PARTIAL ROOT ZONE DRYING IRRIGATION AND DIFFERENT NITROGEN LEVELS AFFECT ON NITROGEN RECOVERY EFFICIENCY FOR DRIP IRRIGATED SUGAR BEET CROP

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Abstract

This study was conducted to determine different nitrogen levels affect on nitrogen recovery efficiency, NRE, by use of drip irrigation under partial root zone drying irrigation and fertigation techniques for sugar beet plant. Research was performed in 2012 and 2013 at Konya - Çumra Plain of Turkey and Stine sugar beet cultivar was used. In study, application of 100% irrigation water requirement of plant, FI (Full Irrigation) and 50% application of FI by using fixed (FPRD50) and alternative partial root drying (APRD50) irrigation techniques, and application of 100% nitrogen requirement of sugar beet, FN (Full Nitrogen) with two deficit nitrogen treatments of 75% (DN75) and 50% (DN50) of FN levels were applied by drip irrigation. Different deficit nitrogen applications affect on crop nitrogen use was researched comparatively under different irrigation techniques and fertigation method. The results showed that among the irrigation treatments, differences in NRE from nitrogen fertilizer were found not significant. DN50 was found the highest NRE of crop from nitrogen fertilizer. The greatest performances combinations in NRE of crop from fertilizer nitrogen were, FIDN50 as 52.6%, APRD50DN50 as 48.5% and FPRD50DN50 as 41.0% interactions. Those results showed that nitrogen requirement of crop can be reduced for drip irrigated sugar beet farming.

Key words: Sugar beet, drip irrigation method, PRD, deficit nitrogen, fertigation, nitrogen recovery.

Irrigated agriculture is the highest water user accounting for more than 70% of global withdrawals and this share is more than 90% in some countries (IWMI, 2007).

Konya Basin, Middle Anatolian Region, lies within a semi-arid climate with annual rainfall ranging from 280 mm to 500 mm and is one of the most important agro-industrial regions of Turkey. Such basin has about 13% of farmlands as well as 3% of available water potential of Turkey and is included as water scant regions through the world. Irrigation area is about 650 000 ha in basin, and cereal and summer crops patterns are about 45% and 55%, respectively. In summer crops, sugar beet is a main commercial field crop in this region having the largest producer of Turkey with about 35% in 115 000 ha sugar beet growing area (Topak *et al.* 2008). Water lost by evapotranspiration is very high during growing season in the basin so irrigation is vital important to maintain and enhance the crop growth and yield. Irrigation water is mainly obtained from the ground water resources. Excess water extraction from groundwater resources of basin is present and is not efficient and not sustainable (Anonymous, 2007; Topak and Acar, 2011). Sugar beet is high water consuming crop (Fabeiro *et al.* 2003) and total water consumption for whole growing season varies from 900 mm to 1200 mm (Dunham, 1993).

Proper irrigation can maximize sugar beet yields while minimizing disease, water costs, fertilizer leaching, and soil erosion. One of the efficient strategies for efficient irrigation water uses is deficit irrigation program in areas having water shortage.

Under well management, deficit irrigation results substantial water savings with little impact on the quality and quantity of the harvested yield. Deficit irrigation can be defined as applying less water than the crop needs for full development and works with deep-rooted crops (Shock *et al.* 2013) such as sugar beet (*Beta vulgaris* L.) (Kırda, 2002). Sugar beet tolerates mid and late-season plant

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water stress and this characteristic make it a suitable crop for production with “limited” irrigation. The potential benefits of deficit irrigation derived from 3 factors: increased irrigation efficiency, and reduced irrigation and water opportunity costs (English and Raja, 1996).

Under limited water resources where water is precious, partial root zone drying, PRD, is a viable irrigation option to increase water productivity while margining the yield, rather than only increasing the economic yield without concerning the value of water in limited water environments (Sepaskhah and Ahmadi, 2010). PRD is a modified form of deficit irrigation (English *et al.* 1990; Stikić *et. al.* 2010; Ibrahim Ali *et al.* 2004). It is a novel irrigation strategy since half of the roots is exposed to dry soil while the other half is growing in irrigated soil (Ahmadi *et al.* 2010). Topak *et al.* (2012) studied deficit drip irrigation effect on dry bean yield in Konya Region of Turkey and suggested 30% deficit irrigation is applicable for dry bean cultivation. However, PRD technique in sugar beet in this region has not been studied so far (Topak *et al.* 2011).

