Iran Agricultural Research (2023) 42(1) 109-120

Shiraz University

Influence of nitrogen management on sweet corn growth, canned yield, and soil properties under various irrigation regimes and tillage systems

Asal Keshavarz[1], Seyed Abdolreza Kazemeini[1], Mohammad Jafar Bahrani[1*], Hooman Razi[1], Mehdi Zarei[2]

[1] Department of Plant Production and Genetics, School of Agriculture, Shiraz University, Shiraz, I.R. Iran
[2] Department of Soil Science, School of Agriculture, Shiraz University, Shiraz, I.R. Iran

* Corresponding Author: bahrani92@hotmail.com
DOI: 10.22099/IAR.2024.47251.1536

ARTICLE INFO
***Article history*:**
Received **01 May 2023**
Accepted **14 January 2023**
Available online **06 March 2024**

***Keywords*:**
Conservation tillage
Harvest index
Irrigation volume
nitroxin inoculated plants
Water use efficiency

ABSTRACT - Optimal nutrient supply, either chemical or biological fertilizers, can be customized for water availability and paired with correct tillage systems. This approach is necessary to ensure high production in corn (*Zea mays* L.). To determine possible impacts of nitrogen (N), various irrigation regimes and tillage systems were evaluated on sweet corn (*Zea mays* L. var Saccharata). Dependent variables were plant growth, yield, water use efficiency (WUE), and soil characteristics. For this purpose, a two-year experiment (2016-2017) was conducted in a split-factorial design, involving randomized complete blocks with three replications at the Agricultural Experimental Station, School of Agriculture, Shiraz University, Shiraz, Iran. The treatments were two tillage systems [conventional (CT) and decreased (RT)] as the main plot. Five N rates were used (0, nitroxin, 150 kg N ha^{-1}, nitroxin + 150 kg N ha^{-1}, and 300 kg N ha^{-1}). The two irrigation regimes were [100% (normal) and 75% of plant water need (PWR)(Kc)] as subplots, respectively. Also, five N rates and sources (0, nitroxin, 150 kg N ha^{-1}, nitroxin + 150 kg N ha^{-1}, and 300 kg N ha^{-1}) were used in combination with two irrigation regimes [100% (normal) and 75% of plant water requirement (PWR)(Kc)]. The findings provided an indication that the canned yield and WUE could be raised by applying 300 kg N ha^{-1}, 75% of PWR, and the CT system. The highest soil N content occurred in RT systems applied with nitroxin + 150 kg N ha^{-1} and 75% of PWR in the first year and under CT systems by applying nitroxin + 150 kg N ha^{-1} and the normal irrigation in the second year. Nevertheless, the maximum soil OC content occurred in the RT system applied with nitroxin + 150 kg N ha^{-1}. To conclude, nitroxin-inoculated sweet corn responded favorably to the RT system with sufficient N rate and irrigation regimes down to 75% of PWR. Moreover, reducing irrigation water volume exerted no notable impact on reducing canned yield while it conserved water more significantly.

INTRODUCTION

Sweet corn is broadly used in the form of fresh, frozen, or processed products (Siddiq & Pascali, 2018). Increasing demand for sweet corn cultivation could be due to its short growth duration and considerable economic value. Harvesting at the “dough” stage, which is almost 18 to 21 days following pollination, is simultaneous with high sugar content (25-30%) and leads to a decrease in total water utilization (Yadav & Supriya, 2014).

The main identified obstacles hindering the development of agriculture, more specifically in arid and semi-arid areas, are rapid population growth and increasing demand for water resources (Abdelhafez et al., 2020; Haghverdi et al., 2017). Water stress can adversely affect access of plant roots to nutrients. The intense water stress leads to a drastic decrease in photosynthesis, physiological disturbance, growth termination, and ultimately, death of plants (Khaliqi & Naghavi, 2016). Researchers have examined the impacts of water stress and the associated parameters that comprise WUE on corn yield and yield components (Mansouri-Far et al., 2010; Paredes et al., 2014). Exploring alternative techniques for reducing evaporation from the soil’s surface is the key to increase WUE (Dastranj & Sepaskhah, 2019).

Application of bio-fertilizers has increased recently and this is due to the environmental pollution of chemical fertilizers and their high prices. Nitroxin bio-fertilizer contains the N identified the fixing bacteria concerning the genus *Azotobacter* and *Azospirillum*, and the number of living cells is 108 g^{-1} of carrier material of each genus of bacteria. Nitroxin stabilizes gaseous N and enhances nutrient uptake in plants (Najafi et al, 2021). It has beneficial effects on the crops’ recorded growth and improves their notable tolerance to possible water stress (Gou et al., 2015; Singh & Shinde, 2017). The very usage of nitroxin in wheat (*Triticum aestivum* L.) cultivation increased the seed yield by up to 27% (Seyed Sharfi & Ghalavand, 2018). Appropriately, the proper management of the nutrient inputs such as integrated fertilizers applications could lead to some potential desirable effects on crop productivity.

Comprehensive research has emphasized how certain crops could respond to N in combination with tillage systems (Alijani et al., 2019; Shoghi-Kalkhoran et al., 2018), whereas some others have probed crop growth and yield under water-restricted conditions and tillage systems (Dianatmanesh et al., 2022). Adjusting tillage systems to soil type under varied climatic conditions and frequent droughts can prompt water conservation, leading to higher yields (Bodner et al., 2015). Results associated with long-term experiment could provide evidence that the corn's grain yield was 10, 8.3, and 7 t ha^{-1} under more conventional cases, decreased as well as no-tillage, respectively, whereas the yield could be raised by applying the decreased than conventional tillage systems in dry years (Simic et al., 2019). If reduced or no-tillage systems are used, the SOC level in the cornfield might be maintained or raised with time (Benjamin et al., 2010).

The impacts of N management, drought stress upon growth, and the yield of diverse crops such as corn have received more focused attention in recent years.

The role of integrated fertilizer applications in mitigating the observed adverse effects related to the resulting water stress in the case of sweet corn has not been thoroughly investigated under water-limited conditions. Considering the above, the purpose of the present research investigation was to determine the very impact of N rates as well as sources on canned yield as well as yield components of sweet corn and specific soil's properties and alleviate the very undesirable effects of drought stress and could lead to reducing the very application of chemical fertilizer under different tillage systems in the south of Iran where corn is extensively cultivated with irrigation.

MATERIALS and METHODS

A two-year experiment (2016 and 2017) was conducted at the Experimental Research Field, School of Agriculture, Shiraz University (52° 46′E, 29° 50′N and 1810 m), Shiraz, Iran. This area has a semi-arid climate, with relatively warm summers, and almost no special rainfall throughout the growing season. Table 1 displays the monthly mean temperatures and rainfall for the two years of the research, and the period of 30 years for the region. The metrological data was collected from the considered weather station of the School of Agriculture, Shiraz University, which is less than a km away from the identified site of the experiment. The location had a silty loam profile, with fine, mixed mesic, Typic Calcixerpets soil, pH of 7.25, and EC = 0.97 dS m^{-1}. SOC mean and total N contents were 0.5% and 0.12%, respectively.

Drip irrigation in all treatments occurred simultaneously, and plant water requirement for each water treatment and the water volume was subjected to measurement by making use of a volumetric meter counter.

