CORVINUS UNIVERSITY OF BUDAPEST

EFFECT OF GROWING TECHNOLOGY ELEMENTS ON EARLINESS OF SWEET CORN

Doctoral Theses

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Background of research and objectives

According to its present growing area, sweet corn is the vegetable grown on the largest acreage in Hungary. According to data of the Hungarian Interprofessional Organization for Fruit and Vegetables and Product Board the greatest growing area was 38,000 hectares in 2003 and not counting the decline in 2005 the growing area has still been around 30 thousand hectares from then. Sweet corn occupies almost one-third of the open field vegetable area and it production value was over 10 billion HUF also in the last year. According to data from USDA, Hungary has become the 4th biggest producer in the world and the biggest exporter of processed products. Currently, Hungary is the second largest exporter in the world. As a result of the rapid growth, Hungary has a share of 34% in the world commerce of sweet corn and 31% of frozen sweet corn, which means that the country came to the first place in Europe since 2002.

Production is mostly carried out in accordance with the demands of the processing industry and foreign buyers in the framework of the so-called systems of production on order. The exact timing, which is based on the knowledge of the growing period of the cropped variety, is an essential element in production being indispensable for ensuring an adequate product quality and for making an efficient use of processing capacities.

Production is dominated mostly by American hybrids, the growing periods of which are given by the breeding companies, generally in terms of unit of heat amount or of days. Hungarian production experiences, on the other hand, reveal that, partly due to the special climatic characteristics of the Carpathian Basin, partly due to smaller or greater differences in the elements of the production technology (habitat, fertilization system, irrigation), the growing periods of the varieties may differ from the values offered. This represents a problem in the timing of harvest which is often a threat to product quality.

The recession in 2005 affected not only Hungary but also the holdings of the USA and Western Europe. In the case of the former ones, however, the increase in fresh consumption partly counterbalanced the rate of decrease. According to the estimates of the Hungarian Statistical Office, sweet corn sales for fresh consumption (domestic market and direct exports) and consumption from own production represent together a total of 2-3%. Based on the experiences from recent years it can be seen that in Hungary demands for fresh products are again on the increase, which in the case of sweet corn offers sales opportunities for the growers already from the second decade of June (from the beginning of the summer school holidays and together the summer holidays).

In order to increase fresh consumption, as well as to maintain and increase the sweet corn exports, it is necessary to promote the investigations in Hungary so as to be able to ensure a further increase in the growing area and yields of sweet corn with the help of the experiences.

With the shortening of the growing period, with suitable early varieties and with the further improvement of the growing technology elements we try to extend the consumption season thereby offering solution for the growers that could help them have some compensation for the financial losses from the diminishment of the growing area in case of market saturation.

In the case of several other vegetable species, a few special technological variations have already been developed for the enhancement of earliness and for the increase of yield stability, which have also become broadly used in the practice of production, seedling raising and temporary plant cover in the first place.

In my work I studied the applicability and the effectiveness of similar technological elements in the case of sweet corn. Accordingly, over three consecutive growing years (2006-2008) I investigated the effect of sowing date, small tunnel cover and transplanting on the growing period in order to find out about the earliness enhancing effect of the different variations.

In the case of the technological variations using direct seeding I studied the possibility to forecast the harvest date through the comparison of several different heat requirement calculation methods and the growing period measured in days, under conditions of the Carpathian Basin. For the purpose of the experiment, I chose a variety that had already performed well under the environmental conditions of Hungary.

In the course of the investigations, I also wanted to understand how the shortening of the growing period influenced yields and quality.

Of the characteristics of grain composition, I studied the amount of simple and compound sugars responsible for sweetness, the carotinoid, the vitamin C and the dry matter content, as well as the issue if there was any relationship between early maturation and compositional parameters.

Material and method

I carried out the experiments at the Experimental and Training Farm of the Faculty of Horticulture, Corvinus University of Budapest, in Soroksár in 2006, 2007 and 2008, under open field conditions.

In the experiment I applied three technological elements as treatments in order to enhance earliness: method of propagation, time of propagation and temporary plant cover, as well as their combinations, arranged as follows:

V1 = no cover, direct seeded, earlier date;

TV1 = use of cover, direct seeded, earlier date;

TP1 = use of cover, transplanted, earlier date;

V2 = no cover, direct seeded, later date; (control)

TV2 = use of cover, direct seeded, later date;

P2 = no cover, transplanted, later date;

TP2 = use of cover, transplanted, later date.

The treatment V2 was considered as the control which is most broadly used in large scale field production, direct seeded in the 2^{nd} and 3^{rd} decades of April with no cover.

For the basic material of the experiment I choose a normal sweet corn variety of short growing period (Spirit) which is broadly used, reliable and sufficiently known among Hungarian growers. Under our climatic conditions the most important requirement for early varieties from the point of production to have, besides a short growing period, as high a tolerance as possible to ground frosts in late spring and to the great fluctuations in temperature occurring in this period.

