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IMPACT OF TRITICALE MASS YIELD ON HARVEST SPEED

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Abstract: This paper analyzes the effect of triticale yield on the speed of the combine during harvest. Monitoring system for the site-specific yield is mounted to harvester with 6 meters wide header. After harvest, the yield is divided into three groups, as well as small, medium and large yield, and then using the Kruskal-Wallis H test analyzed the rate of speed for each group along the plot. It was found for analyzed field that the speeds different and based on the average value ranges group concluded that the speed decreases with increasing yield, and access the subsequent analysis of the differences between the groups using the Mann-Whitney U test. The speed of the combine during harvest triticale in the analyzed plot differ significantly when comparing the three groups, and small and medium impact to Cohen's criteria based on effect size.

Key words: *tritical, speed, yield, Kruskal-Wallis H test, Mann-Whitney U test*

INTRODUCTION

In order to investigate the influence of triticale yield on the speed of the combine during harvest will be used Kruskal-Wallis H test. This test is used to compare the results of a continuous variable with three or more groups. In other words, this test tests the null hypothesis that k independent samples drawn from the same population or populations with the same median. The only assumption of this nonparametric test are that the observed variables have a continuous distribution and that measured at least at the ordinal measurement scale. Research question, therefore, as follows, is there a

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difference in the speed of the combine, depending on the yield into three groups (range)? Sharing the yield in the three groups, and bearing in mind the most direct connection speeds harvest and productivity, classify land at low, middle and highly fertile, and harvesting at low, middle and highly productive. By default, this research also includes the operator's subjective habits that directly affects the speed of the combine. This factor, however, was reduced to a minimum, because the combine operated by an experienced operator. Gradual and sudden speed changes affect the accuracy of yield measurements. Arslan and Colvin [1] showed that average error rates at a constant speed were 3 %, but varying speed between 8 and 11 km/h increased the average error to 5.2 %. When combine speed varied gradually, depending on yield variation, the measurement error almost doubled. Larger errors are observed when ground speed changes abruptly [2]. Many studies [3] [4] [5] have found that non-normal yield distributions are due to a high proportion of low yield measurements. The analyzed field in this paper have also non-normal yield distributions.

MATERIAL AND METHODS

Yield monitoring in combine harvesters is a cornerstone of precision agriculture. It relies on measurement of the grain flow through the harvesting equipment. Typical mechanisms that have been implemented to monitor grain flow through a combine can be grouped into volumetric flow sensors, mass flow sensors, and indirect measurement devices. Among them, impact-type mass flow sensors are widely used in many state-of-the-art yield monitors [6]. They consist of an impact plate and a force transducer that converts the net time-averaged impact force into a voltage signal. This type of structure is so simple that impact-type sensors can be easily mounted on combine harvesters and risk of causing an obstruction of the normal threshing process, even when the sensors are damaged, is minimized [7].

Combine harvester used in this investigation was fitted with a header, 6m wide. A grain mass flow sensor positioned on the top of the clean grain auger, Fig. 1a, and a grain moisture sensor positioned on the middle of the clean grain auger, Fig. 1b. The sensor measures the impact force with which the grain expelled from the paddle elevator strikes against the impact plate. Using this force, as well as known header width, speed of motion and grain auger speed, the moist grain mass yield is calculated. The effect of combine vibrations was eliminated by previous sensor calibration.

Implemented sensors on the respective positions of the basis for the collection of parameters of interest in a combine harvester. Measured values observed in real time can contribute to the optimal operation, and their storage and analysis can make a significant contribution in making decisions related to future processes [8]. The system for measuring rapeseed yield is adjusted to consecutively register yield at 2-second intervals. This was a constant measuring time interval. The only parameter that changed was the distance travelled during that time, which was dependent of the combine harvester speed of motion. It was also registered for each 2-second time interval. During this interval, a number of grain contingents carried by the grain auger paddles were discarded and directed to the impact plate of the mass flow sensor.

Mass flow monitoring started 10 seconds after the adapter with a cutter-bar was lowered for working position, and finished 10 seconds on lifting the cutter-bar.

Practically, there was a time shift for mass flow monitoring, consequently the yield, actually amounting to 10 seconds and representing transport time delay, i.e. the time needed for crop grain to travel through combine technological devices from the time moment of cutting to the time moment of grain striking against the impact plate of the mass flow sensor.

a b

Figure 1. a. Gap between elevator and auger for clear grain and impact plate of mass flow sensor with modul (view from grain tank), b. grain moisture sensor

Various factors such as combine separator design and settings and monitoring systems can affect the data gathering process so that the time shift should be adjusted. Without this adjustment, the grain flow and moisture values cannot be properly coordinated with location and area information to deliver data that accurately represent that location [9].

