

Full Length Research Paper

Effect of fertilization and mulching in fallow period on nitrogen accumulation of dryland wheat

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Understanding mulching influences on nitrogen (N) accumulation in soil is important for developing N management strategies for dryland wheat yield. A two year field experiment was carried out to investigate the effect of three mulching materials (film mulching, nylon mulching, and paper mulching) and different fertilizer (with or without fertilizer) on N accumulation in a winter wheat-fallow system. The results showed that the organic fertilizer application in fallow period could lead to a serial positive effect compared with the non-fertilization including increased N content of wheat at wintering stage, heading stage, and maturity stage, N accumulation at different growth stages, the ratio of N accumulation from emergency to jointing under the condition of film and nylon mulching, the ratio of N accumulation from anthesis to maturity under all mulching, pre-anthesis N translocation amount, post-anthesis N accumulation, and the contribution of post-anthesis N accumulation to N in grains under the condition of nylon mulching, paper mulching and no mulching. In addition, our results also showed that regardless of fertilization, N content of wheat at maturity, N accumulation in plant at anthesis and maturity, N accumulation and its ratio from jointing to anthesis under the film mulching treatment were all greater than those in the other treatments. Mulching increased post-anthesis N accumulation and the contribution of post-anthesis N accumulation to N in grains. In the context of organic fertilizer application, the contribution of post-anthesis N accumulation to N in grains under the treatment of nylon mulching was greater than that in the other treatments. However, without fertilizer, film mulching seemed to be better than other treatments. Therefore, organic fertilizer application and film mulching may be effective strategies for increasing N accumulation in grains, and the quality and yield of dryland wheat.

Key words: Fallow period, fertilizer, mulching, winter wheat, N accumulation.

INTRODUCTION

Wheat (*Triticum aestivum* L.) is one of the most important cereal crops in Shanxi province, China. However, dryland wheat yield and yield stability are seriously influenced by water shortage (including rainfall variety) and nutrient deficiency (Gao et al., 2009). Therefore, recent researches have been focused on a variety of mulch to conserve soil moisture. For example, plastic film mulching has been demonstrated to significantly increase the harvesting of rainwater and wheat yield (Li et al., 2004;

Xie et al., 2005; Deng et al., 2006; Chen et al., 2007). Biomass and grain yield in the mulched plots were 39.5 and 28.9% higher than in the corresponding treatments without mulching (Deng et al., 2006). In addition, straw mulching is also an effective way to reduce soil evaporation at early stages, increase winter wheat yield and improve water utilization efficiency. Combination of water-saving irrigation and straw mulching plays an important role in China water-saving agriculture (Zhao et al., 2004). Under limited irrigation condition, rice husk mulching is found to be beneficial for maintaining optimum soil moisture condition for wheat use, leading to higher grain yield and enhanced water use efficiency (Chakraborty et al., 2008). Further, different mulching

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materials are selected in field experiments to compare their effect.

The results indicate that concrete mulch and straw mulch was effective in conserving soil water compared to plastic film mulch which increases soil temperature. Straw mulch conserves more soil water but decreases wheat grain yield probably due to low temperature. Concrete mulch has similar effect with plastic film mulch on promoting winter wheat development and growth (Yang et al., 2006). Researches also indicate that there is an interactive relationship between soil moisture and nitrogen (N) uptake. Water availability could enhance N uptake. The response of wheat and barley to N fertilization is higher in the year characterized by greater water availability during the most sensitive stages to drought stress (Albrizio et al., 2010). The annual precipitation of Shanxi province is 500 to 700 mm with 60 to 70% of rainfall occurring in wheat fallow period (Liu et al., 2011). However, it is far from enough to satisfy the demand of wheat in spring because of more loss from surface by evaporation in summer (Gregory et al., 2010).

Many of our predecessors have paid more attention to water conservation in the growth stage but largely ignored the full use of rainfall in fallow period. Therefore, our study aimed to explore the effect of different fertilizer and different mulching materials in fallow period on N accumulation of dryland wheat. This would lay a theoretical foundation for conserving soil moisture and improving yield of dryland wheat.

MATERIALS AND METHODS

Field site description

Field experiment was conducted during the two consecutive years of 2008 to 2009 and 2009 to 2010 at the Wenxi Research Farm of University of Shanxi Agriculture. The fields are left fallow during the summer. Chemical characteristics of the soil include organic matter 8.65 g kg⁻¹, total N 0.74 g kg⁻¹, alkali-hydrolyzable N 32.93 mg kg⁻¹ and available phosphoric acid 2.08 mg kg⁻¹. They were measured after previous crops of wheat harvesting and before fallow period processing through potassium dichromate-external heating method, semi-micro Kjeldahl, alkaline hydrolysis diffusion method and 0.5 mol/L NaHCO₃ extract-colorimetric method, respectively.

