



UNIVERSITY OF DEBRECEN
CENTRE OF AGRICULTURAL SCIENCES
FACULTY OF AGRONOMY
DEPARTMENT OF CROP PRODUCTION AND APPLIED ECOLOGY

DOCTORAL SCHOOL OF
CROP PRODUCTION AND HORTICULTURAL SCIENCES

Head of Doctoral School:

Dr. Zoltán Győri
Doctor of the Hungarian Academy of Sciences

Supervisors:

† Dr. László Ruzsányi
Doctor of the Hungarian Academy of Sciences

Dr. Mihály Sárvári
Candidate in Agricultural Sciences

Theses of PhD dissertation

**EFFECT OF FOLIAR TREATMENTS ON
THE SUGAR YIELD OF SUGAR BEET**

By:

Lajos Varga
candidate for PhD

DEBRECEN

2005.

1. INTRODUCTION, AIMS

Sugar is a basic food, which has been known for about 2000 years. Today, the total sugar production of the world is 146 million tons. 75% of the total production is made from sugarcane and 25% from sugar beet. The sugar beet production area is of 6 million ha.

The mission of the Hungarian sugar production is to supply the Hungarian market with high quality sugar. The harvested area of sugar beet is around 50-60 thousand ha, which is 1.3-1.5 of the total arable land.

In the last few years, there were significant changes in the sugar sector in Hungary both in processing and production. The harvested area and the number of operating sugar factories have been halved, the owner structure of sugar companies and the growers has changed.

When comparing yields obtained in Hungary with yields in Western European countries it can be concluded that we are lagging behind.

The main task of Hungarian sugar beet production - considering ecological factors – is to increase sugar yield and to ensure yield stability.

The yield of sugar beet, its sugar content and the amount of molassogenic substances greatly depend on ecological factors and production site that can not be influenced or only by great costs. Among production factors, the plant homogeneity, plant protection, fertilization and irrigation are the most important.

Within plant protection, the role of protection against leaf diseases is significant, because cercospora and powdery mildew are the most frequent leaf diseases of sugar beet that regularly cause damage, therefore, protection against these is an integral part of the production technology.

Among the eight agent groups registered for use against leaf diseases in sugar beet, the most important ones are morpholines, triazoles and strobilurines, the latter being the newest agent group. Advantages of this group are the wide effectiveness and low toxicity. Besides these, bioactive side-effects have also been reported.

Foliar fertilization may play an important role in the application of low amounts of nutrients, supplementation of temporary deficiencies and stimulation of physiological processes. Their combined application with plant protection treatments can be reasonable, because the yield increase is coupled with only minimal cost and the application has multiple refund.

The aim of my study was to examine the effect of fungicides and nutrients as foliar treatments on sugar beet. The analyzed results were obtained from small and large plot trials.

The aim of the investigations was to evaluate the differences in quantity and quality between the results of treatments and to make some supplementary examinations.

I did not aim to examine the plant protection effects of these fungicides, but only the bioactive side effects.

Therefore, the control plots, which were not treated with fungicides, were not evaluated and we assessed the leaf disease rate of sugar beet several times during the vegetation period.

In the large plot trials, I examined the effect of treatments on beet yield, sugar content, sugar yield, molassogenic substances, sugar loss, gross and net sugar yield in both years. In 2001, samples were taken several times on the basis of which I studied the growth dynamics of root weight, sugar content and sugar yield.

In the small plot trials, I examined beet yield, sugar content, sugar yield, molassogenic substances, sugar loss, gross and net sugar yield. There were supplementary examinations: we measured the photosynthetic activity and leaf area during the vegetation period.

2. MATERIALS AND METHODS

2.1. Large plot trials

I investigated the effect of fungicides and nutrients in 4-4 large plot trials in the Danube – Tisza and the Tiszántúl regions in 2001-2002. Among experimental sites, we could only evaluate the results in both years in Cegléd. Trials were set up in Nagyhalász, Hajdúböszörmény, Cegléd and Jászapáti in 2001 and in Kiskunlacháza, Tápiószentmárton, Cegléd, Szentes in 2002.

2.1.1. Treatments

In the large plot trials, we investigated two fungicides, Tango (epoxiconazole+tridemorph) and Juwel (epoxiconazole+kresoxim-methyl) and Epsom salts.

The plot size was 2 ha. Fungicides were sprayed with 400 l ha⁻¹ water by using a field sprayer.

The fungicides were applied two times, in the beginning of July and August, the magnesium application was performed in the beginning of June at leaf closing time, and in the beginning of July in combination with fungicides.

The applied dosages of Epsom salts, Tango and Juwel were 10 kg ha⁻¹, 0.9 ha⁻¹ and 1.0 l ha⁻¹. Treatments and dates of application are shown in Table 1.

Table 1. Treatments of large plot trials, 2001-2002

<i>Number of treatment</i>	<i>1-10 June</i>	<i>1-5 July</i>	<i>1-5 August</i>
1.	-	Tango	Tango
2.	MgSO ₄	MgSO ₄ + Tango	Tango
3.	-	Juwel	Tango
4.	-	Tango	Juwel
5.	MgSO ₄	MgSO ₄ + Juwel	Tango

2.1.2. Weather conditions

The temperature of the vegetation period was higher than the average in both years, which was not favourable for sugar beet, especially in those periods, when high temperature was accompanied with low precipitation. Regarding the weather in 2001, it can be concluded that the amount of precipitation was around the average of 30 years, but its distribution was not even. In 2002, the precipitation of the vegetation period of all 4 sites corresponded to the average of 30 years, but from January to October it was below the average, which is a consequence of low precipitation of the first months of the year and vegetation period.

