Agronomy Research **19**(2), 520–530, 2021
https://doi.org/10.15159/AR.21.099

Influence of humic acids, irrigation and fertilization on potato yielding in organic production

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Received: December 22nd, 2020; Accepted: May 2nd, 2021; Published: May 21st, 2021

Abstract. The study aimed at determining the impact of organic fertilization, humic acids and irrigation on potato yielding in organic production system. Fertilization variants included: Humac Agro; manure; vermicompost; Fertil Bioilsa C-N 40-12.5; manure + Humac Agro; vermicompost + Humac Agro; Fertil Bioilsa C-N 40-12.5 + Humac Agro. Irrigation was carried out using drip lines. The highest tuber yield was determined on treatments fertilized with vermicompost. The combined application of organic fertilizers and humic acids resulted in increased total yield between 6 and 9%, whereas commercial yield from 5 to 10%. Application of fertilization resulted in increased total yield of tubers in individual fertilizer variants from 1.9 to 10.8 t ha^{-1}, and commercial yield from 1.6 to 12.3 t ha^{-1}. Water-use efficiency remained in the range from 35.2 to 113.1 kg mm^{-1}, whereas irrigation water-use efficiency from 9.9 to 166.3 kg mm^{-1}. Humic acids used in the study enhanced fertilizer and water-use efficiency.

Key words: *Solanum tuberosum*, water–use efficiency, tuber yield and its structure.

INTRODUCTION

Intensive agricultural production systems ensuring high efficiency and quality of yields are among the most destructive practices in the field of the Earth's resources, but they are justified by economic requirements and the need to provide food for the growing population. Excessive use of artificial fertilizers and pesticides leads to deteriorating condition of soil, water resources and environmental quality. Modern trends in agriculture reflect the growing interest in the shift from conventional agriculture to organic farming, particularly in production of vegetables consumed by humans.

Potato is one of the most popular and nutritious vegetable plants in the world. It is cultivated in 164 countries, and the tubers are consumed by close to one billion people on an almost daily basis. Development of a thriving, profitable and sustainable sector of organic potatoes depends largely on the soil welfare and biological control of diseases and pests. Soil welfare can be obtained by using a multi–annual crop rotation and appropriate agrotechnical practices, including correct nutrient management.

Soil property enhancers, containing i.a. humic acids (HA) have a positive impact on the state of biological balance and soil welfare. Humic substances area among the most complex and biologically active organic compounds found in soil. They exhibit positive effect on physicochemical properties of soil, but also on the structure and activity of microorganisms, which ensures better supply of nutrients to plants (Canellas & Olivares, 2014). Research has show positive impact of HA on the growth and development of numerous plant species, i.a. potato, sugar beet, tomato, corn and berry plants (Canellas et al., 2013; Suh et al., 2014; Olivares et al., 2015; Schoebitz et al., 2016; Wilczewski et al., 2018; Marenych et al., 2019). According to Nardi et al. (2002), humic substances have a more pronounced impact on root growth than on the above-ground parts of plants, which points to their special significance in the cultivation of root vegetables. In the study of Sanli et al. (2013), the use of leonardite at the amount between 200–600 kg ha^{-1} resulted in increased total yield of potato tubers in the range from 6 to 25%.

All production practices that enhance nutrient use are of interest for farmers, particularly in the context of nitrogen directive, which accepts the use of up to 170 kg N ha^{-1} $year^{-1}$ in natural fertilizers. One such activity is vermicomposting, which according to Jjagwe et al. (2019) constitutes an organically sustainable technology of manure management. Many studies show that vermicompost is more productive than manure and mineral fertilizers used individually or proves the synergy and complementarity of vermicompost with mineral fertilizers (Singh & Chauhan, 2009; Meenakumari & Shehkar, 2012).

The factor that significantly restricts fertilization efficiency is the increasingly common rainfall shortage and its unequal distribution in the potato vegetation period. Total yield is low in drought conditions, and the bulk of the mass comprises of small and medium sized tubers. What is more, the share of deformed, green, infected with common scab, as well as nitrate accumulation in tubers (Simson et al., 2016). Reduced tuber yield or deterioration of their quality forces the need for irrigation. The irrigation technique is highly important. Drip irrigation is believed to be most precise, as it ensures water saving, reduces ridge loosening, increases the total length of the roots and it does not affect the moisture level of air in the crop field (Svoboda et al., 2020).

