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Effect of nitrogen application methods and tillage implements on wheat production in salt affected soils

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Abstract

An efficient nitrogen management practices is imperative in salt-affected soil to avoid the overfertilization. In this context, a field trial was conducted tostudy the effect of tillage practices on nitrogen use efficiency in salt-affected soils for the wheat crop. Implements used in the study were, T_1Cultivator, T_2Disk harrow, T_3 MB Plough, T_4Chisel plough. Whereas three nitrogen application methods were used, A_1Broadcast, A_2 Band Placement, A_3 Side Dressing. The study was conducted in the split-plot design having three replications. Implements were kept in the main plots and nitrogen application methods in subplots. Grain yield data of wheat was recorded. The results of the study showed that grain yield was maximum for three seasons in treatment where nitrogen was applied in band placement and chisel plough was used as tillage implements. From the results, it can be concluded that the application of nitrogen in band placement with chisel plough using as tillage implements can be a very efficient nitrogen management practice in salt-affected soils.

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Introduction

Increasing demand for food for the world population depends upon the use of chemical fertilizers, especially nitrogenous fertilizers (Zhu and Chen 2002). Nevertheless, low nitrogen use efficiency and overuse of fertilizer resulted in environmental pollution and wastages of precious resources (Wang *et al.,* 2017).Therefore, to achieve food security and sustainable agriculture production environmentally friendly efficient N management strategies are urgently needed. Excessive, amounts of nitrogen applied by farmers are not proportional to crop yield (Shen *et al.,* 2013) and this malpractice results in denitrification, volatilization and low nitrogen recovery (Wang *et al.,* 2001). Therefore, improving nitrogen use efficiency is the main objective of sustainable agriculture (Yousaf *et al.,* 2016).

Different researchers showed that deep placement of nitrogen is a very effective management technique to increase the fertilizer recovery and crop yield than broadcast methods (Kapoor *et al.,* 2008; Bandaogo *et al.,* 2015). In these methods, losses of ammonia volatilization are reduced than the broadcast method (Rochette *et al.,* 2013) leading to increase nitrogen use efficiency (Huda *et al.,* 2016).Rice and Smith (1984) stated that nitrogen application in band placement is an efficient application method which improves the fertilizer recovery as compared to the broadcast method. According to Dong *et al.* (2014) placement of nitrogen@ 270 kg ha^{-1} increased the grain yield of maize crops. In a recent study, Tai-wen *et al.* (2018) investigated the effect of three nitrogen rates (no nitrogen application, N@270 and N @ 330kg ha^{-1}) and three topdressing distances (15, 30 and 45 cm) on maize crop. They reported that top dressing of nitrogen with 15 and 30 cm distances increased the total yield of maize by 12.3 and 8.3% respectively. Furthermore, nitrogen application @ 330 kg ha^{-1} increased the N uptake (308.3 kg ha^{-1}) nitrogen use efficiency (28.5%) and nitrogen agronomy efficiency (5.7 kg grain kg^{-1} N) as compared to other nitrogen rates. Similarly, in another study, Khan *et al.*(2018) evaluated the effect of three nitrogen application methods i.e. drilling with the seed, broadcast, and top dressing on the cotton-wheat cropping system. They concluded that drilling of 24 kg N ha^{-1} was a very effective nitrogen management strategy that increased yield and quality of the cotton crop in wheat-cotton crop rotation. wu *et al.*(2017) studied the effect of nitrogen application methods (no nitrogen application; nitrogen broadcast application; nitrogen deep placement) on rice crops. They reported that deep placement of nitrogen significantly increased the productive panicle per m^{-2} and paddy yield of rice. They concluded in another pot experiment that deep placement of nitrogen maintained the higher nitrogen supply for a longer period during rice growth than the broadcast method and plant's root absorb more nitrogen from deeper soil layers. Rao and Dao (1996) in a study stated that wheat growth, yield, nitrogen availability and grain nitrogen increased with the deep placement of nitrogen. According to (Dell *et al.,* 2011; Maguire *et al.,* 2011) deep placement of nitrogen through pressure injection, shallow disk injection, aeration infiltration orchisel injection could reduce the nitrogen losses through volatilization and N_2O emissions. Therefore, a study was planned with the objective to study the effect of tillage practices on nitrogen use efficiency in salt-affected soils for the wheat crop.

Materials and methods

A field study was conducted from 2015 to 2018 at the research farm of Soil Salinity Research Institute, Pindi Bhattian. A salt-affected field {pH_s = 8.68, EC_e = 4.48 (dS m^{-1}) and SAR = 27.36} was selected and prepared by using four tillage implement i.e. cultivator, disc harrow, mould board (M.B) plough, chisel plough according to treatment plan and three nitrogen application methods broadcast, band placement, side dressing were used in this study. Implements were kept in the main plots and nitrogen application methods in subplots. The wheat crop was sown for three consecutive seasons and the recommended dose of fertilizer (120-110-70 NPK kg ha^{-1}) was applied. Whole P, K and ½N were applied as basal dose whereas remaining ½N was applied with first irrigation. The experiment was conducted in

Split Plot Design having three replications. The crop was harvested at maturity and grain yield data was recorded. At the harvest of each crop, soil samples were collected and analyzed for pH_s, EC_e, and SAR (US Salinity Lab. Staff, 1954). Collected data were subjected to analysis of variance (ANOVA) and treatment means were compared through the least significance difference (LSD) test (Steel *et al.,* 1997) using STATISTIX 8.1 package software.

