Research Article

Optimizing Nitrogen Sources and Tillage Practices for Wheat Crop Stand and Phenology

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Abstract | Nitrogen application has a significant impact on wheat crop phenology and crop stand. To optimize nitrogen sources i.e. urea, farmyard manure (FYM) and poultry manure (PM) for improving wheat phenology and crop stand, an experiment was conducted at Agriculture Research Station Perdal Khel, Bannu (South part of Khyber Pakhtunkhwa, Pakistan) during 2016-17. The soil of the experimental area was Loamy sand with Haplic yermosols soil series based on FAO classification. The experiment comprised of three tillage practices i.e. Shallow tillage (ST), Conventional tillage (CT) and Deep tillage (DT) and eight nitrogen treatments (Control, 100% Urea, 100% FYM, 100% PM, 50% Urea/FYM, 50% Urea/PM, 50% FYM/PM and 33.33% each PM/FYM/Urea). These ratios provided a total of 120 kg N ha^{-1}. The wheat cv. Pakhtunkhwa-2015 was sown with seed of 120 kg ha^{-1}. The CT resulted in early phenology (days to emergence (11.5 days), booting (105 days), anthesis (116 days), and physiological maturity (155 days) whereas, DT delayed the phenological events. Among nitrogen ratios sole use of urea had delayed booting (108.1 days), anthesis (122.9 days) and physiological maturity (162.5 days) stages, whereas different ratios of Urea, FYM and PM resulted in early phenological observations. The use of urea, FYM and PM (33.33% each) had produced more tillers m^{-2} (288 tiller m^{-2}) as compared to sole source or control plots. Conclusively, CT performed better than DT for wheat crop phenology and crop stand. Similarly, Urea, FYM and PM applied in equal ratio improved crop stand whereas sole urea delayed phenology of wheat crop. Thus, it is recommended that 120 kg N ha^{-1} supplied as 33.3% from urea, FYM and PM combined with CT practice is more favorable production technology to improve crop stand of wheat.

Received | February 21, 2018; **Accepted** | December 12, 2020; **Published** | March 25, 2021
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Citation | Khan, A., A. Khan, D.F. Khan, S. Khan, Anjum, W. Ali, H. Akbar and A. Khan. 2021. Optimizing nitrogen sources and tillage practices for wheat crop stand and phenology. *Sarhad Journal of Agriculture,* 37(2): 340-347.
DOI | http://dx.doi.org/10.17582/journal.sja/2021/37.2.340.347
Keywords | Tillage practices, Nitrogen sources, Crop stand, Phenology

Introduction

Wheat (*Triticum aestivum* L.) is a staple food and is a leading cereal crop for the entire population and belongs to family Poaceae. Flour of wheat is used for piecrust, bread, biscuit and the vegetative plant parts make valuable livestock feed. During 2014-15, wheat was grown on 9205.5 thousand hectares area and its production was 25.09 million tons in Pakistan (MNFSR, 2014-15). In Khyber Pakhtunkhwa, Pakistan, the area of wheat sown was 732.6 thousand hectare and its production was 1.260 million tons

(MNFSR, 2014-15). In our province the average yield of wheat is ~1000 kg ha^{-1} less than country level average yield. This low productivity might be due to the lack of proper production technology. Thus using proper production technology, appropriate inputs and tillage system, wheat production can be improved as documented by earlier researchers in different parts of the province (Khan *et al*., 2019a; Muhammad *et al*., 2018). Similarly, wheat yield and soil physical properties were improved by application of organic manures and appropriate tillage system (Diacono and Montemurro, 2010).

In Pakistan conventional tillage (CT) is mostly practiced. The CT is commonly used tillage operation by common cultivator, which plough the soil up to the depth of 15-20 cm. Continuous use of CT changed the soils chemical, physical and biological properties (Muhammamd *et al*., 2018). It was observed that CT enhanced microbial biomass and carbon quantity in surface top layer of the soil (Babujia *et al*., 2010). Soil fertility of the topsoil surface soil is increased due to greater soil organic matter (SOM) which results in higher yield with no tillage practice (Chandio *et al*., 2012). Water use efficiency was positively improved with zero and reduced tillage (Salem *et al*., 2015) and thus increased crop productivity (Maltas *et al*., 2013). Shallow tillage reduced the cost of production up to 30% and facilitates sowing of wheat at proper time (Soane *et al*., 2012). Deep tillage increases the abundance of soil micro organisms. Likewise, more enzymatic activities of the soil enzyme were observed with DT in the clay type soil (Ji *et al*., 2014). As a result of DT, the greater soil depth increased the N uptake and hence plant density. Deep tillage disturbed the subsoil which had the potential to increase the soil carbon (Chen *et al*., 2013). In contrast, the deep tillage significantly reduced the agricultural productivity and had negative effects on soil characteristics (Putte *et al*., 2010).

