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FOLIAR UREA AS A SUPPLEMENT OF SOIL NITROGEN APPLICATION FOR WHEAT GROWN UNDER DIFFERENT PLANTING METHODS

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ABSTRACT: Foliar urea application is one of the nitrogen (N) application methods in cereal crops. Yield and yield components may be affected by foliar urea application. A field experiment was conducted at Agriculture Research Center Experimental Station, Giza Governorate, Egypt, to evaluate the effect of soil and foliar application of urea applied in different concentrations and at different stages on yield, yield components, nutrient uptake and grain protein content of wheat (*Triticum aestivum* L). The experiment was laid out in split plot design with three replications. Recommended dose of N fertilizer (90 kg N fad.$^{-1}$) as urea was added at 3 stages (two leaves, tillering and booting stage) as soil application, with flat and/or terrace method of sowing. Soil application of 60 kg N fad.$^{-1}$ as urea was added at 3 stages (two leaves, tillering and booting stage), and 10 kg N as 2.5% urea foliar application at (tillering and booting stage) with flat and/or terrace sowing method. 30 kg N fad.$^{-1}$ soil application as urea added at 3 stages (at two leaves, tillering and booting stage), and 10 kg N as 2.5% urea foliar application at (tillering and booting stage) with flat and/or terrace sowing method. The results revealed that application of N at rate of 60 kg N fad.$^{-1}$ as urea combined with foliar urea produced relative increase since it recorded 4.29%, 2.62%, 13.35%, 1.69%, 12.92%, 15.85%, 14.17% and 1.83% for plant height, spike length, tillers, 1000 grains as well as, straw, grain, biological yields and harvest index, respectively compared with the recommended dose of N as soil application (90 kg N Soil applied). Application of nitrogen at different levels as soil application or combined with foliar urea spray in terrace planting increased nutrients concentrations and its uptake in straw and grains of wheat plants compared with the flat planting. While, the highest values of N, P, K, Fe, Mn and Zn in straw and grains of wheat plants were obtained in plots received 60 kg N fad.$^{-1}$ + foliar urea spray compared with all other treatments. The results indicated that nitrogen use efficiency (NUE) decreased with increasing N rate as soil application. Maximum nitrogen use efficiency (50.61%) was recorded at application of 60 kg N fad.$^{-1}$, as soil application along with 2.5% urea as foliar application and minimum of it (39.4%) was recorded at 90 kg N fad.$^{-1}$, as soil application along with 2.5% urea as foliar application. The plants which fertilized with the rate of 60 kg fad.$^{-1}$ + foliar urea spray with terrace planting gave the best protein content in wheat grains (11.43%). The residual nitrogen in the soil was significantly increased with increasing application of nitrogen fertilizer. It was noted that plots that received 90, 60 and 30 kg N fad.$^{-1}$ significantly retained more nitrogen and was higher by 42.3, 35.9 and 31.1%, respectively than the control treatment.

Key words: Wheat, yield components, foliar urea, NPK uptake.

INTRODUCTION

The role of macro and micro nutrients is critical in crop nutrition for achieving higher yields. The soils of Egypt are deficient in nitrogen and are supplemented with chemical fertilizers for improving the crop productivity. Nitrogenous fertilizers play a vital role in modern farm technology; however only 20-50% of the soil applied nitrogen is recovered by the annual crops **(Bajwa, 1992).** When addition over nitrogen is lost from soil system through

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denitrification, volatilization and leaching. The partial and in-efficient use of nitrogen results in lower crop harvests. Moreover, mineral fertilizers are energy intensive to produce and are very expensive. The present price hike of fertilizers is one of the main constraints to increase the economic yield of crops. Thus efforts are needed to minimize its losses and to enhance its economic use.

Foliar fertilization, that is nutrient supplementation through leaves, is an efficient technique of fertilization which enhances the availability of nutrients. It has been observed that utilization of fertilizers especially urea applied through soil is not as effective as when it is supplied to the plant through foliage along with soil application **(Mosluh *et al.,* 1978)**. It also ensures the ample availability of nutrients to crops for obtaining higher yield **(Arif *et al.,* 2006)**. Several researchers justified the idea that nutrients (like N) may be taken up through roots and leaves and may spread within the plant **(Ahmed and Ahmed, 2005).** The efficiency of N assimilation through foliage, however, depends upon several factors including varieties or genotypes.

Wheat (*Triticum aestivum* L.) is a stable food for a large numbers of the world population including Egypt and considered the first strategic food crop in Egypt. Where, wheat is the major source of calories and protein for a large segment of the world population, the wheat production occupies a central position in forming agricultural policies and dominates all crops in acreage and production.

Terrace planting system was used in cultivation for centuries. Raised terrace cultivation has traditionally been associated with water management **(Sayre, 2003).** Egypt face a water crisis, and they are among the most arid regions in the world, with limited renewable water resources that are unequally distributed in space and time. Limited irrigation is an important constraint for wheat production in rain fed, tropical, arid, and semi-arid regions. In scarce rainfall conditions and less irrigation, the best management option for N and irrigation levels is to maintain the maize-wheat cropping sequence **(Lenka and Singh, 2011). Mohamed (1994)** reported that irrigation at 60% irrigation requirements gave the highest grain yield and harvest index in wheat, while water use efficiency (WUE) was the highest with 85% irrigation requirements. Terrace planting is practiced in many parts of the world to reduce the cost of production and irrigation water **(Abdelhadi *et al.,* 2006).** Raised terraces were introduced to rice-wheat systems in the mid-1990s, initially for wheat, inspired by the success of irrigated maize-wheat on permanent raised terraces (PRT) in Mexico. Many advantages of growing wheat on terrace have been reported including increased yields, opportunities for mechanical weeding and improved fertilizer placement, irrigation water savings, reduced lodging, water logging, seed rate and opportunities for intercropping **(Humphreys and Roth, 2008).**

This study was initiated to investigate the efficiency of foliar application of urea for yield and yield components of wheat and when applied at different growth stages, also nitrogen use efficiency.

MATERIALS AND METHODS

A field experiment was conducted at Agriculture Research Center Experimental Station, Giza Governorate, Egypt. The soil sample at depth (0-30 cm) of the experimental area was taken to analysis and determines some soil physical and chemical properties according to the standard methods **(Rebecca, 2004).** The data of analyses are presented in Table 1a. The soil moisture constants (% per weight) and bulk density (Mg/m^3) at depth of 0 - 60 cm are shown in Table 1b.

The experiment was laid out in split plot design with three replications. The treatments were as follows;

Main plots: Planting methods. Flat method (F), Terrace method (T).

Sub plots:

1- Control (no N fertilizers).

2- Recommended dose of N fertilizer (90 kg N $fad.^{-1}$) as urea was added at 3 stages (at two leaves, tillering and booting stage) as soil application.