2.1.3. Soil and agrotechnical parameters

Soil properties of the experimental sites were diverse, from different types of chernozem to meadow and alluvial soils. The nutrient supply of the soils was satisfactory.

The forecrop was winter wheat and the basic soil preparation was ploughing at all sites. The sowing was performed between 27 March-7 April with 1.25-1.6 U seed norm. Harvesting was done in one round between 28 October-9 November in 2001, and between 17 and 25 October in 2002.

2.2. Small plot trials

The small plot trials were set up in randomised blocks with four repetitions in Hajdúböszörmény in 2002-2003.

2.2.1. Treatments

In our trials, we examined two fungicides with strobilurin active ingredient: Juwel (epoxiconazole + kresoxim-methyl) and Sfera (trifloxystrobin + cyproconazole). The spraying was performed two times by using 450 l ha⁻¹ water in the beginning of July and August with a handheld sprayer. The standard control plots were treated with Tango (epoxiconazole + tridemorph) (Table 2.). The application rate of Juwel and Tango was 1 l ha⁻¹, the application rate of Sfera was 0.75 l ha⁻¹. The applied amount of Epsom salts and potassium-chloride was 10 kg ha⁻¹. Nutrients were applied in combination with fungicides. The plot size was 40.5 m².

Table 2. Treatments and application dates

<i>Treatments</i>	<i>First treatment</i>	<i>Second treatment</i>
	07.03.2002 07.05.2003	08.01.2002 08.05.2003
1. Tango	+	+
2. Juwel	+	+
3. Sfera	+	+
4. Tango + magnesium sulfate	+	+
5. Juwel + magnesium sulfate	+	+
6. Sfera + magnesium sulfate	+	+
7. Tango + potassium chloride	+	+
8. Juwel + potassium chloride	+	+
9. Sfera + potassium chloride	+	+

2.2.2. Weather conditions

The average temperature in the vegetation period (III.-X.) of sugar beet in 2002 ranged about the average of 30 years, but was significantly higher than the average of 30 years in 2003. Between March and October in 2003, there were 85 days when the daily average temperature reached or exceeded 20°C. There were only 49 such days in 2002.

The precipitation in 2002 was 42.2 mm higher than the average of 30 years. The distribution of the rain was not optimal because of the low precipitation in the autumn-spring period before the vegetation period. In the vegetation period of sugar beet in 2003, the precipitation was lower than the average with the exception of July, September and August.

2.2.3. Soil properties and the main agrotechnical features of the trials

The soil of the experiment was chernozem in both years. The nutrient supply of the soil was satisfactory and the water management properties were also favorable. The forecrop was winter wheat and the fall tillage was ploughing in both years. NH_4NO_3 was applied in both years with a dosage of 64 kg nitrogen per hectare. The sowing was made between 29-30 March in 2002, and between 5-6 April in 2003. The seed norm was 1.4 U unit. The variety was Delphine in 2002 and Goldorak in 2003 that are rhizomania tolerant hybrids. The harvest was carried out by hand between 28-29 October in 2002 and between 12-13 October in 2003.

2.3. Examinations

The beet samples were analysed in the sugar factory by an analysing line of VENEMA company. Determination of sugar content was done by a Saccharomat automatic saccharometer. Potassium and sodium contents were measured by flame photometry, the amino-nitrogen content was determined by photometry.

For measuring photosynthetic activity, a LICOR LI-6400 portable photosynthetic measuring device was used, the leaf area was determined by a LICOR LAI-2000 device.

2.4. Evaluation methods

The obtained data were transferred to computer, for their evaluation the MS Excel program was used.

In the dissertation, the measured sugar content means sugar content that was determined by the laboratory of the sugar factory, extractable sugar content was calculated with the Reinefeld formula (REINEFELD et al., 1974). Gross sugar yield was calculated by multiplying measured sugar content with beet yield, while net sugar yield is the result of multiplying extractable sugar content with beet yield.

Data were processed by single- and double factor analysis of variance, correlation analysis and linear regression. The statistical processing was performed using the SPSS 9.0 for Windows program and the methods of SVÁB (1967) were also taken into consideration.

3. RESULTS

3.1. Evaluation of the effect of fungicides and magnesium on sugar beet in large plots trials

3.1.1. Yield

The average beet yield of the four experimental sites was (67.9 t ha^{-1}) in 2001. In the average of treatments, the lowest beet yield was obtained at Hajdúböszörmény (57.6 t ha^{-1}), and the highest beet yield was measured at Jászapáti (76.0 t ha^{-1}).

Comparing those treatments in all four experimental sites, in which the difference between treatments was the additional magnesium application, Tango combined with magnesium gave a higher beet yield than the Tango application without nutrient at three sites (Hajdúböszörmény, Cegléd, Jászapáti). The Juwel - Tango+magnesium application showed a positive effect on yield at three sites (Nagyhalász, Hajdúböszörmény, Cegléd). In the case of Juwel treatments (treatments 3-4) at Hajdúböszörmény, Cegléd, Jászapáti the yield was higher compared to treatments with Tango (treatment 1). At the earlier and later applications of Juwel (treatments 3-4), no obvious tendency was detectable. At Nagyhalász and Hajdúböszörmény, the later application of Juwel, while at Cegléd and Jászapáti the second application gave a higher beet yield.

In the average of the four sites, the lowest and highest yield was obtained in treatment 1 and treatment 5, respectively. Magnesium increased yield with 1.4 and 1.8 t ha^{-1} on average in treatments 1-2 and 3-5. Among fungicides, treatments with Juwel gave higher yields.

