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Nitrogen Partitioning and Translocation in Wheat under Fertilizer-N Levels, Application Time and Decapitation Stress

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Abstract

The decapitation stress in dual purpose wheat can be managed by adopting proper fertilizer-N partitioning and translocation to get both more grain and fodder with higher amount of N-content. The fertilizer-N levels improved N-content at boot stage (24.37 g kg^{-1}), at anthesis stage (13.45 g kg^{-1}), at maturity stage (4.92 g kg^{-1}), grain N-content (18.38 g kg^{-1}), straw N uptake (43.34 kg ha^{-1}), grain N-uptake (58.81 kg ha^{-1}), apparent nitrogen re-translocation (14.88) and apparent nitrogen re-translocation efficiency (57.89) whereas reduced nitrogen harvest index (74.97 %) and nitrogen use efficiency (15.97) as compare to control. The decapitation stress reduced N-content at anthesis stage 12.90 g kg^{-1}, straw N-uptake (37.55 kg ha^{-1}), grain N-uptake (53.68 kg ha^{-1}), apparent nitrogen retranslocation (13.98), apparent nitrogen re-translocation efficiency (56.56) whereas enhanced nitrogen use efficiency (NUE), by 17.02 %. The increase in fertilizer-N level improved linearly N-content at boot stage (25.24 g kg^{-1}), at anthesis stage (13.71 g kg^{-1}), at maturity stage (5.11 g kg^{-1}), straw N-uptake (48.23 kg ha^{-1}), grain N-uptake (63.26 N kg ha^{-1}) but NHI (75.92 %), apparent nitrogen re-translocation (15.62) showed parabolic trend fertilizer-N level while the NUE reduced (13.21 % with 200 kg N ha^{-1}). The two equal split of fertilizer-N application time proved superior in the enhancement of N-content at boot stage, at anthesis stage, straw N-uptake (45.08 kg ha^{-1}) and NUE while the full with 2nd irrigation application improved N-content at anthesis stage (13.87 g kg^{-1}), straw N-uptake (44.35 kg ha^{-1}), apparent nitrogen re-translocation (15.88), apparent nitrogen re-translocation efficiency (59.91). Results suggest that NUE was increased with decapitation compared to non decapitated plants. Late application of N as full dose or even two equal splits applications at sowing and/or with 2nd irrigation had improved the N content , total N uptake, N re-translocation and its efficiency, grain protein, and NUE. The fertilizer-N level enhanced N-content at all growth stages, straw and grain. But NHI and apparent nitrogen re-translocation showed parabolic trend while reduced NUE.

Keywords: Nitrogen, Fertilizer-N, Fertilizer-N time, Fertilizer-N levels, Translocation, Re-translocation, nitrogen harvest index and NUE,

