Responses of Yield, Quality and Water Use Efficiency of Potato Grown Under Different Drip Irrigation and Nitrogen Levels

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Article

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Abstract

Proper irrigation and fertilization are essential to achieve high tuber yield and quality in potato production. Water and nitrogen are required to be improved due to high costs of these agricultural inputs. This study aimed to optimize the use of water and nitrogen in potato to ensure high water use efficiencies as well as achieve optimum yield and tuber quality. Potato plants were subjected to three irrigation treatments, 100% (S100), 66% (S66) and 33% (S33) of field capacity and six N levels, 0 (N0), 100 (N1), 200 (N2), 300 (N3), 400 (N4) and 500 (N5) kg N ha^{-1}. Yield, growth parameters and tuber quality were generally more sensitive to irrigation than nitrogen. The highest total tuber yield was obtained under full irrigation with an application of 300 kg N ha^{-1}. Plants indicated higher values for yield and growth parameters in full irrigation applications, and significantly lower values were obtained at low irrigations. On the contrary, the full irrigation (S100) application caused a decrease in quality characteristics compared to low irrigations (S66 and S33). Water levels treatments indicated that S66 had the highest mean value of WUE in both years. These results indicated that potato can be produced with acceptable yields while saving irrigation water and certain nitrogen level.

1. Introduction

Irrigation and nitrogen management (N) are important factors affecting potato (*Solanum tuberosum* L.) yield, quality, and net profit[5]. Maximum yields for potato are obtained when the soil is constantly at a certain moisture level and the N requirement is adequately supplied[9]. A high level of nitrogen is required to obtain a high plant growth rate for potato plant. Nitrogen increases tuber yield and decreases specific gravity. Nitrogen deficiency reduces leaf area and also reduces tuber size due to premature defoliation. Excess N increases the dry matter content of the plant and decreases tuber growth time[10,17,19,29,31,33].

Applying nitrogen at the right rate, time and place increases N efficiency. Potato need nitrogen most during the tuber growth period. About 58–70% of N during the entire production period is taken at this stage of development[26]. When nitrogen is applied to the plant in the most appropriate form and amount, it has a positive effect on growth and plant development. However, excessive use of nitrogen negatively affects the resistance of the plant against diseases and pests. Due to low nitrogen in the tuber formation phase, drying of the tuber and old leaves occurs and therefore reduces tuber development.

Potato has a limited root system and therefore make low use of nitrogen and therefore nitrogen fertilization is required. Therefore, irrigation and nitrogen management are very important and should be applied correctly[6]. Potato consumes 500–700 mm of water depending on the climate. Potato, which is a very sensitive plant to moisture deficiency in the soil, should not fall below 65% of usable water to obtain high yields[30,34]. The period from the beginning of tuber formation to 15 days before harvest is the period when the potato needs water the most.In conditions where regular irrigation is not done at this stage, secondary growth can be seen in tubers. Irrigation enhances average tuber weight but may not improve tuber per plant[39].

Irrigation method used in potato differs according to the region and water availability. Sprinkler irrigation is the method commonly used in potato growing regions of Turkiye. Today, however, drip irrigation method has been used and has become widespread[11]. Nitrogen can infiltrate under the root through irrigation and precipitation. Accordingly, fertilizers and chemicals that cannot be taken by the plant move underground with the water. Precipitation and irrigation are very effective in determining the rate at which the chemical moves down the soil surface. Therefore, measured irrigation management is important to control the submergence of chemicals and nutrients. Proper application of irrigation method can also facilitate nitrogen uptake, thus minimizing potential seepage losses below the root zone[4]. Although the information in the literature on irrigation and nitrogen management is conflicting, tuber yield and quality are affected by N and irrigation applications. Proper management of nitrogen and water is necessary to achieve growth and marketable tuber. Incomplete irrigation creates differential meats on nutrient uptake, growth, and yield. Nitrogen can replace deficient water, and proper nitrogen management can reduce yield reduction from under-irrigation.

Irrigation scheduling and drip irrigation are two possible options for improve water use efficiency. With optimal management of N, plant growth and yield can be improved[3]. Therefore, attention must be paid to N and water management for the potato to provide quality and marketable tubers. In many parts of the world, Various studies were conducted on irrigation and fertilization of potato. The most limiting nutrient for potato growth, the need for nitrogen varies greatly with climate, soil, variety, irrigation, and cultural practices. Therefore, the aim of this study is to determine the effects of irrigation and N fertilization rates on yield and quality of potato grown with drip irrigation.

2. Materials And Methods

2.1. Site description

Field trials were conducted during the years 2021 and 2022 at research area (N37^{0}94’, E34^{0}96’) Faculty of Agricultural Sciences and Technologies, Nigde Ömer Halisdemir University, Türkiye. The experimental site is at an altitude of 1299 m above sea level and receives an average of 343 mm of precipitation annually. In both years, a rainfall recorder (Turkish State Meteorological Service Nigde Meteorology Station) was used to measure the precipitation during the growing season. At the sowing time, the soil bulk density of experimental field (0–40 cm) was 1.11 g cm^{-3}, field water capacity was 31%, soil pH value was 7.95, soil nitrogen content was 0.138%, soil phosphorus content was 10.85 mg kg^{-1} and soil potassium content was 201.19 mg kg^{-1}.

