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INNOVATIVE SOLUTION DESTINED TO CONTROL SUGAR BEET PRODUCTION, SUGAR PRODUCTION AND SUGAR YILED

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Abstract

The search for innovative strategies for promoting sustainable approach of sugar beet cultures includes identification of new products and management practices destined to weed control. Such products, besides effectiveness against weeds, also involve a good crop tolerance to herbicide, resulting in high production and productivity. Research in the field resulted in the development of market available SMART systems including sugar beet varieties. The purpose of this study is to test the efficacy of an intelligent solution of crop management in specific SMART sugar beet varieties, using a new herbicide based on foramsulfuron, and thiencarbazone-methyl, and the influence of this approach on sugar beet production, sugar yield and production. The experiment was organized in 2023, in a private farm from Cuci village, Mureș County, Romania. Four sugarbeet varieties (Belamia, Hopper, Djerba, and Kipunji) used both as SMART and classic (Class) formulas were used to emphasize the differences in yield, sugar yield, and relative sugar yield. The results of the study show the efficacy of using the SMART system, which has as results improvements in sugarbeet yield and yields traits, expressed by sugar and relative sugar yields for all studied varieties.

***Key words**: efficacy, intelligent approach, new products SMART systems.*

INTRODUCTION

The number of plant species that contain sugary substances in their organs is large, but the sugar beet (*Beta vulgaris* L.) is a crop of particular economic importance, being the only plant that provides the raw material for the production of sugar in the temperate continental climate, especially in European countries and especially in Romania. Sugar beet is a plant that is characterized by a slow initial growth. For this reason, the competitive capacity of sugar beet is relatively low (Kunz et al., 2015). Weeds can cause significant yield losses of up to 95% in Europe (Jursík et al., 2008) both in terms of root quantity and quality (Abou-Zied et al., 2017). In addition, it makes harvesting and then processing the harvested roots difficult. An important element in the protection of sugar beet crops is the correct identification of weeds (Rizk et al., 2023) and then the use of appropriate herbicides (Alaoui et al., 2003). Herbicides and application rates are chosen depending on the weed spectrum, weed growth stages, and crop and weather conditions (Deveikytė et al., 2015; Roland et al., 2017; Vasel et al., 2012). Sugar beet is a crop sensitive to herbicides, which has led to the intensification of research processes in the field, in the current conditions in which more and more active substances that enter the composition of herbicides in general and those used in the beet culture are prohibited on the market of sugar in general (Ouhajjou et al., 2024; Spaeth et al., 2024). As a result, new technologies have appeared on the market to combat weeds in the sugar beet culture, but also new varieties of sugar beet.

The aim of the current study is to test new herbicide formulas in comparison with the classic herbicide recipes in sugarbeet, function of sugarbeet variety in order to try to find alternatives that are as efficient as possible in terms of sugarbeet, sugar, and relative sugar yields.

MATERIALS AND METHODS

The trial was organized as a bifactorial experiment (sugar beet variety x herbicide) in 2023. The experimental field is located in Cuci village, Mures Country, Romania (Latitude 46.4555663 (◦N), Longitude 23.7937994) on an area of 22 Ha. The crop technology consisted in fertilization N_{16}:P_{16}:K_{16}, in doses of 600 kg/Ha, and preemergent herbicidation on phaeozem soil, with glyphosate acid (360 g/L), in September 2022, while in November plowing was performed. The sowing was made on 15 March 2023, ammonium nitrate (33.5%), being used for fertilization 250 kg/ha, and harvesting in mid-September. The classical herbicidation scheme involves the administration of 150 g/L fluazifop-p-butil. The SMART system (Conviso Smart technology) includes administration of 50 g/L foramsulfuron and 30 g/L thiencarbazone-methyl (Bayer & KVS Magdeburg).