1. Introduction

The importance of wheat cannot be ignored in Pakistan as a major cereal crop because it occupies about 66% of the annual food cropped area with an average production of 2716 kg ha^{-1} during 2007-08 (MINFAL, 2008). It is the main staple food ingredient because it supplies 60% of the calories and protein of the average human diet (Khalil and Jan, 2002). To meet the demand of wheat agricultural scientists are continuously working on the wheat improvement and its production crop management practices to make Pakistan self sufficient in wheat crop. However of the use of wheat as dual-purpose (DP) crop (for forage and grain production) is aimed increasing area devoted to wheat grain and forage production. The dual purpose crop depend upon the relative demand of grains and forage, it is advisable to grow early to increase expected forage yield whereas later planting generates greater net returns (Hossain *et al*., 2003). The re-growth after cutting depends on remobilization of nitrogen and non-structural carbohydrate from roots to aerial part re-growth (Skinner *et al*., 1999). The re-growth and biomass distribution of plant can improve the use of more fertilizer-N (Morgan *et al*., 2001). Greater dry matter and grain yield were observed with N fertilization and higher N concentration with increase in fertilizer-N increment (Gibson *et al*., 2007). The remobilization of pre-stored assimilates to the grain enhanced by heavy supply of nitrogen (Yang *et al*., 2000). The fertilizer-N uptake and utilization is associated with both the green surfaces area of the crop canopy and with the dry matter component (Olesen *et al*., 2002). Urea can increase forage biomass and N content (Rao and Popham, 1999). The increase in nitrogen rate decreased nitrogen use efficiency and nitrogen recovery, while can be enhanced with split N application (Beyaert and Roy, 2005). The optimum N rate and field-specific N application improved nitrogen use efficiency and grain yield (Flowers *et al*., 2004). The excessive nitrogen applied to previous crop increases N-content of present crop (Wiatrak *et al*., 2004). The nitrogen uptake increased as the fertilizer-N level increased (Guarda *et al*., 2004). The excessive use of N reduce yield and also cause environmental risks associated with excess nitrogen (Bundy and Andraski, 2004). The fertilizer-N timing had greater impact on grain N accumulation and remobilization in wheat. The late fertilization increased N recovery in grain (Melaj *et al*., 2003). Different genotypes showed variable nitrogen remobilization and translocation efficiency while glutamine synthetase activity was more correlated to N remobilization (Kichey *et al*., 2007). Splitting the N applications were beneficial (Beyaert and Roy, 2005) than single application. The fertilizer-N application at early spring growth stage was not good due to poor N-uptake as compare to two or three split applied at stem elongation or ear emergence, while late N application results in fast N-uptake and improved fertilizer use efficiency (Sieling and Beims, 2007). The fertilizer-N application at early growth stages increased yield, while the late application improved grain N content (Brown and Petrie, 2006). Varietals Forage N variation was associated to environment and total N availability in the soil (MacKown and Carver, 2005). Increasing N fertilization had improved the grain N (Gibson *et al*., 2007) simultaneously enhanced the environmental risk, thus optimum supply of N for arable farming is necessary (Brentrup *et al*., 2004). The nitrogen uptake increased as the fertilizer-N level increased (Guarda *et al*., 2004). The higher N uptake by grain and more grain yield depends on the fertilizer-N supply, while negative correlation was observed between grain yield and N content (Fowler, 2003). The nitrogen harvest index (NHI) of wheat is depended more on genetical potential to utilize the available N (Andersson and Johansson, 2006). The grasses NHI depends more on the warmness of environmental condition, high temperature favor more nitrogen utilization (Gillen and Berg, 2005). The higher NHI can be achieved by using heavy dose of fertilizer-N through increasing the N utilization duration (Yang *et al*., 2000). Nitrogen use efficiency (NUE) is a measure of the extent to which a crop transforms available N to economic yield (Ma *et al*., 1999). The increase in nitrogen rate decreased nitrogen use efficiency and nitrogen recovery, while can be enhanced with split N application (Beyaert and Roy, 2005). The N applied later was utilized more efficiently than early application signifying the split or late N application for higher NUE (Sieling and Beims, 2007). Forage or cuttings remove some N and than grain again increase the total nitrogen recovery hence improves NUE (Zhu *et al*., 2006). Nitrogen loses can be reduced due to defoliation, the defoliated remove a specific amount of nitrogen while the remaining nitrogen could be efficiently used in fast growth and development habit of the crop (Zhu *et al*., 2006). The nitrogen movements from vegetative part to grain were in curvilinear or linear form till the grain filling (Pan *et al*., 2006). Forage availability is reduced during the winter period, therefore cereal (wheat) as dual purpose crop provide good quality of forage and also increases the area devoted to grain production (Arzadun *et al*., 2003). Decapitation before boot stage is advantageous to late cutting both in providing grain plus forage from same crop (Lyon *et al*., 2001). Highest yield obtained with urea when applied at tillering, while late fertilization increased N recovery (Melaj *et al*., 2003). Proper nutrient management and particularly N fertilizer play an important role in crop production. Although it is proved that recently developed wheat cultivars require high N and P for more production. But it has been reported that wheat yield can be limited by both inadequate and excessive N availability (Bundy and Andraski, 2004). In Pakistan limited knowledge work has been done on the dual nature of wheat crop. The present study was conducted to discuss the impact of fertilizer-N levels and timing and decapitation stress on nitrogen partitioning and allocation in dual purpose wheat crop the enhanced grain and forage yield in semiarid environmental condition of Khyber Pakhtunkhwa (KPK), Pakistan. The objectives of our research were to evaluate the different levels of fertilizer-N, application time impact and decapitation stress on nitrogen partitioning and translocation in wheat.