2.2. Experimental design

In each year, the field experiments were conducted according to the split-plot design with 18 sub-plots replicated four times. The treatments were comprised of three irrigation water levels (100% = S100, 66% = S66, 33% = S33 field capacity) and six nitrogen levels (0 = N0, 100 = N1, 200 = N2, 300 = N3, 400 = N4, 500 = N5 kg ha^{-1}). The nitrogen levels were randomized in main plots whereas the irrigation levels were randomized in sub-plots. 'Agria' was used as a variety in experiments during both the years. The disease-free seed tubers of this variety were obtained from Doga Seed Company, Nevsehir, Türkiye. The seeds were sown on the ridge tops with a sowing machine on May 13, 2021, and May 29, 2022, and were harvested on October 4, 2021, and on September 27, 2022 during the first and second year of study, respectively. The entire field (65.1 m × 29.4 m) was divided into four blocks (replications) and each block measured 65.1 m × 5.1 m. Among the blocks, an area measuring 3 m was kept unplanted to facilitate data recording and to prevent irrigation applications from affecting each other. Each block was divided into six main plots. The main plots were consisted of 12 rows and sub-plots consisted of four rows. Two rows between the main plots and one row between the sub-plots were kept unplanted. Experimental research on plants, field studies, collection of plant material and irrigation practices were carried out in accordance with the Standards of the Ministry of Agriculture of the Republic of Türkiye.

2.2.1 Irrigation management and crop water consumption.

After planting potato seeds, drip irrigation systems were placed on the field. Immediately after planting, emitters at 30 cm intervals were placed in a drip tape with an emitter flow rate of 4 L h^{-1}. A system consisting of a screen filter, fertilizer tank, a valve and two pressure gauges was used to measure the irrigation amount and control the pressure. Irrigation started on May 13, 2021 and May 29, 2022. To measure the field capacity, soil samples were taken from 0–20 and 20–40 cm depths with a soil digger. Field capacity was measured as the amount of water retained in a saturated soil after 2–3 days of gravity drainage. Volumetric moisture content was calculated gravimetrically. The amount of irrigation water applied to each plot was calculated with the following Eq. (1)[25].

$$\mathrm{Irrigation Requirement} = [\frac{(\mathrm{Fc} - \mathrm{Sm})}{100} \times \mathrm{R_d}] \times \mathrm{Pa} \times \mathrm{Pw}$$

1

Where "Fc" is field capacity (31%), "Sm" is soil moisture before irrigation (%), "R_d" is root depth (mm), "Pa" is plot area (m^2) and "Pw" is wetted soil percentage.

When the soil moisture value decreased by 30–40% of the field capacity, separate irrigation was applied to each nitrogen plot. To monitor the soil moisture content (%), soil samples were taken every 3–4 days from the full irrigation plot (100% Fc) of each nitrogen application, and the gravimetric method (g/g) soil moisture measurement was performed.

Crop water consumption (ETc, mm) was calculated at 15-day intervals for each nitrogen level using the soil water balance (Eq. 2)[23].

$$\mathrm{ETc} = \mathrm{I} + \mathrm{P} \pm \mathit{\Delta}\mathrm{S} - \mathrm{D} - \mathrm{R}$$

2

where; I is the irrigation water (mm), P is the rainfall (mm), ΔS is the change in soil water storage (mm 60 cm^{-1}) and D is the deep percolation (mm), R is the runoff (mm).

2.2.2. Water and nitrogen use efficiency (WUE and NUE): The WUE (kg mm^{-1} ha^{-1}) were calculated using Eqs. (3) described by Hou et al.[22].

$$\mathrm{WUE} = \frac{\mathrm{Y}}{\mathrm{Et}}$$

3

where Y is the crop yield, ET is the evapotranspiration during the entire growth period.

2.2.3. Fertilization management.

After the completion of the land preparation, fertilizers were applied. P_20_5 – 125 kg ha^{-1} K_20 – 150 kg ha^{-1} was applied to the soil with planting. Likewise, half of the nitrogen dose was applied during planting and the remaining half was applied during tuber bulking. Planting was done with a distance of 30 cm between plants and 70 cm between rows. Plant protection practices were carried out throughout the entire growing season. Potato seeds separated as seeds were sprayed before planting, with Thiamethoxam active ingredient, against pests after emergence and emergence. At the growth stage, fungicide against blight disease were also used as per requirement.

2.3. Data collection

2.3.1. Yield and growth parameters

Plants in each replicated plot growth parameters including the number of tuber $plant^{-1}$, number of $stems^{-1}$, and height of plants (cm) were noted. Tubers in each plot were first classified, then counted and finally weighed. Classifications: Diameter greater than or equal to 45 mm - class 1; greater than 25 and less than 45 cm - class 2; Less than or equal to 25 mm - class 3. 1st, 2nd, and 3rd class yields of tubers were added and ton ha^{-1} weights were calculated.

2.3.2. Tuber quality parameters

At harvest, tuber dry matter (TDM) and specific gravity (SG) were measured each year on all treatments. TDM and SG of treatments were measured by Martin Lishmans's digital potato hydrometer. TDM and SG were measured with approximately 2.5 kg of clean, raw tubers from each treatment. Starch concentration was calculated using the underwater weight of the tubers with Eq. 4[21].

$$\mathrm{Starch}\,(\%\mathrm{FW}) = -183 + (184\mathrm{xSG})$$

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2.3.3. Statistical analysis

All data were subjected to experimental design analysis of variance (ANOVA) to evaluate the effects of treatments on yield, growth components and tuber quality of potato. The SAS Institute (Version 9, Cary, NC, USA, 2002) was used to perform the analysis of variance. Comparison of the means was obtained using the least significant difference (LSD) at the 5% probability level.

