Response of wheat to different N- applications and irrigation systems under arid conditions

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Abstract

The aim of this work was to study, nitrogen fertilization under different irrigation systems and the consequent effect on the performance and yield of wheat in a newly reclaimed soil. The experiments were conducted at El-Bostan farm, Nobaria where the soil is sandy calcareous in nature and of a poor nutritional quality. Three N-fertilizers were used namely ammonium suphate (AS), Urea formaldehyde (UF) and chicken manure (Ch.M). Treatments included three rates of nitrogen: 75, 100 and 125 kgN/fed.

Irrigation of the experiment followed once a week through the growing season (20 weeks) using three irrigation systems,(surface, drip and sprinkler). At maturity, yield and yield attributes were assayed.

Straw yield ranged between 1.11 and 5.89 kg / plot. Ammonium sulphate and urea formaldehyde treatments gave more straw yield under drip irrigation than under surface irrigation. Grains yield ranged between 0.54 and 2.62 kg / plot. Surface irrigation gave the lowest grains yield and drip irrigation gave the highest yield of grains.

N-uptake ranged between 17.4 - 36.5 and 27.7 and 81.6 g N/plot for straw and grain yields respectively. Sprinkler irrigation gave the highest N – uptake under all N – rates and sources compared to drip or surface irrigation. Phosphorus uptake by straw ranged between 0.16 and 1.82 g P / plot and by grains between 4.4 and 28 g P/plot.. Urea formaldehyde and chicken manure treatments recorded higher P uptake by both straw and grains than ammonium sulphate treatment. Surface irrigation gave higher P uptake compared to drip or sprinkler irrigation. Amounts of K uptake by wheat straw ranged between 25.5 and 93.6 g / plot and by grains between 6.0 and 17.7 g/ plot. .

N-utilization efficiency ranged between 29 and 68%. Urea formaldehyde gave a systematic increase in utilization efficiency by increasing N – dose. the values started with 39% for the first dose and went up to 43 % for the second dose then went down to 34 for the third dose. Under sprinkler irrigation, ammonium sulphate and also urea formaldehyde recorded their best performance in connection to N-use efficiency

Sprinkler irrigation combined with the high rate of either urea formaldehyde or chicken manure, gave the best water and nitrogen expenditure.

Introduction

In the newly reclaimed sandy soils of Egypt, modern irrigation systems, such as sprinkler and drip, are being widely used and have proved to be more efficient than surface irrigation. The combination of irrigation systems with organic or slow release fertilizers has been tried in order to attain higher yields. Almost 50% of the reclaimed areas are cultivated with wheat. The productivity in such sandy areas is far less than the yielding ability of most cultivars due to poor soil fertility, decreased water and fertilizer use efficiency and also bad management. Metwally and Khamis (1998) indicated that, the N requirements of wheat could not be met by the separate application of any organic source examined. The best mixture ratio between organic and inorganic N sources was 1:1. The greatest physiological efficiency was noticed, however, where organic N sources were applied alone. Gupta *et al* (2000) reported that, combined application of urea and farm yard manure significantly enhanced available N status over similar N addition through urea alone. They also indicated that, available P and K content of the soil decreased with successive rise in levels of N addition through urea whereas the status of these nutrients increased in plots receiving combined application of urea and manures. Jeffrey and Bouchard (1999) studied the effect of intensity and duration of nitrogen deficiency on wheat grain number in order to develop optimum N fertilizer management strategies. Rates and dates of N fertilizer application were varied in field trials in 1990 – 96 on a sand clay loam soil. They developed a nitrogen deficiency index (NNI), where seven criteria describing the deficiency were estimated for each treatment. Their results indicated that, whatever the grain number component affected (spike number per square meter or grain number per spike), the relative grain number (RGN) appeared to depend on the history of the deficiency.

