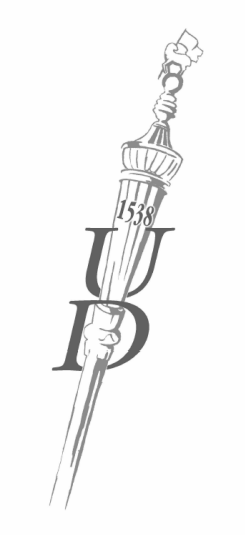
Egyetemi doktori (PhD) értekezés tézisei

FAJTA ÉS ÖNTÖZÉS HATÁSA A BURGONYA TERMÉSMENNYISÉGÉNEK ÉS MINŐSÉGÉNEK ALAKULÁSÁRA MEZŐSÉGI TALAJON

Ábrahám Éva Babett

Témavezető: Dr. Sárvári Mihály
egyetemi docens



DEBRECENI EGYETEM
Hankóczy Jenő Növénytermesztési, Kertészeti és
Élelmiszertudományi Doktori Iskola

Debrecen, 2009

1. Introduction

Potato is one of the most important cultivated plants on Earth. Considering the harvested area, potato is the fourth among the plants for food after winter wheat, maize and rice. Potato was pronounced to be an essential food in a decision by the UNO in 2005, because potato may have significant role in the elimination of the global poverty.

In Hungary the annual potato consumption is 62-68 kg for one person. The area of potato production dropped dramatically in the last few years, in 1999 the harvested area of potato was about 56 thousand hectares and in 2007 it was only 20,470 hectares. The growing area of potato of the world was 19 million hectares and 7,492 thousand hectares in Europe in 2007. The harvested area of potato dropped even in Europe, because it was about 9 million hectares in 2000.

After joining the European Union, the customs traffic rate of potato was extinct, and the foreigner potatoes could go into Hungary without any difficulties. Hungary ought to strive to produce its own domestic necessity from potato. Besides, the increase of the processed products could be desirable and we may utilize better the possibilities of growing early potato as well.

In Hungary, the biggest limiting factor of potato cultivation is the shortage of precipitation and the high average temperature during period of potato tuber development. Potato has a demand for high and even water supply, this crop can reach 100% of its growing capacity if properly irrigated, and the safety of growing and the quality can also be increased. In Hungary, the frequency of dry, droughty years increased in the past years, which extends the risk of potato growing. The water shortage between May and August negatively affects the number of tubers, the tuber size and quality apart from the yield.

As a consequence of the water shortage not only physiological changes (ex. twin growth) occur, but parallel with these, quality decay (dry matter and starch content decrease) happens as well. For safe potato growing irrigation is essential. The actual 16-20 t ha^{-1} average yield could be increased to 35-40 t ha^{-1} if irrigation is applied.

The other big problem of our potato growing is the use of varieties. The varieties Desirée, Kondor and Cleopatra are still dominant. In the last few years some potato varieties were bred in Hungary, their the rate of viral deterioration is slower than of the foreign varieties (ex. Pannónia, White Lady, Hópehely, Rioja etc.). These varieties are competitive with the foreign varieties in productivity, consuming value and in quality parameters.

I examined the effect of these two determining factors in the course of my researches on the establishment of the yield and the quality of tubers. In the future there will be

increasing claim for the knowledge of the quality of food. The quality of potato determines its usability in a large extent, and from the point view of usability, we have to know the quality of the potato varieties.

My research results can be utilized effectively under similar ecological circumstances. Our results can help in the elaboration of cultivar-specific technologies, and they may help the farmers to change the most adaptable potato varieties to the ecological conditions of the growing area. The production of Hungarian, virus resistant varieties can contribute to have seed tubers cheaper, hence the highl input expenses could be reduced.

It is essential to increase the level of the technology and the yield of potato and to reduce the costs of production. Our results have big significance in the improvement of the efficiency of potato growing in the "Hajdúsági löszhát" area, in the statement of the effect of watering and in the determination of cultivar-specific technologies.

2. Materials and methods

2.1. Varieties and researches of the experiment

In our experiment we examined the yield and some quality parameters of 9 medium-early varieties in large plots. Among the examined varieties, 3 were Dutch (Kuroda Desirée és Kondor), and 6 were Hungarian breeding (Rioja, Lorett, Góliát, Kánkán, Hópehely, White Lady). The 9 varieties were examined in 4 replications in randomized blocks: two replications were irrigated and two were non-irrigated. Beside the yield of the varieties, we examined the distribution of tubers according to size, and the effect of irrigation on the quality parameters (underwater weigh, dry matter-, starch-, protein-, vitamin C content, content of reducing sugars, index of frying colour and element content).

2.2. Weather conditions during the experiment

2.2.1. Weather conditions in 2004

In 2004, during the vegetation period of the potato, the amount of the precipitation was 342.6 mm, 2.6 mm lower than the 30 years' average, but the distribution of precipitation was unfavourable. May was extremely dry; the monthly amount of precipitation was only 17 mm, 41.8 mm lower than the average. In July the quantity of rainfall was twice higher than the average (142 mm), which was unfavourable in terms of pathological parameters. The average monthly temperature was 19.3^{o}C in June and 21.1^{o}C in July, which is higher than the requirement of the potato (17-18^{o}C) *(table 1)*.

2.2.2. Weather conditions in 2005

In 2005, the amount of precipitation was sufficient during the vegetation period of the potato, and also the distribution of precipitation was relatively even. The amount of precipitation only in June was lower than the average of the last 30 years, with 25.2 mm. The amount of precipitation was higher than the 30 years' average in April, May, July, August (with 75 mm) and in September. The average monthly temperature was about the 30 years' average; the monthly average temperature only in July (21^{o}C) was higher than the average.

Table 1: **The amount of precipitation (mm) and the monthly average temperature (^{o}C) (Debrecen-Látókép, 2004-2006)**

Month	Monthly amount of precipitation				Monthly average temperature			
	30 years' average	2004	2005	2006	30 years' average	2004	2005	2006
January	37.0	37.2	18.2	22.5	-2.6	-3.3	-0.9	-3.4
February	30.2	41.6	40.6	44.2	0.2	-0.7	-3.7	-1.4
Marc	33.5	46.5	10.5	79.0	5.0	4.8	2.2	3.2
April	42.4	40.1	74.9	92.3	10.7	11.4	10.8	12.1
May	58.8	17.0	75.8	58.3	15.8	14.8	16.2	15.4
June	79.5	61.7	54.3	77.1	18.7	19.3	18.4	18.6
July	65.7	142.2	99.7	31.0	20.3	21.1	21.1	23.2
August	60.7	50.2	135.7	62.4	19.6	20.4	19.7	19.1
September	38.0	31.3	61.7	5.3	15.8	15.3	16.5	17.0
October	30.8	7.0	7.0		10.3	10.8	10.8	11.3
November	45.2	14.6	12.6		4.5	3.5	3.5	6.2
December	43.5	83.5	83.5		-0.2	0.9	0.2	2.2
altogether/ average	**565.3**	**572.9**	**674.5**		**9.84**	**9.86**	**9.57**	**10.29**
Deviation from the 30 years' average		7.6	109.2		-	0.02	-0.27	0.45
Breading season (April-September)		342.5	502.1	326.4	16.82	17.05	17.12	17.57
Deviation from the 30 years' average		-2.6	157.0	-18.7	-	0.23	0.30	0.75

2.2.3. Weather conditions in 2006

In 2006, during the vegetation period of the potato the amount of rainfall was 326.2 mm, 18.9 mm lower than the 30 years' average. The amount of precipitation in April (92.3 mm) was 49.9 mm higher than the average, and the planting date was at the end of April. The amount of precipitation was about the 30 years' average in May, June and August, but the monthly amount of precipitation in July was almost the half of the average. September was droughty; the amount of the rainfall was only 5.3 mm. The monthly average temperature was

1.4°C higher in April and 2.2°C higher in September than the average. In July, in the most critical period the average monthly temperature was 2.9°C higher than the 30 years' average.

2.3. Soil characteristics of the experimental site

The experiment was carried out at the experimental site of the Farm and Regional Research Institute, University of Debrecen, at Látókép. The soil of the experiment field was calciferous chernozem developed on loess with deep mould. The experiment's soil is in good condition, according to the soil physics it is classified as a middle bound loam soil (Arany bound number: 42). The thickness of the mould layer is between 80 and 90 cm, and the evenly mould layer's average mould content is 2.8%. $CaCO_3$ appears in the transitional layer of the soil profile, at the depth of 70–100 cm, and is generally seen as pellicle on the soil aggregates. The lime content of the soil in the calciferous part ranges between 10 and 13%.

The cultivated layer's acidity (KCL pH) is between 6.3 and 6.5, the N content is 0.12-0.15%. The experimental site's soil has good potassium content (240 mg kg^{-1}), the phosphorous content is variable, the average phosphorous content is medium (133 mg kg^{-1}). According to Várallyay's classification, it belongs to category IV. i.e. soil with good water management and water holding capacity. The minimum field water capacity (VKmin) ranges between 33.65 and 46 %, the non-available water (HV) ranges between 8.5-15.7 % in the 0-200 cm soil layer. Soil water table is in 8-10 m depth, the soil can store a substantial amount of water.