Results

Wheat grain yield 2015-16

A glance at data showed that wheat grain yield was remarkably influenced by the tillage practices, nitrogen application methods and their interaction. In Rabi season 2015-16, the maximum wheat grain yield (2.64 t ha^{-1}) was observed with band placement of nitrogen (Table 1).

Table 1. Effect of nitrogen application methods and tillage implements on wheat grain yield (t ha^{-1}) 2015-16.

Treatments	Fertilizer application method			Mean
	Broadcast	Band Placement	Side dressing	
Cultivator	2.28 d	2.51 bc	2.44 c	2.41 C
Disk harrow	2.44 c	2.58 bc	2.52 bc	2.51 B
MB Plough	2.52 bc	2.62 b	2.60 bc	2.58 B
Chisel plough	2.57 bc	2.84 a	2.62 b	2.68 A
Mean	2.45 C	2.64 A	2.55 B	

LSD for Treatment = 0.0958, LSD for Ammendments= 0.0780.

LSD for Treatment * Ammendments= 0.1560.

Among the tillage implement, chisel plough performed better than all other implements used with wheat grain yield of 2.68 t ha^{-1}. Data regarding the interaction of tillage implements and nitrogen application methods showed that the maximum grain yield (2.84 t ha^{-1}) was recorded by chisel plough and band placement of nitrogen. While the minimum grain yield (2.28 t ha^{-1}) was observed with cultivator and broadcasting method of nitrogen application.

Table 2. Effect of nitrogen application methods and tillage implements on wheat grain yield (t ha^{-1}) 2016-17.

Treatments	Fertilizer application method			Mean
	Broadcast	Band Placement	Side dressing	
Cultivator	2.29 f	2.42 ef	2.41 ef	2.37 C
Disk harrow	2.53 def	2.72 bcd	2.51 def	2.59 BC
MB Plough	2.57 def	2.91 abc	2.78 bcd	2.75 AB
Chisel plough	2.66 cde	3.09 a	2.92 ab	2.89 A
Mean	2.51 C	2.78 A	2.66 B	

LSD for Treatment = 0.2223, LSD for Methods= 0.1178.

LSD for Treatment * Methods = 0.2356.

Wheat grain yield2016-17

During 2nd season, wheat grain yield was also positively affected by nitrogen fertilization methods (Table 2). The maximum grain yield (2.78 t ha^{-1}) was documented by band placement followed by side-dressing, while the broadcast method of nitrogen produced the minimum grain yield (2.51 t ha^{-1}). Concerning the tillage practices, chisel plough proved more efficient with grain yield of 2.89 t ha^{-1}, however, it was statistically insignificant with MB plough. Regarding the interactive effect of fertilizer application methods and tillage practices, the

maximum grain yield (3.09 t ha^{-1}) was ensued by chisel plough with band placement however, it was at par with chisel plough and side dressing. The minimum grain yield (2.29 t ha^{-1}) was recorded where cultivator was used as tillage implements and nitrogen was applied through the broadcast method.

Wheat grain yield2017-18

A similar trend was observed in 3rd season, the maximum yield of 2.93 t ha^{-1}was divulged with band placement of nitrogen application. Among the tillage system, the maximum yield (3.02 t ha^{-1}) was observed with chisel plough and minimum (2.51 t ha^{-1}) with cultivator. Interactive effect showed that band placement with chisel plough recorded the highest yield of3.25 t ha^{-1}. While the broadcast method with cultivator showed the lowest yield of 2.46 t ha^{-1}, which was insignificant with band placement and side dressing methods of nitrogen application.

Table 3. Effect of nitrogen application methods and tillage implements on wheat grain yield (t ha^{-1}) 2017-18.

Treatments	Fertilizer application method			Mean
	Broadcast	Band Placement	Side dressing	
Cultivator	2.46e	2.56 e	2.54e	2.51 C
Disk harrow	2.56e	2.87bc	2.75cd	2.72 B
MB Plough	2.62de	3.05b	2.83c	2.83B
Chisel plough	2.79 cd	3.25 a	3.04b	3.02 A
Mean	2.60 C	2.93 A	2.79 B	

LSD for Treatment = 0.1197, LSD for Methods = 0.0954.

LSD for Treatment * Methods = 0.1959.