2. Materials and methods

2.1 Experimental site

The experiments were conducted at Newly Develop Farm, The University of Agriculture, Peshawar during 2004-05 and 2005-06. The environmental conditions of research farm are semi-arid subtropical with a mean annual rainfall less than 360 mm. Due to less rainfall the water requirements of wheat crop are fulfilled by 3-5 times irrigations during entire growing season.

The soil of the experimental site is silty clay loam with alkaline pH 7.7 – 8.2. The total N-content of soil was <0.5 g kg^{-1}. The field was prepared by thorough ploughing with mould board plough. All the phosphorus (Triple Super Phosphate) and potash (Muriate of Potash) fertilizers were applied at sowing time (both @ 50 kg ha^{-1}). The urea was used as N-source. Each experimental unit was 15 m^2 having 10 rows 30 cm apart and 5 m long. All the other agronomic practices were applied uniformly to each plot.

2.2 Fertilizer application and experimental design

The experimental variables consist of (**a**) decapitation stress was imposed to wheat foliage by cutting with soil surface (C_1) at Zadok growth stage 29 (Zadoks *et al*., 1974) compare to no-cut (C_0), where (**b**) N levels were 100(N_1), 150(N_2) and 200(N_3) kg ha^{-1} and (**c**) three application time as full dose at sowing (M_1), full dose at 2nd irrigation (M_2) and split application (M_3) as half at sowing and half with 2nd irrigation. A control plot was also included in each replication. Wheat variety Fakhre Sarhad was planted on 1st November, 2004 and harvested at 2nd May, 2005, similarly the same experiment was repeated on plots with same experimental layout during 2005-06. A total of 19 (2x3x3+1) treatments including one control were laid out in randomized complete block (RCB) design replicated four times.

2.3 Observations

The total-N of tissue analyzed at different growth stages i.e. the plant samples were collected at boot stage, anthesis stage and maturity stage (partitioned into straw and grain). All the samples were grounded to mash size of 2 mm and then nitrogen concentrations were determined by Kjeldahl method (Mulvaney, 1996).

Nitrogen uptake by grain was obtained by measuring the N concentration in grains of each treatment. Total nitrogen uptake (kg ha^{-1}) by grain was recorded by using the formula,

$$\text{Grain N uptake}(\text{kg ha}^{-1}) = \frac{\text{Grain N (g kg}^{-1}\text{) x grain yield(kg ha}^{-1}\text{)}}{1000}$$

Nitrogen uptake by straw was obtained by measuring the N concentration in straw of each treatment. Total nitrogen uptake (kg ha^{-1}) by straw was recorded by using formula,

$$\text{Straw N uptake}(\text{kg ha}^{-1}) = \frac{\text{Straw N (g kg}^{-1}\text{) x Straw yield(kg ha}^{-1}\text{)}}{1000}$$

Nitrogen harvest index was calculated as described by Cox *et al*. (1986).

N harvest index (%) = (grain N/total N assimilation) x 100.

N translocation (re-translocation) was calculated with formula described by Cox *et al*. (1986).

Nitrogen translocation = N assimilation prior to anthesis – [(leaf + Culm) + chaff] N yield at maturity.

