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THE YIELD AND GRAINS QUALITY OF SOME MAIZE HYBRIDS CREATED AT ARDS TURDA

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Abstract

Maize, due to its superior productions and multiple uses, is one of the main crops. 34 maize hybrids created at the Agricultural Research and Development Station (ARDS) Turda were tested in 3 experimental years (2020-2022). The grain yield and their quality (protein, starch, fats and fibers) were analyzed. The three years were very different from the point of view of favorability, in the first two years optimal conditions were met for achieving a higher production and a better quality of the grains, while in the year 2022 the negative influence is evident both on the production as well as on the quality of the grains. It stands out both for the average productions and for the highest productions in each of the three experimental years the hybrids Turda 344, Turda 3356, Turda 2020 and Turda 380 (12,764 kg/ha average and highest yield in 2021, of 16,280 kg/ha and in 2022, of 9,366 kg/ha). Turda 100 had the highest starch content (76.18%), while for fat and fiber were noted the hybrids Turda 199 (5.22%) and Saturn (3.63%).

Key words*: fat, fiber, protein, starch, yield.*

INTRODUCTION

Maize (*Zea mays*) one of the main crop plants, has experienced impressive increases in cultivated areas in the last two decades, occupying the second place in this respect (after wheat), but in terms of the total production achieved, it is in the first place (FAOSTAT, n.d.). These increases are due both to market demand and its multiple uses (human food, animal feed, industry, medicinal purpose, etc.) and to the increase in productions obtained per surface unit. However, the production is variable depending on the climatic conditions, both throughout the vegetation period, and with particular importance in certain phenophases (emergence, anthesis, grain filling) (Șimon et al., 2023), thus, the breeders must consider when creating new lines and hybrids, that they can cope with the stress factors as well as possible (Horablaga et al., 2023).

The discovery of the phenomenon of heterosis, the introduction of hybrids into the crop, the continuous improvement of the production capacity as well as the cultivation methods determined the obtaining of much higher productions than those obtained in the past (Paril et al., 2024).

However, due to the desire to obtain very high productions, the quality improvement must not be omitted. The quality of the maize grains is of particular importance, depending on the uses for which the crop will be used. The quality of maize grains can also be improved through other methods such as biofortification (Garg et al., 2018; Harjes et al., 2008; Hossain et al., 2022), the use of chemical fertilizers (Leonte et al., 2023; B.-G. Yu et al., 2022), biostimulators (Abdo et al., 2022; Luță et al., 2022), with good results.

The use of maize for the production of ethanol, biodegradable polymers and nutritional products has led to the reorientation of breeding programs towards modifying the starch, protein and oil content of the kernels (Niu et al., 2023; Pajić et al., 2010; J.-K. Yu & Moon, 2021), while the use of maize as raw material for hemicellulose and ethanol, but also for animal feed aims to increase the fiber content (Gáspár et al., 2005, 2007).

The aim of this work is to evaluate the yield obtained by 34 hybrids created at ARDS Turda and the grain quality, in three experimental years.

MATERIALS AND METHODS

In the present study, 34 maize hybrids created at the Agricultural Research and Development Station (ARDS) Turda were tested regarding the yield and grain quality, in three years (2020-2022). The hybrids were created and registered at the ARDS Turda in the last 50 years, and regarding their growing period, they are early or semi-early.

The experiment was carried out in the Maize breeding field, the crop was placed according to the randomized blocks method, in three repetitions, at 70,000 plants/ha density. The yield was determined from two 5 m long rows, while the grain quality was determined from grains obtained from 10 random cobs, using the spectrophotometer Bruker Tango NIR.

The crop management was the same and included: three years crop rotation soybean - winter wheat - maize; autumn plowing; mineral fertilization (400 kg/ha NPK 27:13.5:0); pre-emergent (1.5 l/ha a.s. metolachlor 960 g/l) and post-emergence (2 l/ha a.s. tembotrione (44 g/l) and isoxadiphen-ethyl (22 g/l) herbicides.

