Shoot Zn Uptake, Remobilization and Partitioning Affected by Varied N Application Rates throughout the Development of Winter Wheat

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INTRODUCTION

Zinc (Zn) deficiency is a global malnutrition issue, particularly among developing countries where cereals-based foods are predominantly consumed. Recent publications reported that Zn concentrations in wheat grain could be enhanced by nitrogen (N) application (Shi et al., 2010). Further results showed that N nutrition was a critical factor in both the acquisition and grain allocation of Zn in durum wheat under greenhouse conditions (Kutman et al., 2010). The aim of this study was to quantify the uptake, remobilization and grain allocation of Zn in winter wheat as affected by different rates of N application under field conditions.

MATERIALS AND METHODS

The field experiment was conducted in Hebei province during 2007-2008. The soil used had a pH of 8.3, 1.4% organic matter and a DTPA-Zn concentration of 1.7 mg kg^{-1}. Winter wheat (*Triticum aestivum L.*, cv. Kenong9204) was cultivated and a randomized complete block design was laid out with four replicates. Five N rates including no N application (0 kg ha^{-1}), half of optimal N application (99 kg ha^{-1}), optimal N application (198 kg ha^{-1}), plus a half based on the optimal N application (297 kg ha^{-1}) and traditional N application (300 kg ha^{-1}) were applied as urea. Samplings were conducted at regreening, jointing, flowering, filling and mature stages of growth. Zinc concentrations in materials were measured by ICP-AES after digestion with HNO_3-H_2O_2.

RESULTS AND DISCUSSION

(a) Grain yield and grain Zn concentration. Grain yield and grain Zn concentration were increased significantly by N application from 0 to 198 kg ha^{-1}, but above 198 kg ha^{-1} were unchanged. This was consistent with results of Shi et al. (2010). The Zn harvest index was slightly affected by N application rates (Table 1), which was not consistent with other studies (Kutman et al., 2010).

(b) Shoot Zn concentration and content. Appropriate N application (e.g., 198 kg N ha^{-1}) resulted in significantly higher shoot Zn concentrations than that in no or low N applications during the whole growth stage (Fig. 1A), and consequently this treatment accumulated more Zn in shoots (Fig. 1B). These results showed that excess N supply (e.g. 297 and 300 kg ha^{-1}) did not further improve shoot Zn concentrations in field conditions indicating other limiting factors existed (e.g. root uptake).

(c) Shoot Zn remobilization and contribution to grain Zn. With increased N supply, 69% to 82% of shoot Zn content was remobilized to grain. Amounts of grain Zn provided by remobilization of the pre-anthesis Zn stores were significantly increased with enhanced N supply. Consequently, the percentage of grain Zn provided by Zn remobilization ranged from 67% to 100% of grain Zn content in higher N treatments compared to 61% in the control. Although similar amount of N was applied (e.g. 297 and 300 kg ha^{-1}), there

was big difference in source of grain Zn, indicating the importance of N application management in grain Zn accumulation (Table 1).

In summary, sufficient but not excess N application would be essential for reasonable yield, shoot Zn uptake and final grain Zn concentration. And N supply also improved the Zn remobilization from the pre-anthesis stores, which contributed more to grain Zn accumulation of wheat grown in field conditions.

Table 1. The yield, grain Zn concentration and its source from Zn remobilization of pre-anthesis stores and post-anthesis shoot uptake in winter wheat affected by N application rates under field condition.

Parameters	N application rate (kg ha^{-1})				
	0	99	198	297	300
Grain yield (t ha^{-1})	4.2c	5.2b	5.7ab	5.6ab	5.8a
Grain Zn concentration (mg kg^{-1})	22c	25bc	31ab	37a	32ab
Zn harvest index (%)	80b	86a	82ab	84ab	82ab
Shoot Zn remobilization ratio (%)[a]	69	81	74	79	82
Amount of grain Zn provided by:					
Remobilization of pre-anthesis Zn (g ha^{-1})[b]	52	95	116	152	187
Post-anthesis shoot Zn uptake (g ha^{-1})	37	35	60	56	0
Percentage of grain Zn provided by:					
Remobilization of pre-anthesis Zn (%)	61	76	67	75	100
Post-anthesis shoot Zn uptake (%)	39	24	33	25	0

[a] Ratio of net Zn remobilized was calculated by subtracting the straw content at maturity from the shoot content at anthesis, and then dividing by the shoot content at anthesis

[b] Assumes that all of Zn remobilized from the shoot is translocated to grains

Means in one line followed by the same letters are not significantly different (P≤0.05).

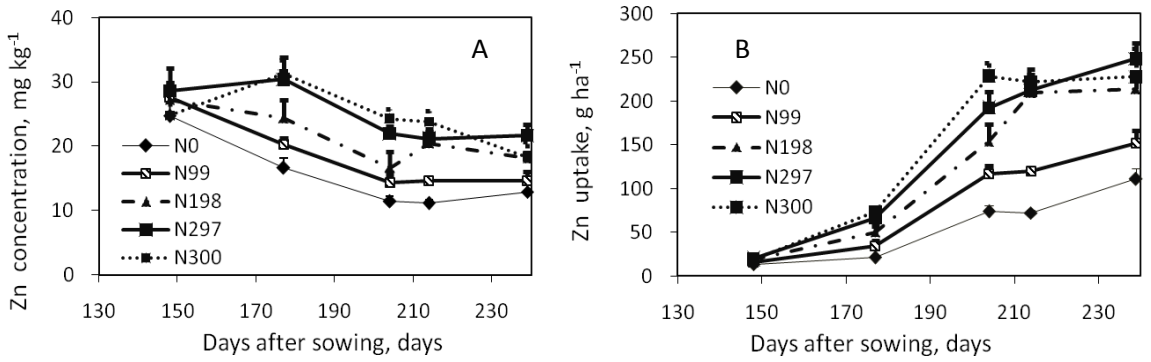

Fig. 1. Shoot Zn concentration (A) and content (B) of winter wheat affected by N application rates from regreening to maturity stages in the field. Values are the means (+SE) of four replicates.

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