In 2002, the average beet yield of the four sites and the treatments was 58.6 t ha^{-1} . The highest yield (70.6 t ha^{-1}) was obtained at Kiskunlacháza in the average of treatments. The yield at Cegléd was almost equal to that of Kiskunlacháza (70.4 t ha^{-1}), but the yield was significantly lower in Tápiószentmárton (51.8 t ha^{-1}) and Szentes (41.5 t ha^{-1}).

At Tápiószentmárton and Szentes, where the average yield level was the lowest, the application of magnesium increased beet yield in both treatment pairs (1-2, 3-5), this increase was the highest at Szentes. At Kiskunlacháza, the additional application of magnesium increased yield in treatments 1-2. We experienced a decrease in treatments 3-5 and at Cegléd in both treatment pairs.

When comparing treatments 1, 3 and 4, both the earlier and later applications of Juwel increased beet yield at Tápiószentmárton and Szentes, we observed a higher yield in treatment 3 and a lower yield in treatment 4 compared to treatment 1 at Kiskunlacháza. In both treatments, we measured lower yields at Cegléd. We registered higher beet yield at all four sites when Juwel was applied in the beginning of July.

Examining the treatments in the average of four experimental sites, we concluded that the lowest yield was obtained in treatment 1 and the highest in treatment 5. The additional magnesium application in both treatments 1-2 and 3-5 increased yields, more significantly in the case of Tango application. When comparing results of treatments 1, 3 and 4, in which Juwel was applied, the yield was higher than in the average of treatment 1. We obtained a higher yield by applying Juwel in the beginning of July than by the later application.

3.1.2. Changes in sugar content

The average sugar content of trials at harvest time was 16.00% in 2001. The highest sugar content (17.70%) in the average of treatments was measured at Nagyhalász. The average sugar content was 16.65% at Hajdúböszörmény, 15.05%, at Cegléd and 14.61% at Jászapáti.

Summing up, it can be stated that the highest sugar content at three out of four experimental sites was provided by the application of Tango in the beginning of July and the application of Juwel in the beginning of August (Hajdúböszörmény, Cegléd, Jászapáti). The lowest sugar content values were obtained at three experimental sites (Nagyhalász, Hajdúböszörmény, Jászapáti) when Tango was applied twice.

Application of magnesium in treatments 1 and 2 increased sugar content at three experimental sites (Nagyhalász, Hajdúböszörmény, Jászapáti), at Hajdúböszörmény and Jászapáti significantly. The sugar content was lower on plots treated with magnesium than on plots without nutrient treatments at Cegléd, but the difference was not statistically significant. Comparing the results of treatments 3 and 5, the application of magnesium decreased sugar content at three sites, and increased it at one site, but not significantly.

Among treatments 1, 3 and 4, treatments 3 and 4 gave a higher sugar content than it was in treatment 1, the difference was significant at $P=5\%$ at Hajdúböszörmény and at $P=10\%$ at Jászapáti.

The value of sugar content was lower in treatment 3 at Cegléd than in treatment 1 and it was significantly higher in treatment 4.

The application of Juwel at the second date gave a higher sugar content in treatments 3 and 4 at three experimental sites (Hajdúböszörmény, Cegléd, Jászapáti), but it was statistically significant only at Cegléd.

The lowest sugar content was measured in treatment 1 and the highest in treatment 4 in the average of the results of the four experimental sites. The sugar content was higher in treatments with Juwel than in treatments with Tango. The application of magnesium with application of Tango two times increased sugar content significantly, but magnesium combined with Juwel – Tango slightly decreased the sugar content. The application of Juwel at the second date provided higher sugar content in treatments 3 and 4.

The sugar content of sugar beet was 15.01 % in the average of sites and treatments in 2002, which was 0.99% lower, than the average of sugar content in 2001. Sugar beet with the highest sugar content was harvested (16.17%) in the average of treatments at Kiskunlacháza, and with the lowest sugar content (13.69%) at Cegléd.

It can be concluded that we obtained significant differences in sugar content at three sites out of four. At all four sites, the lowest sugar content was measured when Tango was applied twice. Application of Tango at both application dates combined with magnesium increased sugar content in all experiments, the increase was significant at two places (Tápiószentmárton, Szentes).

The sugar content was increased by application of Juwel with magnesium at three sites (Tápiószentmárton, Cegléd, Szentes), which effect was significant at Tápiószentmárton. The sugar content decreased slightly, but not significantly at Kiskunlacháza.

Application of Juwel resulted in a higher sugar content at all four sites than that of Tango.

The application of Tango at the first and that of Juwel at the second date gave a higher sugar content at three sites (Kiskunlacháza, Tápiószentmárton, Cegléd) between treatments 3 and 4 than the application of Juwel at the first and Tango at the second date. The difference between these treatments was significant at Tápiószentmárton.

Examining the treatments in the average of the four experimental sites, sugar beet with the lowest and highest sugar content was harvested in treatments 1 and 4, respectively. The additional magnesium application increased sugar content also in treatments 1-2 and 3-5. The application of Juwel at the second date yielded a higher sugar content between treatments 3 and 4.

3.1.3. Molassogenic substances of sugar beet

In treatments 3 and 5 in trials set up in 2001, we found that potassium content decreased in treatment 5 compared to treatment 3, but this decrease was statistically significant only at Cegléd. The additional application of magnesium resulted in lower potassium content at three sites (Nagyhalász, Hajdúböszörmény, Cegléd) in treatments 1-2, while higher values were obtained at Jászapáti, but these changes were not significant. The earlier or later application of Juwel did not change the potassium content.

