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Optimum Applications of Nitrogen Fertilizer and Water Regime for Wheat (*Triticum aestivum* L.) Using ^{15}N Tracer Technique under Mediterranean Environment

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TWO FIELD experiments were conducted under two different soil texture located in two sites. Tracing the nitrogen status in wheat plants – soil - environment system using ^{15}N technique under different water regimes was the aim of this investigation. Three nitrogen rates (100, 80 and 60% of the recommended rate with 5% ^{15}N atom excess labeled ammonium sulfate) through two mode of application (Mode A; nitrogen fertilizer rate splitting into three doses: 25, 25, 50% of added rates at seedling, tillering and jointing, respectively, and Mode B; splitting N rate into two doses: 35 % at seedling and 65% at tillering) conjugated with three water regimes (100, 75 and 50% of crop water requirement (CWR)) were applied under clay loam and loamy sand soils conditions. Wheat grain and straw yields were declined by 16.4 and 4.4% in clay loam soil, and by 34.6 and 20.7% in loamy sand soil as water regime reduced from 100 to 50% CWR, respectively. Application of 80% of the recommended N rate recorded the highest grain yield under Mode A, whereas 100% N rate recorded the highest straw yield under Mode B in both soil textures. The moderate rate of N fertilizer (80%, corresponding to 142.4 and 190.4 kg N ha^{-1} in clay loam and loamy sand soil, respectively) applied with mode A under 75% water regime (4017.7 and 4200.8 m^3 applied irrigation water per hectare in clay loam and loamy sand soil, respectively) recorded the highest N uptake by plant, nitrogen use efficiency (NUE) and consequently wheat yield.

Keywords: Cereal crops, Grain yield, Nitrogen uptake, Nitrogen use efficiency, Soil texture

Introduction

World agriculture lands are limited (World Bank group, 2015), whereas the global demand for food crops is expected to approximately double by 2050 (Tilman et al., 2011). Therefore, crop production will need to increase in order to meet the demand for food especially the three major cereal grains (*i.e*. wheat, rice and maize) which provided 55.9% of the food energy consumed all over the world (Cordain, 1999 and Daryanto et al., 2016), while the available water for agriculture is decreasing (Cai and Rosegrant, 2003). Most Mediterranean countries, particularly the arid and semi-arid regions, are chronically water-stressed (Hamdy, 2012 and Mahmoud et al., 2018). Some researchers reported that there is a significant positive effect of water supply with nitrogen fertilizer interaction on crop productivity (Hussain and Al-Jalaud, 1995 and Bandyopadhyay et al. 2009). At the same time, the over-nitrogen fertilization lead to environmental problems as well as raising the input cost of the crop production. Over the past 60 years, Low and Piper (1957) using ^{15}N tracer technique, followed by more than 100 experiments all over the world, traced the N dynamics in the soil – plant - atmosphere system (Smith and Chalk, 2018).

In arid and semiarid regions there is a need for developing strategies for optimum utilization of water and appropriate nitrogen rate under deficit of irrigation water (Bandyopadhyay et al., 2009). In this regard, Rathore et al. (2017)