The aim of the research was to determine the influence of variable organic fertilization, application of humic acids and supplementary drip irrigation on the size and structure of potato tuber yield in organic production.

MATERIAL AND METHODS

Field experimental design

The research was carrierd in the period 2017–2019 on a farm located in Raszków (50°58' N, 19°95' E, 283 m a.s.l.) Poland. The field experiment was established in the split–plot system in 3 replications. The experimental factors were: organic fertilization and irrigation. The fertilization variants included: control (without fertilization) - C; Humac Agro (400 kg ha^{-1}) - HA; manure (30 t ha^{-1}) - FYM; vermicompost (10 t ha^{-1}) - VC; Fertil Bioilsa C-N 40-12.5 (600 kg ha^{-1}) - FCN; manure + Humac Agro (30 t ha^{-1} + 400 kg ha^{-1}) - FYM + HA; vermicompost + Humac Agro (10 t ha^{-1} + 400 kg ha^{-1}) - VC + HA; Fertil Bioilsa C-N 40-12.5 + Humac Agro (600 kg ha^{-1} + 400 kg ha^{-1}) - FCN + HA. Humac Agro contains 79% of organic substance, 62% humic acids, 16.8 g Fe kg^{-1}, 15.7 g Na kg^{-1}, 15.1 g Ca kg^{-1}, 1.2 g K kg^{-1}, 77 mg B kg^{-1}, 64 mg Zn kg^{-1}, 19 mg Cu kg^{-1}. The characteristics of the remaining fertilizers is presented in Table 1.

Table 1. Physio–chemical parameters of organic fertilizers

Parameter	Farmyard manure	Vermicompost	Fertil Bioilsa C-N 40-12.5
pH	7.4 ± 0.1	7.4 ± 0.2	4.8
dry matter (g kg^{-1})	270.1 ± 12.6	302.0 ± 15.5	954.0
Total N (g kg^{-1})	19.6 ± 1.4	30.2 ± 1.7	115,2
Total C (g kg^{-1})	413.2 ± 9.3	293.1 ± 8.9	427.4
C/N	21.1 ± 1.0	9.7 ± 0.3	3.7
Total P (g kg^{-1})	5.9 ± 0.4	11.8 ± 0.7	10.5
Total K (g kg^{-1})	22.8 ± 1.5	36.3 ± 1.8	2.1
Total Mg (g kg^{-1})	3.7 ± 0.3	9.3 ± 0.6	1,3
Total Ca (g kg^{-1})	12.4 ± 0.8	16.2 ± 1.1	62.3

Irrigation was carried out with the use of subsurface (5 cm) system of T-Tape drip lines. Drip lines with water emitters distributed every 20 cm, spread on the top of the ridges were set at the consumption of 5 dm^3 h^{-1} running $meter^{-1}$. A subsurface drip system was used in the research as it ensures that the water used becomes available to a large part of the plant's root system while keeping the soil surface relatively dry, thus reducing evaporative water loss compared to other irrigation methods. In addition, subsurface drip application offers many other advantages for crop production, including less nutrient leaching compared to surface irrigation, higher yields, a dry soil surface for improved weed control and crop health, which is especially important in organic potato production (Selim et al., 2009; Badr et al., 2010). Irrigation dates were determined based on soil humidity with the use of tensiometers. Irrigation procedures were commenced when the water potential in soil reached - 40 kPa (Bailey, 2000). The total amount of water used for irrigation was 98 mm in 2017, 67 mm in 2018 and 145 mm in 2019, respectively. The tubers of early potato cultivar Vineta were planted at a spacing of 67.5×29 cm in the first decade of April, whereas the harvest was carried out in the first decade of August. The size of the field intended for harvest was 27 m^2. In order to protect potatoes against infection Copper Max New 50 WP (2 kg ha^{-1}) was used twice, whereas SpinTor 240 SC (0.15 L ha^{-1}) was used against potato beetle.

Soil and meteorological conditions

The field experiment was located on a typical brown soil (*BEt*) (*Haplic Cambisol Eutric*) with granulometric composition of sandy loam. The arable layer of the soil (0–25 cm) was characterized by: moderate P abundance (45.1–50.5 mg kg^{-1}) and K abundance (98.5–103.8 mg kg^{-1}); high Mg abundance (56.0–67.0 mg kg^{-1}); acidic to slightly acidic pH value (pH_{KCl} 5.4–6.0); sand content 570–610 g kg^{-1}; silt 240–340 g kg^{-1}; clay 90–150 g kg^{-1}.