3. Results And Discussion

3.1. Meteorological parameters

Mean monthly metrological parameters for both the years are presented in Fig. 1. Maximum mean monthly temperature was observed during the tuber formation in 2021 and tuber expansion month in 2022. Rains during the 2021 growing season were lower than the subsequent season (2022), but not well distributed with most of the rain being received in June (Fig. 1). The total precipitation during the potato growing seasons in 2021 and 2022 was 82.20 mm and 177.60 mm, respectively (Fig. 1). In addition, the low temperature values before planting in 2022 caused the planting time to be delayed.

3.1. Irrigation water applied and crop water consumption

The total water application for each treatment and growing season is shown in Fig. 2. Average total irrigation applied to the crop was 227.70, 280.90, and 335.70 mm for S33, S66, and S100 treatments in 2021, respectively and 160.10, 241.00, and 324.3 mm for S33, S66, and S100 treatments in 2022, respectively. The first-year irrigation amount was higher than the second year because the water deficit period was delayed in the first year. The seasonal crop water consumption (ETc) values determined are given in Table 1. Seasonal average ET_c values varied between 181.78–289.79 mm in 2021 and between 234.48– 369.14 mm in 2022.

Table 1
Crop water consumption (ET_c) for each treatment (mm) in both year

Years	Treatments	N0	N1	N2	N3	N4	N5	Average
2021	S33	144.87	202.72	202.10	194.05	182.48	164.47	181.78
	S66	187.59	249.20	255.94	258.00	242.25	216.91	234.98
	S100	231.60	297.09	311.40	323.89	303.84	270.93	289.79
2022	S33	227.67	246.55	235.75	219.29	250.24	227.40	234.48
	S66	268.81	289.91	311.52	283.31	314.23	292.58	293.39
	S100	344.75	401.58	386.97	348.60	395.19	337.78	369.14

(N0 = 0 kg ha^{-1} ; N1 = 100 kg ha^{-1} ; N2 = 200 kg ha^{-1} ; N3 = 300 kg ha^{-1} ; N4 = 400 kg ha^{-1} ; N5 = 500 kg ha^{-1} ; S33 = 33% FC ; S66 = 66% FC ; S100 = 100% FC)

3.2. Yield and growth parameters

Potato tuber yields varied greatly at different nitrogen and drip irrigation levels (Table 2). S100 irrigation level achieved highest tuber yield under all N levels. Average yield was more sensitive at irrigation levels than nitrogen levels. The reduction in total yield gradual water deficit averaged 14.9% in 2021 and 10.5% in 2022 with S66 reduction in irrigation water while by applying S33 i.e., less amount of water, potato yield decreased by 37.2% in 2021 and 39.8% in 2022. Badr et al.[9] were found similar results: Full irrigation resulted in the highest tuber yield under all N levels. With the decrease in the amount of irrigation, the decrease in the total yield was 7.8% on average with a 20% decrease in the irrigation water. While 40% and 60% less water was applied, the potato yield decreased by 27.3% and 44.6%, respectively. It was observed that as the nitrogen amount increased, the total yield increased up to the N3 level, but decreased after this level. The decrease in tuber yield after a certain level of nitrogen amount created stress on the plant and caused a decrease in yield.

The individual factors of irrigation amount and nitrogen fertilizer rate significantly affected plant height. Also, there were significant interaction. The potato crop achieved maximum growth attributes when it was irrigated with S100 whereas minimum values of plant height were recorded in plots irrigated with S33 in both years. Likewise, as the amount of nitrogen application increased, the plant height tended to increase. For nitrogen fertilization, the highest plant height was obtained from N4 application in 2021 and from N1 application in 2022 (Table 2). The response to lack of water in nitrogen fertilization proves to be an important factor in water deficiency influencing how plants allocate their produce to aboveground and underground organs. Thus, show association with plant height being slightly but consistently shorter in N0 plants. Wang et al.[37] have reported N-fertilization treatments had significantly higher plant height in full irrigation treatment than in other irrigation treatments. Kumar et al.[27] also observed the plant height increased with the increase in N dose up to 180 kg N ha^{-1}. Yuan et al.[39] indicated plant height increased with increasing amount of irrigation from the Ep0.25 to Ep1.25.

Table 2
Total yield and growth parameters of potato different irrigation levels and nitrogen fertilization

Treatments	**Tuber per plant**		**Stem per plant**		**Plant height (cm)**		**Tuber yield (t ha^{-1})**	
Nitrogen fertilization	2021	2022	2021	2022	2021	2022	2021	2022
N0	2.57a	5.74c	2.98bc	5.80a	62.08c	60.56a	19.17a	21.36a
N1	3.16a	6.77ab	2.80c	5.41ab	64.36bc	63.15a	22.77a	21.95a
N2	2.85a	6.43bc	3.08bc	5.16bc	63.65bc	60.73a	24.68a	22.17a
N3	3.17a	7.18a	3.15ab	4.80cd	64.18bc	54.78a	26.37a	22.36a
N4	3.19a	6.01c	3.43a	4.50d	67.73a	58.05a	25.14a	20.33a
N5	3.60a	6.10bc	3.23ab	4.85cd	65.18ab	55.66a	24.43a	18.92a
Irrigation levels								
S33	2.91a	5.85b	2.75b	5.12ab	61.44c	50.88c	18.06c	16.15c
S66	3.07a	6.76a	3.22a	5.36a	65.05b	60.85b	24.46b	24.01b
S100	3.29a	6.51a	3.38a	4.77b	67.10a	64.72a	28.76a	26.84a
Significance								
N	ns	**	*	**	**	ns	ns	ns
I	ns	**	**	*	**	**	**	**
N × I	ns	ns	ns	ns	*	ns	ns	ns