The variety Spirit is a very early one, has a growing period of 85 days, its grains are yellow in colour. Average height is 159 cm, ear height is 37 cm, average ear length 19.6 cm as measured in the variety comparison trials carried out by the Central Agricultural Office (earlier National Institute for Agricultural Quality Control), average ear weight 245 g.

Due to the exceptionally favourable cold and temperature fluctuation tolerance, it is the hybrid that can be sown earliest. According to experiences in the US, its heat unit requirement is 760°C, its height is 182 cm and its ear length is 20.3 cm. It can be used both for canning and freezing industry purposes. The variety was granted official recognitions in 1988 and has been the dominant variety of the early ripening category till now. In Hungary, processing factories start the season with this variety and its sowing is generally scheduled to the 2nd and 3rd decades of April.

The variety is used as a reference variety in the variety comparison trials of the Central Agricultural Office.

For the frame structure of the treatments with cover I used Ø 4.2 mm zinc coated wire coils.

Cover material: fleece cover of Novagryl type made of polypropylene having a weight of 19 g/m^2.

The fleece, 60 cm in width, was stretched over a small tunnel of 40 cm in height and then its edges (25-25 cm, respectively) were covered with soil using a hoe and the its ends were tied to the stakes hammered down at making the frame structure. With the help of the small tunnel frame structure arranged in this manner, each polypropylene stripe covered a twin row of treatments planted out and direct seeded at the same time (TV1-TP1; TV2-TP2).

In the year prior to the experiment the area was under lacy phacelia (*Phacelia tanacetifolia*). After that the pre-crop had been removed the area was ploughed to a depth of 25 cm in November 2005 and then received tillage on the 30th of March 2006.

No farmyard manure was given during the time of the experiment. One week before the first propagation time I marked out the plots and applied the starter fertilizer doses. The experimental area was 49 m long and 35 m wide. Each plot had an area of 7 m in length and 6 m in width, with 3 tramlines of 3 m and also with fringes of 2 x 1.5 m along the two edges of the experiment.

The plots were marked out in the same place in all three years.

The NPK requirement according to the soil test was determined in the already mentioned fertilization system, with a (planned) unhusked ear yield of 16 tons per hectare. Accordingly, a nutrient dose of 222.5 kg/ha N, 22.5 kg/ha P2O5 and 143 kg/ha K2O active ingredient was applied in the form of ammonium nitrate (34%), superphosphate (19.5%) and potash (60%).

Approximately half of the N rate (10 g/m^2) and the total of the P and K rates were applied as starter fertilization (about one week before the first propagation time), while the rest of the N dose was applied on two occasions, at the 6-7 leaf stage and at tasseling, in the form of top dressing. The basal fertilizer application was worked into the soil with a rotary hoe.

In order to enhance the earliness of sweet corn, I used a sowing date (first decade of April) that was approximately 2 weeks earlier compared to the traditional permanent direct seeding usually carried out in the second-third decades of April, as well as seedling raising as the method of propagation.

For the purpose of seedling raising, the seeds were sown in trays with rigid walls having 11x7 holes of 3x3x7 cm in size at a date 3 weeks before the planned date of planting in all three years of the experiment (Table 1). For seedling growing medium and for cover material I used a commercial seedling soil mix POT 20 (composition: white peat 10-20 mm; PG Mix 1 kg/m3 + micro nutrients, bentonite 40 kg/m^3, pH 5.5-6.5). After the seeds had been sown, the trays were placed in a plastic tunnel greenhouse with double cover heated by water screen between the plastic layers and having heating tubes above the soil. In the course of seedling raising, with the daily irrigation no fertilization or plant protection intervention were carried out.

Table 1: Propagation dates of treatments with seedlings (2006-2008, Soroksár)

Treatment	2006		2007		2008	
	Sowing Date	Outplanting Date	Sowing Date	Outplanting Date	Sowing Date	Outplanting Date
TP1	March 16	April 06	March 13	April 04	March 17	April 08
P2	March 29	April 20	March 30	April 19	March 31	April 21
TP2	March 29	April 20	March 30	April 19	March 31	April 21

In the case of the rest of the treatments (V1, TV1, V2, TV2) the method of propagation was permanent direct seeding and the date was the same as the one of the other treatments. The seedlings were in the 3-4 leaf stage at the time of outplanting.

The stand was created to contain 60,607 plants per hectare, according to the recommendations of the owner of the variety, at a spacing of 110+40x22 cm in twin rows. Each plot had an area of 6x7m (8 parallel rows and 30 seeds sown in each row). Sowing depth was 2-3 cm. The edge was the respective outer rows of the 4 twin rows of the plot. Four repeats were carried out in parallel.

The construction of the frame structure and the setting out of the fleece cover were carried out at the same day as direct seeding and outplanting in all three years. The fleece cover was removed when plant height reached the top of the small tunnel, on May 16 in 2006, on May 11 in 2007 and on May 13 in 2008.

<u>Investigations on growing period and on duration of phonological phases</u>

I carried out the heat unit calculation using three methods.

