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Short Communication

Physiological Efficiency and N Recovery of Wheat Influenced by Different N Sources Under Naturally Salt-Affected Soil

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Abstract. A field study was conducted to investigate the effect of different N fertilizer sources (urea, nitrophos, ammonium sulphate and calcium ammonium nitrate) on the productivity of wheat (var. Inqlab) in naturally salt-affected soil (pH = 8.79; ECe = 6.46; Sandy loam). A significant difference was observed in wheat grain and straw yield with the application of different N sources. Maximum wheat grain and straw yields (3203 and 3489 kg/ha, respectively) were recorded when ammonium sulphate was applied. Various N sources followed the order: Ammonium sulphate > urea > calcium ammonium nitrate and/or nitrophos. Comparatively higher N uptake by wheat (117.26 and 114.00 kg/ha) was observed with Ammonium sulphate and urea application, respectively. Similarly, maximum N recovery was observed with both these N sources followed by nitrophos, and calcium ammonium nitrate. However, the highest physiological efficiency (14.29 kg/kg fertilizer applied) was noted with the application of ammonium sulphate.

Keywords: salt-affected soil; N sources; physiological efficiency; N recovery; wheat crop; growth and yield

Rapid population growth and subsequent food shortage especially in Asia and Africa and advancing salinity in arable land due to climate change have increased the importance of finding salt tolerant genotypes (Blumwald *et al*., 2004). Wheat (*Triticum aestivum* L.) is mostly cultivated in the world and globally used as food consumption. Further, wheat is a staple food, contributing a significant role in economics, yield, feeding and strengthening the world (Varga *et al*., 2002). Wheat is a main cereal crop for all over the world's population and a strategic crop for food security across the world (Ibrahim *et al*., 2014). The values of N agronomic efficiency (NAE) in grain ranged from 10 to 30 grain/kg applied N and values over 30 grain/kg applied N are encountered in the well organized systems of growing or at low levels of N fertilization on poor soils (Dobermann, 2005).

Arid and semi-arid regions faces salinity as one of the major abiotic stresses but salt-affected soils are more than 6% of the world surfaces as salt-affected (FAO, 2008; Munns and Tester, 2008). Soil salinity and sodicity are significant issues reducing crop yield. Saline sodic soils having low soil fertility and crops cultivated on such soils affects due to specific ionic toxicities (Na, Cl and B) and deficiencies (Ca, K and Zn) cause reduction in crop production (Tahir *et al*., 2012; 2010). Abedi *et al*. (2011) concluded that higher grain produce (8230 kg/ha) was attained by applying 240 kg N/ha than in control (3930 kg/ha), 120 kg N/ha (4400 kg/ha) and 360 kg N/ha (6530 kg/ha). Marino *et al*. (2009) reported that all the growth and yield parameters showed better performance with increase of N rate. Iqtidar *et al*. (2006) reported that increasing the N level from 50 to 200 kg/ha significantly increased grain produce comparing to control (0 kg N/ha). Noureldin *et al*. (2013) reported that increasing N up to 180 kg/ha significantly increased yield.

Initially the use of mineral fertilizers, improvement in crop cultivars, plant protection measures and increased irrigation coverage had led to green revolution. However, now despite the prime position of wheat in food security and economy of the country, its productivity is very poor with average wheat yields of 2.25 t/ha (Anonymous, 2015). Fertilizer addition in the system is 135 kg N, 65.1 kg P_2O_5 and 2.1 kg K_2O (NFDC, 2016). Under these conditions, unless the system is provided with adequate amount of required nutrients, there will be much depletion in natural fertility of the soil. The

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majority of the soils in Pakistan are calcareous-alkaline and urea is the major N fertilizer used for crop production. Urea upon application to soil is subjected to numerous reactions, transformations and N loss mechanisms such as NH_3 volatilization (Mahmood and Qureshi, 2000). Reduction in such losses still becomes easily manageable if their reactions and transformations are clear and understandable. Therefore, attention has been drawn to the need for methods to reduce ammonia volatilization losses from N fertilizer application. The present study on the N recovery of different N fertilizer sources for wheat was conducted to investigate the effect of different N sources on the productivity of wheat under naturally salt-affected soil.