2.4. Agro-technology used in the experiment

Table 2: **Main agro-technical parameters**

Name	2004	2005	2006
Preparation of soil	Oct. 2003: 35 cm deep ploughing March 2004: harrow 17 April 2004: combinator	Oct. 2004: 35 cm deep ploughing March 2005: harrow 2 May 2005: combinator	Oct. 2005: 35 cm deep ploughing March 2006: harrow 24 April 2006: combinator
Date of fertilizer	April 9: N: 160; P_2O_5: 120; K_2O: 220 kg ha^{-1}	18 April N: 160; P_2O_5: 120; K_2O: 220 kg ha^{-1}	24 April: N: 160; P_2O_5: 120; K_2O: 220 kg ha^{-1}
Planting date	21-22 April	2 May	24 April
Irrigation	22 May: 15 mm (all repetitions)	2 June: 30 mm	19 July: 30 mm
	5 June: 25 mm	28 July: 30 mm.	13 July: 30 mm
	11 June: 30 mm		
	8 July: 30 mm		
Harvesting	22 September	6-27 September	25 September
classification	23-24 September	29-30 September	28 September

The applied fertilizer dose was 165 kg ha^{-1} N, 210 kg ha^{-1} P_2O_5, and 220 kg ha^{-1} K_2O in all the 3 year. The experiment was set up on 50 m^2 parcels, after winter wheat (2004 and 2006) and two rowed barley (2005) as a forecrop. The plant density was 51,000 plants ha^{-1}.

The replications were irrigated 4 times in 2004: on 22 May 2004 with 15 mm; on 05 June 2004 with 25 mm; on 11 June 2004 with 30 mm; on 08 July 2004 with 30 mm. In May we had to irrigate all of the repetitions, because of the drought and the chapped soil. In 2005 the dates of irrigation were 01 June and 28 July with 30 mm. In 2006 the repetitions were irrigated 2 times: 19 and 30 July with 30 mm. Table 2 shows the main agro-technical parameters.

3. Experimental results and discussions

3.1. The effect of irrigation on yield

In 2004, the yield of the non-irrigated experiments was 32.36 t ha^{-1}, and under irrigation the average yield of the 9 examined varieties was 34.64 t ha^{-1}. Irrigation did not increased the yield significantly ($LSD_{5\%}$=2.49 t ha^{-1}). Without irrigation the yield of Hópehely (55.37 t ha^{-1}) and White Lady (46.00 t ha^{-1}) varieties was salient. Under irrigation the yield of Hópehely variety was 53.61 t ha^{-1}. The yield of Rioja (44.87 t ha^{-1}), White Lady (45.98 t ha^{-1}) and Lorett (44.25 t ha^{-1}) varieties were above 40 t ha^{-1} as well. The yield of Desirée (non-irrigated: 17.27 t ha^{-1}, irrigated: 17.35 t ha^{-1}) and Góliát varieties was under 30 t ha^{-1}, as a consequence of diseases caused by the large amount of precipitation. Irrigation decreased the yield of Hópehely variety in a small degree; the yield of White Lady and Desirée varieties did not change, and the yield of the other varieties increased, because of the good watering reaction of varieties. The yield of Lorett, Rioja, White Lady and Hópehely varieties was higher than the yield of Desirée, Góliát, Kánkán and Kondor varieties respectively ($LSD_{5\%}$=4.50 t ha^{-1}) *(figure 1)*.

In 2005, there was not substantial difference between irrigated (46.45 t ha^{-1}) and non-irrigated (44.50 t ha^{-1}). Irrigation increased the yield significantly, but the difference between the yield of irrigated and non-irrigated treatments was on the edge of significance ($LSD_{5\%}$=1.94 t ha^{-1}). The yield of Lorett variety was higher than 50 t ha^{-1} without irrigation. In consequence of the favourable year effect only the yield of Rioja (36.35 t ha^{-1}) and Góliát (38.00 t ha^{-1}) varieties was lower than 40.00 t ha^{-1}. Under irrigated conditions the yield of Hópehely variety was 57.45 t ha^{-1}, and the yield of Desirée (55.28 t ha^{-1}) and Lorett (51.11 t ha^{-1}) varieties was higher than 50 t ha^{-1} as well. The yield of Rioja (36.55 t ha^{-1}) and Góliát varieties (38.00 t ha^{-1}) was lower than 40.00 t ha^{-1}, their reaction for irrigation was less

manifested. The yield of Desirée variety was higher than in 2004. The yield of White Lady was higher than the yield of Rioja respectively ($LSD_{5\%}$=7.82 t ha^{-1}).

In 2006, the yield of the non-irrigated repetitions was 35.93 t ha^{-1}. Irrigation increased the yield respectively to 41.21 t ha^{-1} ($LSD_{5\%}$=2.49 tha^{-1}). Irrigation increased the yield of every variety which proves the importance of the even water supply in July. Without irrigation the yield of Lorett (42.69 t ha^{-1}) and Kuroda (42.16 t ha^{-1}) varieties was higher than 40 t ha^{-1}. Without irrigation the yield of Góliát variety was the lowest with 27.08 t ha^{-1}, but under irrigation it increased to 35.87 t ha^{-1}. Under irrigated conditions the yield of Rioja variety was 35.15 t ha^{-1}; the reaction for irrigation of this variety was unfavourable in 2006 as well. Under irrigation the yield of the Lorett variety was the highest (46.24 t ha^{-1}), and the yield of Kondor, Kuroda, Hópehely, Desirée and White Lady varieties was over 40 t ha^{-1}. The yield of Góliát variety was lower than the yield of Kuroda and Lorett varieties ($LSD_{5\%}$=11.20 t ha^{-1}).

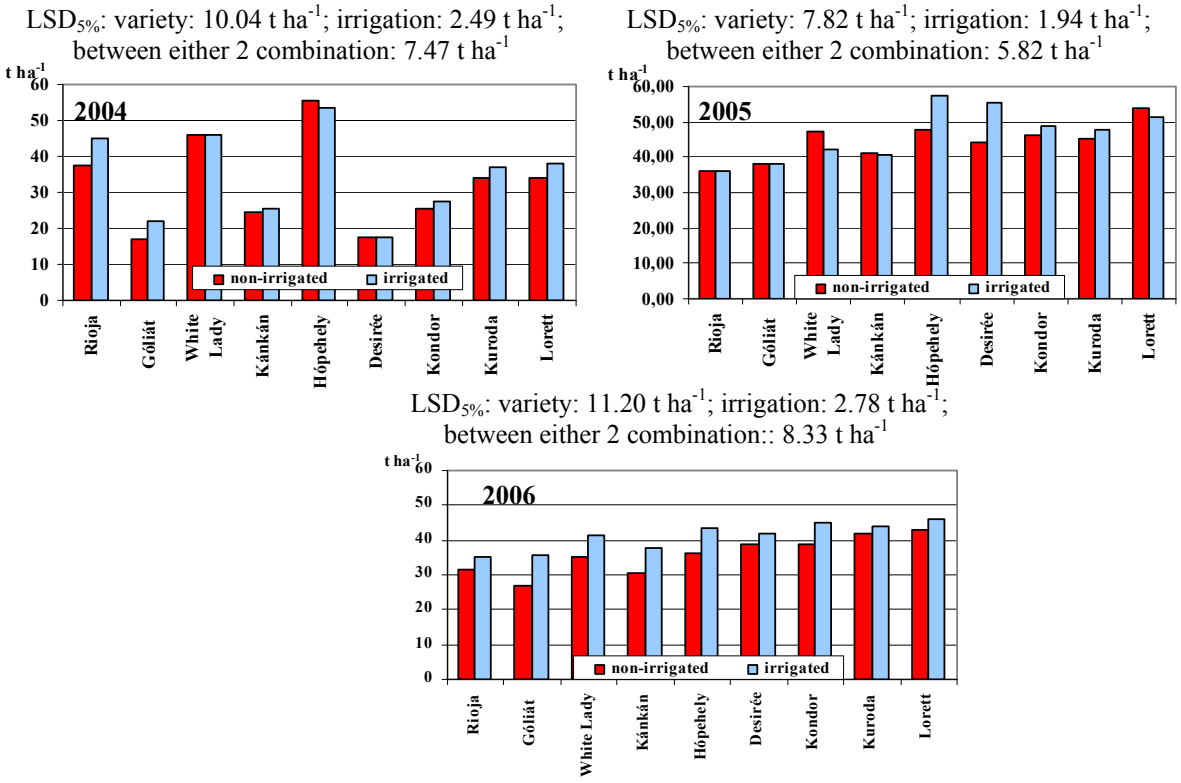


Figure 1: **The effect of irrigation on the yield of potato varieties (t ha^{-1}). Debrecen-Látókép, 2004-2006.**

3.2. The effect of irrigation on the distribution of tubers according to their size

During the experiment the amount of large size tubers was favourable in the case of Kondor, Kuroda and Lorett varieties. The proportion of large size tubers (>6 cm) ranged between 40 and 50%, and the amount of small tubers (>4 cm) was about only 10%. In 2006

the distribution of tubers according to size of Lorett variety wasn't so favourable like in 2004 and 2005, because the proportion of medium tubers was about 50%. The yield of White Lady, Hópehely and Góliát varieties was mainly composed by medium (4-6 cm) and large tubers, but the proportion of small tubers was about 20%. In 2006 the distribution of tubers according to size of White Lady varieties was unfavourable, because the proportion of small tubers was 30-40%. The Rioja and Desirée varieties produced mainly medium size tubers. The tuber distribution according to size in case of Kánkán variety was unfavourable, the proportion of small tubers ranged between 36 and 66%.