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reported that reducing nitrogen and water inputs has been speculated to have negative impacts on wheat grain yield. On the other hand, Karam et al. (2009) found that 150 Kg N ha^{-1} conjugated with 50% of soil water deficit was found to be the optimum combination for maximizing wheat grain yield, whereas Kharel et al. (2011) confirmed that supplemental water increased grain yield and nitrogen use efficiency by 25% and reduced yield loss due to nitrogen stress from 1141 to 480 Kg ha^{-1}. Straw yield and harvest index (HI) followed a similar trend as grain yield according to Bandyopadhyay et al. (2009). López-Bellido et al. (2006) and Rathore et al. (2017) indicated that the nitrogen use efficiency (NUE) was declined as water availability reduced in spite of increasing nitrogen rate and suggested that moderate deficit (80% of evapotranspiration) along with 120 Kg N ha^{-1} could ensure satisfactory wheat grain yield in arid regions. In the same way, Wang et al. (2016) noticed the improvement of water uptake as affected by nitrogen supply during vegetative growth stage, and in the same time, grain yield was increased by 12.8, 25.4 and 34.8% corresponding to 60, 120 and 180 Kg N ha^{-1}, respectively comparing to the unfertilized control. But, unnecessary application of N fertilizers could be negatively effective on soil and environment in terms of soil chemical properties, emission and leaching of N, rising the global worming by increasing N_2O emission (Ross et al., 2008 and Pieri et al., 2011), thus it may be attributed to the presence of nitrogen in the soil prior to crop uptake, which usually around 50-60% of the total applied N (Janzen et al., 2003). Globally, the N fertilizer recovery in wheat is low, *i.e.* approximately 30-50% (Spiertz, 2010). The poor recovery of applied N increases input cost to farmers and environmental problems, therefore, reduce the input cost and environmental impact of nitrogen losses during growth stages through improving NUE is an important challenge. Peak uptake of N is observed between tillering and anthesis stages, where wheat plants accumulate about 50-60% of total N requirements (Grant et al., 2001 and Petersen & Mortensen, 2002). So adjusting the time and rate of application of N fertilizer could be achieve maximum crop production with great saving in the nitrogen quantities (Balasubramanian and Singh, 1982). Similar findings were reported by Delogu et al. (1998), López-Bellido et al. (2005) and Chen et al. (2016) who reported that splitting application of N fertilizer is the best strategy for improving NUE. Also, Abourached et al. (2008) found that splitting nitrogen fertilizer into two doses at the stem elongation and heading stages was better for improving wheat yield.

The aim of this investigation was to find out the proper integral management of irrigation water and nitrogen fertilizer applied in different splitting modes and follow up their effects on nitrogen status and wheat yields under different soil conditions.

Materials and Methods

Two field experiments were conducted during 2015/2016 season in two locations: the first site at Experimental Farm of King Maryout, Alexandria Governorate, Egypt (30° 59` 5° N, 29° 48` 45°E) with Clay loam texture soil and the second site at a privet farm field in Alexandria-Cairo desert road (30° 16` N, 30° 56` E) with Loamy sand texture soil to investigate the effect of irrigation water regimes and nitrogen fertilization rates and splitting modes with application of ^{15}N tracer technique on wheat crop (*Triticum aestivum* L. cv. Giza 168), which provided by Field Crops Research Institute, Agriculture Research Center, Giza, Egypt. Some of the physico-chemical properties of the experimental soils are presented in Tables 1 and 2.

TABLE 1. Physical characteristic of the two sites

Location	Particle Size distribution %			Texture class	Bulk density	F.C %	PWP %
	Sand	Silt	Clay		($g\ cm^{-3}$)	By weight	By weight
1st site	14.40	26.20	59.40	Clay Loam	1.28	33.68	14.92
2nd site	78.80	15.00	6.20	Loamy Sand	1.15	11.20	2.70

TABLE 2. Chemical characteristic of the two sites

Location	sample No.	Soil Depth	pH	EC (dS m^{-1}) (1:2.5)	N	P	K
		cm	(1:2.5)		(mg kg^{-1})	(mg kg^{-1})	(mg kg^{-1})
1st site	1	0-15	8.11	0.55	21.12	1.84	528
	2	15-30	8.13	0.43	22.09	2.13	489
	3	30-50	8.16	0.31	23.53	2.87	272
2nd site	1	0-15	8.22	0.11	20.71	2.45	192
	2	15-30	8.29	0.11	27.12	3.39	197
	3	30-50	8.34	0.12	32.10	4.01	198

TABLE 3. Effect of water regime on wheat yields (Mg ha^{-1}) of clay loam and loamy sand soil

Water regime (%)	Grain Yield (Mg ha^{-1})		Straw Yield (Mg ha^{-1})		Harvest index (HI)	
	1st site	2nd site	1st site	2nd site	1st site	2nd site
100	6.15 a	4.39 a	6.20 a	8.12 a	0.50 ab	0.35 b
75	5.86 b	3.89 b	5.58 a	6.97 b	0.51 a	0.36 a
50	5.14 c	2.87 c	5.93 a	6.44 c	0.46 c	0.31 c

Means in the same column followed by the same letter are not significantly different accordingto Duncan's test at $p < 0.05$.