Table 1a. Physical and chemical properties of soil under study

Property	Value	Property	Value
Sand (%)	27.48	Available micronutrients (mg kg^{-1})	
Silt (%)	34.22	Fe	6.71
Clay (%)	38.30	Mn	6.52
Texture	Clay loam	Zn	4.68
$CaCO_3$ $gkg^{-1}{}_3$	45.6	Soluble ions (meq/L)	
EC (dS m^{-1})	2.96	Ca^{++}	13.8
pH (1:2.5) susp.	7.88	Mg^{++}	10.2
Organic matter (%)	2.29	Na^{+}	4.3
Available macronutrients (mg kg^{-1})		K^{+}	0.68
N	33.30	HCO_3^{-}	5.8
P	5.50	Cl^{-}	8.0
K	360	$SO^{--}{}_4$	15.8

Table 1b. Soil moisture characteristics

Depth	Field capacity (FC) (%) by weight	Wilting point (WP) (%) by weight	Available water (AW) (%) by weight	Bulk density (BD) Mg/m^3
0-15	37.9	18.6	19.3	1.19
15-30	35.8	17.8	18.0	1.23
30-45	32.1	16.1	16.0	1.27
45-60	31.7	15.9	15.8	1.34

3- 60 kg N $fad.^{-1}$ soil application as urea added at 3 stages (at two leaves, tillering and booting stage), and 10 kg N as 2.5% urea foliar application (at tillering and booting stage).

4- 30 kg N $fad.^{-1}$ soil application as urea added at 3 stages (at two leaves, tillering and booting stage), and 10 kg N as 2.5% urea foliar application (at tillering and booting stage).

A surfactant tween-80 was mixed 0.1% *V/V* (1 ml/1 liter) with the solution to increase adhesion of solution with plant foliage.

All plots of the experiment received 30 kg P_2O_5/fad., as calcium super phosphate (15.0% P_2O_5) potassium was added at a rate of 48 kg K_2O/fad., as potassium sulphate (48% K_2O). The soil was prepared flat and raised terrace with furrows made by labors. Also plants of all treatments received foliar sprays of Fe, Zn and Mn in the mineral forms at a rate of 0.5 g/l from the three micronutrients at 30 days after sowing. At harvest, data for agronomic parameters including plant height (cm), spike length (cm), tillers (m^{-2}), 1000 grain weight (g), straw, grain, biological yields (kg $fad.^{-1}$) and harvest index (%) were recorded. Grain samples were taken and dried in an oven at 70°C. One half gram samples of ground plant materials were wet digested using mixture of concentrated sulphric and perchloric acids. Total N was determined in the dry grains using Kjeldahl method; total P was photometrical determined using ammonium molybdate method; while total K was determined using flame photometer. Nitrogen content was determined and converted to protein by multiplying by 6.25. Micronutrients were measured using atomic absorption spectrophotometer, according to **Chapman and Pratt (1978).**

Nitrogen Use Efficiency (NUE)

N-uptake by grains (fertilized) – N uptake by grains (control) ÷ Rate of fertilizer applied ×100

Irrigation Water Applied (IWA)

Submerged flow orifice with fixed dimension was used to measure the amount of water applied, as the following equation **(Michael, 1978).**

$$Q = CA\sqrt{2gh}$$

Where:

Q = discharge through orifice, (L/sec).

C = coefficient of discharge, (0.61).

A = cross-sectional area of the orifice, cm^2.

g = acceleration due to gravity, $cm/sec.^2$ (981 $cm/sec.^2$).

h = pressure head, causing discharge through the orifice, cm.

Water Utilization Efficiency (WUE)

Applied irrigation water is used to describe the relationship between production and the amount of water applied. It was determined according to the following equation **(Jensen, 1983)**:

$$WUE = \frac{\text{yield (kg)/fa.}}{\text{Seasonal applied water (m}^3\text{/fad.)}}$$

Surface soil samples (0 – 30 cm) were collected after harvesting air-dried, ground, good mixed, sieved through a 2 m sieve and analyzed for chemical available N, P, K, Fe, Mn and Zn as descriterrace by **Soltanpour (1985).** The differences between the means of the different treatments were compared by using LSD test at 5% probability according to **Snedecor and Cochran (1980).**

RESULTS AND DISCUSSION

Yield and Yield Components

Effect of planting methods

The results of the effect of planting methods on yield attributes, straw, grain and biological yields and harvest index are revealed in Table 2, the results indicated that the highest plant height (99.17 cm) was recorded from terrace planting method. On the other hand the lowest value (94.66 cm) was recorded in flat method. Similarly, spike length (16.68 cm), tillers (419.07 m^{-2}), 1000 grains (52.84 g) , straw (3.29 ton $fad.^{-1}$), grain (2.55 ton $fad.^{-1}$) yields, biological yield (5.98 ton fad^{-1}) and harvest index HI (42.48%) were higher in terrace planting method compared to flat method. These results may be due to under the terrace planting system, better field air circulation and stronger light penetration appeared to reduce the surface field moisture and canopy humidity. **Hameed and Solangi (1993)** and **Wang *et al.* (2003)** found that wheat planted on terraces and furrow irrigation showed higher yield and water use efficiency than flat-planted system. **Fahong *et al.* (2011)** showed that the grains per spike and 1000-grain weight of wheat significantly increased under terrace planting in comparison with flat planting, and the grain yield increased as a result of the integrative compensation between these yield components.

Effect of nitrogen levels combined with spray urea

Concerning the effect of different levels of N application alone or combined with urea foliar spraying on yield and contributing characters, the results presented in Table 2 reveal that the application of nitrogen levels combined with foliar spray of urea caused more effective increase of yield attributes compared to soil N application and the control treatments. However, the highest values of yield attributes were obtained due to application of N at rate of 60 kg N $fad.^{-1}$ combined with foliar spray of urea. The percentages of relative increasing were 4.29%, 2.62%, 13.35%, 1.69%, 12.92%, 15.85%, 14.17% and 1.83% for plant height, spike length, tillers, 1000 grain weight, straw, grain, biological yields and harvest index,

Table 2. Effect of planting methods and nitrogen level combined with spray urea on yield and yield contributing characters of wheat plants

