Original Research Article

Evaluation of Nitrogen Sources and Polymer Coated Fertilizers on Wheat Yield in Sandy Soil.

Abstract

Controlled-release fertilizers (CRF) are the newest and most technically advanced way of supplying mineral nutrients to crops. Compared to conventional fertilizers, their gradual pattern of nutrient release better meets plant needs, minimizes leaching, and therefore improves fertilizer use efficiency. A field experiment was carried out at south El -kantra Research Station of the Desert Research Center, North Sinai (located at 30°53′27″ N, 32° 44′ 67″ E) to study the effects of different nitrogen sources, application times, and nitrogen rates at 45, 68 and 90 Kg/fed on yield components, nutrients content and uptake by straw and seeds of wheat crop (var. Sakha 93) and the level of available nutrients in the sandy soil.

Results showed that increasing the application rate of the studied materials increased yield components, nutrients content and uptake of wheat and available nutrients in soil. Application of 90 kg/fed of Polymer-Coated Urea (PCU) at the heading stage gave the highest values of yield components as: 6.47, 3.02, 3.35 ton/fed and 51.00g for dry weight of biological yield, grain, straw and 1000-grain, respectively. This study concluded that the efficiency of fertilizers can be significantly improved with the use of PCU as N sources and subsequently the minimized pollution hazard with other studied N sources. The highest value of recovery efficiency (30.99%) was obtained by 90 kg/fed. of PCU at the heading stage treatment when compare with the ordinary source.

Keywords: N fertilizers, Polymer-Coated Urea (PCU), nutrients uptake, efficiency of fertilizers, wheat productivity

Introduction

Nitrogen plays an essential role in plant growth; it is a component of the building blocks of almost all plant structures such as proteins, enzymes and chlorophyll. optimal concentration of N increases leaf area , photosynthetic processes, leaf area length and net assimilation rate as well which eventually contributes towards higher grain yield. Nitrogen is available to plants in two forms, ammonium and nitrate. In most soils, ammonium is quickly converted to nitrate. Nitrate is not held on soil particles and is easily dissolved in water. Thus it is susceptible to leaching. Therefore the timing and rates of nitrogen fertilization are important from both a plant growth and environmental.

Overuse of fertilizers is one of the causes for the degradation of environment and soil. Slow release fertilizers are the newest and most technically basic way of supplying mineral nutrients to crops compare to conventional fertilizers; their gradual pattern of nutrient release meets plant needs, minimizes leaching, and therefore improves fertilizer use efficiency. **(Subbarao, Ch. V. etal.,2013)**

Nitrogen-recovery efficiency for cereal production international has been estimated at only 33% **(Raun and Johnson, 1999).** Some of the N not used by the crop is assumed lost through denitrification, runoff, volatilization, and leaching. Such losses raise concerns about water contamination and greenhouse gas emissions. Low use efficiency of fertilizer N in addition reduces economic returns from fertilizer inputs. Nitrogen-use efficiency can be improved by reducing N losses (**Englesjord et al., 1997).**

Controlled release N fertilizers or CRN consisting of urea with a polymer coating (PCU) Polymer-coated urea fertilizers use a hydrophobic coating that temporarily isolates the urea prill from the soil environment. These polymer coatings may be resins or mineral-based products that act as semi permeable membranes or impermeable membranes with tiny pores. Nutrient release through these membranes is controlled by the properties of the coating material, i.e., its permeability characteristics as affected by temperature and moisture.

Controlled Release Nitrogen (CRN) sources are a group of N fertilizers that may remove or reduce labor intensive and costly in-season N applications, as well as increase NUE. CRN releases N at controlled rates to retain maximum growth and minimize N loss. The two main forms of CRN are compounds of low solubility and coated water-soluble fertilizers (**Blaylock et al., 2005**). Previous work with CRN has been mostly unsuccessful in potatoes as the N release was too early and unpredictable, resulting in delays in tuberization and yield loss.