Determining irrigation timing and evapotranspiration (ET) patterns involved considering daily computations and utilizing the FAO's Penman–Monteith equation (Allen et al., 1998). Water requirements for the corn plants were specified by comparison with related well-watered reference crops. In this experiment, the amount of water required by each treatment was calculated via Eq. (1).

$$V = \frac{(\mathrm{ET0} \times \mathrm{Kc} \times \mathrm{A})}{\mathrm{Ei}} \qquad \text{Eq. (1)}$$

where V refers to the irrigated water's volume (m^3), ET0 is related to the crop's reference ET (mm/day), Kc is standing for the crop's coefficient, A refers to the irrigated area (m^2), and Ei is the irrigation's efficiency.

Determination of the crop's reference, ET0, was done by applying Eq. (2) (the Penman-Monteith equation) (Razzaghi & Sepaskhah, 2012).

$$\mathrm{ET0} = \frac{0.408\Delta(\mathrm{Rn}-\mathrm{G}) + \gamma\left[\frac{890}{\mathrm{T}+273}\right]\mathrm{U2}(\mathrm{ea}-\mathrm{ed})}{\Delta + \gamma(1+0.34\ \mathrm{U2})} \times \mathrm{KC} \qquad \text{Eq. (2)}$$

where ET0 is the crop reference's evapotranspiration (mm/day), Rn is the net solar radiation which is absorbed by at the crop canopy (MJ m^{-2}day^{-1}), G is related to the soil's thermal flux (MJ m^{-2}day^{-1}), T is the air temperature (°C) at 2 m height, u2 refers to the wind's speed at 2 m height (m s^{-1}), ea-ed is the saturation vapor pressure deficit (kPa), Δ represents the slope vapor pressure curve (kPa °C-1), and γ is related to the psychrometric constant (kPa °C-1).

The crop coefficient was recorded as 1.15 for the beginning of the season of crop growth (Kcini), 1.05 for middle (Kcmid), and end of season (Kcend) (Allen et al., 1998). The irrigation efficiency was 80% for drip system. At 6-leaf stage (V6) water deficit treatments were imposed till the end of growing season.

Crop samples were randomly harvested by hand at the beginning of the dough stage (65-70% seed moisture, which corresponds to the corn milking stage, R3 stage, about 22 days following silking) from each plot's two central rows. To determine the fresh marketable weight, the cobs were separated from the plants. These cobs could be regarded as marketable in case they were more than 15 cm, undamaged, and had good grain filling (USDA, 1994). Plant height, cob weight, row number per cob, seeds count per row, 1000-grain fresh weight, the canned yield (weight of all fresh seeds), eHI (ear harvest index; canned yield/cob weight), and WUE (canned yield/crop's water consumption) (Ertek et al., 2006) were measured. When each of the growing seasons was over, the soil's samples were taken with a 10 cm diameter soil auger at a depth ranging from 0 to 30 cm for the very determination of N (Bremner & Mulvaney, 1982), organic carbon (OC) (Nelson & Sommers, 1996) contents as well as electrical conductivity (EC) (Conductivity Meter model: HI 2315). After removing detectable crop residues, the samples were allowed to be dried naturally at room temperature and subsequently subjected to crushing so that they could be passed through a 2 mm sieve.

A general linear model (GLM) of the SAS v.9.1 software (SAS Institute, 2003) was used for data analysis. The comparison of mean values was done by a least significant difference (LSD) at 0.5% probability level when the F test appeared statistically significant by comparing the possible differences between the mean values of each treatment. It operated on the assumption that the data related to the dependent variable would obey some normal distribution and the variances with a homogeneous state. Before combined analysis, some Bartlett test (Bartlett, 1937) was conducted to assess the identified error variances homogeneity. The obtained data were reported separately, as no noteworthy interaction was observable between the year and treatments. The two-way effects occurred only when the three-way interaction effects were insignificant.

RESULTS

The identified results related to ANOVA showed that the possible impact of year was found to be significant on all considered traits, with the very exception of the row number per cob and 1000-grain weight (Table 2). Likewise, plant height, row number per cob, grain number per row, and soil's OC content were shown to be well influenced in a significant manner by means of the considered interaction occurring between the tillage systems and recorded N rates as well as sources. The considered interaction occurring between the N rates, sources, and irrigation regimes, which were well identified in this analysis, could be proved to be significant on the canned yield as well as WUE. The major influence of the applied irrigation regimes was proved to be significant on the plant's height (Table 2). Nitroxin had a positive kind of effect on yield as well as yield components in both irrigation regimes and years. The maximum increases that were observed in canned yield were achieved for the plants that could get the highest rate of urea. The highest canned yield (15253.25 kg ha^{-1}) could be accomplished under the CT system with the very usage of 300 kg N ha^{-1} in 2016, with no noteworthy discrepancy with the RT system with 300 kg N ha^{-1} in 2017 (Fig. 1.a). In the case of both years, no remarkable difference appeared between 75% and 100% of PWR by employing 300 kg N ha^{-1} (Fig. 2.a).

Table 1. Mean air's temperature and the rainfall's values recorded throughout the considered crops' growing season (2015 and 2016) for the considered 30-year period*.

	Temperature (C°)			Rainfall (mm)		
	2016	2017	30-years mean	2016	2017	30-years mean
June	22.1	23.7	20.4	0	0	0.7
July	26.4	25.6	24.4	0	0	0.3
August	23.7	23.8	24.2	0	0	0.2
September	21.3	20.2	21	0	0	0.2
October	15.3	15.7	15.9	0	0	2

*Weather Station Statistics, School of Agriculture, Shiraz University, Shiraz, Iran

Table 2. Sources of variation and mean squares of plant height, cob weight, row number per cob, grain count per row, 1000-grain weight, canned yield, harvest index, water use management, soil N content, soil OC content, soil EC in response to the applied tillage systems, N recorded rates, sources, and irrigation regimes.

