Agronomy Research **17**(3), 761–770, 2019
https://doi.org/10.15159/AR.19.049

Effects of drip irrigation on the yield of strawberry plants grown under arable conditions

T. Nowakowski, J. Chlebowski* and A. Grzybowska

Warsaw University of Life Sciences, Department of Agricultural and Forest Machinery, Street Nowoursynowska 164, PL02-787 Warsaw, Poland
*Correspondence: jaroslaw_chlebowski@sggw.pl

Abstract. The study investigated the effects of drip irrigation on the yield of 'Honeoye' strawberry plants for commercial purposes grown under arable conditions throughout the harvest season. The plants were irrigated at irregular intervals depending on natural precipitation. Crop yields and fruit parameters (diameter, length, individual weight, count per plant) were compared on several harvest dates. Statistical analysis has shown that irrigation has a significant impact on yield and fruit parameters. The irrigated plants yielded more strawberries, which also had a larger diameter, length, and individual weight.

Key words: strawberry, drip irrigation, fruit crop.

INTRODUCTION

To obtain a high yield of high quality strawberries, it is necessary to provide the plants with an adequate water supply when it is most needed. Thus, a good knowledge of the critical stages in the development of strawberry plants and their water requirements is essential for ensuring optimum irrigation effects. The plants need the most water when rapidly increasing weight by absorbing large quantities of nutrients. Indeed, providing appropriate irrigation levels at the right time is a prerequisite for high yields and good fruit quality (Krüger, 2002; Gaworski & Nowakowski, 2009; Nowakowski, 2009a; Nowakowski, 2009b; Rumasz-Rudnicka, 2009). Strawberry plants naturally tend to develop a large number of leaves. Importantly, the more leaves they have, the more buds turn into lateral crowns with more flower clusters (Żurawicz & Masny, 2010). Strawberries are highly sensitive to water deficits, especially from the beginning of April to the end of the harvest season as well as following the August harvest, which is associated with a large surface area of the leaves, high water content, as well as a shallow and rather compact root system (Treder, 2003; Klamkowski et al., 2013).

Unfortunately, one of the main features of Poland's climate is large variability in precipitation throughout the agricultural season. The total amount of rainfall, its intensity, and moisture distribution in the soil strongly affect plant growth and development, leading to variation in the yield and quantity of crops (Kaniszewski, 2005; Vilde et al., 2009; Barwicki et al., 2012; Treder et al., 2014; Chyba et al., 2015; Kroulik et al., 2016; Namaghi et al., 2018). Thus, strawberries cultivated on sandy soils must be irrigated to maintain high productivity of the plantation in the event of long periods without precipitation (Rolbiecki & Rzekanowski, 1997). The installation of an adequate irrigation system on a farm helps increase crop yield and mitigate water deficits during critical periods of increased plant susceptibility (Nowakowski & Strużyk, 2006, Gaworski & Nowakowski, 2009). Of great importance is also water quality and availability for irrigation (Rolbiecki & Rzekanowski, 1997).

The objective of the study was to evaluate changes in crop yield throughout the agricultural season brought about by the drip irrigation of 'Honeoye' strawberries under arable conditions.

MATERIALS AND METHODS

Strawberry plantation

The experiment was conducted on a 2-year plantation of 'Honeoye' strawberries, an early high-yield cultivar widely grown across Europe. The cultivar is characterized by juicy medium-sized fruit with a shiny red skin and a satisfying taste (Hancock et al., 2008). The plants are rather cold-hardy and resistant to leaf diseases, but with a vulnerable root system. This plant prefers sunny positions, sheltered from the wind. Only then the fruit will be tasty, aromatic, sweet and with high aesthetic qualities. It grows best on lighter, aerated soils with good water conditions. It is sensitive to drought, so there is need to maintain sufficient soil moisture content.

The research was conducted in the strawberry production field on the commercial farm in the village of Nowe Przybojewo, Mazovian Province, Poland. It was conducted on a 0.6 ha strawberry plantation with plant rows oriented in the east-west direction, with the terrain slightly inclined to the east. The strawberries were planted on class V poor and light soil (Żurawicz & Masny, 2010).

