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Yield maintenance under drought: expansive growth and hydraulics also matter in reproductive organs

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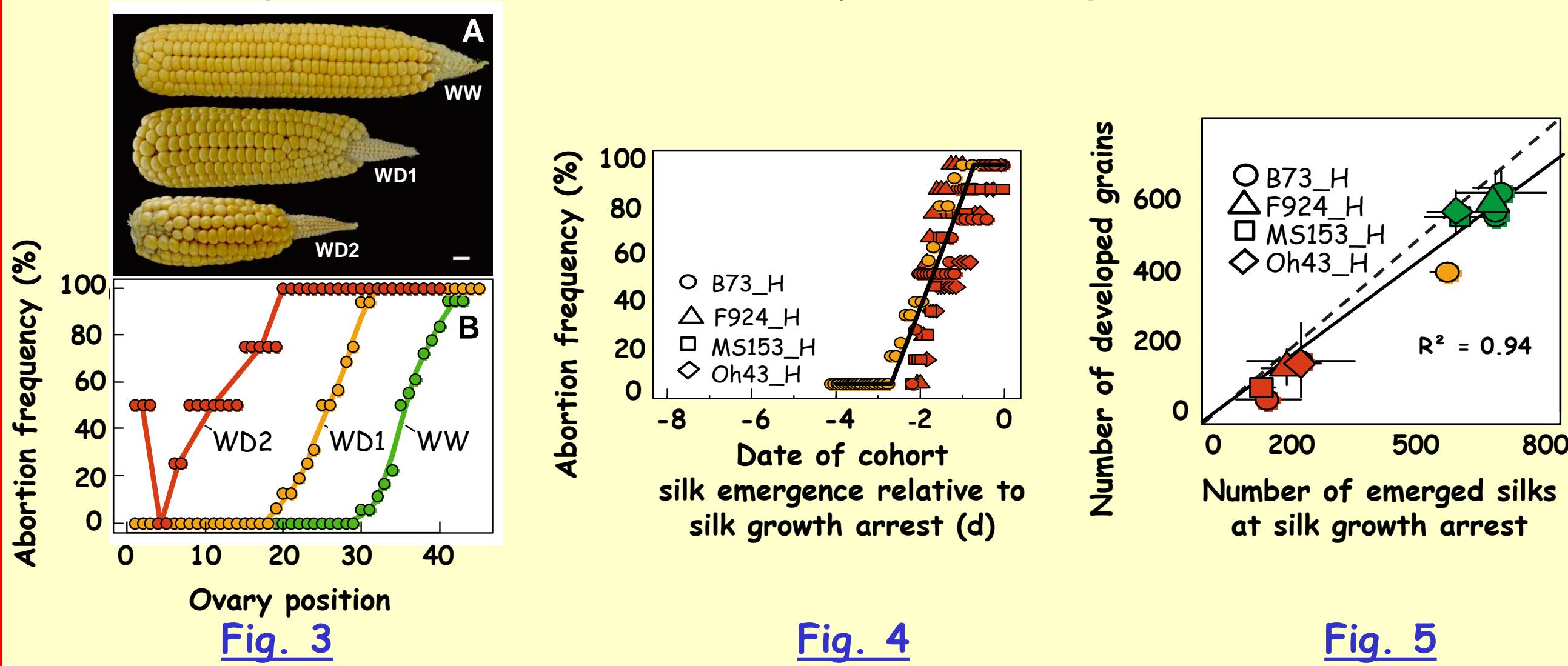


1 Summary

Yield maintenance under drought in maize (*Zea mays*) is associated with flowering synchrony which requires the rapid extension of styles and stigma (silks) to be accessible for pollen. We show here that the control of grain set under moderate water deficits similar to those in the field results from a developmental process linked to the timing of silk growth, itself related to expansive growth and hydraulics processes, in opposition to the common view that abortion is linked to the sugar metabolism in ovaries.