A field experiment was conducted to study the effect of different N fertilizer sources on the productivity of wheat (var. Inqlab) under naturally salt-affected soil (pH = 8.79; ECe = 6.46; Sandy loam) at Soil Salinity Research Institute Farm, Pindi Bhattian. The various treatments planed for this study were as: control, urea, ammonium sulphate (AS), nitrophos (NP) and calcium ammonium nitrate (CAN). A basal dose of P and K was applied at the time of seed bed preparation @ 80 and 50 kg/ha as SSP and SOP, respectively. The N from each source @ 120 kg/ha was applied in two equal splits, i.e., at sowing time and at 45 days after sowing. The experiment was organized in randomized complete block design (RCBD) using three replications having 8 × 6 m^2 plot size. The crop was grown to maturity and plant protection measures were followed whenever required.

Soil sampling (0-15 cm) was done before the crop sowing for physico-chemical analysis (Table 1). The samples were analyzed for soil textural class by hydrometer method (Bouyoucos, 1962). Calcium carbonate was estimated by acid neutralization method (FAO, 1980) and soil organic matter by oxidation with potassium dichromate in sulfuric acid medium under standardized conditions by Walkley and Black procedure. Soil pH was determined in water (soil water ratio 1:1). Electrical conductivity (ECe) of the soil suspension was measured using conductivity meter. The P and K were determined by using AB-DTPA method. For N determination, plant samples (straw and grain) were digested with sulfuric acid and determined by using auto-analyzer (Ryan *et al*., 2001). Data regarding number of tillers per plant, straw and grain yield were recorded. Nitrogen uptake by wheat was calculated based on yield data. Nitrogen recovery by wheat crop was determined

Table 1. Physico-chemical analysis of soil at experimental site

Parameters	Units	Pre-sowing value
pH	-	8.79
ECe	dS/m	6.46
$CaCO_3$	(%)	2.50
Organic matter	(%)	0.36
NO_3 - N	mg/kg	2.17
P	mg/kg	3.56
K	mg/kg	70.00
Sand	(%)	24
Silt	(%)	37
Clay	(%)	39
Soil textural class		Sandy loam

from proportion of applied N taken up by the crop and expressed in terms of percentage and physiological efficiency was determined using following formula:

$$(Y_f - Y_0) / TNU_f - TNU_0$$

where:

TNU_f is total N uptake of N-fertilized plots and TNU_0 is total N uptake of zero-N plots (Isfan, 1990).

The data thus collected were subjected to statistical analysis and treatment differences were determined by using LSD (Gomez and Gomez, 1984).

Significant differences were observed in wheat grain and straw yield when various N sources i.e., urea, ammonium sulphate, nitrophos and calcium ammonium nitrate were applied to the crop. Maximum wheat grain (3203 kg/ha) and straw yield (3489 kg/ha) were recorded with the application of ammonium sulphate (Table 2). The different N sources followed the order: ammonium sulphate > urea > calcium ammonium nitrate and nitrophos. Nitrogen concentration in grain and straw was significantly affected by different N sources (Table 2). Maximum N concentration in straw (0.78%) and grain (4.56%) was observed in plants harvested from control treatment. Among various N sources, maximum N uptake by wheat crop (117.26 and 114.00 kg/ha) was recorded with the application of ammonium sulphate and urea, respectively, as compared to rest of the treatments followed by calcium ammonium nitrate (105.78 kg/ha) and nitrophos (104.29 kg/ha). However, lowest total N uptake (77.80 kg/ha) was recorded from the treatments harvested from control where no N was applied (Table 3).

Table 2. Effect of different N-fertilizer sources on wheat yield, NO_3-N in soil and N concentration in wheat straw and grain (average of four repeats)

Treatments	Crop yield (kg/ha)		N Concentration (%)		Soil NO_3-N after wheat (mg/kg)
	Straw	Grain	Straw	Grain	
Control	1526d	1417d	0.78a	4.56a	5.90c
Urea	3041b	2744b	0.56b	3.53c	6.00d
AS	3489a	3203a	0.49b	3.13d	6.30c
NP	2264c	2047c	0.70ab	4.23b	7.70a
CAN	2494c	2209c	0.54b	4.04b	7.50ab

Values followed by same letter(s) are statistically similar at P = 0.05 level of significance.