The data were processed statistically by variance analysis using ANOVA.

RESULTS AND DISCUSSIONS

Climatic conditions

The data from the Turda meteorological Station indicate that the three experimental years were different from the meteorological point of view and implicitly the favorability for maize crop. In the last decade, an increase in temperatures was observed in the area of the city of Turda (Haș et al., 2022; Simon, 2022), being noted that in the years studied, the temperatures exceeded the multi-year average during the maize growing season. In 2020, it was warm and with precipitation above the average of the area, throughout the growing season, thus favorable conditions for maize were met. This year, the richest precipitations were recorded in the months of May and June, the water requirement being ensured from the first stages of development, and the normal level of precipitation in July and August determined the optimal achievement of anthesis and grain filling.

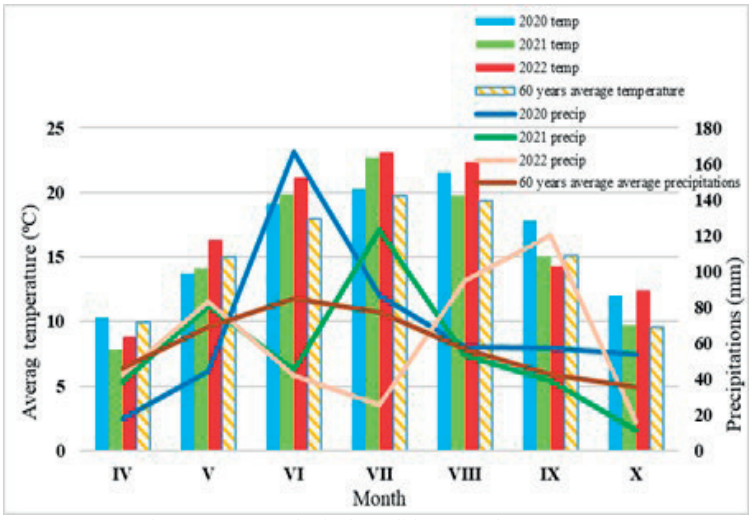

Figure 1. Meteorological conditions, Turda, 2020-2022

The year 2021, one of the most favorable for the maize crop in the last decades, was characterized by high temperatures, associated with a high precipitation, especially in June and July, the period when this plant needs the most water for obtaining high productions.

The extreme temperatures of 2022 associated with a lack of precipitation have made this year to be considered one of the most unfavorable for the maize crop and not only, droughts being reported in several areas of the country (Ciornei et al., 2023), as well as the calamity of

agricultural crops. The high temperatures in the summer months (in some days over 35°C) (Simon, 2022), the deficit regarding the amount of precipitation or even the lack of it for a larger number of days, determined the obtaining of much lower productions, the precipitation being recorded late, only towards the end August and September.

Analysis of variances for yield and quality

The analysis of the variance (Table 1) shows the significant influence that both years, hybrids and the interaction between those factors have on production and some grain quality indices.

Table 1. Analysis of variance regarding maize yield and grain quality for 34 hybrids, Turda, 2020-2022

Variability source	DF	Yield kg/ha	Protein %	Starch %	Fat %	Fiber %
		F test				
Total	203					
Years (Y)	2	781 **	898 **	313 **	122 **	137 **
Hybrid (H)	33	33 **	143 **	18 **	14 **	26 **
Y x H	66	4 **	20 **	3 **	2 **	4 **

**significant at p<0.01 probability levels

Year influence on yield and quality

The influence of the different climatic conditions of the three years is evident in the case of yield (Table 2).