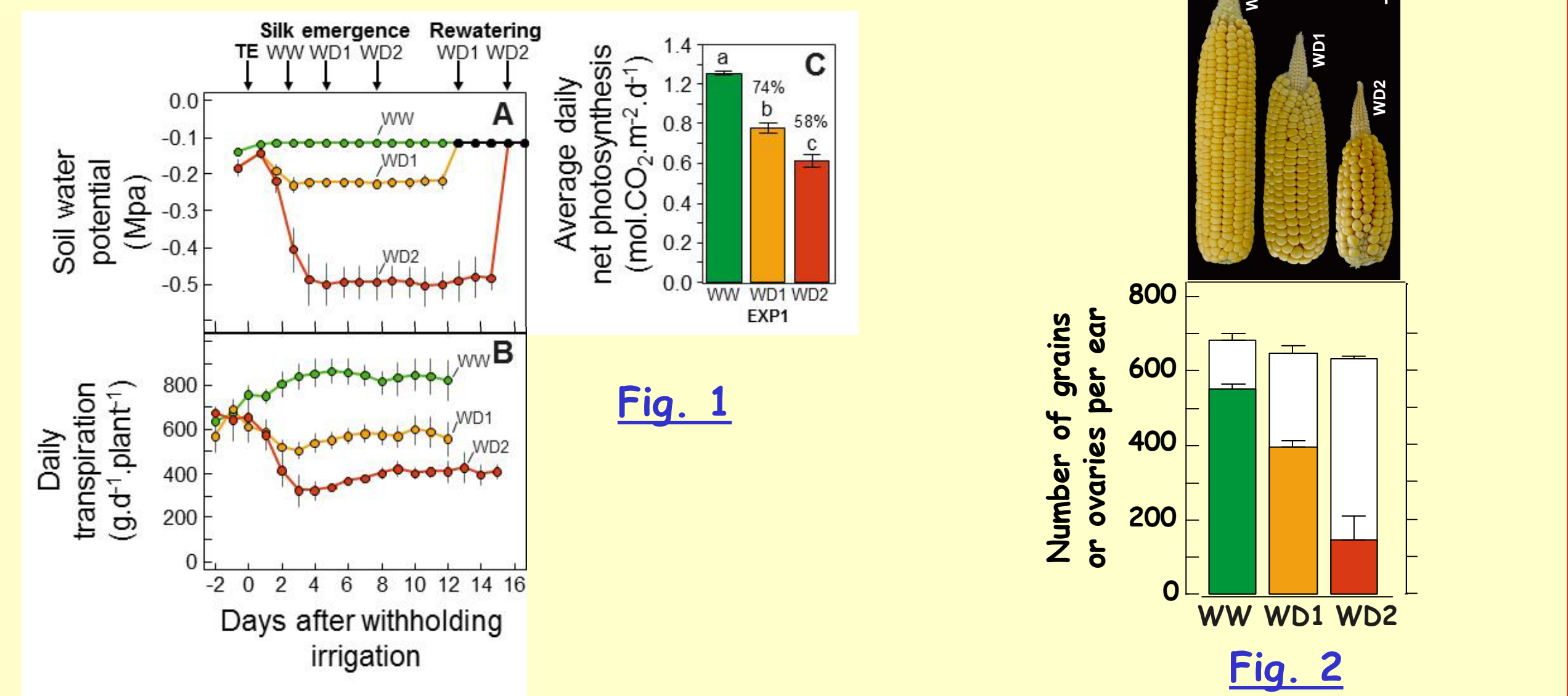
3 A switch to abortion occurs rapidly after first silk emergence.

Silk elongation rate decreased in water deficit and stopped 2-3d after first silk emergence, simultaneously for all ovary cohorts, vs 7-8d in well-watered plants. Abortion rate in different hybrids, treatments and positions on the ear (Fig. 3) was accounted for by the superposition of the sequential emergence of silks originating from ovaries of different cohorts along the ear with the simultaneous silk growth arrest. Abortion occurred in the youngest ovaries whose silks did not emerge 2d before silk arrest (Fig. 4). This mechanism accounted for more than 90% of drought-related abortion in our experiments (Fig. 5).



