Academic Journal of Life Sciences
ISSN(e): 2415-2137, ISSN(p): 2415-5217
Vol. 6, Issue. 5, pp: 34-38, 2020
URL: https://arpgweb.com/journal/journal/18
DOI: https://doi.org/10.32861/ajls.65.34.38

Academic Research Publishing Group

Original Research Open Access

Effect of Water Stress, Nitrogen and Organic Manure Fertilizer on Nitrogen Use Efficiency Indices and Grain Protein Content of Wheat in a Semi-arid Environment

Badr ELdin Abdelgadir Mohamad Ahmed (Corresponding Author)
Assistant Prof. Dept. Crop Science, Faculty of Agriculture, University of Kassala, Sudan
Email: hatoon2145@gmail.com

Faisal Elgasim Ahmed
Prof. Agronomy Dept. Faculty of Agriculture; University of Khartoum, Sudan

Hanadi Ibrahim Dessougi
Associated Prof. Agronomy Dept. Faculty of Agriculture; University of Khartoum, Sudan

Article History
Received: April 22, 2020
Revised: May 13, 2020
Accepted: May 20, 2020
Published: May 23, 2020

Abstract

A field experiment was conducted for two consecutive seasons during 2010/2011 and 2011/2012 on the Demonstration Farm of the Faulty of Agriculture, University of Kassala at New Half. Nitrogen use efficiencies (i.e. agronomic AE, internal IE, physiological PE and recovery RE) and grain protein content were investigated at different level of watering regimes and organic manure application of wheat (*Triticum aestivum* L). The watering regime treatments were irrigation every 7, 14 and 21 days, and the nitrogen fertilizer levels were zero, 43, 86 kg N ha^{-1} without or with 4 tons of chicken manure ha^{-1}. Frequent irrigation, addition of high N level and organic manure significantly increased AE, IE, PE, RE and grain protein content compared to their respective treatments. Mixing of organic manure and nitrogen fertilizer increased AE, IE and RE but resulted in a slightly increase in PE than both treatments when they were added solely. Further, the magnitude of organic manure on AE, IE, RE and grain protein content was significantly greater under normal watering regime. Wheat plants under optimum conditions (frequent watering, high N level plus organic manure) used N, as indicated by AE, PE, IE and RE, more efficiently than under other treatment combination.

Keywords: Wheat; Water stress; Organic manure; Nitrogen use efficiency.

1. Introduction

Although, Sudan is considered as a marginal area of wheat production, the wheat crop ranks second after sorghum and now has become a strategic crop due to the shortage of food in the world and to the drastic change in the consumption habit of the people in Sudan [1].

In recent years, fertilizers are major input costs in Sudanese cropping systems. Farmers are recognizant of these costs and thus they are interested in alternative approaches for improving soil fertility. The development of cropping systems that efficiently use N helps to reduce the cost of N fertilizer inputs and to minimize nitrate contamination [2]. Using organic materials plays important role in overcoming the constraints and increasing crop yield. In this regard, manure and other waste products of plants and livestock have been used as soil amendments for centuries. These materials were the only way of quickly improving soil fertility before the advent of chemical fertilizers [3]. Moreover, Ali, *et al.* [4] reported that nitrogen use efficiency decreased with increasing nitrogen levels under water stress and it was reduced to half its values under normal irrigation. Also, Wang, *et al.* [5] found that agronomic efficiency was higher with addition of organic manure due to its greater effect on soil microbial communities compared to the effect of mineral nitrogen on soil microbial organisms. Moreover, Kumar and Pannu1 [6] concluded that, the maximum physiological efficiency and **a**pparent recovery efficiency were recorded with the application of poultry manure at 75kgN ha^{-1} and decreased significantly with increase in irrigation levels while it decreased among the different level of organic sources when applied in combination with high doses of N. Also, they reported that internal efficiency was non-significant under application of organic manure at 150 and 225 kgN ha^{-1}. Abdel Rahman [7], found that higher protein content values in grains were contributed mainly with lower irrigation rate, whereas other researchers indicated that wheat grain protein percentage was greater with higher water levels [8, 9]. On the other hand, increasing nitrogen rates increased grain protein content [10]. Also, Zeidan, *et al.* [11] reported significant interaction between irrigation intervals and nitrogen fertilizer levels with or without addition of organic manure on grain protein content.