Drip irrigation system with three water regimes were constructed (I_1: 100% of crop water requirements (CWR), the corresponding applied water 5356 and 5601 m^3 ha^{-1} in soil of the first site (clay loam) and second site (loamy sand) soil, respectively, I_2: 75% of CWR and I_3: 50% of CWR. Amount of irrigation water was calculated based on the crop evapotranspiration (Et_c mm/day) using FAO CLIMWAT 2.0 P.M. method (CROPWAT program, *Smith*, 1992). The crop coefficient value (K_c mm/day) of wheat was retrieved according to Doorenobs and Pruitt (1977). Three nitrogen fertilization rates:178, 142.4 and 106.8 Kg N ha^{-1} in clay loam (1st site) soil, and 238, 190.4 and 142.8 Kg N ha^{-1} in loamy sand (2nd site) soil as 100, 80 and 60% of the recommended nitrogen rate, respectively, were used in form of ammonium sulphate (20% N) labeled with 5% ^{15}N atom excess , which added in two splitting modes: Mode A (Nitrogen fertilizer splitting into three doses: 25% at seedling, 25% at tillering and 50% at jointing) and Mode B (Nitrogen fertilizer splitting into two doses: 35% at seedling and 65% at tillering). Phosphorus fertilizer in the form of super phosphate (15.5% P_2O_5) was applied at a rate of 240 and 360 Kg P_2O_5 ha^{-1} for the first and second sites, respectively. Potassium fertilizer was applied only in loamy sand (2nd site) soil at the rate of 120 Kg K_2O ha^{-1} (as potassium sulphate (48% K_2O), because the soil texture of 1st site is clay loam and hence was K-enriched. Seed rate was 80 and 100 Kg ha^{-1} in the first and second sites, respectively. Sub-sub plot area was 12 m^2, row spacing 15cm in-between. Micro-plot with 2 m^2 area was constructed for ^{15}N labeled ammonium sulphate addition. Other agricultural practices were applied as recommended. Split-split plot design with three replicates was used, where irrigation regimes were subjected to the main plots, nitrogen treatments in the sub plots and nitrogen modes in the sub-sub plots.

Measured variables

- At harvest, random samples of 15 plants was collected; spikes and stem per plant and whole plant fresh and dry weight were determined. Leaving 0.5m plot border from all sides, the net sub-sub plot (8.75 m^2) was harvested, grain and straw yield (Mg ha^{-1}) were recorded and harvest index (HI) were calculated.

- Another 15 plants randomly selected for N analysis to compute some nitrogen isotope calculation and Nitrogen Use Efficiency (NUE) according to IAEA-TECDOC no.14 (IAEA 2001) as follows:

N-Uptake = N% * DryYield (Grain or Straw) (1)

FN Remained (kg ha^{-1}) = % FNR in Soil * Rate of Fertilizer added (kg ha^{-1}) (2)

Nitrogen Losses = N inputs - N outputs - changes in soil total N (3)

$$\% NUE = \frac{\text{Ndff (kg ha}^{-1}\text{)}}{\text{Rateof fertilizer (kg ha}^{-1}\text{)}} *100 \quad (4)$$

where:

% NUE = % Nitrogen Use Efficiency,
Ndff = Total nitrogen derived from the fertilizer (kg ha^{-1})
DW = Dry Weight (Mg ha^{-1}).

Statistical analysis

Data collected were statistically analyzed using analysis of variance (ANOVA) as applicable to split-split plot design according to the procedures outlined by Snedecor and Chochran (1967). To compare treatment means L.S.D at 5% level of significance was used according to Steel and Torrie (1980). All statistical analysis was performed by using MSTAT-C (1989) statistical software.

Result and Discussion

Yield

Water regime significantly affected grain and straw yield as well as harvest index (HI) (Table 3). High water availability resulted in significant increase in grain and straw yield, whereas the highest grain yield (6.15 and 4.39 Mg ha^{-1}) and straw yield (6.20 and 8.12 Mg ha^{-1}) in clay loam and loamy sand soil, respectively, resulted from 100% availability. No significant differences between 100 and 75% from available water for HI. On the other hand, reducing water availability from 100 to 50% reduced grain yield by 16.4 and 34.5%, straw yield by 4.4 and 20.7% and reduced HI by 8.0 and 11.4% in clay loam and loamy sand soil, respectively.