3.3. The effect of irrigation on the underwater weight

On the basis of the underwater weight (UWW), we can draw a conclusion for the dry matter and starch content. The UWW is primarily depends on the variety, but the year effect and the agro-technology can modify it. In 2004, the average UWW value was 333.50 grams, and as a result of irrigation, it increased to 344 grams, respectively ($LSD_{5\%}$=10.17 grams). In 2005, the quantity and the distribution of precipitation were sufficient, which is favourable in the point of view of the quality of potato. In 2006, the low precipitation in July influenced the UWW disadvantageously. The UWW value of the non-irrigated replications was 337.86 grams, while it was 342.72 grams in the irrigated replications. The UWW of Rioja variety was salient, in 2004 and 2005 the UWW of Rioja variety ranged between 402.50 and 421.25 grams, which means 22% dry matter content. The UWW of Kuroda and White Lady varieties was favourable as well, the UWW of Kuroda variety ranged between 361-381 grams, and the UWW of White Lady variety ranged between 355.50-381.50 grams, which means 19-21% dry matter content. The UWW of Lorett and Kondor varieties ranged between 280-310 grams in 2004 and 2006 (16-17% dry matter content), which is unfavourable in the point of view of frying quality and storage, but in 2005, as a result of the plenteous water supply their UWW was higher than in 2004 and 2006 (315.50-373.00 grams).

There was significant difference between the UWW values of the varieties every year during the experiment. In 2004, the UWW of Rioja variety was higher than the UWW of the other varieties. In 2005, the difference between the UWW of Rioja and Lorett varieties was significant; while in 2006 the UWW of Rioja variety was higher than of the Góliát, Kánkán, Desirée, Kondor and Lorett varieties, respectively. The UWW of Rioja variety was salient; 406.26 g taking the results of the 3 years of the experiment into account altogether. The UWW of Kuroda (371.13 g), White Lady (368.38 g) and Hópehely (366.08 g) varieties was favourable too, their UWW was higher than the UWW of Lorett (303.42 g) and Kondor

(317.17 g) varieties in the average of the 3 examined years ($LSD_{5\%}$=48.67 g). Irrigation did not influence the UWW significantly in the average of the 3 years of the experiment ($LSD_{5\%}$=9.14 g).

The amount of precipitation influences the UWW, there was medium positive correlation between the amount of precipitation of the breeding season and the UWW (r=0.306**). There was positive correlation between the UWW and the dry matter content (2004: 0.782**, 2005: 0.483**, 2006: 0.854**). The value of correlation coefficient between the UWW and the starch content was: 0.719**in 2004, 0.386* in 2005, and 0.678** in 2006. There was negative correlation between the UWW and the colour of frying index (2004: -0.685**, 2005: -0.510**, 2006: -0.483**). Negative correlation was found between the UWW and the boron (2004: -0.536**, 2005: -0.351*, 2006: -0.629**) and manganese content (2004: -0.420*, 2005: -0.403*, 2006: -0.510**).

3.4. The effect of irrigation on the dry matter content

In 2004, the average dry matter content was 21.93% under non-irrigated and 22.00% under irrigated conditions. The dry matter content of Rioja variety was higher than 26% both under non-irrigated and irrigated cultivations. The dry matter content of Kuroda (non-irrigated: 25.35%), Hópehely (non-irrigated: 22.50%, irrigated: 24.53%) and White Lady (non-irrigated: 23.57%, irrigated: 23.46%) varieties was favourable as well as their UWW. Without irrigation the dry matter contents of Desirée (18.95%) and Lorett (17.22%) varieties were under 20%, which is unfavourable in respect of storage and frying quality *(figure 2)*.

In 2005, the dry matter content of the non-irrigated replications was 22.35%, and with irrigation it was 21.62%. The dry matter content of Rioja variety was 24.83% under non-irrigated and 24.42% under irrigated cultivation. In 2005 the dry matter content of Desirée variety was favourable (non-irrigated: 24.42%, irrigated: 22.08%) in consequence of the even precipitation. Under non-irrigated cultivation the dry matter content of White Lady (22.71%) and Hópehely (22.54%) varieties was higher than the average of the 9 varieties as well. Under irrigation the dry matter content of White Lady variety was 21.20%, and the dry matter content of Hópehely variety was 21.08%. Without irrigation the dry matter content of Góliát variety (20.43%) was the lowest. The dry matter content of Góliát (19.82%) and Lorett (18.19%) were under 20% under irrigation as well.

The dry matter content was lower in 2006 than in preceding years. The average dry matter content was 20.13% without irrigation. As a result of irrigation the dry matter content in the average of the examined varieties increased to 21.39% ($LSD_{5\%}$=1.02%). The dry matter

content of Rioja (non-irrigated: 23.81%, irrigated: 24.48%) and Kuroda (non-irrigated: 23.16%, irrigated: 22.39%) varieties was the highest. The dry matter content of White Lady (non-irrigated: 22.18%, irrigated: 21.81%) and Hópehely (non-irrigated: 20.90%, irrigated: 22.08%) varieties was favourable as well. Without irrigation the dry matter content of Lorett (17.98%), Kánkán (17.88%) and Kondor (17.00%) varieties was low. At such a low dry matter content the potato can not been storage safely. As a result of irrigation the dry matter content of Kánkán variety increased to 23.19%. The dry matter content of Kondor (19.69%) and Lorett (18.34%) varieties was lower than 20% under irrigation as well.

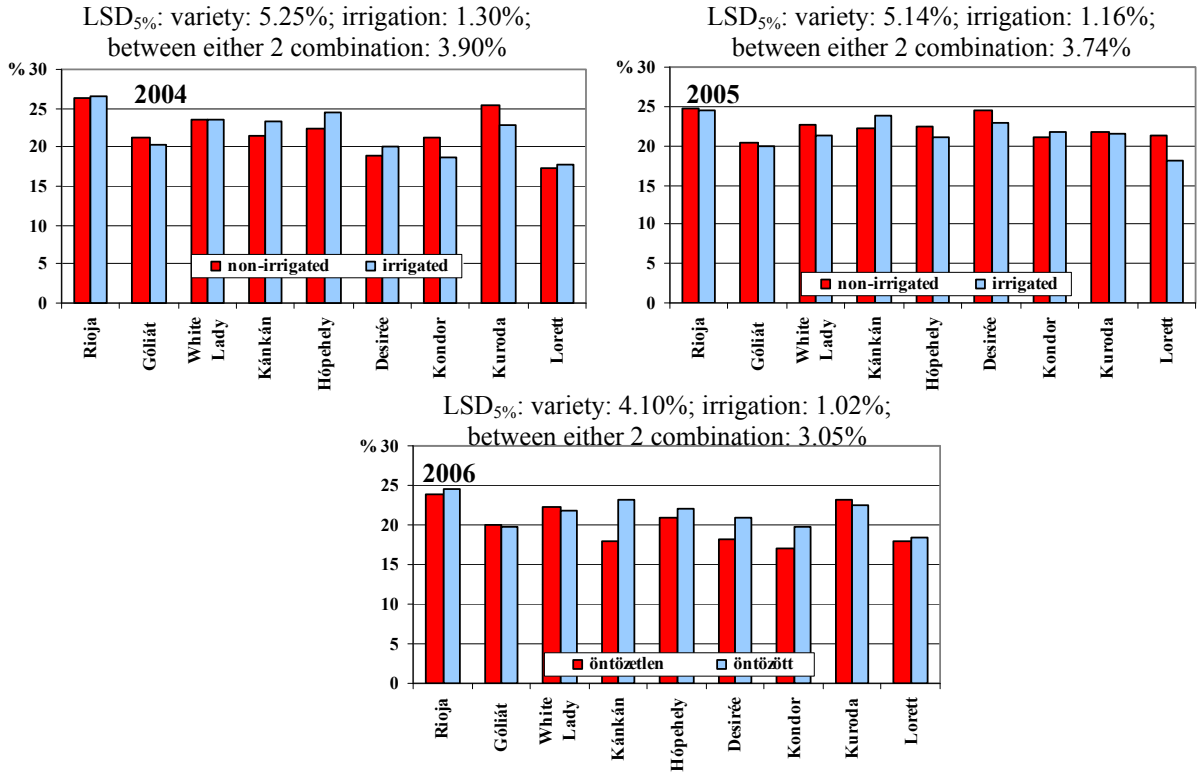


Figure 2: **The effect of irrigation on the dry matter content of potato varieties (%). Debrecen-Látókép, 2004-2006.**

The dry matter content of Rioja (25.06%) variety was the highest in every year, and the dry matter content of Kuroda (22.84%), White Lady (22.49%) and Hópehely (22.27%) varieties was favourable as well. The dry matter content of Kondor (19.88%) and Lorett (18.47%) was the lowest. In the average of the 3 year of the experiment, the dry matter content of Rioja variety was higher than the dry matter content of Lorett variety ($LSD_{5\%}$=4.25%). The dry matter content of Desirée variety was favourable in 2005 both under irrigated and non-irrigated cultivations, but in 2004 and 2006 it was lower than the average of the 9 varieties because of the ecological sensitivity of the variety. In 2004, the large amount of precipitation, and in 2006, the lack of precipitation in July caused the

decrease of yield and the quality of Desirée variety. The reaction for irrigation of Kánkán variety was favourable, under irrigation the dry matter content of Kánkán variety was over 23%.

