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Comprehensive speed breeding: a high-throughput and rapid generation system for long-day crops

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Background:

Breeding cycle time largely determines the efficiency of crop genetic improvement. To shorten the generation time, Watson et al. (2018) proposed a concept of 'speed breeding (SB)' by extending the photoperiod and increasing the light intensity during plant growth and achieved up 4 generations per year for the spring canola (Brassica napus).

Objective:

Establishment of a comprehensive SB platform (CSB) which can be efficiently applied for long day winter crops in combination with high-throughput molecular breeding.

Methods:

The CSB programme including vernalization of germinated seeds, high-density seedling culture, and accelerated flowering and maturation with optimized light regime. First, germinating seeds are placed under 4.5 □ to complete vernalization treatment. Subsequently, the seedling culture is conducted in a 96-well plate with a hydroponic scheme at 22-24 □ and under ~950 μmol·m-2·s-1 light conditions (10 cm under the lamp, red: green: blue = 6: 2: 2) using a 22 h light/2 h dark light cycle. Genotype selection is rapidly completed during the seedling phase. Finally, the target plants are transplanted into pots and cultivated in a growth chamber, in which cold air is directed to circulate from the roof to the air flue and pass the plants, finally flowing back to the roof.

Results:

Using CSB system, a complete life cycle from seed to seed can be achieved in 85 d, 83 d, 65 d, and 75 d for semi-winter type rapeseed 'Zhongshuang 11', winter type wheat 'Yannong 19', spring type rapeseed 'Westar', and spring type wheat 'Chinese Spring', respectively. With additional ~500 μmol·m-2·s-1 of far-red light, the mature seeds of the winter type rapeseed 'Darmor-bzh' could be obtained in 125 d, and the life cycles of 'Westar' and 'Zhongshuang 11' be shorten to 55 d and 66 d, respectively. Based on this approach, we successfully achieved molecular-assisted improvement of the thousand seed weight of an elite restorer '621R' in 8 generations within 23 months in rapeseed.

Conclusions:

In summary, we propose a CSB system for the high-throughput culture and rapid generation of long-day crops. Application of CSB can cycle 4.5 and 5.5 generations per year for semi-winter and spring canola, respectively. Complementation of extra far-red light to CSB not only helps to reproduce winter canola for 3 generations per year but also further accelerate one more generation for other type canola. Moreover, about 4.5 to 5 generations in 1 year can be accomplished for both spring and winter wheat under CSB. This strategy is expected to greatly accelerate gene pyramiding of superior alleles, screening of recombinants for QTL mapping and functional genomics research by rapid purification of multiple mutated alleles.

References:

Watson, A., Ghosh, S., Williams, M.J., Cuddy, W.S., Simmonds, J., Rey, M.-D., Asyraf Md Hatta, M. *et al.* (2018). Speed breeding is a powerful tool to accelerate crop research and breeding. *Nature Plants*, 4, 23–29.