Also, Nanwai *et al* (1998) reported that, Highest grain yield of wheat (7.04 and 6.05 t / ha) was recorded with 125% of the recommended dose of inorganic fertilizers (150, 75 and 50 kg N, P205 and k20/ha) integrated with 25 kg ZnSO4 and organic fertilizer (farmyard manure) at 10 t/ha. Lotfollahi *et al* (1997) conducted experiments in pots to determine the effects of subsoil nitrogen (N) on grain yield and grain protein concentration (GPC) of wheat. using a sandy soil low in available N. Their results showed that, the subsoil N increased root growth and this resulted in increased water use efficiency. Application of 150 mg N at 60 cm depth, 2 weeks after anthesis, significantly increased grain yield and GPC. It was also shown that, although there was an increase in the rate of N uptake by the roots, the main factor that influenced the utilization of subsoil N was the root length density.

Therefore, the aim of this work is to study, in a comparative way, the different aspects of nitrogen fertilization management under different irrigation systems in relation to the performance and yield of wheat in a sandy calcareous soil.

Materials and methods

The experiments were conducted at El-Bostan farm, Nobaria where the soil is sandy calcareous in nature and of a poor nutritional quality. Some physical and chemical characteristics of the soil are shown in Table (1). 100 Kg/fed. Super phosphate was mixed with the soil. The field was divided into three main blocks one was prepared for surface irrigation , the second and the third were equipped for drip and sprinkler irrigation systems respectively. Plots of 2X3.5m (1/600 Fed.) were established in each block to allow for three replicates for each fertilization treatment.

Table (1) : Some physical and chemical properties of the studied soil.

Soil property	Value
Location	El-Bostan
Texture	Sandy Calcareous
EC dS/m	10
pH	8.5
Total N (mg/100g)	65.5
Available-N(mgN/100 g)	5.2
Available P (ppm)	22.2
Available K (ppm)	360
Available SO_4 (ppm)	200
O.M %	0.3
$Ca(CO_3)$%	17.0

Three N-fertilizers were used namely ammonium suphate (AS) , Urea formaldehyde (UF) and chicken manure (Ch.M). Treatments included three rates of nitrogen: 75, 100 and 125 kgN/fed. Ammonium sulphate was applied in three doses, the first (30%) at planting , the second (40%) at tillering and the third (40%) at spike formation. Whereas urea formaldehyde and chicken manure were added as single dose before seeding.

Wheat seeds (sakha 69) as recommended for this region were treated with an appropriate fungicide and sowed at a rate of 70 kg/fed. on the 15th of November 2002. Plant heights were monitored after 6, 12 and 20 weeks from planting.

Irrigation of the experiment followed once a week through the growing season (20 weeks) using the three irrigation systems (surface, drip and sprinkler).

After complete maturity, plots were harvested and the yields of straw and grains were estimated. Samples were taken to determine their content of nutritional elements. Water and Nitrogen Use Efficiencies were calculated using water input and N-uptake data for each N- Fertilizer under each irrigation system. Standard methods of determination were followed according to Cottenie *et al*., 1982 and results were subjected to statistical analysis.

Results and discussion

Straw and grain yield

Straw yield ranged between 1.11 and 5.89 kg / plot (Table 2). The effect of N-source on the straw yield is evident. Also the rate of N – application seemed to be of special effect within each irrigation system. Under surface irrigation, there was a gradual increase of straw yield as the N- rate increased from 75 to 125 kg N/fed. High N-rate of ammonium sulphate yielded almost twice as much straw compared to the low rate. This wide difference, however, is not applicable in case of urea formaldehyde or chicken manure where the differences were much narrower. Drip irrigation treatments gave generally higher straw yield in comparison with surface irrigation. The effect of N-rate is not so much evident as the effect of N – source. Chicken manure again gave the highest straw yield as in the case of surface irrigation. It should be noticed that both ammonium sulphate and urea formaldehyde treatments gave more straw yield under drip irrigation than under surface irrigation.

Sprinkler irrigation, on the other hand, gave remarkably higher straw yield in the ammonium sulphate treatment. This observation does not extend, however to the urea formaldehyde or chicken manure treatments. The latter two N- sources gave relatively lower straw yield than similar fertilization treatments under drip or surface irrigation.