Fig. 1 presents characteristic of precipitation and thermal conditions. The total rainfall for 2017 and 2019 between April and August was close to long-term average, but in 2018 it was lower by 68 mm (19%). An unequal distribution of precipitation in all years of the experiment was determined. Rainfall deficiencies occurred in June 2017, April and May 2018 and in June and July of 2019. On the other hand, excessive rainfall was recorded in April 2017, July 2018 and in May and August 2019 r. Low temperatures in April and May 2017 and 2019 combined with high levels of precipitation delayed potato emergence. Particularly unfavorable humidity and thermal conditions prevailed in June 2019 due to the very low amount of precipitation and air temperature higher than average by 4.5 °C.

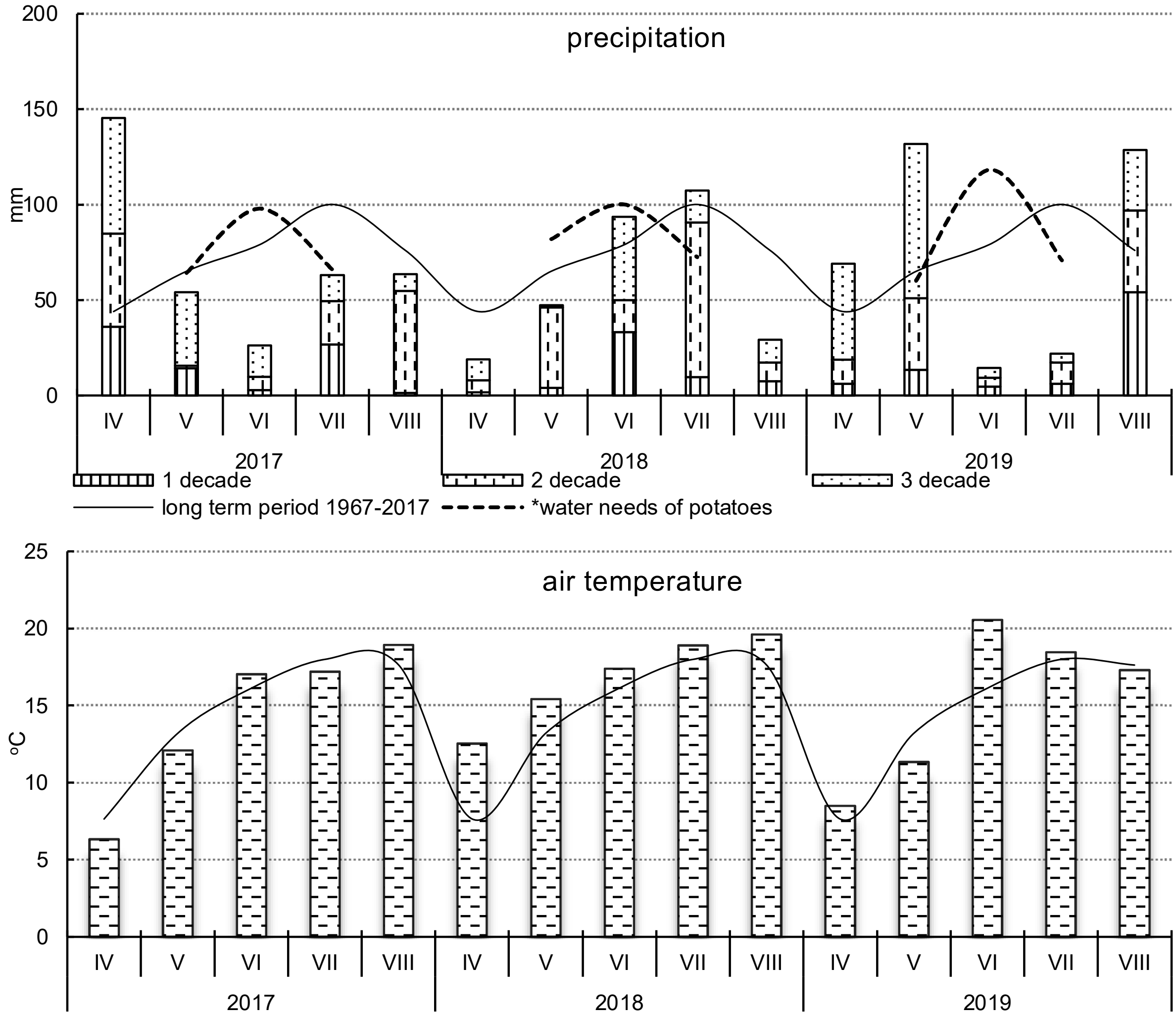

Figure 1. Characteristics of weather conditions, *water needs according to Klatt, citation for Nyc (citation for Nyc, 2006).