As wheat is an irrigated crop, its production is frequently exposed to water deficits at any stage of the crop development. In this regard, Elsiddig, *et al.* [12] reported that irrigation water and nitrogen fertilizers are the most crucial components of the production package (soils of wheat growing areas are inherently deficient in N). The high cost of fertilizer nitrogen raises the question about the feasibility of applying N fertilizer under limited soil moisture conditions.Water supply affects the uptake of nutrients and efficiency of fertilizers use and grain quality. Keeping these in view, in this study, nitrogen use efficiencies (i.e. agronomic AE, internal IE, physiological PE and recovery RE) and protein content were investigated at different level of watering regimes and organic manure application of wheat (*Triticum aestivum* L).

2. Materials and Methods

The proposed study was conducted on the Demonstration Farm of the Faulty of Agriculture, University of Kassala at New Halfa, Sudan (Latitude 15° 19´ N. Longitude 35° 36´E and Altitude 45 m *asl*). The experiment was arranged in strip-split-plot design with three replications. Strip blocks were allotted for the organic manure treatments and the main plots were allotted for watering treatments and the subplots for nitrogen treatments. Seeds were sown manually at a rate of 120 kg/ha, in three lines 15 cm apart, on the second week of November in both seasons.

2.1. Nitrogen use Efficiency Indices

Different indices of nitrogen efficiency were computed as per Dobermann and Fairhurst [13].

Agronomic efficiency (AE= NUE), physiological efficiency (PE), Internal efficiency (IE) and recovery efficiency (RE) were calculated as follows:-

$$\text{AE (kg grain/kg N applied)} = \frac{\text{(grain yield in N fertilized plot - grain yield in no N plot)}}{\text{(quantity of N fertilizer applied in N fertilized plot)}}$$

$$\text{PE (kg grain/kg N uptake)} = \frac{\text{(grain yield in N fertilized plot - grain yield in no N plot)}}{\text{(total N uptake in N fertilized plot - total N uptake in no N plot)}}$$

$$\text{RE (\%)} = \frac{\text{(total N uptake in N fertilized plot} - \text{total N in no N plot)} \times 100}{\text{(quantity of N fertilizer applied in N fertilized plot)}}$$

$$\text{IE (kg grain/kg N uptake)} = \frac{\text{(grain yield)}}{\text{(total N uptake)}}$$

2.2. Grain Protein Content

Protein content for grains estimated by using the improved kjeldahl- method and crude protein percentage was calculated by multiplying the total nitrogen of the grain by 5.7.

2.3. Statistical Analysis

Data were statistically analyzed according to the analysis of variance (ANOVA) for strip-split plot design using MStat-C computer software package [14]. Mean comparisons were worked out by Duncan's Multiple Range Test (DMRT) at 5% level of probability

3. Results

Generally, frequent watering (W1) and application of nitrogen fertilizer and organic manure significantly increased the mean AE, IE, PE,RE and grain protein content compared to their respective treatments (Table 1). The results showed that increasing nitrogen level from 0 to 43 kg N ha $^{-1}$, even mixed with organic manure, had no significant effect on PE (Table 2). However, prolonged watering interval significantly inhabited the positive effects of nitrogen fertilizer on NUE i.e. AE (Table 2). Further, mixing of organic manure and nitrogen fertilizer increased AE, IE and RE but resulted in a slightly increase in physiological efficiency than both treatments when they were added solely. The results revealed that, the magnitude of organic manure on AE, IE, RE and grain protein content was significantly greater under normal watering regime (Table 2). Although, prolonged watering intervals, application of high nitrogen level and organic manure solely resulted in a significant increase in the mean protein content but mixing of these fertilizers was significantly increased the grain protein content under all watering regimes (Table 2 and 3). Correlation analysis between NUE indices (PE, IE, RE and AE) and grain yield per plant was presented in table (4). Generally, all these characters were positively and significantly correlated with each others. In this regard, the mean grain yield per plant had significant strong-positive correlation with IE, RE and AE but it had moderate positive correlation with PE. However, all of NUE indices were showed moderately significant positive correlation with each other in both seasons.