The study plantation was established in the autumn 2015. The preceding crop was triticale, for which the soil had been limed the year before. Immediately after harvesting the grain and collecting the straw, manure was applied at 40 t ha^{-1}. The propagation material consisted of fresh nursing stock, which was planted in double rows, with an inter-row distance of 62 × 90 cm. Young plants, both, immediately after planting and in the first year, were irrigated using the reel irrigator by Irtec company. After the first year, the strawberries were covered with a floating perforated row cover for the winter in order to advance crop production in the subsequent season. The crop cover was removed in the second half of April 2016, at a time when approx. 20% of the blooms were shown. Following mechanical weeding, the plants were sprayed with several fungicides to prevent mildew, leaf spot, and gray mold, as well as treated with calcium fertilizers. Towards the end of the flowering period, during early fruit development, the plantation was mulched with rye straw. The last agricultural procedure prior to the harvest season was the installation of drip tubing along strawberry rows. The plants produced the first crop in the summer of 2017, which was the second year since planting.

Study conditions

Throughout the study period, the experimental strawberry plants were irrigated exclusively using a drip irrigation system. The dates of irrigation treatments mostly depended on the occurrence of natural rainfall, and were designed to maintain optimum soil moisture for strawberry cultivation with a view to obtaining good fruit size and weight, and preventing plant wilting or growth failure.

During the study period, the weather conditions varied, with most days being sunny and dry. The experiment lasted for a total of 27 days (from the installation of the drip tubing to the last harvest), with 5 rainy days (Table 1). Rainfall varied in terms of intensity and amount, which was measured using a rain gauge with a millimeter resolution placed in the vicinity of the experimental plot.

Strawberries are particularly vulnerable to spring ground frost, especially directly after the removal of floating row cover and exposure of the emerging flowers and fruit to low temperatures. In the spring of 2017 Poland saw two major ground frost events, which caused substantial damage not only to strawberries, but also to other kinds of horticultural plantations, and delayed the first crops (www.gismeteo.pl/weather-nowe-przybojewo-265829/).

Table 1. Occurrence of night ground frosts and rain during research

No.	Weather events	Date	Temperature/ Rainfall amount
1	Ground frost	April 16/17, 2017	-3 °C
2	Ground frost	May 09/10, 2017	-7 °C
3	Rainfall	May 24, 2017	3.5 mm
4	Rainfall	June 04, 2017	8.0 mm
5	Rainfall	June 06, 2017	12.0 mm
6	Rainfall	June 12, 2017	7.0 mm
7	Rainfall	June 16, 2017	3.0 mm

www.gismeteo.pl/weather-nowe-przybojewo-265829/

Irrigation system

The irrigation system consisted of T-TAPE Rivulis 508-20-500 drip tubing characterized by:

- tube wall thickness: 0.2 mm,
- emitter spacing: every 20 cm,
- water flow rate: 5.00 $dm^3 h^{-1}$ per 1 m of tubing, or 1.00 $dm^3 h^{-1}$ per emitter.

Eight irrigation treatments were performed during the study at varying intervals (1 to 5 days, depending on natural rainfall) and with varying duration (2 to 4 h). Water for irrigation was drawn from a drilled well. The applied working pressure was 0.11–0.12 MPa. The schedule of irrigation treatments, including their duration and water flow rate, is given in Table 2.

Table 2. Schedule of irrigation treatments performed during the study

No.	Date	Duration, h	Water flow rate per 1 m of tubing, $dm^3 h^{-1}$
1	May 20, 2017	2.0	5
2	May 21, 2017	3.0	5
3	May 26, 2017	4.0	5
4	May 28, 2017	2.0	5
5	May 31, 2017	2.5	5
6	June 03, 2017	3.5	5
7	June 08, 2017	2.0	5
8	June 11, 2017	2.5	5

The experiment encompassed a total of four strawberry rows with a length of 100 m each (Fig. 1). To compare yields and assess the influence of irrigation, two of them (3, 4 rows), similarly to the rest of the plantation, were drip-irrigated. On the other hand, the two control rows (1, 2 rows) were deprived of access to additional water. For that purpose, drip tubing supplying four neighboring rows was removed ("X" marks). The fruit harvested from this segment of strawberry plantation was used in measurements.