In 2004 (0.846**) and 2006 (0.749**) there was positive correlation between the dry matter and the starch content and the protein content as well (2004: 0.711**, 2006: 0.443**). There was negative correlation between the dry matter content and the index of frying colour in each year during the experiment (2004: -0.712**, 2005: -0.592**, 2006: -0.375*) and between the content of reducing sugars (2004: -0.383*, 2005: -0.369*, 2006: -0.395*) as well. The varieties with higher dry matter content had lower index of frying colour and reducing sugar content (Rioja, Kuroda) as well. There was negative correlation between the dry matter content and the phosphorous (2004: -0.462**, 2005: -0.338*, 2006: -0.364*) and manganese (2004: -0.490**, 2005: -0.405*, 2006: -0.487**) content as well. Similarly to the UWW, there was negative correlation between the dry matter content and the boron content (2004: -0.428**, 2005: -0.435*, 2006: -0.650**) as well.

3.5. The effect of irrigation on the starch content

In 2004, the starch content was 14.75% under non-irrigated and 15.52% under irrigated conditions. The starch content of Rioja variety was the highest both under non-irrigated (21.58%) and irrigated (17.91%) cultivation. Similarly to the dry matter content, the starch content of White Lady (non-irrigated: 16.66%, irrigated: 17.63%) and Kuroda (non-irrigated: 17.40%, irrigated: 16.05%) varieties was higher than the average of the 9 varieties. The starch content of Desirée (irrigated: 12.44%, non-irrigated: 13.45%) and Lorett (irrigated: 12.76%, non-irrigated: 12.37%) varieties was unfavourable. As a result of irrigation the starch content of Góliát and Kondor varieties decreased fewer than 14%. The starch content of Rioja variety was higher than the starch content of Góliát, Kánkán, Desirée, Kondor and Lorett varieties, respectively ($LSD_{5\%}$=5.02%) *(figure 3)*.

The even water supply is favourable in a respect of the starch content of potato; the highest starch content was measures in 2005 in. The average starch content was 16.79% under non-irrigated and 17.15% under irrigated conditions. In spite of the even water supply the starch content increased in case of 6 varieties. Under non-irrigated cultivation the starch content of White Lady variety (20.77 %) and under irrigation the starch content of Rioja variety (18.77 %) was the highest. The starch content of Lorett (non-irrigated: 14.57%, irrigated: 14.89%) and Kondor (non-irrigated: 15.48%, irrigated: 15.00%) varieties was low.

During the experiment the starch content was the lowest in 2006. The amount of precipitation was only 31 millimetres in July, and the irrigation increased the starch content

respectively ($LSD_{5\%}$=0.56%), which proves that the even water supply during the development of tubers is very important. The average starch content was 13.86% under non-irrigated and 14.83% under irrigated conditions. With irrigation the starch content increased in case of 7 varieties. The starch content of Rioja variety was the highest both under non-irrigated (17.53%) and irrigated (17.37%) cultivation. The starch content of Kondor (13.00%), Lorett (12.30%), Hópehely (11.65%) and Desirée (11.33%) varieties was extremely low. The starch content of Rioja variety was higher then the starch content of Desirée, Lorett, Kondor and Hópehely varieties ($LSD_{5\%}$=2.98%).

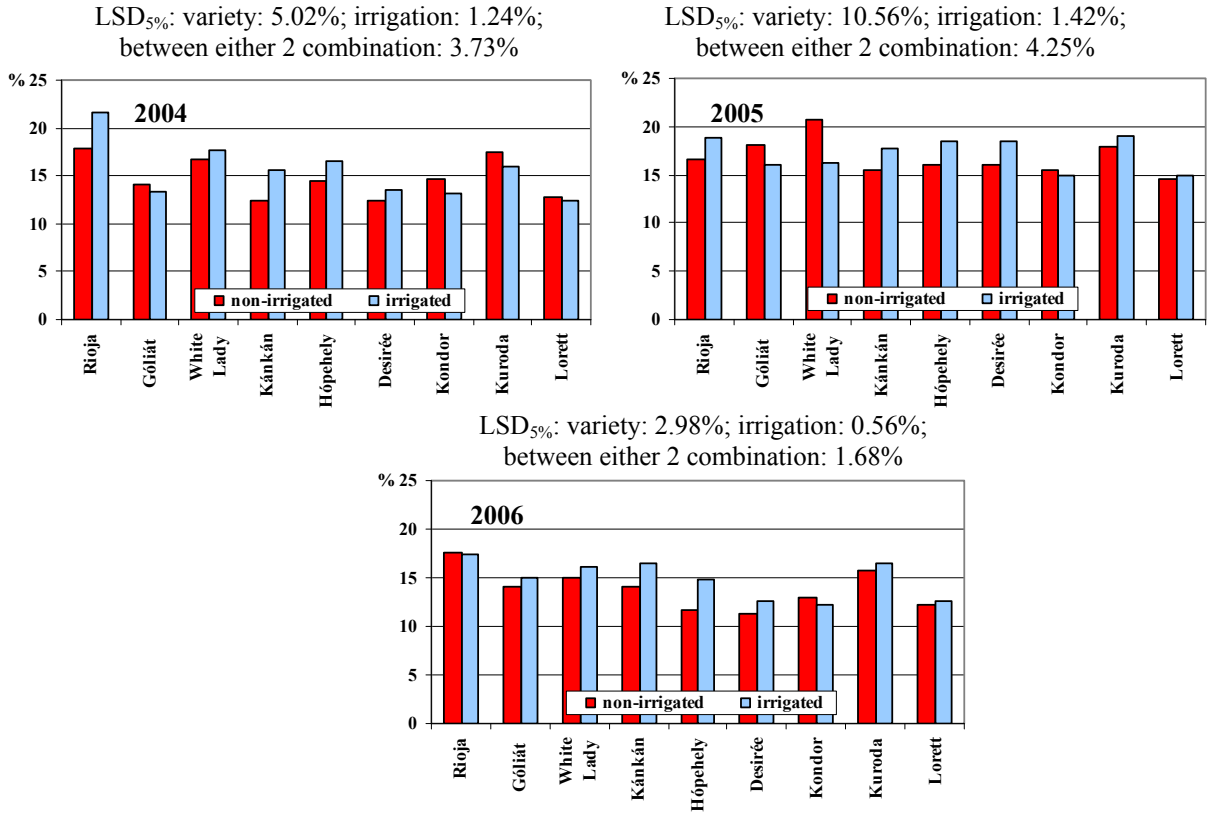


Figure 3: **The effect of irrigation on the starch content of potato varieties (%). Debrecen-Látókép, 2004-2006.**

Irrigation increased the starch content each 3 years, but significant difference was found only in 2006, when the precipitation was low. The starch content of Rioja, White Lady and Kuroda varieties was higher than 15% in every year. The starch content of Kánkán, Hópehely and Desirée varieties increased as a result of irrigation in every year, their quality can be improved by even water supply. The starch content of Lorett variety was low, but it was higher with 2% than in 2004 and 2006 in consequence of the relatively good weather conditions. There was positive correlation between the starch and the protein content (2004: 0.603**, 2006: 0.360*). There was negative correlation between the starch content and the

index of frying colour (2004:-0.645**, 2006: -0.385*) and the boron content (2004: -0.500**, 2006: -0.457**) as well.

3.6. The effect of irrigation on protein content

In 2004, under irrigation the protein content of every examined variety was higher than 2.00%. The protein content was 2.38% under non-irrigated and 2.28% under irrigated conditions. The protein content of the Rioja (non-irrigated:2.78%, irrigated: 2.77%) and Kuroda (non-irrigated: 2.55%, irrigated: 2.56%) varieties was the highest. The starch content was higher in the case of these varieties as well. Without irrigation the protein content of Góliát (2.17%), Hópehely (2.12%) and Lorett varieties (2.05%) was low. Under irrigation the protein content of Hópehely variety increased to 2.38%, the protein content of White Lady variety decreased to 2.16%. Under irrigation the protein content of Góliát (1.94%) and Lorett (1.88%) varieties was lower than 2.00% *(figure 4)*.

