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# Effects of Postponing N Application on Wheat Grain Yield, Protein Quality and Fertilizer-N use Efficiency in Low-Yield Field in Jianghan Plain

[1]Xiao-yan Wang, [2]Chun-bao Gao and [1]Zhang-yong Liu
[1]Engineering Research Center of Wetland Agriculture in the Central Yangtz, Ministry of Education, Jingzhou 434025, China
[2]Hubei Academy of Agricultural Science, Wuhan, Hubei 430064, China

**Abstract:** In 2008 to 2010, the effects of postponing N application on wheat grain yield and process quality were studied in low-yield field in Jianghan Plain in wheat. The results were as follows. When the Topdressing fertilizer N (TN) was postponed from tilling stage to jointing stage, the biomass and the SPAD value in flag leaf reduced, respectively. And grain yield, protein content in grain and stability time of paste, reduced as a result. When the topdressing fertilizer N was postponed from jointing stage to booting stage, the regularity of above index changed conversely. For the treatments with the same topdressing fertilizer date (jointing stage), the appropriate ratio of Basal dressing fertilizer (BN)to topdressing fertilizer was 3:7, with high biomass, high SPAD value in flag leaf, high grain yield and high process quality as a result. The results also indicated that the right stage for more N in organ vegetative to be transferred to grain was jointing stage and the right ratio of BN to TN was 3:7, which was the very basis for high nitrogen fertilizer utilization. Based on the above results, it was suggested that to gain high grain yield and high process quality the appropriate date for topdressing fertilizer N in low-yield field in Jianghan Plain was jointing stage and the ratio of BN to TN was 3:7.

**Keywords:** Grain yield, low-yield field, postponing N application, protein quality, wheat

## INTRODUCTION

It was necessary to apply N fertilizer to increase grain yield and process quality during wheat production. However, over-application of N fertilizer always led up to the decrease of N utilization efficiency and the pollution of the environment, especially the pollution of soil and groundwater (Xinghua *et al*., 2006; Arvind *et al*., 2004; Jaime *et al*., 2001). Therefore, to apply N fertilizer reasonably is an important initiative to get high grain yield, high N utilization efficiency and less environment pollution. Previous studies indicated that increasing N fertilizer promoted the uptake of N, which was of great benefit to chlorophyll content and grain yield (Jinzhe *et al*., 2001; Dongyun *et al*., 2008; Houyou *et al*., 2001). As it was reported, chlorophyll content after anthesis always increased with the percentage of topdressing N (Yuefu *et al*., 2003; Xinkai *et al*., 2005). However, it was also reported that over-application of topdressing N induced to over-green growth in wheat, which went against the transportation of dry matter in vegetable organs to grain and led to poor grain yield and harvest index (Tiancai *et al*., 2007; Dong *et al*., 2007). Most of the above research was carried out in Huang-huai-hai Plain. In fact, there is abundant annual precipitation and light intensity in Jianghan Plain, which was beneficial to semi-winter wheat varieties (Tiancai *et al*., 2007; Liwan, 2002). However, because of unreasonable or insufficient N application during traditional wheat production, both the grain yield and N utilization efficiency kept low (Tiancai *et al*., 2007; Liwan, 2002; Yinxiu and Zhimin, 2000). Therefore, to increase grain yield and NUE in Jianghan Plain, it was necessary to study the effect of postponing N fertilizer application in wheat. Based on the above previous studies, the research was carried out, selected Zhengmai 9023 as experimental cultivar with 5 N treatments.

## MATERIALS AND METHODS

**General situation of the experiment area:** The experiment was carried out through 2008 to 2009 at Experiment Station of Yangtze University, Jingzhou Hubei. The experiment station is located in the central zone of Jinghan Plain. The longitude of the station is 111°150E and the dimension is 29°260 N. The annual rainfall of this area is 1200 mm and during the growth period of wheat, the rainfall was 414.3 mm, respectively.

