Nitrogen translocation efficiency in wheat depends on N sources and tillage practices

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Abstract
Integrated nutrient management (INM) under reduced tillage practices improve soil properties and plant nitrogen (N) dynamics. The effects of urea, farmyard manure (FYM) and soybean residue (SR) under different tillage systems were evaluated in 2-year field experiments for N translocation and translocation efficiencies. Tillage systems included minimum (MT), conventional (CT) and deep (DT) tillages. The INM treatments were urea (60 and 120 kg FN ha^{-1}), FYM (10 and 20 tons ha^{-1} as sole or enriched with ½ FN), SR (10 t ha^{-1} as alone or along with ½ FN) and control. Deeply ploughed plots had higher apparent N translocation (11.3 g kg^{-1} DM) and apparent N translocation efficiency (69%) compared to less disturbed plots. Control plots had higher apparent N translocation efficiency (75%) than fertilised plots. Among the fertilised plots, the order for increased efficiencies were urea > FYM > SR. Increasing the N content of the soil via fertilisation decreased the N translocation and its efficiencies. It was concluded from the experiment that easily mineralisable source of N and DT had higher had higher translocation and its efficiencies over the more recalcitrant sources and CT system. Understanding the mechanistic approach of such studies under INM is recommended for improving the nitrogen indices and productivity on sustainable basis.

Keywords
Nitrogen indices, integrated nutriment management, ploughing, nitrogen sources.

Introduction
Nutrient translocation is the transfer of stored nutrients from vegetative to reproductive organ of plants (Sanford and MacKown 1987), which affects both residue and developing grains composition. The physiological processes involved could be similar to the seasonal withdrawal from previously accumulated reserves in storage tissues (Titus 1989). Unlike woody species, the transfer of N can occur from leaves (whether senescing or not) to storage organs. The translocation of N to the kernel depends on the amount of N mobilised between anthesis and maturity and also upon the conversion efficiency (Gebbing et al. 1999). It was estimated that about 57% of N to wheat grains was re-translocate (Gallagher et al. 1976) mostly in the form of protein and amino acids during grain filling (Schnyder 1993).

Both tillage practices and N fertilisation play an important role in changing the N composition of both straw and developing grains. Reduced tillage increases soil N content, thus making N available for plants, which lowers N translocation amount and efficiency. Surplus soil N at grain filling reduces the mobilisation of N (Papakosta and Gagianas 1991). Translocation is not restricted to sites of low fertility (Nambiar and Fife 1991). At most forested sites, nutrient translocation enables a significant amount of growth to occur in soils with reduced fertility (Katainen and Valtonen 1985). The translocation of nutrients from stored organ results in lesser uptake of mineral nutrients from the soil (Ranger et al. 1995). This study’s objectives were to examine N translocation and efficiency in plots incorporated with various sources and amount of N under a range of tillage practices.

Methods
The effect of different sources of organic and inorganic N added to soil under different tillage practices were assessed in 2-year (2005–2007) field experiments at The University of Agriculture, Peshawar Pakistan (71º, 35´ E and 35º, 41´ N). Spring wheat (cv. Saleem-2000) was used as a test crop in wheat-maize-wheat cropping system. The soil of the experimental farm was a well-drained and fine textured silt clay loam. The experimental site had semi-arid subtropical continental climate with a mean annual rainfall of about 360 mm. The soil is deficient in total N (0.45 g kg^{-1} soil) and AB-DTPA extractable P (3.45 mg kg^{-1} soil), but has adequate AB-DTPA K (105 mg kg^{-1} soil) with a pH of 8.2 and organic matter content of 0.73%. The crop was flood irrigated in addition to rainfall.

