International Journal of Horticultural Science 2006, 12 (4): 65–70
Agroinform Publishing House, Budapest, Printed in Hungary
ISSN 1585-0404

The impact of irrigation on the yield and tuber fraction distribution of potato cultivars

Zsom, E.

University of Debrecen, Centre of Agricultural Sciences, Faculty of Agriculture, Department of Crop Production and Applied Ecology

Summary: Potato is one of the most important plants in human nutrition, it is grown in about 140 countries. As a food, it can be prepared in many ways, it is easily digestable with proteins of high biological value, favourable dietetical-physiological characteristics, high starch content and good taste. An increase in its consumption would be favourable from the dietetical point of view. In Hungary, the growing area of potato has decreased considerably for the last decades and we are lagging behind the Western-European countries regarding yield. The experiments were carried out at the Experimental Site of the University of Debrecen at Látókép between 2002 and 2004. In the large-plot experiment, the yields and the distribution of the tuber fractions were studied for 9 medium early cultivars. The experiment was set up on 50 m2 plots on calcareous chernozem soil. Among the studied cultivars, 3 were of Dutch (Desirée, Kondor, Kuroda) and 6 were of Hungarian breeding ('Góliát', 'Hópehely', 'Kánkán', 'Lilla', 'Százszorszép', and 'White Lady'). The experiment was set up in 4 repetitions in a randomized design, two of the repetitions were irrigated while two were non-irrigated.

Key words: potato, irrigation, potato cultivars

Introduction

The geographical location and climate of Hungary are less favourable for potato growing and seed potato propagation than those of countries with a more northern, north-western location, therefore, the diseases and pests have a more severe impact. After the EU accession, the Hungarian growers can maintain their positions only if they increase the efficacy, utilize the possibilities in technologies and biological bases more efficiently and if they create more favourable market conditions (*Kruppa* et al, 2003).

According to *Epstein & Grant* (1973), *Phene & Sanders* (1976), *Shalhevet* et al. (1983), *Marutani & Cruz* (1989), *Shock* et al. (1998), *Opena & Porter* (1999), *Porter* et al. (1999) and *Fabeiro* et al. (2001), the conditions are favourable for the growth of potato if the nutrients are almost continuously available in large amounts, the diffusion ratio of oxygen in the soil is high, the solar radiation and the nutrient stock of the soil are satisfactory, but among the listed environmental factors, the amount and quality of potato yield is limited mainly by humidity of the soil.

Numerous irrigation experiments have proved that potato is sensitive to water stress, since it has a weak root system and 85% of roots is concentrated in the top soil (upper 30 cm) (*Opena & Porter*, 1999). Water stress results in yield reduction, weaker plant growth and lower amount of biomass produced. During growth, potato evaporates 3–5 mm water per day if the soil moisture level is optimal (*Marutani & Cruz*, 1989).

The poor root system of potato has a low suction capacity, therefore, in dry periods, water becomes a limiting factor in plant development easily. The impact of irrigation is dependent upon the degree of deficiency in the natural water supply and on the plant development stage. In the irrigation experiment of *Lelkes* et al. (1988) at Szarvas with cv. 'Desirée', the average total tuber yield without irrigation ranged between 7 and 50 t/ha. The average yield was 28 t, 80% of which reached the table size. With proper irrigation, yields of 40–47 t/ha were obtained with the average yield being 43.5 t/ha. The yield increment due to irrigation was 15.5 t/ha. The favourable effect meant not only a yield increment, but also a significant reduction in the variation in yield between the years.

Under non-irrigated conditions, especially in dry years, the ratio of small tubers was 40–50%, under irrigated conditions with a proper water supply, this ratio was below 25%, it was even less than 10% for some cultivars. Under good water supply or due to irrigation, the ratio of undersized tubers decreases and the ratio of marketable tubers increases. No significant differences were found int he number of tubers.

Harun-ur-Rashid et al. (1990) found when studying the relationship between the water use of irrigated potato and potato yield that if 40 mm water was given in 12 days (irrigation was started 30 days after planting), the highest number of the tubers were in the size categories of 28–45 mm and larger than 45 mm. The highest ratio of tubers below 28 mm was found in the non-irrigated treatment.

Arends (1999) also found that the lack of water during the period of tuber set and development had a disadvantageous effect on the distribution of tubers between the different size

categories: the ratio of large tubers is reduced. According to his results, the adverse effect of water deficiency is stronger on loose and heavy soils than on mid-heavy loam soil.