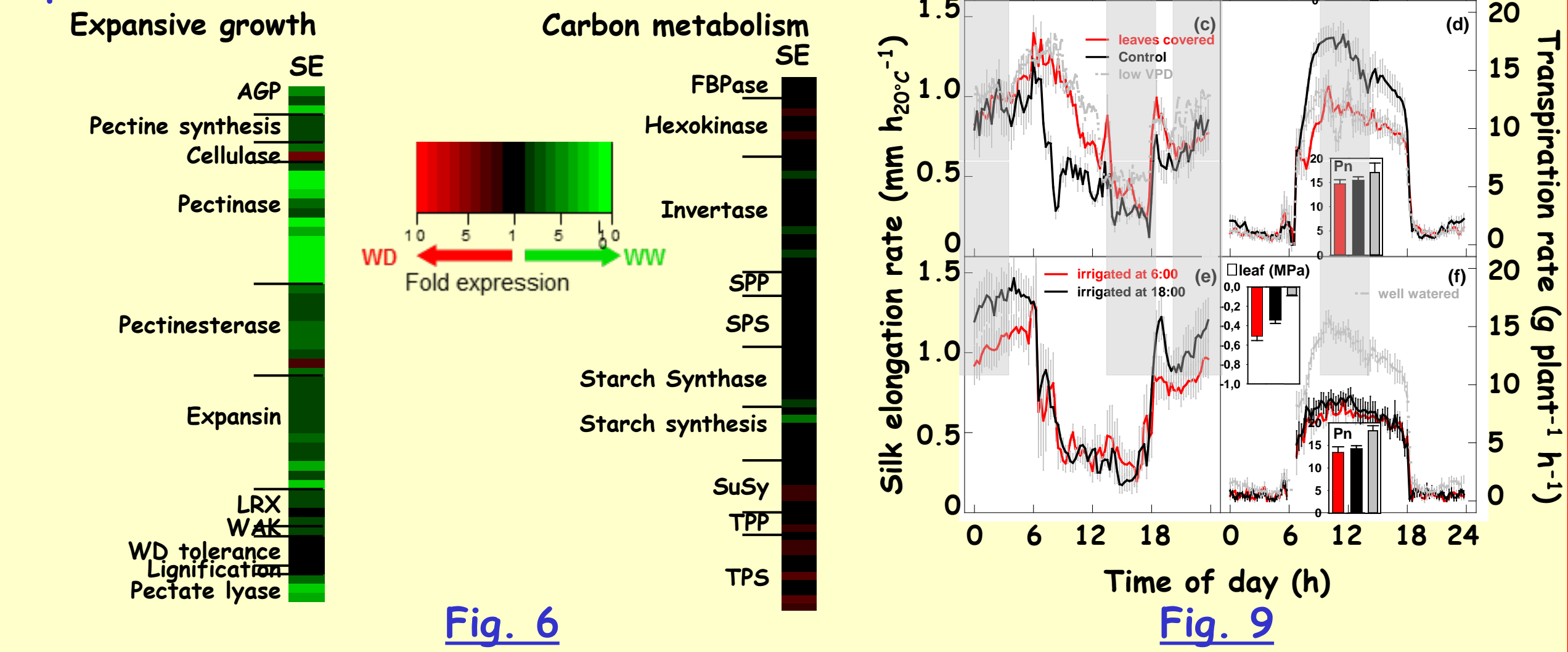
2 Perform realistic water deficits and abortion rates in controlled platforms

Four maize hybrids were grown in pots and subjected to different levels of soil water availability in greenhouse and growth chamber experiments (*Phenodyn* phenotyping platform). Soil water status was managed by weighing pots and adjusting water supply to the target soil water content. Three treatments were applied from tassel emergence (TE) to 7d after first silk emergence (SE), namely well watered (WW), mild deficit (WD1) and moderate deficit (WD2), with soil water potential above -0.10 MPa, around -0.25 MPa and around -0.50 MPa respectively (Fig. 1A). Their impacts on photosynthesis (Fig. 1C), transpiration (Fig. 1B) and seed set (Fig. 2) were similar to those commonly observed in drought prone fields.