**Materials and design:** In the experiment, one wheat varieties (Zhengma i9023) was taken as material. The soil was fine clay. In the top 0.25 m layer, the concentrations of organic-carbon, total nitrogen, available N, available P and available K were 11.00, 1.00, 82.03, 33.25, 51.11 mg/kg, respectively.

**Corresponding Author:** Zhang-yong Liu, Engineering Research Center of Wetland Agriculture in the Central Yangtz, Ministry of Education, Jingzhou 434025, China, Tel.: +86-716-8066314, Fax: +86-716-8066541

Five treatments were designed in the experiment. The ratio of basal dressing N to topdressing N and the respective stage for topdressing N were designed as follows:

A: 70% N as topdressing and 30% as basal dressing, applied at tilling stage (5-6 leaves)
B: 70% N as topdressing and 30% as basal dressing, applied at jointing stage (7-8 leaves)
C: 50% N as topdressing and 50% as basal dressing, applied at jointing stage (7-8 leaves)
D: 50% N as topdressing and 50% as basal dressing, applied when the tip of flag leaf emerges (11-12 leaves)
E: 30% N as topdressing and 70% as basal dressing, applied at jointing stage (7-8 leaves)

The plot area was 2×6.7 m = 13.4 $m^2$ and the row spacing was 0.25 m. Latin square design was applied in the experiment. Fertilizers were applied to each through at 3 d prior to sowing (half of N, 105 kg $P_2O_5/hm^2$, 135 kg $K_2O/hm^2$). The sowing density was 210 plants $m^2$ and sowing date was October 28, 2008. The other field management was the same as common high grain yield field.

**Measurement and analysis:** Dates of a thesis and maturity were noted. Anthesis was recorded when anthers in the central spikelet's of 50% of ears in a plot had extruded and maturity when most of the ears in a plot were no longer green.

The biomass was measured at five growth stages, tilling stage, jointing stage, a thesis, milking stage and maturity. Five plants were cut at ground level each time and separated into flag leaf, $2^{nd}$ leaf and $3^{rd}$ leaf, the left leaves, spike axis and husk, stem and sheath, grains. All plants were oven-dried at 80°C, weighed.

Nitrogen concentrations in the above organs or tissue were determined by the standard macro-Kjeldahl procedure, which was a nitrogen analysis system, produced by Buchi, Switzerland. Before the determination the maternal from different organs or tissue were ground in a Wiley Mill through a 1 mm opening screen. Grain protein content was calculated according to a previous formula (multiply nitrogen content in different organs by 5.7):

Partial factor productivity = grain yield/N fertilizer rate
N amount to produce 1 kg yield = N amount/grain yield

SPAD value in flag leaf was measured on attached flag leaves by Chlorophyll Meter Model SPAD-502 (Japanese) at 9:00-11:00 A.M. at 7 day intervals.

Stability time was measured using a powder instrument produced by Bra bender Technologies Co. Ltd., German.

All statistical ANOVA analysis were performed using SPSS 10.0 (SPSS for window, Chicago, Illinois, USA). Data obtained from the measurements and biochemical analysis was evaluated statistically at the factorial level by means of Variance Analysis (ANOVA) and their significance levels ($p<0.05$ or $p<0.01$) were determined.

## RESULTS AND DISCUSSION

**Changes in biomass:** Table 1 illustrates the progression of biomass changes from tilling stage to maturity. From two years experiments it was indicated that the biomass increased gradually and reached the maximum at maturity and the increase being particularly steep from tilling stage to jointing stage.

As shown in Table 1, when the topdressing N was postponed to jointing stage (A to B), the biomass at maturity increased significantly. The opposite trend was gotten when the topdressing N was postponed to booting stage (C to D). As for the treatments with same topdressing N stage (B, C and E), E got the highest biomass at maturity, which suggested that it was perfect that 70% of the total N fertilizer was applied as topdressing fertilizer.

**SPAD value in flag leaf after a thesis:** As shown in Table 2, the changes of SPAD value in flag leaf was single peaked curve and the peak value reached at 7 DAA. As it was indicated, treatment E always got the highest SPAD value during grain filling.