According to *Antal* et al. (2005), the number of potato plants per unit area should be increased by 10–15% by irrigation. For yields higher than 40 t/ha and for superior quality, continuous and regular irrigation is necessary.

In developing potato production, the exact knowledge of production factors (ecological, biological and agrotechnical), their exploration and the application of cultivar-specific technologies are of special importance, in addition to the improvement of efficacy, the better utilization of opportunities of the technologies and the biological bases, irrigation can increase yields considerably: the temporary periods of water deficiency can be prevented and the amount and quality of yield are enhanced (*Kruppa*, 1998). The areas of Hungary that can be irrigated should be utilized in order to achieve better yields.

In the future, cultivar- and site-specific technologies should be applied in potato production too: the cultivar best adapted to the conditions should be selected according to the purpose and intensity of production.

In the present study, the impact of production factors, primarily that of water supply was investigated on yield and on distribution of tubers among the different size categories for 9 mid-early potato cultivars.

The aim of research on calcareous chernozem soils in the Hajdúság region with cultivars of different purpose of use from Dutch and Hungarian breeding was to verify that it is worth to grow potato int he region intensively and profitably and to give guidance on the cultivars to the growers based on the production experiments.

Materials and methods

The experiment was carried out in the period of 2002–2004 at the experimental field of the University of Debrecen, Centre of Agricultural Sciences, Farm and Regional Research Institute at Látókép.

The soil of the experiment was calcareous chernozem formed on loess, with a medium-level nutrient content. The forecrop was winter wheat in 2002 and corn in 2003 and 2004. Weather was different in the three years. In the growing season of 2002, 2003 and 2004, the precipitation was 94.4 mm and 127.9 mm lower and 4.4 mm higher than the average of 30 years, respectively. 6 Hungarian ('Góliát', 'Hópehely', 'Kánkán', 'Lilla', 'Százszorszép', 'White Lady') and 3 Dutch cultivars ('Desiée', 'Kondor', 'Kuroda') were included in the experiment. The 9 cultivars were studied in four repetitions in a randomized block design, two repetitions were irrigated, while two were non-irrigated.

In the experiment, the yield capacity, the distribution of tubers among the size categories and the inner content parameters (under-water mass, dry matter content, starch content, reducing sugar content, macro-, mezo- and microelement content) and the frying colour index were determined. The examinations were carried out in such a way that the obtained results could be utilized by growers producing under similar ecological conditions and new information will be available which will help in determining the impact of climatic factors and irrigation as one of the major production factors on potato yield in the region in multi-year experiments and after the evaluation of the year effect and the effects of the above production, ecological and biological factors, also in selecting the cultivars that can be grown successfully in the region for different purposes of use.

Weather in the years of the experiment

Weather was different in all experimental years: regarding precipitation, 2002 was an average year, 2003 was dry while 2004 was more humid. Temperature and precipitation data are shown in *Figures 1–3*.

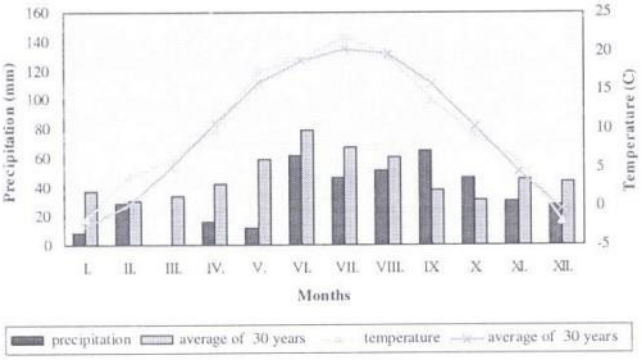


Figure 1. Temperature and precipitation data at Debrecen-Látókép in 2002.

In 2002, the precipitation was especially low in January, April and May. Precipitation was lower than the average of 30 years in June and August, which has a disadvantageous effect on potato yield formation. In 2002, the total amount of precipitation was 94 mm lower than the average of 30 years.

The temperature values were different only by 0.40 °C as compared to the average temperature during the season. The warmest weather was detected in June and July (*Figure 1*).