There were significant differences in potassium content between treatments at Tápiószentmárton and Szentes in 2002. The additional use of magnesium resulted in a higher potassium content in treatments 1-2 at two sites (Tápiószentmárton, Cegléd), and there was a lower potassium content at two sites (Kiskunlacháza, Szentes). The application of magnesium significantly decreased potassium content in treatments 3 and 5 at Tápiószentmárton and Szentes. Comparing treatments 1, 3 and 4, the treatments with Juwel decreased potassium content of beet at Kiskunlacháza and Szentes, but the treatments increased potassium content at Tápiószentmárton and Cegléd. The potassium content of beet was lower when Juwel was applied on the second date at three places (Tápiószentmárton, Cegléd, Szentes), at Tápiószentmárton and Szentes significantly.

Comparing treatments 1, 3 and 4, we found that the sodium content was lower at all sites in 2001 if we applied Juwel earlier or later instead of two Tango applications. The reduction was significant at Hajdúböszörmény and Jászapáti. In the case of a later Juwel application, the sodium content was the lowest at three sites, but the differences were not significant. Application of magnesium in treatments 1-2, reduced sodium content of the beet, in two cases significantly. Magnesium application reduced and increased sodium content in treatments 3 and 5 at two and two sites, respectively.

There were no significant differences in sodium content in 2002. The lowest sodium content was in treatment 1 at harvest time at Kiskunlacháza, Cegléd and Szentes with the exception of one treatment. The application of magnesium reduced sodium content at Tápiószentmárton and increased it at the rest of the sites in treatments 1-2. We obtained higher and lower sodium contents at two and two sites in treatments 3 and 5, respectively.

The application of Juwel at the second date reduced the sodium content at three sites (Kiskunlacháza, Tápiószentmárton, Cegléd).

Examining the results of the four sites in 2001, it can be concluded that every treatment reduced amino-N content of beet compared to treatment 1 at Nagyhalász and Hajdúböszörmény. The same was valid for Jászapáti with the exception of one treatment.

At the same time, the lowest amino-N content of beet was measured in treatment 1 at Cegléd. The additional magnesium application decreased amino-N content in treatments 1 and 2 at three sites, we measured a higher value in treatment 5 between treatments 3 and 5 at three sites.

All treatments at Nagyhalász and Hajdúböszörmény and all treatments excluding one at Jászapáti reduced amino-N content compared to treatment 1, but all treatments increased it at Cegléd. Significant differences were found at Hajdúböszörmény and Cegléd.

The application of magnesium in treatments 1 and 2 reduced amino-N content at three sites (Nagyhalász, Hajdúböszörmény, Jászapáti), while it increased amino-N content of beet in treatments 3 and 5 at three sites (Nagyhalász, Cegléd, Hajdúböszörmény), but it was not statistically significant.

The value of amino-N content was lower in treatment 4 between treatments 3 and 4 at three places (Nagyhalász, Hajdúböszörmény, Cegléd), but the difference was not significant.

3.1.4. Expected sugar loss during sugar processing caused by molassogenic substances

Regarding the expected sugar loss during sugar processing, the sodium content of beet showed moderate and tight correlation with losses.

The amino-N content correlated with loss at Nagyhalász, Hajdúböszörmény and Jászapáti, while the potassium content correlated with amino-N content only at Nagyhalász.

The highest absolute and relative loss was measured at three sites (Nagyhalász, Jászapáti, Hajdúböszörmény) when Tango was applied twice.

The application of magnesium resulted in a lower loss in treatments 1 and 2 at these sites, but its effect was significant only at Hajdúböszörmény.

The additional use of magnesium reduced sugar loss in treatments 3 and 5 at two places, while at one site a similar value was obtained.

Among treatments 3 and 4, we found lower losses in treatment 4 at three production sites (Nagyhalász, Cegléd, Jászapáti), when Juwel was applied at the second date (Table 3.).

Table 3. Absolute and relative losses at experimental sites (%), 2001

<i>Treatment</i>	Nagyhalász		Hajdúböszörmény		Cegléd		Jászapáti	
	<i>Absolute loss</i>	<i>Relative loss</i>	<i>Absolute loss</i>	<i>Relative loss</i>	<i>Absolute loss</i>	<i>Relative loss</i>	<i>Absolute loss</i>	<i>Relative loss</i>
T+T	2.54	14.82	2.43	15.53	2.80	18.69	3.18	23.41
T+T+Mg	2.31	12.91	2.20	13.13	3.06	20.80	2.83	19.42
J+T	2.44	13.65	2.17	12.72	3.04	20.52	2.81	19.08
T+J	2.30	12.89	2.21	12.94	2.62	16.26	2.51	16.22
J+T+Mg	2.34	13.18	2.13	12.76	3.32	22.79	2.83	19.20
Average	2.39	13.49	2.23	13.42	2.97	19.81	2.83	19.47
LSD_{5%}	0.19*	-	0.20*	-	0.44*	-	1.95	-

By evaluating the calculated, expected sugar loss during sugar processing in 2002, it can be concluded that the correlation between the absolute loss and the sodium content was moderate and tight at all sites, while the correlation between loss and potassium and loss and amino-N content was moderate and tight at one and one site, respectively.

There was a significant difference in absolute loss only at Tápiószentmárton. When examining treatments 1, 3 and 4, there was a lower absolute and relative sugar loss in treatments 3 and 4 at Kiskunlacháza and Szentes, there was a higher sugar loss in both treatments at Cegléd, and loss was higher in treatments 3 and 4 than in treatment 1 at Tápiószentmárton. Application of magnesium in treatments 1 and 2 increased and decreased sugar loss at two and two sites, respectively, while the relative loss decreased at three sites.