**: $p < 0.01$, *: $p < 0.05$. ns = non-significant. N: Nitrogen, I: Irrigation. Mean values within the same columns by different letters are significantly different. (N0 = 0 kg ha^{-1} ; N1 = 100 kg ha^{-1} ; N2 = 200 kg ha^{-1} ; N3 = 300 kg ha^{-1} ; N4 = 400 kg ha^{-1} ; N5 = 500 kg ha^{-1} ; S33 = 33% FC ; S66 = 66% FC ; S100 = 100% FC)

The number of tubers per plant was not significantly different for N application and irrigation in 2021. But was significantly different in 2022 (Table 2). While the number of tubers decreased under water deficit conditions the number of tubers was determined tended to increase as the nitrogen content increased. The irrigation level of S100 resulted in higher tuber number per plant in 2021 while the irrigation level of S66 resulted in highest number of tubers per plant in 2022. Number of tubers decreased under N0 in both years and highest tuber number was obtained from N5 application for 2021 and the N3 application for 2022. Onder et al.[30] reported that irrigation levels 66% of full irrigation resulted in highest number of tubers per plant. Mattar et al.[28] observed the number of tubers per plant was highest with the full irrigation. However, in contrast Ghasemi et al.[18] and Fandika et al.[16] indicated that effect of irrigation water on the number of tubers was not significant. Previous studies have found that water stress reduces the number of tubers per plant. Also. the lowest tuber number per plant was found in 0 kg ha^{-1} N application and other treatments were in the same statistical group by Güler[20]. Similarly. Ahmed et al.[2] have reported reduced the number of tubers per plant and the lowest number was obtained when using low application rates of 130 and 180 kg N/fed.

Number of stems per plant varied significantly effected in response to different N fertilization and irrigation levels. When N applications are evaluated, the highest stem values per plant were obtained from N4 application in 2021 and from N0 application in 2022 (Table 2). In addition, the increase in the amount of nitrogen caused an increase in the number of stems in 2021 and a decrease in 2022. The reason is that stem number is not affected much by mineral nutrients. Stem numbers per plant were affected significantly by varied irrigation level. The irrigation level of S100 resulted in higher stem number per plant in 2021. while the irrigation level of S66 resulted in highest number of stems per plant in 2022. Contrary to our research Adhikari and Rana[1] and Kumar et al.[27] showed that effect of various irrigation levels on number of stems per hill was not significant. Factors such as the storage conditions of tubers. the number of viable sprouts during planting. sprout damage and growing conditions during planting. physiological age of the seed tuber and tuber size also affect the number of stems[40].

3.4. Tuber quality parameters

The effects of nitrogen and irrigation on tuber dry matter (TDM), specific gravity (SG) and starch in both years are shown in Table 3. Mean values determined a significant difference ($P < 0.01$) of tuber TDM, SG and starch in irrigation and nitrogen levels in both years. When evaluated for two years, the highest dry matter content was obtained from N2 application for nitrogen. It has been determined that the amount of dry matter in irrigation levels tends to decrease with the increase in irrigation. TDM was greater with deficit irrigation compared to full irrigation in 2022. However, there was no change in 2021. Several research reports have observed there was a reduction in tuber dry matter with increasing N application rate[14,40]. Others have demonstrated that rising N fertilization had no significant effect on tuber dry matter[32]. Increasing N treatments show an increasing trend on TDM in 2021. However, were not alteration in 2022. The higher amount of irrigation in the first year compared to the second year may have triggered excessive nitrogen intake. Therefore, the increase in nitrogen intake may have contributed to the increase in the amount of tuber dry matter.

Table 3
Effect of different nitrogen and irrigation levels on tuber quality parameters

Treatments	**Dry matter (%)**		**Specific gravity (g cm^{-3})**		**Starch (%)**	
Nitrogen fertilization	2021	2022	2021	2022	2021	2022
N0	18.86c	19.63a	1.072e	1.077a	13.23e	14.13a
N1	18.90c	19.46a	1.074d	1.076a	13.60d	13.99a
N2	20.72a	19.31a	1.083a	1.075a	15.25a	13.87a
N3	19.60b	19.09a	1.077c	1.074a	14.09c	13.67a
N4	19.31b	19.35a	1.076cd	1.075a	13.90cd	13.81a
N5	20.39a	19.43a	1.080b	1.076a	14.76b	13.95a
Irrigation levels						
S33	19.66a	19.77a	1.077a	1.077a	14.13a	14.25a
S66	19.59a	19.57a	1.077a	1.077a	14.12a	14.10a
S100	19.64a	18.79b	1.077a	1.073b	14.15a	13.36b
Significance						
N	**	ns	**	ns	**	ns
I	ns	**	ns	**	ns	**
(NXI)	ns	ns	ns	ns	ns	ns

**: $p < 0.01$, *: $p < 0.05$. ns = non-significant. N: Nitrogen, I: Irrigation. Mean values within the same columns by different letters are significantly different. (N0 = 0 kg ha^{-1} ; N1 = 100 kg ha^{-1} ; N2 = 200 kg ha^{-1} ; N3 = 300 kg ha^{-1} ; N4 = 400 kg ha^{-1} ; N5 = 500 kg ha^{-1} ; S33 = 33% FC ; S66 = 66% FC ; S100 = 100% FC)