RESULTS AND DISCUSSION

The influence of the mass yield of dry grain triticale on the speed of the combine was investigated on the farm PKB within the field 40 Padinska Skela. In order to research conducted procedures as required by the Kruskal-Wallis H test was performed categorization of continuous variables by weight of dry grain yield for this plot, so it is divided into the following groups (bands):

- small yield ($\leq 4.490\ t \cdot ha^{-1}$),
- middle yield ($4.491 - 4.970\ t \cdot ha^{-1}$),
- large yield ($\geq 4.97\ t \cdot ha^{-1}$).

Based on the shown distribution, it can be seen that the number of samples within each group each (Tab. 1). Site yield of dry grain triticale on this field per display distribution, is given in Fig. 2 Such groupings yield of dry grain can be defined organizational zone explored part of the plot. This view is particularly characterized by long passes of 2.3 km. Harvesting the plot is done three to five combines, but only one was equipped with tracking devices yield. The results of analysis using appropriate software procedures in SPSS Statistic 21 are given in Tabs 1 and 2.

Figure 2. Representation of site-specific dry grain yield, tons per hectare

Table 1. Average rang of speed for binned mass yield dry grain

	Mass yield dry grain (Binned)	N	Mean Rank	Median
Speed	<= 4.490	2475	4394.31	5.620
	4.491 - 4.970	2445	3912.87	5.480
	4.971+	2456	2753.87	5.220
	Total	7376		5.430

Table 2. Results of Kruskal-Wallis H test for harvest speed

Grouping Variable: Mass yield (Dry) (Binned)	Speed
Chi-Square	772.223
df	2
Asymp. Sig.	.000

Kruskal-Wallis H test revealed a statistically significant difference in the speed of the combine in parts of plots belonging to different groups yield (group 1, *N*=2475: do $4.49\ t \cdot ha^{-1}$); group 2, *N*=2445: $4.491 - 4.970\ t \cdot ha^{-1}$); group 3, *N*=2456: > $4.97 t \cdot ha^{-1}$)), χ^2(2, N=7376)=772.223, p=0.000. Low yields group is characterized by higher median ($M_d = 5.62$) than the other two groups yields, whose median is $M_d = 5.48$ for a group of middle yield and $M_d = 5.22$ for the group of the largest yields. In the above results, the level of significance is 0.000. This is less than the alpha level of 0.005, so we conclude that there is a difference in the speed of combine parts plots with different groups of crops. Review of the medium (average) values of ranks groups, we see that the velocity of this parcel highest in the group with low yields.

However, it is still not known which group are significantly different from each other. For this purpose, there will be used a number of subsequent Mann-Whitney U test between all possible pairs in the group. Therefore will first be applied Bonferroni correction of alpha value to avoid errors of the first kind. Bonferroni adaptation of means to share the alpha value of the 0.05 number of tests to be performed and then use so revised alpha level as a criterion for determining significance to the alpha in all tests together remained at a reasonable level. This would mean more stringent alpha level of 0.05 / 3 = 0.017. For each comparison group after the completion of Mann-Whitney U test will be calculated effect size, ie. strength of relationships between variables and evaluated based on Cohen's criteria.

In the case of comparing the speed of combines in the fields of small and medium yield by Mann-Whitney U test plot was analyzed Z statistics equal to -8.87 with a significance level of p = 0.000, Tab. 4 This leads to the conclusion that there is a significant difference in the average level of speed for these two groups yields. Average value ranges in Tab. 3 for a small contribution to 2639.02 and the average yield of 2279.79. This difference shows the direction of the difference velocity levels. As in calculating the rank lowest value given a value of 1, it is clear that the yield values for speed in the medium yields, on average, received lower rankings.

Table 3. Ranks for combine speed in groups with small and middle yield

	Yield Mass(Dry) (Binned)	*N*	*Mean Rank*	*Sum of Ranks*
Speed	*<= 4.490*	*2475*	*2639.02*	*6531571.00*
	4.491 - 4.970	*2445*	*2279.79*	*5574089.00*
	Total	*4920*		

Table 4. Results of Mann-Whitney U test for combine speed in groups with small and middle yield

Grouping Variable:Yield Mass (Dry) (Binned)	*Speed*
Mann-Whitney U	*2583854.000*
Wilcoxon W	*5574089.000*
Z	*-8.870*
Asymp. Sig. (2-tailed)	*.000*

By using the value of *Z* in the above results, we can calculate the approximate value of effect size:

$$r = \frac{Z}{\sqrt{N}} \quad (1)$$

Where:

N [-] - total number of cases (observations).