Polymer-Coated Urea (PCU) fertilizers are one kind of CRN that have the potential to provide enhanced N release timing. One such PCU is Environmentally Smart Nitrogen (ESN, Agrium U.S. Inc., Denver, CO). ESN was considered to release N to the crop with supplementary control and predictability with a micro-thin polymer coating. The N release rate is controlled by soil temperature, which coincides with plant growth and nutrient demand. The process of release is called temperature-controlled diffusion. In this process, water moves into the fertilizer granule through the coating and dissolves the N into solution. As temperature increases, N moves out through the polymer coating into the soil solution **(Agrium, 2005) and (Trent W. T., et al., 2007).**

Controlled-release N fertilizer consisting of urea with a polymer coating (PCU) that is permeable to water and gradually releases N in response to increasing temperatures over the growing season (**Agrium Inc. 2011**). It costs only 15 to 30% more than uncoated urea and considerably less than other such fertilizer products or earlier generation coated fertilizers (**Hopkins et al. 2008;Wilson et al. 2009**), which makes it a more attractive product for use in field crops. Field experiment of product grains and potato indicated that this PCU may increase crop yield, reduce the need for split N application, and decrease NO_3-N leaching compared with conventional N fertilizers (**Nelson et al. 2009; Wilson et al. 2009; Wilson et al. 2010; Blackshaw et al. 2011; Ziadi et al. 2011 and Bernard G.etal., 2012).** However, the crop yield response was largely dependent on soil moisture, and little difference should be expected where the risk of N loss is low (**Malhi et al. 2010; McKenzie et al. 2010).**

The objectives of this studies were to constitute comparisons of polymer-coated urea with a variety of conventional N fertilizers and application practices on wheat productivity and to demonstrate improved N-use efficiency to reduce the risk of nitrate leaching in irrigation.

Material and method

A field experiment was carried out at south El -kantra Research Station of the Desert Research Center, North Sinai located at 30°53′27″ N, 32° 44′ 67″ E, wheat was cultivated during two successive seasons, i.e. 2014 and 2015. study the effects of different nitrogen sources, application times, and Nitrogen fertilizer rates on chemical composition and productivity of wheat. Treatments were arranged in a split split plot design with three replicates. Nitrogen sources were allocated to main plot (ammonium nitrate (AN, 33 % N) , ammonium sulfate (AS, 20.5% N) and the polymer coated urea (PCU, 43% N), were allocated to the sub-plot the timing application was 50% of the N applied at pre-plant with the remaining applied in 50% at the heading stage while N rates were the sub sub plot treatment (0- 40-68- 90 kg/fed). The plot area was 10.5 m^2 (3.5 long × 3 wide) This experiment included 24 treatments which included different combination of Nitrogen fertilizer sources, application times, and rates used. Yield parameters were recorded for the two seasons. Sprinkler irrigation was used in the experiment. Wheat seeds (var. Sakha 93) were sown on 17th November of both seasons. All treatments received 50 kg K_2O/fed as potassium sulfate while K fertilizer was applied in two equal doses and Phosphorus was applied as super phosphate (15.5% P_2O_5) at the rate of 30 kg P_2O_5 /fed during soil preparation. (**Shehab El-Din and El-Shamy, 2003)**.The other agricultural practices were done as the recommendation of Ministry of Agriculture. Wheat was harvested during May 2015 and 2016. Soil samples were collected from the studied plots at depth (0-30) for physical and chemical analysis (initial analysis in Tables (1).

Table (1). Initial status of some chemical and physical properties of the experimental soil.

Depth	0-30 cm
Particle size distribution %	
Sand	90.5
Silt	2.7
Clay	6.88
Texture class	sand
pH (1:5) Suspension	8.6
EC(1:5) $dS.m^{-1}$ soil extract	0.61
Soluble ions (meq/L)	
Na	4.34
K	0.23
Ca	0.876
Mg	0.605
Cl	4.00
HCO_3	1.77
SO_4	0.281
Available nutrients (mg/kg)	
N	25
P	1.47
K	32

The following data were recoded

1. **Growth and Yield parameters:**

At maturity, One median plot 1 m^2 in the center of each experimental plot was chosen to be harvested for the estimation of biological parameters (biological yields, dry weights of straw and grain and 1000-grain weight).

