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THE IRRIGATION IMPACT ON THE YIELD OF MEDIUM-EARLY POTATOES IN SOUTHERN WIELKOPOLSKA

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Abstract

The work presents the research results of impact and effects of applying irrigation by sprinkling machine on the yield of medium-early potatoes. The research and observation conducted in growing seasons 2011, 2012 and 2013, on the private agricultural and production farm, in Kurów, located in the Ostrów Wielkopolski district, in the borough of Nowe Skalmierzyce, in the Wielkopolska Province. The area of the farm was 31 ha and 4 ha of potatoes were irrigated. The study confirmed that by using interventional irrigation in periods of water deficits, the medium-early potato yield increased by 30%, against the non-irrigated area. The evaluation of the research results also showed that patchy distribution of precipitation, in the analyzed growing season had an adverse influence on the crop. Frequent and long dry periods contributed to losses and decrease in potato yield.

Key words: distribution of precipitation, dry periods, irrigation, productivity of early potatoes, economic efficiency

INTRODUCTION

The weather in recent years has been different from that observed in recent decades. Climate changes have already had, or will have, a negative influence on agriculture. The changes also affect plant production in a direct and indirect way. The direct impact is expressed by changes of the atmospheric conditions for crop productivity, i.e. thermal conditions, precipitation as well as frequency and intensity of extreme appearance (Tubiello *et al.* 2007). Along with climate changes, the indirect factors that determine plant yielding and agricultural development are changed. These are factors such as requirements of plants associated with cultivation and fertilization, occurrence and severity of plant diseases and pests, but also the impact of agriculture at the environment (i.e. increased erosion, degradation of organic matter in soil) (Olesen *et al.* 2011). Knowing the danger that could result in damage in agriculture, some kind of adaptive activities can be developed, which can reduce the negative effects of climate changes.

It is rarely realized how many consequences climate changes cause. Lack of frost and snow cover during winter season also has many negatives. Climatic conditions affect the survival, growth and spread of pathogens of plant diseases and pests, but also build plant resistance. After introducing new plant to cultivation (Ewans 2008) or changes in cultivation technologies, new agrophages or increase in prevalence of previous agrophages occur on these plants.

These factors, at the same time, can have a significant impact on the development of technology and the organization of agricultural production (Ewert *et al.* 2005). However, right next to the climate changes, demand for food for a rapidly growing population in the world and competition for water will be a decisive factor in production systems in agriculture (Godfray *et al.* 2010).

The climate changes may have various consequences, which will occur at different times and at a certain rate, depending on the location of the region. In Poland's latitudes, a warming of the growing season by, for example, 2°C should increase the productivity of wheat by about 10%, while in Southern Europe reduce by a similar amount (Gornall *et al.* 2011). According to Gornall *et al.* (2011), a warming should result in a slight increase in the crop productivity. However, it must be remembered that agricultural practices must also be adapted to climate changes. Along with the extension of the growing season and the temperature rise, the dates of agrotechnical treatments will change as well, and in order to obtain higher yields it will be advisable to use other varieties of plants for cultivation.

The best areas for potato cultivation are in the north-western parts of the country, medium areas are the Middle Polish Lowlands, poor in south-eastern Poland, and the weakest are the southern regions. Potatoes are plants indifferent to soil and that is why they are planted both on soils of wheat and rye complexes (Chmura 2001).

The climate and soil conditions in the majority of Poland favor potato cultivation. Growth, development and yielding depend on the amount and distribution of precipitate and agrotechnical procedures (Nowak 2006). However, according to Głuska (1994), these factors are not favorable for their cultivation in Poland, as there are often droughts in July and August, i.e. in the period of high water needs for these plants. The potato is one of the most important plants in Poland. It has a high production potential and it strongly reacts to the improvement of humidity conditions, which makes it a plant that has great suitability for cultivation in irrigation conditions (Żarski *et al.* 1997, Mazurczyk *et al.* 2004, Nowak 2006, Żarski *et al.* 2011). There are many studies on the influence of irrigation on the yield of different potato varieties in which the effect of mineral and organic fertilization was often studied. Previous research clearly indicated that the varieties react with higher yield while using supplemental irrigation (Chmura 2001, Rzekanowski *et al.* 2004). Apart from irrigation influence, the research also concerns the efficiency of the different types of the irrigation system and its influence on the potato production increase. The sprinkling machine is the most popular solution used for potato irrigation in Poland (Nowak 2006).

