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ORIGINAL ARTICLE

Response of *Solanum tuberosum* L. to drip irrigation and nitrogen application: productivity, nutrition composition, bioactive compounds, antioxidant activity

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Abstract

Sustainable crop cultivation is a crucial goal in modern agriculture, aiming to attain high productivity while conserving natural resources. This requires the implementation of rational cultivation techniques, with proper irrigation and fertilization practices playing a crucial role in ensuring plant well-being and providing natural protection against biotic and abiotic stresses. The health-promoting properties of crops are also significantly influenced by irrigation and fertilization. This study investigated the productivity, nutritional composition, bioactive compounds, and antioxidant capacity of Vineta early potato cultivar tubers under drip irrigation conditions, combined with nitrogen fertilization through fertigation or broadcasting. Two-factor trials included drip irrigation (control or drip) and nitrogen application (broadcast or fertigation). Precise treatments, such as drip irrigation and N-fertigation were found to enhance all productivity traits. Both practices positively impacted tuber nutrient content. The highest levels of total polyphenols and chlorogenic acid were observed in non-irrigated and broadcasted tubers. Drip-irrigated and N-fertigated tubers exhibited high levels of vitamin C and antioxidant activity. In summary, the combination of drip irrigation with appropriate fertilization methods positively influenced potato crops, as evidenced by an increase in productivity and the quality of tubers.

Key words: ascorbic acid, chlorogenic acid, fertigation, polyphenols, potato yield, sugars

Introduction

Potato, a globally popular and nutritious vegetable crop cultivated in 245 countries, serves as a daily staple for nearly a billion people worldwide. The data reveals that approximately 375 million tons of potatoes were produced globally in 2022. Poland ranked 9th in production at 7,081,46 tons (FAO 2024). Due to widespread consumption, potatoes are a valuable source of bioactive compounds, including essential nutrients, proteins, vitamins, minerals, and antioxidants such as polyphenolic compounds (Zaheer and Akhtar 2016; Wichrowska *et al.* 2021).

Potato tuber yields and quality are influenced by various factors like genotype, climate, soil, water availability, agronomic practices, and nutrient management. Drip irrigation and fertigation play crucial roles in enhancing the growth and yield of profitable potato cultivars (Pszczółkowski and Sawicka 2017; Syrotiuk *et al.* 2020). In line with the contemporary trend to develop sustainable agriculture, precise irrigation and fertilization practices are essential components. The rational execution of these practices plays a key role in maintaining crops in good condition, and helping plants better cope with both biotic and abiotic stresses (Rani *et al.* 2023).

Nitrogen fertilizers are vital for supporting higher yields of potato tubers, particularly in coarse-textured soils where potatoes are commonly grown. However, the mobility of nitrogen in the soil can result in an efficiency of less than 55% in nitrogen uptake by potatoes, often requiring high nitrogen doses for optimal yields (Cambouris *et al.* 2016). According to Maltas *et al.* (2018), improving our understanding of nitrogen dynamics in potato crops can enhance nitrogen efficiency, resulting in increased profitability, reduced nitrogen losses, and decreased environmental impact.

Potatoes have high water needs throughout their growth stages, and water scarcity can limit nitrogen utilization, affecting starch content in tubers and impeding proper tuber growth. To address yield decrease and tuber quality deterioration, irrigation is necessary for potato crops (Trawczyński 2013). Drip irrigation, a precise method in many crops, conserves water, reduces ridge loosening, and does not affect air humidity (Rolbiecki *et al.* 2020; Jagosz *et al.* 2021; Rolbiecki *et al.* 2021a, b). Combined with fertilization, drip irrigation enhances water use efficiency and increases potato tuber yield (Mazurczyk *et al.* 2009; Badr *et al.* 2012; Trawczyński 2013; Elzner *et al.* 2018). Drip fertigation is more effective and economical than traditional solid fertilizer use (Trawczyński 2013; Rolbiecki *et al.* 2021b).

