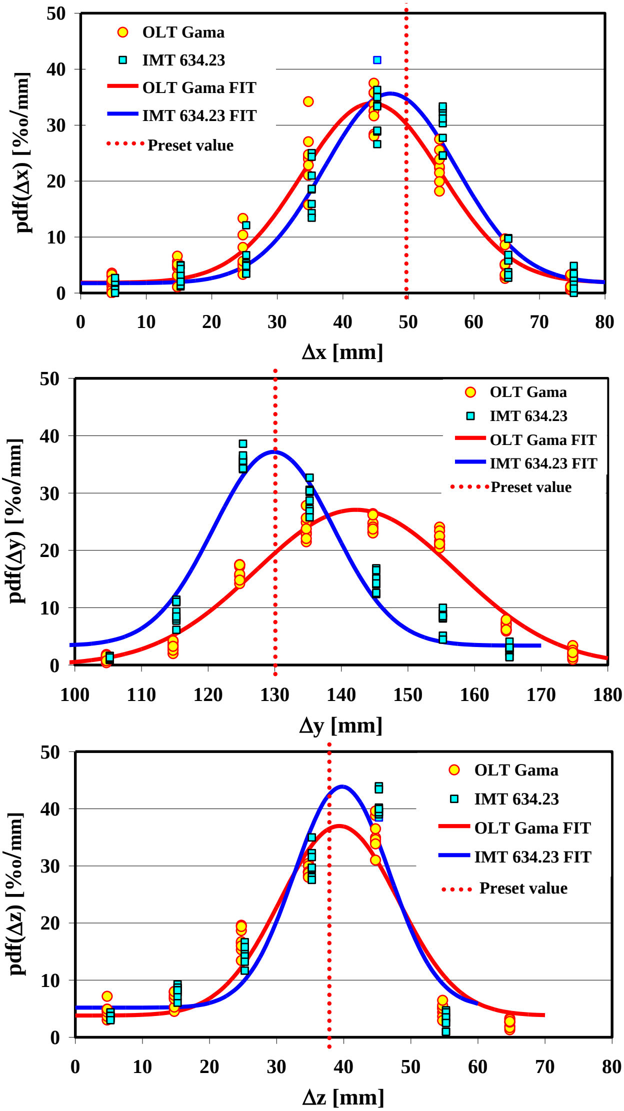

Fig.5. Analytical description of rye seed distribution (Probability Density Functions) by Gaussian function: (a) longitudinal (intra-raw, Δx) distances; (b) lateral (inter-raw, Δy) distances and (c) seeding depths (Δz)

Sl.5. Analitičko opis raspodele semena (funkcija gustina verovatnoće) pomoću Gausove Funkcije: (a) uzdužna (Δx) rastojanja; (b) poprečna (Δy) rastojanja i (c) dubine setve (Δz)

Figures 5a,b,c also show that experimental data, representing longitudinal, transverse and depth pdfs of 8 test series, are grouped fairly well, verifying the relatively stable work of both drills. However, it should be noted that longitudinal pdfs are characterised by slightly higher dispersion, with respect to transverse and depth pdfs.

Table 4. Basic statistical parameters for evaluation of the fitting accuracy of seeding distance and depth distributions by Gaussian function

Tabela 4. Osnovni statistički parametri za ocenu tačnosti fitovanja rastojanja i distribucije pod dubini setve pomoću gausove funkcije

Basic parameters of the fitting accuracy *Osnovni statistički parametric za ocenu tačnosti fitovanja*	Longitudinal distances *Uzdužna rastojanja* (**Δx**)		Lateral distances *Poprečna rastojanja* (**Δy**)		Depths *Dubina* (**Δz**)	
	OLT Gama	IMT 634.23	OLT Gama	IMT 634.23	OLT Gama	IMT 634.23
R-square (Coefficient of Determination) *Koef. determinacije*	0.9332	0.9275	0.9510	0.9295	0.8906	0.8789
Adjusted R-square *Prilagodjeni koeficijent determinacije*	0.9298	0.9239	0.9494	0.9254	0.8842	0.8735
Root-Mean Square Error *Srednja kvadratna greška fitovanja*	3.1291	3.4417	2.1894	3.3998	4.2414	5.1207

Basic parameters related to the fitting accuracy of Gaussian function are listed in table 4. It is evident that R-square and adjusted R-square values reached high values. For both drills, they are beyond 0.92 for longitudinal and transverse seed distributions, but slightly smaller (between 0.87 and 0.891) for depth distributions. In addition, the Root-Mean Square Errors of data fitting are fairly small, between 2.18 and 5.12.

Thus, parameters presented in table 4, together with direct insight in figures 5a,b,c, confirm the applicability of Gaussian model function for analytical description of the longitudinal, transverse and depth rye seed distributions in winter sowing with tested drills.

Paper verifies that seed longitudinal, lateral and depth distribution follows Normal distribution or Gaussian distribution function. According to ISO 7256-2/1984 seed distributions achieved with normal seed drills can be closely represented by Poisson distribution (Müller et al, 2006). Both distribution are pretty similar, except that Poisson proved to be slightly more accurate.

4. CONCLUSION

The paper is focused to analysis and analytical describing of seed distribution in winter rye sowing with two classic seed drills, characterized by old design but still most commonly used in the region of north Kosovo: OLT Gama and IMT 634.23. Measured longitudinal and transverse seed distances, as well as sowing depths, resulted in consequent experimental seed distributions over an area and depth. Further processing of these distributions gave appropriate average distributions of rye seed (figure 2) and appropriate basic statistical description parameters (such as the mean values, quartiles, percentiles, coefficients of variation, amplitude and inter-quartile coefficients, etc.), presented in figures 3 and 4.

Analysis of calculated average seed distributions and statistical description parameters verified the higher sowing accuracy of IMT 634.23 drill, which can be explained by more advanced design – individual seed metering device. However, the applicability of the older seed drill OLT Gama in hard conditions of north Kosovo region has been also verified, but with decreased sowing accuracy.

The paper is also focused to fitting of the experimental data, which verified that probability density functions of rye seeding depth, longitudinal and lateral distance distributions can be adequately described by Gaussian function: R-square values were: 0.9332 (OLT Gama, Δx), 0.9275 (IMT634.23, Δx), 0.9510 (OLT Gama, Δy), 0.9295 (OLT Gama, Δy), 0.8906 (OLT Gama, Δz), 0.8789 (OLT Gama, Δz). This is neither an ultimate, nor the unique model function, but still represents a common approach in modelling a wide variety of statistical phenomena.

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SAŽETAK

Pravilna raspodela semena po površini i dubini predstavlja osnovni uslov za obezbedjenje ravnomerne raspodele biljaka u vegetacionom prostoru. U radu je predstavljena statistička analiza rezultata ispitivanja tačnosti distribucije semena dve uskoredne sejalice u setvi ozime raži. Ispitivanja su izvedena na severu Kosova, u toku setve semena raži primenom dve sejalice Olt Gama 14 i IMT 634.23. Osim komparativne analize rezultata setve koji su dobijeni primenom ove dve sejalice, u radu je testirana i proverena primenljivost Gausove funkcije za analitičko opisivanje uzdužne, poprečne i raspodele semena ozime raži po dubini na eksperimentalnoj parceli.

Ključne reči: setva raži, uskoredna sejalica, Gausova funkcija, fitovanje, opisna statistika

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