The causes for this depletion might be due to two reasons; one is related to the low uptake of N which resulted in shortening the plant growth then reducing the dry matter accumulation in wheat plant The negative effect of water shortage on wheat yields might have been a result of the reduction in dry matter accumulation as well as a result of partial close of stomata and lake the photosynthetic rate which negatively affect the growth and reduced the yield under water stress conditions, as Ventrella et al. (2012) reported, the same point where irrigation significantly increased biomass and wheat yield; Wang et al. (2001 and 2011) and Sun et al. (2010) stated that "limited irrigation greatly affects wheat crop yield", also Li et al. (2015) mentioned that supplemental irrigation significantly increased wheat grain yield by 8.0% while Karam et al. (2009) reported that the relative increments by about 25-35%. The other reason, is related to the constancy of water shortage probably promote the plant to adapt with dry condition in way of adjust their transpiration with the available water, same finding has been reported by Cabrera-Bosquet et al. (2007). These results are in conformity with the findings of Bandyopadhyay et al. (2009), Kharel et al. (2011) and Wang et al. (2016). Also, Zhang et al. (2003) and Liu et al. (2016) mentioned that optimal irrigation levels and mild soil water stress condition (65-70% of available soil water) significantly increased wheat yield, whereas in water shortage the chemical signal from root to plant top resulted in higher reduction in leaf transpiration and lower reduction in photosynthesis ending to higher leaf scale water productivity (Sepaskhah and Ahmadi, 2010, Ghasemi-Aghbolagi and Sepaskhah 2017).

TABLE 4. Effect of nitrogen fertilizer rates and modes on wheat yields of clay loam (1st site) and loamy sand (2nd site) soil

Nitrogen treatment		Grain Yield (Mg ha^{-1})		Straw Yield (Mg ha^{-1})		Harvest index (HI)	
		1st site	2nd site	1st site	2nd site	1st site	2nd site
N-level %	100	5.26 b	3.80 ab	6.43 a	7.42 a	0.45 b	0.34 b
	80	6.91 a	3.87 a	5.23 a	7.17 ab	0.57 a	0.35 a
	60	4.98 bc	3.47 c	6.05 a	6.94 bc	0.45 b	0.33 c
N-mode	Mode A	6.35 a	4.34 a	5.37 b	7.18 a	0.54 a	0.38 a
	Mode B	5.08 a	3.10 b	6.45 a	7.17 a	0.44 b	0.30 b

Means in the same column followed by the same letter are not significantly different according to Duncan's test at $p < 0.05$.

TABLE 5. Effect of water regime on NUE under different soil texture

Water regime (%)	Nitrogen use efficiency (%)			
	1st site		2nd site	
	Grain	Straw	Grain	Straw
100	64.52 b	36.00 a	47.38 c	31.09 a
75	78.37 a	31.30 b	71.70 a	25.92 b
50	62.62 c	30.49 c	58.92 b	25.49 c

Means in the same column followed by the same letter are not significantly different according to Duncan's test at $p < 0.05$.

Increasing nitrogen rate up to 100% of the recommended rate increased wheat straw yield in both clay loam and loamy sand soil (Table 4), this comes true regardless the modes of application, where the availability of N used to enhance the plant growth and improve the biomass accumulation as well as N fertilizer is the basis of high yield (Wang et al., 2012 and Sinclair and Rufty, 2012) as high N supply increased the total plant biomass, thereby causing leaves to compete for the available water, a large biomass production because of a high N fertilization exacerbated water stress. These findings were in agreement with those of Ehdaie et al. (1999 and 2001) and López-Bellido et al. (2008) whom mentioned that wheat straw yield increased by increasing N uptake which increased as N rate increased, whereas the highest grain yield (6.91 and 3.87 Mg ha-1 in clay loam and loamy sand soil, respectively) resulted from 80% nitrogen rate which affected the HI, where the highest HI (0.57 and 0.34%) obtained with 80% nitrogen rate (Table 3). Similar results obtained by Espindula et al. (2010) and Filho et al. (2010) whom reported that the best wheat yields were achieved with nitrogen fertilization level ranging from 70 to 120 kg N ha^{-1}.

Concerning the mode of nitrogen application, data cleared that splitting applied N into three doses (Mode A), reflected in high grain yield as compared to Mode B (Splitting N rate into two doses) (Table 4), this might be due to reducing the amount of N losses during the growing season and also improving the NUE within the soil-water-plant system. On the other hand, Mode B recorded the highest straw yield in both soils in comparison to Mode A, but the differences were not significant in loamy sand soil. It comes true where the high amounts of N were applied in one dose and it caused the increase of the total N uptake which accumulated in plant leaves. Similar results were reported by Abourached et al. (2008).

