

## **Recovery of nitrogen and phosphorus from different sources of fertilizer for growing wheat irrigated with wastewater and well water**

**Evaluación de la recuperación del nitrógeno y fósforo de diferentes fuentes de fertilizantes por el cultivo de trigo irrigado con aguas residuales y de pozo**

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### **Abstract**

The use of nitrogen phosphorous fertilizers and untreated sewage from urban areas by crops is an agronomic, economic and environmental necessity. The aim of this study was to evaluate the response of growing wheat to the application of different nitrogen fertilizers, irrigated with wastewater and well water. Haplic Vertisol soil was used. As indicator crop wheat variety Tlaxcala F2000 was used. Fertilizers applied were: commercial fertilizer (CF) consisting of monoammonium phosphate + urea, organic fertilizer (FO) Vermicomposta, and slow release fertilizer (FL) combination of: urea, H<sub>2</sub>PO<sub>4</sub> and clay. The mixture contains N and P, 8.08 and 6.3 wt%, respectively. The treatments were designed to test the effect of each single one of these materials and the combination FL + FO. The fertilization of N and P was (280-80-0). With the laboratory analysis data of N and P of the plants, the recovery efficiency of these nutrients was calculated. Dates of Sampling Water and Fertilizer water interactions were significant at ( $p < 0.05$ ) for fresh and dry biomass in the experimental cultivation also increased the number of grains by irrigating with wastewater.

**Key words:** Biomass, mining, slow release fertilizer.

### **Resumen**

El empleo de fertilizantes nitrogenados y de aguas residuales no tratadas de origen urbano por los cultivos es una necesidad agronómica, económica y ambiental. El objetivo de este estudio fue evaluar la respuesta del cultivo de trigo a la aplicación de diferentes fertilizantes nitrogenados, irrigado con agua residual y de pozo. Se utilizó un suelo Vertisol Háplico. Se usó como cultivo indicador trigo variedad Tlaxcala F2000. Los fertilizantes aplicados fueron: Fertilizante comercial (FC) constituido por Fosfato monoamónico + urea, Fertilizante orgánico (FO) Vermicomposta; y Fertilizante de lenta liberación (FL) combinación de: urea, H<sub>2</sub>PO<sub>4</sub> y arcilla. La mezcla contiene N y P, 8.08 y 6.3 % en peso, respectivamente. Los tratamientos se diseñaron para probar el efecto simple de cada uno de estos materiales y la combinación de FL+FO. La dosis de fertilización de N y P fue (280- 80-0). Con los datos de los análisis de laboratorio de N y P de las plantas, se calculó la eficiencia de recuperación de estos nutrimentos. Las interacciones fechas de Muestreo por agua y fertilizante por agua, fueron significativas al ( $p < 0.05$ ), para la biomasa fresca y seca en el cultivo experimental, asimismo se obtuvo mayor número de granos al irrigar con agua residual.

**Palabras clave:** Biomasa, extracción, fertilizante de lenta liberación.

## Introduction

The yield of the wheat crop in a given region is the result of the interaction between ecological, technological and genetic factors. The potentiality of growing wheat differs among Mexico producing regions, mainly due to climatic factors. In the wheat crop N is the input with the highest impact on performance and with which the greatest economic return is achieved. However, in many cases, potential crop yields are not achieved due to the reduced availability of inputs, nutrition, management through fertilization, and in some cases the N use efficiency of nitrogen fertilizers. This can be solved by good management practice and the use of fertilizers that involve applying the nutrient source and proper dosage. This decision is critical to achieve optimal efficiency of use of nutrients in wheat crops and thereby increase productivity (Ventimiglia and Torrens, 2013).

Slow release fertilizers with a high controlled solubility are an effective option for increasing the efficiency of nutrient uptake by crops (Vera-Nunez *et al.*, 2012). Furthermore, the use of these prevents losses by leaching, volatilization and denitrification and therefore less pollution to the environment (Havlin *et al.*, 2013). Among the possible disadvantages, the difficult synchronization between the rate of

dissolution and absorption by the plant, except in the early stages of the crop cycle is highlighted (Baligar *et al.*, 2001).

With the use of wastewater in agriculture, crops take advantage of the nutrients contained, including N and P, which represents an economic benefit to the producer (Toze, 2006). Clearly, the need to continue producing grains for a growing world population, will determine the consumption of nitrogen fertilizers; but also, alternatives must be seek to keep improving the recovery efficiency by crops and thus avoid an increase in the global greenhouse effect and destruction of the ozone layer by using fertilizers. Therefore the aim of this study is to evaluate the response of the wheat crop to the application of different nitrogen fertilizers, irrigated with residual or well water.

## Materials and methods

The research was conducted in the experimental greenhouses and soil fertility laboratory of the Graduate School Campus Montecillo. Mexico State, Mexico. A vertisol soil háplico (INEGI, 2001a) was used. Analytical determinations in soil and waste water are shown in Tables 1 and 2 respectively.