The aim of the present research was to determine the effects of drip irrigation and nitrogen fertilization using drip fertigation of the early potato cultivar Vineta grown in very light soil in the moderate climate of central Poland on productivity, nutrition composition, bioactive compounds, and the antioxidant capacity of tubers. For this study, a potato cultivar was selected, for which the response to drip fertigation treatment applied in the soil and climatic conditions existing in the present experiment had not been previously tested.

Materials and Methods

In the field experiment conducted in Kruszyn Krajeński near Bydgoszcz, central Poland (53°04’53” N, 17°51’52” E, 69 m a.s.l.), an early potato cultivar Vineta (*Solanum tuberosum* L.) was cultivated from 2014 to 2016 in light soil with low water retention (54 mm available, including 32 mm readily available). The split-plot design experiment, with four replications, examined two factors: 1) drip irrigation (control without irrigation or drip irrigation) and 2) nitrogen fertilization method (broadcasting or drip fertigation).

Each harvest-designated plot covered an area of 11.25 m^2, with standardized nitrogen fertilization at 120 kg N · ha^{-1}. Nitrogen (N), in the form of ammonium nitrate (N-NH_4 17.2% and N-NO_3 17.2%), was applied at three rates: 40 kg N · ha^{-1} broadcasted before emergence, and two rates of 40 kg N · ha^{-1} each through broadcasting or liquid (fertigation) in late June and mid-July. N-fertigation was implemented using proportional dispensers in spring before soil treatment with a combined cultivator. Phosphorus (P) and potassium (K) fertilization were applied at rates of 100 kg P · ha^{-1} and 150 kg K · ha^{-1} in the spring before cultivation. Full farmyard manure dosage was applied in the previous autumn.

Drip irrigation employed a ‘T-Tape’ linear drip system with 20 cm emitter spacing and a flow rate of 5 l · m^{-1}. Guided by tensiometers (Soil Moisture Equipment Corp, Santa Barbara, CA, USA), irrigation aimed to prevent the soil water potential from dropping below –30 kPa (Mazurczyk *et al.* 2009).

The average air temperature and rainfall during the 2014–2016 growing seasons are presented in Tables 1 and 2. Meteorological conditions were depicted using Walter climate diagrams (Figures 1–3), highlighting diverse weather patterns during the respective vegetation periods in 2014–2016.

The research measured various production-related traits and indicators, including marketable tuber yield (t · ha^{-1}), single tuber weight (g), tubers per plant (pcs), irrigation water use efficiency index (IWUE) (kg · ha^{-1}·mm^{-1}), and nitrogen use efficiency index (NUE) (kg · ha^{-1} · kg^{-1} N). Post-harvest, tuber nutritional value was assessed, covering dry matter (%), starch (g · 100 g^{-1} FM), total and reducing sugars (g · kg^{-1} FM), total protein (g · kg^{-1} DM), and bioactive compounds: total polyphenols (g GAE · kg^{-1} DM), chlorogenic acid (g · kg^{-1} DM), ascorbic acid (mg · kg^{-1} FM), and antioxidant capacity (mmol Fe^{2+} · kg^{-1}).

To determine quality traits, tubers were freeze-dried, ground into flour, and stored until chemical analysis. All analyses were performed in three laboratory replications. Dry matter content was determined

Table 1. Air temperature (°C) data during the vegetation period of the Vineta potato from 2014 to 2016

Studied year	Months of vegetation period						Mean Apr–Sep
	Apr	May	Jun	Jul	Aug	Sep	
2014	9.9	13.3	16.0	21.5	17.2	14.4	15.4
2015	7.5	12.4	15.7	18.5	20.9	13.8	14.8
2016	8.3	14.7	17.7	18.3	16.4	14.3	15.0
2014–2016	8.6	13.5	16.5	19.4	18.2	14.2	15.1
Norm (1986–2015)	8.1	13.3	16.3	18.8	18.0	13.1	14.6

Table 2. Rainfall (mm) data during the vegetation period of the Vineta potato from 2014 to 2016