Assessment of the size and structure of tuber yield and irrigation efficiency

Before the harvest, tuber samples were collected from 10 plants per each field in order to assess the number of tubers per plant and the share of marketable and large tubers (with respective transverse diameter of > 35 and > 50 mm) in the yield. During the harvest, total tuber yield size was determined, whereas the commercial yield was estimated based on the share of marketable fraction, by separating green and deformed tubers.

Water use efficiency (*WUE*) and irrigation water use efficiency (*IWUE*) were calculated according to the equations of Kirda (2002) and Howell et al. (1990). Water use efficiency (*WUE*) for each treatment was calculated as tuber yield divided by seasonal evapotranspiration (*ETa*):

$$ETa = P + I - D \pm \Delta W \quad (1)$$

where *P* is the raifall (mm); *I* is the irrigation applied to individual plots (mm); *D* is the deep percolation; *ΔW* is the change in the water storage of hte soil profile (mm). Since the amount of irrigation water was only sufficient to bring the water deficit to field capacity, deep percolation was ignored.

Irrigation water use efficiency ($IWUE$) was determined as:

$$IWUE = \frac{(Y_I - Y_{NI})}{I} \quad (2)$$

where Y_I is the tuber yield of irrigation treatments (kg ha^{-1}); Y_{NI} is the tuber yield of non-irrigation treatment (kg ha^{-1}); I is the amount of irrigation water (mm).

Statistical analysis

The results were subjected to statistical evaluation using an analysis of variance. Highly significant differences (*HSD*) for the investigated features were verified using Tukey's test at a significance level of $P < 0.05$.

RESULTS AND DISCUSSION

Total yield of non-irrigated potato tubers was on average 24.2 t ha^{-1}, whereas commercial yield 19.0 t ha^{-1} (Table 2). Application of the supplementary drip irrigation resulted in an increase of total tuber yield in individual fertilizer variants in the range from 1.9 t ha^{-1} (13%) to 10.8 t ha^{-1} (44%), and commercial from 1.6 t ha^{-1} (18%) to 12.3 t ha^{-1} (63%). The greatest increase in yield was observed on the treatments fertilized with vermicompost, and the lowest on the control. The yield forming effect of vermicompost results from its properties. As shown by Manivannan et al. (2009) and Demir (2019), application of this fertilizer considerably improves soil properties by expanding the pore spaces, water retention and cation exchange capacity, availability of micro- and macronutrients and microbial activity.

Among the investigated organic fertilizers, Fertil Bioilsa C-N 40-12.5 was characterized by the highest productivity, and the lowest was exhibited by manure. The total yield of potato fertilized with Fertil Bioilsa C-N 40-12.5 in the amount of 600 kg ha^{-1} (66 kg N ha^{-1}) was 34.3 t ha^{-1} and was higher by 4.4 t ha^{-1} than on the treatments fertilized with vermicompost in the amount of 10 t ha^{-1} (91 kg N ha^{-1}) and by 6.9 t ha^{-1} more than after the application of manure at the dose of 30 t ha^{-1} (159 kg N ha^{-1}). These results show a better efficiency of nitrogen used in processed organic fertilizers than in unprocessed fertilizers. In all fertilizer variants, positive effect of humic acids on potato yielding was determined. Application of HA resulted in increased total yield of tubers relative to the control by 5%, and commercial yield by 8%. The total application of organic fertilizers and humic acids resulted in increased total yield between 6 and 9%, whereas commercial yield from 5 to 10%. Similar results were obtained by Selim et al. (2010), who administered humic substances by means of drip irrigation system. A considerably higher efficiency of humic acids was demonstrated by Ekin (2019). This author utilized 400 kg ha ha^{-1} and obtained tuber yield corresponding to mineral fertilization of 100 + 50 + 50 kg NPK ha^{-1} and 44% higher than on control facility. In the three-year experimental period highest tuber yields were obtained in 2017 and 2018. Lowest yield was recorded in 2019, mainly due to the low amount of precipitation and high air temperature in the tuber formation period. Potato yields on irrigated treatments in 2019 were at the level of yields harvested in 2017 and 2018 from non-irrigated treatments (Fig. 2).