Water regime x nitrogen rate interaction had a significant effect on wheat yield. The highest grain yield (7.03 Mg ha-1) in clay loam soil resulted from 75% water regime combined with 80% nitrogen rate under Mode A, and (4.91 Mg ha-1) under loamy sand soil resulted from 75% water regime and 100% nitrogen rate under the same mode as well. The reflection of splitting the N into three doses had been highlighted in these results as final expectation of improving the NUE as well as reducing the amount of N losses according to soils texture. It's worthy to mention that in clay loam texture lower supply of water reduced the N losses by leaching and/or runoff. From the other side, in loamy sand texture the high N application along with less water regime increase the N availability for the wheat plant which resulted in higher yield comparing with the other treatments. On the other hand, the highest straw yield (7.20 and 8.25 t ha^{1}) in clay loam and loamy sand soil, respectively, resulted from 100% water regime with 80% nitrogen rate under Mode B. It could be a result of increasing the amount of available N and uptake as results, in the early stage of plant growth which promote the vegetative part of plant to be more grown. Similar explanation support the result of Sepaskhah and Tafteh (2012) whom they found that grain yield increased at N application rates of 200-300 Kg N ha^{-1} under sufficient soil water conditions. In contrast, Cassman et al. (2002) and Syswerda et al. (2012) reported that wheat yields do not linearly respond to N fertilizer inputs.

Nitrogen status

Nitrogen losses (Kg ha^{-1}) as presented in Fig. 1 differed significantly among water regimes in both clay loam and loamy sand soil.

The data had shown that increasing the water regime from 75 up to 100% of crop water requirement increased N losses by 173.3 and 90.3 %, in clay loam and loamy sand soil, respectively. The losses in clay loam texture shown to be high