PURPOSE, SUBJECT AND METHODOLOGY OF RESEARCH

The purpose of the research was the analysis of the impact of irrigation on the production and economic effects of growing potatoes on a private agricultural and production farm. The study and observations were conducted in the southern part of the Wielkopolska Province, in Kurów, in the Ostrów district. The quantity and quality of collected crops in production conditions from irrigated areas were analyzed and compared to farm yields that were non-irrigated.

The scope of work included the analysis of meteorological data from the Institute of Meteorology and Water Management (IMGW) station in Kalisz, identification of potato water needs, soil moisture measurements by a tensiometer, the determination of the irrigation doses and yield increases in irrigated and non-irrigated areas.

The results of production effects of irrigated and non-irrigated potatoes, in the growing seasons in the years 2011-2013 on the area of 6 ha, were compared and covered by a detailed analysis. The area covered by the analysis was characterized as the very good rye complex of soil.

Measurements of soil moisture in the growing seasons were made by using tensiometers. The dates of irrigation were determined based on the water potential of the soil, observation of weather phenomena and forecasts, as well as readings from pluviometer installed on the farm. Potato irrigation started when the tensiometer indicated 0.03 MPa. The farm had 40,000 potato plants on one hectare. The Galla was the cultivated variety of potato. In each of the analyzed years, the total area occupied by potatoes was 6ha. This area was divided into two plots with the area of 3.00 hectares each, on the soils of class 4a. Irrigation covered 3.00 ha. In 2011 wheat was the preceding plant. In autumn, manure was distributed on fields in the amount of 25 t/ha, and next plowing was carried out during the winter. In the spring, after plowing, fertilizers were spread: potassium salt (300 $kg \cdot ha^{-1}$) and phosphate-ammonium (180 $kg \cdot ha^{-1}$). Then the soil was prepared for potato cultivation. Potatoes were planted with a 4 row planters in ridges every 70 cm and at intervals of 35-40 cm. After planting, Mistral spray was applied directly to the ridges. Actar spray was used against the Colorado potato beetle, after crossing the threshold of harmfulness. Combating of potato blight was carried out 3 times, every 10 – 14 days. Treatments, with deep and contact operations, were made alternately with the help of Pyton, Infinito and Ranmann,. In 2012 and 2013 the agriculture treatments were conducted in the same way and in accordance with the principles of adequate agrotechnics. Also, the doses of manure and mineral fertilizers did not change in subsequent years. In both years wheat was a pre-harvest plant. The dates of irrigation were established on the basis of soil water potential, which was tested using tensiometers, and also based on measurements from pluviometer installed on the farm. Potato irrigation started when the tensiometer indicated 0.03 MPa. In 2011 and 2013 water was taken from a drilled well, whereas in 2012 from a pond on the farm.

RESULTS

Kurów, with geographic coordinates 51 ° 44 ,05’ ,N, 17 ° 57’ 03 ,E, is located in the south-west part of the Wielkopolska Province, in the Ostrów district, in the borough of Nowe Skalmierzyce (Fig.1). It is a climatic region with a low predominance of oceanic influences (region No. 32 according to Okołowicz and Martyn (1984), which is characterized by relatively small temperature amplitudes throughout the year, early spring, long summer and mild and short winter with an unstable snow cover. The average annual temperature specified for the years 1951-2015 was 7.7°C, and the monthly average for the warmest month in the year – July was around 18.0°C.

Source: http://wikitravel.org/upload/pl

Figure. 1. Location of Kurów against the background of the borough of Nowe Skalmierzyce

Table 1. Deviation of monthly precipitation for the study period from the average in the years 1983-2013

Month	Precipitation [mm]			
	Average monthly precipitation of the multiannual period	The difference between the monthly precipitation and average monthly precipitation of the multiannual period		
		2011	2012	2013
November	34	70	-33	-8
December	33	6	-5	-9
January	24	-3	23	19
February	23	-3	-2	-1
March	31	-15	-21	15
April	28	-11	-16	-5
May	52	-24	-28	34
June	60	29	46	40
July	73	10	-35	-34
August	60	-19	-20	-3
September	47	-18	0	22
October	30	-9	4	-17

The average annual precipitate was about 500 mm for the multiannual period. This region belongs to dry and deficit in water areas. Precipitation in the summer period accounted for almost 38% of the annual precipitation. The least precipitation was recorded in the winter, especially in February.

The soils in the borough of Nowe Skalmierzyceare are characterized by high productivity. Soils from I to IV bonitation classification constitute over 70% of agricultural land, and 28% of the area is class III soil. The detailed share of individual quality classes of arable land is: class I and II: 0.2%, class IIIa: 12.0%, class IIIb: 16.0%, class IVa: 30.3%, class IVb: 11.7%, class V: 20.0% and class VI: 9.8%.