Table 2. Potato tuber yields (t ha^{-1})

Fertilization	Irrigation		Year			Mean
	I_0**	I_1	2017	2018	2019	
	total tuber yield					
C*	14.4^{e}	16.3^{f}	13.5^{f}	16.4^{e}	16.1^{d}	15.3^{F}
HA	14.8^{e}	17.2^{f}	14.4^{f}	16.9^{e}	16.8^{d}	16.0^{F}
FYM	24.2^{d}	30.6^{e}	29.4^{e}	30.2^{d}	22.6^{c}	27.4^{E}
FYM+HA	26.2^{cd}	33.4^{d}	32.2^{d}	31.6^{cd}	25.5^{b}	29.8^{D}
VC	24.5^{cd}	35.3^{c}	33.7^{d}	33.1^{c}	22.8^{bc}	29.9^{D}
VC+HA	27.2^{c}	36.2^{c}	36.2^{c}	35.5^{b}	23.6^{bc}	31.7^{C}
FCN	30.2^{b}	38.4^{b}	39.7^{b}	36.2^{ab}	27.0^{ab}	34.3^{B}
FNC+HA	31.9^{a}	41.7^{a}	43.8^{a}	38.0^{a}	28.7^{a}	36.8^{A}
Mean	24.2^{B}	31.1^{A}	30.4^{A}	29.7^{A}	22.9^{B}	
	marketable tuber yield					
C	8.3^{d}	9.8^{f}	8.0^{f}	9.6^{e}	9.5^{d}	9.1^{F}
HA	8.7^{d}	10.8^{f}	8.7^{f}	10.2^{e}	10.5^{d}	9.8^{F}
FYM	18.5^{c}	26.7^{e}	26.3^{e}	24.7^{d}	16.8^{c}	22.6^{E}
FYM+HA	20.7^{bc}	29.2^{d}	28.4^{de}	27.4^{c}	19.1^{c}	24.9^{D}
VC	19.4^{c}	31.7^{c}	30.7^{cd}	29.0^{c}	17.0^{c}	25.6^{D}
VC+HA	22.2^{b}	31.9^{c}	32.0^{c}	31.6^{b}	17.5^{c}	27.0^{C}
FCN	26.1^{a}	34.8^{b}	36.1^{b}	32.6^{ab}	22.6^{b}	30.4^{B}
FNC+HA	27.8^{a}	37.5^{a}	38.6^{a}	34.3^{a}	25.1^{a}	32.7^{A}
Mean	19.0^{B}	26.5^{A}	26.1^{A}	24.9^{B}	17.3^{C}	

*C – control; HA – humic acid; FYM – farmyard manure; FYM+HA – farmyard manure + humic acid; VC – vermicompost; VC+HA – vermicompost + humic acid; FNC – Fertil Bioilsa C-N 40-12.5; FNC+HA – Fertil Bioilsa C-N 40-12.5 + humic acid; **I_0 – without irrigation; I_1 – drip irrigation; Different letters in the kolumns mean a honestly significant difference (HSD) at $P < 0.05$.

The excessive air temperature in June was likely the factor that restricted potato yielding on facilities irrigated in 2019. Similar relationship was observed earlier in a very early cultivar by Elzner et al. (2018). According to Burton (1981), the optimum temperature for the photosynthesis of European potato cultivars is approx. 20 °C, and each 5 °C leaf temperature increment reduces the photosynthesis rate by 25%. Rykaczewska (2015) demonstrated that the combined thermal and drought stress maintaining for two weeks in potato flowering period may reduce the yield of sensitive cultivars by 50%, and of tolerant cultivars by 25%. The number of initiated tubers ranged between 6.1 to 8.0 and depended on fertilization, irrigation, year of study and interaction of these factors (Table 3). On average, potato plants initiated 5.6% more tubers on irrigated fields than on non-irrigated ones. In the study of Mokh et al. (2015), the highest number of potato tubers were initiated under the conditions of field water capacity, whereas the number of tubers at deficit irrigation was