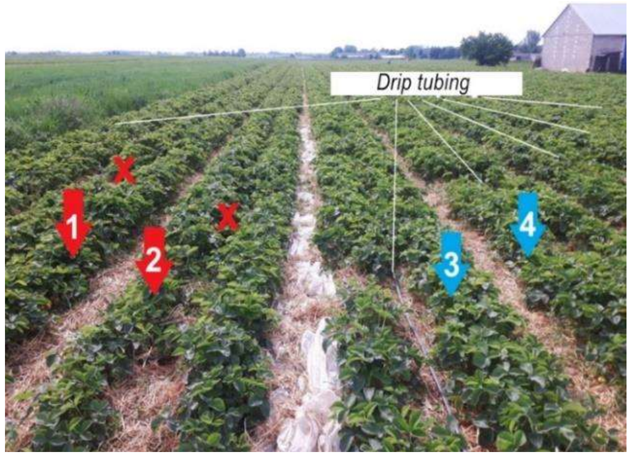

Figure 1. The location of irrigated (3, 4) and non-irrigated (1, 2) rows on the plantation

Yield measurement

The first harvest measurement was made on May 25, 2017, with subsequent ones following at intervals of several days, depending on the degree of fruit ripening. Each time, strawberries were collected from the same segments of the same rows (1, 2, 3, 4). The fruit was harvested seven times. In the first measurement, strawberries were collected from 100 m rows, while in the second measurement crops collected from 3 m long segments were used to compare counts of ripe fruit on the plants. Data on the weight of strawberries collected on the various harvest dates were used to calculate the percentage increase in the yield of irrigated (Ir) vs. non-irrigated (NIr) strawberries, from the formula below:

$$Q_p = \frac{m_{Ir} - m_{NIr}}{m_{NIr}} \cdot 100 \quad (1)$$

where Q_p – increase in yield, %; m_{Ir} – weight of the collected irrigated strawberries, kg; m_{NIr} – weight of the collected non-irrigated strawberries, kg.

Measurements were made for each harvesting, individual fruit characteristics were examined by analyzing the content of two full punnets (one for each cultivation method) in terms of strawberry diameter, length, and weight. The mass measurements were made using an electronic scales Radwag WLT 6/X/2 with an accuracy of 0.1 g. The dimensions were determined using a caliper with an accuracy of 0.05 mm. The measurements of fruit number were made for all collected fruit from a measuring section with a length of 3 m.

The obtained results were developed using statistical analysis methods using the Statistica v.13.1 program, using the ANOVA variance analysis. Statistical differences between groups were estimated using the Duncan test. Statistical tests were assessed at the significance level $p < 0.05$.

RESULTS AND DISCUSSION

The obtained results were subjected to statistical analysis. In order to verify the significance of variation in strawberry yield, in individual measuring systems, analysis of variance in a two-factor system was carried out. Analysis of variance showed a statistically significant variation in yield, at the level of $\alpha = 0.05$, for the studied factors: harvest time and cultivation system (irrigated and non-irrigated plants) (Table 3).

Table 3. Analysis of variance for strawberry yield

Source	Sum of Squares	DF	Mean Square	F-ratio	P-Value
Harvest dates	28,938,434	6	4,823,072	129.08	< 0.0001
System (Ir, NIr)	427,530	1	427,530	11.04	0.0148
Residual	224,182	6	37,364		

Ir – irrigated; NIr – non-irrigated.

The yield of strawberries depended on irrigation and differed between the various harvest dates. At the beginning of the season, the yield of both non-irrigated and irrigated plants was low, but increased with each successive harvest as more strawberries ripened. Similarly, the amount of harvested strawberries declined towards the end of the season. The smallest yield was recorded on the first day of harvest (May 25) at 0.97 kg and 1.24 kg for non-irrigated and irrigated strawberries, respectively, while the greatest yield was obtained on the fifth date. (June 9), at 69.36 kg and 75.66 kg, respectively. In both cases, as well as on the other harvest dates, the weight of strawberries collected from the irrigated rows was greater than that from the non-irrigated ones (but to varying degrees).

