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Absorption and accumulation characteristics of nitrogen in different wheat cultivars under irrigated and dryland conditions

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Abstract

To investigate the N absorption and accumulation characteristics of different wheat cultivars, twelve wheat cultivars with different drought tolerance were planted under both irrigated and dryland conditions. Compared with the irrigated condition, wheat N accumulation was significantly decreased at each growth stage under dryland cultivation, with the maximum decline in weak drought-resistant cultivars (more sensitive) (SN129, SN9-1, 40081, and CZ9578), secondly the moderately-tolerant (40345, 40035, SN121, and ZM175) and then strong drought-resistant cultivars (040521-135, JM47, 9801-C, and ND189). Furthermore, dryland condition decreased the N absorption ratio at anthesis-maturity stage, post-anthesis N accumulation and its contribution to grain N content. On the contrary, the N absorption ratio at jointing-anthesis stage and the contribution of pre-anthesis N translocation to grain N content were increased. Therefore, under dryland condition, we suggest that strong drought-resistant wheat cultivars should be popularly cultivated. These cultivars could significantly improve pre-anthesis N absorption and the translocation from pre-anthesis vegetative organs to post-anthesis grain, resulting in higher N use efficiency and high wheat yield.

Keywords: Drought tolerance; Dryland; Irrigated land; Nitrogen absorption and accumulation; Wheat (*Triticum aestivum* L.).
Abbreviations: ANOVA- Analysis of variance; d- Day; g-Gram; kg-Kilogram; hm- Hectometer; K-Potassium; N-Nitrogen; P-Phosphorus.

Introduction

Wheat (*Triticum aestivum* L.) is the most commonly grown crop in the semi-arid region of Loess Plateau, China. About 70% of the cultivated area of Shanxi province consists of dryland environments, in which available moisture constitute primary constraint on wheat production by affecting N absorption, translocation, and allocation (Gao et al., 2009). The total plant N absorption is proportional to available water, greater under moist than dry environments (Clarke et al., 1990). Nowadays, more and more attentions have been spent on the plant N absorption and accumulation in drylands because of the importance of grain protein concentration in determining the yield and end-use quality of wheat (Clarke et al., 1990; Albrizio et al., 2010). Most studies have mainly focused on the N absorption and accumulation characteristics at different wheat growth stages (Zhao et al., 2006; Ercoli et al., 2008), different wheat genotypes (Dhugga and Waines, 1989; Barbottin et al., 2005; Zhu et al., 2005), and the interactive effects of moisture and N accumulation (Öztürk and Çağlar, 1999). N absorption was found varied at different growth stages, of which, N absorption reached peak at the jointing-anthesis stage. Liu et al. (2010) found drought stress in the jointing-flowering stage had the greatest effects on N assimilation in winter wheat, the second greatest being in the recovering-jointing stage, while that in late filling stage had few effects. However, supplemental irrigation at filling stage increased the N content by 20.9% (Wang et al., 2004). However, there are few reports on the N absorption and accumulation characteristics of different wheat cultivars under irrigated and dryland cultivating condition. The improvement on the wheat yield majorly depends on the variety breeding, improved production condition and cultivating techniques. Selecting of an optimal cultivar is the key approach to ensure high yield of wheat in dryland. Therefore, the objective of this study was to analyze the N absorption and accumulation characteristics of twelve different wheat cultivars under dryland and irrigated land condition, with aim to give a reference for popularization of the optimal cultivars in dryland.

Results

Changes of wheat yield in different cultivars under irrigated and dryland condition

Although there was a slight difference of wheat yield between 2007-2008 and 2008-2009 due to more severe drought stress in 2008-2009 (supplementary data 1), the variation tendency was practically similar. Therefore, the data from 2008-2009 were chosen in this study. The results indicated that the grain yields of 12 wheat cultivars in dryland were all decreased with varied degrees in comparison with that in irrigated condition (Table 1). Further, these 12 wheat cultivars were clustered into three groups: strong drought-resistance (040521-135, JM47, 9801-C, and ND189), moderate drought-resistance (40345, 40035, SN121, and ZM175), and weak drought-resistance (SN129, SN9-1, 40081, and CZ9578) according to the different drought-resistant coefficient (Fig. 1). A significant difference of the drought-resistant coefficient could be observed among these three groups (Table 1).