Table 3. Number of tubers per plant

Fertilization	Irrigation		Year			Mean
	I_0**	I_1	2017	2019	2019	
C*	6.3^{b}	6.6^{c}	6.1^{c}	6.5^{c}	6.8^{b}	6.4^{B}
HA	6.3^{b}	6.7^{c}	6.2^{c}	6.6^{c}	6.8^{b}	6.5^{B}
FYM	7.1^{a}	7.4^{b}	7.0^{b}	7.3^{b}	7.5^{a}	7.3^{A}
FYM+HA	7.4^{a}	7.7^{ab}	7.2^{ab}	7.8^{a}	7.7^{a}	7.6^{A}
VC	7.3^{a}	7.8^{ab}	7.2^{ab}	8.0^{a}	7.5^{a}	7.6^{A}
VC+HA	7.4^{a}	7.9^{a}	7.4^{a}	7.9^{a}	7.6^{a}	7.6^{A}
FCN	7.3^{a}	8.0^{a}	7.4^{a}	7.7^{ab}	7.7^{a}	7.6^{A}
FNC+HA	7.4^{a}	8.0^{a}	7.6^{a}	7.8^{ab}	7.8^{a}	7.7^{A}
Mean	7.1^{B}	7.5^{A}	7.0^{B}	7.4^{A}	7.4^{A}	

*, ** See Table 2.

considerably lower. The highest increase of the number of tubers per plant under the influence of irrigation was determined after the application of Fertil Bioilsa C-N 40-12.5 (9.6%) fertilizers, and lowest on the fields fertilized with manure (4.1%). The number of tubers initiated on fertilizer fields (treatments 3–8) remained at an equal level from 7.3 to 7.7, but it was significantly greater than on the control field (6.4). HA administration did not affect the number of tubers per plant. The highest number of initiated tubers was determined in 2018 and 2019, which were characterized by higher air temperature in June and July than in 2017. Similar phenomenon was observed by Rykaczewska (2015), who revealed that high temperature during potato flowering and tuber development (BBCH 65–79) may result in a secondary tuberization in certain cultivars.