4. Discussion

In the present study, nitrogen use efficiency indices (AE, IE, PE and RE) were found to be greater under frequent irrigation. This was in line with the results reported by Ali, *et al.* [15] who concluded that wheat under adequate irrigation treatments used nitrogen fertilizer more efficiently than under stress conditions. This was further confirmed by correlation analysis where these traits were positively correlated with grain yield. Also, Paradhan, *et al.* [16] reported that AE increased with increasing irrigation level. On the other hand, application of N fertilizer at high level resulted in greater mean values of AE, IE, PE and RE (19, 44, 36 and 39, respectively). Similar results were obtained by Lopez-Bellido, *et al.* [17] in bread wheat treated with high nitrogen level. Moreover, Ibrahim, *et al.* [18] indicated that application of organic fertilizer is important for increasing N recovery efficiency in wheat plant. The significant increase due to the interaction of organic manure and nitrogen fertilizer on NUE indices observed in the present study particularly under frequent irrigation was similar to results reported by Mohammad, *et al.* [19]. He attributed the positive effect of application of organic manure together with nitrogen on NUE to the improvement in grain yield. Further, the positive effect of frequent irrigation with high nitrogen level on AE in this study was agreed with those findings reported by Paradhan, *et al.* [16]. Moreover, the significant increase of grain protein content under prolonged watering interval was agreed with results reported by Ercoli, *et al.* [20] who attributed this to the sensitivity of protein deposition under water stress. Nitrogen application at high level resulted in significantly higher grain protein content probably due to the increase in nitrogen availability for plant uptake. Supporting results were reported by AL-Nouri [21]; Mattas, *et al.* [10]. They attributed the increase in grain protein content to improved availability of N at high level. Furthermore, the substantial increase in grain protein content due to combination of organic manure with high nitrogen level might be due to the increase in grain yield under such treatments as reported by Johnson and Mattern [22] and Upadhaya, *et al.* [23]. The results of present experiments indicated that application of organic manure led to grain protein content enhancement due to its effect on soil structure and consequently increases in plant nutrients uptake. Consistent with the findings of Zeidan, *et al.* [11] our results demonstrated that the application of mixed fertilizer under frequent watering regimes increased grain protein concentration.

In conclusion, it is strongly suggested to use combination of organic and high N level fertilizer particularly under frequent watering interval to achieve highest NUE indices with wheat seed quality because organic manure improved the use efficiency of recommended nitrogen fertilizer and reduced its cost.

References

[1] Ageeb, O. A., Badaruddin, M., and Reynolds, M. P., 1999. *Wheat management in warm environments*. Effect of Organic and Inorganic Fertilizers.

[2] Bellido, L. L., Bellido, R. J., and Bellido, F. J., 2006. "Fertilizer nitrogen effeciency in durum wheat under rained Mediterranean conditions: effect of split application." *Agron. L.*, vol. 98, pp. 55-62.

[3] Lupwayi, N. Z., Girma, M., and Haque, I., 2000. "Plant nutrient contents of cattle manures from small-scale farms and experimental stations in the Ethiopian highlands Agric." *Eco. Env. J.*, vol. 78, pp. 57-63.

[4] Ali, Dawelbeit, S. E., and Salih, A. A., 2008. "Effect of water stress and nitrogen application on grain yield of wheat." In *Proceedings of the Meetings of the National Crop Husbandry Committee, Agricultural Research Corporation, Wad Medani, Sudan.*

[5] Wang, Q. J., Zhang, X. L., Luo, J., Huang, Q. W., Shen, Q. R., and Yong, X. M., 2009. "Effect of different organic-inorganic mixed fertilizer on yield of wheat, nitrogen use efficiency and soil microbial diversity." *Plant Nutrition and Fertilizer Science*, vol. 15, pp. 1003-1009.