Table 4. Absolute and relative losses at experimental sites (%), 2002

<i>Treatment</i>	Kiskunlacháza		Tápiószentmárton		Cegléd		Szentes	
	<i>Absolute loss</i>	<i>Relative loss</i>	<i>Absolute loss</i>	<i>Relative loss</i>	<i>Absolute loss</i>	<i>Relative loss</i>	<i>Absolute loss</i>	<i>Relative loss</i>
T+T	2.88	18.72	2.60	19.13	4.46	33.38	2.68	18.54
T+T+Mg	2.73	17.14	2.43	16.34	4.71	34.52	2.71	17.77
J+T	2.84	17.33	2.98	21.41	4.69	34.16	2.65	16.67
T+J	2.84	16.88	2.07	13.47	4.55	32.64	2.59	16.38
J+T+Mg	2.73	16.75	2.27	14.79	4.52	32.80	2.74	16.65
Average	2.81	17.36	2.47	17.03	4.58	33.50	2.67	17.20
LSD_{5%}	0.22	-	0.50*	-	0.30	-	0.40	-

The absolute loss was lower in treatment 5 between treatments 3 and 5 at three sites (Kiskunlacháza, Tápiószentmárton, Cegléd), at Tápiószentmárton significantly. The relative loss was lower in magnesium treatments at all experimental sites. The relative loss was lower in treatment 4 between treatments 3 and 4 at all sites, the absolute loss decreased at three sites, at Tápiószentmárton significantly. The absolute loss was equal in both treatments 3 and 4 at Kiskunlacháza (Table 4.).

3.1.5. Results of sugar yield

In 2001, the gross sugar yield calculated on the basis of beet yield and measured sugar content was 10.78 t ha^{-1} in the average of four sites and treatments, the net sugar yield was 8.99 t ha^{-1} .

Summing up, the application of Juwel alone (treatments 3 and 4) increased both gross and net sugar yield compared to sugar yield in treatments with Tango (treatment 1) at Hajdúböszörmény, Cegléd and Jászapáti. At Nagyhalász, sugar yield was lower and higher in treatments 3 and 4, respectively, compared to treatment 1.

The application of magnesium increased gross sugar yield in treatments 1 and 2 at three sites (Hajdúböszörmény, Cegléd, Jászapáti), and net sugar yield also increased at three sites (Nagyhalász, Hajdúböszörmény, Jászapáti). In the case of treatments 3 and 5, we measured a lower gross sugar yield on plots treated with magnesium at two sites (Cegléd and Jászapáti), and a higher gross sugar yield at Nagyhalász and Cegléd. For net sugar yield, we obtained a slight decrease and increase at two and two sites, respectively.

Between treatments 3 and 4, the gross and net sugar yield was higher in treatment 4 at all sites, when Tango and Juwel were applied in the beginning of July and in the beginning of August, respectively.

The lowest sugar yield in the average of the four sites was in treatment 1, while the highest was in treatment 4. Additional application of magnesium increased sugar yield in both treatment pairs. The application of Juwel at the second date provided a higher sugar yield than the earlier application in the beginning of July.

The sugar yield was lower in 2002 than in 2001. The gross sugar yield was 8.78 t ha^{-1} in the average of the four sites and the net sugar yield was 6.88 t ha^{-1} .

The lowest sugar yield was in treatment 1 at three out of four sites, at Kiskunlacháza, Tápiószentmárton and Szentés.

At these experimental sites, the additional magnesium application increased also gross and net sugar yield in treatments 1 and 2, but it caused a minimal decrease at Cegléd. In treatments 3 and 5, we found an increase and a decrease at two and two sites, respectively.

Comparing the values in treatments 3 and 4, the earlier and later applications of Juwel increased sugar yield most effectively at two and two sites, respectively.

The lowest beet yield in the average of the four sites was in treatment 1, the highest was detected in treatment 5. Application of magnesium increased sugar yield in both treatments 1-2 and 3-5. The first application of Juwel resulted in a higher sugar yield between treatments 3 and 4, but the difference was minimal compared to treatment 4.

3.1.6. Growth dynamics of beet weight, sugar content and sugar yield

In trials set up in 2001, we studied the growth dynamics of beet on the basis of samples taken in every two weeks in the vegetation period.

The trend line drawn on the basis of measured beet weight showed that the difference in growth dynamics started at the first and second sampling times at all experimental sites. The growth intensity was higher in treatment 3 than in treatment 4 at all sites in this period. The growth of beet weight was the least dynamic in treatment 1 at three sites. The application of Tango two times with magnesium (treatment 2) produced better growth than the application of Tango two times without a nutrient (treatment 1). The additional magnesium use resulted in the same growth tendency in the Juwel - Tango treatment pairs (treatments 3 and 5).

Regarding the change of sugar content, the sugar content growth was the most intensive in treatment 2 at three out of the four experiments, when Tango + magnesium were applied and in treatment 3 when Tango – Juwel were applied.

Summarizing the growth of sugar yield, the most intensive sugar yield growth was observed on plots treated with Juwel - Tango combined with magnesium at three sites. Application of Juwel - Tango produced outstanding growth at three sites. The positive effect of magnesium application could also be detected in combination with Tango.

3.2. Evaluation of the effect of fungicides and nutrients on sugar beet in small plot trials

3.2.1. Results of beet yield

In 2002, the average beet yield was 312.1 kg plot⁻¹ in the nine treatments of small plot trial set up in Hajdúböszörmény. The lowest beet yield was in treatment 1, when Tango was applied without nutrients. The highest beet yield was measured on plots treated with Juwel + potassium.