Table 2. The influence of the year on maize grain yield, Turda, 2020-2022

Year	Yield (kg/ha)	% average	± average
Average	*8,878*	*100*	-
2020	9,952	112	1,074***
2021	10,624	119	1,746***
2022	6,058	68	-2,820^{000}
		p<0.05	346
		p<0.01	573
		p<0.001	1,073

***/^{000} significant at p<0.001, positive, respectively negative values

In the favorable year, 2021, the average yield of the 34 hybrids considerably exceeded the average of the three years. High yield was also achieved in 2020, close to those of 2021. In 2022, the lack of precipitation associated with extreme temperatures led to some of the lowest productions in the last decade, in the case of the present study, the average of the 34 hybrids representing only 68% of the three-year average. The values regarding protein, starch, fat and fiber content (Table 3) were very close in 2020 and 2021. Same as in the case of yield, the year 2022 had an unfavorable influence on the quality of the grains, the accumulation of biochemical constituents in the grain being affected by the extreme temperatures in July and August.

Table 3. The influence of the year on maize grain quality (%), Turda, 2020-2022

Year	Protein %	Starch %	Fat %	Fiber %
Average	*8,48*	*72.79*	*4.38*	*3.03*
2020	9.02**	73.44*	4.63*	3.14*
2021	9.02**	73.43*	4.59^{-}	3.10^{-}
2022	7.41^{00}	71.51^{00}	3.92^{0}	2.84^{0}
p<0.05	0.19	0.38	0.22	0.09
p<0.01	0.43	0.88	0.51	0.20
p<0.001	1.38	2.80	1.62	0.63

*. **/$^{0, 00}$significant at p<0.05 and p<0.01, positive, respectively negative values.

Hybrid influence on yield and quality

The yield varied significantly depending on the hybrid studied (Table 4), with average values of the three years between 6692 kg/ha (HS105) and 12764 kg/ha (Turda 380). The productive superiority of the more recent creations is obvious, the hybrids approved after 2010 being noted: Turda 248 (2012), Marius TD (2013), Turda 332 (2014), Turda 344 (2017), Turda 335 (2021), Turda 2020 (2021) and Turda 380 (2022). These hybrids stood out both due to the yield obtained during the test period (Has et al., 2014; Haș et al., 2018; Haș et al., 2021; Varga et al., 2022) and due to their behavior in various stress conditions (Chețan et al., 2023; Popa et al., 2023; Simon et al., 2023; C. Vana et al., 2022; C. D. Vana et al., 2024).

The hybrids created during the beginning of the improvement of this crop, at Turda, can hardly cope with the cultivation conditions of recent years, but those with a shorter vegetation period could be an option for the successive crop in areas where the climatic conditions allow such agricultural practices. The new hybrids are better adapted and yield much higher.

Table 4. The influence of the hybrid on maize grain yield, Turda, 2020-2022

No.	Hybrid	Yield (kg/ha)	± average
0.	*Average*	*8,878*	-
1.	HD 115	6,898	-1,980 000
2.	HS 105	6,692	-2,186 000
3.	HS 105A	7,285	-1,593 000
4.	Turda 100	6,757	-2,121 000
5.	Turda SU 181	8,102	-776 -
6.	Turda SU 182	8,947	69 -
7.	Turda 145	8,622	-256 -
8.	Doina	7,865	-1,013 0
9.	Turda Mold 188	8,184	-694 -
10.	Turda 165	8,166	-712 -
11.	Turda 199	7,505	-1,373 00
12.	HD 211	7,813	-1,065 0
13.	Turda 228	7,455	-1,423 000
14.	Turda 200	8,136	-742 -
15.	Turda 213	7,734	-1,144 00
16.	Turda 160	7,782	-1,096 0
17.	Elan	7,525	-1,353 00
18.	Turda 200 Plus	8,336	-542 -
19.	Turda Super	8,696	-182 -
20.	Turda SU 210	8,626	-252 -
21.	Turda Star	10,431	1,553 ***
22.	Turda 215	7,544	-1,334 00
23.	Turda 248	10,531	1,653 ***
24.	Turda 165	7,101	-1,777 000
25.	Turda 260	9,191	313 -
26.	Saturn	9,806	928 *
27.	Turda 201	8,899	21 -
28.	Turda Favorit	10,180	1,302 **
29.	Marius TD	10,218	1,340 **
30.	Turda 332	11,036	2,158 ***
31.	Turda 344	12,279	3,401 ***
32.	Turda 335	12,287	3,409 ***
33.	Turda 2020	12,506	3,628 ***
34.	Turda 380	12,764	3,886 ***
		p<0.05 p<0.01 p<0.001	832 1098 1411