Experimental design

The experimental design was a split-plot factorial with 8 treatments and three replicates. The two main plot treatments were zero organic fertilizer (CK1) and organic fertilizer at 2250 kg hm⁻² for wheat (Shanxi Wofeng biotechnology Co., Ltd, > 25% organic content). The four sub-plot mulch treatments were: no mulching (CK2), film mulching (FM, 100 cm-width plastic film was used to cover the whole plot and a culm 1.0 cm in diameter was used for punching holes in the film. The space between the holes was 20 cm), nylon mulching (N, 80% shading with black nylon net, 200 meshes per inch), and paper mulching (P, the whole plot was covered with 45 g/m² raw paper and then with 1.0 cm thickness of fine soil). Altogether, there were a total of 24 plots with each of 50 m². Wheat variety 'Linhan 536' was sown mechanically in rows spaced 20 cm apart at 18 September, 2008 with a density of 3.15 million plants per hectare.

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 mature, 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 4 m²/plot and 50 g grain in each treatment was ground into fine powder to measure N content. The following parameters related to N translocation, accumulation and remobilization within the wheat plant can be calculated by the following equations (Xu et al., 2005; Masoni et al., 2007):

N accumulation and translocation were calculated as follows:

Pre-anthesis N translocation amount = N content in vegetative organ at anthesis – N content in vegetative organ at maturity

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

Post-anthesis N accumulation = N content of the whole plant at maturity – N content of the whole plant at anthesis

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

Statistic analysis

Analysis of variance (ANOVA) was conducted using the SAS 9.0 software package. Comparison among treatments was performed using Duncan's multiple range test at the 0.05 probability level.

RESULTS

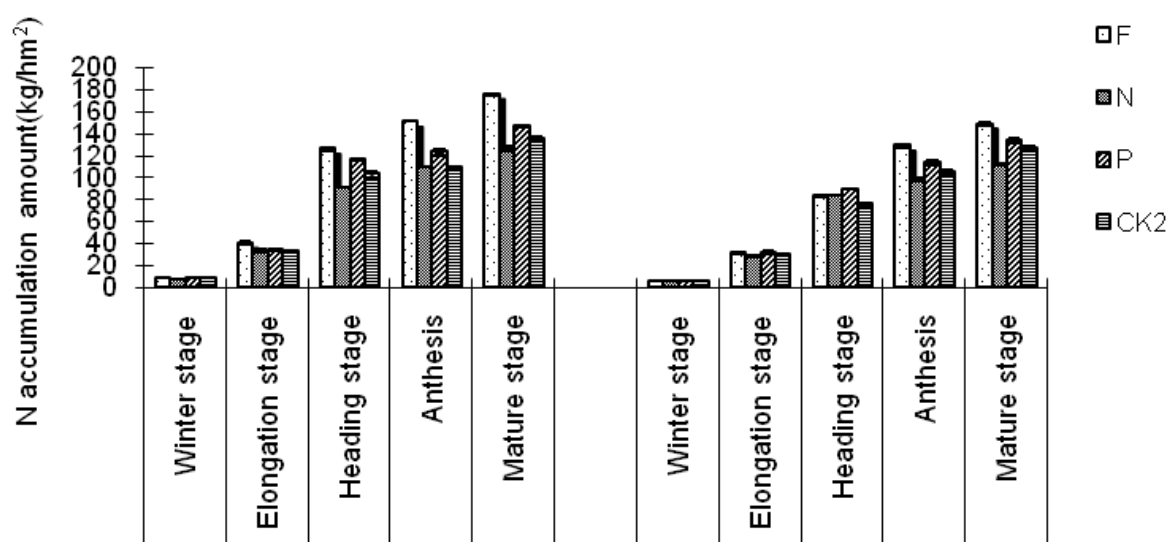
Effect of fertilization and mulching in fallow period on N content of winter wheat at its different growth stages

Overall, no matter fertilization or not, the N content of winter wheat increased at the beginning and then declined when the growth process went on. The N content reached its peak value at the jointing stage. Furthermore, the results (Table 1) suggested that organic fertilizer application in fallow period could result in a significant increase in N content of winter wheat at wintering and heading stage. Besides, it also increased N content of winter wheat at anthesis and maturity stage under film and paper mulching treatment, and even significantly increased N content without mulching. No significant effect was observed at jointing stage. In addition, our analysis also indicated that regardless of fertilization, significant difference could be observed in paper mulching group (with the highest N content) and nylon mulching group (with the lowest N content) at heading stage and anthesis. No significant difference of N content at anthesis was observed between film mulching and paper mulching group. Ultimately, film mulching showed the highest N content at maturity.

Table 1. Changes of N content in each growth stage with different fertilizer and mulch treatment (%).