Analysing the effect of nutrients in the average of fungicides, we concluded that the lowest yield was obtained in treatments without nutrients. Compared to treatments without nutrient application, the yield was 10.7 kg and 15.7 kg higher in the average of treatments, when magnesium and potassium were applied, respectively.

There were no significant differences between the effect of fungicides on beet yield in the average of nutrients, and between the effect of nutrients on beet yield in the average of fungicides. The beet yield was 268.1 kg plot⁻¹ in the average of the nine treatments at Hajdúböszörmény in 2003, which was 14.1 % lower than the yield in 2002.

Similarly to the previous year, the lowest beet yield was in treatment 1, while the highest was measured in treatment 9, where Sfera + potassium were applied.

Comparing beet yields of different fungicide treatments in the average of nutrient treatments, there were no significant differences between fungicides. The lowest beet yield was measured on plots treated with Tango, and the highest on plots treated with Sfera.

Evaluating the effect of nutrients, it can be concluded that the application of nutrients increased beet yield, the increase was 11.1 kg plot⁻¹ in the case of magnesium and 11.8 kg plot⁻¹ in the case of potassium application.

The statistical analysis of beet yields did not show significant differences between fungicide × nutrient, and fungicide and nutrient treatments.

3.2.2. Results of sugar content

The sugar content of sugar beet in the average of the nine treatments was 15.36% in 2002. The lowest sugar content was measured in treatment 7 (14.78%), while the highest in treatment 2 (15.90%). Among fungicides, the lowest sugar content in the average of nutrients was on plots treated with Tango, while the highest was measured on plots treated with Juwel.

Examining the effect of nutrients, we measured the highest sugar content in the average of fungicides in treatments without nutrient application, and the lowest sugar content was obtained on plots treated with magnesium. Analysing the differences between treatments, there were no significant differences between nutrients on the average of fungicides. We have found significant difference in the average of nutrients at $P=5\%$ between the applications of Juwel and Tango.

The sugar content of sugar beet was 16.34% in the average of treatments in 2003. This value was 1% higher than sugar content in the previous year. The lowest sugar content was in the treatment with Juwel + magnesium (15.98%), while the highest in the treatment with Sfera (16.90%). Among the three tested fungicides, the highest sugar content in the average of nutrients (16.48%) was on plots treated with Sfera, and the lowest was on plots treated with Tango (16.22%). Examining nutrients in the average of fungicides, we obtained the highest sugar content in treatments without nutrients, and the lowest sugar content was obtained in treatments with magnesium. When analysing the data with double factor analysis of variance, we have not found significant differences between fungicides and nutrients.

3.2.3. Molassogenic substances of sugar beet

When comparing fungicides, the highest potassium content of beet in the average of nutrient treatments was harvested from plots treated with Tango, and the lowest from plots treated with Juwel in 2002. Evaluating the effect of nutrients, it can be concluded that the application of both magnesium and potassium on leaf reduced the potassium content. There were no significant differences either in the fungicide $\times$ nutrient interaction, or when the two factors were studied separately.

The lowest sodium content of beet in the average of nutrients was measured in treatments with Juwel, and the highest in treatments with Sfera, which effect was statistically significant.

We measured the lowest sodium content in treatments with fungicides alone, and the highest on plots treated with magnesium, which value was significantly higher than the result of treatments without nutrients. We have found significant differences in sodium content between fungicides and nutrients. There was a significant difference between fungicides at $P=1\%$. Among fungicides the lowest amino-N content in the average of nutrients was measured in treatments with Juwel. For Tango and Sfera, we measured similar values.

Evaluating the effect of nutrients in the average of fungicides, the lowest amino-N content was on plots treated with potassium, and the highest on plots treated with magnesium.

We found significant differences at $P=5\%$ between nutrients in the average of fungicides. When comparing fungicides, the lowest potassium content was on plots treated with Sfera, and the highest on plots treated with Juwel in 2003. The highest potassium content was measured in treatments without nutrients. There were no significant differences in potassium content between the different treatments.

In fungicide treatments in the average of nutrients, the lowest and highest sodium contents were obtained in Sfera and Juwel treatments, respectively. We measured the lowest sodium content in treatments without nutrient application, and the highest sodium content was obtained on plots treated with potassium. There were no significant differences between factors and factor combinations.

When examining fungicides in the average of nutrients, the lowest amino-N content was in treatments with Tango, and the highest in treatments with Juwel. Application of nutrients increased amino-N content of beet, application of potassium and magnesium gave almost the same values (38.4-38.2 mmol 1000g⁻¹). There were no statistically significant differences between the factors of treatments.

3.2.4. Expected sugar loss during sugar processing caused by molassogenic substances

The average absolute sugar loss was 3.80% and the relative loss was 24.79% in 2002. Regarding sugar loss caused by harmful non-sugar compounds, the lowest absolute and relative losses among the nine treatments were measured in the treatment with Juwel combined with potassium (3.36%; 21.52%). The highest absolute and relative loss was in the treatment with Sfera + magnesium (4.11%; 27.19%). Comparing fungicides in the average of nutrients, the lowest absolute and relative loss was on the plots treated with Juwel, while the highest was on the plots treated with Sfera. Among nutrients, the lowest sugar loss was measured in treatments with potassium, and the highest was measured in treatments with magnesium. There were significant differences between calculated absolute losses of treatments.