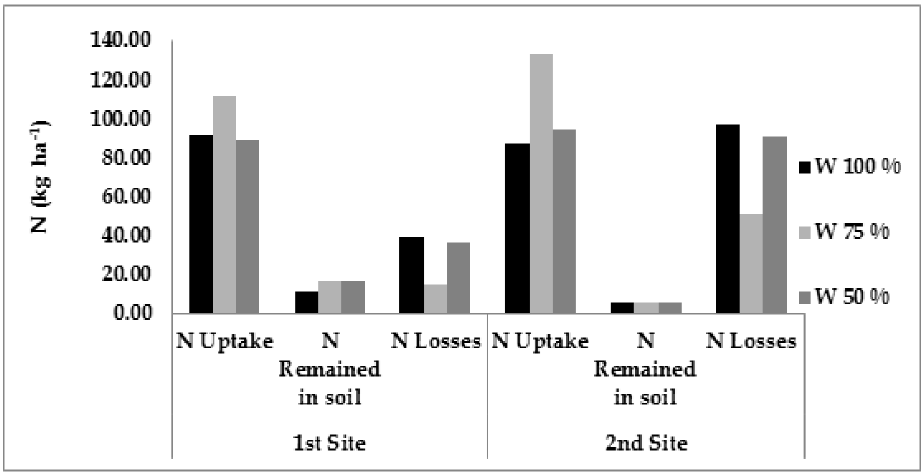

Fig. 1. Effect of water regime on nitrogen losses under different soil texture

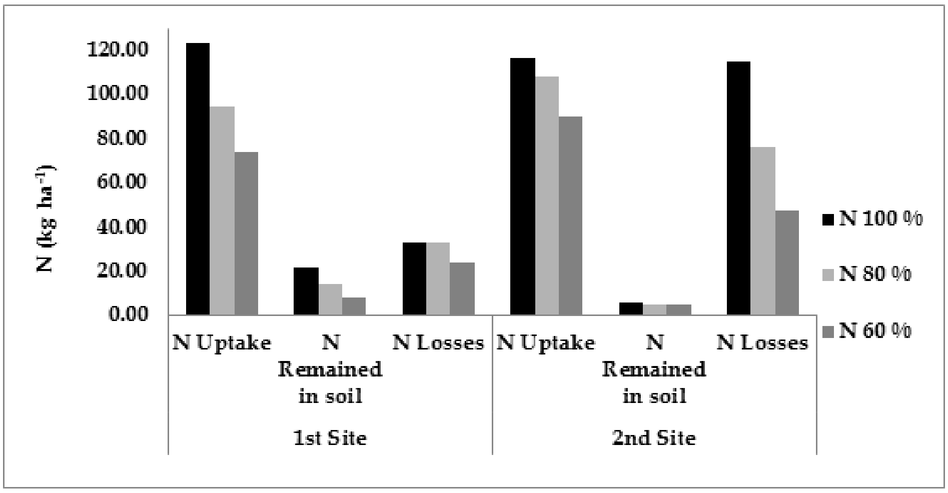

Fig. 2. Effect of Nitrogen rates on Nitrogen losses under different soil texture

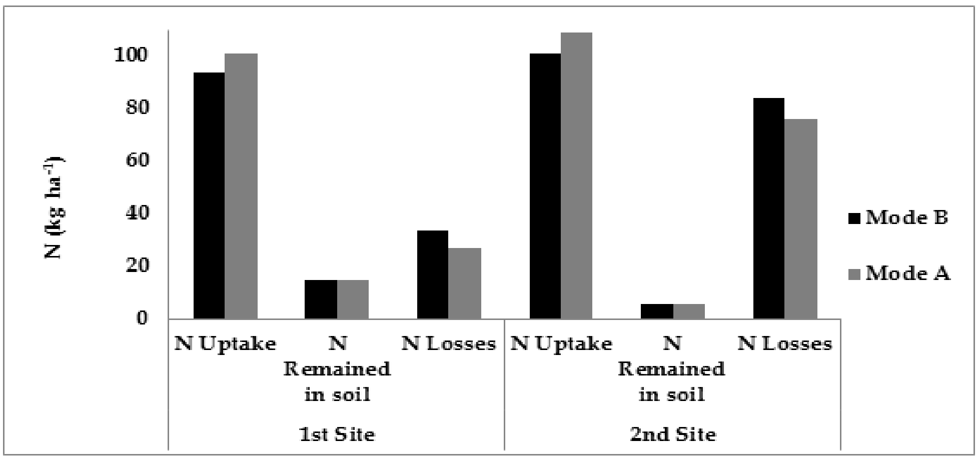

Fig. 3. Effect of Nitrogen Mode on Nitrogen losses under different soil texture

due to the runoff events which have been involved in increasing the N losses in this soil. In contrast, the amount of nitrogen losses (Kg ha^{-1}) in loamy sand soil was higher than clay loam soil, where N losses values closed to those uptakes by plant under 50 and 100 % water regimes, while it increased by 1.5 fold over N uptake at 75% water regime. These losses of N in loamy sand soil used to increase as the high rate of nitrate losses increased by infiltration due to the high amount of water applied, meanwhile in low rate of water promote the NH_3 volatilization to take a place. These results are in agreement with Aulakh et al., (2017), whom reported that the losses of N could be via NH_3 volatilization or/and denitrification in addition to the possibility of fertilizer N losses due to leaching to deeper soil layers.

Both plant N uptake and N remained in soil as well as N losses were differ significantly according to N application rate and mode in both soil textures (Figure 2 and 3). The highest N application resulted in increasing the N losses (Fig. 2) in the form of N_2O or NH_3 which increase exponentially under the availability of soil moisture (Van Groenigen et al., 2010 and Sutton et al., 2011). Also, Huang et al. (2018) reported that N uptake by plant ranged from 258 to 302 kg N ha^{-1}, high N fertilization rates generally resulted in great nitrate losses by leaching, where losses of N negatively correlated with the applied N rate, whereas excessive N application led to higher N losses consequence reduce the utilization of fertilizer N by wheat plants. At the same time Mode A was more effective on reducing N losses in comparison to Mode B, splitting the N doses increasing the NUE and reducing the N losses by different ways. Similar results were obtained by Chen et al. (2016) whom reported that total nitrogen uptake by plant was higher in split application than band application.