The first method is the so-called '*Traditional*' in which I used the following formula:

Heat unit = [(daily maximum temperature + daily minimum temperature):2]-10°C.

In this case I considered only the maximum and minimum values. When the minimum value was below 0°C I regarded the heat unit of that day as zero.

The second method was the *CERES-Maize* method:

Heat unit == Σ (max (T-10^{o}C; 0)*dt)/24, where

T - is the temperature recorded at intervals (°C); dt - is the length of the interval (h).

This method regards temperature values below 10°C as zero, on the other hand considers the values over 30°C with no variation.

The third one, the '*Improved*' method applies essentially the same formula as the first one with the difference that only the values between 10-30°C are considered. If the temperature value is <10°C it is rounded up to 10°C and is substituted in this way, while if the value is >30°C it is rounded down to 30°C and this value is used in the formula.

In the course of the experiment I recorded the dates of the occurrence of the most important phonological phases.

For this I carried out regular (every 3-5 days) observations as follows:

- beginning of germination,
- appearance of tassel (with 50% of plants),
- onset of tasseling (pollen shedding has begun along the axis of the tassel),
- 50% female flowering (silks have reached the 2 cm length in half of the ears),
- full maturity (harvest).

Investigations on morphological characteristics of plants

In order to observe these parameters I selected 20 plants in a random fashion in each treatment and repeat, respectively, after the removal of the fleece and carried out the following measurements:

- tassel length (the full length of the tassel from the flag leaf to its tip) [cm],
- stem diameter (the diameter of the stem section below the ear at the widest part) [mm],
- plant height (measured from the surface of the ground to the flag leaf after the termination of growth) [cm],
- height of ear junction (distance measured from the surface of the ground to the point where the first ear joins the stem) [cm].

Investigations on morphological characteristics of fruit

The harvest was carried out in two passes. This time I picked the ears from the inner two twin rows, together with the husks, to carry out the measurements.

At the first picking, after recording the total weight and ear number per plot (measured rows) and plant number I took 20 ears in a random manner from the harvested fruits. Using these ears to represent the plot, of the morphological characteristics of the ears I carried out the following measurements and calculations:

- unhusked ear weight (ear weight together with husks) [g],
- husked ear weight (ear weight together with no husks) [g],
- full length (ear length from the base to the tip) [cm],
- grain set length (length of ear set with grains suitable for consumption) [cm],
- grain length (length of grains measured at the middle part after breaking the ear) [mm],
- ear diameter (diameter measured at the middle part after breaking the ear) [mm],
- net ear weight percent (proportion of husked/unhusked ear weight) [%],
- grain length/cob diameter proportion (proportion of the grain length of ear broken at the middle part and the diameter) [%],
- yield (average yield per repeat of treatments expressed per hectare) [t/ha].

In the course of the second picking I did not carry out measurements of this type and recorded only the total number of ears and weight.

<u>Investigations on compositional characteristics of grains</u>

The investigation into the compositional parameters of the ears was performed by processing these samples relative to the following components:

- dry matter content [%],
- reducing sugar content [%],
- total sugar content [%],
- vitamin C content [mg/100g],
- carotinoid content [mg/100g].

Grain compositional analyses were performed at the Plant Analysis Laboratory of the Department of Vegetable and Mushroom Growing.

<u>Economic model calculation</u>

Though my work did not include the objective to examine the economical aspects of the technological variations tested nor the length of the thesis permits a detailed analysis of these aspects, nevertheless in order to judge the practical applicability of the methods I think it necessary to say a few sentences about incomes and the different extra costs associated with the different technological variations.

The objective of my investigation included only the major elements of the additional costs compared to the traditional uncovered technology with direct seeding. The cost of seedlings and the major material costs of covering, calculated at prices in 2008-2009, are as follows:

- price of tray seedlings: net of 5.5 HUF/seedling (KITE Zrt.),
- net price of fleece (2.4 m wide): 24.8 HUF/m^2 (can be used for 3 years) (KITE Zrt.),
- net price of wire (4.2 mm): 30 HUF/m (can be used for 10 years) (Ironware shop, Budapest),

In accordance

- net cost of seedlings per hectare (60,607 plants): 333,339 HUF,
- net cost of fleece per hectare, for 3 years (polyethylene band of 6,667 meters per hectare x 2.4 m width, i.e. 16,001 m^2/ha): 396,820 HUF, an average of 123,273 HUF expressed per year,
- net material cost of wire frame per hectare, for 10 years (counting with a rib length of 1.8 m, placed at 1.5 m intervals, 4,445 x 1.8 m per hectare, i.e. 8,001 m): 240,000 HUF, an average of 24,003 HUF expressed per year.

For the statistical evaluation I used the programmes RopStat 1.1 with which I compared single point samples (variables).

