

Association mapping for root traits of maize (*Zea mays* L.) grown at three temperature regimes: allelic response pattern of root traits suggest specificity of alleles to optimal conditions vs. temperature-extremes.

Regina Reimer¹; Benjamin Stich²; Albrecht E. Melchinger³; Tobias A. Schrag³; Peter Stamp¹ and Andreas Hund¹

¹ Institute of Plant Science, ETH Zurich, Universitätsstrasse 2, 8092 Zurich, Switzerland

² Max Planck Institute for Plant Breeding Research, Carl-von-Linné-Weg 10, 50829 Cologne, Germany

³ Institute for Plant Breeding, Seed Science and Population Genetics, University of Hohenheim, Fruwirthstrasse 21, 70593 Stuttgart, Germany

Contact: Regina Reimer, phone: +41446323323, fax: +41446321143, E-mail: reimerr@eth.ch

ABSTRACT

While considerable research has been devoted to unravel the genetic basis of cold or heat tolerance, little has been done to trace the effect of an allele across the whole temperature range a maize plant is exposed to during its lifetime. We used a germplasm set comprising temperate flint and dent inbred lines to tackle this question. Seedlings were grown at 16°C, 28°C and 36°C. Associations were tested between the root traits at the V2-stage and 1415 AFLP markers. Markers with main effects and with environment interaction effects were found. Root traits were controlled by alleles responding to both temperature extremes, indicating general response pathways.

KEYWORDS: corn, QTL, abiotic stress

INTRODUCTION

Plant adaptation to a range of unfavourable climatic conditions is a central aim for plant breeders. Varieties showing a fast emergence and juvenile development under temperature stress conditions are valuable for regions where temperature hampers early seedling development. Beside specific stress response (specific protein expression) plants respond in a similar or same manner to different stresses. The pattern of allele response can give hints on the type of reaction involved in the response. In Figure 1, two hypothetical allele response scenarios to temperature stress are illustrated. Allele-environment interaction effects are shown for optimal and extreme temperature conditions. Class a_x displays the response of two alleles to either cold or heat stress while b_x illustrates a similar response to the temperature extremes. The aim of the study was to identify markers significantly associated with these responses with respect to root traits.

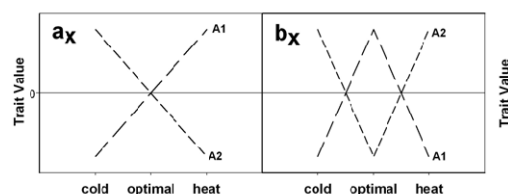


Figure 1: Hypothetical allele response to temperature

MATERIAL AND METHODS

Non-invasive digital measurement of root growth of 74 European flint and dent inbred lines was performed at 16°C, 28°C and 36°C. Seedlings were grown in pouches (Hund *et al.* 2009), hanging in containers with access to nutrient solution. Images were taken at three time points using a flatbed scanner (HP scanjet 4600 series, 'see-through', Hewlett-Packard Company). The binary images were analysed using WinRhizo™, and the length of lateral and axial roots was determined. Best linear unbiased estimates (BLUEs) were calculated for each genotype by environment combination and were used in the second step for the association analysis. The PK_{opt} method described by Stich *et al.* (2008) was used for detection of AFLP-phenotype associations.

Table 1: summary of marker-trait associations in the examined germ-plasm set exposed to three temperature regimes. k_{Lat} :

Trait	No. sig. marker with main effects	Explained proportion of genetic variance (%)	No. sig. marker with environment interaction effects	Classification of allele response (%)	
				a_x	b_x
k_{Lat}	-	-	2	-	100
ER_{Ax}	5	79.5	50	30	70
k_{Lat}/ER_{Ax}	1	44.3	28	18	82
NO_{SeRt}	15	92.6	-	-	-
DW_{Rt}	4	60.6	4	-	100

relative elongation rate of lateral roots, ER_{Ax} : elongation rate of axial roots

RESULTS AND DISCUSSION

The number of markers with main effects ranged from 4 for root dry weight (DW_{Rt}) to 15 for the number of seminal roots (NO_{SeRt}), explaining a proportion of the genetic variance of 60.6 to 92.6 %, respectively (Tab. 1). The detected markers with main effects can be considered as constitutive through all tested environments and with marker by environment interaction effects as responsive to temperature. Alleles underlying the observed root traits can mostly be classified as b_x , as they showed similar responses to both temperature extremes. This indicates that changes in temperature away from the optimum initiate general response pathways like the expression of heat shock proteins (HSP) and reactive oxygen species (ROS). Alleles, showing a response to either temperature as it was the case for the shoot traits (data not shown) may be involved in true tolerance to heat or cold.

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