Apparent N re-translocation efficiency was determined according to the procedure described by Cox *et al*. (1986) using the formula;

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

Nitrogen utilization efficiency was recorded by the formula (Fiez *et al*., 1995).

$$\text{Nitrogen Utilization Efficiency} = \frac{\text{Grain yield}}{\text{Total N uptake (Plant N)}}$$

The data was statistically analyzed using analysis of variance appropriate for randomized complete block design. The mean comparison was done to explain significant variation among the treatments. For such purpose, the sum of square of treatments was further partitioned to answer specific and important questions about the treatment effects (Jan *et al*., 2009). Main effects were compared using least significance different (LSD) test at 0.05 level of probability, when the F-values were significant (Gomez and Gomez, 1980).

3. Results and discussion

The nitrogen concentration in plant tissue at boot stage was significantly enhanced (24.37 g kg^{-1}) with fertilizer-N as compare to control (16.99 g kg^{-1}) over both years (Table 1). The decapitation stress remain non significant. While the N-content at boot stage increased (25.24 g kg^{-1}) with increase in N levels up to 200 kg ha^{-1}. The N-split significantly improved (24.80 g kg^{-1}) N-content at boot stage. The higher N content at boot stage could be due to the greater accumulation of N during early vegetative stage of the crop and/or fertilizer-N uptake and utilization which is directly proportional to crop green leaf area and dry matter (Brown and Petrie, 2006). Our results are in line with the findings of Olesen *et al*. (2002) and were confirmed by Gibson *et al*. (2007). The fertilizer-N application at early growth stages increased vegetative growth, while the late application only improve grain N content, so the higher concentration of N at boot stage is due to the outstanding N-uptake as a consequences of faster growth. The decapitation stress increased N-content at boot stage, which could be justify on the basis of the remobilization of stored N from roots to vegetative parts after cutting and/or higher N uptake as results of imposed stress in the form of cutting (MacKown and Carver, 2005). The late full dose or split doses application of fertilizer-N improved N-content compared to early N applied as full dose. These results are in agreement with the findings of Sieling and Beims, (2007), which were of the opinion that the fertilizer-N application sole at early growth stage was not good due to poor N-uptake as compare to two or three split doses.

The plant tissue N content at anthesis stage were higher (13.45 g kg^{-1}) in the rest compared to control (9.47 g kg^{-1}) over both years data (Table 1). The decapitation stress significantly decreased N-content 12.90 g kg^{-1} of plant tissue at anthesis stage in comparison to no cut 14.00 g kg^{-1} plots. The fertilizer-N significantly increased 13.71 g kg^{-1} N-content of plant tissue with 200 kg N ha^{-1} during both years at anthesis. The full dose of fertilizer-N applied with 2nd irrigation or in two equal split doses improved tissue N content (13.87 and 13.60 g kg^{-1})