Method of planting (M)	Urea treatment (T)	Plant height (cm)	Spike length (cm)	Tillers m^{-2}	1000 grain weight (g)	Straw yield (ton $fad.^{-1}$)	Grain yield (ton $fad.^{-1}$)	Biological yield (ton $fad.^{-1}$)	HI (%)
Flat (F)	Control (without N)	79.78	10.39	294.58	42.10	1.92	1.15	3.07	37.46
	90 kg N Soil applied	95.66	15.07	382.65	51.50	3.18	2.30	5.48	41.97
	60 kg N Soil applied + foliar urea	97.00	14.33	456.35	52.22	3.83	2.95	6.78	43.51
	30 kg N Soil applied + foliar urea	91.33	12.34	316.24	50.28	2.36	1.57	3.93	39.95
	Mean	94.66	13.91	385.08	51.33	2.82	1.99	4.81	41.37
Terrace (B)	Control (without N)	81.37	11.95	310.4 0	43.51	2.24	1.47	3.71	39.62
	90 kg N Soil applied	98.66	16.92	432.21	53.25	3.95	3.00	6.95	43.16
	60 kg N Soil applied +foliar urea	105.66	18.50	467.32	54.30	4.21	3.20	7.41	43.18
	30 kg N Soil applied + foliar urea	93.21	14.63	357.68	50.98	2.75	2.01	4.76	42.22
	Mean	99.17	16.68	419.07	52.84	3.29	2.55	5.98	42.48
LSD .0.05	(M)	0.61	0.48	1.22	0.57	0.04	0.05	0.04	0.15
	(T)	0.86	0.69	1.73	0.81	0.04	0.07	0.06	0.22
	(M*T)	1.22	0.97	2.45	n.s	0.08	0.10	0.09	0.31

respectively compared with the recommended dose of N as soil application (90 kg N $fad.^{-1}$ soil applied). Foliar application of urea has been proved to be an effective technique of N fertilization. The adoption of foliar urea may help reduce the losses due to denitrification, leaching and immobilization, often associated with N fertilization to the soil system **(Gooding, 2005)**. In our experiment, the application of urea through soil + foliar spray at 60kg N $fad.^{-1}$ soil + 2.5% foliar spray generally increased plant height, number of tillers, plant dry weight, straw yield, grain yield, biological yield and harvest index. This suggests the quick absorption of nitrogen due to foliar spray of urea. The above findings are in line with the previous studies. **Maitlo *et al.* (2006)** showed that urea foliar application significantly increased growth yield and yield components of wheat as compared with unsprayed treatment. **Khan *et al.* (2009)** reported that the foliar application of urea significantly increased plant height, spike length, number of grains spike, 100-grain weight grain weight, biological yield and grain yield of wheat.

Interaction effect of planting methods and nitrogen application

Interaction effect of planting method and different nitrogen application as soil or soil with foliar urea are shown in Table 2. The results indicated that the highest values of each of yield attributes, straw, grain yields, biological and harvest index were found in terrace planting method combined with 60 kg N $fad.^{-1}$ + urea spray. However, the lowest values of each of the corresponding parameters were obtained by flat planting with 30 kg N fad.$^{-1}$ + urea spray. **Abdul Majeed *et al.* (2015)** found that the number of grains per spike and 1000-grain weight were significantly higher in terrace planting with the application of 120 kg N ha^{-1} than flat planting at the same rate of N. **Siuliauskas *et al.* (2001)** found that 30 kg N ha^{-1}, applied as foliar spray during heading and at the beginning of milky ripeness increased wheat yield.

Plant Analyses

Nutrient concentrations and its uptake in straw of wheat plants

The results in Table 3 reveal that the application of nitrogen at different levels as soil application or combined with foliar urea spray in terrace planting method increased nutrients concentration of wheat plant straw compared with the flat planting. The highest values of each of N (9.8 g kg^{-1}), P (1.5 g kg^{-1}), K (26.0 g kg^{-1}), Fe (209.8 mg kg^{-1}), Mn (45.8 mg kg^{-1}) and Zn (37.2 mg kg^{-1}) were obtained in plots received 60 kg N fad.$^{-1}$ + foliar spray of urea compared with all other treatments. In case of nutrients uptake, the planting in terrace with soil application of 90 kg N fad.$^{-1}$, 30 kg N fad.$^{-1}$ +foliar spray urea and 60 kg N fad.$^{-1}$ + foliar urea spray caused high nutrients uptake compared with the same treatments in flat planting. However, the N soil application +foliar spray urea were more effective on nutrients uptake by wheat plant compared to the N soil application alone. The maximum N, P, K, Fe, Mn and Zn uptake by straw were (41.26 kg fad.$^{-1}$), (6.31 kg fad.$^{-1}$), (109.46 kg fed^{-1}), (0.88 g fad.$^{-1}$), (0.19 g fad.$^{-1}$) and (0.16 g fad.$^{-1}$), respectively was observed with the application of N at rate of 60 kg fad.$^{-1}$ + foliar urea spray under planting in terrace. The minimum N, P, K, Fe, Mn and Zn uptake by straw were (13.22 kg fad.$^{-1}$), (2.12 kg fad.$^{-1}$), (38.94 kg fad.$^{-1}$), (0.45 g fad.$^{-1}$), (0.091 g fad.$^{-1}$) and (0.064 g fad.$^{-1}$) was observed with the soil application of N at 30 kg fad.$^{-1}$ + foliar spray urea planting in flat. Foliar application of urea has been proved to be an effective technique of N fertilization. **Khan *et al.* (2009)** reported that foliar application of urea significantly increased the N uptake by wheat. It is also due to the foliar urea fertilization during crop growth can improve the mineral status of plants and increase the vigor of plant **(Shaheen, 1989).** From the obtained results it seems that the association of urea as foliar spray with some micronutrients may increase the concentration and uptake of these elements in grains, this effect may be due to the accelerating of micronutrients uptake in the presence of nitrogen as urea foliar spray source. This result is in harmony with those obtained by **Salwau (1992)** who found that Fe, Zn and Mn uptake by wheat grains were significantly increased by foliar application of urea. **Yassen *et al.* (2010)** revealed that spraying wheat plant with (1% urea) showed marked increment in micronutrients concentration and uptake.