SG tended to decrease as applied water increased in 2022; less irrigation water produced higher SG tubers. However, in 2021 SG not effected rising water levels. The highest SG showed S100 for irrigation and N2 for nitrogen levels in over years (Table 3). SG is an important quality factors for processing potato. There is a range of specific gravities that is considered optimal. There are a number of SG that are considered optimal. Many factors such as climatic conditions and N fertilization affect tuber SG[2]. Rising of SG with increasing N application might be due to the rising in dry matter content as there are high correlation between SG in tubers and dry matter. Also. deficit irrigation after tuber initiation in the middle of the growing season create tubers with reduced SG. Yuan et al.[39] reported that as applied water increased SG tended to decrease. In addition. Alva et al.[5] explained that nitrogen increases SG but is not affected by irrigation.

There was a rising in starch with increasing N application rate but was not significantly difference in irrigation regimes in 2021. In 2022, while there was no significant difference between nitrogen levels. it was determined that starch increased as the amount of irrigation increased. The highest starch showed S100 for irrigation and N2 for nitrogen levels in over years (Table 3). Many researchers reported that decreased water content can significantly increase starch content[37,41]. On the other hand, Lin et al.[42] reported that starch content decreased with increasing N fertilizer rates.

3.5. Water Use Efficiency

Water use efficiency (WUE) of potato crops were affected by different irrigation and nitrogen levels during the growing season in each year as shown in Fig. 3,4. There was a significant difference between the years. Comparisons among mean values of the water levels treatments indicated that S66 had the highest mean value of WUE in both years, followed by S33, S100 and S100, S33 in 2021 and 2022, respectively. The effect of irrigation levels on WUE may depend on the level of water stress at different growth periods. In low water stress conditions, transpiration decreases more than photosynthesis under the condition of slight closure of stomata, and as a result WUE increases[13]. According to the results obtained, potato increase WUE up to N3 level in terms of nitrogen, but WUE decreases after this level in both years (Fig. 3). WUE among irrigations increased with increasing water level. WUE would improve under water deficit conditions. Most studies have found an increase in WUE relative to an increase in water stress[7,9,15].

3.6. Relationship between tuber yield, irrigation levels and Etc

Total amount of irrigation applied are given as ton per hectare by linear regression analysis. The relationships between tuber yield and applied water represented in Fig. 5. The potato yield increased with increasing irrigation applied. The regressions determined between irrigation applied and tuber yields were significant and linear. Also, significant linear relationships were observed between potato tuber yield and ETc as shown in Fig. 5. Previous research have indicated that potato yield responds linearly to the quantity of water applied[9,24,30]. Ünlü et al.[35] reported that depending on the irrigation regimes, evaporation and tuber yield were positively affected by nitrogen fertilizer. Badr et al.[9] indicated that relationships between tuber yield and crop ET were linear. The relationship between potato yield and ET is useful to explain the strength of the relationship where yield increases linearly with ET[8,12]. The main purpose in irrigation applications is to obtain the highest efficiency with the optimum irrigation application and the appropriate irrigation regime[38].

4. Conclusions

The results showed that potato tuber yield, quality and water use efficiency varied depending on irrigation water level and nitrogen rates. Yield, growth parameters and tuber quality in potato were generally more sensitive to irrigation than nitrogen. The highest expected plant height was obtained from the S100 application, and the lowest was obtained from the plots irrigated with S33. Likewise, an increasing trend in plant height was detected with the increase of nitrogen applied. The number of tubers per plant increased in both irrigation and nitrogen applications compared to control applications. The highest total tuber yield was obtained under full irrigation with an application of 300 kg N/ha. The increasing N doses produced an increase in the tuber yield at all irrigation supply, while after N3 level increased N level negatively affected tuber yield. The results of the study showed that it is possible to maintain high tuber yield, suitable tuber quality and high WUE of potato by saving irrigation water up to a certain level. Determining the interaction between different levels of water and nitrogen on potato yield and quality by developing appropriate fertilizer and irrigation practices for sustainable agriculture is important in terms of protecting water resources in the long term.

Declarations

Availability of Data and Materials

The datasets generated and/or analysed during the current study are not publicly available due as it is part of the doctoral thesis, and the other part of the study is in progress but are available from the corresponding author on reasonable request.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships in this paper.