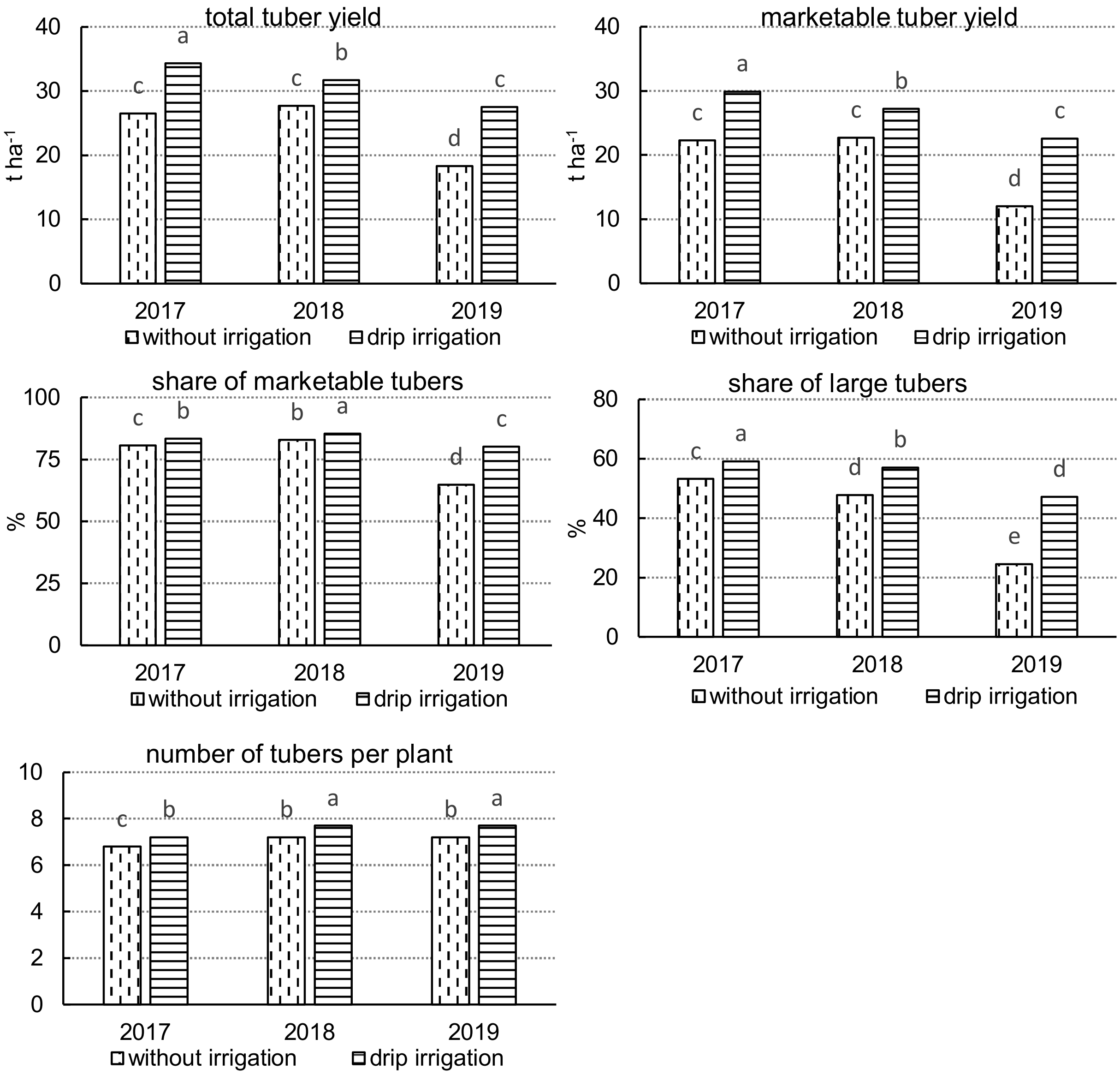

Figure 2. Effect of drip irrigation on tuber yield and its structure.

The share of marketable tubers in the total yield on non-irrigated fields was on average 76.1%, whereas large tubers 41.9% (Table 4). The applied irrigation resulted in increased share of these tuber fractions in yield by 2.8 and 5.9% in 2017, 2.6 and 9.3%

in 2018 and 15.4 and 22.6% in 2019, respectively (Fig. 2). The highest increase in the share of marketable fraction under the influence of fertilization was observed on the fields fertilized with vermicompost (11.9%), whilst the large tuber fraction after the administration of vermicompost and humic acids (17.4%). In general, the highest amount of marketable and large tubers were collected on the fields fertilized with Fertil Bioilsa C-N 40-12.5, significantly lower amounts on the fields fertilized with manure and vermicompost, and the lowest amount on the control field and after the application of HA.

Table 4. Share of marketable and large tubers (%)

Fertilization	Irrigation		Year			Mean
	I_0^{**}	I_1	2017	2018	2019	
	marketable tubers					
C	59.1^{c}	60.8^{d}	59.6^{d}	61.5^{c}	58.9^{c}	60.0^{D}
HA	60.2^{c}	63.5^{d}	61.1^{d}	62.0^{c}	62.4^{c}	61.8^{D}
FYM	76.8^{b}	87.6^{c}	83.4^{c}	91.0^{ab}	72.2^{b}	82.2^{C}
FYM+HA	78.1^{b}	88.2^{c}	88.2^{b}	89.6^{b}	71.7^{b}	83.2^{BC}
VC	78.3^{b}	90.2^{abc}	88.7^{ab}	90.8^{ab}	73.2^{b}	84.2^{BC}
VC+HA	79.7^{b}	89.2^{bc}	90.8^{a}	90.4^{ab}	72.1^{b}	84.5^{B}
FCN	87.8^{a}	92.1^{ab}	92.1^{a}	94.1^{a}	83.6^{a}	89.9^{A}
FNC+HA	88.8^{a}	92.5^{a}	92.4^{a}	93.4^{ab}	86.1^{a}	90.7^{A}
Mean	76.1^{B}	83.0^{A}	82.0^{B}	84.1^{A}	72.5^{C}	
	large tubers					
C	20.1^{c}	24.7^{c}	23.0^{b}	23.2^{d}	21.0^{c}	22.4^{C}
HA	21.8^{c}	26.8^{c}	24.3^{b}	23.3^{d}	25.2^{c}	24.3^{C}
FYM	46.1^{b}	62.0^{b}	65.6^{a}	60.6^{b}	35.9^{b}	54.0^{B}
FYM+HA	46.7^{b}	61.5^{b}	65.7^{a}	56.6^{bc}	40.0^{b}	54.1^{B}
VC	46.2^{b}	62.6^{b}	66.0^{a}	59.5^{b}	37.7^{b}	54.4^{B}
VC+HA	45.1^{b}	62.5^{b}	68.9^{a}	54.3^{c}	38.3^{b}	53.8^{B}
FCN	54.4^{a}	67.8^{a}	69.0^{a}	69.9^{a}	44.3^{ab}	61.1^{A}
FNC+HA	55.0^{a}	68.1^{a}	67.4^{a}	72.3^{a}	44.9^{a}	61.5^{A}
Mean	41.9^{B}	54.5^{A}	56.2^{A}	52.5^{B}	35.9^{C}	