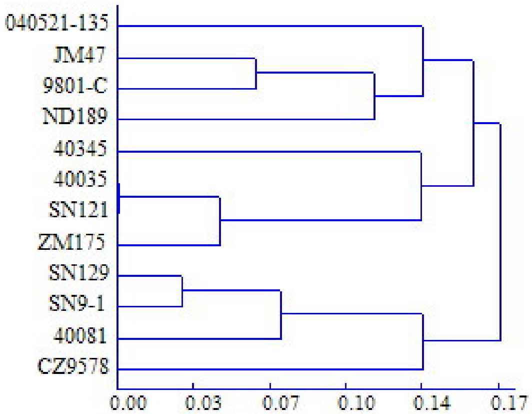

Fig 1. Dendrogram of drought-resistant coefficient in 12 different wheat cultivars. This figure was generated by SAS 9.0 software using K-means Clustering with the clustering coefficient bounded by the unit interval [0, 1]. The numbers of figure 1 indicated the similarity degree of drought-resistant coefficient of different wheat cultivars

Changes of N accumulation at different growth stages in different wheat cultivars

The N content gradually accumulated along with the progression of wheat development, and reached the peak value at maturity (Table 2). However, compared with irrigated land, dryland condition caused a significant decrease in wheat N accumulation at all growth stage (except for ND189 and 4034 cultivars), with the maximum decline in weak drought-resistant cultivars, secondly the moderate and then strong drought-resistant cultivars. This finding indicated that the strong drought-resistant cultivars might have a better ability to absorb N in dryland.

Changes of N absorption and its ratio in different wheat cultivars

The results revealed that dryland condition led to a decrease in wheat N absorption, especially in the weak drought-resistant cultivars (Table 3). Importantly, this dryland condition showed the highest influence on wheat N accumulation from anthesis to maturity, secondly from emergence to jointing stage, and then from jointing to anthesis. In addition, dryland condition decreased the N absorption ratio at anthesis-maturity stage, but increased the N absorption ratio at jointing-anthesis stage. As for the effect on N absorption ratio at emergence-jointing stage, there was a slight difference among the different drought-resistant cultivars, resulting in an increased N absorption ratio in strong and moderate drought-resistant cultivars, but decreased in weak drought-resistant cultivars.

Changes of pre-anthesis N translocation, post-anthesis N accumulation, and their contribution to grain N content in different cultivars

Compared with irrigated land, dryland condition reduced the post-anthesis N accumulation and its contribution to grain N content, but increased the contribution of pre-anthesis N translocation to grain N content (Table 4). However, dryland condition exert a different effect on the pre-anthesis N translocation for the different drought-resistant cultivars, leading to an increased pre-anthesis N translocation in strong drought-resistant cultivars, but decreased in moderate and weak drought-resistant cultivars (Table 4).

Discussions

Many experiments have reported that the character of N absorption, translocation, and reallocation varied in different winter wheat cultivars (Dhugga and Waines, 1989; Zhu et al., 2005; Yan et al., 2008). Compared with the region that has adequate rainfall or irrigated land, wheat in drylands often suffers from double stress (water deficit and nutrition deficiency), which undoubtedly influence the N absorption, translocation, and reallocation of wheat (Xu et al., 2006). Thereby, further study on the N accumulation characteristics of different wheat cultivars is still necessary for the popularization of applicable wheat cultivar. In this study, our results indicated that dryland condition reduced wheat N accumulation at all growth stages; N absorption and its corresponding ratio at anthesis-maturity, but increased N absorption and its corresponding ratio at jointing-anthesis. Importantly, dryland condition led to an increase in N absorption ratio at emergence-jointing stage for strong and moderate drought-resistant wheat cultivars, but a decrease in weak drought-resistant wheat cultivars. Therefore, N absorption was less affected under drought stress in strong and moderate drought-resistant wheat cultivars.