compared to early application (12.87 g kg^{-1}) of N at sowing. Similarly, full late N application improved the N content with no cut, whereas split application decreased N content at anthesis. The probable reasons for improved N concentration at anthesis in fertilized plots might be due to the fertilizer-N uptake and utilization, which is directly proportional to crop green leaf area (Brown and Petrie, 2006). This supports the hypothesis that at peak growth stage the nitrogen is associated with the green surfaces area of the crop canopy, so the N content will be higher. The higher nitrogen concentration with fertilizer-N at anthesis is line with Olesen *et al*. (2002). The poor N-content with decapitation stress at anthesis stage can be justify on the basis of short photosynthetic activities duration and low dry matter production due cutting stress, which as a result accumulated low N content at anthesis stage (MacKown and Carver, 2005). The increased N-content with fertilizer-N rate at anthesis is in agreement with Gibson *et al*. (2007) who stated that the fertilizer-N uptake improved by additional N, while Bundy and Andraski, (2004) explained it as both limited and excessive fertilizer-N effects on wheat N-content therefore N recommendation should be based on pre-plant soil testing to reduce the environmental risk and yield loss. The late full dose or two equal split doses had higher N content than sole early N application. The findings are in line with the results of Sieling and Beims, (2007) who stated that the fertilizer-N split application is better than sole and later application results in fast N-uptake, similarly according to Kichey *et al*. (2007) nitrogen remobilization and translocation depend upon N absorbed at post-flowering and genotypic characteristic because glutamine synthetase activity was more correlated to N remobilization.
Plant tissue N content at maturity was higher (4.92 g kg^{-1}) in plots received fertilized compared to (4.39 g kg^{-1}) control plots (Table 1). The decapitation stress and fertilizer-N application time had no significant impact on plant tissue N-content at maturity stage. The fertilizer-N levels significantly improved (5.11 g kg^{-1}) N-content with 200 kg N ha^{-1} at maturity stage. The nitrogen higher concentration at maturity stage might be due higher N-uptake with fertilizer-N application and could be the consequences of higher N at boot and anthesis stages. These results are supported by the findings of Olesen *et al*. (2002) who stated that fertilizer-N is associated with dry matter and leaf area of the plants and were confirmed by Gibson *et al*. (2007). The decapitation stress had no impact on N-content at maturity stage as more N-content observed at boot stage and less at anthesis stage with cutting indicating that plant N-uptake continue after anthesis stage to fulfill it requirement. The fertilizer-N application time had no impact on N-content at maturity. The possible reason might be the varietal character to maintain certain amount of N in the form of structural compounds.
The nitrogen content of grain was significantly higher (18.38 g kg^{-1}) in fertilized treatments as compare to control 17.21 g kg^{-1} (Table 1). The decapitation stress and fertilizer-N application time had no significant impact on grain N-content. The fertilizer-N significantly increased N-content in grains with increase in fertilizer-N rate up to 150 kg ha^{-1} but further increase did not improve grain N-content during both years. The quality of grains is determined by the grain protein content (Souza *et al*., 2004). Cultivars with high grain protein are more suitable for quality bread production while with low protein is more suitable for noodle making. Our results that fertilizer-N increased grain N-content is in agreement with Zhu *et al*. (2006), who reported greater N in fertilized plots compared to unfertilized plots and Subedi *et al*. (2007) optimum grain protein content and grain yield can be obtained from spring wheat while provided with the proper amount of fertilizer-N. The decapitation stress had not influence on grain N-content, which could be associated to lesser re-translocation from vegetative part to the grains. The fertilizer-N improved N-content with raise in fertilizer-N rate up to certain level but further increase did not improve grain N-content, which is in line with Brentrup *et al*. (2004) who stated that the reduced or very high N rate are risky, so the optimal supply of N for arable farming is necessary. The fertilizer-N application timing had no effect on grain N-content, which is in contradiction to the findings of Farrer *et al*. (2006), who reported that the variability in grain protein attributed to timing and rate of N application.
Straw N uptake was higher in fertilized plots (43.34 kg ha^{-1}) compared to control plots (26.35 kg ha^{-1}) over average data of the two years (Table 2). The decapitation stress significantly reduced (37.55 kg ha^{-1}) N-uptake by straw compared to (49.14 kg ha^{-1}) no cut plots. The fertilizer-N levels significantly improved (from 37.81 to 48.23 kg ha^{-1}) straw N-uptake with the increase in fertilizer-N rate during both years. The fertilizer-N application method and its application time significantly affected straw N-uptake (44.35 kg ha^{-1} with late and 45.08 kg ha^{-1} with split). The improvement of total nitrogen uptake by straw with fertilizer-N results are in line with finding of Rao and Popham, (1999) urea can increase forage biomass and N content, similar observation recorded by Gibson *et al*. (2007) The straw N content were higher because it utilizes both the applied and soil nitrogen. The decapitation stress reduced N-uptake by straw the possible reason might be higher demand due forage removal and then again for growth and development, according to MacKown and Carver, (2005) selection of dual purpose wheat based on fall forage biomass without greatly changing forage total N. The fertilizer-N levels improved straw N-uptake with the increase in fertilizer-N rate are in agreement with Gibson *et al*. (2007) higher N concentration obtained with fertilizer-N increment. The delayed full dose or split doss of fertilizer-N enhanced straw N-uptake, the N-content depends upon N availability to plants so the delayed or split application increases it utilization time, this might be possible reason for higher straw N-uptake.
The total nitrogen uptake by grain was significantly enhanced (58.81 N kg ha^{-1}) with fertilizer-N treatments as