Studied year	Months of vegetation period						Sum Apr–Sep
	Apr	May	Jun	Jul	Aug	Sep	
2014	40.7	65.7	44.9	55.4	57.3	25.9	289.9
2015	15.6	21.6	33.0	50.4	20.3	52.4	193.3
2016	28.7	51.4	98.1	133.8	55.3	8.1	375.4
2014–2016	28.3	46.2	58.7	79.9	44.3	28.8	286.2
Norm (1986–2015)	26.9	50.2	54.9	71.4	59.7	47.5	310.6

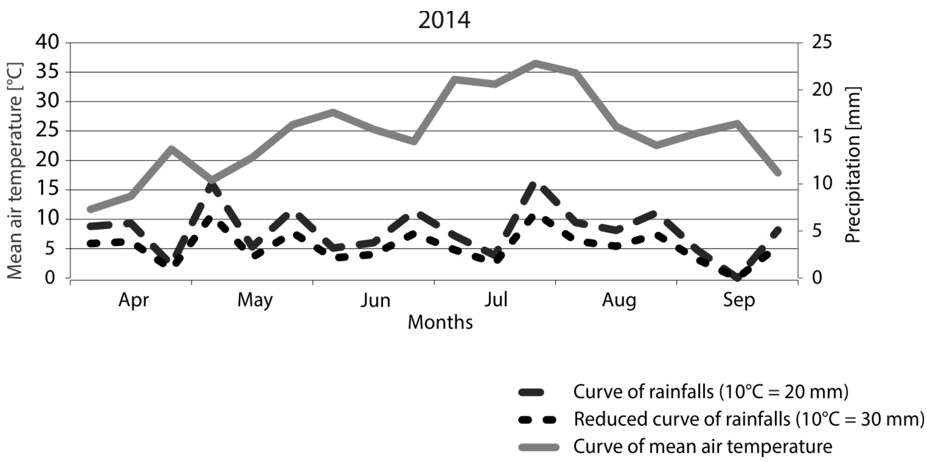

Fig. 1. Climatic diagram for meteorological conditions of the field experiment in the vegetation period (IV-IX) in the year 2014

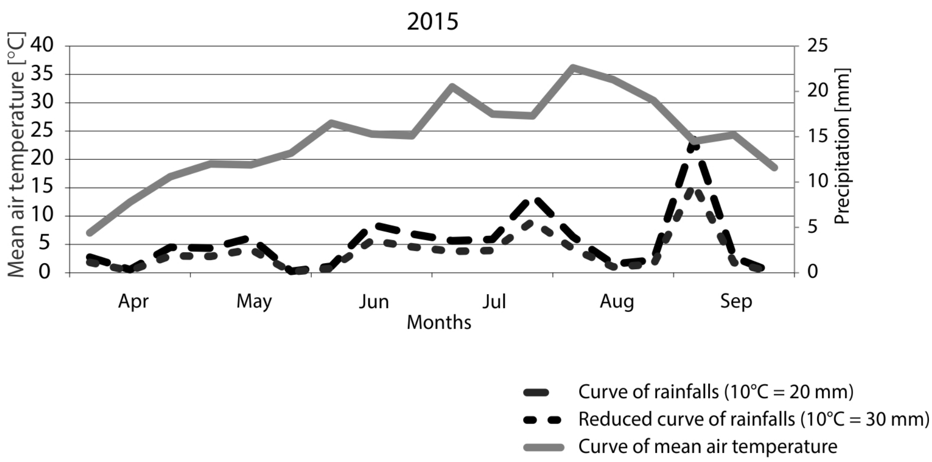

Fig. 2. Climatic diagram for meteorological conditions of the field experiment in the vegetation period (IV-IX) in the year 2015