Four sugar beet varieties were used: Belamia, Hopper, Djerba, and Kipunji. They were cultivated as both SMART sugar beet varieties (SMART Belamia, SMART Hopper, SMART Djerba, and SMART Kipunji) and classic (Class) ones, together with Grandiosa Class. The experimental pattern was organized by placing SMART cultures separately from the classic ones (Table 1).

Table 1. The experimental pattern

No.	Experimental variant	Description
1.	ab_1	SMART Belamia
2.	ab_2	Belamia Class
3.	bb_1	SMART Hopper
4.	bb_2	Hopper Class
5.	cb_1	SMART Djerba
6.	cb_2	Djerba Class
7.	db_1	SMART Kipunji
8.	db_2	Kipunji C lass

a - Belamia variety; b - Hopper variety; c - Djerba variety; d - Kipunji variety; b1 - SMART herbicidation system; b2 - classical herbicidation system.

The statistical approach involves the use of XLSTATISTICS. Means, standard errors of means and variabilities were calculated for sugarbeet yield, sugar yield, and relative sugar yield. For emphasizing the influence of herbicidation system on sugarbeet production, sugar yield, and relative sugar yield, Principal Components Analysis (PCA) was used.

Factor loadings tables and representations in principal plans axes were made. We consider PCA as an appropriate tool for the study, because we obtain strong and very strong simple Pearson correlations between analyzed parameters, and because according to Keiser - Meyer - Olkin (KMO) and Bartlett tests, threshold values above 0.500 and $p < 0.01$ are obtained (Merce&Merce, 2009). KMO for sampling adequacy was 0.671 for sugarbeet production, and sugar yield interaction, and 0.647 for sugarbeet production, and relative sugar yield interaction.

RESULTS AND DISCUSSIONS

Mean values for sugarbeet yield, sugar and relative sugar yields differ function of experimental variant (Table 2).

Concerning sugarbeet yield, we find means within 53.65 t/ha corresponding to Djerba variety, which was classically treated, and 62.13 t/ha, which was treated against weeds using SMART system. The sugar yield means frame within the interval 7.40 t/ha (Djerba Class) - 8.45 t/ha (SMART Belamia), while means of sugar relative yield between 13.30% (Kipunji Class) and 14.13% (SMART Belamia). Thus, results that even though the highest sugarbeet yield corresponds to SMART Kipunji variety, the highest sugar yield and sugar beet yield is produced by SMART Belamia. In all cases, yields and relative yields corresponding to SMART system of fight against weeds led to superior values compared to means obtained when classic (Class) weed control is applied. We observe statistically significant differences only for sugarbeet yield. Djerba varieties regardless treatment, and Kipunji variety classical treated differ significantly from the other varieties, but between them the differences are not significant. SMART Kipunji sugarbeet variety mean yield differs significantly from SMART Djerba, Djerba Class, and Kipunji Class mean yields. All production traits analyzed are characterized by low variability, according to the values of the coefficient of variation CV% (Table 2).

Table 2. The sugarbeet yield, sugar yield, and sugar content

Variety	N	Sugarbeet yield (t/ha)		Sugar yield (t/ha)		Relative sugar yield (%)	
		$\overline{X} \pm s_{\overline{X}}$	CV%	$\overline{X} \pm s_{\overline{X}}$	CV%	$\overline{X} \pm s_{\overline{X}}$	CV%
SMART Belamia	20	$59.75a \pm 0.85$	1.42	$8.45a \pm 0.52$	6.15	14.11a±1.02	7.22
Belamia Class	20	$58.58a \pm 0.84$	1.43	$7.79a \pm 0.83$	10.65	$13.38a \pm 0.99$	7.40
SMART Hopper	20	$60.79a \pm 0.61$	1.00	$8.37a \pm 0.81$	9.67	$13.63a \pm 0.85$	6.23
Hopper Class	20	$59.20a \pm 0.84$	1.41	$7.83a \pm 0.73$	9.32	$13.23a \pm 0.98$	7.41
SMART Djerba	20	$55.26b \pm 0.87$	1.57	$7.80a \pm 0.76$	9.74	$14.13a \pm 0.92$	6.51
Djerba Class	20	$53.65b \pm 1.19$	2.21	$7.40a \pm 0.67$	9.05	$13.80a \pm 0.81$	5.86
SMART Kipunji	20	$62.13ac \pm 1.74$	2.81	$8.26a \pm 1.04$	12.59	$13.30a \pm 1.15$	8.64
Kipunji Class	20	$55.40b \pm 1.27$	2.29	$7.53a \pm 0.85$	11.28	13.60a±0.93	6.83