By contrast, when the topdressing N was postponed from tilling stage to jointing stage, treatment B got higher SPAD value than A. However, the SPAD value of D decreased when the topdressing N was put off until booting stage (C). As for the treatments with same topdressing date, the larger the percent of topdressing N it took up (treatment E), the higher the SPAD value was.

**Nitrogen concentration in different organs at maturity:** As shown in Table 3, the nitrogen concentrations were different significantly among different treatments at maturity, even in different organs.

The N concentration in grain was greatest and that in stem and sheath was lowest. As for the leaves, the N concentration in flag leaf was lowest and that in the left-leaves was highest, which suggested that most N in flag leaf might have been transported to grain during grain filling.

As for different treatments, treatment E got the highest grain N concentration and treatment A was lowest. For treatment A and treatment B, which had the same ratio of N and different topdressing N application date, the N concentration in B was higher than that in A. However an opposite trend was got from the comparison between treatment C and treatment D. It was suggested that the optimal period for topdressing N was jointing stage. As for treatment B, C and E, the N

Table 1: Changes in biomass at different stages (g/m$^2$)

| Year | Treatments | Tilling stage | Jointing stage | Anthesis | Milking stage | Maturity |
|---|---|---|---|---|---|---|
| 2008-2009 | A | 124.6 a | 474.4 a | 857.9 c | 1112.6 d | 1311.7 c |
| | B | 125.3 a | 408.1 b | 907.6 b | 1183.7 b | 1364.8 b |
| | C | 101.4 b | 354.2 c | 882.5 b | 1232.2 a | 1379.9 b |
| | D | 102.1 b | 365.0 c | 892.7 b | 1146.8 c | 1324.2 c |
| | E | 98.9 c | 336.5 d | 948.9 a | 1273.1 a | 1452.8 a |
| 2009-2010 | A | 91.1 a | 319.9 b | 637.2 b | 811.6 d | 989.7 e |
| | B | 92.2 a | 338.2 a | 498.8 e | 822.5 d | 1043.2 d |
| | C | 72.8 b | 293.1 c | 536.9 d | 917.7 b | 1141.9 b |
| | D | 74.7 b | 282.7 c | 583.8 c | 875.2 c | 1096.9 c |
| | E | 65.4 c | 251.0 d | 696.8 a | 963.2 a | 1217.0 a |

Different capital letters and small letters in the same column mean significantly t 1 and 5% levels, respectively. The same symbol was used for other tables

Table 2: Effects of different treatments on SPAD value in flag leaf among different treatments

| Treatment | Anthe-sis | 7 DAA | 14 DAA | 21 DAA | 8 DAA | 35 DAA |
|---|---|---|---|---|---|---|
| N0 | 35.7 e | 38.0 f | 35.0 e | 30.3 f | 27.9 f | 23.4 c |
| A | 42.3 d | 47.5 e | 46.3 d | 43.8 e | 33.7 e | 25.5 b |
| B | 43.2 d | 49.5 d | 47.4 d | 45.6 d | 38.7 d | 26.2 b |
| C | 45.8 c | 51.8 c | 49.2 c | 47.2 c | 418 c | 27.3 b |
| D | 48.3 b | 54.0 b | 51.8 b | 49.5 b | 45.0 b | 29.2 a |
| E | 50.9 a | 57.0 a | 54.1 a | 51.7 a | 48.6 a | 31.8 a |

Table 3: Effects of different treatments on nitrogen concentration in different organs at maturity (%)

| Treatment | Leaf flag leaf | 2nd leaf and 3rd leaf | The left leaves | Spike axis and husk | Stem and sheath | Grain |
|---|---|---|---|---|---|---|
| A | 1.042 a | 1.504 a | 1.464 a | 0.947 b | 0.685 a | 2.336 d |
| B | 1.034 a | 1.350 c | 1.434 a | 0.938 b | 0.329 d | 2.416 c |
| C | 0.969 c | 1.109 e | 1.155 b | 0.811 d | 0.557 c | 2.608 a |
| D | 0.930 d | 1.413 b | 1.431 a | 0.993 a | 0.669 b | 2.560 b |
| E | 0.997 b | 1.187 d | 1.135 b | 0.865 c | 0.663 b | 2.688 a |