**Table 1.** Physical and chemical characteristics of the experimental soil.

Variables	Method	Value	Units
N	MicroKjeldahl	0.07	%
Extractable P	Olsen	34	mg kg <sup>-1</sup>
Organic matter	Walkle y Black	1.4	%
C.I.C.	Ammonium acetate	39	cmolc kg <sup>-1</sup>
pH (2:1 relation)	Potentiometer	7.76	
C.E.	Conductimeter	0.69	dSm <sup>-1</sup>
Sand	Bouyoucos	10	%
Silt		17	%
Clay		73	%
Textural class		Clayey	

C.E = Electrical conductivity, CIC = Cation exchange capacity.

**Table 2.** Physical and chemical characteristics of the tested water

Variables	Value		Units
	AR	AP	
N total	72	32	mg L-1
N-NO3	6 22.27	meq L-1	
N-NH4	55	8.64	meq L-1
Soluble P-PO4	11	0.86	mg L-1
Total P	39	0.60	mg L-1
PH	7.05	7.45	
C.E.	0.59		dS m-1

AR = wastewater, AP= well water, C.E. = Electrical conductivity.

As indicator crop wheat variety Tlaxcala F2000 was used, a new variety of bread wheat (*Triticum aestivum* L.) that is classified as intermediate cycle, developed for rainfed conditions by the National Institute of Livestock Agriculture and Forestry Research (INIFAP). Average crop cycle is 118 days with a range from 107 to 135 days (Villasenor *et al.*, 2000a).

Fertilizers applied were: commercial fertilizer (FC) constituted by monoammonium phosphate + urea, organic fertilizer (FO) Vermicomposta; and slow release fertilizer (FL) combination of: urea, H<sub>2</sub>PO<sub>4</sub> and clay. The mixture contains N and P, 8.08 and 6.3% by weight, respectively. Treatments were designed to test the simple effect of each of these materials and the combination of FL + FO with different types of water, wastewater (AR) and well water (AP) and the control where no fertilizer is added of any kind, and only irrigation (T).

The dose of N and P fertilization for wheat was recommended in the Bajío (280-80-0). Wheat plants were sampled at intervals of 55, 67 and 97 days after sowing (DAS). In each sampling the fresh weight of each EU was taken and in the last, the number of grains was counted. The samples were washed with distilled water and dried in an oven for 48 h at 70 °C. Subsequently the dry weight of the dry biomass was taken. Each EU was prepared for chemical analysis, for determination of total N by the

microKjeldahl method and P by spectrophotometry (Alcantar and Sandoval, 1998). With the data for N and P, the efficiency of recovery was calculated for N and P respectively with the following equation:

$$E_{frec\ N} = [(NT - N_{control}) / \text{Dose in treat}] \times 100$$

where:

$E_{frec\ N}$  = Nitrogen recovery efficiency

$NT$  = Nitrogen content in plant in treatment

$N_{control}$  = Nitrogen content in plant in control treatment

Dose in treat = Fertilizer dose applied in the treatment

Likewise the recovery efficiency of phosphorus was calculated. The analysis of variance of the seven variables measured listed below were performed: Recovery efficiency of N and P; Removal of N and P; Fresh and dry biomass, and number of grains. SAS statistical package was used.

## Results and discussion

The analysis of variance (DHS) for fresh biomass showed that the interactions type of fertilizer by water type and sampling date by water type were significant (P <0.05) (Table 3).

**Table 3.** Wheat response to the application of three types of fertilization and two water sources for irrigation.

Type of Fertilization <sup>a</sup>	Fresh		Dry		Grains		Rec. of Nt	
	Biomass (g)		Biomass (g)		(no./plant)		(%)	
	DHS <sub>0.05</sub> = 5.96		DHS <sub>0.05</sub> = 1.28		DHS <sub>0.05</sub> = 65.26			
	AR	AP	AR	AP	AR	AP	AR	AP
FC	18.72	16.04	4.24	3.56	458	418		
FO	22.52	15.44	5.35	5.04	526	370		
FL	23.53	18.56	4.39	2.76	608	566		
FL + FO	26.12	21.57	4.77	5.68	486	537		
Control	16.11	17.22	3.44	2.53	411	306		

  

Days after Sowing	DHS <sub>0.05</sub>		DHS <sub>0.05</sub>		DHS <sub>0.05</sub>	
	= 2.58		= 49.34		= 0.58	
	AR	AP	AR	AP	AR	AP
55	14.01	11.63	396	385	13.65	13.95
67	21.31	15.39	906	740	11.58	9.72
97	28.97	20.28	1187	1126	8.96	9.11

FC = Commercial fertilizer, FL = Slow release fertilizer, FO = Organic fertilizer, T = Control, AR = wastewater and AP = well water.

In the same table, the response of type of fertilizer and water type is presented; it is observed that the fresh biomass of wheat was higher, at a level of significance ( $p < 0.05$ ) in the treatments irrigated with wastewater that those to which well water was added except for the witness which was not fertilized.

Table 3 shows the biomass observed in different sampling dates for each type of water, in which it is observed that higher yields of fresh biomass are obtained with wastewater.