Nutrient Concentrations and Uptake in Grains of Wheat Plants

Nitrogen concentration

The results regarding N concentration in grains of wheat plants have been shown in Table 4. It is obvious from the results that N concentration within the plant grains of wheat plants increased by increasing N concentration either in soil or by foliar application. The maximum N concentration in grains was recorded when application of urea by broadcasting at 60 kg N fad.$^{-1}$ as soil application along with 2.5% urea as foliar application which was 1.75%. Minimum absorption of N was noted in control treatment which was 0.83%. Soil application however, showed marginal increasing trend for N in grains of wheat plant when N application was raised from 30 to 90 kg N fad^{-1}. The higher N concentrations reflect the higher absorption of NH_4^+ ions when the urea spray with 2.5%. These results are in line with **Tea *et al.* (2007)** they reported that foliar nitrogen fertilization on wheat at optimum timing increased the remobilization of urea (N) to grain and increased grain protein content. The results also are in agreement with **Swenson *et al.* (2009).**

Nitrogen uptake

The enhanced yield of a crop is often associated with optimum nutrient uptake particularly N. It has been observed that integrated application of N through soil and foliage facilitated the higher N uptake in plants. There was a substantial increase in N uptake in grains of wheat plants sprayed with urea as compared with control. The maximum N uptake

Table 3. Concentrations and uptake of N, P, K, Fe, Mn and Zn in straw of wheat plants

Treatment		Concentration						Uptake					
Method of planting (M)	Urea treatment (T)	N	P	K	Fe	Mn	Zn	N	P	K	Fe	Mn	Zn
		g kg^{-1}			mg kg^{-1}			Kg fad.$^{-1}$			g fad.$^{-1}$		
Flat (F)	Control (without N)	4.4	0.07	1.35	167.5	31.6	22.6	8.45	1.34	25.92	0.32	0.06	0.043
	90 kg N soil applied	7.1	0.13	2.18	192.0	39.8	29.2	22.58	4.13	69.32	0.61	0.13	0.093
	60 kg N soil applied +foliar urea	8.8	0.16	2.50	204.7	42.6	34.7	33.70	6.13	95.75	0.78	0.16	0.13
	30 kg N soil applied + foliar urea	5.6	0.09	1.65	188.4	37.8	26.9	13.22	2.12	38.94	0.44	0.089	0.064
	Mean	6.5	0.11	1.92	188.1	37.95	28.35	19.49	3.43	57.48	0.54	0.11	0.082
Terrace (T)	Control (without N)	4.9	0.08	1.43	174.7	32.8	24.1	10.98	1.79	32.03	0.39	0.073	0.054
	90 kg N soil applied	8.0	0.13	2.27	200.5	41.6	30.7	31.6	5.13	89.67	0.79	0.16	0.12
	60 kg N soil applied +foliar urea	9.8	0.15	2.60	209.8	45.8	37.2	41.26	6.31	109.4	0.88	0.19	0.16
	30 kg N soil applied +foliar urea	6.1	0.11	1.71	199.2	39.9	28.0	16.78	3.02	47.02	0.55	0.11	0.077
	Mean	7.2	0.12	2.00	196.05	40.02	30.0	25.15	4.06	69.54	0.65	0.13	0.10
LSD 0.05	(M)	0.023	NS	0.043	3.27	1.09	1.19	0.78	0.34	1.49	0.011	0.004	0.004
	(T)	0.032	0.013	0.061	4.63	1.55	1.68	1.11	0.48	2.12	0.015	0.005	0.005
	(M*T)	NS	NS	NS	NS	NS	NS	1.57	NS	2.99	0.021	0.008	0.007

Table 4. Concentration and uptake of N, P, K, Fe, Mn, Zn in grains of wheat plants

Treatment		Concentration						Uptake					
Method of planting (M)	Urea treatment (T)	N	P	K	Fe	Mn	Zn	N	P	K	Fe	Mn	Zn
		g kg^{-1}			mg kg^{-1}			Kg fad.$^{-1}$			g fad.$^{-1}$		
Flat (F)	Control (without N)	0.81	0.20	0.46	134.8	22.9	17.6	9.31	2.30	5.29	0.15	0.030	0.020
	90 kg N soil applied	1.51	0.32	0.63	148.7	23.6	20.2	34.73	7.36	14.49	0.34	0.054	0.046
	60 kg N soil applied + foliar urea	1.68	0.43	0.82	161.0	28.0	24.0	49.56	12.68	24.19	0.47	0.083	0.071
	30 kg N soil applied + foliar urea	1.07	0.21	0.52	152.3	26.7	21.6	16.79	3.29	8.16	0.24	0.042	0.034
	Mean	1.27	0.29	0.61	149.2	25.3	20.85	27.60	6.41	13.03	0.30	0.052	0.04
Terrace (T)	Control (without N)	0.85	0.26	0.44	138.0	30.7	20.7	12.49	3.82	6.46	0.20	0.045	0.030
	90 kg N soil applied	1.80	0.42	0.63	158.62	33.54	23.64	54.00	12.60	18.90	0.47	0.10	0.071
	60 kg N soil applied +foliar urea	1.83	0.51	0.91	175.64	35.10	28.61	58.56	16.32	29.12	0.56	0.11	0.092
	30 kg N soil applied + foliar urea	1.62	0.38	0.64	157.31	32.87	25.30	32.56	7.63	12.86	0.32	0.066	0.051
	Mean	1.52	0.39	0.65	157.4	33.05	24.6	39.40	10.1	16.83	0.38	0.080	0.061
LSD 0.05	(M)	0.037	0.013	0.016	2.19	1.36	1.01	0.91	0.34	0.39	0.006	0.003	0.002
	(T)	0.053	0.019	0.023	3.10	1.92	1.43	1.28	0.48	0.55	0.009	0.004	0.003
	(M*T)	0.075	0.027	0.032	4.38	NS	NS	1.81	0.67	0.77	0.013	0.006	0.005

in grains was recorded due to application of urea by broadcasting at 60 kg N fad.$^{-1}$ as soil application along with 2.5% urea as foliar application which was 54.07 kg N fad^{-1}. The minimum N uptake was noted in control treatment which was 11.2 kg fad^{-1}. N uptake as expected increased with the increase in foliar application of urea irrespective of soils used. **Khan *et al.* (2009)** reported that foliar application of urea significantly increased the N uptake by wheat. The foliar spray of 4% urea solution was found to be most effective dose for N uptake by wheat. The high efficiency of foliar urea application was found in this study is in agreement with the findings of **Yildirim *et al.* (2007)** who found highest N uptake by broccoli leaf applying 1% urea solution. **Zahran and Abdoh (1998)** found same result for onion and **Zeidan (2003)** for faba bean. The later recommended that urea might be used as foliar N source to obtain higher growth, yield, N content and uptake.

The results showed that higher N uptake by grains was observed with 60 kg N fad.$^{-1}$ application on terrace system conjunction with 2.5% foliar spray of urea than the same rate in flat planting. Similarly, higher N uptake in straw was also observed with 60 kg N fad.$^{-1}$ application on terraces in conjunction with 2.5% foliar spray of urea. Overall, higher N accumulation in grain and straw was observed under terrace planting than under conventional flat planting. The higher uptake of N under the terrace planting system was associated with greater biomass production of crops and lower loss of applied fertilizer **(Jat *et al.,* 2011)**. In terrace planting, higher N use and agronomic and recovery efficiencies were observed because about one third of applied N fertilizer is also added on terraces during their construction, given that initially fertilizer is broadcasted and then terraces are made by taking soil from furrows on the terraces, leaving more fertile top soil on terraces under the changed land configuration than under flat planting.