[6] Kumar, P. and Pannu1, R. K., 2012. "Effect of organic sources of nutrition and irrigation levels on yield, nutrient uptake and nutrient use efficiency of wheat." *Int. J. Life Sc. Bt and Pharm. Res.*, pp. 187-192. Available: http://www.ijlbpr.com/index.php?m=content&c=index&a=show&catid=117&id=470

[7] Abdel Rahman, G., 2009. "Water use efficiency of wheat under drip irrigation systems at Al-Maghara area, North Sina, Egypt." *American-Eurasian J. Agric. and Environ. Sci.*, vol. 5, pp. 664-670.

[8] Pleijel, H., Gelong, J., Sild, E., Danielsson, H., Younis, S., Karlesson, P. K., Willim, G., Skarby, L., and Sellden, G., 2000. "Effect of elevated carbon dioxide, ozone and water viability on spring wheat growth and yield." *Physiologia Plantarum*, vol. 108, pp. 61-70.

[9] Seleimani, M., Abdalaal, S., Ibrahim, M., and Zahran, B., 2010. "Production of grains and dough quality of bread wheat grown with different water regimes." *J, Agro. Crop Science.*, vol. 2, pp. 11-17.

[10] Mattas, K. K., Uppel, R. S., and Singh, R. P., 2011. "Nitrogen management and varietal effects on quality of durum." *Res. J.of Agric. Sci.*, vol. 2, pp. 279-283.

[11] Zeidan, C. M., Abdelhameed, I. M., Bassiouny, A. M., and Wally, A. A., 2009. "Effect of irrigation intervals, nitrogen and organic fertilizer on yield, yield attributes and crude protein content of some wheat cultivars under Newly Reclaimed Saline Soil Condition." *Research Journal of Agriculture and Biological Sciences*, vol. 3, pp. 748-752.

[12] Elsiddig, K., Ludders, P., Ebert, G., and Adiko, S. G. K., 1998. "Response of rose apple (eugenia jampos l) to water and nitrogen supply." *J. of Applied Botany*, vol. 72, pp. 203-206.

[13] Dobermann, A. and Fairhurst, T., 2000. *Assessing nitrogen efficiency. In: Nutrient disorder and nutrient management*. 1st ed. Tham. S.C. IRRI. International Rice Research Institute, Philippine, pp. 155-161.

[14] Nielsen, G., 1992. *Microsoft program for design, management and analysis of agronomy research experiment*. USA: Michigan State University.

[15] Ali, Nadeam, T., Shakal, A., Chattha, T. H., and Hussain, A., 2012. "Effect of irrigation of different growth stages and phosphorous application methods on agronomic traits of wheat (Triticum aestivum L)." *J.of Food,Agric. and Environment*, vol. 10, pp. 1371-1375.

[16] Paradhan, S., chopra, U. K., Bandyopadhyaya, K. K., Singh, R., Jain, A. K., and Chand, I., 2013. "Effect of water and nitrogen management on water productivity and nitrogen use efficiency of wheat in Semi-arid Environment." *Int. J. of Agri. and Food Sci. Technology*, vol. 4, pp. 727-732.

[17] Lopez-Bellido, L., Lopez-Bellido, R. J., Castillo, J. E., and Lopez-Bellido, F. J., 2001. "Effects of long-term tillage, crop rotation and nitrogen fertilization on bread-making quality of hard red spring wheat." *Field Crop Res.*, vol. 72, pp. 197-210.

[18] Ibrahim, M., Ul-Hassan, A., Igbal, M., and Valeem, E. E., 2008. "Response of wheat growth and yield to various levels of compost and organic manure." *Pakistan J.of Bot.*, vol. 40, pp. 2135-214.

[19] Mohammad, F., Khan, T., Afridi, A. M., and Fatima, A., 1997. "Effect of nitrogen and carbonic anhydrase, net photosynthetic rate and yield of wheat." *Photosynthetica*, vol. 34, pp. 595-598.