Results

The longest growing period measured in days (absolute) was seen in the case of the **uncovered treatment (V1) sown at the earlier date** in the average of the three years (89 days). The protraction of the growing period had already been forecast by the slower rate of germination (12 days). The number of days elapsed till 50% female flowering was also the longest (70 days) for the plants of this treatment. The growing period was increased compared to the absolute growing period of the covered treatment (TV1) sown at the same time as the treatment V1 and the beginning of harvest was delayed to 4 days later in the average of the experimental years (2006-2008). Compared to the direct seeded uncovered control (V2) sown in the 2nd decade of April, the absolute growing period was 9 days longer, yet the beginning of harvest occurred 6 days earlier on average. It is true that sowing occurred approximately 2 weeks earlier, but it was these plants that were exposed to the inclemency of weather for the longest period.

The emergence time of the **covered treatment (TV1) sown at the earlier date** showed big fluctuations (6-13 days) over the 3 experimental years. It occurred 9 days after sowing in the average of the experimental years. At the same time, its absolute growing period was identical with that (85 days) seen in the variety comparison trials of the Central Agricultural Office. The number of days elapsed till 50% female flowering showed big fluctuations (from 59 days to 74 days) and this period was 65 days in the average of the three years, which suggests that the application of cover reduced this period by 5 days compared to the treatment V1 and at the same time the beginning of harvest occurred 10 days earlier than with the plants of the control treatment (V2) in the average of the three experimental years.

The length of the vegetative section of the **covered treatment (TP1) planted at the earlier date** was seen relatively stable in the average of the three years (54 days). If this vegetative period is relatively stable in the case of the covered treatment planted at the earlier date, despite the spring weather with characteristic big temperature fluctuations, the forecast of the beginning of harvest becomes more calculable. Considering the full length of the growing period, I obtained 72 days in the average of the three years. The beginning of harvest, compared to the control (V2), as a result of the technological elements applied, occurred 23 days earlier in the average of the years 2006-2008, but in 2007, when there was a favourable year from the point of earliness, this earliness was 28 days.

The seeds of the **uncovered treatment sown in the 2nd decade of April at a date traditionally used both in the case of field and sweet corn (V2) considered as control** had a stable emergence in 9 days in the average of the experimental years. Also the growing period measured in days was most stable with this treatment and also the most securely predictable (81 days). The growing period measure in days as seen by me was somewhat different from that of 85 days determined by the Central Agricultural Office. In my opinion, the reason could be that, in contrast to the variety comparison trials of the Central Agricultural Office, the experiment was carried out on a sandy soil with low humus content and as a result of the quicker warming up of the soil the growing period expressed in days was reduced.

The emergence of seedlings occurred after 8 days in average with the **covered treatment (TV2) planted at the later date**, i.e. the cover did not have any significant effect. The vegetative period took 59 days in the average of the experimental years. This period took 69 days in response to an unfavourable year (2006), i.e. this treatment had the greatest fluctuation in the vegetative period measured in days among the treatments of the later propagation date. The beginning of picking also took place 4 days earlier, similarly in the average of -2006-2008, compared to the control (V2).

The vegetative period of **the uncovered treatment (P2) planted at the later date**, was short, only 47 in average. After outplanting the absolute growing period was 65 days in average, whereas the beginning of picking took place 16 days earlier in the average of the three years, compared to the control (V2), practically independently from the effect of the year.

In the average of the three years the length of the vegetative and generative periods of **the covered treatment (TP2) planted at the later date**, was substantially the same as the data seen in the case of the above mentioned treatment (P2). Comparing the emergence time of the direct seeded treatments with those described in the literature, according to Long (1988) the emergence time of seeds not presoaked is 7-10 days, I reached a basically similar conclusion after the experiment was completed.

Independently from the year, the beginning of picking in the two treatments occurred in 65 days in average from the outplanting date. According to my findings, the (absolute) growing period measured in days was the shortest in the case of the above mentioned two treatments (P2, TP2). The fleece cover did not have any influence on the growing periods, compared to one another, of the treatments planted at the later date (P2 and TP2).

<u>Estimation of onset of harvest using heat unit calculation methods</u>

In the estimation of the growing period by heat unit calculation I considered the heat sum demand of 760°C, seen in US experiments, to be the basis. My investigation comprised the heat sum requirements of the plants in the uncovered treatments direct seeded at two different dates (V1 and V2).

The heat sum requirement calculated by the method which I call *Traditional* is 575°C in the average of 2006-2008 in the case of the treatment V1: The fluctuation is, on the other hand, 61°C (547-608°C) depending on the year. Using this method I saw a difference of 185°C compared to the US data. Considering the fact that the daily heat unit increase can be as high as 10-15 (-18)°C in the period of ripening, this method can result in a 13-19 day difference in the estimation of onset of harvest.

Studying the heat sum requirement of the treatment V2, the calculated heat sum in the average of the years of the experiment is 610°C. According to my observations the application of the traditional method showed a fluctuation of 91°C (569-660°C) in the treatment V2 depending on the year. The difference compared to the measurements carried out in the US (760°C) is 150°C. The difference is already somewhat smaller in the case of the later sowing date, but is still rather considerable and may result in a 10-15 day modification in the estimation of onset of harvesting.