Based on the data gathered from the experimental plantation, it was also possible to calculate the overall yield per hectare (for all harvest dates taken together), which would amount to 10,732 kg for the non-irrigated strawberries and 13,178 kg for the irrigated ones. For non-irrigated strawberries, the changes in yield for harvest terms were varied from 64 kg ha^{-1} to 4,563 kg ha^{-1} and for irrigated strawberries from 81 kg ha^{-1} to 4,978 kg ha^{-1} (Fig. 2). Thus, the overall seasonal yield of irrigated plants would be greater by approx. 2,446 kg (Q_p = 22.79%) as compared to plants utilizing exclusively rainwater. The highest increase in strawberries yield, caused by irrigation, was in the second harvest term (May 27) and was Q_p = 162.8%. In next harvest term sit was varied from Q_p = 66.7% (May 30) to Q_p = 9.1% (June 09). The overall yield should be deemed rather low in light of the paper by Żurawicz et al. (2005). In that study, encompassing 18 cultivars of drip-irrigated strawberries, yields ranged from 8,800 kg to 35,806 kg, with an average of 24,720 kg ha^{-1}.

The presented findings also show the significance of weather conditions to strawberry cultivation. The much lower yields, obtained in the present study, were largely attributable to the spring ground frosts. The ground frosts that occurred in the spring considerably damaged the plantation, inhibiting growth and delaying fruit formation, thus substantially decreasing the overall yield.

At each harvesting term, on the individual irrigated plants, there were more fruit than on non-irrigated plants (Fig. 3). This was confirmed by the analysis of variance, which also showed that the number of fruit varied statistically depending on the harvest term (Table 4). On average, throughout the whole season, from individual non-irrigated plants were collected 11.9 strawberries, while from irrigated once it was 14.3 strawberries. Ochmian et al. (2009) for strawberries of the 'Aga' cultivar were collected 36 fruit per plant.

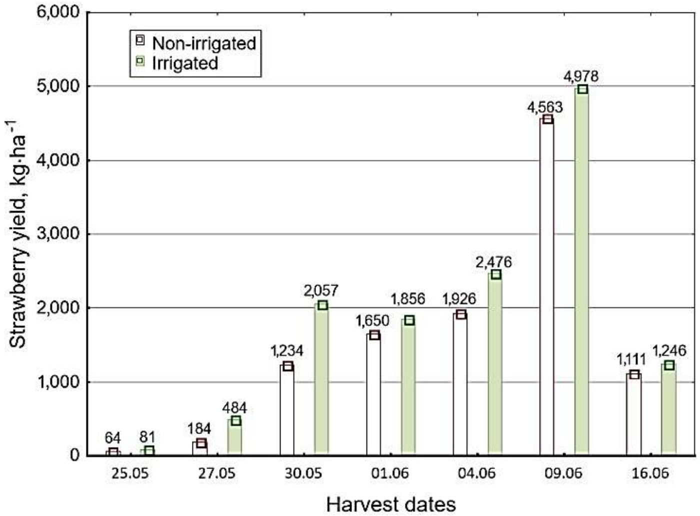

Figure. 2. Strawberry yield converted to kilogram per hectare vs. harvest date for irrigated and non-irrigated plants.

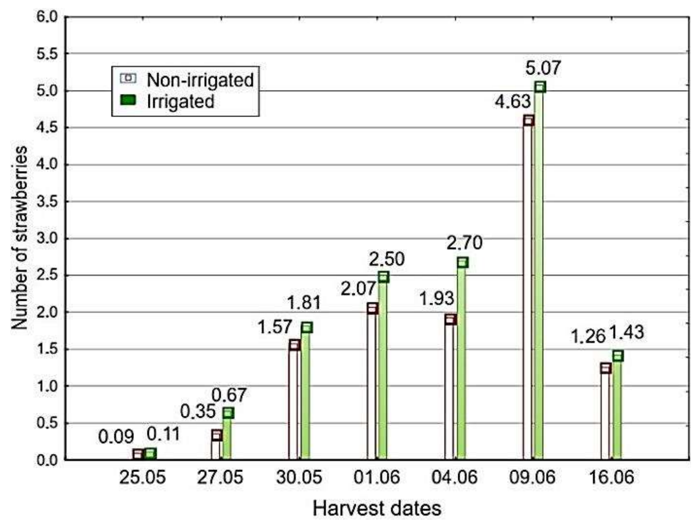

Figure 3. Number of fruit on individual strawberry plant: irrigated and non-irrigated.

Table 4. Variance analysis of fruit number on individual plant

Source	Sum of Squares	DF	Mean Square	F-ratio	P-Value
Harvest dates	29.10028	6	4.85005	164.496	< 0.0001
System (Ir, NIr)	0.40763	1	0.40763	13.825	0.0098
Residual	0.17691	6	0.02948		

Ir – irrigated; NIr – non-irrigated.