	df	Plant height	Cob weight	Row number per cob	grain count per row	1000-grain weight	Canned yield	eHI	WUE	Soil N content	Soil OC content	Soil EC
Year (Y)	1	467.33*	2318.85*	10.26^{ns}	249.06**	504.92^{ns}	14461905.47*	999.14*	0.54375*	0.0035749**	1.16061**	4.17387**
Error (a)	4	40.88	168.19	4.03	10.94	5682.79	1131457.4	93.03	0.018585	0.0000381	0.000025	0.08975
Tillage (T)	1	138.22^{ns}	1715.95^{ns}	1.46^{ns}	22.62^{ns}	14925.76^{ns}	731768.99^{ns}	404.82**	0.00975^{ns}	0.00010059^{ns}	0.09514**	0.0036^{ns}
Y × T	1	26.47^{ns}	8871.37**	3.69^{ns}	2.14^{ns}	1567.14^{ns}	4253019.43^{ns}	267.2*	0.06564^{ns}	0.00120342**	0.00382^{ns}	0.8978^{ns}
Error (b)	4	118.73	8871.37**	0.84	8.48	1903.66	718212.5	15.45	0.01164	0.0004784	0.00138	0.1346
Nitrogen (N)	4	11427.09**	26042.28**	35.25**	189.95**	160173.51**	150883838.4**	843.06**	2.4273**	0.00293783**	1.58242**	4.1508**
Y × N	4	36.51^{ns}	7976.04**	9.74^{ns}	18.03*	19853.28**	2752475.2^{ns}	351.9**	0.04693*	0.00011299^{ns}	0.01778^{ns}	0.3575**
T × N	4	796.59**	4091.1**	5.18*	79.72**	3382.85^{ns}	4053779.7*	779.31**	0.05974*	0.0000492^{ns}	0.12504**	0.1912^{ns}
Y × T × N	4	24.46^{ns}	2902.73^{ns}	9.30^{ns}	12.94^{ns}	7619.43**	15189243.4**	1087.48**	0.23046**	0.00051985**	0.00011^{ns}	0.0488^{ns}
Irrigation (I)	1	1693.05**	1843.2^{ns}	8.75^{ns}	96.19**	10074.95**	3566268^{ns}	16.57^{ns}	0.5836**	0.00018844^{ns}	0.0993^{ns}	0.1248^{ns}
Y × I	1	20.53^{ns}	527.09^{ns}	1.05^{ns}	40.13*	7.89^{ns}	66507.4^{ns}	109.93^{ns}	0.00001^{ns}	0.00002068^{ns}	0.00045^{ns}	0.0957^{ns}
T × I	1	0.6^{ns}	44.97^{ns}	1.12^{ns}	14.98^{ns}	1272.83^{ns}	2503876.7^{ns}	91.55^{ns}	0.03766^{ns}	0.00001488^{ns}	0.00422^{ns}	0.0001^{ns}
N × I	4	168.25^{ns}	1901.32*	2.89^{ns}	19.78*	2780.19^{ns}	3876373*	188.71^{ns}	0.09061**	0.00049777**	0.01012^{ns}	0.0615^{ns}
Y × T × I	1	7.89^{ns}	1277.49^{ns}	1.07^{ns}	20.47^{ns}	7117.64*	522315.7^{ns}	75.69^{ns}	0.00587^{ns}	0.00000101^{ns}	0.000004^{ns}	0.0021^{ns}
Y × N × I	4	12.56^{ns}	952.47^{ns}	0.51^{ns}	34.55**	465.04^{ns}	1675352.6^{ns}	212.98^{ns}	0.03026^{ns}	0.00006729^{ns}	0.00005^{ns}	0.0986^{ns}
N × T × I	4	191.23^{ns}	868.06^{ns}	2.25^{ns}	2.45^{ns}	1071.91^{ns}	1413382.2^{ns}	97^{ns}	0.02^{ns}	0.00003754^{ns}	0.0041^{ns}	0.042^{ns}
Y × N × T × I	4	40.37^{ns}	2686.18**	3.39^{ns}	11.77^{ns}	1259.09^{ns}	1368365.2^{ns}	224.72*	0.01324^{ns}	0.00070869**	0.00001^{ns}	0.1215^{ns}
Error (c)	72	81.17	598.42	2.52	6	1407.17	1300939.1	88.49	0.02069	0.00009662	0.01259	0.0768
CV (%)		6.44	10.5	9.67	8.36	10.46	11.09	16.79	11.07	5.93	7.65	20.9

*, ** and ns are significant at 0.05, 0.01 probability level and not significant, respectively.

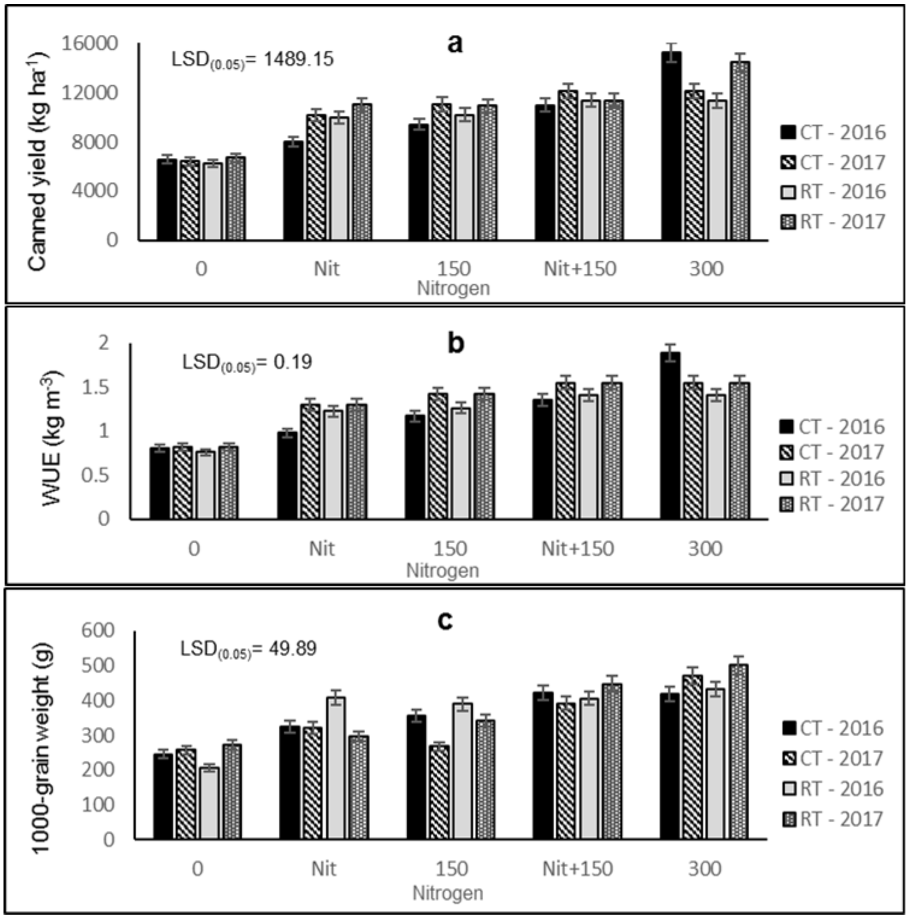


Fig 1. Impact of year, tillage systems as well as the N recorded rates as well as sources upon the canned yield (a), WUI (b) and 1000-grain weight (c). Vertical bars do represent the standard deviation.

WUE was considerably influenced by the interaction between year and tillage systems, in addition to recorded N rates and sources (Table 2). The highest WUE (1.89 kg m-3) appeared by the CT system by means of employing 300 kg N ha^{-1} in 2016 (Fig. 1.b), 22% higher than in 2017. The highest WUE was achieved when the crop was irrigated under water deficit conditions (75% of PWR) through the mere usage of 300 kg N ha^{-1} (Fig. 2.b). The effect of tillage systems was not significant on 1000-grain weight, while N rates and sources, in addition to irrigation regimes, had significant effects (Table 2). The highest 1000-grain weight (500.93) occurred by applying 300 N kg ha^{-1} and 75% of PWR under RT in 2017 (Fig. 1.c). Interaction between year, tillage systems, and irrigation regimes showed that the plants sown under the RT system with 75% of PWR had the highest 1000-grain weight (Fig. 3). Decreased irrigation volume increased plant height as well as the maximum plant height (143.62 cm) was achieved when crop was objected under 75% of PWR that was 5.7% higher than 100% of PWR (Fig. 4). The highest plant height (173.43 cm) and the rows number per cob (9.33) occurred by sowing crops into the RT system by applying 300 N kg ha^{-1} (Fig. 5.a, Fig. 5.b). The highest grain count per row (34.72) was achieved under the RT system using nitroxin + 150 kg N ha^{-1}, which led to no noteworthy difference compared to when applying 300 N kg ha^{-1} (Fig. 5.c). The highest grains number per row was obtained under water deficit conditions (75% of PWR) with the application of nitroxin + 150 kg N ha^{-1} in 2016, 10.07 % higher than in 2017 (Fig. 6). Interactions between years, tillage systems, N rates, sources, and the considered irrigation regimes had significant effects on eHI, cob weight, and soil N content (Table 2). Meanwhile, water deficit conditions (75% of PWR) had a positive effect on eHI in both years in interaction with N rates and sources. The maximum eHI (191.16) was recorded under the RT system, water deficit conditions (75% of PWR) by means of employing 300 kg N ha^{-1} in 2016, 3.44% higher than 2017 (Fig. 7a). The highest cob weight (289.24 g) was obtained under RT system and 100% of PWR with the very usage of 300 N kg ha^{-1} as comparison is made to other types of treatment in 2016, while the highest one was in 2017, when the crop was subjected to normal irrigation under RT system with application of nitroxin (292.2 g) (Fig. 7.b).

