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Mechanisms Controlling Flower Abortion in Soybean

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Summary

During development a large proportion of flowers in soybean (*Glycine max* L. Merr.) abort, which is exacerbated by environmental stresses such as water scarcity. Alleviation of the high rate of flower abortion could lead to increased yields. This report highlights our recent studies on 1) how intra-raceme variation in pod set percentage is controlled under non-stressed conditions, and its relation to cytokinin and auxin content, 2) how variation in pod set percentage is associated with the source/sink relationship and cytokinin availability, and 3) whether abortion induced by water stress can be attributed to an impairment of pistil or stamen function. The first study revealed that the concentration of cytokinins was greater at more proximal floral positions several days after anthesis, as was the probability of pod set, indicating that pod set probability was significantly associated with the cytokinin concentration at different floral positions within individual racemes. The second study showed that cytokinin plays a promotive role in increasing pod number in the plants with high levels of assimilate availability. The third study suggested that flower abortion caused by a pre-anthesis water deficit was not attributable to an impairment of stamen function, but was due to an impairment of pistil function.

Introduction

Soybean yield is determined by the seed number per unit area and individual seed weight. The seed number depends on the number of floral buds that initiate pods and attain maturity. Soybean plants produce an abundance of floral buds; however, a large proportion of them abscise during development. A reduction in this abscission could increase pod and seed number, and thereby lead to an increased yield. However, the physiological mechanism controlling reproductive abortion remains unclear.

Possible physiological factors affecting abortion include quantity of certain plant hormones (Huff and Dybing, 1980; Heindl *et al.*, 1982; Carlson *et al.*, 1987) and deficiency in, or competition for, carbohydrates and nutrients (Brevedan *et al.*, 1978; Brun and Betts, 1984). Most reproductive abortion

occurs at an early stage of embryo development after fertilization (Kato, 1964). Water deficit during this period is a dominant environmental factor accelerating the rate of abortion (Kato, 1964; Westgate and Pearson, 1993). Water stress imposed during flowering reduces photosynthesis and the amount of photoassimilates allocated to flowers, and thereby increases the rate of abortion (Raper and Kramer, 1987).

This report highlights our recent studies on 1) how intra-raceme variation in pod set percentage is controlled under non-stressed conditions, and its relation to cytokinin and auxin content, 2) how variation in pod set is associated with the source/sink relationship and cytokinin availability, and 3) whether abortion induced by water stress can be attributed to an impairment of pistil or stamen function.

Roles of Auxin and Cytokinin in Soybean Pod Setting

Many studies have shown the promotive effects of exogenously applied cytokinin on pod set; however, the effects of auxin application remain unclarified. We examined changes in the endogenous concentrations of auxin and cytokinin in racemes and the effects of application of the two hormones on pod set to clarify the role of auxin and cytokinin in soybean pod set. The long-raceme soybean genotype IX93-100 was grown in pots and in the field.

Auxin (IAA, indoleacetic acid) concentration in racemes was high for a long period from pre-anthesis to 9 days after anthesis (DAA) in the first flower on a raceme, while cytokinin concentration was high for a short period, with a peak at 9 DAA. Moreover, IAA concentration was higher in the distal portions of racemes, whereas cytokinin concentration was higher in proximal portions of racemes. In pot-grown plants, IAA applied to racemes tended to reduce the number of flowers and pods. In contrast, 6-benzylaminopurine (BA) applied to racemes before anthesis tended to reduce the number of flowers and pods, and BA applied around 7 DAA significantly increased the pod set percentage. These results indicate that endogenous auxin and cytokinin concentrations in racemes change in a different manner, and that cytokinins have a positive, and auxin a negative, effect on pod set when respective hormones are applied to racemes after the anthesis stage (Nonokawa *et al.*, 2007).

Effects of Source/sink Ratio and Cytokinin Application on Pod Set

Pod set is significantly affected by the availability of assimilate and cytokinin in the flowers, but their synergistic effects on pod set remain unclear. To examine whether pod set at specific nodes can be influenced by increasing the source/sink ratio and applying cytokinin, the source/sink ratio was manipulated

by removing floral buds, excluding specific nodes, and applying cytokinin to the remaining nodes in the soybean cultivar 'Enrei'. As the source/sink ratio increased, the number of pods per node of control plants increased in curvilinear fashion, reaching a plateau at high source/sink ratios. In contrast, in the cytokinin-applied plants, the number of pods per node increased without the plateau associated with an increasing source/sink ratio, either by increasing the number of flowers or by increasing the pod set percentage, depending on the year. The results indicate that cytokinin plays a promotive role in increasing pod number in plants with high levels of assimilate availability (Yashima *et al.*, 2005).

Viability of Pistil and Stamen under Water Stressed Condition

It has not yet been elucidated whether flower abortion can be caused by pre-anthesis water deficits, and whether abortion is due to an impairment of the pistil or stamen. To address these issues, experiments were conducted using soybean genotype IX93-100 grown under environmentally controlled conditions (30/20°C day/night temperature, $60 \pm 10\%$ relative humidity, 600 μmol m^{-2} s^{-1} photon flux density). When plants began to flower, the water supply was restricted to a level at which the water potential (Ψ_w) of the leaves fell below -1.5 MPa. This treatment was imposed on half of the plants and lasted for 3 d, after which the plants were re-watered to the original level. Well-watered (WW) and water-deficient (WD) plants were reciprocally hand pollinated (WW$\times$WD and WD$\times$WW) daily. Pod set percentage of the artificially pollinated flowers was measured.

Water stress caused by restriction of watering for 3 d during the pre-anthesis stage significantly increased abortion of the proximal flowers of self-pollinated plants. The pistils of well-watered plants, pollinated with either stressed or non-stressed pollen, produced pods at a considerable rate. However, only a small percentage of flowers with water-stressed pistils developed pods, even when they were crossed with non-stressed pollen. These results suggest that flower abortion following pre-anthesis water deficit is not attributable to impairment of stamen function, but is due to an impairment of pistil function (Kokubun *et al.*, 2001).

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