In 2003, precipitation was 143 mm less than the average of 30 years. The amount of precipitation was satisfactory only in May and July, in August only 1 mm of rain fell as compared to the average of 60 mm. The monthly mean temperatures were higher than the average of 30 years in May-August. The growing season was more warm in 2003 but there was a severe lack of water in March and April, which hindered emergence, the lack of precipitation in June and August rendered the development and enhanced the development of diseases (*Figure 2*).

In 2004, the weather conditions were more favourable than in 2003. The total amount of precipitation was 603 mm, which was 36 mm higher than the average of 30 years. Only May was very dry, only 17 mm of rain fell in this month, therefore, an irrigation with 15 mm was performed to induce emergence in all the four repetitions. However, in July, the amount of precipitation was twice as high as the average, which had a disadvantageous effect on the health of the plants (*Figure 3*).

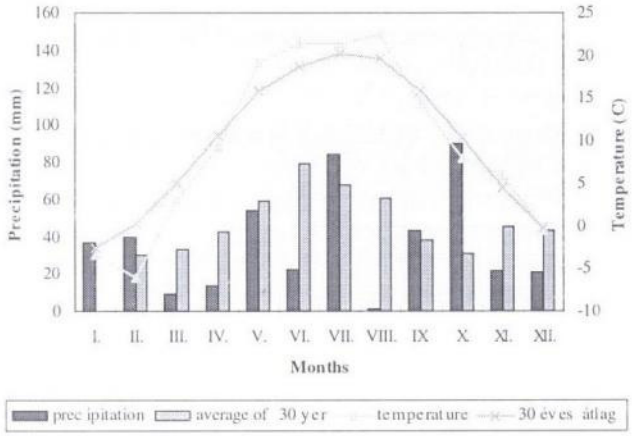


Figure 2. Temperature and precipitation data at Debrecen-Látókép in 2003.

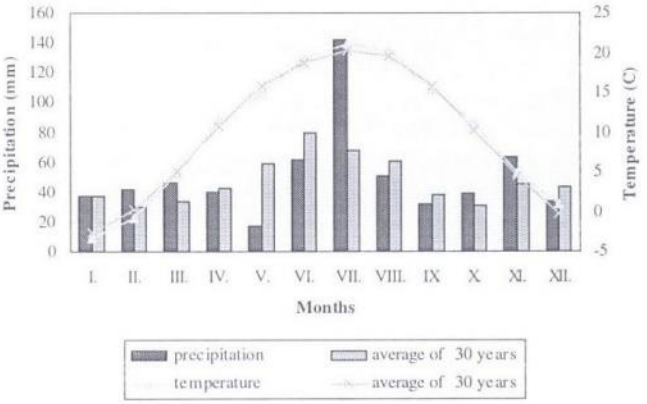


Figure 3. Temperature and precipitation data at Debrecen-Látókép in 2004.

Soil of the experiment

The experiment was carried out on calcareous chernozem soil formed on loess with a deep humus layer, the nutrient supply of which was satisfactory. The soil had good water management: good water capacity and drainage. The ground water level is at 8–10 m depth, the soil can store a large amount of water from precipitation.

Applied agrotechniques

The basic cultivation in autumn was deep ploughing of 35 cm in all three years in September, followed by dick-harrow. Planting was performed with a two-row Cramer type planting machine on 3–4 April 2002, 23–24 April 2003 and 21–22 April 2004. The forecrops were winter wheat in 2002 and corn in 2003 and 2004. The size of the plots was 102 m^2 in 2002, 64 m^2 gross area, 49.5 m^2 net area in 2003 and 64 m^2 gross area, 49 m^2 net area in 2004. In all three years of the experiment 165 kg N, 120 kg P_2O_5, and 220 kg K_2O active ingredients were applied per ha. Plant protection was applied as is usual in the practice. In all three years of the experiment, four irrigations were carried out in the irrigated treatments, the applied water norms were 4 x 40 mm in 2002, 3 x 30 mm and 1 x 35 mm in 2003, while in the rainy year of 2004, the dosages were 1 x 15, 1 x 25 and 2 x 30 mm. Potato was harvested at 3 October 2002, 25-26 September 2003 and 22 September 2004. The plant density in all the three years of the experiment was 51 thousand plants/ha.