The experiment was conducted as a Randomised Complete Block (RCB) design with split plot arrangement and three replications. Twelve integrated nutrients management (INM) treatments of N in the form of urea N (FN), farmyard manure (FYM) and soybean residue (SR) were arranged in subplots and three tillage practices [minimum tillage (MT), conventional tillage (CT) and deep tillage (DT)] in main plots. The INM treatments were 0kg N ha^{-1} (Control), 60kg N ha^{-1} (FN60), 120kg N ha^{-1} (FN120), 10 tons FYM ha^{-1} (FYM 10), 20 tons FYM ha^{-1}(FYM20), FYM10+½FN60, FYM10+½FN120, FYM20+½FN60, FYM20+½FN120, 10 tons SR ha^{-1} (SR10), SR10+½FN60, and SR10+½FN120. DT practices were carried out by chisel plough which tilled the soil up to 45 cm followed by a common cultivator. Common cultivator was used for CT which tilled the soil for 30cm. MT practice was done by the use of rotivators to bury only the FYM/SR up to 4-6cm deep. FYM was obtained from the Dairy farm of The University of Agriculture, Peshawar having 1.06 % total N, 16.2% organic matter, whereas the SR was harvested the previous year having 3.12% total N and 18.7% organic carbon. Incorporation of FYM and SR in the field was made 45 days before sowing in all seasons at 4-6cm soil depth using common cultivator and irrigated as flood irrigation. Urea (46% N) was applied in a split application, half at sowing and the other half just after first irrigation (after 27 days). Subplots of 3 x 5 m with 10 rows 30 cm apart with 5 meter length, and 3 replications were used in the experiment.

Wheat components (leaves, stem, spike, straw and grains) N contents were measured at anthesis and maturity stage depend on the crop stage following Kjeldahl procedure. From the measured N contents, apparent N translocation and its efficiency was calculated as proposed by Cox et al. (1986) using the following formulae. Analysis of variance (ANOVA) and least significance difference (LSD) test at $p < 0.05$ was used for hypothesis testing.

$$Apparent\ N\ translocation = N\ assimilation\ prior\ to\ anthesis - N\ yield\ at\ maturity\ (leaves + stem)$$

$$Apparent\ N\ translocaton\ efficiency\ (\%) = \frac{Apparent\ N\ translocation}{N\ assimilation\ prior\ to\ anthesis} \times 100$$

Results and discussion

Apparent N translocation

Apparent N translocation (ANRt) was significantly higher during first year than following year. Plots tilled deeply (DT) had more ANRt than minimum tilled plots (MT) during 2005-06, however the effects were non-significant during the following year. Combined over both years data (Figure 1) revealed that ANRt was greater for DT than either MT or conventional tillage (CT). The prolonged effects of MT resulted in higher percent mean than the other tillage practices. The lower N contents in DT plots (Soon et al. 2001) compared to the others resulted in less accumulation of N in the plant tissue (Kristensen et al. 2003) and thus increased these N indices. Similarly, the higher source sink competition for low N content in DT plots (Lopez-Bellido et al. 2001) increased the N utilisation in term of more grain productivity (Pan et al. 2006) and thus increased the translocation from vegetative to reproductive parts when compared to other tillage practices.

Apparent N translocation efficiency

Apparent N translocation efficiency (ANRtE) was higher for DT plots over MT, however was not different than CT plots across seasons (Figure 1). Greater ANRtE in DT plots would be associated with greater translocation of N from vegetative parts to reproductive parts. The uptake of less mineral N available at grain filling in DT as a consequence of greater N loss resulted in greater translocation (Zhou et al. 2007) and thereby increased efficiency. ANRTE ranged from 64 % (10 tons SR + 60 kg FN ha^{-1}) to 75 (control) in 2005-06, while ranged from 65% (10 tons SR ha^{-1}) to 75% (control plots) in the following year (Table 1). Plots having 20 t FYM ha^{-1} applied solely or combined with 60 kg N ha^{-1} resulted in statistically similar ANRtE. The greater translocation of N from vegetative part to reproductive parts at maturity in control resulted in higher ANRtE compared to fertilised treatments. Figure 2, indicated no differences in ANRtE in plots having organic or inorganic N. Incorporation of FYM whether sole or mixed with N did not exceed in ANRtE among themselves or from plots having N or soybean residue (SR). Within those plots having SR, sole SR incorporation was neither different from plots having supplemented SR with FN, nor different from those plots having N. The greater mineralisation of organic matter (Aulakh et al. 2000) into available N resulted in vagarious plant growth, and thus resulted in low translocation of N when compared to control plots. The higher available N in fertilised plots increased early N content in vegetative parts (Halvorson et al. 2000), but the translocation to grain was much lower when compared to the control (Gooding et al. 2007). The higher need of N by grains was met by reserve N in the control plots and thus increased the translocation efficiencies of N into reproductive parts of the crop compared to fertilised plots. Transformation of plant N from vegetative parts to grains through source sink competition (Aulakh et al. 2000) might be the other possible reason.