The maximum soil N content was obtained under CT systems and normal irrigation by applying nitroxin + 150 kg N ha^{-1} in the very first year (0.212%), while the highest one was recorded under RT systems, water deficit conditions (75% of PWR) by applying nitroxin + 150 kg N ha^{-1} in second year (0.198%) (Fig. 7.c). Nitroxin application had positive effects on soil OC content in both tillage systems. Soil OC content increased by applying nitroxin + 150 kg N ha^{-1} under both RT as well as the CT systems (1.7 and 1.69%, respectively) compared with the very usage of 300 kg N ha^{-1} (Fig. 8). No noteworthy difference was found for soil EC between both tillage systems and irrigation regimes. Furthermore, the highest soil EC was found by applying nitroxin + 150 kg N ha^{-1} (2.036 dS m-1) in 2016. However, in 2017, raising N rates and more sources enhanced soil EC (Fig. 9).

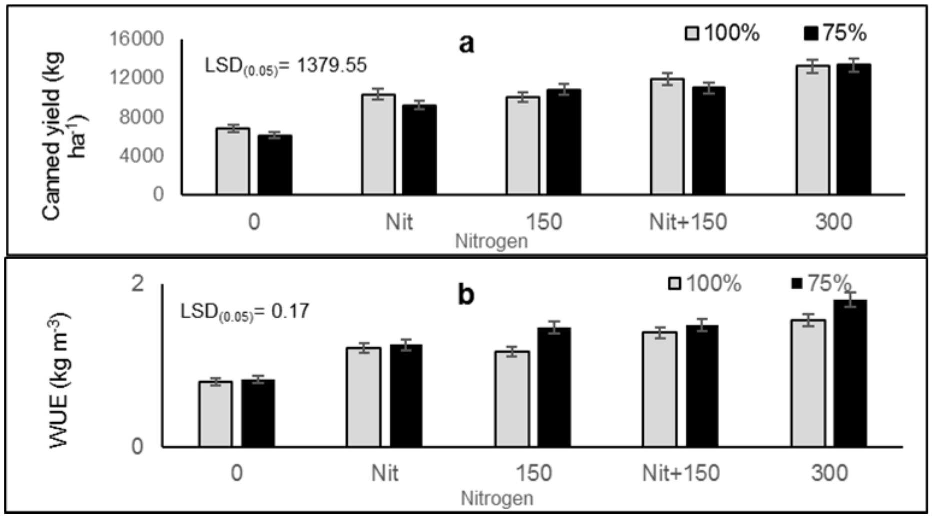


Fig 2. Impact of the N rates and sources as well as the considered irrigation regimes upon canned yield (a) as well as WUE (b). Vertical bars do indicate the standard deviation.

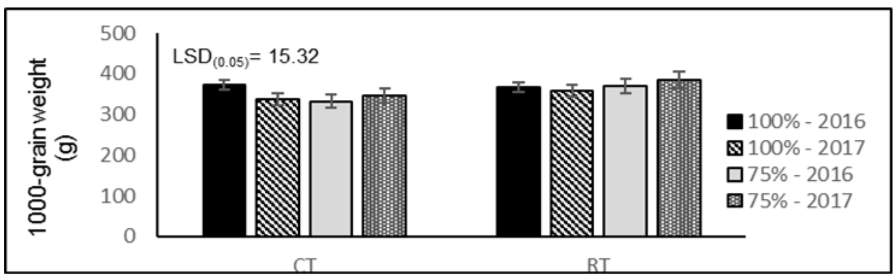


Fig 3. Impact of year, tillage systems, and irrigation regimes on 1000-grain weight. Vertical bars indicate standard deviation.

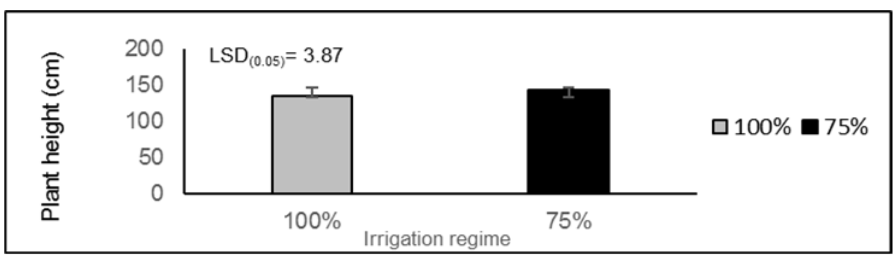
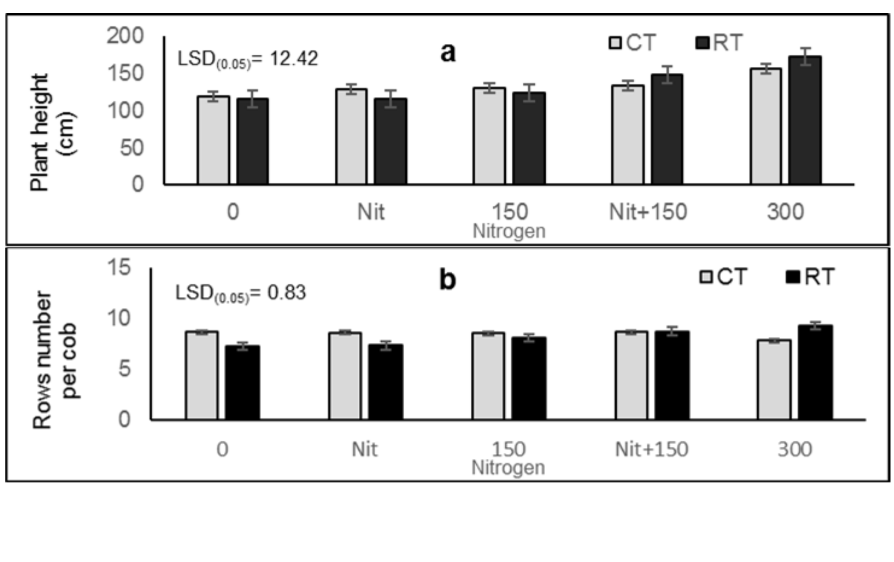


Fig 4. Impact of the applied irrigation regimes on plant height. Vertical bars indicate standard deviation.



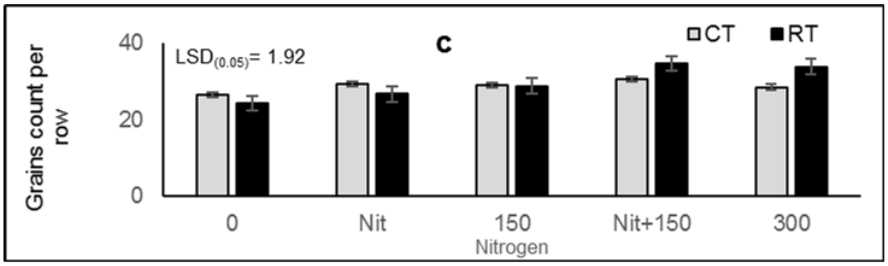


Fig 5. Impact of the tillage systems, recorded N rates, and N sources on plant height (a), row number per cob (b), and grain count per row (c). Vertical bars indicate standard deviation.