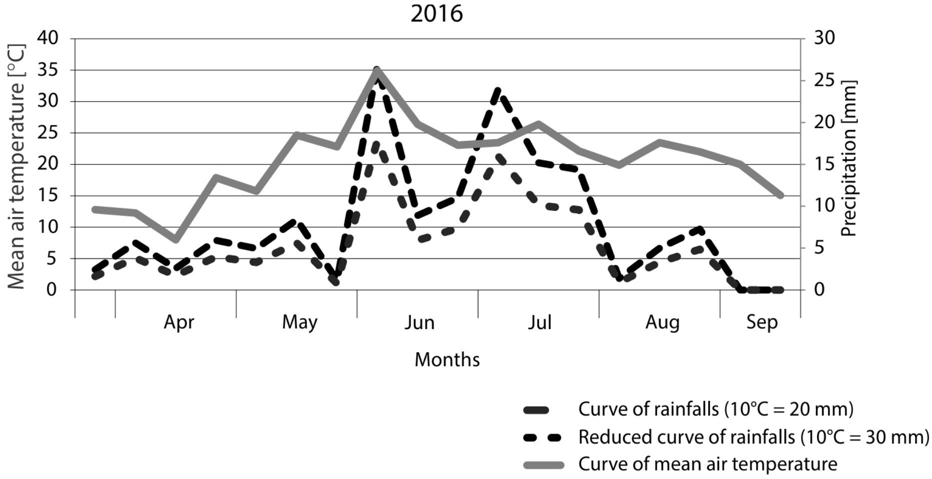

Fig. 3. Climatic diagram for meteorological conditions of the field experiment in the vegetation period (IV-IX) in the year 2016

using electro-assisted phytoremediation (Liu *et al.* 2002). Starch was determined following ICC-Standard no. 123 (ICC-Standard 1994). Carbohydrate analyses were based on procedures outlined by Talburt and Smith (1987). Total protein content was determined using the Kjeldahl method (Sweeney and Rexroad 1987). The total content of polyphenolics was assessed according to Singleton and Orthofer (1999). Chlorogenic acid was determined following Griffiths *et al.* (1992). L-ascorbic acid was determined using the method of Kapur *et al.* (2012). Antioxidant capacity was assessed using the Fluorescence Recovery After Photobleaching method, following Benzie and Strein (1999).

Statistical analyses, including two-way ANOVA with the Statistica® 13.1 package, assessed differences in potato tuber traits. The ANOVA *test* assumes that, the data *are* normally distributed and the *variances* across groups *are homogeneous*. Significance was determined through Tukey's multiple confidence intervals ($p = 0.05$), and LSD (lowest significant difference) was calculated.

Results

From 2014 to 2016, drip irrigation significantly increased the marketable yield of Vineta potatoes by 76%, from 23.68 to 41.74 t · ha^{-1} (Table 3). N-fertigation also contributed, leading to a 10% increase from 31.16 to 34.26 t · ha^{-1}. Although no significant interaction was observed between drip irrigation and N-fertigation over the 3 years, their combined use resulted in higher yields (averaging 43.62 t · ha^{-1}) than individual methods.

Drip irrigation increased single tuber weight by 15%, from 86.1 to 98.7 g, while N-fertigation led to an 8% rise from 89.0 to 95.9 g (Table 4). No significant interaction was noted over the 3 years, but combined methods produced higher single tuber weights (averaging 103.4 g) than individual approaches.

On average, from 2014 to 2016, drip irrigation increased the number of tubers per plant by 93%, from 7.0 to 13.5 (Table 5). N-fertigation raised the average number from 9.7 to 10.8, an 11% increase. Despite no significant interaction, combined methods resulted in more tubers (averaging 14.3) than individual approaches.

The average IWUE for N-fertilization methods was 174 kg · ha^{-1}·mm^{-1} (Table 6). N-fertigation, compared to broadcasting, positively impacted the IWUE, yielding 179 kg · ha^{-1} with 1 mm of water in drip irrigation and N-fertigation. Drip irrigation increased NUE, raising nitrogen productivity from 197 to 348 kg · ha^{-1}·kg^{-1} N (Table 7). The highest NUE, averaging 363 kg · ha^{-1} · kg^{-1} N, was achieved with liquid ammonium nitrate fertigation.

