Scientific Papers. Series B, Horticulture. Vol. LXIII, No. 1, 2019
Print ISSN 2285-5653, CD-ROM ISSN 2285-5661, Online ISSN 2286-1580, ISSN-L 2285-5653

THE INFLUENCE OF THE HYBRID AND THE SOWING PERIOD ON THE PRODUCTION OF SWEET CORN

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Abstract

Sweet corn has become a niche crop for small and medium-sized farmers in Romania. The large number of hybrids on the market requires a study of their behavior in different agricultural areas. In this regard studied an assortment of sweet corn hybrids: Accentuate F1, Royalty F1, Sweet Thing F1, Golda F1 and Bantam F1 under South-West Romanian pedoclimatic conditions. The crop developed during two different sowing-times: the first one mid April and the second one was in early May. The purpose of this study was to identify corn hybrids with good quantitative and qualitative yield, depending on the sowing season. In this respect, some morphological and productive characteristics, as well as yield quality, were under an analysis. Productive values obtained first sowing-times were higher, for all analyzed characters and in terms of qualitative values variations influenced by both hybrids and sowing time were registered. The best yields were the ones for Accentuate F1 (10.35 t/ha^{-1}) and Royalty F1 (9.8. t/ha^{-1}). Low yield in the second sowing time is the result of the environmental climatic conditions, as the consequence of temperature increase and a lower atmospheric humidity level.

Key words*: yield, sugar, proteins, starch.*

INTRODUCTION

Milk is an important food both for humans and Sweet corn belongs in convar. *saccharata* spp. *Zea mays* L., the *Poaceae* family and it is a crop plant for human consumption and as industry raw material. Due to its rich content it is superior to other vegetables due to its high content in dry matter, proteins, but especially in sugars. The *saccharata* convariety differs from common corn by the presence of some genes that affect the metabolism of carbohydrates in the seeds. From this point of view, sweet corn hybrids fall into three categories of sugars: standard (*su*), super sweet (*sh2*), and sugar-enhanced (*se*) (Hale et al., 2005). Sugar-enriched cultivars are characterized by a double sugars content compared to other types of sweet corn, creamy texture and good flavor (Alan et al., 2014; Lertrat & Pulam, 2007).
Sweet corn is consumed when at a technological maturity, baked or boiled, but it can also be used to prepare mixes of vegetables, soups, pasta and other delights. The flour obtained from physiologically mature seeds is used to prepare a wide variety of delicious pastry products. Young sweet corn ear, up to 10 cm long, are preserved by thermosterilization or marinade.
Sweet corn can be turned into syrup which is then used as a sweetener in soft drinks, into starch or it can be used as an ingredient when preparing salad, roasted rice and other foods (Uwah & Ogar, 2014).
This corn species is considered a source of vitamins, fibers, minerals, carbohydrates, amino acids and carotenoids. It is known as one of the most important sources of dietary protein among vegetables due to its quite high protein (3.5 g/100 g edible portion), (Alan et al., 2014). But the sweet corn is not only characterized by a diverse biochemical composition but also by therapeutic features. Immature sweet corn seeds can be a superior source of carotenoids,

compared to other corn seeds, with benefits for human health (Jiangfeng et al., 2016). Sweet corn is one of the few vegetable sources that contain zeaxanthin and lutein, some of the main carotenoids that protect eye photoreceptor cells (Pacurar-Grecu et al., 2017). The carotene content has recently been of high interest due to its importance in human nutrition (Dinu & Soare, 2016).

Global sweet corn cultivation areas are in a steady and significant increase (Caner et al., 2016). Sweet corn is a recent crop in Romanian agriculture (Pacurar-Grecu et al., 2018). Although, there are excellent soil and climate conditions, sweet corn is grown on small areas, with the need to expand the crop due to its high food and economic value. In recent years, sweet corn has become a popular plant in Romania, due to support measures, with the help of NRDP *(National Rural Development Program Romania*) and has become a niche plant for small and medium-sized farmers.