Grains yield as shown in Table (2) reflected a rather different trend. Grains yield ranged between 0.54 and 2.62 kg / plot. Surface irrigation gave the lowest grains yield and drip irrigation gave the highest yield of grains. The effect of N - rate, again, seemed not to be of major impact on grain yield as seen from Table (2), the source of nitrogen played the principal role in grains production. Slow released N- fertilizer as urea formaldehyde in this case and also organic sources as chicken manure gave relatively higher grain yields. This may be due to the continuous supply of N – along the growing season and especially at the stage of grains formation. Misra and Prasad (2000) .affirmed that for sustained production in a rice - wheat cropping system, integrated nutrient management involving both organic manures / residues and chemical fertilizers was essential. In this connection it should be noted that ammonium sulphate, readily soluble and available, could be a good source of nitrogen at the beginning of plant development but not at the final stages of growth unless added to the soil in several doses.

Nitrogen, phosphorus and potassium uptake by wheat plants

N-uptake (Table3) by wheat straw ranged between 17.4 and 36.5gN/plot. Although the differentiation in straw yield among different treatment was so wide and noticeable, the N- uptake does not reflect a great differences among treatments this may indicate different N – concentrations in straw of different treatment. On the contrary, N- Uptake by grains is much more variable among different N - fertilizer and irrigation treatments. N – uptake by grains ranged between 27.7 and 81.6 g N/plot. Sprinkler irrigation gave the highest N – uptake under all N – rates and sources compared to drip or surface irrigation.

Grant *et al* (2001) stressed the importance of N fertilization timing for wheat. Also, Patel *et al* (1994) stated that wheat grain yield was not significantly affected by N source in a field experiment on loamy sand soil. Metwally and Khamis (1998) concluded that, the N requirements of wheat could not be met by the separate application of any organic source examined.

Phosphorus uptake by straw ranged between 0.16 and 1.82 g p / plot (Table4). Grains P ranged between 4.4 and 28 g p/plot. In general, P uptake by straw was considerably low in comparison with grains P uptake. Organic N- fertilizers seemed to provide more P to the plant in comparison with ammonium sulphate. Urea formaldehyde and chicken manure treatments recorded higher P uptake by both straw and grains than ammonium sulphate treatment. In this respect the N - rate also gave an additional effect since higher rates of Urea formaldehyde or chicken manure means higher rates of organic matter which in turn increase the availability of soil phosphorus through the effect on soil ph and on the solubility of phosphates due to produced organic acids in the soil. The effect of the irrigation system on P uptake is evident in this case. . *Ottman and Pope ,* (2000) reported similar results on irrigated wheat.

Surface irrigation gave higher P uptake compared to drip or sprinkler irrigation. This might be due to the abundance of water under surface irrigation which helps in the hydrolysis of organic N - fertilizer in the soil .

As seen from Table (5), amounts of K taken up by wheat straw ranged between 25.5 and 93.6 g / plot. Ammonium sulphate treatments gave lower amounts of K compared to urea formaldehyde and chicken manure treatments. The lowest N - rate (75 kg / fed.) gave the lowest K uptake compared to the other two rates (100 and 125 kg N/fed). Uptake of K by grains ranged between 6.0 and 17.7 g/ plot. Such amounts are extremely low compared to N – uptake or even P uptake by grains. K content in grains seems not to be effected by the different variables like irrigation regime, N - source or N - rate. Khan *et al* (2000) and Olesen *et al* (2000) empathized the positive effect of organic N applications on nutrients absorption.