Tables 8 and 9 assessed the impact of drip irrigation and N-fertilization on tuber nutrient and bioactive compound content. Drip irrigation significantly enhanced levels of tested nutrients, bioactive compounds, and antioxidant capacity.

Irrigation and N-fertilization methods significantly impacted dry matter and starch content in tubers (Table 8). Drip-irrigated and N-fertigated plots showed higher levels than the non-irrigated control and broadcast-fertilized plots. The highest dry matter (21.0%) and starch (13.68 g · 100 g^{-1}) were observed in tubers from drip-irrigated and N-fertilized plots.

Total sugar content in tubers from drip-irrigated and N-fertigated plots was higher than in the control and broadcast-fertilized plots (Table 8). Drip-irrigated plots exhibited elevated reducing sugar levels compared to the control. The method of fertilization

Table 3. Marketable yield ($t \cdot ha^{-1}$) of the Vineta potato in the years 2014–2016

Treatment		Years			Mean
Irrigation	Fertilization	2014	2015	2016	
Control (without irrigation)	boadcasting	17.64	25.63	24.22	22.45
	fertigation	18.09	28.25	28.40	24.91
Drip irrigation	broadcasting	39.36	39.50	40.75	39.87
	fertigation	45.51	41.52	43.82	43.62
Influence of irrigation					
Control		17.86	26.94	26.31	23.68
Drip irrigation		42.43	40.51	42.28	41.74
Difference: drip irrigation – control		24.57	13.57	15.97	18.06
Influence of fertilization					
Broadcasting		28.50	32.56	32.48	31.16
Fertigation		31.80	34.88	36.11	34.26
Difference: fertigation – broadcasting		3.30	2.32	3.63	3.10
$LSD_{0.05}$[1] for irrigation		5.885	3.715	2.198	3.483
$LSD_{0.05}$ for fertilization		2.186	1.534	2.435	1.008
$LSD_{0.05}$ for fertilization × irrigation		3.092	ns[2]	ns	ns
$LSD_{0.05}$ for irrigation × fertilization		6.250	ns	ns	ns

[1]least significant difference (Tukey's confidence half-interval) at $p < 0.05$;
[2]not significant at $p < 0.05$

Table 4. Weight of a single tuber (g) of the Vineta potato in the years 2014–2016

Treatment		Years			Mean
Irrigation	Fertilization	2014	2015	2016	
Control (without irrigation)	boadcasting	81.6	85.6	84.3	83.83
	fertigation	85.0	90.4	89.7	88.37
Drip irrigation	broadcasting	90.1	95.5	96.7	94.10
	fertigation	103.6	101.2	105.4	103.40
Influence of irrigation					
Control		83.3	88.0	87.0	86.1
Drip irrigation		96.8	98.3	101.0	98.7
Influence of fertilization					
Broadcasting		85.8	90.5	90.5	89.0
Fertigation		94.3	95.8	97.5	95.9
$LSD_{0.05}$[1] for irrigation					4.987
$LSD_{0.05}$ for fertilization					3.259
$LSD_{0.05}$ for fertilization × irrigation					ns[2]
$LSD_{0.05}$ for irrigation × fertilization					ns

[1]least significant difference (Tukey's confidence half-interval) at $p < 0.05$;
[2]not significant at $p < 0.05$

showed no significant impact on reducing sugar content. The interaction of factors played a crucial role, resulting in the highest total sugars ($6.02\ g \cdot kg^{-1}$ FM) and reducing sugars ($3.85\ g \cdot kg^{-1}$ FM) in tubers from drip-irrigated and N-fertilized plots.

Protein content varied based on the N-fertilization method, with fertigation showing a more favorable impact than broadcasting (Table 8). The significant interaction between irrigation and N-fertilization methods resulted in tubers treated with drip irrigation and broadcasting fertilization exhibiting the highest protein content at $112.05\ g \cdot kg^{-1}$ DM.