The variance caused by fungicides and nutrients was significant at $P=1\%$ and at $P=5\%$, respectively. The calculated losses were lower in 2003 than in 2002, which are likely to be caused by a dryer crop year. The absolute sugar loss was 2.60%, and the relative loss was 15.94%. The lowest absolute and relative losses were measured in treatments with Sfera (2.29; 13.54%), while the highest in treatment with Juwel+potassium (2.92; 18.06%).

Among the three fungicides in the average of nutrients, the lowest absolute and relative sugar losses were measured in the treatment with Sfera and the highest were detected in the treatments with Juwel. Examining nutrients, the sugar loss was the lowest in treatments without nutrients, the application of nutrients increased sugar loss, the highest loss was in the case of additional potassium application. There were no significant differences between absolute losses in treatments.

3.2.5. Sugar content

Among fungicides in the average of nutrients, the highest gross and net sugar yield was obtained when Juwel, and the lowest when Tango was applied in 2002. Among nutrients in the average of fungicides, both magnesium and potassium increased the gross and net sugar yields, the latter caused a higher increase. Examining the effect of nutrients and fungicides, there were no significant differences between gross sugar yields. We have found a significant difference in net sugar yield between Juwel and Tango.

In 2003, the lowest gross and net sugar yield was observed in treatments with Tango and the highest in treatments with Sfera. Evaluating the effect of nutrients, it can be concluded that both nutrients raised gross sugar yield, but net sugar yield was slightly reduced by using magnesium and increased by potassium application.

The statistical appraisal of measured net and gross sugar yields did not show significant differences between fungicides, nutrients and the combinations of these.

3.2.6. Changes in the photosynthetic activity in the vegetation period

We carried out photosynthetic measurements three times in 2003. The first measurement was performed before the first leaf treatment on 25 July. In the average of the two examined treatments, in which we applied Juwel and Tango alone, the photosynthetic activity at the first measuring date was $27.82 \mu\text{mol m}^{-2} \text{s}^{-1}$, which decreased later in the vegetation period.

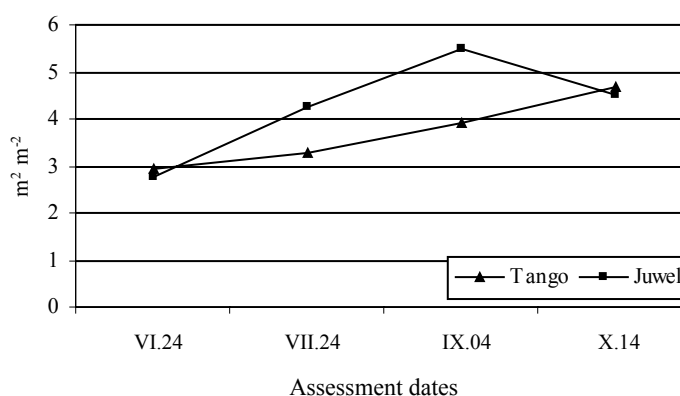
According to the measurement which was made in the beginning of September (4 September), the value of the photosynthetic activity was $16.36 \mu\text{mol m}^{-2} \text{s}^{-1}$. The photosynthetic activity at the first measuring date was almost equal in the two fungicide treatments. The photosynthetic activity on the plots treated with Juwel exceeded the photosynthetic values of plots treated with Tango at the second measuring date (24 July). The difference was minimal between treatments at the third measuring date.

The stoma permeability in the two examined treatments was similar at the first and the third assessment dates, but at the second assessment date it was significantly higher in the treatment of Juwel. At the second assessment date in the end of July, the intercellular CO₂ level was significantly higher on the plots treated with Juwel, which is likely to be a result of higher stoma permeability. We have found significant differences between the results of transpiration at P=10% at the second assessment date. At that time the transpiration rate in the Juwel treatment was double of that in the Tango treatment. A higher transpiration rate could be observed at the third assessment date, which can also be a consequence of higher stoma permeability.

3.2.7. Leaf area

The value of LAI index in the average of two treatments increased until the third assessment date, after this we experienced a slight decrease in the middle of October. Among the four assessment dates, the highest LAI value in the average of two treatments was obtained at the third assessment date, on 4 September (4.71 m² m⁻²). When comparing the two fungicides the LAI values were higher on the plots treated with Juwel at the second and third assessment dates than on the plots treated with Tango. The difference was significant at P=5% (LSD_{5%}: 0.76) at the second assessment date and at the third assessment date at P=10% (LSD_{5%}: 1.22). Changes in the LAI index are shown in Figure 1.

Figure 1. Changes in leaf area index in the vegetation period, 2002



4. NEW SCIENTIFIC RESULTS

- 1.** The bioactive effect of kresoxim-methyl and trifloxystrobin on yield as stated by the literature has been confirmed in sugar beet.
- 2.** In treatments with Juwel that contains kresoxim-methyl, we measured a higher photosynthetic activity, stomata opening, transpiration rate and a higher leaf area index than in the treatments with Tango.
- 3.** In plots treated with Juwel, the growth of beet yield, sugar content and sugar yield was more intensive in the vegetation period compared to treatments by Tango. As a result of Juwel application, beet yield, sugar content and sugar yield were higher at harvest time.
- 4.** The amount of molassogenic substances was lower or significantly lower when fungicides containing strobilurin active ingredients were applied, consequently, the expected sugar during sugar beet processing was lower.
- 5.** The application of Juwel in the beginning of July helped primarily the growth of beet root weight, while its application in the beginning of August increased the sugar content. The application in August is better concerning sugar yield and molassogenic substances.
- 6.** The combined application of magnesium and potassium with the examined fungicides (Tango, Juwel, Sfera) had a positive effect on sugar yield.
- 7.** The effect of applying fungicide with kresoxim-methyl active ingredient and magnesium as a foliar treatment on sugar yield was higher at sites where the average yield was lower.