In the valorisation of the agricultural production space according to Institute of Soil Science and Plant Cultivation (IUNG – Puławy), Nowe Skalmierzyce was rated at 71.7 points (the national average is 66.6 points, and the Wielkopolska Province – 63.8 points).

The average annual precipitation in the years 1983-2013 was 494 mm. The distribution of precipitation in the last 30 years was characterized by high variability of precipitation, as well as their unfavorable distribution over time. The average precipitation of the multiannual period 1983-2013 in the summer half-year was 321 mm, while for the winter semester: 172 mm. The wettest month in the year was July with the average precipitation of 73 mm, while the month with the smallest average precipitation was February (23 mm).The average precipitation in the growing season was 319 mm. Table 1 presents the average monthly precipitation in the years 1983-2013 along with deviations from the average for individual months in the hydrological years in which the research was conducted.

The average annual air temperature was 8.8 °C. The average air temperature in the years 1983-2013 in the summer half-year was the same as the average temperature for the growing season and was equal to 15.2 °C whereas the average temperature in the winter half-year for the observation period was 2.4 °C. Table 2 presents average monthly temperatures from many years and deviations from the average for individual months from 3 hydrological years in which the research was conducted.

Table 2. Deviation of the monthly average temperatures for the study period from the average in the years 1983-2013

Month	Temperature [°C]			
	Average monthly temperatureof the multiannual	The difference between the average monthly temperature and average monthly temperature of the multiannual		
		2011	2012	2013
November	3.1	2.4	0.9	2.5
December	0.8	-6.5	2.2	-2.4
January	-1.3	1.4	1.3	-1.6
February	-0.6	-2.4	-4.2	0.0
March	3.9	0.0	1.8	-6.2
April	9.1	2.3	0.6	-1.0
May	13.7	1.0	2.1	0.8
June	15.9	2.6	0.7	1.6
July	18.0	-0.1	2.2	2.0
August	17.6	1.5	1.8	1.6
September	13.0	2.8	1.8	-0.4
October	8.2	1.4	0.6	2.7

Precipitation in the hydrological year 2010/2011 was 505 mm, and it was 12 mm higher than the average precipitation for the multiannual period. It was classified as medium-wet. In the growing season of 2011 the precipitation was 286 mm, and it was 33 mm lower than the average precipitation for the growing season in the past 30 years. It was classified as medium-dry (Fig.2.).

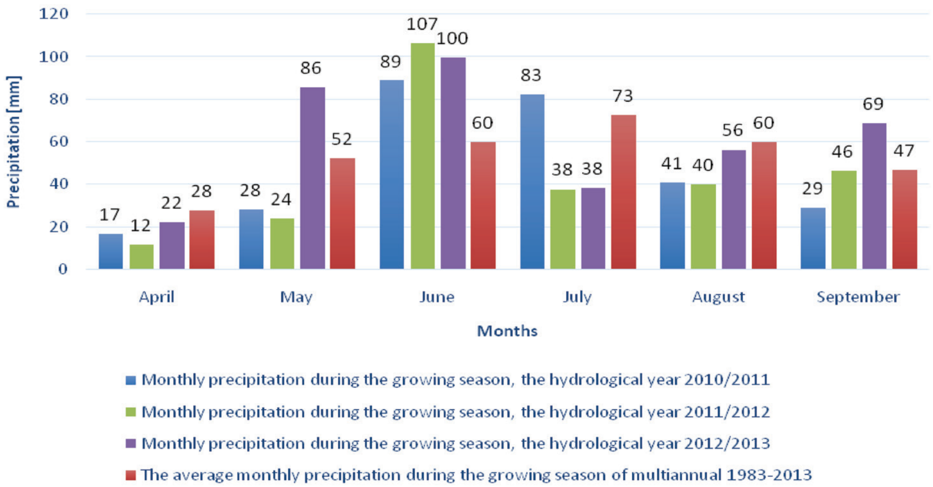

Figure 2. The course of monthly precipitation in the growing season, in the 2010/2011, 2011/2012 and 2012/2013 hydrological year against the background of average monthly rainfall in the years 1983-2013

The air temperature in each month of the growing season in 2011 was about 1.5°C higher than the average monthly temperatures in the growing season of the multiannual period. The exception was July when the average temperature was 17.9°C and was 1.1°C lower than the average July temperature in the years 1983 – 2013.