By the application of the calculation method which I call *Improved*, the calculated Heat sum requirement of the uncovered treatment sowed at the earlier date (V1) was 652°C in the average of the years of the experiment (2006-2008). The difference in the result of the calculation compared to the data (760°C) in the variety description can again be considered as significant (108°C). Similarly, a significant shift occurred in the estimation relative to the end of the growing period. The highest fluctuation measured for the treatment, depending on the year, was 49°C (631-680°C).

The average of the heat sum of the uncovered treatment V2 sown at the later date which can be considered as traditional in the casa of maize was 656°C. This time the difference compared to the value provided in the variety description (760°C) was 104°C. Within the method, the difference in the heat sum in the case of the treatment V2, depending on the year, was 54°C (632-686°C). The difference compared to the measurement data from the US was practically the same in the control treatment (V2) as in the treatment (V1) where the measured heat sum difference was again 104°C.

Using the third, the so-called *CERES-Maize* method, the heat sum of the plants of the uncovered treatment sown at the earlier date (V1) was 631°C, which could be considered considerable and a difference of 129°C could be seen as compared to the US observations (760°C). The fluctuation between the years was also significant within the treatment V1. It was 88°C (599-687°C).

The heat sum of the plants of the uncovered treatment sown at the later date, calculated using the (648^{o}C) *CERES-Maize* model was substantially the same as the result calculated with the improved method (656^{o}C). The greatest fluctuation between the years was seen in the treatment V2. It was 99^{o}C (608-707^{o}C). This difference can be attributed to the fact that the heat sum calculated in the (warm) year 2007 was 707^{o}C which was the nearest to the value 760^{o}C provided as reference.

According to the experiences from using the heat sum calculation models, the *Improved* and the *CERES-Maize* methods provided basically identical heat sum requirements for the uncovered treatment sown at the later date (V2). At the same time, in the case of the treatment sown at the earlier date (V1) rather different results were seen. According to my observations, the considerable differences were due to the fact that the models give reliable results, as indicated by the sources from the literature, when the heat fluctuations and the base temperature of the given area are determined correctly. Otherwise, the models have difficulty in dealing with the effect of low temperature. Another possible explanation is that in the case of the Central Agricultural Office the time of sowing is the first or second decade of May and in this period corn plants will already develop from the beginning and are rarely affected by low soil or air temperatures. At the same time, the daily temperature fluctuation is also much lower in this period, as opposed to the sowing date in the first decade of April.

Contrary to the date from the literature, according to the observations from the trial between 2006-2008 the growing period in days was a more reliable indication to determine the onset of harvest than the growing period calculated on the basis of the heat sum.
My experiences from the experiment confirm the conclusion that the growing periods of different varieties show considerable variations in different geographical areas.

The observations of the literature on the stability of the generative period and on the variability of the vegetative period correspond with the results of my experimental observations. The period elapsed from 50% female flowering to the onset of harvest was substantially permanent depending on the year but independently from the treatment.

According to my findings, considering the models used for heat unit calculation, in order to forecast the onset of harvest as precisely as possible, it would be advisable to determine the suitable base temperature as appropriate for the Hungarian production conditions also for sweet corn variety types (similarly to field corn).

At the same time, for a proper comparison, it would be necessary to find out what kind of ecological conditions the areas in the US had where the heat sum requirements reported in the variety descriptions were measured.

Effect of treatments on plant morphological characteristics

Analysing the date taken together (using their mean) I saw that the direct seeded treatments (V1, TV1, V2, TV2), independently from the date of propagation and from the cover, developed significantly longer tassels in the average of the experimental years than the treatments propagated by seedlings (TP1, P2, TP2) (at $p<0.01$ level). In an unfavourable year (2006) tassel length was below 40 cm, regardless of the treatment, whereas in a warm year (2007) it was as great as that or very near to it.

Relative to stem diameter, an important characteristic of plant resistance to wind damage, according to my observations, the direct seeded uncovered treatments (V1, V2) had the most favourable stems. Compared to the covered direct seeded treatments (TV1, TV2) the difference measured in stem diameter was not significant, but in the case of the transplanted treatments (TP1, P2, TP2) the level of the abovementioned difference was also statistically demonstrably, significantly higher (at $p<0.01$ level). The tendency detected was observable independently from the year and variation was only seen in the level of the difference.

Analysing the measurement results of ear junction height I reached similar conclusions to that of the stem diameter, i.e. in the direct seeded treatments (V1, TV1, V2, TV2) the junctions of the ears were situated significantly higher in the average of the experimental years (2006-2008) than in the transplanted treatments (TP1, P2, TP2). I note that in the year 2006, considered as unfavourable, the ears, independently from the treatment, were joined to the stem at a lower height than required by machine harvest conditions. In a warm year (2007) the ears of the covered transplanted treatments planted at the later date (P2, TP2) and in a year with favourable rainfall distribution (2008) also the ears of the transplanted covered treatments (TP1, TP2) reached the junction height of 40 cm prescribes as indispensable for machine harvest.