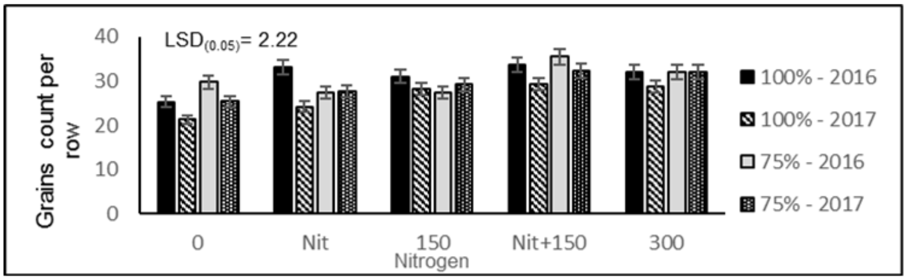


Fig 6. Impact of year, N rates, N sources, and irrigation regimes on grain count per row. Vertical bars indicate standard deviation.

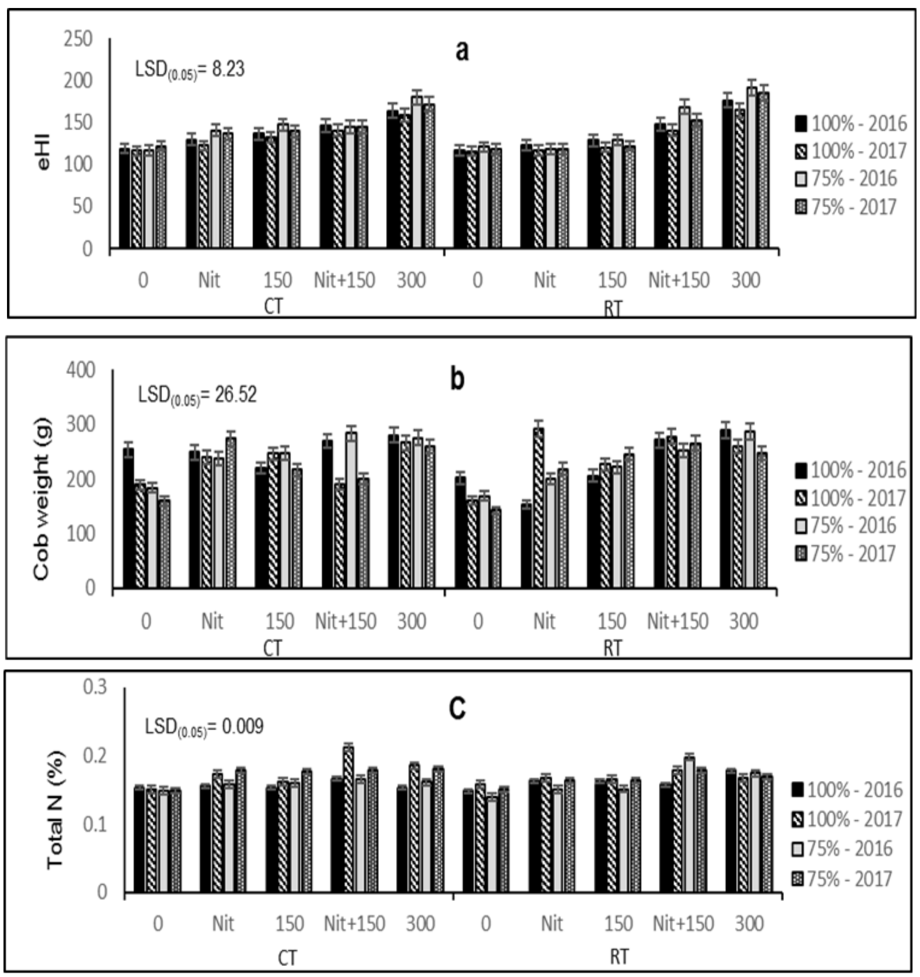


Fig 7. Impact of year, tillage systems, recorded N rates, N sources, and irrigation regimes on eHI (a), cob weight (b), and soil N content. Vertical bars indicate standard deviation.

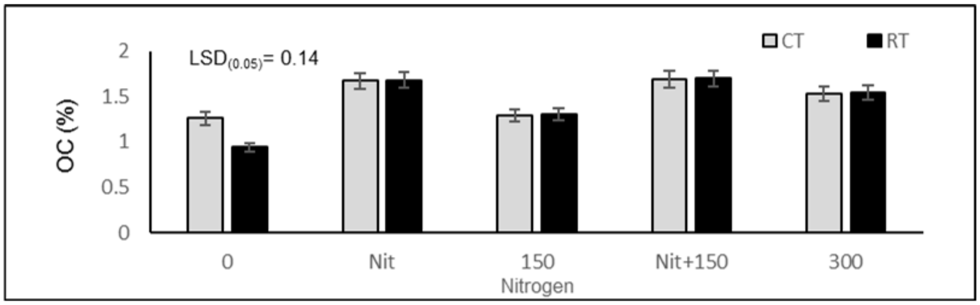


Fig 8. Impact of tillage systems, recorded N rates, and N sources on soil OC content. Vertical bars indicate standard deviation.

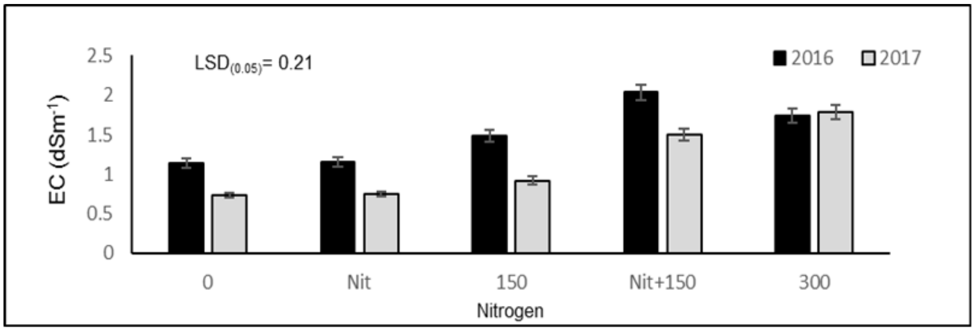


Fig 9. Impact of N rates and sources on soil EC in 2016 and 2017. Vertical bars indicate standard deviation.

DISCUSSION

The two-year meteorological data showed an increasing trend of air temperatures in 2017, increasing the rate of PWR with no significant effect on the length of the plant growing season. Inoculation of corn seeds with nitroxin and using 150 kg N ha^{-1} enhanced yield components, particularly cob weight compared to the very usage of 150 kg N ha^{-1} with no nitroxin inoculation, which increased canned yield. Inoculated plants had higher seed counts per row as well. Therefore, crop canned yield was found to be responsive to raised N rates and sources, as expected. Plant and microorganism symbiosis can accelerate plant growth through N fixation or growth hormone production (Buráňová et al., 2015; Valizadeh & Sabbagh, 2016). As highlighted by Nouraki et al. (2016), the considered combination of chemical and bio-fertilizer enhances the considered rate of water and nutrient absorbance which could increase crop growth rate. This combination increases grain yield, yield components, and biological function, such as plant height of sweet corn. Furthermore, nitroxin inoculation had a positive effect on eHI. Kemal and Abera (2015) noticed that integrating management strategies involving chemical and bio-fertilizers enhanced the sustainability of crop production.