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Figures

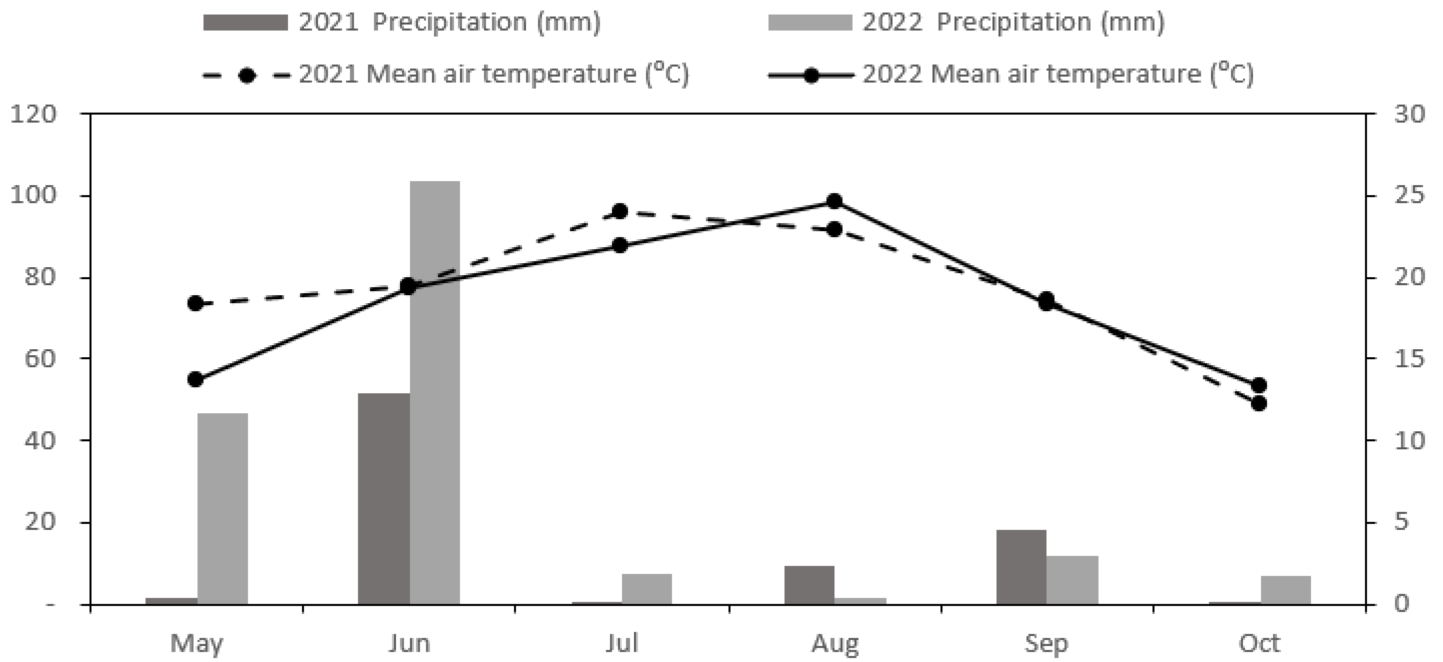

Figure 1

Mean air temperature and precipitation during the growing season of 2021-2022

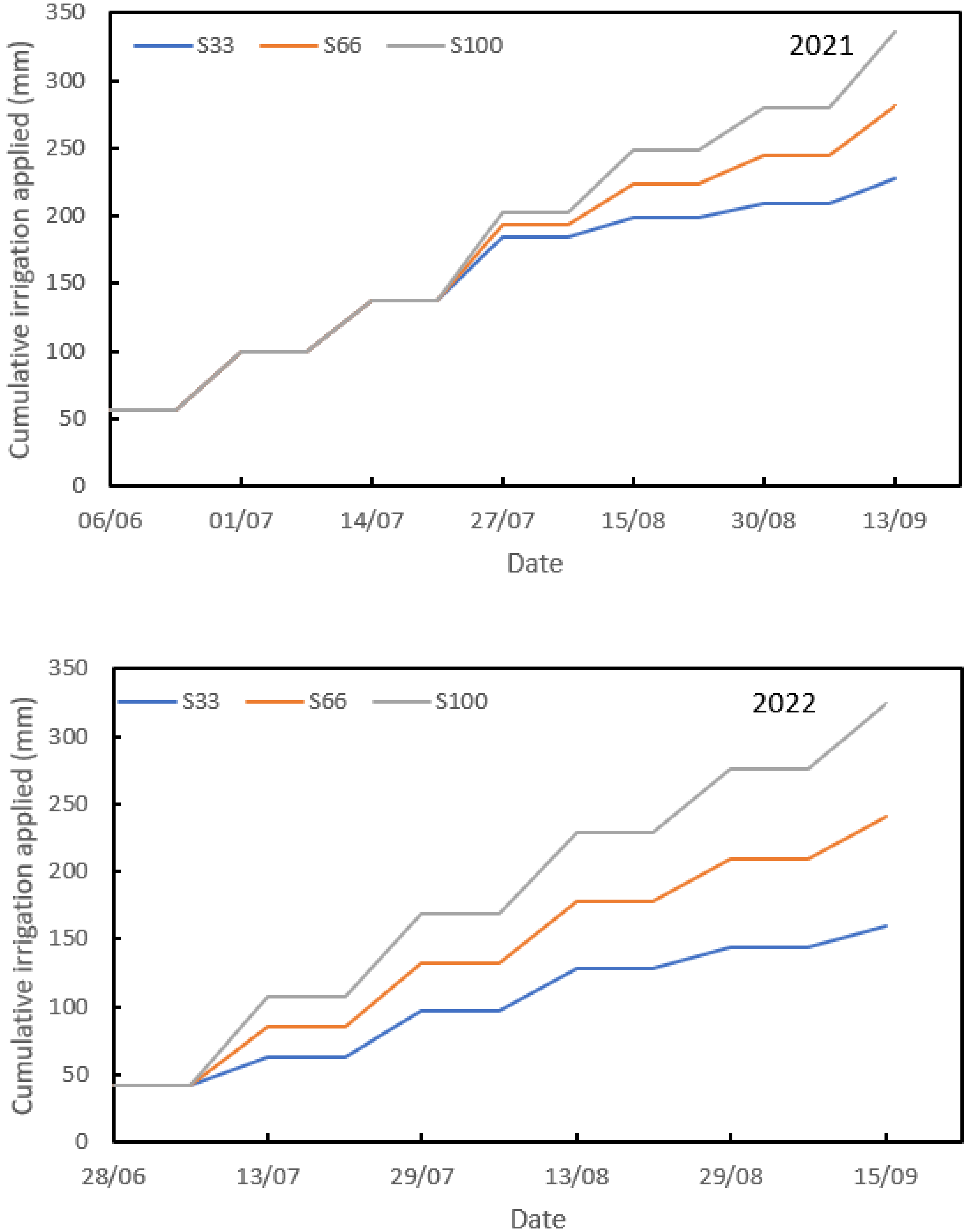

Figure 2

Water applied amount for each irrigation level during the years 2021 and 2022