N uptake by plant and N remained in soil were affected significantly by water regime, nitrogen rate and mode of application, whereas the highest nitrogen uptake affected by interaction (142.3 and 172.0 kg ha^{-1}, in clay loam and loamy sand, respectively) resulted from 75% water regime along with 100% N rate under mode A. Similar tendency with somewhat exception at nitrogen remained in soil (24.9 and 7.0 kg ha^{-1}, in clay loam and loamy sand, respectively) which resulted from 75 and 50% water regime, respectively with 100% rate under mode B, it comes true whereas the low water regime permit a low amount of N to be released and in meanwhile encourage the rest of N-fertilizer to remain in soil. On the other hand, the highest N losses (59.8 and 150.9 kg ha^{-1}, in clay loam and loamy sand, respectively) resulted from 100 % water regime + 100% N rate under mode A in clay loam soil versus mode B in loamy sand soil as a result of both high volume of water and a large amount of soluble/available N which lost by different ways. The results are partially on line with Wang et al. (2012) whom recorded a high plant N uptake with high irrigation and reported that increasing N rate from 174 up to 226 kg ha^{-1} the economic N rate that achieved the remarkable wheat yield. Also, Wang et al. (2010 and 2016) reported that too much application of N and applied water resulted in high NO_3-N remained in soil after harvested wheat.

Nitrogen Use Efficiency (NUE)

In Table 5 the values of nitrogen use efficiency (NUE) as percentage are presented and showed that the NUE in both soil textures significantly affected by water regimes.

TABLE 6. Effect of nitrogen rates and modes on Nitrogen Use Efficiency (NUE) under different soil

Nitrogen treatment		(NUE) %			
		1st site		2nd site	
		Grain	Straw	Grain	Straw
N-level %	100	69.12 b	29.39 b	48.99 c	22.15 c
	80	66.67 a	28.22 c	65.93 a	26.53 b
	60	69.72 c	40.19 a	63.08 b	33.80 a
	L.S.D at 5%	0.29	0.30	0.57	0.24
N-Mode	Two doses (A)	66.10 b	34.28 a	56.67 b	26.37 b
	Three doses (B)	70.90 a	30.91 b	62.00 a	28.62 a
	L.S.D at 5%	0.24	0.24	0.46	0.20

The water regime had a direct effect on NUE as a result of either enhancing the N uptake by wheat plants and / or reducing the amount of lost N. Similar findings were mentioned by Cabrera-Bosquet et al. (2007) whom reported that the water regime have a significant effect on nitrogen uptake and nitrogen use efficiency. A positive correlation between availability of soil moisture and NUE of straw in both soil textures had been recorded, although NUE of grain seems to be negatively correlated with water regime. The highly significant NUE of grain resulted from application of 75% water regime comparing to 100% water regime which recorded the highest NUE for straw. It's worthy to mention that with optimum / moderate water regime the application of N fertilizer could be efficient, where the slow release of N-fertilizer is used to be consumed probably. Similar findings were mentioned by López-Bellido et al. (2006) and Rathor et al. (2017) whom they reported that 80% of evapo-transpiration recorded the highest NUE. Also, Li et al. (2004) found similar results where under the water stress the nitrogen use efficiency in wheat was reduced.

Increasing N rate from 60 up to 100% decreased the nitrogen use efficiency of straw by 26.9 and 34.5 % in clay loam and loamy sand soil, respectively (Table 6), a consequence of increasing the nitrogen losses by different ways along with increasing nitrogen rate (Figure 2), whereas the lowest N rate (60%) recorded the highest NUE under mode A, as the NUE declined with rising N fertilizer rate as reported by Ehdaie et al. (1999 and 2001) and López-Bellido et al. (2008). In high nitrogen application, nitrogen uptake efficiency was less than 5%, where in poorly fertilized plants, nitrogen uptake efficiency was at around 70%, in meanwhile the NUE was three times higher in the low N rates than in the high N rates as reported by Cabrera-Bosquet et al. (2007), where the excess application of N fertilizer decrease the nitrogen use efficiency as large amount of NO_3^- remained in the soil profile, which were susceptible to be lost (Legg and Meisinger,1982 and Aulakh and Malhi, 2005), accumulated NO_3^- in the soil layer could be lost with large amount of applied water.

The water regime x N rate x N mode interaction significantly affected the NUE (Table 6) of both grain and straw yield in both soil textures. The application of 75% water regime along with 80% N rate under mode A recorded the highest NUE of grain 80.3 and 87.0 % in clay loam and loamy sand soil, respectively. Higher water regime led to higher N uptake; in contrast, it has been shown that high application of nitrogen decrease the NUE (López-Bellido et al. 2005 and Dawson et al. 2008). Although, with the high application of nitrogen along with low availability of water cause to reduce the NUE due to the small amount of soluble N to be utilized by plant (Gholamhoseini et al. 2013).