$\overline{X}$ - mean; $s_{\overline{X}}$ – standard error of mean; CV% - coefficient of variation; *Different letters signifies differences at significance threshold of 0.05%.

Similarly with our results, research in the field shows the positive influences of using appropriate treatments against weeds on sugarbeet, and sugar yields (Abdollahi & Ghadiri, 2004; Gouda, 2019; Wilson et al., 2002).

Correlations between sugarbeet yield and sugar yield (Table 3), on one hand, sugarbeet yield, and relative sugar yield (Table 4), on the other hand calculated function of experimental variants, are, in majority, strong and very strong. The simple correlations between sugarbeet yield and sugar yield are in great majority of cases strong and very strong and positive, except SMART Djerba, Djerba Class, and SMART Hopper (Table 3). Between sugarbeet yield and relative sugar yield are reported more weak correlations compared to those emphasized between sugarbeet and sugar yields, but majority of them are strong and very strong.

The sugarbeet production of SMART Djerba variety is weakly correlated with relative sugar yield of Hopper and Djerba varieties corresponding to both systems of weed treatment. Also, weak correlations are observed between SMART Belamia sugarbeet yield and Djerba Classic relative sugar yield, and between Djerba Classic sugarbeet yield, and relative sugar yield (Table 4).

Thus, it results that in Hopper and Djerba varieties, whatever strategy of weed fighting, sugarbeet yields are not very good predictors for sugar and/or relative sugar yields.

According to PCA, the graphic representation of factors in the plan of the principal components (Figure 1, Table 5) emphasizes the relationships between sugarbeet and sugar yields considering variety (Factor 1), and treatment against weeds (Factor 2).

Factor 1 (variety) is responsible for 85.22% of variance, while Factor 2 (treatment against weeds) is responsible for 14.78% of variance.

Factor 1 (variety) is positively correlated with all factor loadings (Table 6), meaning sugarbeet and sugar yields regardless treatment. Factor 2 (treatment against weeds) is positively correlated with sugarbeet yield in Hooper variety, and sugar yield in Belamia, Djerba, and Kipunji varieties.

The analysis shows that sugarbeet yields whatever variety, influence both sugarbeet and sugar yields, while treatments against weeds have major influence on sugar yields, except Hooper variety, where it influences the sugarbeet yield.

These results are consistent with findings of Abd El Latef et al. (2023) who report that sugarbeet yields may have influence on sugarbeet traits in specific experimental conditions.