Adequate soil fertility is one of the requirements for efficient sugar beet production. Nitrogen (N) is the most yield-limiting nutrient, and N management is critical to obtain optimum sugar beet yield and quality (Davis and Wastfall, 2014; Koocheki *et al.* 1997).

Nitrogen has the greatest influence on crop yield and also is a key component of enzymes, vitamins, chlorophyll and other cell constituents, which are essential for crop growth and development. Indicators of nitrogen deficiency in plants are poor growth rate, yellow leaves because of lack of chlorophyll as well as stunted through lack of leaf expansion.

Improving nutrient efficiency is a worthy goal and fundamental challenge facing the fertilizer industry, and agriculture in general. The fertilizer industry supports applying nutrients at the right rate, right time, and in the right place as a best management practice for achieving optimum nutrient efficiency (Roberts, 2008).

The effectiveness of variable rate of nitrogen application heavily relies on the capability of detecting nitrogen status while the fertilizer is being applied (Noh *et al.* 2006).

Cai and Ge (2004) informed that content of nitrogen in beet plant increased with the elevation of nitrogen amount, which showed significantly positive correlation: the absolute content of nitrogen increased gradually with the growing proceeding, and reached the peak in root formation, then decreased.

Nutrient use efficiency, NUE, can be expressed several ways. Mosier et al. (2004) described 4 agronomic indices commonly used to describe NUE: partial factor productivity (PFP, kg crop yield per kg nutrient applied); agronomic efficiency (AE, kg crop yield increase per kg nutrient applied); apparent recovery efficiency (RE, kg nutrient taken up per kg nutrient applied); and physiological efficiency (PE, kg yield increase per kg nutrient taken up).

Differences in the scale of farming operations and management practices such as tillage, seeding, weed and pest control, irrigation, harvesting usually result lower NUE. Nitrogen recovery in crops grown by farmers rarely exceeds 50% and is often much lower. A review of best available information suggests average N recovery efficiency for fields managed by farmer ranges from about 20% to 30% under rain fed conditions and 30% to 40% under irrigated conditions (Roberts, 2008).

Prasad (2009) reported that crop varieties and cropping systems, soil management, agronomic management (timely sowing and transplanting), weed control, water management (proper irrigation scheduling and moisture conservation) in rain-fed agriculture, fertilizer materials and their methods of application are highly correlated with nitrogen use efficiency.

Sugar beet profits are based on three key factors: root yield, sucrose content, and sucrose recovery efficiency. Nutrients especially nitrogen, N, can affect all three factors. Excess N in the soil can both reduce sucrose content and conversely, N deficiency in the soil can reduce root and sugar yields (Moore *et al.* 2009). In a research, nitrogen use up to 240 kg/ha increased sugar yield and water use efficiency (Taleghani 1998). Increased root yield under no water stress conditions with increased N amount was much more by comparison to water stress conditions. In examine root yield, no water stress treatment by using 150 kg N ha^{-1} resulted the highest yield. Water stress treatment particularly constant water stress had the maximum water use efficiency (Esmaeili, 2011).

Leilah *et al.* (2005) researched the effect of adding 250 kg N/ ha into two equal portion (at 45 and 60 days after planting), three equal portion (at 45, 60 and 75 days after planting), and four equal portion (at 45, 60, 75 and 90 days after planting) in a newly reclaimed sandy soil at Kalabsho region in the northern district of Belkas, Dakahlia Governorate, Egypt, during the two successive seasons of 1994/95 and 1995/96. Addition of 250 kg N/ ha in four equal portions was recommended for maximizing sugar beet production.

This study was, therefore, performed to determine different N levels affect on nitrogen recovery efficiency, NRE, of sugar beet crop by using drip irrigation under PRD and fertigation techniques.

MATERIAL AND METHOD

A field study was conducted at the Experimental Station of Çumra Vocational School, about 50 km far from Konya city center of Turkey, at about 1000 m above the sea level. Climate in this region is semi-arid with total annual precipitation of about 323 mm. The experimental site has no rainfall whatsoever in summers.

The soil in this area is alluvial origin with high lime contents and scant organic matter. The soils have no salinity as well as drainage problems such as water table (Ertaş, 1984). Some physical properties of experimental site related to irrigation were presented in Table 1.