Phosphorous concentration and uptake

Results in Table 4 show that phosphorous concentration in wheat grain increased by foliar application of nitrogen than soil application. The relative increase of phosphorous concentration treated with 90 kg N fad.$^{-1}$ as soil application and 60 kg N fad.$^{-1}$ as soil application along with 2.5% urea as foliar application were 27.6 and 62.1% compared with 30 kg N fad.$^{-1}$ as soil application along with 2.5% urea as foliar application. There was insignificant effect of soil and foliar spray of urea on phosphorous uptake of wheat grain. Maximum P uptake (14.5 kg fad.$^{-1}$) was observed with the soil application of 60 kg N fad.$^{-1}$ along with 2.5% urea as foliar spray. The minimum (5.46 kg fad.$^{-1}$) P uptake was obtained by the soil application of 30 kg N fad.$^{-1}$ soil + 2.5% foliar spray of urea.

Potassium concentration and uptake

There was no significant effect of soil and foliar spray of urea on potassium concentration of wheat grain. The maximum K concentration (0.86%) was attained by soil application of 60 kg N fad.$^{-1}$ in conjunction with 2.5% foliar spray of urea. The minimum K concentration (0.58 %) was observed with 30 kg N fad.$^{-1}$ applied to the soil along with 2.5% foliar spray of urea. Almost similar trend was observed for the K uptake of wheat grains. However, K uptake was significantly affected. The application of 60 kg N fad.$^{-1}$ to soil with 2.5% foliar urea yielded maximum K uptake (26.65 kg fad.$^{-1}$).

Grain-micronutrient concentrations and uptake

Table 4 shows that soil application of 60 kg N fad.$^{-1}$ in conjunction with 2.5% foliar spray of urea increased Fe, Mn and Zn concentrations by 23.4, 17.5 and 37.7% compared with control treatment respectively. Also, soil application of 60 kg N fad.$^{-1}$ in conjunction with 2.5% foliar spray of urea increased grain-Fe, Mn and Zn uptake by 200, 159 and 224% over control treatment, respectively. Similar results were observed by **McCrimmon *et al.* (1993) and Magolbo *et al.* (2015)** who reported that nitrogen fertilizers were significantly increased micronutrient concentrations and uptake. **Chude *et al.* (1993)** reported the effect of source of nitrogen on micronutrients and showed that ammonium nitrate increased uptake of Fe, Al, Cu and Zn but not Mn. However, in this study nitrogen fertilizer rate with urea as nutrient source did not show any consistent trend with micronutrient uptake.

Protein content (%)

Data illustrated in Fig. 1 show that soil applied N at recommended dose or different levels of soil application combined with foliar spray urea resulted in increases of protein content as compared with the control treatment. Foliar spray with urea gave greater protein content (%) more than without urea spray. Concerning the interaction between planting methods and foliar spray with urea, Fig. 1 show that the plants which fertilized with the rate of 60 kg fad.$^{-1}$ + foliar spray of urea with terrace planting gave the highest protein content in wheat grains (11.43%). These results may be due to urea application as a source of nitrogen fertilizer had a great role in enhancing the metabolism processing due to the importance of nitrogen in building carbohydrates, protein and fats in the plant tissues. The obtained results are in agreement with those obtained by **Abdo (2001)** who found a slight increase in mungbean seed protein content resulted from 1% urea spray. **Tea *et al.* (2007)** reported that foliar nitrogen fertilization on wheat at optimum timings increased the remobilization of urea (N) to grain and increased grain protein content. Also, **López-Bellido *et al.* (2008)** and **Giambaivo *et al.* (2010)** stated that due to an increase in nitrogen uptake which consider as a building blocks in the synthesis of proteins.

The maximum grain protein content in soil applied 90 kg fad.$^{-1}$ with terrace planting method (11.25%) might be due to the prolong availability of nitrogen to crop in soil applied method as compared to foliar applied. The extent of grain protein content increased significantly with increased N level, which might be resulted from maximum amount of N available to crop during crop growth period. Our findings are in line with the results of **Cowell and Doyle (1993)**, who stated that maximum grain protein content requires consistent and prolonged availability of N through soil and increased N levels increased the grain protein content accordingly. In contrast, **Selles *et al.* (1996)** confirmed that foliar applied N may produce leaf burn and in turn caused reduction in grain protein content.

Nitrogen use efficiency (NUE)

The results showed that NUE was affected by N application rates. The results indicated that NUE decreased with increasing N rate as soil application. Means comparison in treatment compound of N application indicated that maximum nitrogen use efficiency (50.61%) was recorded at application of 60 kg N fad.$^{-1}$ as soil application along with 2.5% urea as foliar application and minimum of it (39.4%) was recorded at 90 kg N fad.$^{-1}$ as soil application along with 2.5% urea as foliar (Fig. 2). These results agree with the finding of **Raun and Johnson (1999)** who reported that rates of high nitrogen decrease NUE in cereal. **Lopez-Bellido and Lopez-Bellido (2001)** indicated that a decrease in NUE with increasing fertilizer rates is because yield rises less than the N supply in soil and fertilizer. **Biswas and Ma (2016)** reported similar results and indicated that NUE decreased with increasing N rates. The nitrogen use efficiency steeply linearly decreased with increasing N levels both in soil and foliar methods however, the decrease was more in soil applied method in comparison to foliar application. The nitrogen use efficiency increased with the nitrogen levels might be due to the maximum availability of N at higher levels for growth and development of crop. Foliar application of N is readily available to crop through stomata of leaves and attain maximum nitrogen use efficiency as compared to soil applied method, **Khattak *et al.* (2017)**.

Wheat terrace planting with an application of 60 kg N fad.$^{-1}$ as soil application along with 2.5% urea as foliar application recorded higher N use efficiency compared with flat planting with the same rate of N application, as a result of higher grain yield and N uptake in plant dry matter (Fig. 2). The higher fertilizer use efficiency in terrace planting was attributed mainly to accumulation of fertile topsoil on terraces, weeds infestation in furrows and mineralization of native as well as applied nutrients, **Jat *et al.* (2011)** and **Hassan *et al.* (2005).** Terrace planting improved plant growth by providing better soil conditions than flat planting. Similarly, **Fahong *et al.* (2004)** reported that generally in flat planting after wheat germination, N fertilizer is applied normally by broadcasting on the soil surface and flood-irrigated, but that it can be band-applied into the furrows with terrace planting, enhancing N use efficiencies. Terrace planting of wheat resulted in increases in grain yield, N uptake in plant dry matter, and use efficiency.