2. **Determination of nitrogen, phosphorus and potassium in straw and grain of plant**
   N, P and K were determined in acid digested solution, which was prepared according to **(Cottenie *et al.* 1982**).
3. ***Soil properties of the experiment***

3.1. Mechanical analysis was determined according to **(Piper, 1950)**

3.2. Some chemical properties

soil reaction (pH) was determined electrometrically in soil suspension 1:5 using bench Beckman Glass Electrode pH-Meter, total soluble salts were determined in soil suspension 1:5 was determined according **(Jackson 1973),**

3.3. Determination of available nitrogen, phosphorus and potassium in soil

N, P and K were determined in acid digested solution, which was prepared according to **(Page *et al.*, 1984 and Klute, 1986**

4. Nutrient efficiency parameters were evaluated using the following equations **(Yadvinder *et al.*, 2004)**:

A- Recovery efficiency of N (RE) = 100 x (N uptake kg/fed of treated- N uptake kg/fed of untreated)/ applied N kg/fed

B- Physiological efficiency of N (PE) = (grain yield kg/fed of treated - grain yield kg/fed of untreated)/ (N uptake kg/fed of treated- N uptake kg/fed of untreated)

C- Agronomy efficiency of N (AE) = (grain yield kg/fed of treated - grain yield kg/fed of untreated)/ applied N kg/fed

Statistical analysis. Data of the present work were statistically analyzed and the differences between the means of the treatments were considered significant when they were more than the least significant differences (L.S.D) at the 5% level by using computer program of Statistix version 9 **(Analytical software, 2008).** Regression analyses were performed using Statistical Product and Service Solutions (SPSS 18.0).

Results and Discussion

Effect of nitrogen sources, application times and nitrogen fertilizer rates on yield parameters of wheat.

Data in Table (2) showed that yield components of wheat plants significantly affected by different treatments in two seasons. Polymer-Coated Urea (PCU) was significantly higher than the conventional fertilizers (AS or AN) in enhancing yield parameters of wheat (dry weights of biological yields, straw, grain and 1000-grain weight). PCU produced greater yields in at the heading stage (twice split) comparisons when applied (once split) pre-plant at the same N rate, Also, yield components increased with increasing the rates of N fertilizers. The most effective treatment was 90kg/fed of PCU at the heading stage gave the highest value of yield components as 6.47, 3.02, 3.35 ton/fed and 51.00 (g) dry weights of biological yields, grain, straw and 1000-grain weights respectively. The second season took the same trend of the first season so taking the average values of two seasons were taken for yield components. The polymer coating did avoid at least some N losses. Hence using these materials as a source of N applied once at pre plant produced lower yields than applied twice split at heading stage was lost via de-nitrification, leaching, or ammonia volatilization. Regardless of the loss mechanism this fact supported by **Blaylock, et al., (2005), Blackshaw, et al., (2011), Johnson et al., (2011) and Nelson, et al., (2014)** reported that split-N application resulted in greater wheat biomass (2.77 Mg ha^{-1}) and greater N uptake (28.5 kg ha^{-1}) than fall-applied N in 2005.

Table(2). Effect of nitrogen sources, application times and nitrogen fertilizer rates on yield components of wheat.

N sources	time application	N Rates	**Biological dry yield (t/fed.)**	**Grain dry weight t/fed.**	**Straw dry weight t/fed.**	**1000 grains dry weight (g)**
AS	pre-plant stage	0	3.82	1.69	2.12	24.10
		45	3.96	1.93	2.03	32.57
		68	4.55	2.22	2.33	37.47
		90	5.48	2.55	2.8	45.15
	heading stage	0	3.86	1.72	2.15	24.40