Table 1

Some physical properties of experimental field

Depth (cm)	Texture**	Field Capacity (%)*	Wilting Point (%)*	Available Water Capacity, AWC, mm/30 cm
0–30	C	30.55	18.89	45
30–60	C	32.74	19.42	57
60–90	C	32.93	19.76	57

*: % water by weight **: C, clay.

The Stine sugar beet variety was planted by machine on 18 April 2012 and 3 May 2013. After sowing plants, the plots were irrigated by sprinkler irrigation method, a watering volume of 25 mm. In both experimental years, beet plants were thinned to a distance of about 0.2 m on the rows at the 4th week after planting.

In study, N levels were designated as main and irrigations were sub-main plot treatments. Certain N levels were calculated by pure form and applied nitrogen sources were DAP (for base application) and urea (46% N for surface application) forms.

In this study, irrigation water and nitrogen requirements of sugar beet crop were reduced and those amounts were applied by different drip irrigation techniques. N treatments were as follows: application of 100% nitrogen requirement of plant, FN (Full Nitrogen), and two conventional deficit nitrogen treatments of 75% (DN75) and 50% (DN50) of FN with a total of 3 N levels. Irrigation treatments were as follows: application of 100% irrigation water requirement of plant, FI (Full Irrigation), and 50% application of FI by using alternative (APRD50) and fixed partial root drying (FPRD50) with a total of 3 irrigation treatments.

In FI treatment, lateral lines were placed for each row and those were arranged just next to the crop row so that both sides of the crop rows were wetted by this way.

In APRD50 treatment, laterals were installed just center of two crop rows and those were parallel to the crop rows. In such treatment, irrigation events were performed by rotation (laterals were used by every other lateral use). One side of the crop rows was irrigated like the FI treatment while the other side was exposed to dry condition. In next irrigation event, irrigation was performed as opposite the previous one.

In FPRD50 treatment, each lateral was installed for two crop rows with a lateral spacing of 90 cm and those laterals were just in crop rows. In such plots, one side of the crop rows was irrigated while other side was exposed to dry conditions in whole growth season.

Field trials were designated as divided experimental plots with tree replications. FI irrigation treatment was designated as control and irrigation program was made in accordance of FI. In irrigation treatments, irrigation was started at 35-40% water depletion from the available water capacity through the crop root zone depth and other irrigations were performed in the reference of FI.

There was 3.0 m separation between each plot to minimize water movement among treatments. Each experimental plot was 30 m x 2.7 m (6 rows per plot) and had a total area of 81.0 m^2. In the study, whole plots were irrigated by drip irrigation system. The drippers were inline type and placed 0.30 m apart from each other and had 2 L/h discharge rate at 1.0 atm pressure. Emitter spacing was determined by field test just before the experiment at research site. Lateral spacing was 0.45 m apart. Thus, the percentage of wetted area that related dripper spacing to lateral spacing was about 90%, according to the principles of Keller and Bliesner (1990).

By analysis of experimental soil in respect to fertility, N, P, K contents of research soil were determined and then N, P, K requirements of sugar beet was determined. In this purpose, soil samples were taken from 0-30, 30-60 and 60-90 cm soil depths. In those soil samples, total N, (NH4+NO3), was determined by Bremner, (1960), Jackson (1962) and available phosphorus, P, was measured by Olsen *et al.* (1954). Potassium, K, in soil was determined by using 1 N Ammonium Ashetat extraction with fleymfotometre (Jackson, 1962; Kacar, 1994). For optimum yield of sugar beet, as a pure form of 90 kg P (P_2O_5)/ha, 270 kg K (K_2O)/ha, 220 kg N/ha are needed (Şiray, 1990; Arıoğlu, 1997) and those levels were used in basic fertilizer applications in present study. From soil analysis, 57 kg N/ ha, 20 kg P/ ha and 700 kg K/ ha was determined before the experiment in research site.

According to soil analysis, as a pure form, 36 Kg N / ha was applied to base for all treatments and Diammonium Phosphate, DAP, was used for this purpose. Pure phosphorus as 70 kg P /ha was applied to all plots with sowing. The rest of N amounts were applied to FN, DN75 and DN50 plots with four equal parts in first four irrigations events by fertigation. Therefore, total N applications were as follows: FN: 160 kg N/ ha; DN75: 120 kg N/ ha and DN50: 80 kg N/ ha.