Method of evaluation

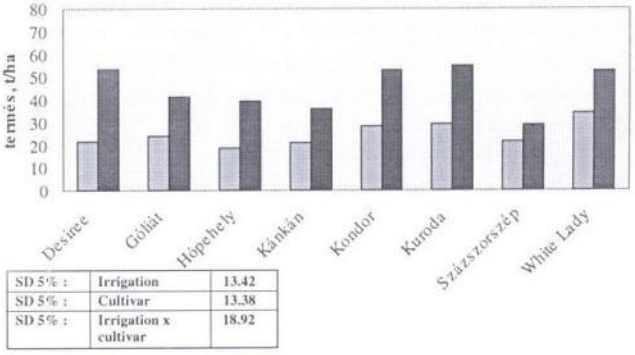
To test the differences between the irrigation treatments and cultivars, SD5% calculated according to Sváb (1981) was used, which was calculated for irrigation, cultivar and the irrigation x cultivar interaction. In order to clarify the irrigation x cultivar interaction, linear regression analysis and a correlation analysis according to Wealson were applied. The data obtained were evaluated by one-way and two-way analysis of variance (*Sváb* 1981), and LSD test.

Results

Impact of irrigation on the amount of yield

Year 2002 was an average year for potato. Under non-irrigated conditions, the studied 8 cultivars had an average yield of 25 t/ha. The average yield of the irrigated treatments was 42 t/ha, which was 70% higher than that of the non-irrigated treatments. Under non-irrigated conditions, cvs. 'Kondor', 'Kuroda' and 'White Lady' had the highest yields, under irrigation, the highest yields were obtained also for these cultivars plus 'Desirée'. The lowest yields in the non-irrigated treatments were obtained for cvs. 'Hópehely', 'Kánkán', 'Százszorszép' and 'Desirée'. Under irrigated conditions, cvs. 'Százszorszép', 'Kánkán' and 'Hópehely' had the lowest yields. Yield increment due to irrigation was different for the 8 cultivars.

Regarding the yield data of 2002, the yield increasing effect of irrigation is statistically verifiable: irrigation significantly increased (SD5 %= 13.42) the yield of cvs. a 'Desirée', 'Góliát', 'Hópehely', 'Kánkán', 'Kondor', 'Kuroda' and 'White Lady' (*Figure 4*).



SD 5% :	Irrigation	13.42
SD 5% :	Cultivar	13.38
SD 5% :	Irrigation x cultivar	18.92

Figure 4. The impact of irrigation on potato yield in 2002, t/ha (blue: not irrigated; red: irrigated)

Yield increased by 70% on average in irrigated treatments as compared to non-irrigated treatments, ranging between 70–90 % in most cases, but for cv. 'Desirée' and 'Hópehely', the values were 140% and 110%, respectively. The lowest

increment between 35–55% was detected for cvs. 'Százszorszép' and 'White Lady'.

There were significant difference among cultivars (SD5%=13.38): yields of cvs. 'Desirée', 'Kondor', 'Kuroda' and 'White Lady' were significantly higher than those of cvs. 'Kánkán', 'Százszorszép' and 'Hópehely'. The interaction between irrigation and cultivar did not have a significant effect on yield.

2003 was a very dry year for potato, especially the period between May and July.

In this year, the newly registered cultivar 'Lilla' of Keszthely breeding was also included in the experiment.

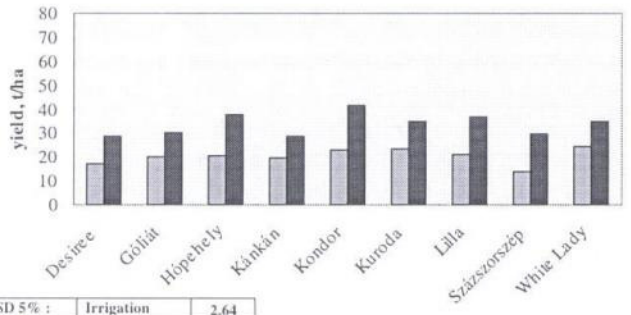
In 2003, the average yield of the selected cultivars in the non-irrigated and irrigated treatments was 20 t/ha and 34 t/ha, respectively (*Figure 5*). Yield increment due to irrigation was 70% on average as compared to 2002.

In 2003, cvs. 'White Lady', 'Kuroda' and 'Kondor' had the highest yields in the non-irrigated treatments. In irrigated treatments cvs. 'Kondor', 'Hópehely', 'Lilla', 'Kuroda' and 'White Lady' gave the highest yields.