Conclusion

Cultivated wheat crop (*Triticum aestivum* L.) under 75% of crop water requirements (CWR) combined with 80% of the recommended nitrogen rate splitting into three doses (Mode A), recording higher nitrogen use efficiency (NUE) without significant reduction in yields in both clay loam and loamy sand soils in comparison to 100% of both CWR and/or nitrogen rate. N losses positively correlated with water regime and significantly reduced as nitrogen fertilization rate decreased. Application of nitrogen in form of Ammonium Sulphate (20% N) could be the best form in term of enhancing the nitrogen uptake, reducing the nitrogen losses and improving the NUE as results, in both textures under Mediterranean Environment. Further research considering the Nitrogen balance in soil-plant-environment using the ^{15}N tracer technique is encouraged, as it could be a promised tool to identify the nitrogen status in different environments.

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التطبيقات المثلى من التسميد النيتروجيني وحمية المياه لنبات القمح باستخدام تقنية إقتفاء الأثر (^{15}N) "تحت ظروف منطقة البحر الأبيض المتوسط"

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أجريت تجربتين حقليتين في موقعين مختلفين لتمثيل قوامين مختلفين من التربة. حيث كان الهدف الرئيسي من التجربة هو تتبع حالة النيتروجين في نبات القمح – التربة - البيئة المحيطة، وذلك بإستخدام النظير المستقر للنيتروجين ^{15}N تحت تأثير كلا من: نوع القوام، مستويات مياه الري، معدل ونظام تطبيق السماد النيتروجيني. حيث تم إستخدام ثلاث معدلات من النيتروجين (١٠٠، ٨٠، ٦٠٪ من الكميات الموصى بها من النيتروجين محملة بالنيتروجين المرقم بنسبة وفرة ٥٪ من النظير المستقر للنيتروجين ١٥ في صورة سلفات أمونيوم)، وذلك من خلال إستخدام نظامين للإضافة (نظام A : تقسم كمية السماد النيتروجين علي ثلاث دفعات: ٢٥، ٢٥، ٥٠٪ خلال المراحل العمرية: بعد الإنبات، طور التفريع، عند طرد النورات ، بالترتيب، ونظام : B إضافة السماد النيتروجيني علي دفعتين: ٣٥٪ بعد الإنبات و ٦٥٪ عند طور التفريع) مقترنة بثلاث مستويات من المياه (١٠٠، ٧٥، ٥٠٪ من الإحتياجات المائية للمحصول) والتي تم تطبيقها في التربة الطميية السلتية والتربة الرملية السلتية.

وأوضحت النتائج المتحصل عليها إنخفاض كلا من محصول الحبوب ومحصول القش بنسبة ١٦,٤ و ٤,٤ ٪ في التربة الطميية السلتية، و بنسبة ٣٤,٦ و ٢٠,٧ ٪ في التربة الرملية السلتية كنتيجة لإنخفاض كمية المياه المضافة من ١٠٠ إلي ٥٠ ٪ من الإحتياجات المائية للمحصول، علي التوالي. هذا بالإضافة إلي أن تطبيق مستوى النيتروجين ٨٠ ٪ من الكميات الموصى بها من النيتروجين سجل أعلى نتيجة من محصول الحبوب عند إستخدام النظام A كتطبيق للإضافة، في حين سجل المستوى ١٠٠ ٪ من الكميات الموصى بها للنيتروجين مقترنا بنتطبيق نظام B أعلى محصول قش في كلا القوامين تحت الإختبار.

هذا وقد أوضحت النتائج أيضا أن المعدل المتوسط من إضافة السماد النيتروجيني (٨٠ ٪، ممثل في ١٤٢,٥ و ١٩٠,٤ كجم للهكتار في التربة الكميية السلتية وكذلك في التربة الرملية السلتية، بالترتيب) والمقترن بتطبيق نظام الإضافة A تحت مستوى ٧٥ ٪ من المياه (٤٠١٧,٧ و ٤٢٠٠,٨ متر^3 للهكتار في كل من التربة الطميية السلتية والتربة الرملية السلتية، بالترتيب) سجل أعلى معدل من النيتروجين الممتص بواسطة النبات، وكفاءة إستخدام النيتروجين (NUE) وبالتبعية محصول القمح.