The concentration of total polyphenols, including chlorogenic acid, depended on irrigation, the

Table 5. Number of tubers (pcs) per plant of the Vineta potato in the years 2014–2016

Treatment		Years			Mean
Irrigation	Fertilization	2014	2015	2016	
Control (without irrigation)	boadcasting	6	7	7	6.7
	fertigation	6	8	8	7.3
Drip irrigation	broadcasting	12	13	13	12.7
	fertigation	14	14	15	14.3
Influence of irrigation					
Control		6.0	7.5	7.5	7.0
Drip irrigation		13.0	13.5	14.0	13.5
Influence of fertilization					
Broadcasting		9.0	10.0	10.0	9.7
Fertigation		10.0	11.0	11.5	10.8
$LSD_{0.05}$[1] for irrigation					1.242
$LSD_{0.05}$ for fertilization					0.655
$LSD_{0.05}$ for fertilization × irrigation					ns[2]
$LSD_{0.05}$ for irrigation × fertilization					ns

[1]least significant difference (Tukey's confidence half-interval) at $p < 0.05$;
[2]not significant at $p < 0.05$

Table 6. Irrigation water use efficiency of the Vineta potato in the years 2014–2016

Treatment	Increase of yield [$kg \cdot ha^{-1} \cdot mm^{-1}$]	
	range	mean
Drip irrigation	114–211	174
Drip irrigation + broadcasting[1]	117–204	169
Drip irrigation + fertigation[2]	112–236	179

[1](Drip irrigation + broadcasting) – (control + broadcasting);
[2](Drip irrigation + fertigation) – (control + fertigation)

Table 7. Nitrogen use efficiency of the Vineta potato in the years 2014–2016

Treatment	Increase of yield [$kg \cdot ha^{-1} \cdot kg^{-1}$ N]			
	2014	2015	2015	Mean
Control + broadcasting	147	214	202	187
Control + fertigation	151	235	237	208
Mean	149	224	219	197
Drip irrigation + broadcasting	328	329	340	332
Drip irrigation + fertigation	379	346	365	363
Mean	354	337	352	348

fertilization method, and their interaction (Table 9). Control plots showed higher levels than tubers from drip-irrigated and N-fertigated plots.

Vitamin C content in tubers was influenced by irrigation and fertilization methods, with a significant interaction between these factors (Table 9). Drip-irrigated tubers exhibited higher vitamin C levels than control plots, and fertigation increased vitamin C content compared to broadcasting. The maximum vitamin C content (221.4 $mg \cdot kg^{-1}$ FM) was observed in tubers from drip-irrigated and N-fertigated plots.

Regarding antioxidant capacity, both irrigation and N-fertilization methods significantly enhanced the properties of tubers, with the highest values (6.09 mmol $Fe^{2+} \cdot kg^{-1}$) observed in tubers drip-irrigated with liquid N-fertigation (Table 9).

Table 8. Nutritional value of Vineta potato tubers depending on irrigation and nitrogen fertilization in the years 2014–2016

Treatment: Irrigation	Treatment: Fertilization	Dry matter [%]	Starch [g · 100 g⁻¹ FM]	Total sugars [g · kg⁻¹ FM]	Reducing sugars [g · kg⁻¹ FM]	Total protein [g · kg⁻¹ DM]
Control (without irrigation)	broadcasting	19.8 ± 0.02[1]	13.23 ± 0.01	5.16 ± 0.02	3.22 ± 0.02	111.25 ± 0.05
	fertigation	20.5 ± 0.01	13.48 ± 0.02	5.28 ± 0.03	3.29 ± 0.01	111.85 ± 0.05
	mean	20.15	13.36	5.22	3.26	111.55
Drip irrigation	broadcasting	21.0 ± 0.01	13.68 ± 0.00	6.02 ± 0.01	3.86 ± 0.02	112.05 ± 0.10
	fertigation	20.8 ± 0.01	13.52 ± 0.01	5.95 ± 0.04	3.83 ± 0.04	111.93 ± 0.06
	mean	20.90	13.60	5.99	3.85	111.99
Mean for broadcasting		20.40	13.46	5.59	3.54	111.65
Mean for fertigation		20.65	13.50	5.62	3.56	111.89
$LSD_{0.05}$[2] for irrigation (A)		0.635	0.064	0.095	0.064	ns
$LSD_{0.05}$ for fertilization (B)		0.215	0.015	0.024	ns	0.194
$LSD_{0.05}$ for A × B		0.601	0.069	0.091	0.060	0.602