The precipitation in the hydrological year 2011/2012 was 405 mm. It was the lowest precipitation in the 3 years' research period. The precipitation was 88 mm lower than the average for the multiannual period. It was classified as dry. The precipitation during the growing season was also 53 mm lower than the average of the multi-year. The average precipitation during the growing season was 319 mm, while in the growing season of 2012 it was only 266 mm. This period was described as dry (Fig.2). The growing season in 2012 was characterized by average temperatures in individual months slightly higher than the average monthly air temperatures in the years 1983-2013.The exception was June, which was 0.1°C cooler. The air temperature in the remaining months of the growing season of 2012 was about 1.1°C higher than the average monthly temperatures of the growing season in the multiannual period.

The hydrological year 2012-2013 was considered wet. The precipitation was 545 mm, and it was 52 mm higher than the average precipitation for multi-years. The growing season of the year 2013 was also the richest in water period of the three research years. The deviation from the average of the 30 years' period was 52 mm, and precipitation during the growing season in

2013 was 372 mm. It was classified as wet (Fig. 2). Average temperatures during the growing season in particular months were slightly higher than the average monthly air temperatures in the years 1983-2013.The average temperature in each month of the growing season in 2013 was on average 0.7°C higher than the average monthly temperatures of the growing season for the multiannual period. The exception was September when the average temperature was 12.6°C and it was about 1.3°C lower in relation to the average temperature in the years 1983 – 2013.

[Photo: Paweł Lorenz]

Figure 3. Potato plantation irrigated

[Photo: Paweł Lorenz]

Figure 4. Potato plantation non-irrigated

The pictures below show fields planted with potatoes. Some of them were irrigated (Fig.3), and the other ones were non-irrigated (Fig.4).The effects of irrigation can be seen in the form of twice as much developed terrestrial part of the potato. The pictures were taken on the same day.

Table 4. Dates and doses of irrigation in the growing seasons 2011, 2012 and 2013

Plant	Dates and doses of irrigation [mm]					
	2011		2012		2013	
Medium-early potato	28.03	25	28.03	25	7.04	25
	28.04	25	28.04	25	24.04	25
	23.05	25	24.05	25	29.05	25
Average dose	25		25		25	
Total dose	75		75		75	

During the three-year study period a significant effect of irrigation by sprinkling machines on the yield of medium-early potato was observed. The average yield of potatoes, non-irrigated and irrigated, during the research was about 400 dt·ha^{-1}. In the fields where irrigation was applied, the yield was 30% higher than in the non-irrigated ones. The potato irrigation by sprinkling machine, increased yield by an average of 100 dt·ha^{-1}. The substantial difference in increases was in 2013 and amounted to 110 dt·ha^{-1}, and the smallest in the year 2012 – 90 dt·ha^{-1} (Table 5).

Table 5. The commercial yield of medium-early potato, Gallaw variety, in 2011, 2012 and 2013 in dt·ha^{-1}

Plant	2011			2012			2013			Average for years	
	Plants non-irrigated	Plants irrigated	Avg for year	Plants non-irrigated	Plants irrigated	Avg for year	Plants non-irrigated	Plants irrigated	Avg for year	Plants non-irrigated	Plants irrigated
Medium-early potato	32.0	42.0	37.0	35.0	44.0	39.5	30.0	41.0	35.5	32.3	42.3

The influence of irrigation, which contributed to the increase in yield, was reflected in the financial aspect. The average potato price was PLN 633.3 per ton (Central Statistical Office 2013). In the analyzed period, the average profit obtained from the sale of non-irrigated potatoes amounted to PLN 20333.3

per hectare. In the fields which were irrigated by sprinkling machine the profit amounted to PLN 26733.3 per hectare, which meant an average cost of PLN 6,400 more per hectare. The analysis does not take into account costs related to production, plant protection products or irrigation. The best year for potato cultivation was 2013 when the yield was higher on average by 300 $dt \cdot ha^{-1}$ per hectare for non-irrigated areas, and by 410 $dt \cdot ha^{-1}$ per hectare for the irrigated ones. In 2013, irrigation showed the best economic effect, because the average difference in profits per hectare amounted to PLN 8,800. This was the result of a large difference between irrigated and non-irrigated yields, and the good price of potatoes (Table 6).