Similarly, N recovery of wheat was significantly affected by different N sources (Table 3). Maximum N recovery (31.57% and 28.97%) was recorded with the application of ammonium sulphate and urea, respectively. Significant difference in agronomic efficiency was noted due to various N sources (Table 3). The maximum agronomic efficiency (14.29 grain/kg of N applied) was observed when ammonium sulphate was supplied and it was minimum (6.33 and 5.03 grain/kg of N applied) with calcium ammonium nitrate and nitrophos treated plots, respectively. Different N fertilizer sources followed the order: ammonium sulphate > urea > calcium ammonium nitrate and nitrophos.

Table 3. Effect of different N-fertilizer sources on total N uptake (straw+grain), N recovery and physiological efficiency of wheat (average of four repeats)

Treatment	Total N uptake (kg/ha)	N recovery (%)	Physiological efficiency*
Control	77.80c	0.00c	0.00d
Urea	114.00a	28.97a	10.62b
AS	117.26a	31.57a	14.29a
NP	104.29b	21.19b	5.03c
CAN	105.78b	22.38b	6.33c

Values followed by same letter(s) are statistically similar at P = 0.05 level of significance.

In our study, when N was applied in various sources, higher grain yield was obtained with ammonium sulphate application followed by Urea. The reason might be comparatively better N utilization from ammonium sulphate under saline condition. Sulfur present in ammonium sulphate increased crop production owing to improved soil conditions for healthy crop growth. Abdou (2006) and El-Tarabily *et al*. (2006) reported that application of elemental sulfur or sulfur containing fertilizers in salt-affected soils inhibited uptake of unnecessary toxic elements (Na^+ and Cl^-), which encouraged selectivity of K/Na and ability of calcium ion to decrease the harmful effect of sodium ions in plants (Zaman *et al*., 2002; Wilson *et al*., 2000). Elemental sulfur is considered the source for reducing soil pH which mobilizes nutrients from unavailable phases to available pools therefore increasing N and micronutrient availability (Rice *et al*., 2006; Wei *et al*., 2006). On calcareous soils, added S is oxidized slowly under the effect of autotrophic bacteria (Jaggi *et al*., 2005). This SO_4 as a result of S oxidation is further oxidized to H_2SO_4 and reacts with the native $CaCO_3$ to form ($CaSO_4.2H_2O$) which is the cheapest soluble calcium source (Abd El-Hady and Shaaban, 2010) and in the soil solution; this dissolved calcium probably replaced the adsorbed Na^+ ion providing favorable environment for plant growth (Abdelhamid *et al*., 2013). Beneficial effects of sulfur on plant establishment under saline-sodic environment had also been reported in maize (Manesh *et al*., 2013), sunflower (Zaman *et al*., 2002), canola (Al-Solimani *et al*., 2010) and wheat (Ali *et al*., 2012; Ali and Aslam, 2005). Similarly Wei *et al*., (2006) reported that varying levels of sulfur and gypsum significantly ($P < 0.05$) increased yield attributes of wheat crop than non amended soil.

Significant increase in wheat growth parameters with treatments receiving ammonium sulphate can be explained by the ameliorative role of sulfur in alleviating the harmful effects of salinity and sodicity by replacing the Na^+ from exchange site. After leaching of Na^+ from root zone, crop might also benefited by the improved physical properties of soil leading to more reproductive growth in these treatments (Mohamed *et al*., 2012; Tzanakakis *et al*., 2011; Hussain *et al*., 2001).

Significant yield increases in wheat with addition of S and Ca have been described by (Mahmood *et al*., 2010). Its requirement is the same as of phosphorus (Ali *et al*., 2012 and 2008; Jez, 2008). Likewise, favourable soil pH affects crop nutrient availability (Wei *et al*., 2006) and it is very probable that reduced pH by sulfur containing fertilizer application in our study enhanced availability of essential plant nutrients, due to synergic effect with N (Rahman *et al*., 2011) leading to better N recovery that influenced physiological efficiency of wheat resulting in better grain yield.

Ammonium sulphate followed by urea fertilizer application produced better yield under naturally salt-affected soil as compared to calcium ammonium nitrate and nitrophos. Furthermore, the ammonium sulphate was found to be the best source of N for wheat production in salt-affected soil.

Conflict of Interest. The authors declare that there is no conflict of interest.

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