[1]mean ± standard deviation; [2]least significant difference (Tukey's confidence half-interval) at $p < 0.05$

Table 9. Bioactive compounds of Vineta potato tubers depending on irrigation and nitrogen fertilization in the years 2014–2016

Treatment: Irrigation	Treatment: Fertilization	Total polyphenols [g GAE · kg⁻¹ DM]	Chlorogenic acid [g · kg⁻¹ DM]	Ascorbic acid [mg · kg⁻¹ FM]	Antioxidant capacity [mmol Fe^{2+} · kg⁻¹]
Control (without irrigation)	broadcasting	5.25 ± 0.00[1]	4.89 ± 0.02	210.5 ± 0.12	5.29 ± 0.05
	fertigation	5.12 ± 0.01	4.42 ± 0.03	212.4 ± 0.16	5.47 ± 0.08
	mean	5.19	4.66	211.5	5.38
Drip irrigation	broadcasting	4.91 ± 0.03	4.11 ± 0.02	220.9 ± 0.11	6.01 ± 0.04
	fertigation	4.84 ± 0.01	4.04 ± 0.01	221.4 ± 0.12	6.09 ± 0.02
	mean	4.87	4.08	221.2	6.05
Mean for broadcasting		5.08	4.50	215.70	5.65
Mean for fertigation		4.98	4.23	216.90	5.78
$LSD_{0.05}$[2] for irrigation (A)		0.191	0.064	0.318	0.032
$LSD_{0.05}$ for fertilization (B)		0.022	0.022	0.241	0.069
$LSD_{0.05}$ for A × B		0.188	0.060	0.349	ns

[1]mean ± standard deviation; [2]least significant difference (Tukey's confidence half-interval) at $p < 0.05$

Discussion

In the present study, the productivity traits of early potato cultivar Vineta tubers increased in the plots where drip irrigation and nitrogen fertigation were applied. Drip irrigation led to a significant 76% increase in marketable yield. Comparatively, Rolbiecki *et al.* (2021b) showed a 55% increase in the marketable yield of the medium-early potato cultivar Courage with drip irrigation, while, Mazurczyk *et al.* (2009) reported an 88% increase in tuber yield for the medium-early Triada cultivar. Elzner *et al.* (2018) observed significant marketable yield improvements in very early Monika and semi-early Jolana cultivars in regions with low rainfall. The research by Badr *et al.* (2012) and Elzner *et al.* (2018) suggests that irrigated crops can yield several times more tubers than non-irrigated ones.

In the present studies, fertigation enhanced tuber yield over 3 years, with the highest yields in plots using both drip irrigation and fertigation. Numerous studies support the yield increase in tubers with drip fertigation (Mazurczyk *et al.* 2009; Badr *et al.* 2012; Trawczyński 2013; Elzner *et al.* 2018; Rolbiecki *et al.* 2021b), emphasizing its effectiveness and economic advantages over traditional solid fertilization (Trawczyński 2013; Rolbiecki *et al.* 2021b; Nowacki 2018).

In the current research, drip irrigation increased single tuber weight and the number of tubers per plant, while fertigation additionally boosted single tuber weight. Plots with both drip irrigation and fertigation had higher single-tuber weights than those with only one method. Rolbiecki *et al.* (2021b) reported positive effects on tuber weight and number with both drip irrigation and fertigation. Walworth and Carling (2002) observed a lower tuber count without drip irrigation. Water deficiency during tuber initiation and development, as noted by Nagaz *et al.* (2007), can reduce yield by impacting both the number and weight of tubers.