Corn may be very sensitive to drought, however, our results indicated that the limited water supply did not only significantly decrease sweet corn growth and yield components; but plant height and grains number per row increased with 75% of PWR under higher N rates as well. Wang et al. (2017) provided a report that the applied irrigation treatments could exert a notable impact on plant growth under N-fertilizer rates. As indicated the highest canned yield was obtained with 75% of PWR by applying 300 kg N ha^{-1} which confirmed previous findings by Ertek and Kara (2013), who provided the report that the highest sweet corn's fresh cob yield with 15% deficit irrigation. Sufficient N supply in some cases would ameliorate the considerable adverse observed impacts of water-deficit stress. Similar to our findings, El-Hendawy and Schmidhalter (2010) and Sampathkumar et al. (2012) mentioned that moderate levels of drought stress (0.75–0.80 ETc) led to no reduction of the corn's grain yield, and with higher water deficits only a mild reduction occurred. Our results confirmed those of Agami et al. (2018), finding that adequate N nutrition would improve wheat yield under water-deficit conditions by maintaining relevant metabolic activities. Furthermore, water use efficiency increased with the decrease in irrigation volume. Kresović et al. (2016) provided a report that corn irrigation water use efficiency (IWUE) increased with the considered normal irrigation, while the highest WUE was obtained with a moderate water deficit. Furthermore, the higher as well as lower WUE in the water-stressed plants and well-watered ones may have been owing to some more notable reduction of plant transpiration by decreasing the green leaf area due to the observed water stress (Karam et al., 2003). In the current investigation, exposure of plants to the water deficit conditions led to increasing 1000-grain weight in 2017, which was shown to differ from the results obtained by Aydinsakir et al. (2013), who found the very maximum 1000-grain weight in fully irrigated treatment. No notable differences could be, however, seen between CT as well as RT's systems for all considered yield components, but they were significantly affected by N recorded rates as well as sources in many cases. The identified interactions between the tillage systems and N recorded rates and sources indicated that N rates and sources should be subjected to adjustment for specific tillage systems, which had differences from the results which had been obtained by Khan and McVay (2014), who indicated no special important interaction between the considered tillage systems and the recorded N rates, and concluded that N need not be adjusted for tillage systems. As reported frequently, conservation tillage needs higher N rates for the production of similar yields with conventional tillage (Alijani, et al., 2019; Pantoja et al. 2015), but our results showed that no noteworthy difference could be seen between CT and RT systems with N rates and sources and was remarkably more under RT when comparison is made to CT systems by applying 300 N kg ha^{-1} in the second year.

Soil OC content responded to tillage systems, but soil N and EC did not differ under diverse tillage systems. Soil N and OC contents were higher with applying nitroxin + 150 kg N ha^{-1} in both years, but soil EC was higher with nitroxin + 150 kg N ha^{-1} and 300 kg N ha^{-1} in the first as well as the second year, respectively. Soil OC content responded to the tillage systems, but soil N and EC displayed no special difference under different tillage systems, which could comply with the obtained results of Alijani et al. (2019), who showed some noteworthy difference for soil organic matter (SOM) between CT and RT systems. RT systems can lead to raised SOM accumulation in the soil layers of the surface, representing only the soil profile fraction which is utilized by wheat as well as corn rather than 0–30 cm soil depth. Conservation tillage practices might result in a buildup of higher SOM due to a reduction in the macro-aggregates breakdown, where carbon could be retained (Jat et al., 2017). Nevertheless, the replacement of chemicals with biological fertilizers causes the nutrients to be slowly absorbed by plants without environmental pollution and can ameliorate the physical as well as chemical qualities of soil (Roy, 2020).

CONCLUSION

The results showed that the application of nitroxin as a sweet corn seed treatment in combination with other N rates accelerated its vegetative and reproductive growth and improved plant resistance to water stress; so it may act as a suitable kind of substitute to using chemical fertilizers. Crop canned yield was found to be responsive to the raised N rates regarding tillage systems. Moreover, in the first year, nitroxin inoculation had a positive effect on eHI under both irrigation regimes and tillage systems, especially in reduced ones. No noteworthy discrepancy between CT and RT systems was found for most of the yield components. The highest canned yield was obtained with 75% of PWR in combination with 300 N kg ha^{-1} compared to normal irrigation as well. In general, adaptation of suitable management practices, like N rate and tillage systems by farmers could lead to improving sweet corn yield and soil properties under water stress conditions. Nitroxin which was inoculated with sweet corn could have good adoption into the RT system and with a sufficient N supply which is accompanied by 75% irrigation of PWR and could be regarded as an optimal practice in the region. Reducing irrigation water down to 75% of PWR had no significant impact on the reduction of the canned yield, but it significantly saved more water. More research is required to evaluate the possible impact of the combined nitroxin and N supply on the soil's microbial biomass as well as activity, as well as bacterial N fixation in drought stress conditions.

STATEMENTS and DECLARATIONS

The authors declare that no funds, grants or other support were received during the preparation of this manuscript.
The authors have no relevant financial or non-financial interests to disclose.
All authors contributed to the study conception and design. Material preparation, data collection and analysis were performed by "Asal Keshavarz". The first draft of the manuscript was written by "Asal Keshavarz" and all authors commented on previous versions of the manuscript. All authors read and approved the final manuscript.

DATA AVAILABILITY

The datasets generated and analyzed during the current study are available from the corresponding author on reasonable request

REFERENCES

Abdelhafez, A. A., Metwalley, S. M., & Abbas, H. H. (2020). Irrigation: Water resources, types and common problems in Egypt. In Omran, E-S. E, and Negm, A. M. (Eds.), *Technological and Modern Irrigation Environment in Egypt: best management Practices & evaluation* (pp. 15–34). Springer Cham. doi:10.1007/978-3-030-30375-4

Agami, R. A., Alamri, S. A. M., Abd El-Mageed, T. A., Abousekken, M. S. M., & Hashemb, M. (2018). Role of exogenous nitrogen supply in alleviating the deficit irrigation stress in wheat plants. *Agricultural Water Management*, 210, 261–270. http://dx.doi.org/10.1016/j.agwat.2018.08.034.

Allen, R. G., Pereira, L. S., Raes, D., & Smith, M. (1998). Crop evapotranspiration: Guidelines for computing crop plant water requirements, irrigation and drainage. Crop Evapotranspiration: Guidelines for computing crop plant water requirements. Irrigation and drainage. paper 56. FAO, Rome.

Alijani, KH., Bahrani, M. J., & Kazemeini, S. A. (2019). Is it necessary to adjust nitrogen recommendations for tillage and wheat residue management in irrigated sweet corn? *Archives of Agronomy and Soil Science*, 65 (14), 1-14. https://doi.org/10.1080/03650340.2019.1587162

Aydinsakir, K., Erdal, S., Buyuktas, D., Bastug, R., & Toker, R. (2013). The influence of regular deficit irrigation applications on water use, yield, and quality components of two corn (*Zea mays* L.) genotypes. *Agricultural Water Management*, 128, 65– 71. https://doi.org/10.1016/j.agwat.2013.06.013

Bartlett, M.S. (1937). Properties of sufficiency and statistical tests. Proceeding of the Royal Society of London. Series A. *Mathematical, Physical, and Engineering* Sciences, 160, 268–282.