*. **. ***/0, 00, 000significant at p<0.05, p<0.01 and p<0.001, positive, respectively negative values

Table 5. The influence of the hybrid on protein and starch, Turda, 2020-2022

No.	Hybrid	Protein (%)	Starch (%)
0.	*Average*	*8.48* -	*72.79* -
1.	HD 115	9.29 ***	71.69 0
2.	HS 105	9.03 ***	72.64 -
3.	HS 105A	8.85 ***	72.35 -
4.	Turda 100	9.35 ***	76.18 ***
5.	Turda SU 181	8.80 ***	73.11 -
6.	Turda SU 182	8.70 *	74.85 ***
7.	Turda 145	8.01 000	74.45 ***
8.	Doina	8.75 **	72.28 -
9.	Turda Mold 188	8.59 -	72.06 -
10.	Turda 165	8.25 00	72.83 -
11.	Turda 199	8.91 ***	72.09 -
12.	HD 211	9.51 ***	70.94 000
13.	Turda 228	9.90 ***	70.34 000
14.	Turda 200	8.86 ***	72.66 -
15.	Turda 213	8.59 -	70.56 000
16.	Turda 160	9.52 ***	74.95 ***
17.	Elan	9.04 ***	72.52 -
18.	Turda 200 Plus	8.21 00	74.06 **
19.	Turda Super	8.64 -	71.28 00
20.	Turda SU 210	8.63 -	72.92 -
21.	Turda Star	8.72 **	71.21 000
22.	Turda 215	9.13 ***	74.29 **
23.	Turda 248	7.30 000	73.67 -
24.	Turda 165	8.75 **	73.00 -
25.	Turda 260	8.98 ***	71.11 000
26.	Saturn	8.06 000	70.52 000
27.	Turda 201	7.89 000	73.82 *
28.	Turda Favorit	8.11 000	72.25 -
29.	Marius TD	7.03 000	73.64 -
30.	Turda 332	7.40 000	73.88 *
31.	Turda 344	7.27 000	73.69 *
32.	Turda 335	7.36 000	72.82 -
33.	Turda 2020	7.56 000	73.22 -
34.	Turda 380	7.36 000	73.04 -
	p<0.05 p<0.01 p<0.001	0.17 0.23 0.30	0.90 1.19 1.53

*. **. ***/0, 00, 000significant at p<0.05 p<0.01 and p<0.001, positive, respectively negative values

A regression was observed regarding the protein content of the new hybrids, which is lower than that of the old hybrids. This aspect is also due to the increase in the frequency of genotypes from the dent type germplasm, productive but with a lower protein content, compared to the flint type genotypes, which stand out for their superior quality (Table 5). The lower values of the protein content are also due to the unfavorable influence of the year 2022, when the values were significantly reduced.

The hybrids that stood out for their high productions were also noted for their higher starch content. The Turda 100 hybrid is worth noting, which statistically significantly exceeded the experimental average for both protein content and starch, for the latter having the highest value among the 34 hybrids analyzed (76.18%). Among the hybrids created in recent years, it stands out for its starch content, Turda 332 and Turda 344.