The increase in fresh biomass is due to an increased availability of N in the soil and fertilizer in the early stages of development of wheat, in addition to an adequate supply of water, as Hossain *et al.* note (2006).

The statistical results for dry biomass of the crop showed a similar behavior to the fresh biomass dynamics for the type of fertilizer and water to a level of significance ( $p < 0.05$ ). For the dry biomass it was observed that is greater for the combination treatment FL + FO plus well water and less for the control T with any of the two types of water (Table 3).

This is because the N requirement of the crop is low between emergency and early tillering and dry matter production increases (Carrillo-Romo *et al.*, 2010).

The result of the statistical analysis applied to a significance level ( $p < 0.05$ ) for the number of grains of the crop under study showed that there is positive interaction between the type of fertilizer and water type and number of grains between the date of sampling and the type of water (Table 3).

The same table shows that the number of grains was higher for the treatment FL, both irrigated with waste water and with well water and lower for the control with the two types of water used. This is because there is a relationship between the contribution of N from both the fertilizer and from wastewater with the number of grains obtained. This is because N fertilization at planting time promotes tillering and increases the number of spikes, and thus the number of grains which are also favored by the contribution of N from wastewater (Ramirez *et al.*, 2010).

Also, Table 3 shows that the number of grains increases in each sampling date, being higher when irrigated with

wastewater. The number of grains was favored with proper fertilization and irrigation in the cultivation of wheat. These results agree with those reported by Hernández-Cordova and Soto-Carreño (2012) and Caceres *et al.* (2005) who state that under optimum nitrogen fertilization and water, the number of grains of cereals is favored.

With respect to the nitrogen extracted from the plant according to information derived from Table 3 is observed as sampling dates that the of NT decreases as sampling dates pass and only in the second sampling is higher when irrigated with wastewater. Possibly this is due to the application of N in wet conditions that stimulated mineralization in the soil and its loss by denitrification (Mora-Ravelo *et al.*, 2007; Ceron-Corner and Ancizar-Aristizabal, 2012).

Table 4 shows the statistical analysis of the N recovery efficiency in which it is observed that only the sampling by fertilizer interaction must be interpreted. The recovery efficiency of N was greater with the combination FL + FO, finding that this efficiency is greater at 67 days after sowing regardless of the type of fertilizer.

Fertilization may favor factors such

as organic N mineralization of soil or water use efficiency and, then, N uptake provided by the soil of fertilized plants is not maintained as in the control. However, the method of the difference attributes the higher N accumulated in plants fertilized only to the contribution of N from the fertilizer. Therefore, the method of the difference allows only calculating the apparent recovery of the fertilizer that is not always equal to the actual recovery. The greater absorption of N was due to a greater demand from the plant and a higher availability of N.

The extracted phosphorus was higher in treatments with residual water. In samplings two and three (67 and 97 DAS), the P removed was lower for all treatments and generally higher when FL was applied and lower with FO. The increased absorption of P was due to increased demand from the plant and increased availability of this nutrient (Havlin *et al.*, 2013). The results of the analysis of variance for P recovery efficiency indicate that is significant with ( $p < 0.05$ ) for the interaction between sampling dates and type of fertilizer (Table 3). Slow release fertilizers and combinations of these with organic matter were more efficient than the

**Table 4.** Analysis of variance for three characteristics of wheat with three fertilizer sources and two of water.

<b>F.V.</b>	<b>Nt (P&lt;)</b>	<b>Rec. N (P &lt;)</b>	<b>Rec. P (P &lt;)</b>
M	<b>0.0001</b>	<b>0.0001</b>	<b>0.0001</b>
R	0.972	0.7086	0.2260
Error (a) M*REP	0.839	0.3536	0.4698
F	<b>0.019</b>	<b>0.0001</b>	<b>0.0001</b>
A	0.204	0.0731	0.1518
M*F	0.163	<b>0.0001</b>	<b>0.0001</b>
M*A	<b>0.034</b>	0.2099	0.4576
F*A	0.781	0.9026	0.5178
M*F*A	0.290	0.9918	0.9919
	S = 0.3458	S = 65.43	S = 61.12

A= Water, M =Sampling, R= Repetition, F=Fertilizer and S= standard sampling deviation.

commercial fertilizer. The recovery efficiency of P was greater with the combination FL + FO, finding that this efficiency is greater at 97, regardless of the type of fertilizer. The efficiency of fertilizers applied depended on its chemical composition by its effect on the cation/anion balance for the uptake of N and P by the crop and sufficient supply of water (Vera-Nunez *et al.*, 2012; Inzunza *et al.*, 2010).

### Conclusions

- The treatment with slow release fertilizer plus residual water enhanced the increase of fresh and dry biomass in the wheat crop.
- The number of grains increased over time as observed in each sampling date and was higher in the fertilized treatment with slow-release fertilizer (FL) which can be compared to the number of grains of control treatments which were not fertilized.
- The wastewater contributed to the absorption of N and P in wheat and the increase in fresh and dry biomass.
- The recovery efficiency of N and P was higher in treatments with slow-release fertilizer + organic fertilizer, with respect to commercial fertilizer and the control.

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