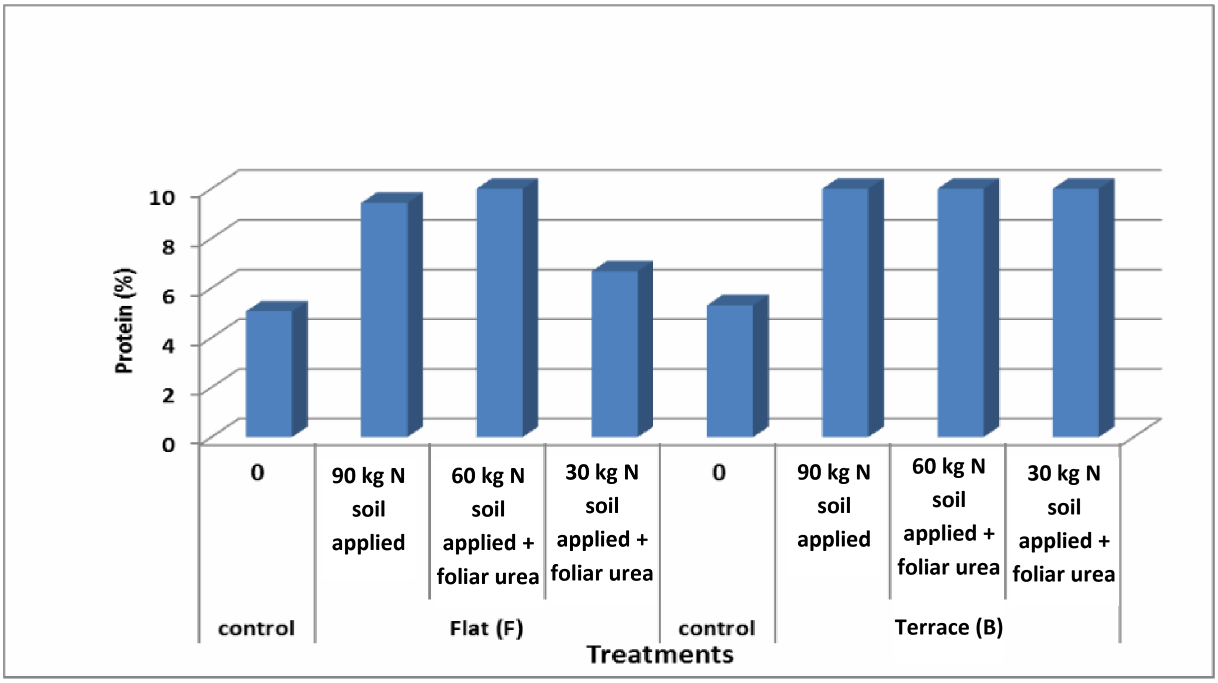

Fig. 1. Effect of nitrogen treatments combined with planting methods (flat and terrace) on protein content (%) in wheat grains

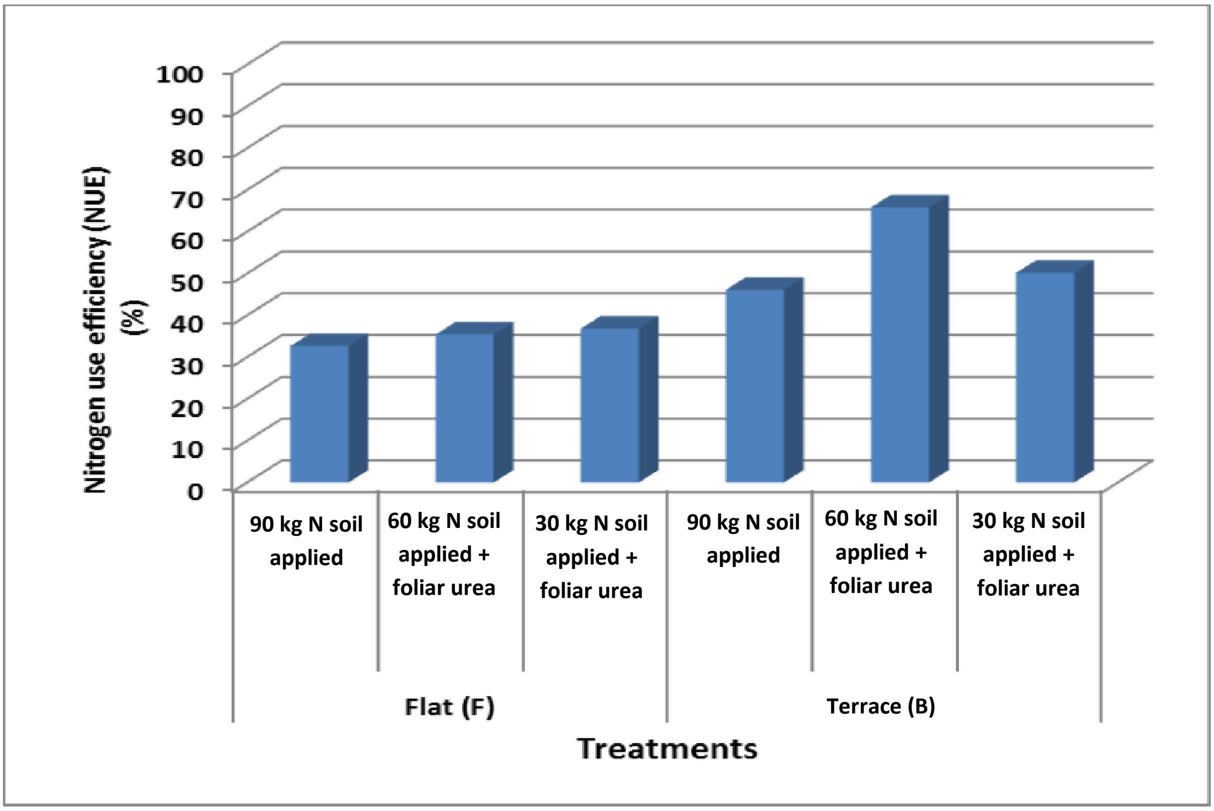

Fig. 2. Effect of nitrogen treatments combined with planting method (flat and terrace) on Nitrogen use efficiency (%) by wheat grains

In case of the interaction between nitrogen fertilizers and planting methods the highest value of ARE was achieved with 60 kg N fad.$^{-1}$ + foliar spray urea in terrace planting. **Moller *et al.* (2009)** found that foliar N fertilization that respond efficiently in terms of productivity, nitrogen use efficiency, and grain protein content. Raised terrace improved N use efficiency by 10% in a study conducted in China **(Fahong *et al.,* 2004).** In another study in Mexico, **Limon-Ortega *et al.* (2000)** reported 13.2% increase in N use efficiency due to terrace planting systems compared with traditional flat bed.