[20] Ercoli, E., Lulli, L., Mariotti, M., Masoni, A., and Arduini, I., 2008. *Post-anthesis dry matter and nitrogen dynamics in durum wheatas affected by nitrogen supply and soil water availability* vol. 28. Europ: J. Agronomy. pp. 138-147.

[21] AL-Nouri, M. A., 2005. *Effect of nitrogen fertilization and supplementary irrigation on growth, yield and quality characteristics of some local bread wheat varieties (Triticum aestvium L)*. Msc. thesis, Faculty of Agric, Almosal University, Irag.

[22] Johnson, V. A. and Mattern, P. J., 1987. *Wheat, rye and triticale in olson, R.A frey, K.J.(eds). Nutritional quality of ceral grains. Genetic and agronomy improvement*. Inc., Madison,WI,USA., pp. 133-182.

[23] Upadhaya, V. B., Tiwari, J. P., Koshta, L. D., and Kwatra, S., 1993. "Studies on correlation and regression of growth and yield of wheat (Triticum aestivum) varieties under late sown conditions." *Res. J., J.N.K.V.V.*, vol. 27, pp. 10-15.

Table-1. Mean of AE, PE, IE, RE and grain protein content as affected by water stress, N and organic manure

2010/2011						**2010/2011**				
treatments	**AE(kg kg^{-1})**	**PE(kg kg^{-1})**	**IE(kg kg^{-1})**	**RE%**	**Grain Protein %**	**AE(kg kg^{-1})**	**PE(kg kg^{-1})**	**IE(kg kg^{-1})**	**RE %**	**Grain Protein %**
+M	21.9	35.8	42.5	35.8	12.4	23.0	34.4	39.4	35.1	13.2
-M	9.8	33.3	40.8	20.7	13.9	12.6	34.1	35.1	28.8	14.2
$LSD_{0.05}$	0.9	4.3	0.6	0.6	1.1	2.3	3.2	4.5	0.9	1.0
W1	20.7	43.1	42.2	34.6	12.4	23.2	39.4	38.4	41.4	12.8
W2	13.0	35.8	42.5	27.0	13.4	17.0	35.4	37.7	28.1	14.0
W3	13.8	24.9	40.2	23.1	13.7	12.9	28.2	35.6	29.1	14.2
$LSD_{0.05}$	2.0	4.2	0.8	0.6	0.6	0.4	3.5	1.6	9.6	1.0
N0	10.9	33.2	40.7	22.7	12.6	13.2	33.7	36.6	30.6	13.3
N1	18.5	33.9	42.1	27.2	12.9	20.2	33.5	36.8	32.2	13.8
N2	18.2	36.7	42.5	34.9	14.0	19.9	35.5	39.0	33.1	14.0
$LSD_{0.05}$	0.7	1.8	1.3	2.4	0.6	1.5	2.3	1.4	2.5	0.4

Table-2. Mean of AE, PE, IE, RE and grain protein content as affected by interactive effects of water stress, N and organic manure on wheat plant

			2010/2011		**2011/2012**	
treatments			**AE(kg kg^{-1})**	**Grain Protein %**	**AE(kg kg^{-1})**	**Grain Protein %**
W1	-M	N0	13.4	13.3	8.9	13.2
		N1	12.1	10.9	14.3	12.4
		N2	16.7	11.7	12.6	12.4
	+M	N0	8.9	13.1	24.3	13.2
		N1	14.3	12.9	40.6	14.0
		N2	12.6	14.4	38.7	14.5
W2	-M	N0	4.6	13.0	7.8	14.0
		N1	13.0	10.7	19.2	11.4
		N2	11.8	14.1	16.3	14.5
	+M	N0	16.7	13.1	18.4	13.7
		N1	15.6	12.9	17.1	14.0
		N2	16.8	15.0	23.4	14.1
W3	-M	N0	6.4	15.0	7.0	14.1
		N1	14.4	12.0	17.5	11.5
		N2	6.2	12.7	9.0	13.3
	+M	N0	13.7	14.3	12.8	14.5
		N1	15.0	13.9	12.1	14.8
		N2	27.3	15.7	19.5	15.8
$LSD_{0.05}$ MWN			0.8	1.5	3.7	0.8