Nitrogen utilization efficiency

The N-utilization efficiency % was calculated using the total N - uptake by straw and grains of one unit area (feddan) and dividing by the amount of N applied in each fertilization treatment and multiplying by 100, Table 6. The percentages representing the N- utilization efficiencies (Tables) reflect the combined effect of N - source, N – dose and irrigation system. So, it is easy to compare the utilization efficiency of fertilize nitrogen under each irrigation system, on one hand, and among the three irrigation systems used, on the other. From Table (6), it is clearly shown that under surface irrigation, ammonium sulphate gave the lowest values. N rate played a little role since the values ranged between 29 and 35. Urea formaldehyde gave a systematic increase in utilization efficiency by increasing N - dose the values started with 39% for the first dose and went up to 43 % for the second dose then went down to 34 for the third dose. Here, it is interesting to note that under surface irrigation, a readily soluble and available N - source like ammonium sulphate might be easily lost in drainage water and thus lower efficiency of N - fertilizer could be encountered. On the other hand, urea formaldehyde, being slow released, may take much more time to hydrolyze and to be ready for plant absorption and therefore is less susceptible to loss by leaching.

It is important to note that higher rates of N in this case, did not mean higher utilization efficiency. This observation was repeatedly noticed. Chicken manure treatments recorded the highest efficiency reaching 68% but again dropped down to 41% with the highest N - rate.

Under drip irrigation system, Table (6), a similar trend is noticed but with slightly different magnitude. The performance of ammonium sulphate is much better under this system giving 51% for the first N rate and 43% for the second and 33% for the third rate. The increase in N-use efficiency of ammonium sulphate under drip irrigation might be due to diminished possibility of leaching losses of nitrogen. Urea formaldehyde, also, recorded higher N-use efficiency under this system. Chicken manure, on the other hand, reflected values similar to that under surface irrigation especially under the lowest N-rate (75kg/fed) . In general, N-use efficiency of chicken manure (Table 6) fluctuated between 49 and 51%.

Under sprinkler irrigation, ammonium sulphate and also urea formaldehyde recorded their best performance in connection to N-use efficiency . It is worthy to note that increased N-use efficiency can be related to either higher yield or rather better quality (N%). Therefore, it is important to take the yield into consideration.

Water and Nitrogen expenditure in relation to grain production

Dividing the amounts of irrigation water input in each irrigation system on the grain yield of each corresponding treatment would give an indication of how much water (m^3) is needed to produce 1 kg of wheat grains. Also, dividing the consumed amount of fertilizer nitrogen by the yield of grains, would give another indication of how much nitrogen (kg N) is needed to produce 1 kg of wheat grains. Table (7) contains the calculated water and nitrogen expenditure for all studied treatments. It is shown that surface irrigation recorded the highest water expenditure. It is also obvious that increasing the rate of nitrogen might decrease the water expenditure. Differences among N-sources are also evident, chicken manure seems to contribute more positively in this respect than ammonium sulphate . On the other hand, nitrogen consumption does not reveal that much differences either in relation to N-source or N-rate. However, under drip and sprinkler irrigation, the best expenditure of N is noticed. Similar conclusions were drawn by *Sandhu et al* (2000) . Therefore, taking the yield of grains of each treatment into consideration, it could be stated that sprinkler irrigation combined with the high rate of either urea formaldehyde or chicken manure, gave the best water and nitrogen expenditure.

Table (2): Straw and grain yield of wheat (kg/plot) as affected by adopted irrigation and fertilization regimes.

Fertlization Irrigation	Yield	Ammon. Sulfate kg/fed.			Urea formald. kg/fed			Chicken manure kg/fed		
		75	100	125	75	100	125	75	100	125
Surface	Straw	1.83	2.54	3.37	3.44	4.03	4.27	5.02	5.67	5.00
	Grains	0.54	0.99	1.03	0.95	1.63	1.60	1.67	2.40	1.94
Drip	Straw	2.91	3.68	3.86	4.11	5.23	5.30	5.66	5.29	5.89
	Grains	1.11	1.05	1.05	1.45	1.83	2.22	2.16	2.03	2.53
Sprinkler	Straw	4.53	4.11	4.31	3.53	4.23	5.86	4.44	2.84	3.70
	Grains	1.82	1.87	2.14	1.36	2.06	2.62	1.67	1.97	2.54

LSD 0.05 I = 0.7330 ** I X S = 0.7364*
straw S = 0.7330 ** I X R = 0.8269 **
R = 0.7330 ** S X R = 1.432^{ns} I X S X R = 1.432^{ns}
LSD 0.05 I = 0.7776 ^{ns} I X S = 5.062 ^{ns}
Grains S = 0.7776 ^{ns} I X R = 4.087 ^{ns}
R = 0.7776 ** S XR = 4.087^{ns} I X S X R = 7.079^{ns}

Table (3): N-uptake (gN/plot) by wheat straw and grains at maturity stage as affected by adopted irrigation and fertilization treatments.