Benjamin, J. G., Halvorson, A. D., Nielsen, D. C., & Mikha, M. M. (2010). Crop management effects on crop residue production and changes in soil organic carbon in the central great plains. *Agronomy Journal*, 102, 990–997. doi:10.2134/agronj2009.0483

Bodner, G., Nakhforoosh, A., & Kaul, H. P. (2015). Management of crop water under drought: A review. *Agronomy for Sustainable Development*, 35, 401-442. doi:10.1007/s13593-015-0283-4

Bremner, J. M. (1996). Nitrogen-Total. In: Sparks D. L., Page A. L., Helmke P. A., Loeppert R. H., Soltanpour P. N., Tabatabai M. A., Johnston C. T., Sumner M. E. (ed), *Methods of soil analysis: part 3-chemical methods*. *SSSA Book Ser. 5.3.* (pp. 1085-1121). Madison (WI): Soil Science Society America.

Buráňová, S., Černý, J., Kulhánek, M., Vasák, F., & Balik, J. (2015). Influenced of mineral and organic fertilizers on yield and nitrogen efficiency of winter wheat. *International Journal of Plant Production*, 9 (2), 257-272.

Dianatmanesh, M., Kazemeini, S. A., Bahrani, M. J., Shakeri, E., Alinia, M., Amjad, S. F., Mansoora, N., Poczai, P., Lalarukh, I., Abbas, M. H. H., Abdelhafez, A. A., & Hamed, M. H. (2022). Yield and yield components of common bean as influenced by wheat residue and nitrogen rates under water deficit conditions. *Environmental Technology and Innovation*, 28, 1-13. https://doi.org/10.1016/j.eti.2022.102549

El-Hendawy, S. E., & Schmidhalter, U. (2010). Optimal coupling combinations between irrigation frequency and rate for drip-irrigated maize grown on sandy soil. *Agricultural Water Management*, 97, 439–448. doi:10.1016/j.agwat.2009.11.002

Ertek, A., & Kara, B. (2013). Yield and quality of sweet corn under deficit irrigation. *Agricultural Water Management*, 129, 138−144. doi:10.1016/j.agwat.2013.07.012

Ertek, A., Şensoy, S., Gedik, I., & Küçükyumuk, C. (2006). Irrigation scheduling based on pan evaporation values for cucumber (*Cucumis sativus* L.) grown under field conditions. *Agricultural Water Management*, 81, 159−172. doi:10.1016/j.agwat.2005.03.008

Gou, W., Tian, L., Ruan, Z., Zheng, P., Chen, F., Zhang, L., Cui, Z., Zheng, P., Li, Z., & Gao, M. (2015). Accumulation of choline and glycinebetaine and drought stress tolerance induced in maize (*Zea mays*) by three plant growth promoting rhizobacteria (PGPR) strains. *Pakistan Journal of Botany*, 47, 581–586.

Haghverdi, A., Dean, Y. C., Reichertd, D. L., & Irmak, S. (2017). Impact of irrigation, surface residue cover and plant population on sugar beet growth and yield, irrigation water use efficiency and soil water dynamics. *Agricultural Water Management*, 180, 1–12. doi:10.1016/j.agwat.2016.10.018

Jat, H. S., Datta, A., Sharma, P. C., Kumar, V., Yadav, A. K., Choudhary, M., Choudhary, V., Gathala, M. K., Sharma, D. K., & Jat, M. L. (2017). Assessing soil properties and nutrient availability under conservation agriculture practices in a reclaimed sodic soil in cereal-based systems of North-West India. *Archives of Agronomy and Soil Science*, 64, 531–545. doi:10.1080/ 03650340.2017.1359415.

Karam, F., Breidy, J., Stephan, C., & Rouphael, J. (2003). Evapotranspiration, yield and water use efficiency of drip irrigated corn in the Bekaa Valley of Lebanon. *Agricultural Water Management*, 63, 125−137. doi:10.1016/S0378-3774(03)00179-3

Khan, Q. A., & McVay, K. A. (2014). Impact of tillage, irrigation method, and nitrogen rate on sugar beet productivity. *Agronomy Journal*, 106, 1717–1721. doi:10.2134/agronj14.0081.

Khaliqi, M., & Naghavi, M. R. (2016). Study of the effect of drought stress on protein patterns and morpho-physiological traits in plants. *Journal of Biosafety*, 9 (2), 22-33.

Kemal, Y. O., Abera. M. (2015). Contribution of integrated nutrient management practice for sustainable crop productivity, nutrient uptake and soil nutrient status in maize based cropping systems. *Journal of Nutrition*, *2* (1), 1-10. doi:10.18488/journal.87/2015.2.1/87.1.1.10

Kresović, B., Tapanarova, A., Tomić, Z., Životić, L., Vujović, D., Sredojević, Z., & Gajić, B. (2016). Grain yield and water use efficiency of maize as influenced by different irrigation regimes through sprinkler irrigation under temperate climate. *Agricultural Water Management*, 169, 34−43. doi.org/10.1016/j.agwat.2016.01.023

Mansouri-Far, C., Sanavy, S. A. M. M., & Saberali, S. F. (2010). Maize yield response to deficit irrigation during low-sensitive growth stages and nitrogen rate under semi-arid climatic conditions. *Agricultural Water Management*, 97, 12–22. doi:10.1016/j.agwat.2009.08.003

Najafi, S., Nazari nasi, H., Tunturk, R., Tunturk, M., Sayeed, R., Amirnia, R. (2021). Biofertilizer application enhances drought stress tolerance and alters the antioxidant enzymes in medicinal pumpkin (*Cucurbita pepo* convar. pepo var. Styriaca). *Horticulturea,* 7(12), 588-596. 10.3390/horticulturae7120588. http://www.mdpi.com/journal/horticultureae.

Nelson, D. W., & Sommers, L. E. (1996). Total carbon, organic carbon, and organic matter. In: Madison, W. (Ed.), *Methods of soil analysis part 3−Chemical Methods, 3th ed*, (pp. 539−580). New York, USA: American Society of Agronomy.

Nezhadahmadi, A., Prodhan, Z. H., & Faruq, G. (2013). Drought tolerance in wheat: A review. *Scientific World Journal*, 2013, 1-12. https://doi.org/10.1155/2013/610721.

Nouraki, F., Alavi-Fazel, M. Naderi, A. Panahpor, E., & Lack, Sh. (2016). Integrated application of biological and chemical fertilizers in types of maize hybrids (*Zea mays* L.) for sustainable agriculture in Iran. *Academia Journal of Agricultural Research*, *4*(2), 63-66.

Paredes, P., de Melo-Abreu, J. P., Alves, I., & Pereira, L. S. (2014). Assessing the performance of the FAO Aqua Crop model to estimate maize yields and water use under full and deficit irrigation with focus on model parameterization. *Agricultural Water Management*, 144, 81–97. doi:10.1016/j.agwat.2014.06.002

Pantoja, J. L., Woli, K. P., Sawyer, J. E., Barker, D. W., & Al-Kaisi, M. (2015). Stover harvest and tillage system effects on corn response to fertilizer nitrogen. *Soil*

*Science Society of America Journa*l, 79, 1249–1260. doi:10.2136/sssaj2015.01.0039

Razzaghi, F., & Sepaskhah, A. R. (2012). Calibration and validation of four common ET0 estimation equations by lysimeter data in a semi-arid environment. *Archives of Agronomy and Soil Science*, 58, 303−319.