Table 6. The influence of the hybrid on fat and fiber, Turda, 2020-2022

No.	Hybrid	Fat (%)	Fiber (%)
0.	*Average*	*4.38* -	*3.03* -
1.	HD 115	4.39 -	2.86 ^{0}
2.	HS 105	4.88 *	3.02 -
3.	HS 105A	4.77 *	2.80 ^{0}
4.	Turda 100	3.62 ^{000}	3.08 -
5.	Turda SU 181	4.35 -	2.85 ^{0}
6.	Turda SU 182	3.60 ^{000}	2.11 ^{000}
7.	Turda 145	5.03 **	3.44 ***
8.	Doina	4.32 -	2.93 -
9.	Turda Mold 188	4.04 -	3.31 **
10.	Turda 165	4.82 *	3.06 -
11.	Turda 199	5.22 ***	3.52 ***
12.	HD 211	4.06 -	2.62 ^{000}
13.	Turda 228	5.10 ***	2.88 -
14.	Turda 200	4.02 -	2.94 -
15.	Turda 213	5.18 ***	2.75 ^{00}
16.	Turda 160	3.65 ^{000}	2.66 ^{000}
17.	Elan	4.87 *	3.47 ***
18.	Turda 200 Plus	4.04 -	2.97 -
19.	Turda Super	4.16 -	2.93 -
20.	Turda SU 210	3.76 ^{00}	2.83 ^{0}
21.	Turda Star	4.55 -	2.97 -
22.	Turda 215	4.18 -	3.23 *
23.	Turda 248	4.49 -	3.09 -
24.	Turda 165	5.17 ***	3.31 **
25.	Turda 260	4.99 **	3.17 -
26.	Saturn	5.07 ***	3.63 ***
27.	Turda 201	4.31 -	3.16 -
28.	Turda Favorit	4.03 -	2.61 ^{000}
29.	Marius TD	4.57 -	3.21 *
30.	Turda 332	4.06 -	3.52 ***
31.	Turda 344	3.65 ^{000}	2.74 ^{00}
32.	Turda 335	4.15 -	3.24 *
33.	Turda 2020	3.94 ^{0}	2.91 -
34.	Turda 380	3.86 ^{00}	3.16 -
	p<0.05	0.38	0.17
	p<0.01	0.51	0.23
	p<0.001	0.65	0.29

*, **,***/$^{0, 00, 000}$significant at p<0.05, p<0.01 and p<0.001, positive, respectively negative values

The fat and fiber content of the 34 hybrids varied significantly (Table 6), with average values between 3.60 (Turda Su182) and 5.22 (Turda 199), respectively between 2.11 (Turda Su182) and 3.63 (Saturn).

Hybrid x year interaction influence on yield and quality

Each of the 34 studied hybrids obtained the lowest production in 2022, in some cases the values representing approximately half of the production obtained in the previous year (Figure 2). In the case of old hybrids, the yield in 2020 and 2021 had very close values, the differences between the two being several hundred kg/ha. However, the hybrids Doina, Turda Mold 188 and Turda 200 are worth noting, which obtained higher productions in 2020 than in 2021.

In the case of recently created hybrids, the superiority of the productions obtained in 2021 is statistically significant, both compared to the experimental average and to each of the other two years. The hybrids created in the last years (Turda 344, Turda 335, Turda 2020 and Turda 380) stand out for productions that exceeded 10,000 kg/ha in 2020 and 2021, and in 2022 they managed to yield between 6,712 kg/ha (Turda 332) and 9,366 kg/ha (Turda 380), demonstrating their increased adaptability to stress factors. Besides obtaining the highest production in unfavorable conditions, the Turda 380 hybrid stood out by obtaining the highest production in the most favorable year, exceeding 16,000 kg/ha.