5. RESULTS APPLICABLE IN PRACTICE

1. There was no noticeable difference in the plant protection impact of fungicides.
2. The bioactive side-effect of fungicides containing strobilurins can be applied successfully for increasing the sugar yield of sugar beet.
3. The essential point of application is to follow the application rules of fungicides. The application has to be started at the time determined by forecasting, they have to be used only once a year. It is important to keep the pesticide rotation, and to apply them in combination with synergistic contact fungicides in order to prevent resistance against pesticides.
4. Applying nutrients and fungicides in combination is economically advantageous, because it can increase the sugar yield significantly with minimal cost.
5. It is reasonable to apply magnesium from mezo nutrients and potassium from macro nutrients as a foliar treatment in sugar beet.
6. Application times of these fungicides have to be considered when harvesting is planned, because these treatments prolong the vegetation period of sugar beet. A later harvest is more practical, in the case of an earlier strobilurin application earlier harvesting can be planned.

6. RELATED PUBLICATIONS

1. Ruzsányi L., Lesznyák Mné, **Varga L.** (2002): A termőtáj, a tenyésztő és a cukorrépa minősége közötti összefüggések, II. Crop Production Scientific Day, „Integration tasks in the domestic crop production”, Budapest, Proceedings, Editors: Pepó P.-Jolánkai M., 205-212. p.
2. **Varga L.** (2002): A cukorrépa cukortartalmának és produkciójának változása a tenyésztőben, Agrártudományi Közlemények, Special volume, 103-107. p.
3. **Varga L.** (2003): A cukorrépa minőségi paramétereinek változása fungicidek tápelemekkel való kombinált felhasználása esetén, 49th Plant protection Scientific Days, Budapest, Editors: Kuroli G.-Balázs K.-Szemessy Á., 170. p.
4. **Varga L.** (2003): Bioaktív hatású fungicidek és magnézium felhasználás hatása a cukorrépa termésmennyiségére, minőségére különböző tápanyagellátási szinteken, XIII. Plant Protection Forum, Keszthely, 86. p.
5. **Varga L.** (2003): The effect of foliar fertilization with fungicides on sugar beet (*Beta vulgaris* L.) at different nutrition levels, II. Alps-Adria Scientific Workshop, Trogir, Croatia, Editor: Gyuricza Cs., 189-193. p.
6. **Varga L.** (2003): Lombkezelések hatása a cukorrépa termésminőségére, Youth Scientific Forum, Keszthely, CD publication
7. **Varga L.** (2003): Lombkezelések hatása a cukorrépa minőségi mutatóira és levélelem tartalmára, III. Crop Production Scientific Day, Gödöllő, Proceedings, Editors: Csorba Zs.-Jolánkai P.-Szöllősi G., 284-288. p.
8. **Varga L.**, Ruzsányi L. (2003): Examination the effect of strobilurins on sugar beet (*Beta vulgaris* L.), The environment resources and sustainable development, Oradea, 142-146. p.
9. Ruzsányi L., **Varga L.** (2003): The effect of foliar fertilization with fungicides on sugar beet (*Beta vulgaris* L.), 14th International Symposium of Fertilizers (CIEC), Debrecen, Editors: Schnug, E.-Németh T.-Nagy J.-Kovács Z.-Dövényi-Nagy T., 657-663. p.

10. **Varga L.** (2003): A cukorhozam-növelés lehetőségének vizsgálata lombkezeléses kísérletben, Agrártudományi Közlemények, Special volume, 202-206. p.
11. **Varga L., Ruzsányi L.** (2003): Evaluation of effect of different foliar treatments in sugar beet, Buletin of the University of Agricultural Sciences and Veterinary Medicine, Cluj-Napoca, 59. 247. p.
12. **Varga L., Ruzsányi L.** (2003): Bioaktív mellékhatással rendelkező fungicidek vizsgálata kisparcellás kísérletben, XLV. Georgikon Days, Keszthely, CD publication
13. **Varga L., Ruzsányi L.** (2003): Levélkezelések hatása a cukorrépa (*Beta vulgaris* L.) produkciójára, Növénytermelés, 52. 5. 485-494. p.
14. **Varga L., Ruzsányi L.** (2003): A cukorrépa (*Beta vulgaris* L.) cukorhozamának változása lombkezelések hatására, DAB, 20th November 2003., in press
15. **Varga L., Ruzsányi L.** (2004): An investigation on the use of fungicides with bioactive side-effects and minerals as foliar treatments in sugar beet production, 39th Croatian Symposium on Agriculture, Opatija, Proceedings, Editor: Žimbrek, T., 571-572. p.
16. **Varga L., Ruzsányi L.** (2004): Fungicidek önálló, illetve tápelemekkel kombinált alkalmazásának összetett hatása cukorrépára (*Beta vulgaris* L.), 50th Plant Protection Scientific Days, Budapest, Editors: Kuroli G.-Balázs K.-Szemessy Á., 159. p.
17. **Varga L., Sárvári M.** (2004): Response of sugar beet (*Beta vulgaris* L.) to foliar treatments in different years, III. Alps-Adria Scientific Workshop, Dubrovnik, Croatia, Editors: Hidvégi Zs.-Gyuricza Cs., 373-377. p.
18. **Varga L., Sárvári M.** (2004): Impact of fungicides with bioactive side-effects and minerals as foliar treatments on some sugar beet (*Beta vulgaris* L.) properties, The environment resources and sustainable development, Oradea