Corn importance and economic benefits cover a wide range of uses: food, industrial, mechanized technology, export product and profit source (Pânzaru & Medelete, 2017).

A major problem is crop adaptability to environmental conditions, especially temperature and humidity. For this, it is necessary to test hybrids with a high capacity to adapt to climatic conditions (Matei, 2016) in various sowing times (Horgos et al., 2010).

The great number of sweet corn hybrids on the market makes necessary the study of their behavior in different agricultural areas. The purpose of this study was the study of sweet corn hybrids with good productivity and nutritional value, under South-West Romanian pedoclimatic conditions.

MATERIALS AND METHODS

The study was carried out in 2015 and 2016, in the teaching field of the Faculty of Agriculture and Horticulture, University of Craiova (44°19' North latitude and 23°48' East longitude) on a reddish-brown preluvosoil. The biological material consisted of five sweet corn hybrids: Accentuate F1, Royalty F1, Sweet Thing F1, Golda F1 and Bantam F1. The crop took place during two different sowing-times: the first one was in mid-April and the second one was in early May. It was sowed at a 70 cm distance between rows and 30 cm between plants per row (47620 plants/ha). The experimental design was a randomized complete block, with three replications. During vegetation specific technology to this type of crop was followed. For basic fertilization 20 t/ha vegetal compost was used.

In order to achieve the objectives set, some morphological features were analysed: plant height, foliar surface, average leaf/plant number, ear length, number of rows/ear and number of grains per row, but also productivity and quality: total soluble substance, reducing sugar, non-reducing sugar, proteins and starch.

In order to sort out growth parameters, specific experimental rules were followed. Plant height (cm) was measured from the base of the plant to the last leaf base.

The foliar surface (cm2) was calculated when all the leaves were active by applying the equation LA = 0.75 × L × W, where 'L' is leaf width and W 'is leaf width (Montgomery, 1911).

The total soluble substance (TSS) content was determined by Optech refractometer at 20ºC and the results were expressed in ºBrix.

Reducing sugars (%) were extracted in distilled water (1:50 w/v), 60 minutes at 60˚C and assayed colorimetric with 3.5 dinitrosalicylic acid using glucose as standard. Absorbance was recorded at 540 nm using a Thermo Scientific Evolution 600 UV-Vis spectrophotometer with VISION PRO software (Soare et al., 2017).

Non-reducing sugars were converted by hydrochloric acid hydrolysis, 15 min at 100 ° C to reducing sugars. After neutralization, total sugar content (%) was assayed for colorimetric with 3,5 dinitrosalicylic acid. Non-reducing sugars (%) is the difference between total soluble sugars and reducing sugars (Băbeanu et al., 2017). The results were expressed as% relative to the kernel fresh mass.

The starch content was determined by using Ewers polarimetric method. Starch from the ethanol-insoluble material is extracted into hot dilute hydrochloric acid. After having cooled, phosphotungstic acid is added to precipitate the proteins and the solution is filtered. The optical rotation of the filtrate is measured using a Carl Zeiss JENA polarimeter and the results were calculated with a specific optical rotation of the starch [α] D20 ˚ = 184.6˚.

Protein content (%) was determined by the Kjeldahl method in two steps: acid digestion and N distillation. Nitrogen content in the sample was converted to crude protein content by multiplying the N percentage by the conversion factor (6.25).

Statistical calculation: The data recorded were statistically processed by using an analysis of variance (ANOVA) with a significant level of $p < 0.05$ by Duncan's multiple range test.

RESULTS AND DISCUSSIONS

An important role during the vegetation period is also played by the climatic conditions, especially temperature and humidity. In Southern Romania, cultivation conditions are similar to semi-arid ones; therefore it is necessary to identify drought-tolerant varieties by using classical methods, such as selection (Soare et al., 2016). Table 1 illustrates the climatic conditions during the experimental period of the hybrids studied.