Table 3. The Pearson correlation matrix between sugar beet and sugar yields

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	**1.00**	0.99	0.78	0.78	0.75	0.99	0.99	0.99	0.99	0.85	0.82	0.95	0.75	0.71	0.95	0.90
2	0.99	**1.00**	0.82	0.87	0.63	0.99	0.96	0.99	0.95	0.89	0.90	0.98	0.83	0.78	0.98	0.93
3	0.78	0.82	**1.00**	0.88	0.32	0.17	0.75	0.76	0.84	0.99	0.91	0.92	0.97	0.99	0.91	0.61
4	0.78	0.87	0.88	**1.00**	0.72	0.80	0.70	0.82	0.87	0.92	0.88	0.92	0.96	0.90	0.93	0.83
5	0.75	0.63	0.32	0.72	**1.00**	0.70	0.82	0.69	0.64	0.38	0.24	0.52	0.18	0.19	0.51	0.51
6	0.99	0.99	0.17	0.80	0.70	**1.00**	0.97	0.92	0.98	0.81	0.82	0.93	0.73	0.66	0.94	0.95
7	0.99	0.96	0.75	0.70	0.82	0.97	**1.00**	0.98	0.97	0.81	0.75	0.92	0.69	0.67	0.91	0.85
8	0.99	0.99	0.76	0.82	0.69	0.92	0.98	**1.00**	0.99	0.84	0.85	0.95	0.76	0.71	0.95	0.94
9	0.99	0.95	0.84	0.87	0.64	0.98	0.97	0.99	**1.00**	0.91	0.90	0.98	0.84	0.79	0.98	0.91
10	0.85	0.89	0.99	0.92	0.38	0.81	0.81	0.84	0.91	**1.00**	0.95	0.96	0.98	0.97	0.96	0.72
11	0.82	0.90	0.91	0.88	0.24	0.82	0.75	0.85	0.90	0.95	**1.00**	0.95	0.97	0.93	0.96	0.83
12	0.95	0.98	0.92	0.92	0.52	0.93	0.92	0.95	0.98	0.96	0.95	**1.00**	0.92	0.89	1.00	0.87
13	0.75	0.83	0.97	0.96	0.18	0.73	0.69	0.76	0.84	0.98	0.97	0.92	**1.00**	0.99	0.92	0.68
14	0.71	0.78	0.99	0.90	0.19	0.66	0.67	0.71	0.79	0.97	0.93	0.89	0.99	**1.00**	0.88	0.58
15	0.95	0.98	0.91	0.93	0.51	0.94	0.91	0.95	0.98	0.96	0.96	0.75	0.92	0.88	**1.00**	0.87
16	0.90	0.93	0.61	0.83	0.51	0.95	0.85	0.94	0.91	0.72	0.83	0.87	0.68	0.58	0.87	**1.00**

1 - SMART Belamia; 2 - Classic Belamia; 3 - SMART Hopper; 4 - Classic Hopper; 5 - SMART Djerba; 6 - Classic Djerba; 7 - SMART Kipunji; 8 - Classic Kipunji; 1-8, sugarbeet yield; 9-16, sugar yield.

Table 4. The Pearson correlation matrix between sugar beet yield and relative sugar yield

Variable	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16
1	**1.00**	0.99	0.78	0.78	0.75	0.99	0.99	0.99	0.97	0.81	0.81	0.96	0.69	0.39	0.83	0.81
2	0.99	**1.00**	0.82	0.87	0.63	0.99	0.96	0.99	0.99	0.86	0.90	0.98	0.78	0.48	0.91	0.86
3	0.78	0.82	**1.00**	0.88	0.32	0.72	0.75	0.76	0.87	0.89	0.90	0.91	0.96	0.88	0.92	0.51
4	0.78	0.87	0.88	**1.00**	0.17	0.80	0.70	0.82	0.91	0.91	0.95	0.89	0.96	0.74	0.99	0.79
5	0.75	0.63	0.32	0.17	**1.00**	0.70	0.82	0.69	0.56	0.58	0.23	0.28	0.10	0.12	0.67	0.41
6	0.99	0.99	0.72	0.80	0.70	**1.00**	0.97	0.91	0.96	0.77	0.83	0.95	0.68	0.33	0.84	0.89
7	0.99	0.96	0.75	0.70	0.82	0.97	**1.00**	0.98	0.94	0.78	0.75	0.94	0.63	0.35	0.78	0.75
8	0.99	0.99	0.76	0.82	0.69	0.91	0.98	**1.00**	0.98	0.81	0.85	0.96	0.71	0.39	0.86	0.87
9	0.97	0.99	0.87	0.91	0.56	0.96	0.94	0.98	**1.00**	0.91	0.93	0.99	0.84	0.57	0.95	0.84
10	0.81	0.86	0.89	0.91	0.58	0.77	0.78	0.81	0.91	**1.00**	0.93	0.93	0.97	0.85	0.95	0.58
11	0.81	0.90	0.90	0.95	0.23	0.83	0.75	0.85	0.93	0.93	**1.00**	0.92	0.96	0.73	1.00	0.80
12	0.96	0.98	0.91	0.89	0.28	0.95	0.94	0.96	0.99	0.93	0.92	**1.00**	0.86	0.61	0.94	0.78
13	0.69	0.78	0.96	0.96	0.10	0.68	0.63	0.71	0.84	0.97	0.96	0.86	**1.00**	0.90	0.96	0.59
14	0.39	0.48	0.88	0.74	0.12	0.33	0.35	0.39	0.57	0.85	0.73	0.61	0.90	**1.00**	0.75	0.18
15	0.83	0.91	0.92	0.99	0.67	0.84	0.78	0.86	0.95	0.95	1.00	0.94	0.96	0.75	**1.00**	0.78
16	0.81	0.86	0.51	0.79	0.41	0.89	0.75	0.87	0.84	0.58	0.80	0.78	0.59	0.18	0.78	**1.00**