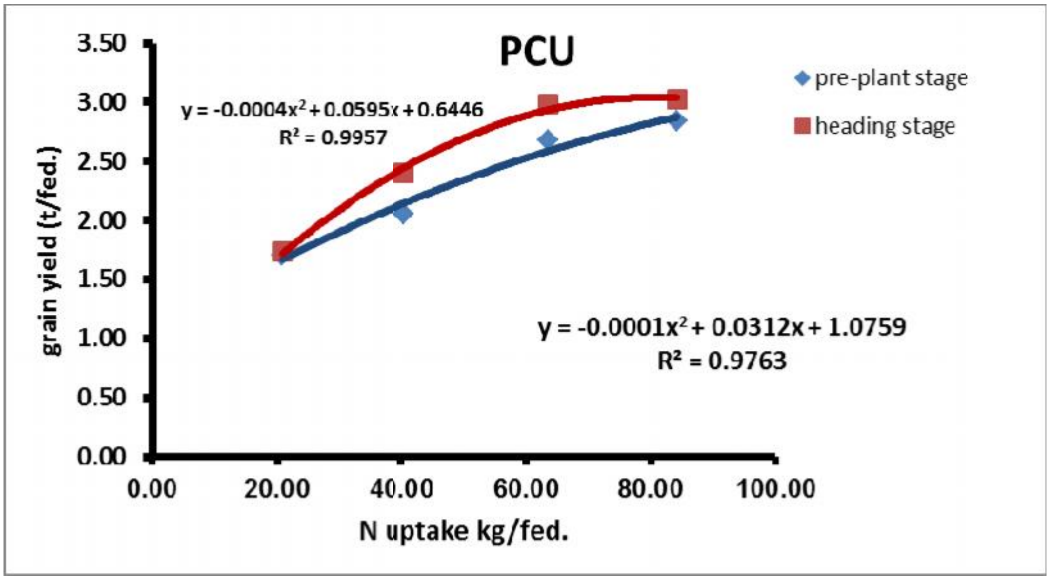
		45	4.13	2.22	2.33	37.44
		68	4.76	2.55	2.68	43.08
		90	5.72	3.07	3.21	50.90
AN	pre-plant stage	0	3.89	1.7	2.13	24.20
		45	4.44	2.04	2.13	33.35
		68	5.55	2.35	2.46	38.37
		90	6.05	2.83	2.95	46.23
	heading stage	0	3.93	1.73	2.16	24.30
		45	4.55	2.25	2.34	36.65
		68	5.23	2.58	2.7	42.16
		90	6.29	3.11	3.27	50.80
PCU	pre-plant stage	0	3.93	1.71	2.14	24.30
		45	4.54	2.05	2.38	36.70
		68	5.23	2.68	2.86	44.30
		90	6.28	2.84	3.22	44.80
	heading stage	0	3.98	1.74	2.14	32.57
		45	5.74	2.4	2.38	44.00
		68	6.05	2.98	2.86	47.10
		90	6.47	3.02	3.35	51.00
LSD 0.05 for N source			0.09	0.08	0.18	1.90
Time Application			0.1	0.04	0.02	0.20
N rates			0.09	0.11	0.13	2.15
N source x T. Application			0.16	0.09	0.18	1.92
N source x N rates			0.16	0.18	0.26	3.72
N rates x T. Application			0.15	0.13	0.16	2.65
3 Factors			0.23	0.24	0.31	5.64

AS= ammonium sulphate AN= Ammonium nitrate PCU=polymer coated urea

Effect of application of nitrogen sources, application times and nitrogen fertilizer rates on nutrients uptake by wheat

The previous results from yield and nutrients content were assured in results of nutrients uptake in Table (3) showed that the treatment Polymer-Coated Urea (PCU) gave higher nutrients uptake by wheat plant during two seasons than other studied treatments. The N, P and K uptake increased with increasing the rate of N application for all treatments. The highest significant increase was by using 90kg/fed of PCU at the heading stage treatment gave values of 30.17, 2.55and 78.66for N, P and K kg/fed uptake by straw, respectively. For seeds, it gave values of 84.18, 8.58 and 19.20 kg/fed uptake, respectively. The nutrients uptake in seeds and straw in second season showed similar trends of as the first season. These results could be due to the fact that the successive releases of N from PCU corresponded well to the requirements of N in the growth stages of wheat. Nutrient release rates of PCU are known to be significantly affected by temperature and moisture content **(Geng et al., 2015).** Thus, the N release longevity of PCU in field condition was longer compared with the conventional fertilizers. on the other hand, the rapid hydrolyses process of urea caused heavy N losses this fact supported by (Khan et al., 2015), these results in accordance with those obtained by **Blaylock, et al., (2005). Henry, et al., (2010) and Nelson**, et **al.,(2014)** reported that split-applied N resulted in greater wheat tissue N concentration.

Relationship between total N uptake **and wheat grain yields** at timing of application of PCU was show in figure (1) There was a good quadratic relationship between yield and N uptake at pre-plant stage (R^2 = 0.9763), and at the heading stage (R^2 = 0.9957) These indicate that The increasing rate of Polymer-Coated Urea (PCU) fertilizer had a potential to increase grain yield. This figure will be modified later according to target grain yields for economic considerations of the application rate of PCU fertilizer



Fig(1). Relationship between total N uptake **and wheat grain yields**

Table(3). Effect of **application of nitrogen sources,** application times, and Nitrogen fertilizer rates on nutrients uptake in grain and straw of wheat.