The main limitation to the production of wheat is the poor management of nutrients and fertilizers which caused a great reduction in wheat yield (Fageria *et al*., 2010). The current focus is on the integrated nutrient management both from organic and inorganic sources for improving production (Ibrahim *et al*., 2020; Khan *et al*., 2019b). Pakistani soil has very low organic matter due to continuous application of synthetic fertilizer (Akhtar *et al*., 2019b; Khan *et al*., 2019a). Improved soil structure, microbes, organic content and fertility is important for sustaining and maintaining crop production, which can be obtained from integrated nutrient management (Khan *et al*., 2018). Crop yield and yield components were increased with integrated nutrients management strategies over sole application of organic or inorganic sources (Akhtar *et al*., 2019a). Thus, the N been derived from organic sources can compensate the N requirement to be provided by inorganic, thus would reduce the cost of inputs for crop production. Sustainable and profitable returns can be achieved by using on-farm resources of nutrients. This is only possible by integrated nutrients management using both organic and inorganic sources for N fertilizers. Therefore, a field experiment was conducted with the objectives (1) to find out the optimum tillage system, (2) to optimize the nitrogen sources i.e. urea, FYM and PM and (3) to understand the interactive response of tillage and N sources for improved wheat stand and establishment.

Materials and Methods

Experimental site

To evaluate the effect of integrated nitrogen and tillage practices on wheat phenology and crop stand, a field trial was established at the Agriculture Research Station Perdal Khel, Bannu, (South part of Khyber Pakhtunkhwa Province) during Rabi, 2016-17. The soil of experimental site was deficient in organic matter (0.54%), have less total nitrogen contents (0.052%), with soil bulk density of 1.21 g cm^{-3}, pH (7.81), EDTPA available phosphorous (3.1 mg kg^{-1}) and potash (97 mg ha^{-1}). The soil of the experimental site was Loamy sand with Haplic yermosols soil series based on FAO classification. The temperature ranged from 4 °C (December) to 36 °C (October) with average rainfall of less than 9 mm between September to January, and around 30-40 mm in Feb to April during a calendar.

Treatments and experimental design

The experiment was laid out in split-plot RCB design with four replications. Main plots had tillage (i.e. shallow (ST), conventional (CT) and deep (DT)) tillage operations while, nitrogen treatments (Control, 100% Urea, 100% FYM, 100% PM, 50% urea/FYM, 50% urea/PM, 50% FYM/PM and 33.3% urea/FYM/PM) were applied to subplots. These ratios provided 120 kg N ha^{-1} to all plots, except control. Chisel plough and cultivator was used to carry out deep and conventional tillage operations, which tilled the soil to the depth of 40 and 25 cm, respectively. Soil was ploughed vertically and horizontally in both DT and CT systems and planking was done to level the field. Rotavator was used for performing ST operations for 10 cm depth. The PM and FYM have 1.99% and 0.98% total nitrogen, and 2.3% and 0.5% phosphorus contents on dry weight basis, respectively. Ploughing and manure incorporation was made on October 3, 2016. However, N from urea source was supplied to the soil in two splits i.e. 50% at sowing and 50% with the application of water as first irrigation (after 21 days of sowing). Weeds were eradicated manually with help of hand hoe as well as with application of herbicides. The wheat cv. Pakhtunkhwa-2015 was sown in Nov 11, 2016, and harvested on 23 April, 2017. The sub plot size was 2.7 x 3 m having 9 rows, 30 cm apart and 3 m long. Recommended dose of phosphorous (60 kg P_2O_5 ha^{-1}) and potash (60 kg ha^{-1}) was applied uniformly to all plots as single super phosphate and sulphate of potash, respectively. Other all agronomic and cultural practices like irrigation, hoeing and weeding were carried out uniformly for all sub plots.

Observations and measurements

Days were counted from date of sowing to completion of 80% seedling emergence in each plot and was considered the days to emergence data. Number of seedlings emerged in three central rows were counted and converted into square meter for recording emergence m^{-2}. Days to boot stage, anthesis and maturity (physiological) were noted as the days difference between date of seed sowing and the date when 80% plants reached to boot, anthesis and physiological maturity, respectively. For recording tillers m^{-2}, tillers were counted in the two central rows of the plots and converted to tillers m^{-2}.