N absorption and translocation are considered as important procedures to determinate N use efficiency (Li et al., 1991). The contribution of pre-anthesis total aboveground N to grain N ranged from 57 to 76%, indicating the importance of pre-anthesis storage of N for achieving high grain N concentrations (Xu et al., 2005). The rate of contribution of pre-anthesis N translocation to N accumulation in grain was suggested higher than that of post-anthesis N translocation contribution (Ma et al., 2009). This indicated that in order to improve grain N content, we not only need to improve post-anthesis N accumulation, but also pay more attention to improve the translocation from pre-anthesis vegetative organs to post-anthesis grain (Li et al., 2011). Our path analysis found the direct path coefficient of pre-anthesis N translocation to N accumulation in grain (0.916) higher than that of post-anthesis N translocation (0.641), suggesting more important role of pre-anthesis N translocation to N accumulation in grain, which seemed to be in accordance with previous reports. Besides, our results also indicated a slight difference of pre-anthesis N translocation among the different drought-resistant cultivars, mainly, an increase in strong drought-resistant cultivars, but conversely decrease in moderate and weak drought-resistant cultivars under dryland condition. Therefore, in order to improve the N use efficiency of wheat in the arid region, we should pay more attention on breeding wheat cultivars that belong to nutrition efficiency phenotype.

Materials and methods

Description of field site

Field experiment was conducted during the two consecutive years of 2007-2008 and 2008-2009 in experimental station of Shanxi Agricultural University, China. The fields were left fallow during the summer. Soil samples of cultivated horizon (20 cm) contained 0.180% of total N, 12.6g kg^{-1} of organic matter, 142.82 mg kg^{-1} available N, 62.81 mg kg^{-1} available P, and 93.55 mg kg^{-1} exchangeable K. During these two years, the temperatures in all growth stages of wheat were higher than that in previous seven years, but precipitation showed a

Table 1. Effects of irrigation on wheat yields of different cultivars.

Drought resistance	Cultivars	Irrigated land	Dryland	Drought coefficient
Strong	040521-135	4428.48±25.02 h	4137.48±115.19 c	0.93±0.02 a
	JM47	6215.46±95.05 f	5231.83±53.15 a	0.84±0.00 b
	9801-C	5217.26±205.23 g	4232.51±103.53 c	0.81±0.05 b
Moderate	ND189	6896.18±137.65 e	5152.58±60.43 a	0.75±0.01 c
	40345	6920.80±104.97 e	4373.97±70.88 b	0.63±0.02 d
	40035	7656.05±116.64 c	4125.08±60.81 c	0.54±0.02 e
	SN121	6370.58±112.34 f	3431.71±52.12 de	0.54±0.02 e
	ZM175	7356.41±104.18 d	3746.61±135.98 d	0.51±0.03 e
Weak	SN129	5181.07±96.42 g	2065.41±149.62 g	0.40±0.02 f
	SN9-1	8788.57±95.87 b	3308.45±249.71 e	0.38±0.02 fg
	40081	8524.06±162.72 b	2766.58±117.47 f	0.32±0.01 g
	CZ9578	10758.81±211.21 a	2454.08±274.50 f	0.23±0.03 h

Notes: The ANOVA difference was displayed using a letter marked method. The same lowercase letter indicated there was no significant difference between the groups, but the different letters indicated significant difference was present at p = 0.05 level. The same was as below.

Table 2. Changes of N accumulation at different growth stages in different wheat cultivars under irrigated and dryland condition.