N sources	time application	N Rates	**Biological dry yield (t/fed.)**	**Grain dry weight t/fed.**	**Straw dry weight t/fed.**	**1000 grains dry weight (g)**
AS	pre-plant stage	0	3.82	1.69	2.12	24.10
		45	3.96	1.93	2.03	32.57
		68	4.55	2.22	2.33	37.47
		90	5.48	2.55	2.8	45.15
	heading stage	0	3.86	1.72	2.15	24.40
		45	4.13	2.22	2.33	37.44
		68	4.76	2.55	2.68	43.08
		90	5.72	3.07	3.21	50.90
AN	pre-plant stage	0	3.89	1.7	2.13	24.20
		45	4.44	2.04	2.13	33.35
		68	5.55	2.35	2.46	38.37
		90	6.05	2.83	2.95	46.23
	heading stage	0	3.93	1.73	2.16	24.30
		45	4.55	2.25	2.34	36.65
		68	5.23	2.58	2.7	42.16
		90	6.29	3.11	3.27	50.80
PCU	pre-plant stage	0	3.93	1.71	2.14	24.30
		45	4.54	2.05	2.38	36.70
		68	5.23	2.68	2.86	44.30

		90	6.28	2.84	3.22	44.80
	heading stage	0	3.98	1.74	2.14	32.57
		45	5.74	2.4	2.38	44.00
		68	6.05	2.98	2.86	47.10
		90	6.47	3.02	3.35	51.00
LSD 0.05 for N source			0.09	0.08	0.18	1.90
Time Application			0.1	0.04	0.02	0.20
N rates			0.09	0.11	0.13	2.15
N source x T. Application			0.16	0.09	0.18	1.92
N source x N rates			0.16	0.18	0.26	3.72
N rates x T. Application			0.15	0.13	0.16	2.65
3 Factors			0.23	0.24	0.31	5.64

AS= ammonium sulphate AN= Ammonium nitrate PCU=polymer coated urea

Effect of application of nitrogen sources, application times, and Nitrogen fertilizer rates **on Nutrient efficiency parameters of wheat**.

Recovery efficiency, physiological efficiency and agronomic efficiency of wheat were affected by different treatments (Table 4). The highest values of recovery efficiency (30.99%) were obtained by 90kg/fed of Polymer-Coated Urea (PCU) at the heading stage treatment and agronomic efficiency (8.08 kg grain/kg N uptake) were obtained by 68kg/fed of PCU at the heading stage treatment of wheat was possibly due to more availability of N from PCU, while The highest value of physiological efficiency was obtained by 45kg/fed of PCU at the pre-plant stage treatment. also Increasing NPK dose decreased physiological efficiency of wheat but it increased recovery efficiency and agronomic efficiency. The data also showed that with using only a rate of 68kg/fed of PCU source gave recovery efficiency higher than applying 90kg/fed of the ordinary source. In both season first and second. Nitrogen use efficiency in rice is often low as a result of high N loss through volatilization, leaching, and denitrification. Controlled-release fertilizers generally better granular urea fertilizer in reducing N losses, stimulating plant growth, and increasing nitrogen use efficiency **Kiran et al.,(2010).** PCU has higher N recovery compared to AS or AN. Pre-plant N fertilizers is much less effective than split and heading stage treatments and is apparently subject to much greater N loss by leaching since N that is not recovered by the crop during the growing season is most likely lost .These results in accordance with those obtained by **Salvagiotti and Miralles**, (**2008**), **Rehab H. Hegab (2013)** and **Chen, et al.(,2017).** The lower recovery efficiency was possibly due to less availability of N due to lower grain yields during the particular year This fact supported by **(Yadvinder et al, 2004**).