Fertlization Irrigation	Yield	Ammon. Sulphate kg/fed.			Urea formaldehyde. kg/fed			Chicken manure kg/fed		
		75	100	125	75	100	125	75	100	125
Surface	Straw	17.41	20.19	34.30	21.53	23.31	23.24	27.56	31.83	27.54
	Grains	27.74	29.08	40.08	28.16	49.04	48.87	56.40	81.65	59.15
Drip	Straw	25.72	30.53	35.19	19.65	23.82	26.62	28.47	23.18	36.49
	Grains	38.67	42.06	33.50	42.58	41.32	50.30	58.40	58.63	70.78
Sprinkler	Straw	27.54	32.45	29.51	21.65	22.74	33.56	23.87	15.25	24.21
	Grains	70.16	61.24	68.36	39.77	67.44	67.34	45.64	50.09	68.33

LSD 0.05 I = 6.998^{ns} I X S = 6.063^{ns}
straw S = 6.998* I X R = 6.154**
R = 6.998^{ns} S X = 6.154^{ns} I X SXR = 10.66^{ns}

Table (4): P-uptake (gP/plot) by wheat straw and grains at maturity stage as affected by adopted irrigation and fertilization treatments.

Fertlization Irrigation	Yield	Ammonium sulfate kg/fed.			Urea formald.kg/fed			Chec.manure kg/fed		
		75	100	125	75	100	125	75	100	125
Surface	Straw	0.16	0.23	0.29	0.26	0.42	0.45	0.69	1.05	0.78
	Grains	10.50	9.94	12.44	18.14	18.09	22.70	28.19	25.58	22.98
Drip	Straw	0.93	088	O96	1.02	1.15	1.17	1.81	1.32	2.12
	Grains	4.44	4.94	4.87	7.43	8.46	8.47	12.28	11.82	14.12
Sprinkler	Straw	0.68	0.82	0.69	0.63	0.72	0.99	1.82	0.79	1.07
	Grains	6.15	5.35	6.47	5.14	6.96	5.42	7.87	9.57	10.90

LSD 0.05 $I = 0.2596^{*}$ $I \times S = 0.1656^{**}$
straw $S = 0.2596^{*}$ $I \times R = 0.2159^{ns}$
$R = 0.2596^{**}$ $S \times R = 0.2159^{**}$ $I \times S \times R = 0.3740^{**}$
LSD 0.05 $I = 1.464^{**}$ $I \times S = 3.272^{ns}$
grains $S = 1.464^{ns}$ $I \times R = 2.844^{**}$ $R = 1.464^{**}$ $S \times R = 2.844^{ns}$
LSD 0.05 $I = 1.464^{**}$ $I \times S = 3.272^{ns}$
grains $S = 1.464^{ns}$ $I \times R = 2.844^{**}$ $R = 1.464^{**}$ $S \times R = 2.844^{n}$ $I \times S \times R = 4.927^{ns}$

Table (5): Table (5): k-uptake (g/plot) by wheat straw at maturity stage affected by adopted irrigation and fertilization treatments.