Drought resistance	Condition	Cultivar	Wintering	Jointing	Booting	Anthesis	Maturity
Strong	Irrigated land	040521-135	4.90±0.02 f	58.28±0.37 c	109.07±8.92 d	120.80±3.96 e	155.81±0.85 e
		JM47	7.61±0.08 a	72.48±1.02 a	158.49±5.88 a	177.76±3.31 a	237.97±3.94 a
		9801-C	6.71±0.03 b	56.12±2.24 c	96.07±6.70 e	123.15±4.58 e	163.83±1.45 d
		ND189	6.04±0.09 cd	68.03±1.38 b	146.79±3.29 b	170.40±1.38 b	235.73±1.6 a
		Mean	6.31	63.73	127.60	148.03	198.34
	Dryland	040521-135	4.20±0.11 g	41.64±1.27 e	87.40±0.55 ef	111.09±1.53 f	136.28±0.91 f
		JM47	6.30±0.11 c	66.96±1.27 b	131.73±1.88 c	160.75±2.28 c	201.73±2.81 b
		9801-C	5.31±0.10 e	51.95±0.68 d	77.90±1.76 f	108.59±0.38 f	134.19±1.90 f
		ND189	5.89±0.34 d	58.43±1.69 c	115.00±4.70 d	148.48±1.01 d	191.11±5.30 c
		Mean	5.43	54.74	103.01	132.23	165.83
	Decreased rate		14.03	14.10	19.28	10.67	16.39
Moderate	Irrigated land	40345	6.79±0.01 e	67.89±0.70 d	145.40±0.36 c	164.09±0.21 c	228.02±0.94 b
		40035	9.45±0.12 a	76.89±1.08 b	174.71±4.18 a	194.49±0.63 a	266.01±0.40 a
		SN121	8.84±0.07 b	72.51±1.75 c	132.35±0.52 d	150.76±1.40 d	202.24±1.01 c
		ZM175	8.36±0.11 c	88.87±0.72 a	164.72±4.29 b	190.18±0.20 b	268.81±2.48 a
		Mean	8.36	76.54	154.29	174.88	241.27
	Dryland	40345	6.82±0.01 e	58.09±0.09 e	110.66±2.19 e	132.99±0.94 f	164.60±1.03 e
		40035	8.77±0.06 b	50.59±1.19 f	116.07±5.51 e	137.15±1.99 e	171.89±2.08 d
		SN121	8.49±0.04 c	46.67±0.62 g	83.35±4.36 f	107.06±0.94 h	131.81±1.74 g
		ZM175	8.00±0.03 d	56.52±1.13 e	84.49±0.00 f	117.59±0.10 g	150.50±0.96 f
		Mean	8.02	52.97	98.64	123.69	154.70
	Decreased rate		4.05	30.80	36.07	29.27	35.88
Weak	Irrigated land	SN129	7.01±0.03 d	70.11±0.35 d	118.79±0.64 d	142.88±0.37 d	195.25±1.51 d
		SN9-1	8.15±0.06 c	85.79±0.75 c	212.70±1.40 b	230.87±1.79 b	309.26±4.56 b
		40081	14.18±0.13 a	128.29±2.71 b	194.01±10.56 c	210.70±1.04 c	295.33±0.16 c
		CZ9578	13.48±0.14 b	166.42±1.99 a	271.65±1.52 a	291.38±4.31 a	374.80±4.47 a
		Mean	10.71	112.65	199.29	218.96	293.66
	Dryland	SN129	4.06±0.03 g	22.62±0.15 g	45.83±1.06 f	56.39±0.32 g	70.10±0.60 g
		SN9-1	3.86±0.01 h	35.13±1.62 f	67.16±0.10 e	84.18±0.26 e	104.24±0.21 e
		40081	5.93±0.02 e	40.20±0.25 e	59.02±3.48 e	75.03±1.76 f	95.35±1.15 f
		CZ9578	5.63±0.03 f	39.80±1.89 e	64.56±1.71 e	81.02±3.06 e	97.11±1.67 f
		Mean	4.87	34.44	59.14	74.16	91.70
	Decreased rate		54.53	69.43	70.32	66.13	68.77

$$\text{Decreased rate}(\%) = \frac{\text{N content in irrigated land} - \text{N content in dryland}}{\text{N content in irrigated land}} \times 100\%$$

Table 3. Changes of N accumulation and its ratio of different stages in different wheat cultivars under irrigated land and dryland.

Drought resistance	Condition	Emergence-Jointing		Jointing-Anthesis		Anthesis-Maturity	
		N absorption (kg/hm^{-2})	Ratio (%)	N absorption. (kg/hm^{-2})	Ratio (%)	N absorption (kg/hm^{-2})	Ratio (%)
Strong	Irrigated land	63.73	32.74	84.30	42.18	50.31	25.08
	Dryland	54.74	33.26	77.48	46.70	33.60	20.04
	Decreased rate	**14.10**	**-1.57**	**8.08**	**-10.72**	**33.21**	**20.08**
Moderate	Irrigated land	76.54	31.90	98.34	40.69	66.39	27.41
	Dryland	52.97	34.42	70.73	45.56	31.00	20.02
	Decreased rate	**30.80**	**-7.91**	**28.08**	**-11.97**	**53.30**	**26.97**
Weak	Irrigated land	112.65	37.87	106.30	36.36	74.71	25.77
	Dryland	34.44	37.28	39.72	43.55	17.54	19.17
	Decreased rate	**69.43**	**1.57**	**62.64**	**-19.79**	**76.52**	**25.62**

Table 4. Changes of N translocation in different wheat cultivars under irrigated land and dryland condition.