Table (4). Effect of **application of nitrogen sources,** application times, and Nitrogen fertilizer rates on recovery N efficiency (%), physiological efficiency and agronomic efficiency of wheat

N sources	time application	N Rates	**recovery efficiency (%)**	**physiological efficiency (kg grain/kg N uptake)**	**agronomic efficiency (kg grain/kg N applied)**
AS	pre-plant stage	0	0.00	0.00	0.00
		45	5.21	20.23	1.05
		68	6.48	24.40	1.58

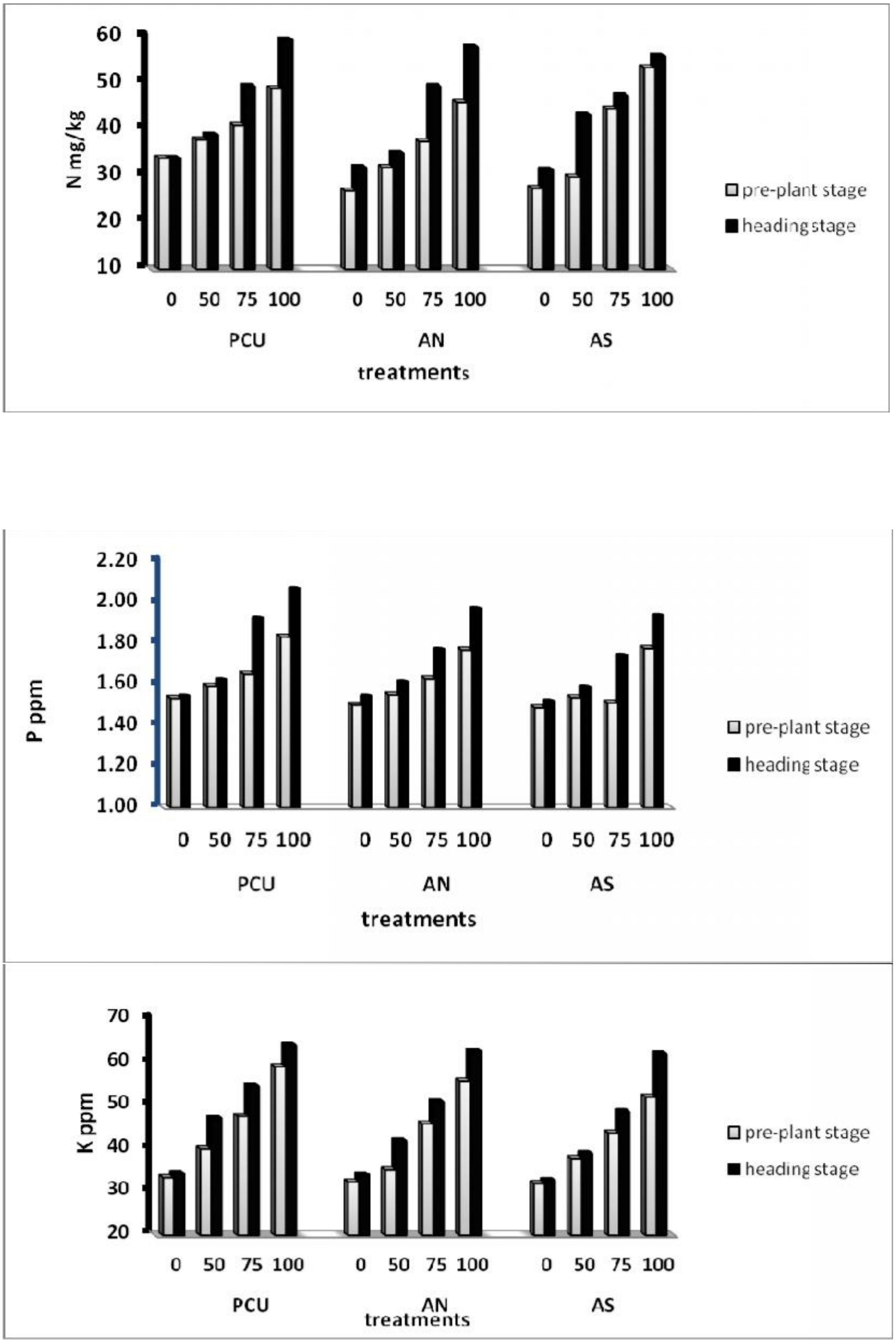
		90	9.05	24.61	2.23
	heading stage	0	0.00	0.00	0.00
		45	9.30	24.00	2.23
		68	10.17	24.56	2.50
		90	13.16	23.32	3.07
AN	pre-plant stage	0	0.00	0.00	0.00
		45	6.57	23.10	1.52
		68	12.40	25.19	3.12
		90	16.75	24.55	4.11
	heading stage	0	0.00	0.00	0.00
		45	9.30	24.74	2.30
		68	16.45	25.01	4.11
		90	21.33	23.58	5.03
PCU	pre-plant stage	0	0.00	0.00	0.00
		45	7.41	44.40	3.29
		68	14.76	42.68	6.30
		90	16.43	33.42	5.49
	heading stage	0	0.00	0.00	0.00
		45	19.15	33.45	6.41
		68	27.91	28.94	8.08
		90	30.99	22.95	7.11