*, ** See Table 2.

Water use efficiency (WUE) was on average 66.6 kg mm^{-1} and it remained in the range from 35.2 to 113.1 kg mm^{-1} (Table 5). The highest WUE value was found for the fertilized field FNC+HA, and lowest on the control field. Humic acids significantly increased the efficiency of water use in all fertilizer facilities (treatments 3–8). In the three-year period of study, the highest water productivity was obtained in 2017 (78.4 kg mm^{-1}), and lowest in 2019 (49.7 kg mm^{-1}). The low water use efficiency in 2019 was linked to the highest evapotranspiration (Et_a) in the entire study cycle. Irrigation water use efficiency (IWUE) was in a very broad range of 9.9 to 166.3 kg mm^{-1} and on average it amounted to 67.2 kg mm^{-1}. The conducted study presents similar mean WUE and IWUE values. Ati et al. (2012) and Mokh et al. (2015) demonstrated a markedly higher IWUE value (vs. WUE), whereas in the study of Eissa (2018) the WUE index attained higher value than IWUE. The greatest water use efficiency was determined on the field fertilized with vermicompost, and lowest on the control field. Humic acids increased irrigation water use efficiency (IWUE) only on the fields fertilized with manure and Fertil NC. IWUE was significantly affected by the weather conditions in the individual years of study. The highest irrigation water use efficiency, with a mean of 79.1 kg mm^{-1} was determined in 2017, which was characterized by the lowest total precipitation in the period from May to July observed throughout the study.

Table 5. Water productivity (kg mm^{-1})

Fertilization	WUE				IWUE			
	Year			Mean	Year			Mean
	2017	2018	2019		2017	2018	2019	
C*	35.2^{f}	39.7^{e}	35.5^{d}	36.8^{F}	18.3^{e}	9.9^{d}	22.0^{d}	16,7^{F}
HA	37.5^{f}	40.8^{e}	37.0^{d}	38.4^{F}	23.5^{e}	16.4^{d}	28.1^{d}	22.7^{F}
FYM	76.5^{e}	72.7^{d}	48.9^{c}	66.0^{E}	47.5^{d}	54.7^{c}	74.5^{bc}	58.9^{E}
FYM+HA	83.8^{d}	76.2^{cd}	54.9^{bc}	71.6^{D}	40.9^{d}	65.6^{bc}	91.7^{a}	66.1^{D}
VC	85.8^{d}	79.5^{c}	49.6^{bc}	71.6^{D}	166.3^{a}	101.0^{a}	63.4^{c}	110.2^{A}
VC+HA	93.0^{c}	85.2^{b}	51.2^{bc}	76.5^{C}	114.7^{b}	88.1^{a}	68.6^{c}	90.4^{B}
FCN	102.6^{b}	87.1^{ab}	58.8^{ab}	82.8^{B}	100.1^{c}	66.8^{bc}	70.3^{c}	79.0^{C}
FNC+HA	113.1^{a}	91.4^{a}	62.1^{a}	88.9^{A}	121.6^{b}	71.6^{b}	87.3^{ab}	93.5^{B}
Mean	78.4^{A}	71.6^{B}	49.7^{C}		79.1^{A}	59.3^{C}	63.2^{B}	

* See Table 2.

CONCLUSIONS

The results of this study confirm the significant effect of drip irrigation on the increase in the yield of potato tubers by increasing the number of tubers and the share of marketable and large tubers in the total yield. The use of humic acids increases the yield of tubers, especially in the case of their combined application with organic fertilizers, and additionally increases of the water use efficiency. Processed natural fertilizers such as Fertil Bioilsa N-C 40-12.5 and vermicompost show higher yield forming efficiency in potato cultivation than manure.

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