The three basic parameters of individual strawberries were: diameter, length, and weight (although the studied fruit also differed in terms of appearance, shape, and degree of ripeness). In order to check the significance of variation in the diameter, length and weight of fruit, an analysis of variance was carried out. The analysis showed statistically significant variation in the fruit parameters tested at the level of $\alpha = 0.05$ depending on the harvest term and cultivation system (irrigated and non-irrigated plants) (Table 5).

Table 5. Analysis of variance for parameters of strawberry fruit size (diameter, length, weight)

Source	Sum of Squares	DF	Mean Square	F-ratio	P-Value
Diameter					
Harvest dates	24,084	6	4,014	227.81	<0.0001
System (Ir, NIr)	382	1	382	21.71	<0.0001
Residual	30,236	1,716	18		
Length					
Harvest dates	5,905	6	984	46.40	<0.0001
System (Ir, NIr)	701	1	701	33.03	<0.0001
Residual	36,395	1,716	21		
Weight					
Harvest dates	16,864.8	6	2,810.8	180.38	<0.0001
System (Ir, NIr)	220.8	1	220.8	14.17	0.0002
Residual	26,739.2	1,716	15.6		

Ir – irrigated; NIr – non-irrigated.

The irrigated strawberries exhibited slightly larger values for all of these three characteristics. On the basis of Duncan's test (Table 6) it can be concluded that the fruit differed in diameter, length and weight depending on the harvest term and formed separate homogeneous groups. The exception was the fruit diameter and weight in the last two harvest terms (June 09 and June 16), and length in the last three harvest terms (June 04, June 09 and June 16), which created a single homogeneous groups.

The fruit of the largest size and weight were obtained at the beginning of the harvest season.

The differences were up to 2 mm in terms of diameter and length, and 1.9 g in terms of weight (Table 7).

All the measured characteristics gradually decreased with each subsequent harvest for both types of strawberries. The weight of individual fruit collected from non-irrigated plants ranged from 3.0 g to 29.0 g, with a mean of 13.7 g, while that for fruit from irrigated plants ranged from 2.0 g to 32.0 g, with a mean of 14.5 g.

Table 6. Homogenous groups for diameter, length and weight of fruit on the basis of Duncan`s test depending on harvest term

Harvest terms	Average	Homogenous group					
		1	2	3	4	5	
Diameter							
May 25	40.23						×
May 27	37.87					×	
May 30	34.85				×		
June 01	31.99			×			
June 04	29.86		×				
June 09	28.69	×					
June 16	28.41	×					
Length							
May 25	34.42					×	
May 27	33.46				×		
May 30	32.19			×			
June 01	30.54		×				
June 04	29.31	×					
June 09	29.05	×					
June 16	28.67	×					
Weight							
May 25	19.23						×
May 27	17.82					×	
May 30	15.29				×		
June 01	12.67			×			
June 04	10.80		×				
June 09	10.01	×					
June 16	9.84	×					

Table 7. Measures of individual non-irrigated (NIr) and irrigated (Ir) strawberries harvested on five dates