Root yield was measured by manual harvesting the center two rows from a six-row subplot on 6 October 2012 and 28 September 2013.

To assess the effectiveness of nitrogen fertilizer, Nitrogen Recovery Efficiency, NRE, can be used. NRE can be calculated as follows (Norton and Silvertooth,1999):

$$NRE= [(F-C)/N]*100$$

where:

F- total N uptake in fertilized plots, kg/ha

C- total N uptake in unfertilized (check) plots, kg/ha

N- total fertilizer N applied kg N/ha.

Monitoring of soil moisture content allows a good assessment of the crop's water needs. In treatments, soil water content measurements were made one day before irrigation in each a treatment until harvest for all treatments by use of plastic access tubes 42 mm in diameter and 1.0 m long in the soil and using a Time Domain Refroctometer (TDR) (Imko, Trime-FM3-T3 probe, Imko Micromodültechnik GMBH, Ettlingen-Germany). The soil moisture content in the first 15 cm soil layer was measured by the P3-rod probe designed for use in the upper soil. Irrigations were started on 8 June (2012) and 15 June (2013) lasted on 12 (2012) and 10 (2013) September.

RESULTS AND DISCUSSION

The study was conducted in two years and results as averages obtained from 2012-2013 growth periods were as follows:

A. Nitrogen Content in Root

Irrigation treatments significantly affected N levels in root (Table 2) and APRD50 produced the highest N level as 0.68% and followed by FPRD50 as 0.64% and lowest one was in FI as 0.55% in sugar beet root. The increase in applied water resulted lower N level in root yield. In examine the N levels effect on N content of root, the highest N was obtained from FN as 0.68% (the highest N fertilizer application) and the lowest one was obtained from the lowest N fertilizer application of DN50 as 0.55%. N levels had significant effect on N levels in root. In examine irrigation x N level interaction, the highest N contents were found in APRD50FN as 0.74% and FPRD50FN as 0.72% while the lowest one was obtained from FIDN50 as 0.53%.

Table 2

Nitrogen content in root, %

Years	Irrigation Treatments	N Levels			
		FN	DN75	DN50	Mean
2012-2013	FI	0.57 bc	0.55 bc	0.53 c	0.55 b
	APRD50	0.74 a	0.67 ab	0.63 abc	0.68 a
	FPRD50	0.72 a	0.66 ab	0.55 bc	0.64 a
	Mean	0.68 a	0.63 ab	0.55 b	0.62

Significant at 5%.

B. Nitrogen Content in Leaf

Data listed in Table 3 reveal that irrigation treatments had no significant effect on nitrogen contents in sugar beet leaves. The nitrogen contents of leaf for FI, APRD50 and FPRD50 treatments were obtained 2.97%, 3.13% and 2.95%, respectively. However, N levels had significant effect on nitrogen content of leaf. The highest N contents were obtained from FN fertilizer application as 3.32% and followed by DN75 as 3.08%. The differences between FN and DN75 were no significant. In examine irrigation treatment x N level interaction, the highest N contents were found in APRD50FN as 3.42% and followed by FPRD50FN as 3.34% while the lowest one was obtained from FPRD50DN50 as 2.44%.

Table 3

Nitrogen content in Leaf, %

Years	Irrigation Treatments	N Levels			
		FN	DN75	DN50	Mean
2012-2013	FI	3.19 ab	2.97 ab	2.76 bc	2.97
	APRD50	3.42 a	3.21 ab	2.78 bc	3.13
	FPRD50	3.34 a	3.07 ab	2.44 c	2.95
	Mean	3.32 a	3.08 a	2.66 b	3.02

Significant at 5%.

C. Nitrogen Uptake by Root

Data presented in Table 4 show that irrigation treatments had no significant effects on nitrogen uptake from root. The highest nitrogen uptake from root was obtained from APRD50 treatment as 115.4 kg/ha. On the other hand, N levels had significant effects on nitrogen uptake from root. The highest one was obtained from FN treatment as 121.3 kg/ha while the lowest one was found in DN50 as 102.4 kg/ha. The interaction between irrigation treatment and N levels had significant effects on nitrogen uptakes from root and the highest nitrogen uptakes from root of sugar beet crop were found in APRD50FN as 122.4 kg/ha, and followed by FPRD50FN as 121.0 kg/ha, FIFN as 120.6 kg/ha, APRD50DN75 as 117.1 kg/ha, FIDN50 as 111.3 kg/ha and FIDN75 as 110.5 kg/ha while the lowest one was obtained from FPRD50DN50 as 89.4 kg/ha.