AS= ammonium sulphate AN= Ammonium nitrate PCU=polymer coated urea

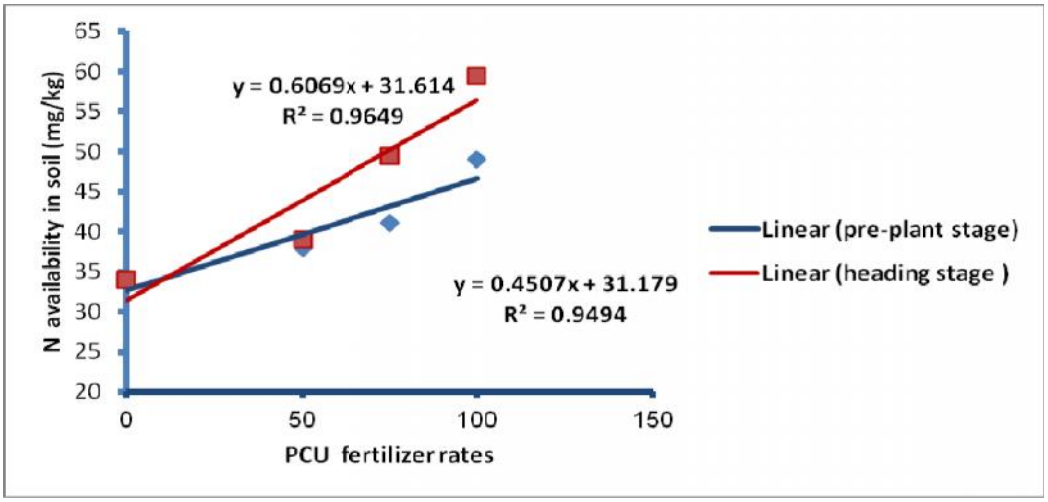
Effect of application of nitrogen sources, application times, and Nitrogen fertilizer rates **on nutrient availability in soil**

The availability of N, P and K in soil after completing the experiment is presented in Figure (2). The application of studied materials increased the available nutrients in soil. When compared with other materials, Polymer-Coated Urea (PCU) was higher in increasing the nutrient availability in soil. The most effective treatment 90kg/fed of PCU at the heading stage gave higher significant increases on available nutrients in soil than the conventional fertilizer at layer 0-30 cm by (93, 2.07 and 94mg/kg) for available N, P and K, respectively. Due to the slow release nature, slowly released fraction of stored urea, additionally contributed to ponded water N concentration throughout the growing season. The previous facts are assured by the results obtained by **Ellison et al., (2013)** and **Heiniger, et al., (2014)** .

The constant value from the linear regression as show in figure (3) is 31.179 at pre-plant stage However, this value increased to 31.614 in heading stage at soil N availability, This indicate that application of Polymer-Coated Urea (PCU) had a potential to increase N content. This slowly released and steady supply of N may be responsible for greater use efficiency in PCU generally reported in literature **Tang, et al., (2007). Yang et al. (2012)** reported that using controlled-release urea (CRU) in rice without additional fertilizer application during the growing season significantly increased N availability in soil and improved yields by 13.6%–26.5%.



Fig(2). Effect of application of nitrogen sources, application times, and Nitrogen fertilizer rates **on nutrient availability in soil.**



Fig(3). Interaction between Polymer-Coated Urea (PCU) fertilizer and nitrogen availability in soil.

Conclusions:

Previous results showed that the use of PCU is much better than conventional fertilizers; however, Application of Polymer-Coated Urea (PCU) had an important role for increasing crop productivity and minimizes the pollution hazard through improving the use efficiency. Yield components, nutrients content and uptake by wheat were increased with using the PCU, compared with the other materials. Also, a split applications heading stage of N sources are more effective than a single pre plant application. The apparent recovery efficiency of N was increased significantly by using the PCU source. we can recommended that, wheat crop should be treated by interaction between 90kg/fed of PCU at the heading stage to gave the highest nutrients uptake and productivity of wheat under sandy soil of Sinai region conditions.

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