Harvest time	Function	Diameter, mm		Length, mm		Weight, g	
		NIr	Ir	NIr	Ir	NIr	Ir
May 25	Mean	39.3	41.2	33.4	35.4	18.3	20.2
	Median	39.0	41.0	33.0	35.0	17.0	20.0
	Min	29.0	32.0	23.0	25.0	8.0	11.0
	Max	48.0	51.0	43.0	44.0	28.0	30.0
	SD	5.2	4.3	5.0	4.1	5.3	4.4
	CV%	13.2	10.5	14.9	11.6	29.0	21.9
May 27	Mean	37.7	38.0	32.9	34.0	17.7	17.9
	Median	38.0	37.0	32.0	34.0	18.0	17.0
	Min	22.0	28.0	19.0	22.0	5.0	8.0
	Max	50.0	52.0	49.0	47.0	29.0	32.0
	SD	5.2	4.9	4.8	4.9	4.6	5.2
	CV%	13.8	13.0	14.5	14.3	26.2	28.9
May 30	Mean	34.6	35.1	31.4	33.0	15.0	15.6
	Median	34.0	35.0	31.0	33.0	14.0	15.0
	Min	24.0	30.0	21.0	26.0	5.0	10.0
	Max	46.0	41.0	49.0	40.0	26.0	22.0
	SD	5.2	2.9	4.9	3.6	4.8	3.0
	CV%	15.2	8.4	15.9	11.0	34.0	20.1
June 01	Mean	31.8	32.2	30.1	31.0	12.5	12.9
	Median	31.0	32.0	30.0	31.0	12.0	12.0
	Min	22.0	25.0	21.0	19.0	5.0	6.0
	Max	47.0	42.0	42.0	42.0	27.0	25.0
	SD	4.2	3.7	4.7	4.4	4.2	3.7
	CV%	13.3	11.5	15.6	14.1	33.2	28.9
June 04	Mean	29.0	30.8	28.3	30.3	10.4	11.2
	Median	29.0	31.0	28.0	30.0	10.0	11.0
	Min	19.0	24.0	20.0	20.0	3.0	6.0
	Max	39.0	42.0	41.0	43.0	20.0	22.0
	SD	3.8	3.1	4.2	4.0	3.3	3.0
	CV%	13.0	10.1	14.8	13.1	31.7	26.6
June 09	Mean	28.3	29.1	28.6	29.5	9.6	10.4
	Median	28.0	29.0	28.0	29.0	9.0	10.0
	Min	21.0	22.0	18.0	20.0	4.0	2.0
	Max	41.0	44.0	43.0	44.0	21.0	23.0
	SD	3.9	3.9	4.7	4.9	3.5	3.8
	CV%	13.9	13.5	16.4	16.6	36.6	36.2
June 16	Mean	27.9	28.9	28.4	28.9	9.3	10.4
	Median	25.0	29.0	26.0	28.0	7.0	10.0
	Min	22.0	21.0	20.0	22.0	5.0	5.0
	Max	45.0	41.0	47.0	38.0	18.0	22.0
	SD	5.9	4.0	6.4	4.3	4.3	3.9
	CV%	21.3	13.8	22.5	14.9	46.6	37.4

SD – standard deviation, CV – coefficient of variation.

The analysis of the results allows to conclude that the increase in yield due to the irrigation is associated with increasing number of fruit on individual plants, their diameter and length, and hence the weight of a single fruit. In their two-year study on 'Honeoye' strawberries Boček et al. (2011) reported a mean weight of 11.2 g per fruit in 2009, and 14.8 g the following year. In turn, Masny & Żurawicz (2007) obtained an average fruit weight of 8.59 g to 13.77 g, with a mean of 11.44 g. Much lower values were reported by Rolbiecki & Rzekanowski (1997): 7.97 g for 'Senga Sengana' strawberries grown on drip-irrigated experimental plots and 5.81 g for the same cultivar grown on non-irrigated control plots.

CONCLUSIONS

The statistical analysis showed that the use of irrigation in the field cultivation of strawberries 'Honeoye' not only significantly increased the yield, but also allowed to obtain fruit of a larger diameter, length and weight, what is improved by the F statistic and the critical significance level ($p < 0.05$).

Analysis of the results shows that the yield potential of strawberries was largely dependent on irrigation and varied across harvest dates. Drip irrigation led to a considerable increase in yield as compared to the non-irrigated plants (by 22.79% in all measurements of harvest terms. The magnitude of the difference was probably mitigated by the occurrence of natural rainfall during the study period and the water holding capacity of the soil. The observed increase in yield primarily resulted from the higher fruit count per plant as well as greater individual fruit weight (on average by approx. 6%). While strawberries from the irrigated and non-irrigated rows did not differ visually, significant differences were found in terms of their size and weight.

Most scientific papers on the yield of strawberries are obtained on experimental plantations. Therefore, yields obtained from real commercial plantation allow to compare them with yield potential obtained from experimental studies.

REFERENCES

Barwicki J., Gach S. & Ivanovs, S. 2012. Proper utilization of soil structure for crops today and conservation for future generations. In: *11th International Scientific Conference Engineering for Rural Development*, Jelgava, pp. 10–15 (in Latvia).

Boček S. & Tvrzníková M. 2011. Results of two years assessment of productivity and disease resistance of strawberry (Fragaria × grandiflora Ehr.) varieties with regard to the possibility of their use in organic farming). In: *Rostliny v podmínkách měnícího se klimatu,* Lednice, pp. 6–17 (in Czech Republic).