Effects of N addition on soil available concentrations of macro and micronutrients

The applied urea can be hydrolyzed to ammonia/ammonium, by the enzyme urease, and ammonium is further converted into nitrate by ammonia oxidizing bacteria and ammonia oxidizing archaea, leading to an increase in inorganic N in soils and concurrent reduction in soil pH **(Zhang *et al.,* 2012)**. The residual nitrogen in the soil was significantly increased with application of nitrogen fertilizer (Table 5). It was noted that plots that received 90, 60 and 30 kg N fad.$^{-1}$ significantly retained more nitrogen and was higher by 42.3, 35.9 and 31.1%, respectively than the control treatment. The probable insignificant increase in residual nitrogen could be attributed to more losses through leaching or volatilization. Wheat terrace planting with an addition of the same rate of N fad.$^{-1}$ as soil application recorded slight increase in inorganic N in soils (3.1%) compared with flat planting. Although it has been reported that species from acidic and alkaline soils usually prefer different forms of nitrogen **(Van den Berg *et al.,* 2005)**, both high NO^-_3 –N concentration and high NH^+_4 –N concentration can suppress root elongation.

Residual phosphorus was more and similar in plots that received 0 and 30 kg N fad^{-1}. The plots that received 60 and 90 kg N fad.$^{-1}$ were statistically similar but significantly lower by 16.4% and 23.1% compared with control treatment **(Brady, 1984)**. Terrace planting with an application the same rate of N fad.$^{-1}$ as soil addition of recorded slight increase in phosphorus in soils (4.2%) compared with flat planting. The trend was found in this study is in agreement with the findings of **Ngetich *et al.* (2013)**.

Similar, Residual potassium was more and similar in plots that received 0 and 30 kg N fad^{-1}. The plots that received 60 and 90 kg N fad.$^{-1}$ were statistically similar but significantly lower by between 14.4% and 10.2% compared with control treatment in influencing retention of available P and K respectively than the control The possible explanation for decreased P and K may be due to ability of nitrogen fertilizer to mediate their utilization during plant growth **(Brady, 1984)**.

The available concentration of Fe significantly increased with N addition, application of N with rates 90, 60 and 30 kg fad.$^{-1}$ caused relative increase in available concentration of Fe reached about 37.7, 30.6 and 16.7%, respectively compared to control treatment, which is consistent with other studies **(Tian *et al.,* 2015 and 2016)**. High soil available phosphorus (SAP) can reduce Fe solubility by immobilizing Fe **(Mandal and Haldar, 1980)**. Thus, the relationship between SAP and available Fe would be negative, which is supported by our study. When N addition promoted the uptake of SAP, a high level of Fe would be released, thereby increasing the available Fe in soil.

In our study, the available concentration of Mn in the soil showed a significant difference among N additions. However, application of N with rates 90, 60 and 30 kg fad^{-1} caused relative increase in available concentration of Mn reach about 23.3, 18.5 and 8.8%, respectively compared to control treatment. Previous studies found that N addition caused large increases in available Mn concentrations **(Tian *et al.,* 2015, 2016; Wang *et al.,* 2017).**

The available concentrations of Zn significantly changed with the N addition, and the available Zn have maximum value in the 90 kg N fad.$^{-1}$ treatment and significantly decreased with increasing N addition. The minimum value of available Zn concentration appeared in the 30 kg N fad^{-1}. Application of N with rates 90, 60 and 30 kg fad,$^{-1}$ caused relative increase in available concentration of Zn since it reached about 26.7, 23.7 and 11.3%, respectively compared to control treatment.

Table 5. Concentrations of N, P, K, Fe, Mn and Zn in soil after harvesting of wheat plants

Treatment		Concentration					
Method of planting (M)	Urea treatment (T)	N	P	K	Fe	Mn	Zn
		mg kg^{-1}					
Flat (F)	Control (without N)	34.2	9.70	465.0	6.90	7.00	4.78
	90 kg N soil applied	49.4	7.10	390.0	9.38	8.65	5.95
	60 kg N soil applied + foliar urea	46.8	7.90	415.0	8.90	8.24	5.86
	30 kg N soil applied + foliar urea	44.6	8.90	440.0	7.65	7.68	5.22
	Mean	43.75	8.40	427.5	8.21	7.89	5.45
Terrace (T)	Control (without N)	35.6	9.80	470.0	6.90	7.24	4.75
	90 kg N soil applied	49.9	7.90	410.0	9.62	8.92	6.12
	60 kg N soil applied + foliar urea	48.1	8.40	425.0	9.12	8.65	5.92
	30 kg N soil applied + foliar urea	46.9	8.90	450.0	8.46	7.82	5.39
	Mean	45.12	8.75	438.75	8.52	8.16	5.54
LSD 0.05	(M)	0.75	0.19	6.03	0.076	0.057	0.049
	(T)	1.06	0.28	8.53	0.11	0.081	0.070
	(N*T)	n.s	0.39	n.s	0.15	0.11	0.099

Applied irrigation water

The judicious and safe use of inputs (fertilizer, water, herbicides) is having great importance **(Singh *et al*., 2014)**. Results in Table 6 showed that monthly applied irrigation water for wheat plants in all season of growth. Wheat plants are sown on raised terraces and irrigation providing in wide furrows and saving the irrigation water was by 23.3% compared with flat planting method. Furrow irrigated raised terrace planting is more profitable than flat planting. Many advantages of growing wheat on furrow irrigated raised terrace planting system over the conventional flat planting have been reported by **(Sayre and Hobbs 2004; Ram *et al.* 2005)**. **Kumar *et al.* (2010)** also found that with furrow irrigated terrace planting systems, on average 40% water was saved as compared to flat planting.

Water utilization efficiency (WUE)

Water utilization efficiency (WUE) differed under different planting methods (Table 7). The maximum WUE was recorded in terrace planting, which was significantly higher than flat planting. The WUE varied from 0.68to 1.28 kg grain/m^3 under flat planting method, while it was 1.13 to 1.80 kg grain/m^3 under terrace planting method. The relative increase with terrace planting recorded 69.0, 40.6 and 66.2% at 90, 60 and 30 kg fad.$^{-1}$ N as urea, respectively. Terrace planting systems have advantages like better irrigation management, crop establishment and weed control, and less soil compaction **(Dhillon *et al.*, 2004)**. During the last decade, the practice of raised-terrace planting has been popularized in the Indo Gangetic Plains (IGPs) for enhancing productivity and saving irrigation water. The other advantages of terraces include improved

Table 6. Monthly and seasonal applied irrigation water to wheat crop (m^3/fad.)