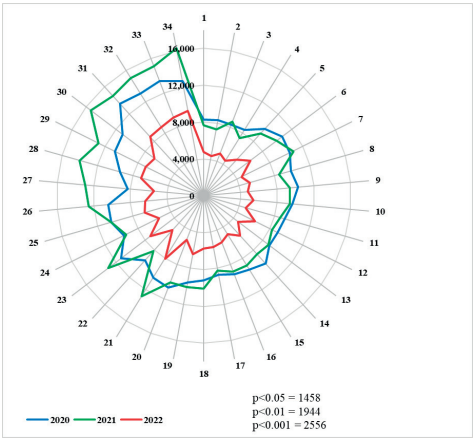

Figure 2. The influence of hybrid x year interaction on grain yield (kg/ha)

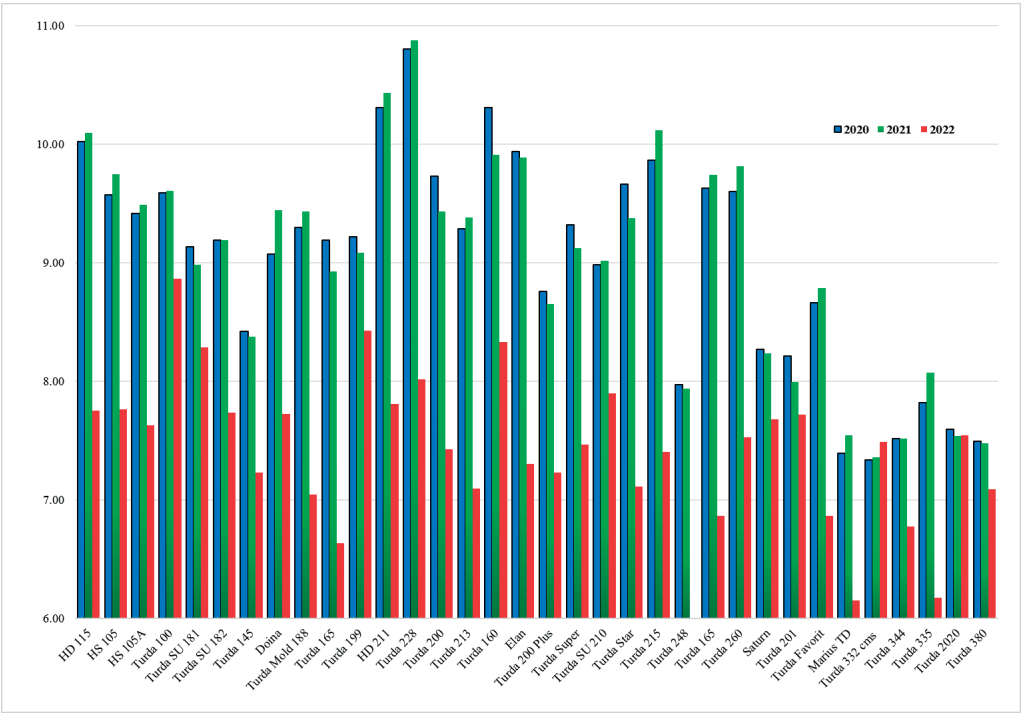

Figure 3. The influence of hybrid x year interaction on protein content (%)