Table 4

Total nitrogen uptake by root, kg/ha

Years	Irrigation Treatments	N Levels			
		FN	DN75	DN50	Mean
2012-2013	FI	120.6 a	110.5 a	111.3 a	114.1
	APRD50	122.4 a	117.1 a	106.6 ab	115.4
	FPRD50	121.0 a	112.6 ab	89.4 b	107.7
	Mean	121.3 a	113.4 ab	102.4 b	112.4

Significant at 5%.

Norton and Silvertooth (1999) stated that 168 kg N /ha resulted 145 kg/ha and 210 kg/ha nitrogen uptake for 1996 and 1997, respectively for cotton plant at Casa Grande sandy loam soil (fine-loamy, mixed, hyperthermic, Typic Natriargid (reclaimed) at the University of Arizona Maricopa Agricultural Center (MAC) located northwest of Casa Grande, AZ. In our study, the highest N uptake was observed from the highest N applied level of FN around 120 kg/ha.

Our study findings were lower than the results of Norton and Silvertooth (1999). The possible reasons might be the differences in crop variety, soil properties and environmental factors.

D. Nitrogen Use from Fertilizer

Data presented in Table 5 reveal that irrigation treatments had no significant effect on nitrogen use from fertilizer. The highest nitrogen use was obtained from APRD50 treatment as 48.1 kg/ha and the lowest one was found in FPRD50 as 43.4 kg/ha. Different N levels had significant effects on nitrogen use. The highest one was obtained from FN level as 53.6 kg/ha while the lowest one was found in DN50 as 38.4 kg/ha. The interaction between irrigation treatment and N levels had significant effects on nitrogen use and the highest nitrogen use of sugar beet crop were found in APRD50FN as 55.2 kg/ha, and followed by FIFN as 54.2 kg/ha while the lowest one was obtained from FPRD50DN50 as 33.1 kg/ha.

Table 5

Nitrogen use from fertilizer, kg/ha

Years	Irrigation Treatments	N Levels			
		FN	DN75	DN50	Mean
2012-2013	FI	54.2 a	45.4 ab	42.8 ab	47.5
	APRD50	55.2 a	49.8 ab	39.4 ab	48.1
	FPRD50	51.2 ab	45.9 ab	33.1 b	43.4
	Mean	53.6 a	47.0 ab	38.4 b	46.33

Significant at 5%.

E. Nitrogen Recovery Efficiency

Data presented in Table 6 shows the effect of irrigation treatments and N levels on nitrogen use recovery efficiency (NRE). As seen in Table 6, those irrigation treatments had no significant on NRE. It varied from 41.1 % (FI treatment) and 37.7% (FPRD50 treatment). Different N levels had significant effects on NRE. The highest one was obtained from DN50 as 47.4% and the lowest one was found in FN as 32.9%. The interaction between irrigation treatment and N levels had significant effects on NRE and the highest NRE was found in FIDN50 as 52.6%. Our results were lower than results mentioned some European Countries such as Portual, Sweeden and France (Brentrup and Palliere, 2010). It can be stated that increasing N rates resulted decreasing NRE so our findings are inline with Norton and Silvertooth (1999).

Table 6

Nitrogen recovery efficiency, NRE, %

Years	Irrigation Treatments	N Levels			
		FN	DN75	DN50	Mean
2012-2013	FI	33.4bc	37.3abc	52.6a	41.1
	APRD50	34.0bc	38.1abc	48.5ab	40.1
	FPRD50	31.5c	40.7abc	41.0abc	37.7
	Mean	32.9b	38.7ab	47.4a	39.67

Significant at 5%.

CONCLUSION

The study aimed to research effects of different nitrogen rates on NRE for different drip irrigated sugar beet crop. Increasing N rates has resulted decreasing NRE so less amount of N applications are highly preferable to reduce the fertilizer cost as well as sustainable environment. In regions where the water resources are limited, PRD is a viable irrigation alternative for sustainable use of water resources.

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