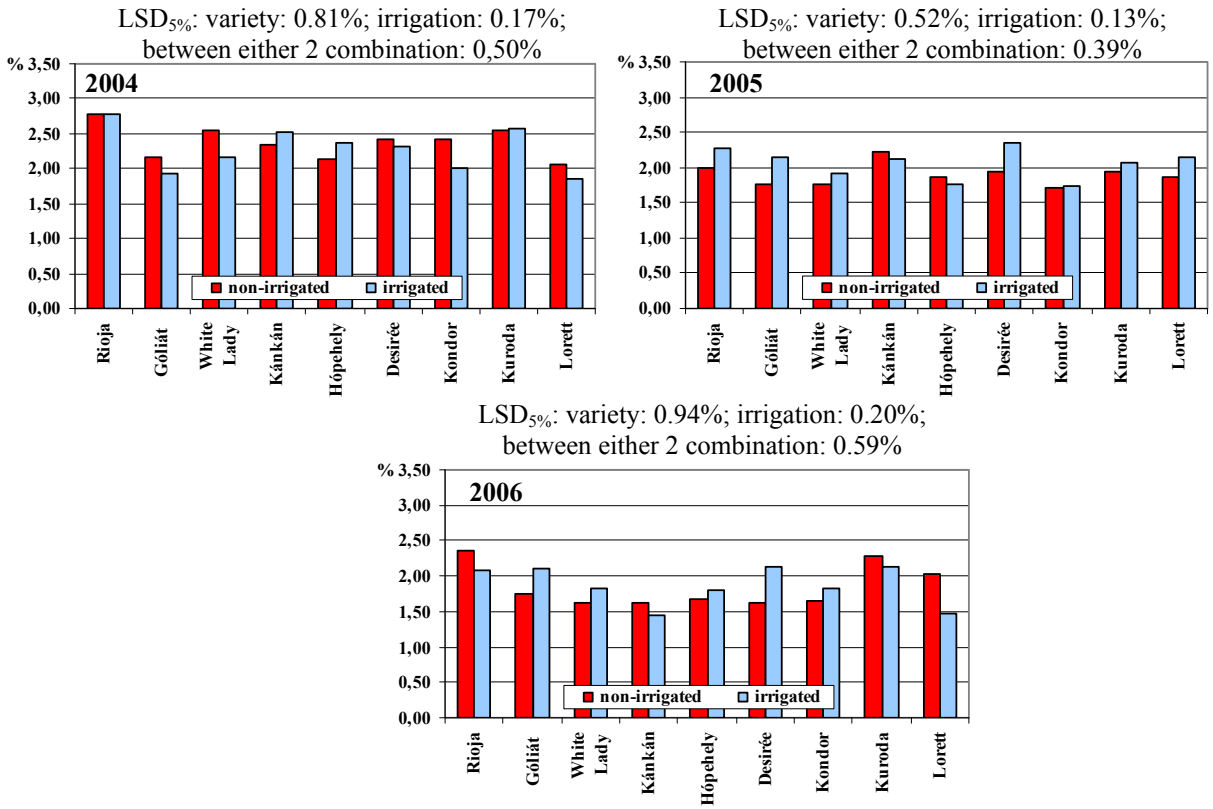


Figure 4: **The effect of irrigation on the protein content of potato varieties (%). Debrecen-Látókép, 2004-2006.**

In 2005, without irrigation the average protein content of the varieties was 1.90%. Irrigation increased the average protein content to 2.06%, respectively ($LSD_{5\%}$=0.13%). Irrigation increased the protein content in case of 7 varieties. Without irrigation only the protein content of Kánkán variety was higher than 2.00%. The protein content of Rioja (non-

irrigated: 1.99%, irrigated: 2.28%), Kuroda (non-irrigated: 1.95%, irrigated: 2.08%) and Desirée (non-irrigated: 1.94%, irrigated: 2.35%) varieties was favourable as well. Without irrigation the protein content of Góliát (1.78%), White Lady (1.76%) and Kondor (1.72%) varieties was low. The protein content of White Lady (1.92%), Hópehely (1.76%) and Kondor (1.74%) varieties was lower than 2.00% under irrigation as well.

In 2006, the protein content was lower than in the precedent years. In 2006 the average protein content was 1.85% under non-irrigated cultivation and 1.87% under irrigation. The protein content of Rioja (non-irrigated: 2.38%, irrigated: 2.09%) and Kuroda (non-irrigated: 2.30%, irrigated: 2.14%) varieties was the highest in 2006 as well. Without irrigation the protein content of Hópehely (1.67%), Kondor (1.65%), Desirée (1.64%), Kánkán (1.63) and White Lady (1.62%) varieties was low. As a result of irrigation the protein content of Desirée variety increased to 2.12%. Under irrigation the protein content of Lorett (1.48%) and Kánkán (1.45%) varieties was very low.

The highest protein contents were measured in 2004, without irrigation the protein content of all varieties was higher than 2%. The varieties with higher protein content (Rioja, Kuroda) had higher starch content as well, which shows the positive correlation between these two factors. The protein content of Rioja variety was the highest; 2.38% taking the results of the 3 years of the experiment into account. The protein content of Kuroda variety was high (2.26%) as well, while the protein content of Lorett variety was 1.89% in the average of the 3 year of the experiment. In 2004, the protein content of Rioja variety was higher than the protein content of Lorett variety, respectively, but the difference between the protein content of the varieties was not significant ($LSD_{5\%}$=0.58%) in the average of the 3 years of the experiment. The shortage of precipitation during the summer is disadvantageous in the point of view of protein content of potato tubers; the lowest protein content was measured in 2006 in the case of most of the varieties. The amount of precipitation in July influences the protein content in a large measure (0.524). There was positive correlation between the protein- and the starch content and between the protein content and the UWW as well in every year during the experiment. Similarly to the starch content, the protein content of Rioja and Kuroda varieties was high. The protein content is in correlation with the frying quality. There was negative correlation between the protein content and the content of reducing sugars (2004: -0.401*, 2005: -0.367*, 2006: -0.429**). There was negative correlation between the protein content and the index of frying colour in 2004 (0.653**) and 2006 (-0.410*) as well.

3.7. The effect of irrigation on vitamin C content

We applied of 2 different kinds of methods for measuring the vitamin C content. With titration we examined the vitamin C content every year, with HPLC in 2005 and 2006. The value measured by HPLC method was lower than the value of the titration, because we can measure other reducing compounds beside the ascorbic acid with titration. The even water supply has a favourable effect on the vitamin C content of potato tubers; the highest vitamin C content was measured in 2005. The average vitamin C content measured by titration was 25.73 mg% without irrigation and 27.49 mg% with irrigation. With HPLC the vitamin C content 4.43 mg% under non-irrigated and 14.94 mg% under irrigated cultivation. In 2004 the vitamin C content of the varieties was 20.38 mg% without irrigation and 19.17 mg% under irrigated cultivation. The lower amount of precipitation is unfavourable from the point of view of the vitamin C content as well; the vitamin C content of tubers in 2006 was the lowest. The vitamin C content in the average of the varieties was 21.39 mg% under non-irrigated, and 22.15 mg% under irrigated cultivation. With HPLC, the vitamin C content was 10.79% without irrigation and it was 10.85 mg under irrigated conditions. The differences between the Vitamin C content of the varieties were shown by all the 2 method. The Vitamin C content of White Lady and Kánkán varieties was high, and the Vitamin C content of Kondor and Góliát varieties was low. There was significant difference between the Vitamin C content of the varieties determined by titration every year of the experiment, but the difference between the vitamin C content of potato tubers determined with HPLC was significant only in 2006. There was not significant difference between the Vitamin C content of the varieties in the average of the 3 year during the experiment. The average Vitamin C content of White Lady variety was 30.77 mg% with titration, and 16.98 mg% with HPLC. The average Vitamin C content of Kánkán variety was favourable as well, with titration the vitamin C content of Kánkán variety was 26.75 mg% with titration, and 15.28 mg% with HPLC. The Vitamin C content of Kondor variety was the lowest in the average of the 3 examined years (titration: 18.59 mg%, HPLC: 10.49 mg%).

Under irrigation in 2004 the vitamin C content of the varieties decreased slightly, in 2005 and 2006 the vitamin C content increased, but the change wasn't significant in the average of the varieties. There was positive correlation between the two kind of vitamin C measurement (2005:0.653**, 2006: 0.819**).

3.8. The effect of irrigation on index of frying colour

The index of frying colour is result of a subjective method. The lower if index of frying colour is more favourable. For the food industry the value under 3 is very good, between 3 and 4 is acceptable.

The index of frying colour was the lowest in 2005 and the highest in 2006 which proves that the relatively favourable year effect and the even water supply have favourable effect on the frying quality of potato as well. The index of frying colour depends on the variety in the first place; there was significant difference between the indexes of the varieties in every year. The index of frying colour of Rioja variety was under value 2.00 in every year, and the index of Lorett variety changed about value 3 in every year. There was significant difference between the indexes of frying colour of the varieties in the average of the years as well; the average colour of frying index of Rioja variety was lower than the index of the other varieties, respectively. The colour of frying colour of Lorett variety was higher than the indexes of Rioja, Desirée, Kuroda, Hópehely and Kondor varieties ($LSD_{5\%}$=0.78).