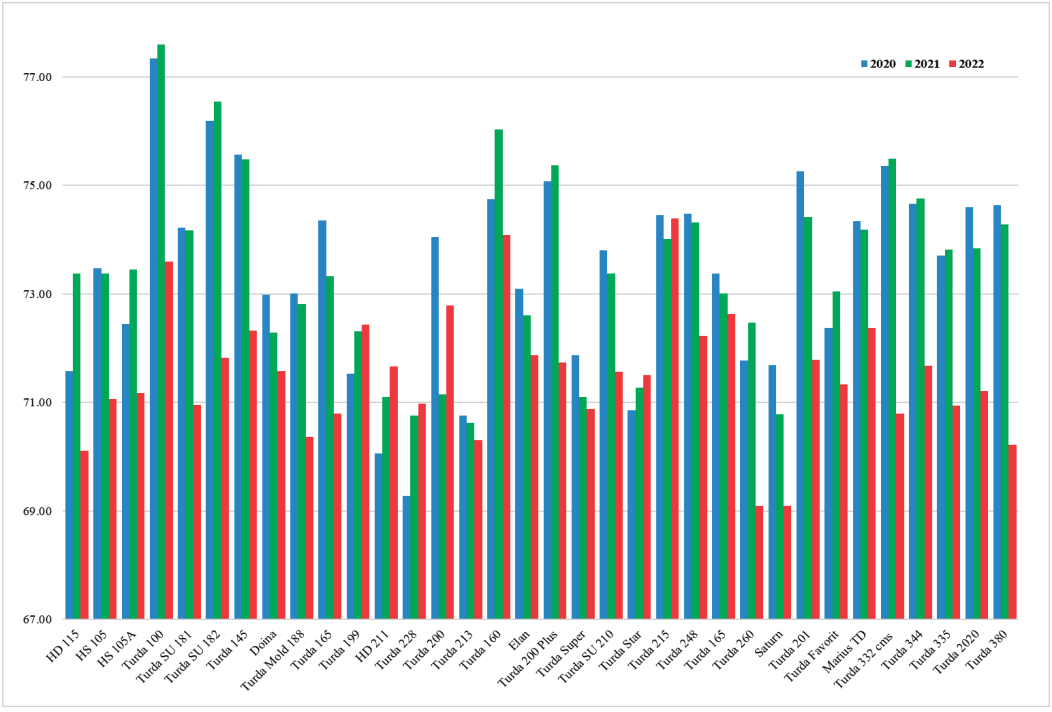

Figure 4. The influence of hybrid x year interaction on starch content (%)

The influence of unfavorable environmental conditions was evident in the case of proteins (Figure 3), for which much lower values were recorded in 2022 compared to the other two experimental years, for all hybrids. The statistically significant differences were up to 1.88%, compared to the experimental average ($p<0.001 = 0.87$). For most hybrids, in 2021, the accumulation of the highest amount of protein was achieved, the hybrid Turda 228 with 10.87% being remarkable. For this hybrid, the highest protein content was also obtained in 2020, of 10.80%.

The favorability of the years 2020 and 2021 is also reflected in the case of starch (Figure 4), which had significantly higher values in those two years, compared to 2022. Turda 100 had the highest starch content, 77.34% (2020), respectively 77.59% (2021). Higher values were also determined for the more recently created hybrids, Turda 380, Turda 2020, Turda 332, Turda 344.

The positive correlation between starch and yield is well-known, while both are negatively correlated with protein. Figure 5 shows the negative relationship between protein and yield, respectively starch in the case of the studied hybrids.

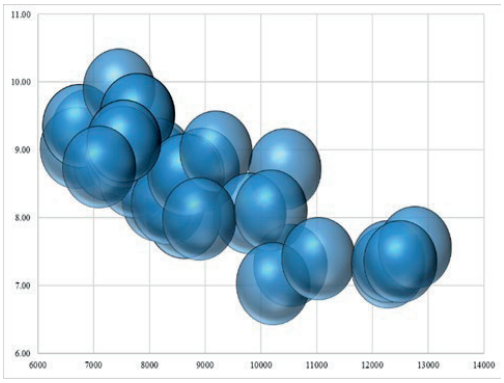

Figure 5. The relation between yield, protein and starch

CONCLUSIONS

Maize is a crop strongly influenced by climatic conditions, both in terms of quality and in terms of grain quality. However, under optimal cultivation conditions, the productions of this plant are impressive. In the case of the 34 studied hybrids, the highest yields were obtained by the majority of hybrids in 2021, followed almost by 2020 while in 2022 the average yield represented only 68% of the three-year average. Turda 380 obtained the highest average yield (12,764 kg/ha), including the highest one in the unfavorable year 2022, of 9,366 kg/ha, followed by Turda 2020, Turda 335, Turda 344 and Turda 332.

Due to the dent type germplasm, the new creations stand out for high productions and a rich starch content, while the older creations recorded higher values for the other biochemical constituents. Turda 228 had the highest protein content, standing out for the higher percentages of 2021 and 2020 (10.87% and 10.80%).

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