Month	Applied water (m^3/fad.)		Rate of savings in irrigation water (%)
	Raised terraces (B)	Farmer practices Flat (f)	
17/11	489	585	16.4
21/12	310	417	25.7
21/1	335	435	23.0
18/2	341	446	23.5
19/3	305	422	27.7
Seasonal (m^3/fad.)	1780	2305	22.8

Table 7. Water utilization efficiency under different methods of planting and urea pplication

Urea treatment	Water utilization efficiency (Kg/m^3 water)			The rate of increase (%)
	Raised terraces (B)	Farmer practices Flat (f)	Mean	
90 kg N soil applied	1.69	1.00	1.35	69.0
60 kg N soil applied + foliar urea	1.80	1.28	1.54	40.6
30 kg N soil applied + foliar urea	1.13	0.68	0.91	66.2
Mean	1.54	0.99		

soil structure due to reduced compaction through controlled trafficking, and reduced waterlogging and machinery operations period due to better surface drainage. There are several reports of reduced irrigation or time requirement, with similar or higher yield for wheat on terraces compared with conventional-tilled wheat (**Hobbs and Gupta 2003; Wang *et al.,* 2004**). Also, farmers are showing interest in terrace planting systems due to greater opportunities for relay cropping, *e.g.* wheat + sugarcane, mechanical management of weeds, reduced irrigation time, and improved yields on fine-textured soils prone to waterlogging.

Conclusion

Among the major nutrient required by crops, nitrogen is perhaps the most important of the nutrients because of its biological roles and because it is required in large quantities by the plants. In light of the results, it can be concluded that the application of N at rate of 60 kg N $fad.^{-1}$ as urea combined with foliar urea (2.5%) showed significantly higher results for plant height, spike length, tillers, 1000 grains, straw, grains, biological, protein content in grains $fad.^{-1}$, as soil application yield and harvest index, respectively compared with the recommended dose of N as soil application (90 kg N $fad.^{-1}$ as soil application). Application of nitrogen at different levels as soil application or combined with foliar urea spray in terrace planting increased nutrients concentrations and its uptake in straw and grains of wheat plants compared with the flat planting. The results indicated that nitrogen use efficiency decreased with increasing N rate as soil application.

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الرش الورقى لليوريا كمكمل للإضافات الأرضية لنباتات القمح النامية تحت طرق زراعة مختلفة

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الرش الورقى باليوريا واحدة من طرق الإضافة المستخدمة للأسمدة النتروجينية لمحاصيل الحبوب، حيث يتأثر المحصول ومكوناته بالرش الورقى لليوريا، أجريت تجربة حقلية بمزرعة محطة البحوث الزراعية بالجيزة، مركز البحوث الزراعية، محافظة الجيزة، مصر، لتقييم تأثير استخدام الرش الورقى والإضافات الأرضية لليوريا بمعدلات مختلفة وفى مراحل نمو مختلفة على محصول القمح ومكوناته والمغذيات الممتصة ومحتوى الحبوب من البروتين، تم تصميم التجربة فى قطاعات منشقة مرة واحدة وثلاث مكررات وقد تم اختبار معدلات إضافة مختلفة من اليوريا وفى مراحل نمو مختلفة لنباتات القمح وكانت كالتالى: المعدل الموصى به وهو ٩٠كجم نيتروجين/فدان فقط، ٦٠ كجم نيتروجين/فدان و ٣٠ كجم نيتروجين/فدان كإضافات أرضية عند ثلاث مراحل من مراحل النمو وهي (مرحلة ظهور الورقة الثانية – مرحلة التفريع القاعدي – مرحلة بداية الإزهار) و١٠كجم نيتروجين/فدان تضاف رشاً على النباتات بتركيز ٢,٥% عند مرحلتي (التفريع القاعدي وبداية الإزهار) وذلك مع طريقتين من طرق الزراعة وهي الزراعة على مصاطب والزراعة في قطع مستوية، ٣٠ كجم نتروجين/للفدان كإضافات أرضية عند ثلاث مراحل من مراحل النمو وهى (مرحلة ظهور الورقة الثانية – مرحلة التفريع القاعدى – مرحلة بداية الازهار) و١٠ كجم نتروجين تضاف رشا على النباتات بتركيز ٢,٥% عند مرحلة (التفريع القاعدى وبداية الإزهار) وذلك مع طريقتين من طرق الزراعة وهى الزراعة على مصاطب والزراعة فى قطع مستوية، وأظهرت النتائج أن إضافة ٦٠كجم نتروجين /للفدان فى صورة يوريا كإضافات أرضية بالإشتراك مع الرش الورقى لليوريا أدت إلى زيادة نسبية بمقدار ٤,٢٩%، ٢,٦٢%، ١٣,٣٥%، ١,٦٩%، ١٢,٩٢%، ١٥,٨٥%، ١٤,١٧% و١,٨٣% فى كلا من ارتفاع النبات وطول السنبلة، عدد الأشطاء، وزن ١٠٠٠ حبة، محصول القش، محصول الحبوب والمحصول البيولوجى ودليل الحصاد على التوالي مقارنة مع إضافة ٩٠كجم نتروجين /للفدان فى صورة يوريا كإضافات أرضية، أدت الإضافات من النتروجين بالمعدلات المختلفة كإضافات أرضية أو بالإشتراك مع الرش الورقى مع طريقة الزراعة على مصاطب الى زيادة فى تركيز وامتصاص المغذيات فى القش والحبوب لنباتات القمح مقارنة بطريقة الزراعة في القطع المستوية، وقد تم الحصول على أعلى قيمة من النتروجين، الفوسفور، البوتاسيوم، الحديد، المنجنيز والزنك في كلا من القش والحبوب لنباتات القمح النامية فى الأرض المعاملة بواسطة ٦٠ كجم نتروجين /للفدان فى صورة يوريا كإضافات أرضية بالإشتراك مع الرش الورقى لليوريا مقارنة مع كل المعاملات الأخرى، وأظهرت النتائج ان كفاءة استخدام النتروجين قد انخفضت مع زيادة الإضافات الأرضية من اليوريا وأقل القيم من كفاءة استخدام النتروجين (٣٩,٤%) قد تحققت مع إضافة ٩٠كجم نتروجين /للفدان فى صورة يوريا كإضافات أرضية، أفضل قيم من محتوى البروتين فى الحبوب (١١,٤٣ %) تحققت مع النباتات التى زرعت على مصاطب مع إضافة ٦٠ كجم نتروجين /للفدان فى صورة يوريا كإضافات أرضية بالإشتراك مع الرش الورقى لليوريا، يزداد النتروجين المتبقى فى التربة معنويا مع زيادة معدل الإضافة من اليوريا وقد أظهرت النتائج أن الأراضى المضاف إليها ٩٠،٦٠ و٣٠ كجم نتروجين /للفدان فى صورة يوريا قد احتفظت بشكل كبير بمزيد من النتروجين مقارنة مع معاملة الكنترول وكانت نسبة الزيادة ٤٢,٣%، ٣٥,٩% و٣١,١% على التوالى.

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