Fertlization Irrigation	Yield	Ammon. Sulfate kg/fed.			Urea formald. kg/fed			Chicken manure kg/fed		
		75	100	125	75	100	125	75	100	125
Surface	Straw	25.58	44.90	67.43	48.19	61.76	76.94	93.61	113.45	89.93
	Grains	5.99	7.58	9.26	9.80	14.09	14.95	15.26	15.93	12.91
Drip	Straw	38.84	72.32	72.04	45.09	66.30	74.15	90.63	74.02	111.87
	Grains	7.40	8.44	8.04	10.60	10.99	13.30	14.41	14.89	17.71
Sprinkler	Straw	49.82	57.56	60.40	37.61	42.29	62.48	65.10	51.98	62.88
	Grains	9.73	9.98	11.42	7.26	14.42	10.47	12.79	13.82	16.92

LSD 0.05 $I = 1.225^{**}$ $I \times S = 12.49^{*}$
Straw $S = 1.225^{**}$ $I \times R = 12.82^{**}$ $R = 1.255^{**}$ $S \times R = 12.82^{ns}$ $I \times S \times R = 22.21^{*}$
LSD 0.05 $I = 1.749^{**}$ $I \times S = 3.777^{ns}$
Grains $S = 1.749^{ns}$ $I \times R = 2.922^{ns}$ $R = 1.749^{ns}$ $S \times R = 2.922^{ns}$
$I \times S \times R = 5.062^{ns}$

Table (6): Utilization efficiency of applied N-fertilizers
(a) under Surface irigation System.

N-Source	N-Rate Kg/fed	N-Uptake (kg/fed.) straw	grain	total	N-Utilization Efficiency %
Ammonium Sulphate	75	10.45	16.64	27.09	36.12
	100	12.11	17.45	29.56	29.56
	125	20.58	24.05	44.63	35.70
Urea Formaldehyde	75	12.92	16.90	29.82	39.76
	100	13.99	29.42	43.41	43.41
	125	13.94	29.32	43.25	34.61
Chicken Manure	75	16.54	33.84	5038	67.17
	100	19.10	48.99	68.09	68.09
	125	16.47	35.49	51.96	41.57

(b) under Drip irigation System

N-Source	N-Rate Kg/fed	N-Uptake (kg/fed.) straw	grain	total	N-Utilization Efficiency %
Ammonium Sulphate	75	15.43	23.20	38.63	51.51
	100	18.32	25.24	43.56	43.56
	125	21.11	20.10	41.21	32.79
Urea formaldehyde	75	11.79	25.55	37.34	49.79
	100	14.29	24.79	39.08	39.08
	125	15.97	30.18	46.15	36.92
Chicken Manure	75	17.08	35.04	52.12	69.49
	100	13.91	35.18	49.08	49.08
	125	21.89	42.47	64.36	51.49

(c) under Sprinkler irigation System

N-Source	N-Rate Kg/fed	N-Uptake (kg/fed.) straw	grain	total	N-Utilization Efficiency %
Ammonium Sulphate	75	16.52	42.10	58.62	78.16
	100	19.47	36.74	56.21	56.21
	125	17.71	41.02	58.73	46.98
Urea formaldehyde	75	12.99	23.86	36.85	49.13
	100	13.64	40.46	54.10	54.10
	125	20.14	40.40	60.54	48.43
Chicken Manure	75	14.32	27.38	41.70	55.60
	100	9.15	30.05	39.20	39.20
	125	14.53	41.00	55.53	44.42

Table (7): Water and fertilizer nitrogen expenditure in relation to wheat grains production under different irrigation systems.

Irrigation System	Water Input M^3	N-Fert.	Water Expenditure M^3/kg Grains			N-Expenditure KgN/kg Grains		
			75	100	125	75	100	125
Surface	10310	AS	32.2	17.3	16.7	0.23	0.17	0.20
		UF	18.1	10.5	10.7	0.13	0.10	0.13
		Ch.M	9.8	7.2	8.9	0.07	0.07	0.11
Drip	2280	AS	3.4	3.6	3.6	0.11	0.16	0.20
		UF	2.6	2.0	1.7	0.14	0.09	0.09
		Ch.M	1.8	1.9	1.5	0.06	0.08	0.08
Sprinkler	6600	AS	6.0	5.9	5.1	0.07	0.09	0.09
		UF	8.1	5.3	4.2	0.15	0.08	0.08
		Ch.M	6.6	5.6	4.3	0.08	0.09	0.08

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