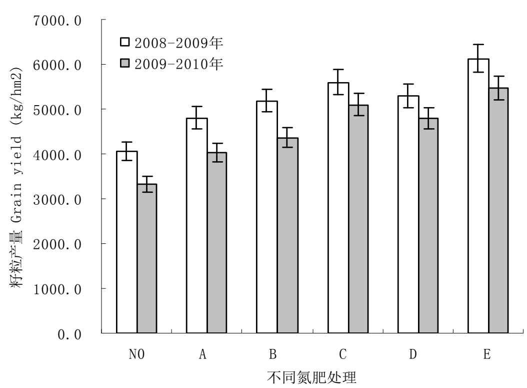


Fig. 1: Effects of different treatments on grain yield

Table 4: Effects of different treatments on grain protein content and quality traits of paste

| Year | Treatment | Protein content in grain (%) | Stability time (min) |
|---|---|---|---|
| 2008-2009 | A | 14.6 d | 6.3 d |
| | B | 15.1 c | 6.7 c |
| | C | 16.3 b | 7.1 b |
| | D | 16.0 b | 6.9 b |
| | E | 16.8 a | 7.6 a |
| 2009-2010 | A | 13.7 d | 6.6 d |
| | B | 14.3 c | 6.9 c |
| | C | 15.5 b | 7.4 b |
| | D | 15.1 b | 7.2 b |
| | E | 16.2 a | 7.9 a |

concentration in grain was highest in E and lowest in B, which suggested that the optimal N ratio was 3:7 (just as treatment E) for basal dressing N and topdressing N, respectively.

**Grain yield at maturity:** As shown in Fig. 1, postponing N application markedly affected grain yield. After two years experiment, treatment E got the highest grain yield all the way. When comparing the treatments A and B, or C and D, which had the same N application date, it was found that jointing stage was proper date for topdressing N. As for treatment B, C and E, the larger the percent of topdressing N, the higher the grain yield.

**Protein content in process quality:** Table 4 demonstrated that averaged over all treatments, the protein content was 15.8 and 15.0% in 2 years experiment respectively and the average stability time of paste was 6.9 and 7.2 min, respectively.

Contrasting all the treatment, treatment E got the highest protein content and stability time throughout two years. For the treatments with same topdressing N application date, such as A and B, or C and D, the process quality of B was better than that of A and C was better than D. The above data indicated that the jointing stage was the right stage for topdressing N to get high process quality. When comparing treatment B, C and E, it was found that the treatment E had the highest protein content and stability time, suggesting that the ratio of 3:7 was the best ratio for basal dressing N to topdressing N.

**Nitrogen use efficiency:** As shown in Table 5, treatment E got the highest Partial Factor Productivity (PFP) through the experiment from 2008 to 2010 and

Table 5: Effects of different treatments on nitrogen use efficiency

| Year | Treatment | Nitrogen rate (kg/hm$^2$) | Grain yield (kg/hm$^2$) | Partial Factor Productivity (PFP) (kg/kg) |
|---|---|---|---|---|
| 2008-2009 | A | 180 | 4807.1 | 26.7 |
| | B | 180 | 5190.0 | 28.8 |
| | C | 180 | 5591.3 | 31.1 |
| | D | 180 | 5287.5 | 29.4 |
| | E | 180 | 6126.8 | 34.0 |
| 2009-2010 | A | 180 | 4039.8 | 22.4 |
| | B | 180 | 4365.0 | 24.3 |
| | C | 180 | 5099.8 | 28.3 |
| | D | 180 | 4793.7 | 26.6 |
| | E | 180 | 5475.0 | 30.4 |

treatment at got lowest PFP. To compare A with B and C with D, it was found the jointing stage was the right stage to got high partial factor productivity. As for the treatments B, C and E, which had same topdressing N application date and different N ratio, E got highest PFP and B got lowest PFP, which indicated that 3:7 was the best ratio to application N fertilizer.

