The Relative Contribution of Post-Flowering Uptake of Zinc to Rice Grain Zinc Density

Stomph TJ[1], Hoebe N[1], Spaans E[1], Van der Putten PEL[1]

[1]Wageningen University, Centre for Crop Systems Analysis, PO Box 430, 6700 AK Wageningen, The Netherlands (tjeerdjan.stomph@wur.nl)

INTRODUCTION

In cereal breeding and agronomy there is an active search for options to enhance grain Zn density in order to improve the mineral nutrition of humans. An issue in the debate on ways to reach this target is the role of internal reallocation versus direct uptake during grain filling. An analysis of earlier published data on rice indicates that the Zn content in the grains at crop maturity would roughly equal the uptake between flowering and maturity (Jiang *et al.* 2008). However, this does not seem to be the case in all studies on cereals (e.g. Kutman *et al.* 2011). Such Zn budget studies do not provide full insight into the role of re-translocation versus direct allocation or into the role of different plant tissues in providing Zn to the grain.

METHODS

Two greenhouse experiment were conducted in Wageningen, The Netherlands. Rice was grown hydroponically to allow easy manipulation of Zn nutrition levels.

Greenhouse Experiment 1

Rice cultivar Handao 502 was grown at two different levels of Zn nutrition up to flowering, aiming to reach on average 20 or 40 mg kg^{-1}Zn in the crop. After flowering, no Zn was provided to the plants except for half of the plants earlier grown at the lower nutrition level. For these the same nutrition level was maintained aiming at 20 mg kg^{-1} Zn in the crop.

Greenhouse Experiment 2

Rice cultivar Qindao was grown at a single Zn nutrition level. Plants were given stable isotope (Zn^{70}) either between transplanting and panicle initiation, between panicle initiation and flowering of from flowering onwards. At panicle initiation, flowering and full maturity Zn density and the ratio between Zn and Zn^{70} were assessed in roots, leaves, stems, panicles structures and grains.

RESULTS AND DISCUSSION

Dry matter and grain production in Exp. 1 did not differ between treatments ($P>0.10$). The total plant Zn concentration differed significantly ($P<0.05$) between the two target concentrations, although overall concentrations were higher than targets (32.3 and 56.4 mg kg^{-1} when targets were 20 and 40 mg kg^{-1} respectively). When no Zn was applied after flowering the grains obtained their Zn mainly from stems, although also leaves and at the higher plant Zn nutrition level roots and panicle structures significantly decreased in Zn content (Table 1).

The Zn^{70} applied during grain filling in Experiment 2 (Fig. 1B) was observed in all organs, although roughly half ended up in the grains. The Zn earlier allocated to other organs, when Zn was applied either between transplanting and panicle initiation or between panicle initiation and flowering (Fig. 1A), also partly ended up in the grains (Fig. 1B). The Zn^{70} from application prior to flowering that ended up in the grain mainly came from stems (data not shown).

The combined information from both experiments indicates that when continuous Zn uptake is possible plants roughly maintain their Zn in all organs and take up enough Zn to fill their grains. The internal allocation and re-allocation, though, is complicated as freshly taken up Zn is allocated to all organs and all organs re-translocate some of their Zn present at flowering towards the grains. The

stem seems to be a major contributor to grain Zn in rice. This was especially the case when additional Zn uptake was made impossible during grain filling. As these experiments provided either no or *ad libitum* Zn during all growth stages it remains to be tested how important concurrent uptake is conditions when Zn uptake is gradually reduced over time (Cf. Waters and Grusak,2008).

Table 1. Change in organ Zn content (µg/plant) between flowering and grain maturity for plants grown at three Zn supply regimes.

Organ	Continuous 20 mg kg^{-1}	Until flowering 20 mg kg^{-1}	40 mg kg^{-1}
Roots	20.4	-15.2	-29.3
Stems	-13.6	-118	-179
Leaves	5.3	-46.2	-80
Panicle structures	-19.7	-16.6	-38.7
Grains	145	105	150
F-value interaction		*P<0.01*	
SED of interaction		*28.5*	

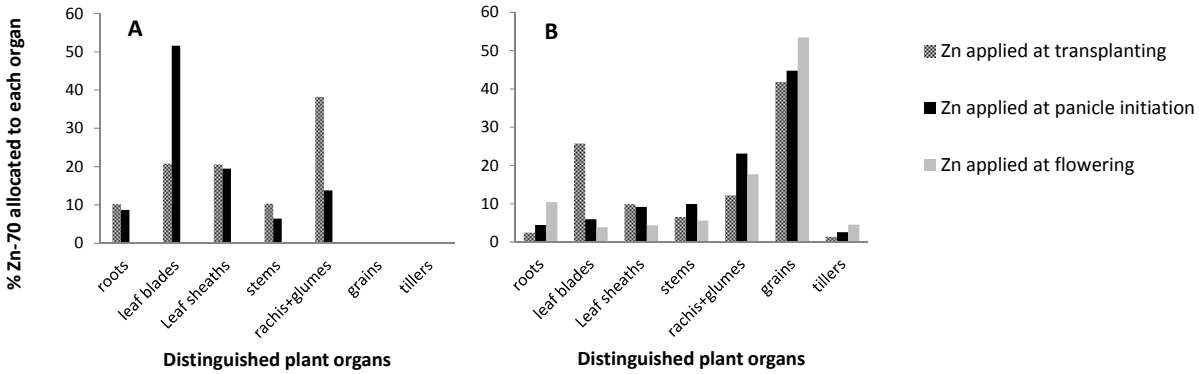

Fig. 1. Relative allocation of Zn-70 to different organs in dependence of the time of application. Data are presented for observations at either flowering (A) or grain maturity (B).

CONCLUSIONS

On the basis of the presented experiments with stable the isotope Zn^{70}, we surmise that Zn taken up after flowering ends up in all different plant organs, while Zn found in all organs at flowering can partly be traced back in the grain implying a very dynamic movement of Zn during plant growth and grain filling, with a role for both allocation and re-allocation processes and flows. This is equally true when plants can take up Zn during grain filling or when they cannot.

Enhancing grain Zn would therefore potentially gain from both maintaining or even enhancing Zn uptake after flowering and targeted enhanced (re-)allocation of the internally available Zn to the grain, with special attention to the options for stronger reallocation from the stem.

REFERENCES

Jiang, W., Struik, P.C., Zhao, M., Van Keulen, H., Fan, T.Q. and Stomph, T.J. (2008) Indices to screen for grain yield and grain zinc mass concentrations in aerobic rice at different soil-Zn levels *NJAS-Wag. J. Life Sci.* 55: 181-198.

Kutman, U.B., Yildiz, B., Cakmak, I. (2011) Effect of nitrogen on uptake, remobilization and partitioning of zinc and iron throughout the development of durum wheat. Plant Soil 342: 149-164.

Waters, B.M. and Grusak M.A. (2008) Whole-plant mineral partitioning throughout the life cycle of *Arabidopsis thaliana* ecotypes Comlubia, Landsberg *erecta*, Cape Verde islands and the mutant line *ysl1ysl3 New Phytologist* 177:389-405.