Examining the average of the data of final plant height over 2006-2008, as opposed to what had been expected, it was seen that the height of the covered treatment direct seeded at the earlier date (TV1) was superior to the average height of the other treatments. The plants of the uncovered control treatment direct seeded at the later date (V2) were smaller in the average of the three experimental years than the plants in the treatments outplanted at the same date (P2, TP2).

Relative to the morphological parameters examined, except for plant height, considering the average of the three years, it can be concluded that direct seeding had a favourable effect. I had favourable experiences also with the effect of covering and transplanting on plant height.

Effect of treatments on morphological characteristics of ears

The direct seeded propagation method had more favourable influence on unhusked ear weight than seedling raising. The highest mean weight in the average of the experimental years (2006-2008), on the other hand, was measured for the samples of the covered treatment direct seeded at the earlier date (TV1), which according to my statistical calculations was significantly favourable at $p<0.01$ confidence level, except for the control treatment (V2), compared to the other treatments. The 245 g average weight indicated on the basis of the variety comparison trails was successfully reached in the average of 2006-2008, except for the covered treatment planted at the earlier date (TP1) and the uncovered treatment planted at the later date (P2). The treatment TP1 produced lower weights in 2006 and in 2007, whereas in a favourable year (2008) an average weight of 300.8 g was obtained. A basically similar tendency was observable in the case of the treatment (P2). In the evaluation of the results of unhusked ear weight, on the other hand, it is advisable to pay attention to the fact that these two treatments (TP1, P2) are highly exposed to the inclemency of weather.

The favourable effect of cover on unhusked ear weight was detectable not only at the earlier but also at the later propagation date (TV1, TP2).

The effect of the treatments on husked ear weight was characterized by a substantially similar trend to that of the unhusked ear weight, naturally calculating with the appropriate proportions after husking.

The average full ear size of 19.6 cm reported in the variety description was not achieved in the average of the three experimental years (2006-2008). The longest average lengths were characteristic to the average samples of the direct seeded covered treatment (TV2) sown at the later date and the ones of the direct seeded covered treatment (TV1) sown at the earlier date. The average length of 19.6 cm was achieved only in one year, in the war and dry 2007 by the treatment TV2. The explanation probably consists in the fact that the variety comparison trials are sown somewhat later (in early and middle May) when plants are rarely affected by adverse temperatures.

In the ear lengths set with healthy grains suitable for consumption I observed a similar tendency to that characterizing the total ear length, i.e. the highest ear set was shown by the ears of the covered treatment (TV1) sown at the earlier date and the ones of the direct seeded covered treatment (TV2) sown at the later date. On the other hand, when comparing the ratio of total ear length and set length, the most favourable proportion in the average of the experimental years (2006-2008) was observed in the case of the covered treatment (TP1) planted at the earlier date.

Evaluating ear diameter and grain lengths, I reached the conclusion that the results were most favourable in the case of the direct seeded covered treatment (TV1) sown at the earlier date and the direct seeded uncovered control (V2) sown at the later date. i.e. the greatest ear diameter was accompanied by the longest grains. At the same time, a favourable average grain length can be reported in the case of the covered treatment (TP1) planted at the earlier date, where a smaller ear diameter was set with long grains. A similarly favourable effect was seen in the case of the covered treatment (TV2) sown at the later date and the uncovered treatment (V1) sown at the earlier date, where a smaller ear diameter was set with shorter grains, but on the whole a favourable proportion was obtained. Of the earliness enhancing technological elements, according to my observations, the application of cover had positive effect on ear diameter and grain length and on the favourable proportion of these two parameters.

The theoretically planned yield of 16 t/ha was reached or surpassed in the average of the three experimental years by two treatments: in the case of the covered treatment (TV1) sown at the earlier date and the uncovered control (V2) sown at the later date. The application of cover at the later propagation date had clearly positive effect on yields, as a calculated average yield of 15.7 t/ha and one of 15.2 t/ha were achieved in the case of the treatments sown (TV2) and planted (TP2) at that time.

<u>Effect of treatments on composition parameters of grains</u>

Based on the experiences from the three experimental years (2006-2008) the treatments did not have any significant effect on reducing sugar content (level of simple sugars). The use of transplants had favourable effect on the level of simple sugars (glucose, fructose etc.) in both propagation times (TP1, P2, TP2), while the application of cover had more favourable influence at the earlier date of propagation. On the other hand, when the year was unfavourable (2006), the grains of the control treatment (V2) had the highest reducing sugar content (2.8%). Compared to certain data (1%), the reducing sugar content was higher in each case, while based on results published by other authors (2.3-3.2%) these average values were only reached by the covered treatment (TP1) planted at the earlier date (2.2%) and the others only managed to come close (1.8-2%).

Analysing the results of total sugar content I found that the covered treatment (TP1) planted at the earlier date was significantly superior to the results of the other treatments, but at the same time was significantly inferior to the interval found in the literature (21-29.6%). According to my opinion, its explanation consists in that the publication found in the literature referred probably to super sweet varieties. I did not manage to find any statistically demonstrable difference between the total sugar contents of the other treatments. Also, no clear conclusion could be drawn on the effect of the earliness enhancing technological elements and therefore further experiments would be necessary.