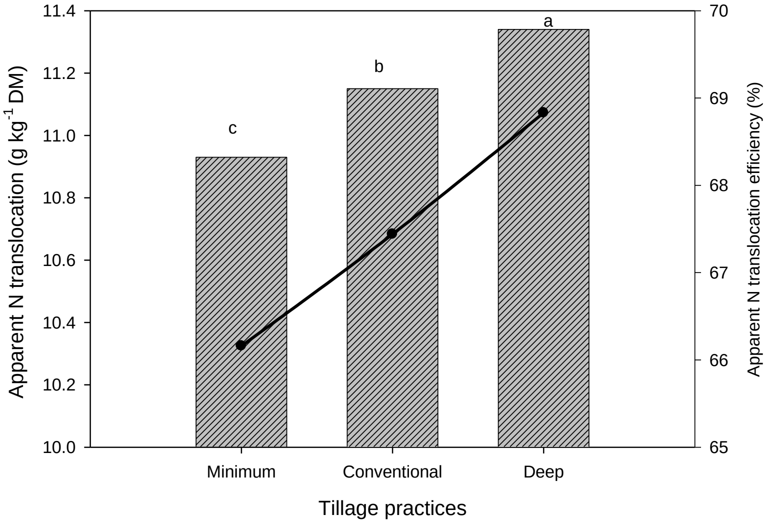

Figure 1. Apparent N translocation and its efficiencies in response to tillage averaged over seasons and integrated nutrient management treatments.

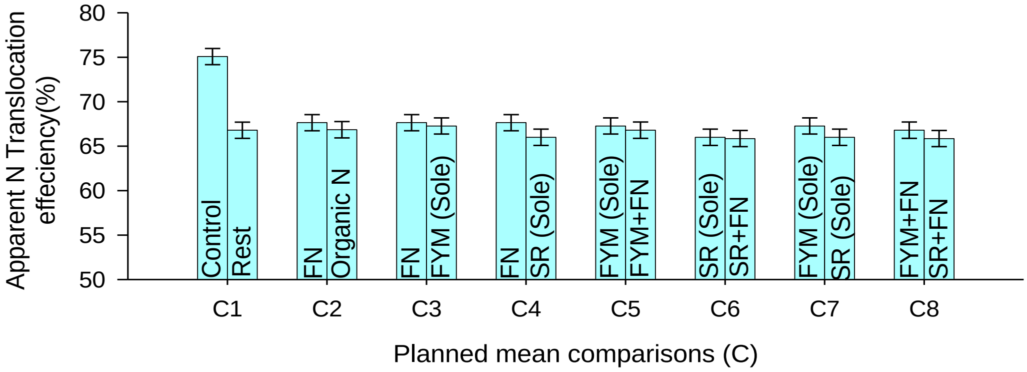

Figure 2. Planned mean comparisons for apparent N translocation efficiency (%)averaged over years, tillage and replications. Vertical bars are standard errors of means. FN= urea N, FYM = Farmyard manure, SR= Soybean residue.

Table 1. Apparent N translocation efficiency (% of grand mean) as affected by various integrated nutrient management treatments. FN= urea N (kg ha^{-1}), FYM = Farmyard manure and SR = soybean residue (tons ha^{-1}).

Integrated nutrient management treatments	Years		
	2005-06	2006-07	Mean
		%	
Control	75	75	75
FN-60	66	70	68
FN-120	69	66	68
FYM-10	69	65	67
FYM-20	68	67	67
FYM-10 + FN-30	66	68	67
FYM-10 + FN-60	67	67	67
FYM-20 + FN-30	67	66	66
FYM-20 + FN-60	67	67	67
SR-10	67	65	66
SR-10 + FN-30	64	68	66
SR-10 + FN-60	65	66	66
$LSD_{0.05}$	**2.2**	**2.7**	**2.6**

Conclusions

It was concluded from the experiment that deep ploughing had higher N translocation amount and efficiency than MT plots. Increasing soil N content via fertilisation decreased N translocation and efficiency. Control plots had higher apparent N translocation efficiency (75%) than fertilised plots. Among the fertilised plots, the order for increased efficiencies were urea > FYM > SR. Application of mixed organic and inorganic N reduced N translocation and efficiency compared to sole sources.