Table 1. Rainfall, temperatures and humidity in during the growing period*

Month	Temperature (^{0}C)						The relative humidity of the air (%)		Rainfall (mm)	
	minimum		maximum		medium					
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
April	0.1	0.9	25.5	28.9	11.8	14.6	56	68	35	48
May	8.0	4.8	28.2	29.2	18.2	15.8	70	75	86	89
June	10.9	11.7	33.2	35.1	20.7	21.9	68	73	85	71
July	12.4	13.0	36.7	34.2	25.3	23.9	55	59	14	44
August	12.7	9.7	36.7	35.4	23.8	23.1	59	60	88	34

*rp5.ru/vremea in craiova

In this study, the differences in plant height are significant both between hybrids and between the two sowing times (Table 2). Thus, plant height ranged from 139.6 cm (Sweet Thing F1) to 191.7 cm (Royalty F1) for the first sowing time and from 108.5 cm (Sweet Thing F1) to 169.5 cm (Bantam F1), for the second sowing time. The variations of plant vegetative growth are the result of hybrids genetic vigour and also of a more intense rainfall in May-June (Table 1). The shorter plant size during the second sowing time might also be a consequence of the sowing period. A sowing delay results in a significant decrease in plant height, as Rehana Mohi-ud-din et al. also noted (2017). Some authors, in a study on sweet corn crop in Van (Turkey), claimed that the sowing time did not cause any size variations between hybrids in terms of plant growth (Caner et al., 2016).

As it concerns the number of leaves, the studied hybrids had a similar number of leaves, between 8-9 leaves/plant, regardless of the sowing time, as it was also stated by Uwah & Cynthia (2014).

Foliar surface plays an essential role in capturing the light resulting into a higher accumulation of dry matter and, of course, of biomass. Therefore, a large foliar surface is responsible for an increase of yield. As it regards the hybrids studied, the foliar surface was larger for the taller ones. Hybrids Accentuate F1, Royalty F1, Golda F`1 and Bantam F1 with more vigorous and much taller plants have also recorded higher foliar surface values, thus achieving a direct correlation between plant height and foliar surface. Hybrid Sweet Thing F1, which is shorter, compared to the other hybrids, recorded a small foliar surface both during the first and second sowing times, i.e. 256.12 cm^2 and 213.74 cm^2 (Table 2). On the whole, one can notice that the foliar surface of all hybrids was larger during the first sowing time compared to the second one, conclusion also reached by Ojobor & Odiri (2018).

Table 2. The main morphological characters in sweet corn hybrids

Hybrids	Plant height (cm)	No. of leaves/plant	Leaf area (cm^2)	Ear length (cm)	The number of rows per ear	The number of grain per row
First sowing time						
Accentuate F1	165,8b	8	342.03b	19.3c	16	592a
Royalty F1	191.7a	8	400.94a	20.5b	16	528b
Sweet Thing F1	139.6c	8	256.12c	18.6c	14	378e
Golda F1	175.3b	8	389.43a	21.5a	16	480c
Bantam F1	174.6b	8	426.56a	18.7c	16	464d
LSD 5%	15.33	-	44.81	0.93	-	11.15
Second sowing time						
Accentuate F1	146.2b	9	337.85ab	19.5a	16	502a
Royalty F1	164.4a	9	382.70a	19.1ab	16	481b
Sweet Thing F1	108.5c	8	213.74c	11.2c	14	216c
Golda F`1	154.8ab	9	305.30b	18.5b	16	372b
Bantam F1	169.5a	9	313.45b	18.3b	16	385ab
LSD 5%	14.70	-	62.27	0.84	-	19.23

The differences between the averages indicated by different letters are significant ($p \leq 0.05$).