According to the data in the national literature the average vitamin C content of grains is 7 mg/100g (calculated per fresh weight). Except for the covered treatment (TV2) sown at the later date, higher levels were detected in the grains of the other treatments in the average of the 3 years (7.1-9.4 mg/100g), but I must note that the values were lower in the first experimental year (4.2-6.6 mg/100g). The highest vitamin C content characterized the average samples of the grains of the uncovered treatment (V1) and the covered planted treatment (TP1). In a favourable year (2008) significantly higher vitamin C contents (14.3 and 14.7 mg/100g) could be measured in the case of the aforementioned treatments (TP1) and (V1). According to my findings, the early propagation date has favourable effect on the vitamin C content of sweet corn.

Among the earliness enhancing technological elements, the later propagation date and the application of cover and the use of seedlings at the earlier date have favourable effect since the highest carotinoid content was detectable in the samples of the control (V2), the P2 and the TP1 treatments, considering the average of the experimental years (2006-2008).

Income and cost model

Considering the average of the three years, the highest average net income (additional income – costs of plastic cover and/or seedlings), compared to the control treatment (V2), was produced by the covered plants transplanted in early April designated as TP1, but also favourable results were produced by the covered and uncovered treatments planted at the later date (around April 20) (of the latter two the covered produced a higher income but it was only enough to meet the costs of the application of cover).

New or novel scientific results

From the investigations carried out over the years 2006-2008 I reached the following scientific conclusions which are also applicable in the practice:

1. None of the three heat unit calculation methods (traditional, CERES-Maize, improved) confirmed the heat sum of 760°C required till the beginning of harvest of the variety Spirit, based on US measurements and reported in the variety catalogue, but significant difference was seen between the experience gathered under local condition and the US measurement data.
2. The *CERES-Maize* and the *Improved* heat unit calculation methods show substantially similar results and therefore both methods are equally suitable for the determination of the heat sum requirements of sweet corn varieties under the production conditions of Hungary, but heat requirement assessment using the *Traditional* method is less precise.
3. The length of the growing period expressed in days is a more reliable basis for forecasting the onset of harvest of the normal sweet hybrid corn variety Spirit than the nowadays used assessment methods based on heat sum.
4. I did not observe any significant diminishment in composition quality (sugar content, vitamin C content, carotinoid content) in response to the application of earliness enhancing technological elements, in contrast to the generally expressed opinions, according to which the early ears have lower composition characteristics compared to the eats from mass production.
5. In the case of the direct seeded treatments, independently from the time of sowing, the plants grown under the small tunnel covered with fleece ha excellent morphological characteristics (favourable stem diameter, ear height) and also the ears had very good morphological characteristics, considering unhusked ear weight, husked ear weight, total length, set length, grain length and total yield.
6. As a result of the combination of the earliness enhancing technological elements applied, the onset of harvest occurred 6 days earlier in the case of the uncovered treatment sown at the early date, 10 days earlier in the case of the covered direct seeded treatment, 23 days earlier in the case of the covered transplanted treatment, 4 days earlier in the case of the covered treatment sown at the later date and 16 days earlier in the case of both the uncovered and covered transplanted treatments, compared to the control treatment.

7. In the case of the variety comparison trials of very early or early varieties, which go for the fresh market and for the first deliveries to the processing industry, I recommend that the currently used sowing date in May should be changed for the 2^{nd} and 3^{rd} decades of April, similarly to the practice of production.

Conclusions and recommendations

Considering the mean results of the experiments between 2006 and 2008 relative to the earliness enhancing effect of the treatments applied to the effect on plant and ear morphological characteristics and on grain composition values, I made the following conclusions:

The longest growing period measured in days (absolute) was recorded in the case of the **uncovered treatment (V1) sown at the earlier date**. Compared to the absolute growing period of the covered treatment (TV1) sown at the same date, the growing period and the onset of harvest became 4 days longer. Compared to the control treatment (V2), the absolute growing period was 9 days longer, still the onset of harvest occurred 6 days earlier.

The growing period of the **covered treatment (TV1) sown at the earlier date** was the same as the 85 days measured in the variety comparison trials of the Central Agricultural Office, but at the same time the onset of harvest occurred 10 days earlier in the average of the three experimental years than with the plants of the control treatment (V2).

The growth of the vegetative period of the **transplanted treatment (TP1) planted at the earlier date** was relatively stable in the average of the three years. Considering the growing period expressed in days, I measured 72 days in the average of the three years. Compared to the control (V2), the onset of harvest, due to the technological elements applied, occurred 23 days earlier in the average of the years 2006-2008, but in the case of a year (2007) favouring earliness 28 day earliness was observed.

The growing period measured in days was the most stable in the **uncovered treatment (V2) sown at the later date** and considered as the control. Therefore, the time of harvest can be predicted with the greatest security in the case of this technological variation (81 days), between July 9 and 12.