References

Aulakh MS, Khera TS, Doran JW, Kuldip-Singh and Bijay-Singh (2000). Yields and nitrogen dynamics in a rice–wheat system using green manure and inorganic fertilizer. Soil Science Society of America Journal 64 (5), 1867-1876.

Cox MC, Qualset CO and Rains DW (1986). Genetic variation for nitrogen assimilation and translocation in wheat III Nitrogen translocation in relation to grain yield and protein. Crop Science Journal 26, 737-740.

Gallagher JN, Biscoe PV and Hunter B (1976). Effects of drought on grain growth. Nature 264, 541–542

Gebbing T, Schnyder H and Kühbauch W (1999). The utilization of pre-anthesis reserves in grain filling in wheat Assessment by steady-state 13CO2/12CO2 labelling. Plant Cell and Environment 22, 851–858.

Gooding MJ, Gregory PJ, Ford KE and Ruske RE (2007). Recovery of nitrogen from different sources following applications to winter wheat at and after anthesis. Field Crop Research 100, 143-154.

Halvorson AD, Black AL, Krupinsky JM, Merrill SD, Wienhold BJ and Tanaka DL (2000). Spring wheat response to tillage system and nitrogen fertilization within a crop–fallow system. Agronomy Journal 92 (2), 288-294.

Katainen HS and Valtonen E (1985). Nutrient re-translocation in relation to growth and senescence of Scots pine needles. In: Crop physiology of forest trees. Tigerstedt PMA, Puttonen P and Koski VJ Eds. Helsinki Finland 23-28 July 1984, 54-64.

Kristensen HL, Debosz K and McCarty GW (2003). Short-term effects of tillage on mineralization of nitrogen and carbon in soil. Soil Biology and Biochemistry 35, 979-986.

Lopez-Bellido L, Lopez-Bellido RJ , Castillo JE and Lopez-Bellido FJ (2001). Effects of long-term tillage crop rotation and nitrogen fertilization on bread-making quality of hard red spring wheat. Field Crop Research 72, 197-210.

Nambiar EKS and Fife DN (1991). Nutrient re-translocation in temperate conifers. Tree Physiology 9, 185-207.

Pan J, Zhu Y, Jiang D, Dai T, Li Y and Cao W (2006). Modeling plant nitrogen uptake and grain nitrogen accumulation in wheat. Field Crop Research 97, 322-336.

Papakosta DK and Gagianas AA (1991) Nitrogen and dry matter accumulation remobilization and losses for Mediterranean wheat during grain filling. Agronomy Journal 83, 864–870.

Ranger J, Marques R, Colin-Belgrand M, Flammang N and Gelhaye D (1995). The dynamics of biomass and nutrient accumulation in a Douglas (Pseudotsuga menziesiiFranco) stand studied using a chronosequence approach. Forest Ecology and Management 72, 167-183.

Sanford DA and van MacKown CT (1987). Cultivar differences in nitrogen remobilization during grain fill in soft red winter wheat. Crop Science 27, 295–300.

Schnyder H (1993). The role of carbohydrate storage and redistribution in the source-sink relations of wheat and barley during grain filling-a review. New Phytologist 123, 233–245.

Soon YK, Clayton GW and Rice WA (2001). Tillage and previous crop effects on dynamics of nitrogen in a wheat–soil system. Agronomy Journal 93 (4), 842-849.

Titus JS (1989). Nitrogen recycling in the apple. Annales des Sci Forestieres 46, 654-659.

Zhou X, Wang H, Chen Q and Ren J (2007). Coupling effects of depth of film-bottomed tillage and amount of irrigation and nitrogen fertilizer on spring wheat yield. Soil and Tillage Research 94, 251-261.