In 2004, the index of frying colour was 2.48 without irrigation and 2.52 under irrigation. The index of Rioja variety was the lowest (about 1 value) both under non-irrigated and irrigated cultivation. The index of frying colour of Góliát variety (non-irrigated: 3, irrigated: 2.93) and Lorett variety (non-irrigated: 3.53, irrigated: 3) was high. Irrigation increased the index of frying colour of White Lady and Kondor varieties. Under irrigation the index of White Lady variety approximated the 3 value, which effects destruction of quality. The index of frying colour of Kondor variety was 2.75.

In 2005, the average index of frying colour was 2.41 without irrigation, and under irrigation the value of the index was 2.56. The index of Rioja variety was the most favourable (without irrigation: 1.25, under irrigation: 1.80) and the index of Desirée variety (non-irrigated: 1.85, irrigated: 2.28) was favourable as well. Without irrigation the index of frying colour of Kondor (2.88) and Lorett (3.25) varieties was high. As a result of irrigation the index of frying colour of Góliát variety increased from 2.46 to 3.23, and the index of Lorett variety increased to 3.63. Irrigation influenced the index of frying colour of Kondor variety (2.39) favourable.

In 2006, the index of frying colour was 2.68 without irrigation and 2.54 under irrigation. In 2006 the amount of precipitation was lower than the requirement of potato; therefore irrigation decreased the index in case of 6 varieties. As a result of the even water supply, the decomposition of starch to sugar was not considerable. In 2006 the index of frying colour of Rioja variety was the most favourable both under non-irrigated (1.60) and irrigated

(1.90) cultivation. Without irrigation the index of frying colour of Lorett (3.33), Hópehely (3.15) and White Lady (3.05) varieties was high. As a result of irrigation the index of Lorett variety increased to 3.55 worsening further the frying quality. The index of White Lady variety decreased to 2.80, and the index of Hópehely variety decreased to 2.50.

3.9. The effect of irrigation on the content of the reducing sugar content (%)

The content of reducing sugar was measured by subjective method as well. The food industry requires low reducing sugar content (for chips under 0.20%, for French fries: 0.30%).

The reducing sugar content of Hópehely, Kánkán, Desirée, White Lady and Rioja varieties was lower than 0.20% compared to the average value calculated for the investigated years of 200-2006. The average reducing sugar content of Kuroda variety was 0.22%, which is suitable for making French fries. The average reducing sugar content in the case of Kondor (0.33), Góliát (0.34%) and Lorett (0.71) varieties was high. The reducing sugar content in 2004 was the lowest and the highest was in 2005, which is inconsistent with the values of colour of frying index

In 2004, the average reducing sugar content was 0.17% without irrigation and 0.16% under irrigation. Expect the Lorett variety the reducing sugar content of the varieties was under 0.20% which suitable for the requirement of chips preparation. The reducing sugar content of Lorett variety was 0.50% both under no-irrigated and irrigated cultivations. In 2004, there was significant difference between the reducing sugar content of varieties. The reducing sugar content of Lorett variety was lower than the reducing sugar content of Góliát, White Lady, Hópehely, Desirée and Kondor varieties respectively ($LSD_{5\%}$=0.36%).

In 2005, the average reducing sugar content was 0.36% without irrigation and 0.32% under irrigation. The reducing sugar content of Kánkán variety was 0.00% without irrigation. Without irrigation the reducing sugar content of Góliát (1.05) and Lorett (1.25) varieties was high, their quality wasn't suitable even for making French fries. Under irrigation the reducing sugar content of Kondor variety increased to 1.25%.

In 2006, the average reducing sugar content was 0.17% under non-irrigated and 0.16% under irrigated cultivation. The reducing sugar content of Hópehely (0.05%) and the Kánkán (0.10%) varieties was the most favourable. As a result of irrigation the reducing sugar content of Hópehely variety increased to 0.10% and the reducing sugar content of Kánkán variety increased to 0.18%, but their qualities were henceforward convenient for the requirements of making chips. The reducing sugar content of Lorett variety was 0.50% without irrigation and 0.50% under irrigated cultivation.

3.10. The effect of irrigation on the element content of varieties (mg)

During the experiment we measured the macro-, mezzo- and micro-element content of the varieties. The experiment was for the determination of the element content of the varieties and the revelation of correlation between the element content and other quality parameters. The element content is concerned mg 1000g dry matter content^{-1}, but I used only the mg notation for the sake of simplicity.

3.10.1. The effect of irrigation on phosphorous content

The phosphorous content of the tubers was 2512 mg under irrigation, and 2589 mg under non-irrigated cultivation in the average of the years of the experiment, hence irrigation did not increase the phosphorous content (LSD5%=180 mg). Examining the years of the experiment separately, irrigation influenced the phosphorous content in the average of the examined varieties, but explicit relation can not be stated. The phosphorous content of the tubers increased in 2004 and 2005 as a result of irrigation, and significantly decreased in 2006.

The phosphorous content of potato depends on the variety. There was significant difference between the phosphorous content of the varieties. The phosphorous content of Desirée (2547.64-3187.74 mg), Kondor (2146.62-3126.34 mg), Kuroda (2154.33-3053.48 mg) and Lorett (2317.55-4058.55 mg) varieties was high, while the phosphorous content of Hópehely (1542.37-2648.73 mg) was low in all the 3 investigated years. The phosphorous content of Hópehely variety was lower than the phosphorous content of Desirée and Kondor varieties in 2004 and than of Desirée, Lorett and Kuroda varieties in 2005, respectively. In the average of 2004-2006 years, the phosphorous content of Lorett (3108 mg) was higher than the phosphorous content of Hópehely (2073 mg) variety (LSD5%=960 mg).

There was positive correlation between the phosphorous- and manganese content (2004: 0.407*, 2005: 0.635**, 2006: 0.635**), and between the phosphorous- and copper content (2004: 0.509**, 2005: 0.776**, 2006: 0.776**).

3.10.2. The effect of irrigation on potassium content

The potassium of the tubers content of the potato tubers depend on the year. The potassium content was lower in 2006 than in 2004 and 2005. In 2004 and 2005 the average potassium content ranged between 18000-19000 mg, while in 2006 the average potassium content ranged between 13000-14000 mg. There positive correlation between the potassium content of potato tubers and the amount of precipitation in the breeding season (r=0.388**) and the amount of precipitation in July (0.561**) as well. The irrigation increased potassium content only in 2005 significantly. The average potassium content was 17104 mg under

irrigated and 16994 mg under non-irrigated cultivation. In the average of 2004-2006 years, irrigation did not influence the potassium content ($LSD_{5\%}$=1066 mg) considerably. The potassium content of Góliát and Kánkán varieties was high in every year, while the potassium content of the other varieties were variable. The potassium content of Góliát variety ranged between 16465 and 20201 mg, and the potassium content of Kánkán variety ranged between 14110 and 20557 mg during the experiment. In 2006, the potassium content of Hópehely variety was lower than the potassium content of Góliát, Kánkán, Rioja and White Lady varieties ($LSD_{5\%}$=6943 mg), respectively. The potassium content of Góliát (18897 mg) and Kánkán (18243 mg) varieties was the highest in the average of the years as well. The potassium content of Hópehely variety was just 14600 mg, but there was not significant difference between the average potassium content of the varieties ($LSD_{5\%}$=6851 mg).

There was positive correlation between the potassium and the magnesium content (2004: 0.628**, 2005: 0.564**, 2006: 0.604**).

3.10.3. The effect of irrigation on calcium content

The average calcium content of potato tubers was over 500 mg in 2004 and 2006, while in 2005 it was just 425 mg both under non-irrigated and irrigated cultivation. The irrigation influenced the calcium content in 2006 significantly. The lowest calcium content was measured in 2005, there was negative correlation between the calcium content of potato tubers and the amunt of precipitation during the breeding season (0.407). The calcium content decreased at the most of the varieties as a result of irrigation in every year during the experiment. Irrigation decreased the calcium content in the average of the 3 years as well (non-irrigated: 538.64 mg, irrigated: 479.38 mg, $LSD_{5\%}$=48.48 mg). The calcium content of Hópehely (339.27-470.18 mg) and White Lady (302.28-530.81 mg) varieties was low, while the calcium content of Kánkán (454.13-816.64 mg) and Kondor (457.75-896.11 mg) varieties were higher than the average of the varieties in every year during the experiment. The difference between the calcium content of the varieties was significant only in 2004. In 2004, the calcium content of Desirée variety was higher than the calcium content of Rioja variety, respectively. In the average of the 3 year of the experiment the calcium content of Kondor variety was the highest (597.81 mg), and the calcium content of Hópehely variety was the lowest (393.56 mg), but there was not significant difference between the calcium content of the varieties ($LSD_{5\%}$=318.44 mg).