The length of the ear, the number of rows/ear and the average number of grains/ear varied not only from one hybrid to another but also between sowing times (Table 2). During the first sowing time, the length of the ear recorded higher values, up to 21.5 cm (Golda F1), compared to the second one up to 19.5 cm (Accentuate F1), the lowest values were recorded both during the first and the second sowing times for Sweet Thing F1. Similar results have been also registered by Erdal et al., (2011) on the length of the ear. Sweet Thing F1 can be recommended as a raw material for the canning industry because of the smaller size of the ear. One can say that the variability in terms of the ear size and development can be the consequence of several factors, especially that of the hybrid, sowing time, as well as of the adverse climatic conditions, as Arash et al., (2011) has also argued. According to other authors, short-sized ear could be the result of drought stress, which caused a decrease in photosynthesis and total biomass (Rivera-Hernandez et al., 2010).

The number of rows/ear ranged from 14 to 16 rows regardless of the sowing time, this aspect was influenced more by the hybrid. Our results are similar to those obtained by Arash et al., (2011), who argued the fact that the number of rows on ear is more influenced by genetic factors rather than crop management.

The average number of grains/ear recorded great variation from 203 to 592 during the first sowing time and in the second one from 216 to 502. The highest values were recorded during the first sowing time for Accentuate F1 and the lowest for Sweet Thing F1, it can be said that the values are influenced by both the hybrid and the sowing time.

Regarding the average weight of the ear, an important element of productivity, it recorded variations from 127 g (Sweet Thing F1) to 255 g (Accentuates F1) during the first sowing time, and during the second one from 80 g to 245 g, for the same hybrids. In this case, one could say that the heavy weight is related to the length of the ear, so the longer hybrids also registered good yield, similar observations asserted by other researchers, too Erdal et al., (2011).

According to consumers' preferences much of the production is sold in detail, an important aspect for the farmers in order to know the genetics of the cultivar, especially on the development of the ear, Romanian consumers showing a greater preference for the bigger ones.

The most important aspect related to corn for both researchers and farmers is production capacity (Bonea et al., 2015). Thus, it is important to identify sweet corn hybrids with good adaptability to stress conditions, higher temperature and lower humidity. Fresh ear yield/ha has registered a variation from 5050.7 kg/ha to 10340.3 kg/ha during the first sowing time and from 3181.6 kg/ha to 9726.5 kg/ha during the second one. The best production was registered for Accentuate F1 and the poorest for

Sweet Thing F1. We speak also of high productivity in the case of Royalty F1 and Golda F1 (Table 3). Temperature increase and humidity decrease during the crop period (Table 1) led to a productivity decrease. Fresh ear production/ha was significantly influenced by the sowing time, an aspect that has been noticed also by Rajablarijani & Mirshekari, (2014).

Table 3. The yield at sweet corn hybrids

Hybrids	Average weight ear (g)	Fresh ear yield (t/ha^{-1})
First sowing time		
Accentuate F1	255[a]	10.35a
Royalty F1	246ab	9.8ab
Sweet Thing F1	127d	5.1d
Golda F`1	224bc	8.9bc
Bantam F1	204c	8.2c
LSD 5%	28.02	1.12
Second sowing time		
Accentuate F1	245a	9.73a
Royalty F1	213b	8.5b
Sweet Thing F1	80d	3.3e
Golda F`1	190b	7.6c
Bantam F1	150c	6.0d
LSD 5%	26.90	0.8

The differences between the averages indicated by different letters are significant ($p \leq 0.05$).

Sweet corn seeds qualitative benefits are illustrated in Table 4. Thus, the TSS varied during the first sowing time from 14.3 to 26.5% and during the second one from 14.3 to 28.5%, Golda F1 hybrid being with the lowest values whilst Bantam F1 hybrid with the highest ones. One could say that the hybrid and sowing time resulted into a TSS content increase, an idea also supported by Ugur & Maden (2015). TSS values illustrated by this study are superior to those recorded by Mohi-ud-din et al. (2017) carried out on an assortment of sweet corn hybrids during different sowing times.

Sweet or super sweet taste is one of the main factors in terms of qualitative corn grains and is related to glucose, fructose, sucrose and sugar content. Among all these, sucrose is the main ingredient that is t be found in sweet corn grains (Lertrat & Pulam, 2007; Szymanek et al., 2015).