Statistical Analysis

The recorded data on plant stand and phenological parameters were analyzed using Statistix 8.1 software follow the procedure for Split-plot RCB design. The means were separated using least significant difference (LSD) test (Jan *et al*., 2009).

Results and Discussion

Days to emergence

Emergence was significantly ($p \leq 0.05$) affected by tillage practices and nitrogen sources (Table 1). However, the interaction of tillage practices with N sources was found non-significant. The DT had significantly delayed (11.9 days) emergence when compared to shallow tillage (11.5 days) and conventional tillage (11.3 days) plots. Among the N sources delayed emergence was observed in control plots (11.9 days) as compared with fertilized crops. In comparison sole synthetic delayed (12.6 days) the emergence as compared with sole organic (11.1 days).

Table 1: *Effect of tillage practices and N treatments on days to emergence, booting and anthesis of wheat.*

Treatments	Days to		
	Emergence	Boot	Anthesis
Tillage practices (T)			
Shallow	11.5 b	105.0 c	116.0 c
Conventional	11.3 b	106.3 b	118.9 b
Deep	11.9 a	107.6 a	121.4 a
LSD (0.05)	0.30	1.16	2.16
N sources (N)			
Control	11.9 b	105.3 d	115.3 f
100% N from Urea	12.6 a	108.1 a	122.9 a
100% N from FYM	11.3 cd	106.7 bc	117.1 e
100% N from PM	10.8 e	107.3 ab	118.3 d
50% N from Urea + 50%N from FYM	11.8 bc	106.0 cd	119.6 c
50% N from Urea + 50% N from PM	11.5 bc	106.1 cd	120.8 b
50% N from FYM + 50% N from PM	11.0 de	105.6 d	116.6 e
33.33% from each	11.7 bc	105.6 d	119.5 c
LSD (0.05)	0.49	0.90	1.02
Control vs rest	***	***	***
Control	12.6	105.3	115.3
Rest treatments	11.4	106.5	119.3
Interaction			
T x N	Ns	Ns	Ns

FYM: Farmyard manure; PM: poultry manure.

Days to booting

Booting in wheat was significantly ($p \leq 0.05$) varied with operations of various tillage and application of nitrogen treatments (Table 1). Similarly, the difference between control vs rest was significant but the tillage x N sources interaction was non-significant. Significantly delayed booting was recorded in the plots of deep tillage (107.6 days) as compared with shallow tillage (105 days) and conventional tillage plots (106.3 days). Among the N sources delayed booting was observed in the plots fertilized with sole inorganic fertilizers (108.1 days) while earlier booting (105.3 days) was observed with integrated N application 33.33% from each source (Urea, FYM and PM).

Days to anthesis

Anthesis in wheat was significantly affected by main factors (i.e. tillage and N sources) but was not affected by the interactive response of these main factors (Table 1). Significantly higher days to anthesis (121.4 days) were observed in deep tilled plots as compared with shallow tillage (116 days) and conventional tillage (119.9 days). Among the N sources sole inorganic application had delayed anthesis of wheat (122.9 days) while lower days to anthesis were recorded in control plots (115.3 days). Fertilized plots took more number of days to anthesis (119.3 days) as compare with control plots (115.3 days).

Days to physiological maturity

Tillage operations and nitrogen sources had affected the physiological maturity of wheat, but their interaction was found non-significant (Table 2). The DT plots had delayed the physiological maturity by two days over CT and six days over ST. This indicated that DT took 161 days to reached physiological maturity, CT took 159.2 ad ST about 155.1 days. The longest physiological maturity in wheat was observed in plots having sole commercial fertilizer i.e. 100% urea applied N (162.5 days) in contrast to 154.8 days observed for control units. Fertilized plots took more number of days to physiological maturity (158.9 days) as compare with control plots (154.8 days).

Emergence m^{-2}

Main factors like tillage practices and N sources as well as their interaction were found to have significant effects on emergence m^{-2} (Table 2). Regarding different tillage practices, shallow tillage plots resulted in higher wheat emergence m^{-2} (92.2) as compared to conventionally ploughed plots (88.3) and deep tillage (85.7) plots. Significantly higher emergence m^{-2} (93.9) was observed with integrated N application 50% from FYM and 50% N from PM, while lower plants emergence m^{-2} were recorded in control plots (83.9). The interactive response of tillage and N treatments (Figure 1) indicated that ST preformed better for emergence m^{-2} across all treatments except control, and 50% N derived from urea/FYM. More specifically the emergence was improved with ST followed by CT when 33% N was derived from each urea, FYM or PM sources.