There was positive correlation between the calcium and the boron content (2004: 0.398*, 2005: 0.490*, 2006: 0.386*), and between the calcium and iron content in 2005 (0,400*) and 2006 (0.348*).

3.10.4. The effect of irrigation on magnesium content

The magnesium content of potato tubers was the lowest in 2004; the average magnesium content was 764 mg in 2004, while in 2005 and 2006 the average magnesium content ranged between 865-930 mg. The amount of precipitation and the year effect influences the magnesium content of tubers (r=0.301**). The distribution of precipitation is important in the point of view of the magnesium content of tubers, there was negative correlation between the magnesium content and the amount of precipitation in June (r=-0.423**). The difference between the magnesium content of the varieties was significant only in 2005. In 2006 irrigation influenced the magnesium content of potato tubers significantly. The magnesium content of Góliát and Lorett varieties (800-1030 mg) was high in every year during the experiment, while the magnesium content of the other varieties were variable. In the average of the 3 year of the experiment the irrigation did not influenced the magnesium content considerably. In the average of 2004-2006 years, the magnesium content of Góliát variety (951.48 mg) was the highest, and the magnesium content of Kondor variety (807.43) was the lowest, but the difference was not significant ($LSD_{5\%}$=183.32 mg).

There was positive correlation between the magnesium and the potassium, sulphur (2004: 0.378*, 2005: 0.457**, 2006: 0.484**) and manganese content (2004: 0.384*, 2005: 0.546**, 2006: 0.631**).

3.10.5. The effect of irrigation on sulphur content

The lowest sulphur content was measured in 2004, in the case of the most of the varieties. The average sulphur content ranged between 1100 and 1200 mg in 2004 and between 1440 and 1500 mg in 2005. The even water supply is favourable from the point of view of sulphur content of the potato tubers; there was positive correlation between the sulphur content and the amount of precipitation of the growing season (r=0.417). As a result of irrigation, sulphur content increased every year, but the difference was significant only in 2004. In the average of the 3 year of the experiment, irrigation did not have significant effect on the sulphur content. The sulphur content of Rioja, White Lady, Kánkán, Hópehely and Lorett varieties was favourable, and the sulphur content of Desirée, Kondor and Kuroda varieties was lower than the average of the 9 examined varieties. In 2004, the sulphur content of Rioja variety was higher than the sulphur content of Kuroda, Góliát and Kánkán varieties. In the average of the 3 years of the experiment, the sulphur content of Rioja (1497.76 mg) and White Lady (1465.48 mg) varieties was higher than the sulphur content of Kondor (1192.70 mg) and Desirée (1195.34 mg) varieties, respectively (LSD5%=262.42 mg).

3.10.6. The effect of irrigation on sodium content

The average sodium content of potato tubers ranged between 70-90 mg. The sodium content was variable; tendencies and differences among the varieties could not be figured out. The sodium content in the average of the 3 years of the experiment was 80.00 mg under irrigated, and 83.87 mg under non-irrigated cultivation. Irrigation did not influence the sodium content according to the result of the 3 year ($LSD_{5\%}$=9.42 mg). In 2006 the sodium content of Góliát variety was higher than the sodium content of the a Hópehely, Lorett and Kuroda varieties. In the average of 2004-2006 years the sodium content of Góliát variety was the highes (105.32 mg) and the sodium content of the Kuroda variety was the lowest (69.97 mg), but the difference between the sodium content of the varieties was not significant ($LSD_{5\%}$=55.76 mg).

There was positive correlation between the sodium and the iron content (2004: 0.409*. 2005: 0.346*, 2006: 0.634**).

3.10.7. The effect of irrigation on iron content

The iron content of potato tubers was the lowest in 2004 (47 mg) and was the highest in 2006 (75-90 mg). There was closed positive correlation between the iron content of potato tubers and the amount of precipitation in July (r=0.521). Irrigation did not influence the iron content of potato tubers in 2004 and 2005. In 2006 the iron content of tubers decreased, but the difference wasn't significant. The average iron content in the 3 year of the experiment was 66.13 mg without irrigation and 66.02 mg under irrigation. Irrigation did not influenced the iron content of potato considerably in the average of the years of the experiment ($LSD_{5\%}$=7.30 mg). The iron content changed differently during the examination, relations and differences between varieties could not be established. In 2006 the iron content of Kánkán variety was higher than the iron content of Hópehely, Lorett and Desirée varieties. In the average of the 3 year of the experiment the iron content of Kánkán variety was the highest (90.84 mg) and the iron content of Lorett variety was the lowest (51.13 mg), but the difference between thr iron content of the varieties was not significant ($LSD_{5\%}$=66.65 mg). There was positive correlation between the iron and the sodium content in every year of the experiment.

3.10.8. The effect of irrigation on manganese content

The average manganese content of potato tubers ranged between 5-6 mg. Among of the varieties the manganese content of Desirée, Kondor, Góliát and Lorett varieties were high, their average manganese content was higher than 6 mg during the experiment. The manganese content of Hópehely, White Lady and Kuroda varieties was lower than 5 mg. There was not significant difeerence between the manganese content of the varieties in the average of the 3

year of the experiment ($LSD_{5\%}$=2.63 mg). The manganese content in the average of the 3 year of the experiment was 5.48 mg without irrigation and 5.51 mg under irrigation, irrigation did not influenced the average manganese content ($LSD_{5\%}$=0.48 mg).

There was negative correlation in every year between the manganese content and the under water weight, and between the manganese content and the dry matter content. There was positive correlation between the manganese content and the phosphorous-, and in addition the magnesium content. Irrigation didn't influence the phosphorous content significantly, and there wasn't significant connection neither between the manganese content of the varieties.

3.10.9. The effect of irrigation on boron content

The average boron content of potato tubers ranged between 4.55-6.10 mg during the experiment. The boron content of Kánkán, Lorett, Desirée and Góliát varieties were high during the experiment, while the boron content of White Lady variety was low, but there wasn't significant difference between the boron content of the varieties. The difference between the boron content of the varieties was not significant in the average of the 3 years of the experiment as well ($SzD_{5\%}$=1.80 mg). The average boron content of White Lady variety was the lowest (4.53 mg) and the average boron content of Lorett variety was the highest (6.11 mg). Irrigation did not influence the boron content during the experiment. In the average of the 3 years of the experiment the boron content was 5.60 mg under non-irrigated and 5.42 mg under irrigated cultivation ($LSD_{5\%}$=0.41 mg).

Boron has part in the carbohydrate metabolism, and therefore there was negative correlation between boron content and the dry matter, starch content and UWW. There was positive correlation between the boron and the calcium content in every year.

3.10.10. The effect of irrigation on copper content

There was significant difference between the copper content of the varieties in every year. The copper content of Lorett, Kuroda, Desirée and Kondor varieties were high, the copper content of Hópehely was low in every year during the experiment. In the average of the years of the experiment the copper content of Lorett variety (6.60 mg) was higher than the copper content of Hópehely (3.62 mg) and Kánkán (3.92 mg) varieties. The copper content of the varieties depends on the year; the average copper content was the highest in 2005, the lowest in 2006. There was closed positive correlation between the boron content of the potato tubers and the amount of precipitation during the breeding season (r=0.655**) and between the amount of precipitation in July (0,337**). Irrigation didn't have effect on the copper content in 2004 and 2006. In 2005 as a result of irrigation the copper content decreased, but

the difference was not significant. The copper content in the average of the 3 years of the experiment was 5.17 mg without irrigation and 5.04 mg under irrigation. Irrigation did not influenced the copper content in the average of the years of the experiment as well ($LSD_{5\%}$=0.28 mg). There was negative correlation between the copper content and the vitamin C content in every year, and positive correlation between the copper content and the phosphorous content. In 2005 and 2006 there was positive correlation between the copper content and the under water weight and between the dry matter content. In 2004 and 2006 there was positive correlation between the copper content and the magnesium content.

3.10.11. The effect of irrigation on zinc content

The average zinc content of potato tubers changed between 10.80 and 13.04 mg. The highest zinc content was measured in 2004. The zinc content of the varieties was variable during the experiment. In the average of the 3 years of the experiment the zinc content was 11.60 mg under non-irrigated and 11.19 mg under irrigated cultivations, but the difference between the irrigated and non-irrigated replications was not significant. There was not significant difference between the zinc content of the varieties as well. In the average of the 3 years of the experiment the zinc content of Kuroda variety was the highest (12.60 mg) and the zinc content of Hópehely variety was the lowest (10.53 mg).

In 2004 and 2006 there was positive correlation between the zinc content and the magnesium content.

3.11. Effect of irrigation on the photosynthetic activity

We measured the photosynthetic activity of Lorett, Rioja and Kuroda varieties. In 2004 we measured the photosynthetic activity at 2 times. The photosynthetic activity ranged between 19-30 µmol CO_2 $m^{-2}sec^{-1}$ at 29 May, and it changed between 10-24 µmol CO_2 $m^{-2}sec^{-1}$ at 25 July. The photosynthetic activity decreased slightly under irrigation because of the diseases caused by the excessive water supply. The photosynthetic activity of Rioja variety was the highest both under non-irrigated and irrigated conditions which shows the salient resistance against pathogenic organisms of the variety.