## DISCUSSION AND CONCLUSION

Nitrogen is one of the most important factors limiting crop production in many parts of the world, no matter advanced countries or developing countries (Xinghua *et al*., 2006; Arvind *et al*., 2004). Yet more fields can become productive by reasonable nitrogen application (Jaime *et al*., 2001; Jinzhe *et al*., 2001; Dongyun *et al*., 2008). In many experiment, it has been found that increasing nitrogen fertilizer rate led to high grain yield when the nitrogen fertilizer rate changed within 225 kg/hm$^2$ (Xinghua *et al*., 2006; Dongyun *et al*., 2008; Houyou *et al*., 2001). It was also reported that different rate of basal dressing fertilizer N to topdressing fertilizer N induced different grain yield and process quality (Xinghua *et al*., 2006; Yuefu *et al*., 2003). Most of the experiments were carried out in high-yield field and there was no last word about the right rate of basal dressing fertilizer N to topdressing fertilizer N and about the right application stage for topdressing fertilizer N. When it comes to low-yield field in Jianghan Plain, fewer studies were carried out about nitrogen application and grain yield. After two-year field experiment in Jianghan Plain, we found that the grain yield could achieve 6126.8 kg/hm$^2$ easily here, with 180 kg N/hm$^2$ (30% as basal dressing N before sowing and 70% as topdressing N at jointing stage) and without irrigation during the whole growth period. But when the rate of basal dressing N to topdressing N increased or it was applied in ahead or was postponed, the grain yield decreased. Further studies indicated that when the rate of basal dressing fertilizer to topdressing fertilizer was 3:7 and the topdressing stage was jointing stage, the biomass at an thesis and the SPAD value in flag leaf during grain filling were highest. Those were the physiology basis for high grain yield for treatment E. Nitrogen Use Efficiency (NUE) was under observation all along, especially nowadays when the resources shortage becomes more and more critical. It was reported that partial factor productivity images NUE in some degree (Qingjiang *et al*., 1997; Dong *et al*., 2007). Fortunately, we found that treatment E achieved highest Partial Factor Productivity (PFP), 30.4-34.0 kg/hm$^2$. According to our results, PFP decreased when topdressing stage of N was postponed to booting stage or brought forward to tilling stage. PFP also decreased when topdressing rate of N was 30 or 50%. All the above results indicated that treatment E was the best treatment to achieve high grain yield and high N use efficiency.

Previous studies have demonstrated that nitrogen fertilizer affected protein content in grain (Xinghua *et al*., 2006; Jinzhe *et al*., 2001). It was reported that postponed nitrogen fertilizer could increase protein content (Guozhang and Yonghua, 2003; Yu *et al*., 2006). On the other hand it was reported postponing N fertilizer induced to over-green and low protein content in the end (Tiancai *et al*., 2007; Liwan, 2002). Most of the above studies were carried out in high-yield field. Our experiment in low-yield field in Jianghan Plain indicated that postpone N fertilizer stage from tilling stage to jointing stage, protein content in grain increased, but the trend was opposite when N fertilizer stage was postponed until to booting stage. At the same time, it was found that increasing the rate of basal dressing N to topdressing N, (3:7 to 5:5, 5:5 to 7:3, respectively) led to high grain protein content. Further studies indicated that the N concentration in different leaves of treatment E (30% as basal dressing N before sowing and 70% as topdressing N at jointing stage) was much less than that of other treatments, which suggested that the contribution N in leaves in treatment E is higher than that of other treatments. It was also found from our research that the protein process quality of treatment E was best. The stability time of paste in treatment E was 7.6-7.9 min.

The above results in this experiments suggested that it was possible for wheat grain yield to achieve 6000 kg/hm$^2$ in Jianghan Plain, with 180 kg N/hm$^2$ and 30% as basal dressing N and 70% as topdressing N at jointing stage, with higher PFP and higher stability time of paste. If this nitrogen application method in wheat could be spread in Jianghan Plain, it would increase total wheat grain yield greatly and relieve the pressure of food security in our country in some degree.

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