In the case of the **covered treatment (TV2) sown at the later date** the application of cover did not have any significant effect on seed emergence. The onset of harvest occurred 4 days earlier compared to the control (V2). This earliness enhancing effect, according to my findings, was due to the fleece cover.

The absolute growing period of the **uncovered treatment (P2) planted at the later date**, according to my observations, was 65 days in average, but at the same time the onset of harvest occurred 16 days earlier in the average of the three year compared to the control treatment (V2), practically independently from the effect of the year.

The length of the vegetative and generative periods of the **covered treatment (TP2) planted at the later date**, in the average of the three years, was substantially the same as the data seen with the aforementioned treatment (P2). Independently from the year, the onset of harvest of the two treatments occurred on average 65 days after the date of outplanting. According to my findings, the growing period measured in days (absolute) was the shortest in the case of the aforementioned two treatments (P2, TP2). The fleece cover had no influence of the growing period of the plants grown from seedlings planted out at the later date (P2 and TP2).

According to the experiences obtained with the heat sum calculation methods, the *Improved*, the *CERES-Maize* methods gave the same assessment for the heat sum requirement of the covered treatment (V2) sown at the later date. At the same time, quite different results were seen in the case of the uncovered treatment (V1) sown at the earlier date.

A possible explanation could be the different sowing date used in the variety comparison trials (first or second decade of May). In this period the sweet corn grows already from the very beginning and is rarely exposed to low soil or air temperatures, in contrast to the sowing date in the first decade of April.

For a more precise determination of the origin of the differences, in my view, further experiments are necessary to be set up.

Plant morphological characteristics were favourably influenced in the case of the earlier propagation date by the direct seeded covered treatment (TV1) and by the uncovered treatment (V2 control) direct seeded at the later date.

Unhusked ear weight was more favourably influenced by the propagation method of direct seeding than by seedling raising. The highest average weight on the other hand in the average of the experimental years (2206-2008) was measured for the covered treatment (TV1) direct seeded at the earlier date. The favourable effect of cover on unhusked ear weigh was observable not only at the earlier, but also at the later propagation date (TV2, TP2).

In the case of the husked ear weight the findings were substantially the same as the tendency of the unhusked ear weight.

The average full ear size of 19.6 cm reported in the variety description was not achieved in the average of the three experimental years (2006-2008). The longest average lengths were characteristic to the average samples of the direct seeded covered treatment (TV2) sown at the later date and the ones of the direct seeded covered treatment (TV1) sown at the earlier date.

In the ear lengths set with healthy grains suitable for consumption, which is important for a good market appearance, I observed a similar tendency to that characterizing the total ear length, i.e. the highest ear set was shown by the ears of the covered treatment (TV1) sown at the earlier date and the ones of the direct seeded covered treatment (TV2) sown at the later date.

Evaluating ear diameter and grain lengths, I reached the conclusion that the results were most favourable in the case of the direct seeded covered treatment (TV1) sown at the earlier date and the direct seeded uncovered control (V2) sown at the later date. i.e. the greatest ear diameter was accompanied by the longest grains. At the same time, a favourable average grain length can be reported in the case of the covered treatment (TP1) planted at the earlier date, where a smaller ear diameter was set with long grains.

The theoretically planned yield of 16 t/ha was reached or surpassed in the average of the three experimental years by two treatments: in the case of the covered treatment (TV1) sown at the earlier date and the uncovered control (V2) sown at the later date. The application of cover at the later propagation date had clearly positive effect on yields, as a calculated average yield of 15.7 t/ha and one of 15.2 t/ha were achieved in the case of the treatments sown (TV2) and planted (TP2) at that time.

In the analysis of grain composition parameters, based on the experiences from the three experimental years (2006-2008), it can be concluded that the treatments did not have any significant effect on simple sugar levels. The use of transplants had favourable effect on the level of simple sugars in both propagation times (TP1, P2, TP2), while the application of cover had more favourable influence at the earlier date of propagation.

Analysing the results of total sugar content I found that the covered treatment (TP1) planted at the earlier date was significantly superior to the results of the other treatments. No clear conclusion could be drawn on the effect of the earliness enhancing technological elements and therefore further experiments would be necessary.

The highest vitamin C content was found in the average samples of the grains of the uncovered treatment (V1) and the covered planted treatment (TP1). In a favourable year (2008) significantly higher vitamin C contents (14.3 respectively 14.7 mg/100g) could be measured in the case of the aforementioned treatments (TP1) and (V1). According to my observations, the early propagation date has favourable effect on the vitamin C content of sweet corn.

Considering the average of the three years, detracting the major accompanying costs from the calculated net income per hectare, it can be concluded that the transplanted production technologies applied in the treatments TP1, P2 and TP2 can be recommended for test on a greater area, for the practice of production.

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4. **Orosz F.**- Ferenczy A.- Slezák K. (2007): A fátyolfóliás takarás hatása a helyrevetett csemegekukoricára. Kertgazdaság, 39 (3), 3-8.
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