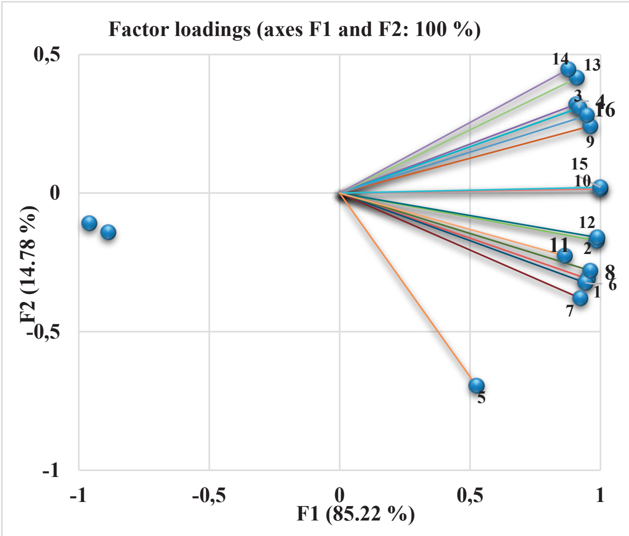
1 - SMART Belamia; 2 - Classic Belamia; 3 - SMART Hopper; 4 - Classic Hopper; 5 - SMART Djerba; 6 - Classic Djerba; 7 - SMART Kipunji; 8 - Classic Kipunji; 1-8, sugarbeet yield; 9-16, relative sugar yield.

Table 5. The Eigenvalues corresponding to principal factors

Issue	Eigenvalue	Variability (%)	Cumulative %
Factor 1	15.3397	85.2203	85.22
Factor 2	2.6603	14.7797	100.00
Cumulative %	18.0000	100.0000	100.00

Table 6. The factor loadings

	F1	F2
1	0.9531	0.3018
2	0.9835	0.1650
3	0.9102	-0.3241
4	0.9203	-0.3151
5	0.5325	0.7755
6	0.9412	0.3138
7	0.9216	0.3710
8	0.9594	0.2704
9	0.9878	0.1544
10	0.9596	-0.2377
11	0.9477	-0.2802
12	0.9998	-0.0162
13	0.9124	-0.4078
14	0.8766	-0.4426
15	0.9996	-0.0221
16	0.8740	0.2395



1 - SMART Belamia; 2 - Classic Belamia; 3 - SMART Hopper; 4 - Classic Hopper; 5 - SMART Djerba; 6 - Classic Djerba; 7 - SMART Kipunji; 8 -Classic Kipunji; 1-8, sugarbeet yield; 9-16, sugar yield.