Chyba J., Kroulik M., Brant V. & Masek J. 2015. Yield crop dependence on soil properties and soil water availability. In: *14th International Scientific Conference Engineering for Rural Development,* Jelgava, pp. 530–535 (in Latvia).

Gaworski M. & Nowakowski T. 2009. Irrigation of field crops. *Agrotechanika* **2**, pp. 44–47. (in Polish).

Hancock J.F., Sjulin T.M. & Lobos G.A. 2008. Strawberries. In: *Temperate Fruit Crop Breeding*, Springer Science & Business Media, pp. 393–438.

Kaniszewski S. 2005. Irrigation of field vegetables. Plantpress, Kraków (in Polish).

Klamkowski K., Treder W., Sowik I., Tryngiel-Gać A. & Masny A. 2013. Comparison of response of three strawberry cultivars grown under greenhouse conditions to water deficiency. *Infrastructure And Ecology of Rural Areas* **2(I)**, pp. 137–146 (in Polish).

Kroulik M., Brant V., Chyba J. & Zabransky P. 2016. Effect of plowing and deep loosening on cone index and water flow. In: *15th International Scientific Conference Engineering for Rural Development,* Jelgava, pp. 723–736.

Krüger E., Schmidt G. & Rasim S. 2002. Effect of irrigation on yield, fruit size and firmness of strawberry cv. Elsanta. *Acta Horticulturae* **567**, pp. 471–474.

Masny A., & Żurawicz E. 2007. Growth and yielding of late strawberry cultivars in central Poland conditions. *Roczniki Akademii Rolniczej w Poznaniu* **41**, pp. 345–349. (in Polish).

Namaghi M.N., Davarynejad G.H., Ansary H. & Nemati H. 2018. Effects of mulching on soil temperature and moisture variations, leaf nutrient status, growth and yield of pistachio trees (Pistacia vera.L). *Scientia Horticulturae* **241**, pp. 115–123.

Nowakowski T. & Strużyk A. 2006. Wybrane aspekty nawadniania upraw polowych. *Technika Rolnicza Ogrodnicza Leśna* **9-10**, pp. 24–28 (in Polish).

Nowakowski T. 2009a. Systemy deszczowania i nawadniania. *Wiadomości Rolnicze* **03(55)**, pp. 36 (in Polish).

Nowakowski T. 2009b. Woda źródłem plonów. *Wiadomości Rolnicze* **04(56)**, pp. 21 (in Polish).

Ochmian I., Grajkowski J., Popiel J., Strzelecki R. & Ostrowska K. 2009. The comparison of plant growth and yielding of 'Aga' strawberry cultivar grown in the fertile soil which was fertilized by the fertilizers which have the differentiated chemical composition. *Folia Pomer. Univ. Technol. Stetin. Agric., Aliment., Pisc. Zootech.* **269 (9)**, pp. 33–40.

Rolbiecki S. & Rzekanowski C. 1997. Influence of sprinkler and drip irrigation on the growth and yield of strawberries grown on sandy soils. *Acta Horticulturae* **439(2)**, pp. 669–671.

Rumasz-Rudnicka E., Koszański Z. & Kowalewska R. 2009. Influence of drip irrigation and nitrogen fertilizer on chemical composition of fruits and leaves of raspberries. *Acta Agrophysica* **13(3)**, pp. 771–779 (in Polish).

Treder W. 2003. Nawadnianie plantacji truskawek jako czynnik warunkujący jakość owoców. *Ogólnopolska Konferencja Truskawkowa*, Skierniewice, pp. 88–92 (in Polish).

Treder W., Klamkowski K., Jakubiak B. & Rudnicki W. 2014, Evaluation of quality of rainfall forecasting using COAMPS and UM models. *Acta Horticulturae* **1038**, pp. 663–670.

Vilde A., Rucins A. & Pirs E. 2009. Impact of soil humidity on draft resistance of plough body. In: *8th International Scientific Conference Engineering for Rural Development,* Jelgava, pp. 43–49 (in Latvia).

Żurawicz E. & Masny A. 2010. Porady dla producentów truskawek. *Hortpress*, Kraków (in Polish).

Żurawicz E., Kruczyńska D. & Masny A. 2005. Productive value of the newest strawberry cultivars in Central Poland. *Zeszyty Naukowe Instytutu Sadownictwa i Kwiaciarstwa* **13**, pp. 75–80 (in Polish).