Soil properties

Data regarding the soil salinity index i.e (pH_s, EC_e and SAR) showed that tillage implements and nitrogen application methods significantly improved these properties at the end of the study (Table 4-6). With respect to soil pH_s a minimum value of 8.51 was recorded where chisel plough was used with band placement and this reduction was 1.95 % as compared to its initial value of 8.68. The minimum reduction (0.69%) in soil pH_s was observed where cultivator was used and nitrogen was broadcasted. Similarly, EC_e and SAR were also improved remarkably with the use of tillage implements and methods of nitrogen application methods. A maximum reduction of 11.16% and 9.57% was observed in EC_e and SAR respectively in treatment where chisel plough was used with band placement of nitrogen.

Table 4. Effect of nitrogen application methods and tillage implements on soil pH_s at the end of study.

Treatments	Broadcast	Band Placement	Side dressing
Cultivator	8.62	8.59	8.61
Disk harrow	8.59	8.56	8.57
MB Plough	8.58	8.54	8.55
Chisel plough	8.55	8.51	8.52

Discussion

To achieve the increasing demand for cereal foods, the use of mineral fertilizers is necessary. Nevertheless, farmers usually apply excessive nitrogen fertilizer that may cause destruction of water ecosystems and become a threat to the environment. Therefore, efficient nitrogen management and use of natural resources are imperative. Recently, different researchers have reported the suitable nitrogen management technologies that improve the nitrogen

use efficiency and crop yield (Constantin *et al.*,2010; Gaudin *et al.*,2015; Li *et al.*,2017).In the current study, we used three different methods of nitrogen application and four tillage practices to increase the nitrogen use efficiency in salt-affected soils for the wheat crop. The results of the study demonstrated that the maximum grain yield of wheat was obtained where band placement was used for nitrogen application and chisel plough was used for land preparation.

Table 5. Effect of nitrogen application methods and tillage implements on soil EC_e (dS m^{-1}) at the end of study.

Treatments	Broadcast	Band Placement	Side dressing
Cultivator	4.32	4.38	4.39
Disk harrow	4.15	4.13	4.14
MB Plough	4.16	4.07	4.13
Chisel plough	4.04	3.98	4.02

A possible reason for improved grain yield with band placement of nitrogen may be explained by that nitrogen was applied near the root zone and availability of nitrogen was easy as compared to other methods of nitrogen application. According to Nakamura *et al.*(2008) if fertilizer is placed far away from plants, the availability of nutrients is low in the root growing zone. Furthermore, in band placement starter nitrogen demand of plant is fulfilled during early growth stages which effectively promoted wheat root growth and consequently final grain yield (Osborne and Riedell 2006). Moreover, tillage practices during the soil preparation create the ideal conditions for plant emergence, root penetration and development (Licht and Al-Kaisi, 2005). Among all the tillage practices chisel plough go deeper to soil depth and conserve the moisture contents of soil,increased the infiltration rate,decreased the bulk density and penetration resistance (Leghari *et al.*,2015; Amin *et al.*,2014).

Table 6. Effect of nitrogen application methods and tillage implements on soil SAR at the end of study.

Treatments	Broadcast	Band Placement	Side dressing
Cultivator	26.75	26.41	26.65
Disk harrow	25.97	25.84	26.04
MB Plough	25.83	25.43	25.35
Chisel plough	24.74	23.68	24.86

Therefore, suitable fertilization location as in band placement promoted root growth, soil resources are utilized efficiently and thereby increased the grain yield of wheat while in broadcast methods of nitrogen application distance between plant's root and the fertilization locations increased and ultimately final grain yield of wheat also decreased. Our results are also supported by the findings of (Tai-wen *et al.,* 2018) who described that optimized fertilization locations can alleviate nutrient competition, increase fertilizer use efficiency and grain yield. Improved moisture contents in the deeper soil layer increased the nitrogen use efficiency, quality and yield of cereal crops (Gauer *et al.,* 1992) which is inconsistent with findings of the current study. While in broadcast methods nitrogen is lost through volatilization and limited availability of inorganic cannot lead to higher yields even if soil moisture contents are higher (Christensen *et al.,* 1994).

The application of a suitable dose of nitrogen in salt-affected soil created a favorable condition by reducing the soil pH significantly (Zhao *et al.,* 2014). Furthermore, deep tillage through chisel plough increased the soil permeability and soluble salts leached out from root zone, cut off the capillary

movement of groundwater and prevented the rise of Dissolved salts to the soil surface (Xiong *et al.,* 2012). Similar, findings are reported by (Costa *et al.,* 2016) that disc harrowing in sodium affected soil improved the SAR, bulk density and infiltration of water and increased the yield of sunflower crop as compared to with no-till.

Conclusion

From the above results, it can be concluded that the application of nitrogen in band placement with chisel plough using as tillage implements can be a very efficient nitrogen management practice in salt-affected soils which facilitate the wheat crop to absorb more nitrogen from fertilizer in a deeper layer of soil and produced higher grain yield.

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