Table-3. Mean of AE and grain protein content as affected by interactive effects of water stress, N and organic manure on wheat plant

2010/2011							2011/2012				
treatments		AE(kg kg^{-1})	PE(kg kg^{-1})	IE(kg kg^{-1})	RE%	Grain Protein %	AE(kg kg^{-1})	PE(kg kg^{-1})	IE(kg kg^{-1})	RE %	Grain Protein %
+ M	W1	30.7	42.8	43.8	48.1	13.7	34.6	40.3	43.0	47.6	13.9
	W2	16.4	37.5	42.6	34.4	13.7	19.6	36.4	39.3	28.5	13.8
	W3	18.7	27.2	41.1	24.6	14.6	14.8	26.5	35.6	29.1	15.0
- M	W1	10.7	43.4	40.6	20.9	12.0	11.9	38.4	33.7	35.2	12.7
	W2	9.8	34.1	42.5	19.6	12.6	14.4	34.3	36.2	27.7	13.3
	W3	9.0	22.5	39.3	21.5	13.2	11.2	29.8	35.4	23.5	13.0
$LSD_{0.05}$		1.7	8	2.4	2.7	1.5	0.7	6.4	3.1	8.1	0.8
+ M	N0	16.9	35.0	40.9	30.2	13.5	18.4	34.8	38.6	34.1	13.9
	N1	23.8	35.4	42.6	35.9	13.7	23.3	32.1	38.6	34.4	13.8
	N2	24.9	37.1	44.8	41.1	14.6	27.2	35.8	42.0	36.7	15.0
- M	N0	4.9	31.4	40.6	15.1	11.3	7.9	32.5	34.7	27.0	14.6
	N1	13.1	32.4	41.6	18.4	13.2	17.0	34.8	34.9	29.9	11.3
	N2	11.5	36.3	40.2	28.6	12.8	12.6	35.1	35.9	29.5	12.8
$LSD_{0.05}$		1.1	1.7	1.8	4.2	0.8	2.2	3.2	2.0	NS	0.7
W 1	N0	11.9	41.3	25.7	40.2	12.0	16.6	39.2	39.8	36.0	12.8
	N1	26.5	43.8	34.7	42.2	11.8	27.5	37.6	30.8	38.3	12.8
	N2	23.6	43.9	43.6	44.2	13.3	25.7	41.3	44.6	41.0	13.0
W 2	N0	10.6	36.2	22.5	42.3	12.8	13.1	34.6	30.2	37.1	13.7
	N1	14.3	35.1	24.3	43.0	13.0	18.1	36.1	28.8	36.4	14.0
	N2	14.3	36.0	34.2	42.5	14.4	19.8	35.3	25.4	39.7	14.5
W 3	N0	10.1	22.1	19.7	39.8	13.0	9.9	27.2	21.7	35.2	13.3
	N1	14.7	22.3	22.5	41.0	14.0	14.8	26.8	27.8	35.6	14.7
	N2	16.7	30.1	26.9	40.6	14.2	14.2	29.7	29.4	36.1	14.5
$LSD_{0.05}$		0.2	NS	NS	NS	1.1	2.6	NS	NS	NS	0.2

Table-4. Correlation coefficient between means NUE indices (PE, IE, RE& AE) and grain yield due to the effects of watering interval, organic manure and nitrogen level during 2010/2011(below) and 2011/2012(above) seasons

	PE	IE	RE	AE	yield $plant^{-1}$
PE		0.4^{**}	0.5^{**}	0.5^{**}	0.5^{**}
IE	0.3^{*}		0.5^{**}	0.6^{**}	0.8^{**}
RE	0.4^{**}	0.5^{**}		0.5^{**}	0.7^{**}
AE	0.4^{**}	0.5^{**}	0.8^{**}		0.6^{**}
yield $plant^{-1}$	$o.4^{**}$	0.6^{**}	0.9^{**}	0.8^{**}	