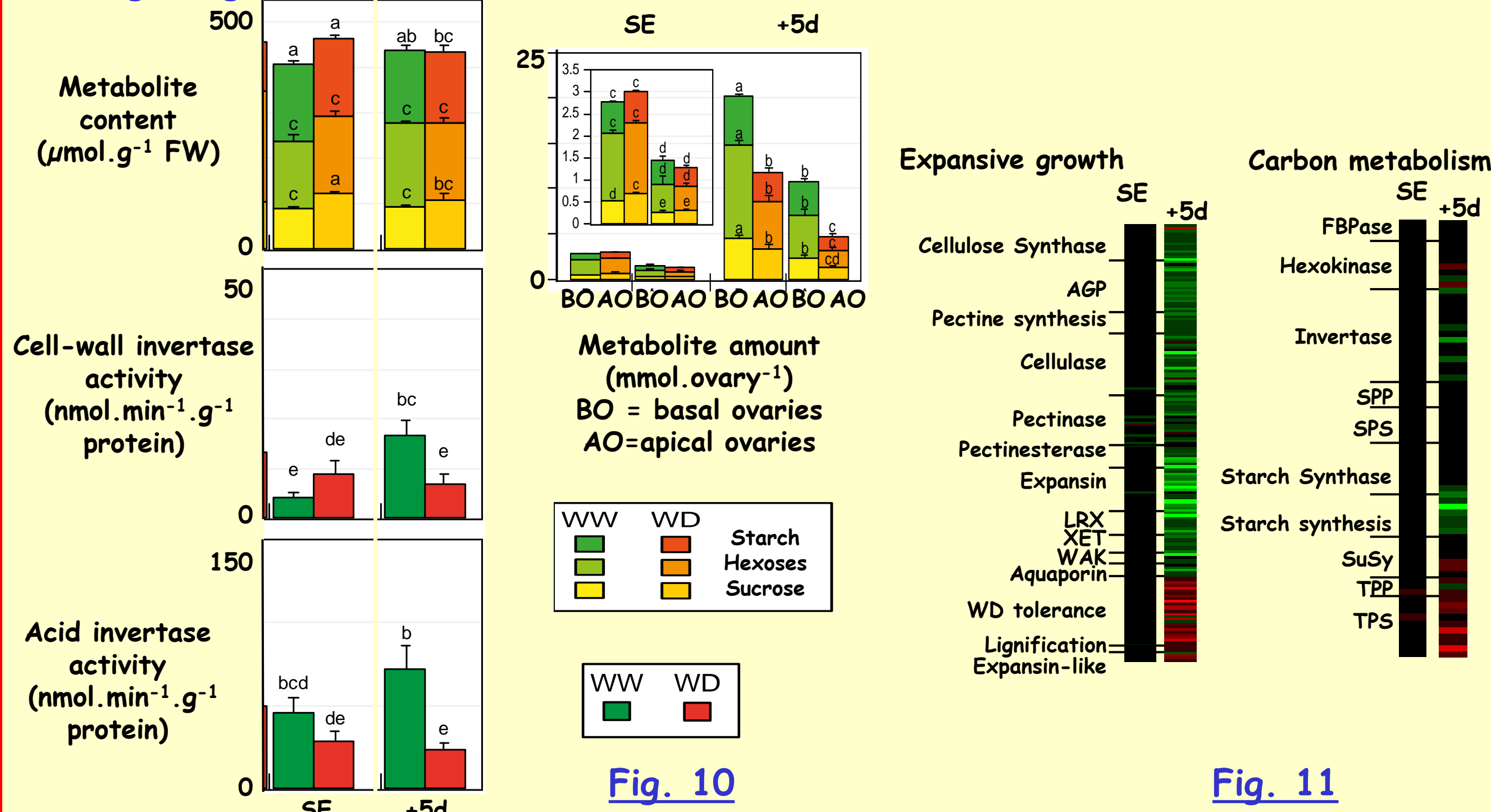
4 Silk growth is controlled by xylem water potential

Analyses of transcripts and metabolites indicate that the first molecular events induced by drought occur at first silk emergence (SE), in silks rather than in ovaries, and involve genes affecting expansive growth rather than sugar metabolism (Fig. 6). Silk elongation rate was measured using displacement transducers (Fig. 7). Time courses revealed that silk elongation rate closely followed changes in soil water status and evaporative demand, with day-night alternations similar to those in leaves (Fig. 8, Fig. 9). Day-night alternations were steeper with high than low plant transpiration rate, manipulated via evaporative demand or by covering part of leaf area (Fig. 9). Half times of changes in silk elongation rate upon changes in evaporative demand or soil water status were of 10-30 minutes (Fig. 8), similar to those in leaves, suggesting a common hydraulic control of expansive growth in both vegetative and reproductive structures.