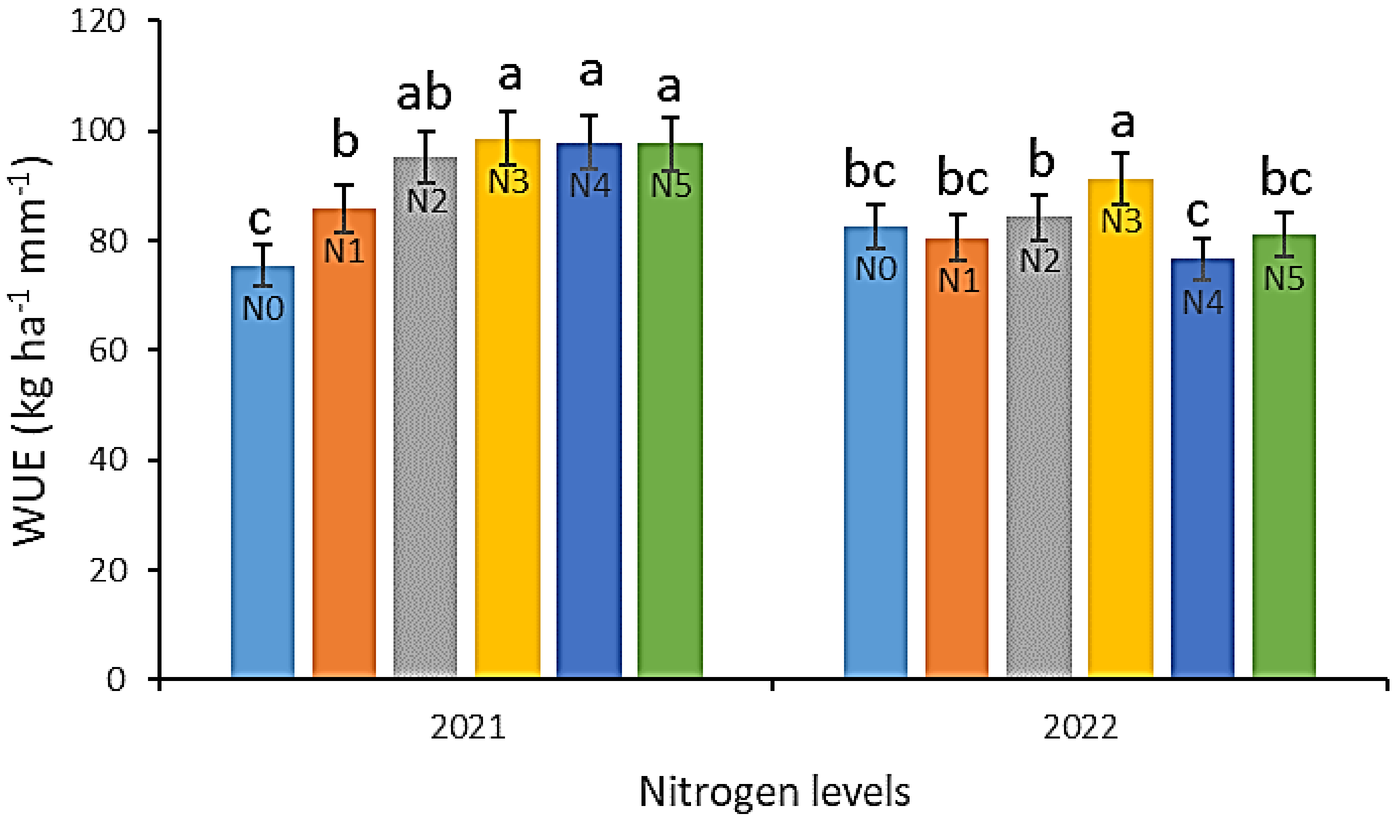

Figure 3

Effect of different nitrogen levels on water use efficiency of potato. Different letters are significantly different. (N0 = 0 kg ha^{-1} ; N1 = 100 kg ha^{-1} ; N2 = 200 kg ha^{-1} ; N3 = 300 kg ha^{-1} ; N4 = 400 kg ha^{-1} ; N5 = 500 kg ha^{-1})