Drought resistance	Condition	Post-anthesis N accumulation (kg/hm^2)	Pre-anthesis N Translocation (kg/hm^2)	Contribution of post-anthesis N accumulation to grain (%)	Contribution of pre-anthesis N translocation to grain (%)
Strong	Irrigated land	50.31	87.52	35.93	64.07
	Dryland	33.60	88.39	27.22	72.78
	Decreased rate	**33.21**	**-0.99**	**24.22**	**-13.58**
Moderate	Irrigated land	66.39	115.77	36.30	63.70
	Dryland	31.00	83.33	27.08	72.92
	Decreased rate	**53.30**	**28.02**	**25.40**	**-14.48**
Weak	Irrigated land	74.71	143.51	34.71	65.29
	Dryland	17.54	43.37	28.89	71.11
	Decreased rate	**76.52**	**69.78**	**16.77**	**-8.92**

decrease before and after growth period of wheat (Supplementary data 1).

Experimental design

The experiment was a two-factor, split-split plot arrangement of treatments in a randomized complete block design with three replications. The main plot treatments comprised the dryland and irrigation plots, which received 3750 m^3/hm^2 of water in total, but divided equally over five applications (750 m^3/hm^2 of water each time): first before sowing, then over-wintering, jointing, heading, and finally grain filling stage. One meter interval and high ridge (0.3m) were placed to benefit irrigation. Irrigated plots were located 50 m away from the dryland plot to eliminate the possibility of the plot receiving any water from underground through percolation from the irrigated plots. The subplot factors were different wheat cultivars: 040521-135, JM47, 9801-C, ND189, 40345, 40035, SN121, ZM175, SN129, SN9-1, 40081, and CZ9578. Altogether, there were a total of 72 plots with each of 16 m^2. Wheat seed (Shanxi Agriculture Technology Popularizing Station) was sown mechanically in rows spaced 20 cm apart at 28 September 2007, giving a density of 2.25 million seedlings per hectare. Basal applications of N, P, and K fertilizer contained 140 kg/hm^2 pure N, 150 kg/hm^2 P_2O_5 and 150 kg/hm^2 K_2O.

Sampling and detection

At the different growth periods, 20 culms were randomly collected from each plot, and then leaf area, tillers number, and dry weight were determined. Dry wheat was ground into fine powder to measure the N content using the standard macro-Kjeldahl procedure (Koutroubas et al., 2008). After wheat maturation, 20 culms of each plot were identically obtained to assay spikes per plant, grain number per spike, and grain weight at maturity. Further, economic yield of wheat was determined by harvesting 4m^2/plot. A 50g grain from each treatment was ground into fine powder to measure N content. The parameters, related to N translocation, accumulation and remobilization within the wheat plant(Xu et al., 2005; Masoni et al., 2007), and drought-resistant coefficient(Wu et al., 2007) were calculated by the following equations:

$$\text{Pre-anthesis N translocation amount} = \text{N content in vegetative organ at anthesis} - \text{N content in vegetative organ at maturity}$$

$$\text{Contribution of pre-anthesis N to grain N}(\%) = \frac{\text{pre-anthesis N translocation}}{\text{grain N content at maturity}} \times 100$$

$$\text{Post-anthesis N accumulation} = \text{N content of the whole plant at maturity} - \text{N content of the whole plant at anthesis}$$

$$\text{Contribution of post-anthesis remobilized N to grain N}(\%) = \frac{\text{post-anthesis remobilized N}}{\text{grain N content at maturity}} \times 100$$

$$\text{Drought-resistant coefficient} = \frac{\text{wheat yield in dryland}}{\text{wheat yield in irrigated land}}$$

Statistical analysis

All data were analyzed by Microsoft Excel and the results were measured as average ± standard deviation ($\bar{x}$±s). Analysis of variance (ANOVA) was conducted using the SAS 9.0 software package. Comparison among treatments was performed using Duncan's multiple range tests at the 0.05 probability level.

Conclusion

For rainfed wheat production, we suggest the strong drought-resistant cultivars should be selected. These cultivars could improve the translocation from pre-anthesis vegetative organs to post-anthesis grain, resulting in higher N use efficiency.

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References

Albrizio R, Todorovic M, Matic T, Stellacci AM (2010) Comparing the interactive effects of water and nitrogen on durum wheat and barley grown in a Mediterranean environment. Field Crop Res. 115(2): 179-190.