Table 2: *Effect of tillage practices and N treatments on days to physiological maturity and crop stand of wheat.*

Treatments	Days to physiological maturity	Emergence m^{-2}	Tillers m^{-2}
Tillage practices (T)			
Shallow	155.1 b	92.2 a	278.5 a
Conventional	159.2 a	88.3 b	267.8 b
Deep	161.0 a	85.7 c	261.7 b
LSD (0.05)	3.4	2.45	9.81
N sources (N)			
Control	154.8 f	83.9 c	225.5 e
100% N from Urea	162.5 a	87.5 b	271.4 c
100% N from FYM	157.3 de	91.8 a	263.8 d
100% N from PM	157.7 cde	93.5 a	265.1 d
50% N from Urea + 50% N from FYM	159.1 bcd	85.9 bc	282.8 b
50% N from Urea + 50% N from PM	160.3 b	86.7 b	285.0 ab
50% N from FYM + 50% N from PM	156.3 ef	93.9 a	272.6 c
33.33% from each	159.3 bc	86.6 b	288.6 a
LSD (0.05)	1.9	2.18	5.82
Control vs rest	**	***	***
Control	154.8	83.9	225.5
Rest treatments	158.9	89.4	275.6
Interaction			
T x N	Ns	**	**

FYM: Farmyard manure; PM: poultry manure.

Tillers m^{-2}

All the tillage practices and different nitrogen treatments either used as sole factors or in the interactive ways significantly affected tillers m^{-2} (Table 2). Maximum tillers m^{-2} (278.5) were recorded in shallow tillage as compared with conventional tillage (267.8) and deep tillage (261.7). Among the N sources maximum tillers m^{-2} (288.6) were observed with integrated N application i.e. 33.3% from each source (Urea, FYM and PM). However, minimum tillage was observed in control plots (225.5). Interaction of tillage practices and N sources (Figure 2) showed that tillers m^{-2} increased with decreasing ploughing depth except in plots having 50% N derived from urea/FYM or FYM/PM. However, in case of 50% N derived from urea/FYM or FYM/PM, the DT performed better than CT for tiller m^{-2}. Tillers m^{-2} increased with integrated N application and maximum tillers m^{-2} (302) were recorded in shallow tillage plots with N application 33.33% from each source (Urea, FYM and PM).

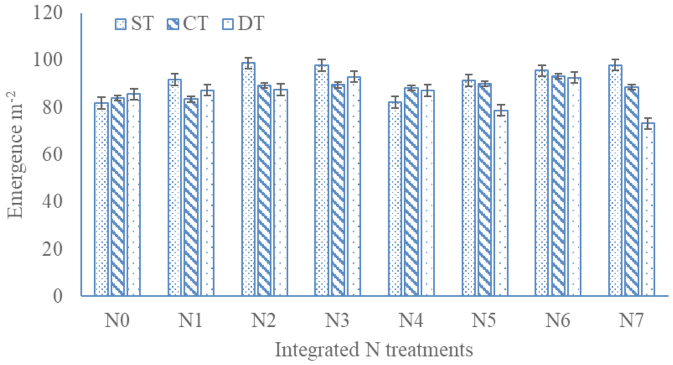

Figure 1: *The interactive response for emergence m^{-2} of wheat in response to tillage system (ST: Shallow; CT: Conventional; DT: Deep tillage) and nitrogen treatments (N_0: Control; N_1: 100% N from Urea; N_2: 100% N from FYM; N_3: 100% N from PM; N_4: 50% N from Urea + 50% N from FYM; N_5: 50% N from Urea + 50% N from PM; N_6: 50% N from FYM + 50% N from PM; N_7: 33.33% from each). Vertical bars are standard error of means.*

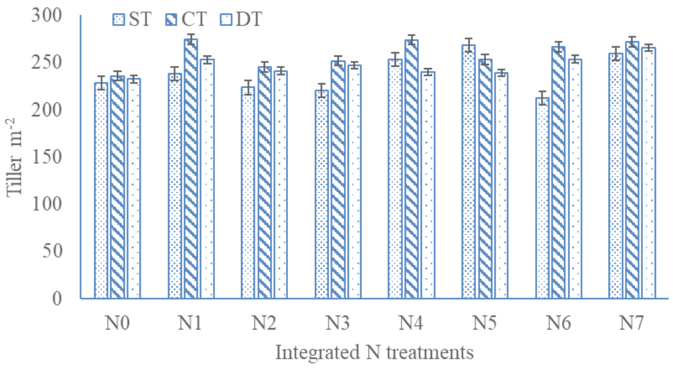

Figure 2: *The interactive response for tiller m^{-2} of wheat in response to tillage system (ST: Shallow; CT: Conventional; DT: Deep tillage) and nitrogen treatments (N_0: Control; N_1: 100% N from Urea; N_2: 100% N from FYM; N_3: 100% N from PM; N_4: 50% N from Urea + 50% N from FYM; N_5: 50% N from Urea + 50% N from PM; N_6: 50% N from FYM + 50% N from PM; N_7: 33.33% from each). Vertical bars are standard error of means.*