compare to (34.18 N kg ha^{-1}) control (Table 2). The decapitation stress reduced significantly N-uptake (from 63.94 to 53.68 N kg ha^{-1}) by grain. The fertilizer-N levels significantly improved grain N-uptake (63.26 N kg ha^{-1}) with the increase in fertilizer-N level (200 kg N ha^{-1}). The improvement in N-uptake with fertilizer-N application by grain might be due to higher grain yield in the fertilized plots which in turn had increased the grain N uptake. Our findings agree the results of Fowler, (2003). The decapitation stress reduced N-uptake compared no-cut plants. Zhu *et al*. (2006) observed that nitrogen used efficiently due to fast growth and development after cut application, and thus contradict to our results. The fertilizer-N levels improved grain N-uptake with the increasing fertilizer-N rate, which could be due the optimum grain yield been observed in plots having fertilizers (Boberfeld and Banzhaf, 2006). The fertilizer-N application time influenced grain N-uptake. Melaj *et al*. (2003) observed higher grain N uptake with delayed fertilizer-N application, Yang *et al*. (2000) observed with delayed and heavy fertilizer-N application.

The nitrogen harvest index significantly lower (74.97 %) with fertilizer-N treatments during both years as compare to (76.96 %) control (Table 2). The decapitation stress had no significant impact on NHI. The fertilizer-N levels significantly increased NHI (75.92 %) with the increase in fertilizer-N level up to 150 kg N ha^{-1}, while further increase 200 kg N ha^{-1} showed no improvement in NHI. The fertilizer-N application time and its application method had no significant impact on NHI. The nitrogen harvest index depends on genetical potential to utilize the available N (Andersson and Johansson, 2006). The nitrogen harvest index enhanced with fertilizer-N compared to control plots, which is supported by Brown and Petrie, (2006). The supplies of fertilizer-N improve N-content, so the N availability improved NHI. The decapitation stress had no impact on nitrogen harvest index. The possible reason for this might be the decapitation stress was applied at early growth stage and thus have negligible or no effect on NHI. The fertilizer-N levels increased nitrogen harvest index up to certain limit which are in agreement with Yang *et al*., (2000) who stated that higher NHI can be achieved by using fertilizer-N. The fertilizer-N application time had no impact on nitrogen harvest index. It could be explained as the grasses NHI have direct relation with degree warmness of environmental condition compared to soil N (Gillen and Berg, 2005), however Beyaert and Roy, (2005) reported that NHI can be enhanced with split N application.