The photosynthetic activity was about 15-25 µmol CO_2 $m^{-2}sec^{-1}$ at the end of May. The photosynthetic activity of Lorett variety was higher than the other varieties because of the vigorous early growth of the variety. The photosynthetic activity ranged between 44-75 µmol CO_2 $m^{-2}sec^{-1}$ at 25 July. The value of photosynthetic activity was high, because there was enough precipitation before the measurement and the sunshine was undisturbed, but the temperature of the leaves was high (28°C). The photosynthetic activity of the varieties was high in the middle of July, but for 10 August it decreased to 8.5-18.5 µmol CO_2 $m^{-2}sec^{-1}$,

because as a consequence of the warm and vaporous weather and the pathological diseases the foliage decreased. There was not substantial difference between the photosynthetic activities of the varieties at 10 August. There wasn't substantial difference between the photosynthetic activities of the varieties in 2005, because the water supply was even.

We measured the photosynthetic activity in 3 times in 2006 as well. The photosynthetic activity of the varieties ranged between 15 and 29 μmol CO_2 m^{-2} sec^{-1} at 26 June. The photosynthetic activity of Lorett variety was the highest both under non-irrigated, and irrigated cultivations. The photosynthetic activity changed between 12 and 26 μmol CO_2 m^{-2} sec^{-1} at 10 July. The photosynthetic activity of Lorett variety was the highest in 10 July as well and the photosynthetic activity of Rioja variety was the lowest. The measured values were lower in 10 July than a year before, because the sky was cloud over and there hadn't been precipitation for 10 days preceding the measurement. The photosynthetic activity of Lorett variety was the highest at 10 August as well (20-25 μmol CO_2 m^{-2} sec^{-1}), and the photosynthetic activity of Rioja variety was the lowest (17-18 μmol CO_2 m^{-2} sec^{-1}).

4. Summary

The results show that the varieties bred in Hungary can compete with the Dutch varieties in yield and in quality. Among the Hungarian varieties the Hópehely and White Lady varieties were superior in the point of view of productivity, dry matter content, protein content and vitamin C content, and their frying quality was favourable as well. The dry matter content of Rioja variety was salient and its index of frying colour remained under the value of 2 in every year during the experiment. The yield of Lorett variety was salient in every year and the distribution of tubers according to size was favourable as well. The starch content of Lorett variety only in 2005 was higher than 14%, but its element content is high. The even water supply have cardinal importance in the point of view the quality of the potato, even in a wet year, the starch content, the protein content and the vitamin C content increased under irrigation, and the value of the main quality parameters was more favourable in 2005 than in 2004 and 2005.

5. New and up-to-date scientific results

1. On the base of the results of our experiment it can be stated, that irrigation and even water supply increased the yield in the average of the examined varieties respectively, and the quality also improved as a result of irrigation. In 2005, the average yield was 44.50 t ha^{-1} without irrigation and 46.45 t ha^{-1} under irrigated cultivation. The difference between the irrigated and non-irrigated replications was on the edge of significance ($LSD_{5\%}$=1.94 t ha^{-1}) in 2005. In 2006, the yield of the non-irrigated replications was 35.93 t ha^{-1}, and under irrigation the average yield was 41.21 t ha^{-1}, the irrigation applied twice in July increased the yield respectively ($LSD_{5\%}$=2.78 t ha^{-1}). In 2005, in the rainiest year, the yield maximum of the varieties ranged between 36.30 t ha^{-1} (Rioja) and 57.45 t ha^{-1} (Hópehely).
2. There was negative correlation between the dry matter content and the phosphorous- (2004: r=-0.462**, 2005: -0.338*, 2006: -0.364*), boron- (2004: -0.428**, 2005: -0.435*, 2006: -0.650**) and manganese (2004: -0.490**, 2005: -0.405*, 2006: -0.487**) content in each year during the experiment in the average of the varieties and irrigations.
3. The protein content of the potato tubers depends on the year effect primarily. The protein content was higher in those years (2004 and 2005) when the summer was rainy during the development of the tubers. In 2006, there was lower precipitation during the summer than in 2004 and 2005, and the protein content was 1.85% under irrigated and 1.87% under non-irrigated cultivations. The difference between the varieties is distinct. The varieties with higher protein content (Rioja, Kuroda) had higher starch content as well, which shows the positive correlation between these two factors (2004: 0.645**, 2006: -0.385*), while the starch and protein content of Lorett variety was low during the experiment.
4. The protein content is in correlation with the frying quality. The varieties with higher protein content have more favourable frying quality (Kuroda, Rioja varieties). In the average of the varieties and irrigations, there was negative correlation between the protein content and the content of the reducing sugars every year (2004: r=-0.401*, 2005: -0.367*, 2006: -0.429**) and in 2004 (-0.653**) and 2006 (-0.410*) between the protein content and the index of frying colour.
5. The vitamin C content depends on the variety. The vitamin C content of The White Lady was high every year during the experiment. With even water supply, the vitamin C content can be increased. On the basis of our results, the vitamin C content was the

highest in the rainiest year, in 2005, on the basis of the results of titration measurement and HPLC methods as well. In 2005 the average Vitamin C content was 25.73 mg% under non-irrigated and 28.88 mg% under irrigated cultivations measured by titration, and measured with HPLC the average Vitamin C content was 14.43 mg% without irrigation and 14.94 mg% under irrigation.

6. In the average of the 9 examined varieties and the irrigations there was negative relationship between the Vitamin C content and with the phosphorous and copper content as well. There was negative correlation between the vitamin C content and the phosphorous content every year of the experiment in the case of all vitamin C measurements (titration: 2004: r=-0.532**, 2005: -0.392*, 2006: -0.362*; HPLC: 2005: -0.458**, 2006: -0.537**). There was negative correlation between the copper content and the vitamin C content in the case of both methods (titration: 2004: r=-0.543**, 2005: -0.333*, 2006: -0.487**; HPLC: 2005: -0.334*, 2006:-0.666**).
7. There is a relation between the contents of certain elements of potato. There was a positive correlation between the magnesium and potassium (2004: r=0.628**, 2005: 0.564**, 2006: 0.604**) and the sulphur (-2004: 0.378*, 2005: 0.457**, 2006: 0.484**) and manganese content (2004: 0.384*, 2005: 0.546**, 2006: 0.631**) of the tubers as well. There was a positive correlation between the boron- and the calcium content (2004: 0.398*, 2005: 0.490*, 2006: 0.386*) and between the iron- and sodium content every year during the experiment (2004: 0.409*. 2005: 0.346*, 2006: 0.634**). There was a positive correlation between the phosphorous and manganese ((2004: 0,407*, 2005: 0,635**, 2006: 0,635**) and the copper content (2004: 0.509**, 2005: 0.776**, 2006: 0.776**) as well.

6. Results that can be utilised in practise

1. The quality of potato is complex, it depends on the dry matter content, the protein content, the frying quality and the element contents of tubers too. The even water supply is favourable to the quality of the potato, even in a wet year, in 2005, the starch content, the protein content and the vitamin C content increased under irrigation.
2. The quality of potato is sufficient also in the case of chernozem soils. On chernozem soils the water supply can be more even with irrigation and agro-technology. With irrigation potato is marketable, and the quantity of the physiological diseases could be reduced, the health condition, the quality and the product safety could be increased.

3. Among the varieties the Rioja variety rose above the others on the basis of dry matter content and frying quality. The quality Rioja variety was suitable for making fried potato.
4. The starch content of variety Lorett was 12-13% in 2004 and 2006, but in a favourable year, it was 14.5-15.0%. The low starch content is disadvantageous from the point of view of storage and food industry processing. The Lorett variety excelled with its yield capacity and the number of its large-sized tubers.
5. Desirée has been one of the most popular variety in Hungary since the end of the 1960ies, but nowadays the variety is not up-to-date (resistance parameters) any more. In favourable years, the yield and the quality of the variety are good, but its plant pathological sensitivity and to the climatic effects is high. The yield and the quality of tubers of Desirée variety decreased both under water shortage and under large amount of precipitation.
6. The Hópehely and White Lady varieties can compete with the Dutch varieties from the point of view of their yield quantity and quality as well. The yield quantity and quality of these varieties are favourable both under irrigated and non-irrigated cultivation. The dry matter content, the starch content and the vitamin C content of the White Lady and Hópehely varieties are high, and their frying quality is favourable too.
7. The distribution of tubers according to their size was unfavourable in the case of Kánkán variety, the proportion of small tubers ranged between 30 and 60%. We do not suggest the cultivation of Kánkán variety at the Hajdúság region. The Kánkán variety produces lots of tubers, but the variety is not able to develop the tubers even under irrigated cultivation.
8. Among the examined varieties the following ones are suggested to be produced in the Hajdúság region: Lorett, Kuroda, White Lady, Hópehely, Rioja and Kondor, both under irrigated and non-irrigated cultivations. We suggest the growing of Desirée and Góliát variety only under irrigated conditions and we do not suggest the production of the Kánkán variety.

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