The sugar accumulation is influenced by hybrids, technology, environmental conditions, soil quality and harvest time. Corn seeds taste and consistency are related to sugar content, the higher it is, sweeter the corn is. As sweet corn achieves its physiological maturity, its starch content increases whilst its soluble sugars one decreases, this change greatly affects the taste.

The reducing sugar of sweet corn seeds ranged from 2.10% (Accentuate F1) to 3.30% (Bantam F1) during the first sowing time and from 1.90% (Accentuate F1) to 3.48% (Royalty F1), in the second one, and non-reducing sugar has reached a variation from 3.84% to 6.07% during the first sowing time and from 4.32% to 6.88% in the second one (Table 4). A low humidity level and higher temperatures that characterized the second sowing time resulted into a sugar content increase, an aspect also stated by other authors Arash et al., (2011). Our results are based also on data illustrated by different research. In a study investigating the effects of fertilizer on sweet corn grown on sandy soil, reducing sugar content ranged from 1.4% to 2.59% and non-reducing sugar content from 2.2% to 4.42% (Orosz et al., 2009).

Starch in sweet corn grains has recorded variable content from one hybrid to another and was influenced by sowing times. The highest values were registered in the case of Bantam F1 hybrid for both sowing times (24.1% and 25.7%) (Table 4), but it should be mentioned the fact that these hybrids are made for consumption in the milk-wax stage, when carbohydrate content is high, and starch is low. In the present study the values fall within the parameters specific to this consumption purpose.

The results obtained in terms of protein content have shown that sweet corn is an important source of proteins. For the s hybrids studied, it ranged from 9.74% to 11.38% during the first sowing time and from 10.67% to 12.21% in the second one; with higher values for Bantam F1. Our results on protein content are similar to those reported by Alan et al., (2014) and Păcuraru-Grecu et al., (2018).

Table 4. Some quality characteristics in sweet corn hybrids

Hybrids	TSS (^{0}Brix)	Reducing sugar (%)	Non-reducing sugar %	Starch (%)	Protein (%)
	First sowing time				
Accentuate F1	15.2c	2.10c	3.84d	10.2d	10.32b
Royalty F1	17.9b	2.11c	3.93d	12.1c	9.74c
Sweet Thing F1	14.9c	2,.7ab	4.62c	12.7c	10.18b
Golda F`1	14.3c	2.2bc	5.12b	14.0b	10.25b
Bantam F1	26.5.a	3.30a	6.07a	24.1a	11.38a
LSD 5%	1.21	0.48	0.24	1.01	0.36
	Second sowing time				
Accentuate F1	16.7c	1.90b	4.32c	8.3c	11.36c
Royalty F1	20.9b	3.48a	5.56b	19.0b	10.67d
Sweet Thing F1	17.5c	3.02a	5.47b	10.3d	10.84d
Golda F`1	14..3d	2.11b	5.75b	11.7c	11.75b
Bantam F1	28.5a	3.02a	6.88a	25.7a	12.21a
LSD 5%	1.11	0.81	0.30	1.11	0.30

The differences between the averages indicated by different letters are significant ($p \leq 0.05$).

CONCLUSIONS

In Romania, sweet corn crops are register a rise and it could be an alternative for the small farmers, enriching the range of less cultivated species. Given the conditions of the S-V Romanian area, sweet corn productivity was influenced by the sowing time and hybrid type.

Hybrids Accentuate F1, Royalty F1 and Golda F1 can be considered as stable and adaptable to environmental conditions, with the best productivity.

The first sowing time proved to be more advantageous due to the higher sweet corn hybrids production capacity.

During the second sowing time, vegetative growth and productivity were lower because of plant early maturity as a result of the high temperatures and poor rainfall.

For quality key attributes, the values were varied and were significantly influenced both by the hybrid type and the sowing time.

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