Cv. 'Százszorszép' (14 t/ha) and 'Desirée' (17 t/ha) had the lowest yield in the non-irrigated treatment, they have not even reached 20 t/ha, while in the irrigated treatment, the lowest yields were obtained for cvs. 'Desirée' (29 t/ha), 'Százszorszép' (30 t/ha), 'Kánkán' (29 t/ha), and 'Góliát' (30 t/ha).

It was in this year, that the newly registered cultivar 'Lilla' from Keszthely was included in the experiment, its yield was above the average yield of all cultivars both under irrigated and non-irrigated conditions. Without irrigation, its average yield was 21 t/ha, while under irrigation, its yield was 76 % higher, 37 t/ha. However, it should be noted that there were large variations in the yield of 'Lilla' among plots, that is the yield was not even and yield safety is variable.

Irrigation significantly increased the yield of all 9 cultivars. There were significant differences in yield between the cultivars (SD5% = 2.76): the yield of cvs. 'Góliát', 'Hópehely', 'Kondor', 'Kuroda', 'Lilla' and 'White Lady' was higher than that of cvs. 'Százszorszép' and 'Desirée'. In contrast to the previous year's results, the irrigation x cultivar interaction was significant also (SD5%= 3.90), irrigation had a greater effecct as verified by the regression coefficient, which was b=13.46 for irrigation (y=13.46x + 6.83, R=1), that is larger than the effect of cultivars (b=1.28) (y=1.28x + 20.58, R= 0.94).



SD 5% :	Irrigation	2.64
SD 5% :	Cultivar	2.76
SD 5% :	interaction	3.90

Figure 5. The impact of irrigation on potato yield in 2003, t/ha

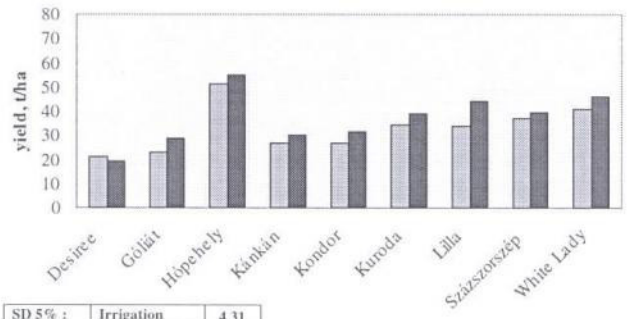
2004 was more humid than the previous two years, therefore, a lower effect on yield could be expected due to irrigation. The average yield of non-irrigated repetitions was 33 t/ha in 2004, while the yield of the irrigated repetitions was 12% higher (37 t/ha) (*Figure 6*). Among the three years, irrigation had the lowest effect in this year, since the yield increment due to irrigation was 70% in both 2002 and 2003.

Under non-irrigated conditions, the highest yield was obtained for cvs. 'Hópehely' (51 t/ha) and 'White Lady' (41 t/ha). A medium yield, similar to the mean yield of all cultivars was produced by cvs. 'Kuroda' (34 t/ha) and 'Lilla' (34 t/ha).

In non-irrigated treatments, the yield of cvs. 'Desirée' (21 t/ha), 'Góliát' (23 t/ha), 'Kánkán' (26.6 t/ha) and 'Kondor' (26.7 t/ha) was low.

Under irrigation, the mean yield of the 9 cultivars was 37 t/ha. High yields were obtained for cvs. 'Hópehely', (55 t/ha), 'White Lady' (46 t/ha) and 'Lilla' (44 t/ha), while cv. 'Desirée' had the lowest yield (19.35 t/ha), irrigation had a yield-reducing effect on this cultivar. Cv. 'Góliát' also had a low yield: without irrigation 23 t/ha, under irrigation 28.6 t/ha.

As compared with the results of the previous two years, it can be seen that while yields were increased by 70% in 2002 and 2003 by irrigation, the yields were increased by 12% only in the humid year of 2004.



SD 5% :	Irrigation	4.31
SD 5% :	Cultivar	4.50
SD 5% :	Interaction	6.37

Figure 6. The impact of irrigation on potato yield in 2004, t/ha

Summing up, it can be stated that 2002 was medium dry (average), 2003 was extremely dry and 2004 was humid for potato. The yield increasing effect of irrigation was the highest (70%) in the average (2002) and dry (2003) years, while in the humid year of 2004 it was much lower (12%).