Roy, A. (2020). Biofertilizers for agricultural sustainability: Current status and future challenges. In: *current trends in microbial biotechnology for sustainable agriculture*. (pp. 525–553), Singapore: Springer. doi:10.1007/978-981-15-6949-4_21

Sampathkumar, T., Pandian, B. J., Ranghaswamy, M. V., & Manickasundaram, P. (2012). Yield and water relations of cotton-maize cropping sequence under deficit irrigation using drip system. *Irrigation Drainage*, 61, 208–219. doi:10.1002/ird.644

SAS Institute. (2003). *SAS users' guide*. Cary (NC): SAS Institute.

Seyed Sharifi, M., & Ghalavand, A. (2018). Effect of nitroxin biofertilizer on yield and yield components of wheat under different nitrogen levels. *Journal of Crop Nutrition Science,* 4(1), 1-10.

Shinde, B., & Thakur, J. (2015). Influence of Arbuscular mycorrhizal fungi on chlorophyll, proteins, proline and total carbohydrates content of the pea plant under water stress condition. *International Journal of Current Microbiology and Applied Science*, 4, 809–821.

Shoghi-Kalkhoran, S., Ghalavand, A., Modarres-Sanavy, S. A. M., Mokhtassi-Bidgoli, A., & Akbari, P. (2018). Integrated fertilization systems enhance quality and yield of sunflower (*Helianthus annuus* L.). *Journal of Agricultural Science and Technplogy*, 15, 1343-1352.

Siddiq, M., & Pascali, M. A. (2018). Peas, sweet corn, and green beans (2nd ed.). *Handbook of vegetables and vegetable processing* (pp. 761–783). Wiley-Blackwell. doi:10.1002/9781119098935.ch33

Simic´, M., Dragicevic´, V., Mladenovic´ Drinic´, S., Vukadinovic´, J., Kresovic´, B., Tabakovic´, M., & Brankov, M. (2020). The contribution of soil tillage and nitrogen rate to the quality of maize grain. *Agronomy*, 10, 1–14. doi:10.3390/agronomy10070976

Singh, N., & Shinde, B. (2017). Efficacy of AM fungi against drought stress on sweetcorn cultivars with special reference to biochemical contents. *International Journal of Bioassays*, 6, 5399–5406. doi:10.21746/ijbio.2017.06.004

USDA. (1994). United States standards for grades of sweet corn. In: *Shipping point and market inspection instructions for sweet corn*. Retrieved from: http://www.ams.usda.gov/AMSv1.0/getfile?dDocName=STELPRDC5050261.

Valizadeh, Sh., & Sabbagh, S. K. (2016). Effects of Nitroxin fertilizers on expression Chitinase and Cupi4 genes in cucumber seedlings infected to *Pythium Aphanidermatum*. *Agricultural Biotechnology Research*, 14 (2), 63-71.

Wang, Y., Janz, B., Engedal, T., & de Neergaard, A. (2017). Effect of irrigation regimes and nitrogen rates on water use efficiency and nitrogen uptake in maize. *Agricultural Water Management*, 179, 271−276. doi:10.1016/j.agwat.2016.06.007

Yadav, V. K., & Supriya, P. (2014). *Value addition in Maize Maize: nutrition dynamics and novel uses,* Chaudhary D P, Kumar S and Langyan (Eds.). (pp. 141-152). New Dehli, India: Springer India. doi:10.1007/978-81-322-1623-0_12

.

تحقیقات کشاورزی ایران (۱۴۰۲) ۴۲(۱) ۱۰۹-۱۲۰

دانشگاه شیراز

تأثیر مدیریت نیتروژن بر رشد و عملکـرد ذرت شـیرین و برخـی ویژگی‌های خاک تحت رژیم‌های متفـاوت آبیـاری و سـامانه‌هـای خاک‌ورزی

عسل کشاورز[۱]، سید عبدالرضا کاظمینی[۱]، محمدجعفر بحرانی[۱*]، هومن راضی[۱]، مهدی زارعی[۲]

[۱] گروه تولید و ژنتیک گیاهی دانشکده کشاورزی دانشگاه شیراز، شیراز، ج.ا. ایران

[۲] گروه علوم مهندسی خاک دانشکده کشاورزی، دانشگاه شیراز، شیراز، ج.ا. ایران

*نویسنده مسئول

اطلاعات مقاله

تاریخچه مقاله:

تاریخ دریافت: ۱۴۰۲/۰۲/۱۱

تاریخ پذیرش: ۱۴۰۲/۱۰/۲۴

تاریخ دسترسی: ۱۴۰۲/۱۲/۱۶

واژه‌های کلیدی:

خاک‌ورزی حفاظتی

راندمان مصرف آب،

شاخص برداشت، حجم آب

گیاهان تلقیح شده با نیتروکسین

چکیده- عرضه بهینه عناصر غذایی (شیمیایی یا زیستی) همراه با دسترسی به آب و کاربرد سامانه‌های خاک‌ورزی مناسب، پیش نیاز تولید بالای ذرت (*Zea mays* L.) است. به منظور ارزیابی اثرات نیتروژن، رژیم‌های آبیاری و سامانه‌های خاک‌ورزی بر رشد، عملکرد و راندمان مصرف آب ذرت شیرین (*Zea mays* L. var sacchrata) و برخی ویژگی‌های خاک، آزمایشی در دو سال زراعی ۱۳۹۵ و ۱۳۹۶ در مزرعه تحقیقاتی دانشکده کشاورزی دانشگاه شیراز (منطقه باجگاه) به صورت کرت‌های خرد شده فاکتوریل در قالب طرح بلوک‌های کامل تصادفی با ۳ تکرار انجام شد. عامل اصلی شامل خاک‌ورزی در دو سطح (خاک‌ورزی متداول و کم خاک‌ورزی)، منبع نیتروژن در ۵ سطح (شاهد، نیتروکسین، ۱۵۰ کیلوگرم اوره، ۱۵۰ کیلوگرم اوره + نیتروکسین و ۳۰۰ کیلوگرم اوره) به‌عنوان عامل نخست، و تنش آبی در دو سطح (۷۵ و ۱۰۰ درصد نیاز آبی گیاه) به‌عنوان عامل دوم در نظر گرفته شد. نتایج دو سال نشان داد که عملکرد کنسروی ذرت شیرین و همچنین راندمان مصرف آب با کاربرد ۳۰۰ کیلوگرم اوره در هکتار، ۷۵ درصد نیاز آبی و انجام خاک‌ورزی متداول افزایش یافت. بیشترین میزان نیتروژن خاک از برهمکنش سامانه کم خاک‌ورزی، کاربرد نیتروکسین + ۱۵۰ کیلوگرم اوره در هکتار و ۷۵ درصد نیاز آبی در سال نخست، و در آبیاری معمولی در سال دوم بدست آمد. با این حال، بیشترین میزان کربن آلی خاک به سامانه کم خاک‌ورزی و کاربرد نیتروکسین + ۱۵۰ کیلوگرم اوره در هکتار تعلق داشت از این رو، ذرت شیرین تلقیح شده با نیتروکسین به سامانه کم خاک‌ورزی با میزان نیتروژن کافی سازگاری خوبی داشت و همراه با رژیم آبیاری تا ۷۵ درصد نیاز آبی گیاه می‌تواند به عنوان روشی بهینه در منطقه به کار رود. علاوه براین کاهش حجم آب نه تنها عملکرد کنسروی را به صورت معنی داری کاهش نداد، بلکه بصورت قابل ملاحظه ای موجب صرفه جویی در مصرف آب در آبیاری‌گردد.