Barbottin A, Lecomte C, Bouchard C, Jeuffroy MH (2005) Nitrogen Remobilization during Grain Filling in Wheat. Crop Sci. 45(3): 1141.

Clarke JM, Campbell CA, Cutforth HW, Depauw RM, Winkleman GE (1990) Nitrogen and phosphorus uptake, translocation, and utilization efficiency of wheat in relation to environment and cultivar yield and protein levels. Can J Plant Sci. 70(4): 965-977.

Dhugga K, Waines J (1989) Analysis of nitrogen accumulation and use in bread and durum wheat. Crop Sci. 29(5): 1232-1239.

Ma DY, Guo TC, Yue YJ, Song X, Zhu YJ, Wang CY, Wang YH (2009) Effects of nitrogen application at different developmental stages on nitrogen accumulation and translocation in winter wheat. Plant Nutrition and Fertilizer Science. 15(2): 262-268.

Liu EK, Mei XR, Gong DZ, Yan CY, Zhuang Y (2010) Effects of drought on N absorption and utilization in winter wheat at different developmental stages. Chinese Journal of Plant Ecology. 34(05): 555-562.

Ercoli L, Lulli L, Mariotti M, Masoni A, Arduini I (2008) Post-anthesis dry matter and nitrogen dynamics in durum wheat as affected by nitrogen supply and soil water availability. Eur J Agron. 28(2): 138-147.

Gao YJ, Zhang JC, Liu WG, Dang ZP, Cao WX, Qiang Q (2009) Effects of mulch, N fertilizer, and plant density on wheat yield, wheat nitrogen uptake, and residual soil nitrate in a dryland area of China. Nutr Cycl Agroecosys. 85(2): 109-121.

Koutroubas SD, Papakosta DK, Doitsini A (2008) Nitrogen utilization efficiency of safflower hybrids and open-pollinated varieties under Mediterranean conditions. Field Crop Res. 107(1): 56-61.

Li B, McKeand SE, Allen HL (1991) Genetic variation in nitrogen use efficiency of loblolly pine seedlings. Forest Sci. 37(2): 613-626.

Li C, Jiang D, Wollenweber B, Li Y, Dai T, Cao W (2011) Waterlogging pretreatment during vegetative growth improves tolerance to waterlogging after anthesis in wheat. Plant Sci. 180(5):672-8.

Zhao M, Zhou J, Rong Y, Zheng X, Zhai B, Li S (2006) Characteristics of nitrogen accumulation, distribution and translocation in winter wheat on dryland. Plant Nutr Fertilizer Sci. 2: 143-149.

Masoni A, Ercoli L, Mariotti M, Arduini I (2007) Post-anthesis accumulation and remobilization of dry matter, nitrogen and phosphorus in durum wheat as affected by soil type. Eur J Agron. 26(3): 179-186.

Yan M, Jiang H, Ding X, Yin Y, Yu J, Wang J, Jiao Y (2008) Effects of Irrigation Treatments on Wheat Nitrogen Uptake and Distribution of Two Winter Wheat. Chinese Agri Sci Bulletin 2: 459-462.

Wu N, Guan Y, Shi Y (2007) Drought-resistance index in rice backcross lines after anthesis. Pak J Bio Sci. 10(16): 2659-2664.

Öztürk A, Çağlar Ö (1999) The effect of drought in different growth stages on uptake, translocation and utilization of N in winter wheat. Dev Plant Soil Sci. 86(3):135-138.

Wang Z, Wan B, Li S (2004) Influence of water deficit and supplemental irrigation on nitrogen uptake by winter wheat and nitrogen residual in soil. J Appl Ecology. 15(8): 1339.

Xu ZZ, Yu ZW, Wang D, Zhang YL (2005) Nitrogen accumulation and translocation for winter wheat under different irrigation regimes. J Agron Crop Sci. 191(6): 439-449.

Xu ZZ, Yu ZW, Wang D (2006) Nitrogen translocation in wheat plants under soil water deficit. Plant Soil. 280(1): 291-303.

Zhu XK, Guo WS, Zhu DM, Zhu PF, Feng CN, Peng YX (2005) Studies on differences of accumulated N amount in different genotypes of winter wheat. Journal of Yangzhou University. 26(3): 52.