According to the statistical calculations, irrigation increased significantly

a.) the yield of all 9 cultivars in the extremely dry year (2003),

b.) the yield of 7 cultivars 'Desirée', 'Góliát', 'Hópehely', 'Kánkán', 'Kondor', 'Kuroda' and 'White Lady' in the average year,

c.) the yield of 5 cultivars 'Góliát', 'Kondor', 'Kuroda', 'Lilla' and 'White Lady' in the wet year (2004).

There were significant differences in yield among the cultivars: yields of 'Kondor', 'Kuroda' and 'White Lady' were significantly higher in all three years.

The irrigation x cultivar interaction increased the yield significantly only in the extremely dry year, in which the

yield increasing effect of irrigation had a higher influence on the yield, than the differences among the cultivars.

The effect of water supply on the distribution of potato tubers among the different size categories

In the case of potato for processing, the size of the tubers should be 55 mm or above for pommes frites, 41–55 mm for chips and below 40 mm for puree. With respect to this, we examined the distribution of tubers between the size categories of small (under 4 cm), medium (diameter: 4–6 cm) and large (diameter 6 cm or above) for the nine cultivars studied with and without irrigation.

In 2002, irrigation had the lowest impact on the size of the tubers for cvs. 'White Lady' and 'Százszorszép' (the change in the three categories was maximum 10%). The largest difference due to irrigation was observed for cvs. 'Hópehely' and 'Kuroda', the ratio of large tubers increased by 24% and 26 %, respectively.

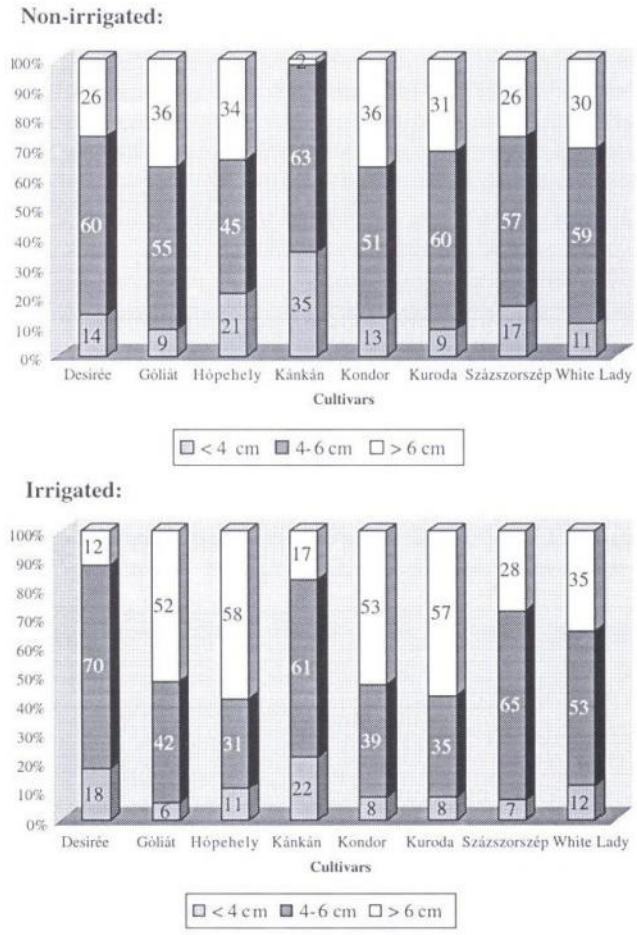


Figure 7. Changes in the size categories under irrigated and non-irrigated conditions in 2002

As a result of irrigation, the ratio of small tubers decreased for most of the cultivars (by 3–13%), while e.g. for 'White Lady' and 'Kuroda', it did not change considerably. The reduction in the ratio of small tubers due to irrigation was the largest for cvs. 'Kánkán', 'Hópehely' and 'Százszorszép'.

Without irrigation, cv. 'Kánkán' had the largest ratio of small tubers (35%), which reduced to half as a result of irrigation. Therefore, it is useful to irrigate also 'Kánkán', as its yield increased by 70 % from 21 t/ha to 36 t/ha due to irrigation.

As a result of irrigation, the increase in the ratio of large tubers (24 %) was the highest for cv. 'Hópehely' and if we consider that it increased the yield from 18 t/ha to 39 t/ha, therefore the positive effect of irrigation on yield cannot be questioned.