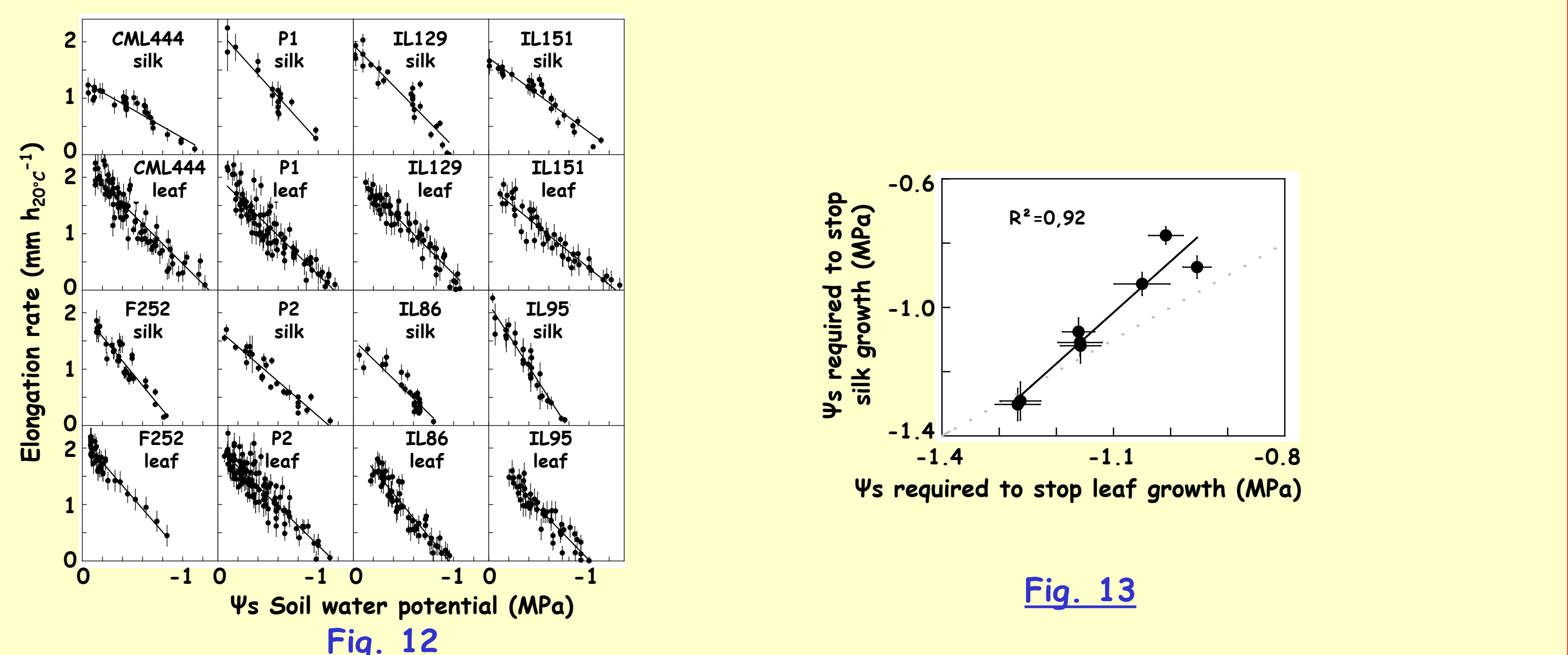
5 Carbon metabolism in ovaries was still unaffected at silk emergence

Changes in concentration and amount of sugars (Fig. 10), in activities of enzymes (Fig. 10) and in transcript levels (Fig. 11) of genes of sugar metabolism occurred 5 d after silk emergence in apical ovaries that eventually aborted, i.e. after the switch to abortion of these ovaries. Hence, we propose that, under moderate water deficits corresponding to most European drought scenarios, changes in ovary carbon metabolism during flowering time are a consequence rather than a cause of the beginning of ovary abortion.



6 Perspectives

These results confer a pivotal role to hydraulic controls of expansive growth processes in grain yield elaboration upon changes in environmental conditions. They have large consequences in plant breeding, modelling and phenotyping. Genotypes largely differ for the sensitivity of silk elongation rate to xylem water potential (Fig. 12), and sensitivities of silk and leaf growth were correlated (Fig. 13). This opens the way for genetic studies of the traits, genes and physiological processes controlling grain set under non-optimal climatic scenarios. These sensitivities and their genetic variability have to be included in the formalisms of crop models simulating yield in maize (e.g. APSIM model). An original method for phenotyping silk growth is currently developed by our group (companion poster IDT6-014).



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