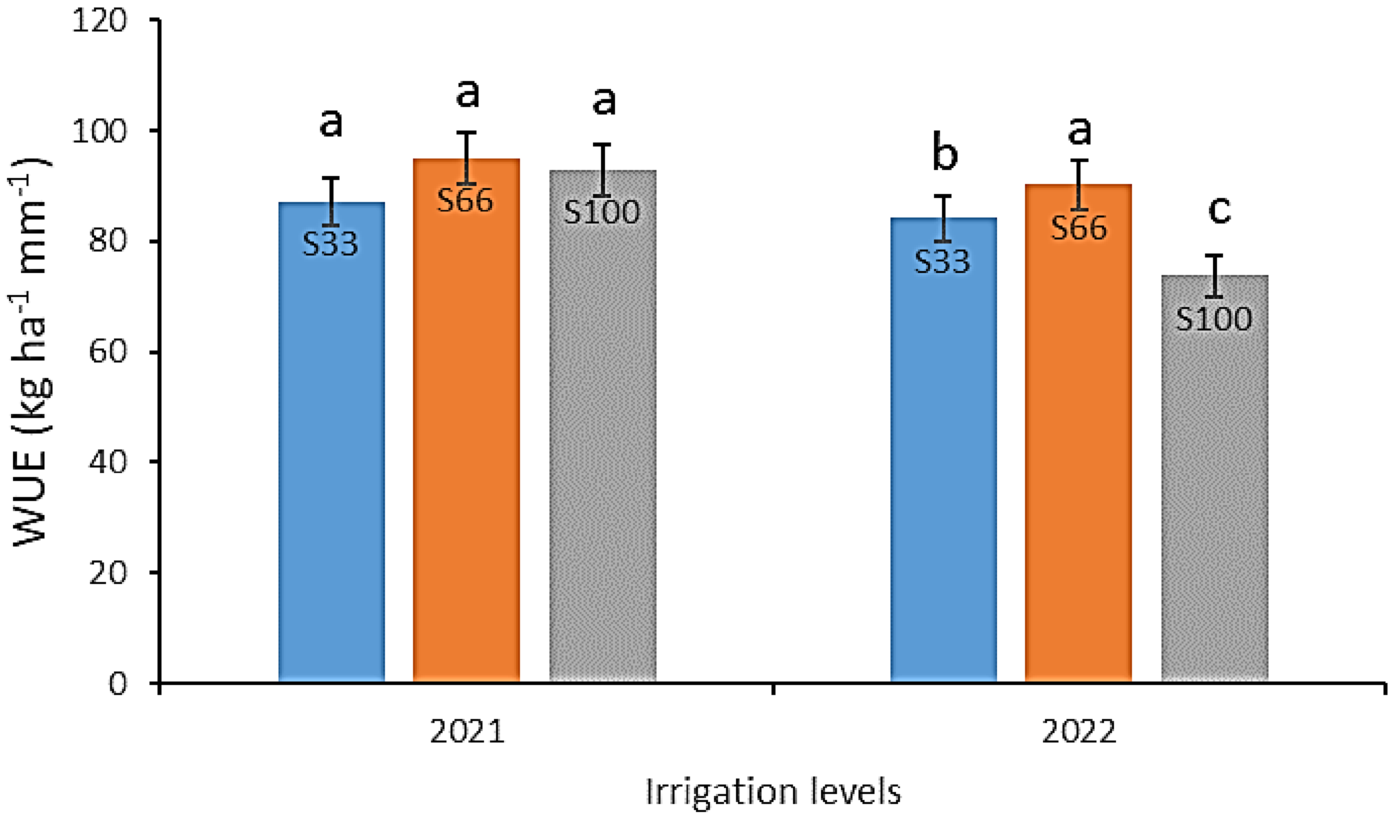

Figure 4

Effect of irrigation levels on water use efficiency of potato. Different letters are significantly different. (S33 = 33 % FC ; S66 = 66 % FC ; S100 = 100 % FC)

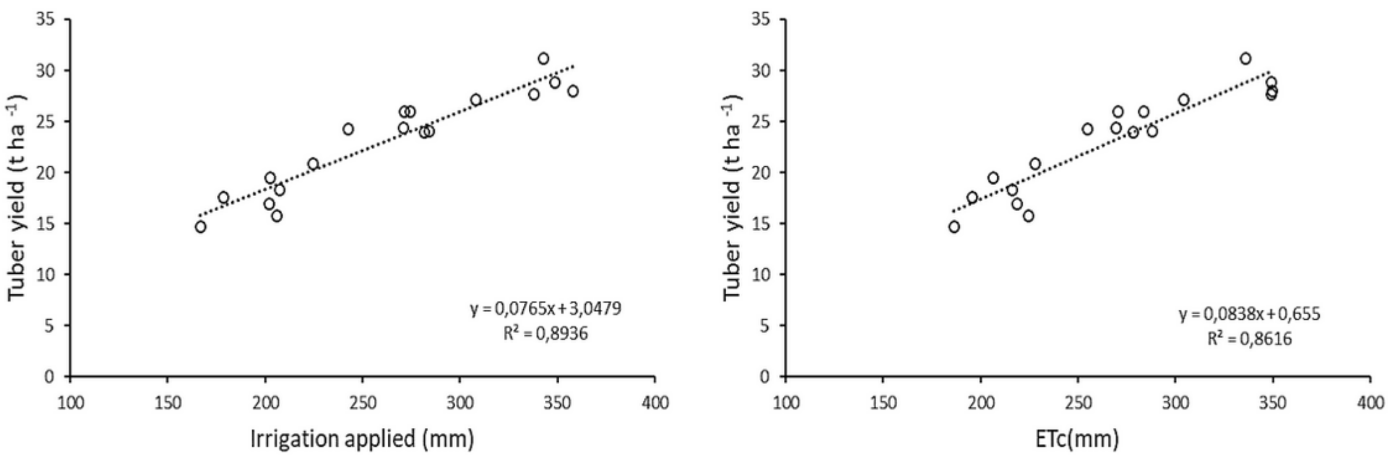

Figure 5

Relationship between tuber yield, irrigation applied and Etc of potato