In the case of speed measurements *N* arose every two seconds during the combine on the grounds and along the corresponding walk.

In statistics, the effect size *r* is a measure of strength of the relationship between two variables in a statistical population or its random samples. The impact is calculated based on the data descriptive statistics that convey the estimated value of relationships without any conclusion on whether the apparent relationship in the data reflects a true relationship in the population. In this way, the effect size *r* is the complement of inferential statistics such as the *r* value [10].

In the case of comparing recorded in groups of small and medium-yield triticale in the analyzed plot ($Z = -8.87\ i\ N = 4920$) effect size value is 0.13. It would be considered a very small impact according to Cohen's criteria [11]. In his influential book on statistical significance, Cohen gave his general impression of the level of influence *r* contained in research in order to differentiate less than significant impact. For Cohen, the size of the impact of about 0.1 may be a "small" effect, around 0.3 a "medium" effect and 0.5 to infinity "large" impact. Since then, these values have been widely cited as a standard for assessing the magnitude of the effects that are found in the survey, despite Cohen's personal warning about the inadequacy of the general public. [12]. In the case of comparing recorded in groups with medium and high yield given in Tables 5 and 6 (Z = -19.997 and N = 4901) effect size is just over that. 0286, and it is considered a secondary influence on Cohen's criteria. When comparing the speed of a group of small and large yields given in Tabs 7 and 8, *Z* statistic is equal to -26.110 to 4931 treated cases, the effect size is 0.37 and still be considered a secondary influence on Cohen's criteria.

Table 5. Ranks for combine speed in groups with middle and large yield

	Yield Mass(Dry) (Binned)	N	Mean Rank	Sum of Ranks
Speed	4.491 - 4.970	2445	2856.08	6983104.00
	4.971+	2456	2047.74	5029247.00
	Total	4901		

Table 6. Results of Mann-Whitney U test for combine speed in groups with middle and large yield

Grouping Variable: Yield Mass(Dry) (Binned)	Speed
Mann-Whitney U	2012051.000
Wilcoxon W	5029247.000
Z	-19.997
Asymp. Sig. (2-tailed)	.000

Table 7. Ranks for combine speed in groups with small and large yield

	Yield Mass(Dry) (Binned)	N	Mean Rank	Sum of Ranks
Speed	<= 4.490	2475	2993.29	7408389.00
	4.971+	2456	1934.63	4751457.00
	Total	4931		

Table 8. Results of Mann-Whitney U test for combine speed in groups with small and large yield

Grouping Variable: Yield Mass(Dry) (Binned)	*Speed*
Mann-Whitney U	*1734261.000*
Wilcoxon W	*4751457.000*
Z	*-26.110*
Asymp. Sig. (2-tailed)	*.000*

CONCLUSIONS

Based on these analyzes can not be made a general conclusion about the speed of the combine, depending on yield at harvest triticale. However, the Kruskal-Wallis H test and Chi-Square, mean rank and median, are a powerful and reliable tool for analyzing the dependence of the speed of the combine's yield and can be applied when any need for each plot individually. The analyzed land speed is varied by group. Subsequent Man-Whitney test for the analyzed plot with triticale showed that the rate between the groups differ significantly, but according to Cohen's criteria of small and medium-sized influence of certain based on the value of effect size.

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UTICAJ MASENOG PRINOSA TRITIKALA NA BRZINU ŽETVE

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Sažetak: U ovom radu analizirana je uticaj prinosa tritikala na brzinu kretanja kombajna tokom žetve. Sistem za merenje lokacijski specifičnog prinosa postavljen je na kombajn širine zahvata 6 metara. Nakon žetve prinos je podeljen u tri grupe, kao mali, srednji i velik prinos, i potom pomoću Kruskal-Volisovog H testa analizirana je brzina za svaku grupu prinosa duž parcele. Ustanovljeno je da se na analiziranoj parceli brzine razlikuju i na osnovu srednjih vrednosti rangova grupa zaključeno je da brzina opada sa smanjenjem prinosa, pa se pristupilo naknadnoj analizi razlike među grupama pomoću Man-Vitnijevog U testa. Brzine kretanja kombajna tokom žetve tritikala na analiziranoj parceli razlikuju se statistički značajno pri poređenju sve tri grupe, i to sa malim i srednjim uticajem prema Koenovom kriterijumu.

Ključne reči*: tritikale, brzina, prinos, Kruskal-Volisov H test, Man-Vitnijev U test*

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