Figure 1. The PCA plot of the cases and variables on the factor plane concerning sugarbeet production and sugar yield

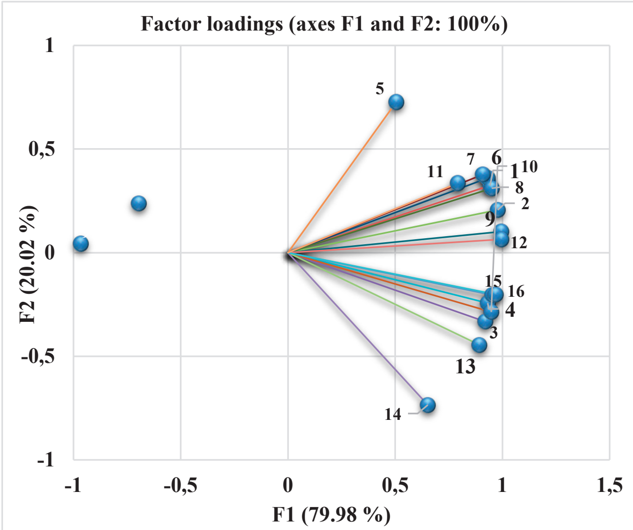
The graphic representation of factors in the plan when PCA is implemented (Figure 2, Table 7) shows the relationships between sugarbeet yields and relative sugar yields. We identified two factors, Factor 1 (sugarbeet variety), and Factor 2 (treatment against weeds). Factor 1 (sugarbeet variety) is responsible for 79.98% of variance, while Factor 2 (treatment against weeds) is responsible for 20.02% of variance. Factor 1 (sugarbeet variety) is positively correlated with all factor loadings (Table 8), and this emphasizes that sugarbeet yields and relative sugar yields are positively correlated, within the same variety, regardless of treatment. Factor 2 (treatment against weeds) is positively correlated with sugarbeet yield in Belamia, Djerba variety, and Kipunji varieties on one hand, and relative sugar yield in Belamia, and Kipunji varieties. In this case, similarly with previous discussion, sugarbeet yields regardless variety, influence both sugarbeet and sugar yields, while treatments against weeds have major influence on yield performances of Belamia and Kipunji varieties.

Table 7. The Eigenvalues corresponding to principal factors

Issue	Eigenvalue	Variability (%)	Cumulative %
Factor 1	14.3946	79.9801	79.98
Factor 2	3.6031	20.0199	100.00
Cumulative %	17.9977	100.0000	100.00

Table 8. The factor loadings

	F1	F2
1	0.2484	0.2138
2	0.2577	0.1359
3	0.2422	-0.2192
4	0.2455	-0.1606
5	0.1330	0.4790
6	0.2453	0.2373
7	0.2393	0.2484
8	0.2504	0.2047
9	0.2620	0.0670
10	0.2498	-0.1887
11	0.2510	-0.1348
12	0.2624	0.0423
13	0.2354	-0.2935
14	0.1719	-0.4845
15	0.2551	-0.1327
16	0.2087	0.2210



1 - SMART Belamia; 2 - Classic Belamia; 3 - SMART Hopper; 4 - Classic Hopper; 5 - SMART Djerba; 6 - Classic Djerba; 7 - SMART Kipunji; 8 -Classic Kipunji; 1-8, sugarbeet yield; 9-16, relative sugar yield.

Figure 2. The PCA plot of the cases and variables on the factor plane concerning sugarbeet production and relative sugar yield

CONCLUSIONS

According to the present study, the implementation of Conviso Smart technology in sugarbeet production emphasizes superior performances of SMART sugarbeet varieties. The highest sugarbeet yield corresponds to SMART Kipunji variety, while the highest sugar yield and sugarbeet yield is produced by SMART Belamia. In all cases, yields and relative yields corresponding to SMART system of fight against weeds led to superior values compared to means obtained when classic weed control is applied. Strong and very strong correlations between sugarbeet yield and sugar yield, and between sugarbeet yield, and relative sugar yield, are obtained.

According to PCA sugarbeet yields regardless variety, influence both sugarbeet, sugar yields, and relative sugar yields. Treatments against weeds have major influence on sugar yields, except Hooper variety, where it influences the sugarbeet yield, and on relative yield performances of Belamia and Kipunji varieties.

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