Fertilizer	Mulch material	Wintering	Jointing	Heading	Anthesis	Maturity
Organic	F	1.33±0.00 ^b	1.80 ±0.07 ^{bcd}	1.45±0.01 ^a	1.32±0.00 ^{ab}	1.33±0.01 ^a
	N	1.31±0.00 ^{bc}	1.63±0.05 ^e	1.31±0.00 ^b	1.20±0.00 ^d	1.20±0.02 ^{cd}
	P	1.49±0.01 ^a	1.95±0.03 ^a	1.42±0.01 ^a	1.33±0.03 ^a	1.29±0.01 ^b
	CK2	1.50±0.01 ^a	1.83±0.03 ^{bc}	1.33±0.03 ^b	1.24±0.02 ^{cd}	1.28±0.01 ^b
CK1	F	1.22±0.02 ^e	1.70±0.01 ^{de}	1.33±0.01 ^b	1.27±0.01 ^c	1.30±0.02 ^{ab}
	N	1.26±0.01 ^d	1.69±0.05 ^{de}	1.25±0.00 ^c	1.21±0.02 ^d	1.18±0.01 ^d
	P	1.32±0.00 ^b	1.89±0.07 ^{ab}	1.31±0.00 ^b	1.28±0.03 ^{bc}	1.28±0.03 ^b
	CK2	1.30±0.01 ^c	1.73±0.03 ^{cd}	1.25±0.02 ^c	1.22±0.03 ^d	1.23±0.02 ^c

Notes: Values in the same line with different small letters are significantly different at 5% probability levels, respectively. Not significant if there are the same letters among treatments (the same as below).

**Figure 1.** Changes of N accumulation in each growth period with different fertilizer and mulch treatment (kg/hm²).

Effect of fertilization and mulching in fallow period on N accumulation of winter wheat at its different growth stages

Fertilization and mulching had significant effects on wheat N accumulation. Total N accumulation of whole plant gradually increased and reached the maximum at maturity. The results (Figure 1) suggested that organic fertilizer application in fallow period could improve N accumulation of whole plant at different growth stages. Compared with fertilization control (that is without fertilization), all the N accumulation demonstrated a significant increase at wintering, heading and maturity regardless of mulch treatment. However, at jointing stage, N accumulation was only significantly increased under film and nylon mulch treatment. At anthesis, N accumulation exhibited a significant increase, only CK2 excluded. Besides, our analysis also indicated that film mulching showed the highest N accumulation from

jointing to maturity under the condition of organic fertilizer application in fallow period. Nylon mulching showed the lowest N accumulation from heading to maturity. The paper mulching also had a significant effect on N accumulation in comparison with mulching control (that is without mulching) at wintering, heading, anthesis and maturity.

Without fertilization, N accumulation of whole wheat was shown significantly decreased under the following treatment, film mulching > paper mulching > no mulching > nylon mulching at anthesis and maturity.

Effect of fertilization and mulching in fallow period on N uptake and corresponding ratio of winter wheat at its different growth stages

Fertilization and mulching also had a significant effect on N uptake and corresponding ratio of wheat. N uptake in

Table 2. Changes of N uptake and corresponding ratio in each growth period with different fertilizer and mulch treatments.

Fertilizer	Mulch material	Emergency-jointing		Jointing-anthesis		Anthesis-maturity	
		N uptake (kg/hm ²)	Ratio (%)	N uptake (kg/hm ²)	Ratio (%)	N uptake (kg/hm ²)	Ratio (%)
Organic	F	40.18±1.48 ^a	22.88	110.28±0.41 ^a	62.79	25.17±1.00 ^{ab}	14.33
	N	33.22±0.95 ^b	27.08	75.41±0.12 ^e	59.65	17.79±1.60 ^d	14.07
	P	33.68±0.44 ^b	21.89	89.44±2.64 ^c	61.27	22.86±0.80 ^{bc}	15.66
	CK2	31.98±0.50 ^{bc}	25.53	76.63±1.92 ^e	56.53	26.96±1.21 ^a	19.88
CK1	F	31.18±0.20 ^c	20.96	97.49±1.11 ^b	65.54	20.08±1.82 ^{cd}	13.50
	N	27.89±0.79 ^d	24.81	70.61±1.48 ^f	62.83	13.89±0.76 ^e	12.36
	P	31.87±1.24 ^{bc}	23.87	81.62±2.27 ^d	61.13	20.02±2.64 ^{cd}	14.99
	CK2	30.32±0.56 ^c	32.53	74.23±2.19 ^{ef}	58.90	21.48±2.04 ^{bcd}	17.04

Table 3. Changes of N translocation in each growth stage with different fertilizer and mulch treatments.