Days to emergence and emergence m^{-2}

The wheat emergence days and emergence m^{-2} varied significantly with tillage operations and treatments. Maximum seedling was emerged in shallow tillage plots which took minimum number of days. This might be due to the availability of nutrients in the soil (Dolan *et al*., 2006), which improved the soil status which promotes emergence (Khan *et al*., 2009) and hence phenological observations. The earlier seedling emergence in plots operated with ST could be related to two mechanisms a) conservation of the more moisture (Khan *et al*., 2015), and (b) reduced losses of soil moisture as evaporation in less disturbed soil (Licht and Al-Kaisi, 2005). In both cases, the seeds had optimum moisture availability for starting its germination phase, and thus took less days to emergence, without failure of seeds for emergence. In response to nitrogen treatments integrated use of organic and inorganic fertilizers had enhanced the emergence and also improved crop stand. This might be due the reason that integration of tillage practices and incorporation of nitrogen fertilizers in both organic and inorganic form improved soil water holding capacity (Al-Kaisi and Yan, 2005) and SOC (Dolan *et al*., 2006). These results are supported by Khan *et al*. (2009) and were confirmed by Basir *et al*. (2016).

Phenological observation during reproductive phase

Data regarding days to booting, anthesis and physiological maturity showed that deep tillage delayed all the phenological attributes as compared with shallow tillage and conventional tillage. Similar results were also reported by Khan *et al*. (2008) that deep tillage delayed phenological development than conventional and minimum tillage. Sole application of nitrogen from urea, FYM and PM shows delayed phenological attributes as compared with the application of these sources mixed with synthetic sources of nutrients. The possible reason might be the adequate availability of nutrients and good soil condition that prolonged vegetative growth period and crop growth (Loamy *et al*., 2003) and hence the phenological attributes were delayed. These results follow the results of earlier researcher (Khan *et al*., 2009: Deldon, 2001) who observed delayed phenological attributes in fertilized plots compared with no N applied.

Tiller m^{-2}

Data regarding tillers m^{-2} reveled that maximum number of tillers were observed in shallow tillage as compared with conventional and deep tillage. Among the N treatments, maximum numbers of tillers m^{-2} were recorded from the plots of integrated fertilizers application than the sole application of fertilizers. The mix application of organic and inorganic sources might have enhanced available water for the development of roots as reported by Hossain *et al*. (2002) and confirmed by Matsi *et al*. (2003). The improved soil properties had thus improved the plant stand, with potentially higher tillers plant^{-1}. It was also documented by Badaruddin *et al*. (1999), that plants have more tiller potential when received the N from both inorganic as well as organic source compared to either source. Basir *et al*. (2016) also confirmed that reduced tillage and plots having organic matter incorporated produced maximum number of tillers m^{-2} as compared with deep tillage and control plots.

Conclusions and Recommendations

Among the tillage operations, CT improved the crop stand but delayed the phenological observation. It was concluded that the application of urea had delayed wheat phenological events, where the crop stand in term of emergence and tillers was improved with mixed application of organic and inorganic sources i.e. 33.3% from all the three sources (urea, FYM, and PM). Thus, it is recommended that 120 kg N ha^{-1} supplied as 33.3% from urea, FYM and PM combined with CT practice is more favorable production technology to improve crop stand of wheat.

Novelty Statement

The phenological observations delayed with conventional tillage practice and sole urea application at the rate of 120 kg N ha^{-1}. The Crop stand improved with conventional tillage practices as well as using 120 kg N ha^{-1} derived from three sources i.e. 33.3% each from urea, FYM, and PM.

Author's Contribution

Arsalan Khan: Conducted field studies and recoded field data, initial draft.
Aminullah Khan: Helped and supervised in field data collection at the experimental site.
Dil Fayaz Khan: Did overall supervision on experimental site.
Sajid Khan: Carried out data manipulation and statistical analysis.
Anjum: Designed Tables/figures and determined the initial soil properties.
Waqar Ali: Revised the initial draft.
Habib Akbar: Convinced the idea of research.
Ahmad Khan: Supervised the student throughout the studies and finalized the draft for submission

Conflict of interest
The authors have declared no conflict of interest.

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