'Kuroda' was different from all other cultivars, as the increase in the ratio of large tubers due to irrigation was 26%, which verifies the positive effect of irrigation and the yield was also very high due to irrigation, 54 t/ha. The yield of cv. 'Kuroda' was high even without irrigation, almost 30 t/ha.

In 2003, irrigation increased the ratio of large tubers for most of the cultivars ('Góliát', 'Hópehely', 'Kánkán', 'Kondor', 'Kuroda', 'Lilla', 'Százszorszép' and 'White Lady') by 5–20 %. Due to irrigation, the ratio of large tubers decreased only for one cultivar, cv. 'Desirée' similarly to 2002, but the reduction was small.

As a result of irrigation, the ratio of medium-sized tubers increased considerably for cvs. 'Desirée' and 'Százszorszép', it remained unchanged for cv. 'White Lady', while for all other cultivars ('Góliát', 'Hópehely', 'Kánkán', 'Kondor', 'Kuroda', 'Lilla') irrigation decreased the ratio of medium-sized tubers by 9–15 % (*Figure 8*).

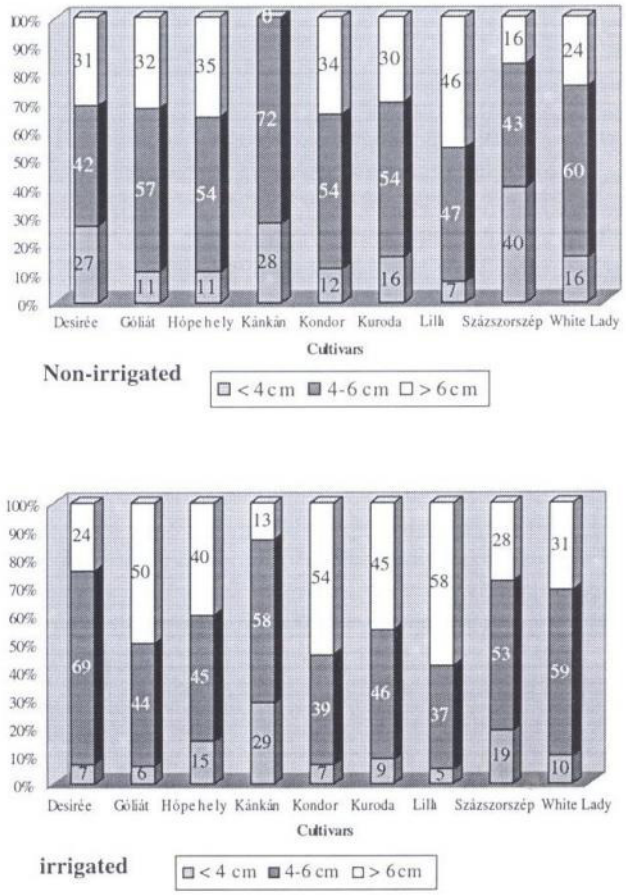


Figure 8. Changes in the size categories under irrigated and non-irrigated conditions in 2003

2004 was wet for potato: the highest ratio of large tubers without irirgation was obtained for cvs. 'Lilla' (54 %), 'Hópehely' (45%) and 'Kondor' (42%).

Irrigation had a favourable effect on the tuber size categories of cvs. 'Desirée' and 'Kuroda', it had an unfavourable effect in the case of cvs. 'Hópehely', 'Góliát', 'Kánkán' and 'Lilla' and it did not cause a significant change for cvs. 'White Lady', 'Százszorszép' and 'Kondor' (*Figure 9*)