Fertilizer	Mulch material	Pre-anthesis N translocation (kg/hm ²)	Post-anthesis N accumulation (kg/hm ²)	Contribution of pre-anthesis N translocation to grain N (%)	Contribution of post-anthesis N accumulation to grain N (%)
Organic	F	25.17±1.41 ^{ab}	83.16±1.41 ^a	23.23±1.30 ^c	76.77±1.30 ^a
	N	17.79±1.72 ^{bc}	63.36±1.72 ^c	21.92±2.12 ^c	78.08±2.12 ^a
	P	22.86±3.44 ^{ab}	70.02±3.44 ^{bc}	24.61±3.70 ^{bc}	75.39±3.70 ^{ab}
	CK2	26.96±3.13 ^a	53.72±3.13 ^d	33.41±3.88 ^{ab}	66.59±3.88 ^{bc}
CK1	F	20.08±0.71 ^{abc}	75.96±0.71 ^{ab}	20.91±0.74 ^c	79.09±0.74 ^a
	N	13.89±0.73 ^c	41.08±0.73 ^e	25.27±1.32 ^{bc}	74.73±1.32 ^{ab}
	P	20.02±4.91 ^{abc}	48.56±4.91 ^d	29.19±7.16 ^{abc}	70.81±7.16 ^{abc}
	CK2	21.48±4.23 ^{ab}	36.79±4.23 ^e	36.86±7.26 ^a	63.14±7.26 ^c

winter wheat was mainly occurred at jointing to anthesis stage. The results (Table 2) suggested that organic fertilizer application in fallow period could improve N uptake amount at every stage. N uptake ratio showed an increase at emergency - jointing stage (film and nylon mulching) and anthesis-maturity (all mulching treatment), respectively. In addition, our results also showed that regardless of fertilization, N uptake amount kept on gradually increasing at jointing to anthesis stage under the following treatment:

Nylon mulching < no mulching < paper mulching < film mulching

N uptake ratio showed the highest under film mulching treatment but lowest under CK2. Both of the N uptake and corresponding ratio showed the highest under CK2 treatment but lowest under nylon mulching treatment.

Effect of fertilization and mulching in fallow period on pre-anthesis N translocation amount, post-anthesis N accumulation and contribution to grain N

From the results, we might assume that contribution of

pre-anthesis N translocation to grain N was higher than post-anthesis N accumulation. The detail results (Table 3) indicated that organic fertilizer application in fallow period could enhance pre-anthesis N translocation amount and post-anthesis N accumulation. Organic fertilizer application increased the contribution of pre-anthesis N translocation to grain N but decreased contribution of post-anthesis N accumulation to grain N under nylon mulching, paper mulching and CK2 treatment; whereas under film mulching treatments. Our results also depicted there was a varied effect between pre-anthesis N accumulation and post-anthesis N accumulation under different mulching treatments. That is, regardless of fertilization, post-anthesis N accumulation kept on gradually increasing under the following treatments:

Nylon mulching < paper mulching < film mulching < no mulching

However, pre-anthesis N translocation kept on gradually increasing under the following treatments:

No mulching < nylon mulching < paper mulching < film mulching

Mulching all decreased the contribution of post-anthesis

N accumulation to grain N with the best effect under paper mulching. Mulching all increased the contribution of pre-anthesis N accumulation to grain N with the best effect under nylon mulching and fertilization but with best effect under film mulching and without fertilization.

DISCUSSION

Accumulation and translocation of nitrogen (N) in the vegetative organs and grains of winter wheat are important processes in determining yield and quality (Xu et al., 2006). Previous reports suggested that the N uptake and accumulation at different growth stage varied (Cox et al., 1985). For example, in wheat, the accumulation of N is generally rapid prior to heading and remains relatively unchanged thereafter (Campbell et al., 2008). N accumulation is found increased until flowering then tends to level off in wheat. At maturity, wheat has the greatest N accumulation (Gan et al., 2010). Therefore, top addressing N at the jointing and anthesis stage is recommended for higher grain yield and protein content in the grain. In this study, we also found N accumulation of wheat gradually increased and reached the maximum at maturity. N uptake and corresponding ratio uptake reached its peak value at jointing and anthesis stage which was in accordance with previous reports. In addition, grain nitrogen and yield were positively and significantly correlated with the N translocation amounts and contributions, respectively, suggesting that the sink strength might be involved in the translocation of N from a vegetative organ to the grain (Xu et al., 2005).

The rate of contribution of pre-anthesis N translocation to N accumulation in grain was higher than that of post-anthesis N translocation contribution (DongYun 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 study also indicated that organic fertilizer application in fallow period could improve the pre-anthesis N translocation amount and post-anthesis N accumulation and all the mulching could enhance the contribution of pre-anthesis N translocation to grain N. Further analysis indicated that film mulching could be the optimum material to improve pre-anthesis N translocation amount and post-anthesis N accumulation. Therefore, fertilization in conjunction with film mulching may be an effective strategy for increasing N accumulation in grains, and the quality and yield of dryland wheat.

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