In the current experiment, N-fertigation, compared to broadcasting, positively impacted the IWUE, improving water utilization under conditions of scarcity. Drip fertigation enhanced both IWUE and tuber yield in various studies (Mazurczyk *et al.* 2009; Badr *et al.* 2012; Trawczyński 2013; Elzner *et al.* 2018; Rolbiecki *et al.* 2021b). In the present study, NUE improved under drip irrigation, reaching peak values when combined with fertigation. According to Rolbiecki *et al.* (2021b), the cultivation of the mid-early cultivar Courage demonstrated a notable increase in nitrogen productivity with drip irrigation. Likewise, research conducted in Egypt by Badr *et al.* (2012) indicated that full irrigation led to the highest NUE, while the lowest NUE was associated with greater water deficit treatment.

In the current study, dry matter and starch levels increased in tubers with drip irrigation and N-fertigation. Gunel and Karadogan (1998) and Wichrowska *et al.* (2021) reported similar findings, highlighting the impact of irrigation on enhancing both dry matter and starch content in tubers. Additionally, Ekelöf *et al.* (2015) demonstrated that irrigation and fertigation contribute to increased starch content. However, conflicting reports, like those by Karam *et al.* (2014), suggest a reduction in starch content under irrigation.

In this research, tubers from drip-irrigated and fertigated plots elevated total sugars, with only drip irrigation positively affecting reducing sugar content. Research by Wichrowska *et al.* (2021) found that irrigation increased saccharose but decreased monosaccharide content, while Yari *et al.* (2020) reported that irrigation significantly increased glucose content in tubers.

Danilchenko *et al.* (2008) showed that potato proteins' various fractions possess a well-balanced amino acid composition and high nutritional value. In the present study, drip irrigation had no impact on tuber protein content, but the concentration increased with N-fertigation. In contrast, other studies, like Gunel and Karadogan (1998), suggest that irrigation might lead to a decrease in tuber protein content.

In this study, control tubers N-fertilizated through broadcasting positively influenced the levels of bioactive compounds like total polyphenols and chlorogenic acid. The increased polyphenol levels may result from limited water availability and heightened polyphenolic defense compounds under stress conditions (Lombardo *et al.* 2017). Similarly, Wichrowska *et al.* (2021) found higher concentrations of total polyphenols and chlorogenic acid in non-irrigated and broadcasted tubers than in those from drip-irrigated and N-fertigated plots.

In this study, irrigated tubers showed higher vitamin C levels than control tubers. Moreover, N-fertigation further enhanced the vitamin C content. Similarly, Wichrowska *et al.* (2021) found elevated vitamin C levels in tubers with both drip irrigation and fertigation, establishing a positive correlation between vitamin C content and antioxidant capacity. They also noted a negative correlation between polyphenolic compounds and antioxidant capacity. Lombardo *et al.* (2017) observed that polyphenolic compound synthesis is linked to the host's defense response against various stresses, and their content is influenced by the growing environment and genetics. In the present study, tubers subjected to drip irrigation and N-fertigation exhibited high antioxidant properties, aligning with findings by Wichrowska *et al.* (2021), that showed positive effects of irrigation and fertigation on tuber antioxidant properties.

In summary, in accordance with the hypothesis, precise drip irrigation and N-fertigation treatments positively affected the condition of early potato cultivar Vineta plants, enhancing both tuber productivity and quality. Recent research demonstrated improved tuber yield traits with these practices, along with positive effects on nutrient concentration, ascorbic acid, and antioxidant capacity. The increase in total polyphenols, including chlorogenic acid, was more pronounced in broadcasted and non-irrigated tubers. These findings, for the first time, demonstrated that alleviating water stress and employing precise N-fertigation not only increased yields but also enhanced the overall tuber quality of the Vineta potato. Future research should focus on further evaluating the impact of precise irrigation and fertilization on the Vineta potato, particularly with respect to resistance to biotic and abiotic factors.

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