The apparent nitrogen re-translocation was significantly enhanced (14.88) with fertilizer-N treatments during both years as compare to (8.55) control (Table 3). The decapitation stress significantly reduced (13.98 as compare to no cut 15.77) apparent nitrogen re-translocation. The fertilizer-N levels significantly increased (15.62) apparent nitrogen re-translocation with the increase in fertilizer-N level up to 150 kg N ha^{-1}, while further increase showed no improvement in apparent nitrogen re-translocation. The fertilizer-N full dose application with 2nd irrigation significantly enhanced (15.88) apparent nitrogen re-translocation compared to other N treatments. The apparent nitrogen re-translocation was enhanced with fertilizer-N, the results are in agreement with Kichey *et al*. (2007) who stated that glutamine synthetase activity was more correlated to N remobilization. The decapitation stress reduced apparent nitrogen re-translocation. The possible reason might be the roots accumulate very less amount of nitrogen and tanslocated within short time to other parts (Vouillot and Barret, 1999). The other possibility may be the cutting stress because higher proportion of N comes from the flag leaf, than second and third leaf, which results in the reduction of N re-translocation. However, Skinner *et al*. (1999) reported that the re-growth of defoliated crop depends upon non-structural carbohydrates and nitrogen reserves remobilization from roots to growing parts. The fertilizer-N levels increased apparent nitrogen re-translocation up to certain limit and no improvement observed with additional nitrogen. These results are in line with Morgan *et al*. (2001) who declared that higher level of fertilizer-N have positive relation with dry matter distribution and hence the N. However, these are in disagreement with the findings of Beyaert and Roy, (2005) who stated that the increase in nitrogen rate decreased nitrogen recovery. The fertilizer-N full dose application with 2nd irrigation enhanced apparent nitrogen re-translocation, which is supported by Pan *et al*. (2006). The remobilization of N depends on decrease of N concentration however Kichey *et al*. (2007) reported that nitrogen remobilization and translocation depend upon glutamine synthetase activity.

The apparent nitrogen re-translocation efficiency was significantly improved (57.89) with fertilizer-N treatments during both years as compare to (46.23) control (Table 3). The decapitation stress significantly reduced (56.56) apparent nitrogen re-translocation efficiency as compare to no cut (59.22). The apparent nitrogen re-translocation efficiency significantly amplified (60.71) with fertilizer-N levels up to 150 kg N ha^{-1}, while further increase showed no improvement. The fertilizer-N full dose application with 2nd irrigation significantly enhanced (59.91) apparent nitrogen re-translocation efficiency than other N treatments. The apparent nitrogen re-translocation efficiency improved with fertilizer-N compared to control plots. These results are not in line with the studies of Beyaert and Roy, (2005), who stated that the apparent nitrogen re-translocation efficiency decreased with fertilizer-N levels. The apparent nitrogen re-translocation efficiency reduced with decapitation stress. The possible reason might be the short growth period due decapitation stress or could be due to the water deficiency during grain filling stage (Yang *et al*., 2000) which had enhances re-translocation of assimilates to sink. However, Tahir and Nakata, (2005) reported that the heat stress reduced N remobilization and thus re-translocation efficiency. The apparent nitrogen re-translocation efficiency improved with fertilizer-N levels up to certain limit. Our results are in agreement with Beyaert and Roy, (2005) who stated that with increasing rate of N, apparent N recovery and efficiency reduced. The fertilizer-N full dose late application enhanced apparent nitrogen re-translocation efficiency and is supported by Sieling and Beims, (2007), who said that nitrogen applied later was utilized more efficiently than early application.

The nitrogen use efficiency was significantly reduced (15.97) with fertilizer-N treatments during both years as compare to (36.00) control (Table 3). The decapitation stress significantly enhanced nitrogen use efficiency. The nitrogen use efficiency significantly decreased (13.21 with 200 kg N ha^{-1}) with increase in fertilizer-N levels. The fertilizer-N split application significantly enhanced (17.02) nitrogen use efficiency compared to full application as early or late application. Nitrogen use efficiency (NUE) is a measure of the extent to which a crop transforms available N to economic yield (Ma et al., 1999). The higher soil N in the fertilized plots might have not improved the efficient utilization of the N than limited N available in the soil (Ma et al., 1999) and thereby decreased the NUE in the plots having fertilizer N. Boberfeld and Banzhaf, (2006) reported that low yielding wheat cultivars utilize nitrogen more efficiently due to more protein content compared to high yield cultivars, and such can be genetic characteristics of the cultivar. The decapitation stress enhanced nitrogen use efficiency, the limited short cycle, and rapid re-growth had efficiently utilized the soil N and thus has increased the NUE in decapitated plants compared to un-decapitated plants (Zhu et al., 2006). The nitrogen use efficiency decreased with fertilizer-N levels improvement, which is in line with Beyaert and Roy, (2005) who stated that increasing rate of N reduced NUE. The fertilizer-N split application enhanced nitrogen use efficiency can be explained that on time availability of soil N for prolonged time had resulted in the efficient utilization of the N and thus had increased the NUE compared to full application of the N fertilizers. The results are in line with the findings of Sieling and Beims, (2007), who stated that N applied in split doses had higher NUE than single application.