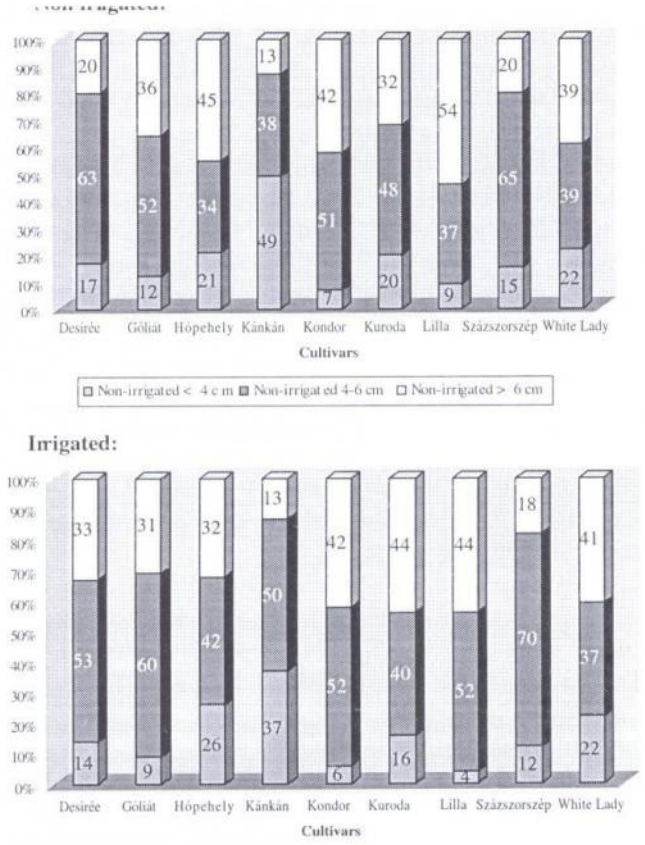


Figure 9. Changes in the size categories due to irrigation in 2004

Conclusions

Based on the obtained results, it can be stated that year, cultivar and irrigation have a significant effect on the yield of potato and the size of tubers. However, the yield-increasing effect of irrigation is dependent upon the year. In a dry year such as 2003, irrigation increased the yield significantly, even by 100% for certain cultivars, while in a more favourable, wet year the yield increment was smaller (12% in average in our experiment).

References

Antal, J. Kruppa, J. Pocsai, K. & Sárvári, M. (2005): Burgonya. In (szerk.): Antal, J.: Növénytermesztéstan 2. Mezőgazda Kiadó. 51–88 p

Arends, P. (1999): Az öntözés jelentősége és szempontjai Hollandiában. In szerk. Kruppa, J.: A burgonya és termesztése III. Agroinform Kiadó, Budapest. 114–118.p

Epstein, E. & Grant, W.J. (1973): Water stress relations of the potato plant under field conditions. Agron. J. 65, 400–404.

Fabeiro, C. Martin de Santa Olalla, F. & de Juan, J.A. (2001): Yield and size of deficit irrigated potatoes. Agric. Water Manage. 48, 255–266.

Harun-Ur-Rasid, Islam, T., Sarker, H. & Alam, J. (1990): Water use and yield relationships of irrigated potato. Agricultural Water Management. 18. (2): 173–179.

Kruppa, J. (1998): A vízstressz (vízhiány vagy vízbőség hatása a burgonya minőségére és egészségi állapotára). In: A burgonya és termesztése. (Szerk.: Kruppa J.) Holland-Magyar Burgonyaprogram, Kisvárda, 128.

Kruppa, J., Győri, Z. & Sárvári, M. (2003): A burgonya minőségét, piacosságát befolyásoló ökológiai és agrotechnikai tényezők. Burgonyatermesztés, 8: 7–14.

Lelkes, J. (1988): A mai korszerű szántóföldi öntözéstechnika jellemzése. Az öntözéses gazdálkodás újabb kutatási eredményei. Öntözési Kutató Intézet, Szarvas.157–161.p.

Marutani, M. & Cruz, F. (1989): Influence of supplemental irrigation on development of potatoes in the tropics. HortScience. 24 (6): 920–923.

Opena, G.B. & Porter, G.A. (1999): Soil management and supplemental irrigation effects on potato. II. Root growth. Agron. J. 91: 426–431.

Phene, C.J. & Sanders, D.C. (1976): High-frequency trickle irrigation and row spacing effects on yield and quality of potatoes. Agron. J. 68: 602–607.

Porter, G.A., Opena, G.B., Bradbury, W.B., McBurnie, J.C. & Sisson, J.A. (1999): Soil management and supplemental irrigation effects on potato. I. Soil properties, tuber yield, and quality. Agron. J. 91: 416–425.

Shalhevet, J., Shimshi, D. & Meir, T. (1983): Potato irrigation requirements in a hot climate using sprinkler and drip methods. Agron. J. 75: 13–16.

Shock, C.C., Feibert, E.B.G. & Saunders, L.D. (1998): Potato yield and quality response to deficit irrigation. HortScience. 33 (4): 655–659.