Table. 6. Differences in profits from the sale of medium-early potato in 2011, 2012 and 2013

Medium-early potato – differences in profits [$zł \cdot t \cdot ha^{-1}$]					
Year	Purchase price PLN/t – gross	Plants non-irrigated	Plants irrigated	Average profit	Differences in profits
2011	500.0	16000.0	21000.0	18500.0	5000.0
2012	600.0	21000.0	26400.0	23700.0	5400.0
2013	800.0	24000.0	32800.0	28400.0	8800.0
Average	633.3	20333.3	26733.3	23533.3	6400.0

CONCLUSIONS

1. In the analyzed growing seasons, a significant influence of irrigation on the production effects of medium-early potatoes was found. The application of emergency irrigation by sprinkling machine, in periods critical to the growth and development of potatoes as well as water deficits in the soil, resulted in the yield increase of 10 $t \cdot ha^{-1}$ i.e. by about 30% in relation to non-irrigated fields.
2. The influence of irrigation was also reflected in economic effects. In the analyzed years from 2011 to 2013, the average profit gained from the sale of potatoes was higher by PLN 6,400, compared to non-irrigated fields.
3. The observation shows that the patchy distribution of precipitation during the growing season had a very unfavorable impact on the yield, and the frequent and long periods of drought caused lower yields as well as irreversible changes in plants.

REFERENCES

Chmura, K. (2001). *Przyrodnicze i agrotechniczne uwarunkowania uprawy ziemniaka w południowozachodniej Polsce*. Zeszyty Naukowe Akademii Rolniczej we Wrocławiu, Rozprawy CLXXX, 410, 109.

Głuska, A. (1994). *Wpływ ilości i rozkładu opadów w głównych miesiącach wegetacji (VI –IX) na plon ziemniaka w zależności od terminu sadzenia i wczesności odmiany*. Biul. Inst. Ziemn. 44, 65–79.

Godfray, Ch.J., Beddington, J.R., Crute, I.R., Haddad, L., Lawrence, D., Muir, J.F., Pretty, J., Robinson, S., Thomas, S.M., Toulmin, C., (2010). *Food Security: The Challenge of Feeding 9 Billion People*, Science 327, 812.

Gornall, J., Betts, R., Burke, E., Clark, R., Camp, J., Willett, K., Wiltshire, A. (2011). *Implications of climate change for agricultural productivity in the early twenty-first century.* Phil. Trans. R. Soc. B. 365, 2973–2989.

Evans, N. (2008). *Range and severity of a plant disease increased by global warming*. J. R. Soc. Interface 5, 525–531.

Ewert, F., Rounsevell, M.D.A., Reginster, I., Metzger, M.J., Leemans, R. (2005). *Future scenarios of European agricultural land use I. Estimating changes in crop productivity*. Agric. Ecosyst. Environ. 107, 101–116.

Mazurczyk, W., Wierzbicka, A., Lutomirska, B. (2004). *Klimatyczne uwarunkowania produkcji biomasy ziemniaka w Polsce Centralnej.* Zesz. Probl. Post. Nauk Rol. 500, 219–224.

Nowak, L. (2006): *Nawadnianie roślin okopowych*. W: Nawadnianie roślin (pod red. S. Karczmarczyka i L. Nowaka), PWRiL Poznań, 367–381.

Okołowicz, W., Martyn, D. (1984). *Regiony klimatyczne*. [W:] Atlas Geograficzny Polski. PPWK, Warszawa. 11.

Olesen, J.E., Trnka, M., Kersebaum, K.C., Skjelvåg, A.O., Seguin, B., Peltonen-Sainio, P., Rossi, F., Kozyra, J., Micale, F. (2011). *Impacts and adaptation of European crop production systems to climate change*. Europ. J. Agronomy. 34, 96–112.

Rzekanowski, Cz., Rolbiecki, St., Rolbiecki, R. (2004). *Productive results of sprinkler irrigation of potatoes on the light soils in central Poland.* Agricultural Engineering XLI, 2, 56–60.

Tubiello, F.N., Soussana, J.F., Howden, S.M. (2007). *Crop and pasture response to climate change*. PNAS, 104, 19686–19690.

Żarski, J., Dudek, S., Peszek, J. (1997). *Warunki opadowe produkcji ziemniaka średniowczesnego na glebie bardzo lekkiej*. Pam. Puł. 110, 129–135.

Żarski, J., Dudek, S., Kuśmierek-Tomaszewska, R. (2011). *Potrzeby i efekty nawadniania ziemniaka na obszarach szczególnie deficytowych w wodę*. Infrastruktura i Ekologia Terenów Wiejskich, 5, 175–182.

http://wikitravel.org/upload/pl/thumb/b/b9/Mapa_Nsk.jpg/550px-Mapa_Nsk.jpg – available on line: 13.03.2018

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