Table 1: The wheat N-content at boot stage, anthesis stage, maturity stage and in grain as affected by fertilizer-N levels, application time and decapitation stress.

Treatment	Boot (N g kg^{-1})	Anthesis (N g kg^{-1})	Maturity (N g kg^{-1})	Grain (N g kg^{-1})
Control	16.99	9.47	4.39	17.21
Rest	24.37	13.45	4.92	18.38
Decapitation stress				
No-cut	24.08	14.00	4.94	18.55
Cut	24.66	12.90	4.90	18.20
kg N ha^{-1}				
100	23.06	13.15	4.95	17.52
150	24.80	13.48	4.71	18.84
200	25.24	13.71	5.11	18.76
$LSD_{(0.05)}$ for N	0.50	0.23	0.15	0.55
N application time (M)				
Full at sowing (Early)	23.59	12.87	4.86	18.51
Full with 2nd irrigation (Late)	24.72	13.87	4.89	18.06
½ Sowing + ½ 2nd Irrigation	24.80	13.60	5.01	18.55
$LSD_{(0.05)}$ for M	0.50	0.23	0.15	0.55

Table 2: The wheat straw & grain N-uptake and N-harvest index as affected by fertilizer-N levels, application time and decapitation stress.

Treatment	Straw (N kg ha^{-1})	Grain (N kg ha^{-1})	N-Harvest Index (%)
Control	26.35	34.18	76.96
Rest	43.34	58.81	74.97
Decapitation stress			
No-cut	49.14	63.94	74.67
Cut	37.55	53.68	75.26
kg N ha^{-1}			
100	37.81	52.20	74.12
150	43.98	60.97	75.92
200	48.23	63.26	74.87
$LSD_{(0.05)}$ for N	2.76	2.40	0.70
N application time (M)			
Full at sowing (Early)	40.60	58.41	75.37
Full with 2nd irrigation (Late)	44.35	54.80	74.59
½ Sowing + ½ 2nd Irrigation	45.08	63.22	74.94
$LSD_{(0.05)}$ for M	2.76	2.40	ns

Table 3: The wheat apparent-N retranslocation, N-retranslocation efficiency and nitrogen use efficiency as affected by fertilizer-N levels, application time and decapitation stress.

Treatment	Apparent-N retranslocation	Nitrogen retranslocation Efficiency	Nitrogen Use efficiency
Control	8.55	46.23	36.00
Rest	14.88	57.89	15.97
Decapitation stress (C)			
No-cut	15.77	59.22	17.26
Cut	13.98	56.56	14.68
kg N ha^{-1} (N)			
100	14.37	56.58	19.03
150	15.62	60.71	15.68
200	14.65	56.38	13.21
$LSD_{(0.05)}$ for N	0.68	1.79	0.49
N application time (M)			
Full at sowing (Early)	13.96	56.48	15.71
Full with 2nd irrigation (Late)	15.88	59.91	15.18
½ Sowing + ½ 2nd Irrigation	14.79	57.28	17.02
$LSD_{(0.05)}$ for M	0.68	1.79	0.49

4. Conclusion

The results of nitrogen partitioning predicted that reduction in yield of dual purpose wheat crop can be handle with improvement in fertilizer-N level and its application time especially through split application method.

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