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Full Length Research Paper

Long distance transport of assimilates is shown to exist in soybean plants

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Effect of source-sink distance on soybean yield was studied. Our hypothesis was that soybean can redistribute assimilates from lower leaves to young pods formed at youngest part of stems across the main stem to maintain yield. We artificially created two, four, six, eight, and ten-nodes of source-sink distances in soybean plant. A reduction in the seed yield of remained sink occurred with the increase in distance from the source. This was mostly due to a reduction of pod number caused by the increase of the distance from the source. No pod reduction was found at the 2-node distance compared with control plant. Reduction in seed size occurred for the 2- and10-node distance from the source. When source-sink distance was four, six, eight nodes, seed size was similar to control. Our findings suggest soybean plants are able to transport and use assimilates as far as 8 nodes distance. The successful translocation of assimilate from lower nodes is mainly used for pod formation and seed filling over a short distance, but can be translocated over a long distance and used for growth of remaining seed. This suggests the reproductive sink of soybean plants has an internal mechanism to off-set yield loss to ensure seed survival.

Key words: Pod number, seed size, assimilate translocation, node number.

INTRODUCTION

For the past several decades, effect of altered source-sink relationship on soybean yield has been extensively studied (Board and Harville 1998; Liu and Herbert 2006). Former studies indicated that when equilibrium is broken between sources and sinks in individual soybean plant through pods or leaf removal, the direction of assimilate transport is changed (Board and Harville, 1998). A positive correlation between leaf area and seed weight across the main axis in soybean was reported, and was defined as source-sink parallelism (Dong et al., 1993). Assimilates of pods and seeds in certain node were mainly supplied from the leaf developed from the same node, namely local supplying characteristic (Pate, 1977). Wang et al. (1983) stated that pods gained assimilates not only from the attached leaf but also from the leaves at the adjacent nodes (above or below). They found a strong adjacent compensation in assimilate distribution process, because pods weight at the nodes with leaf removal was 60% of the same nodes with leaf attached. Fu et al. (1999) found that a mature trifoliate leaf from a certain node supplied most assimilates to the pods attached in the axis of the same leaf petiole, and only small part of the assimilates transported to the adjacent node, particularly to the adjacent pods at same side of the stem using ^{14}C technique. They then proposed that assimilates in soybean plant had the characteristic of same side transport.

Although the reproductive sink has greater strength to attract assimilates, no appropriate design has quantified how much and how far the assimilates are transported. Our objective of current research was to investigate whether soybean plant as a whole, is able to redistribute the available assimilates to components across the main

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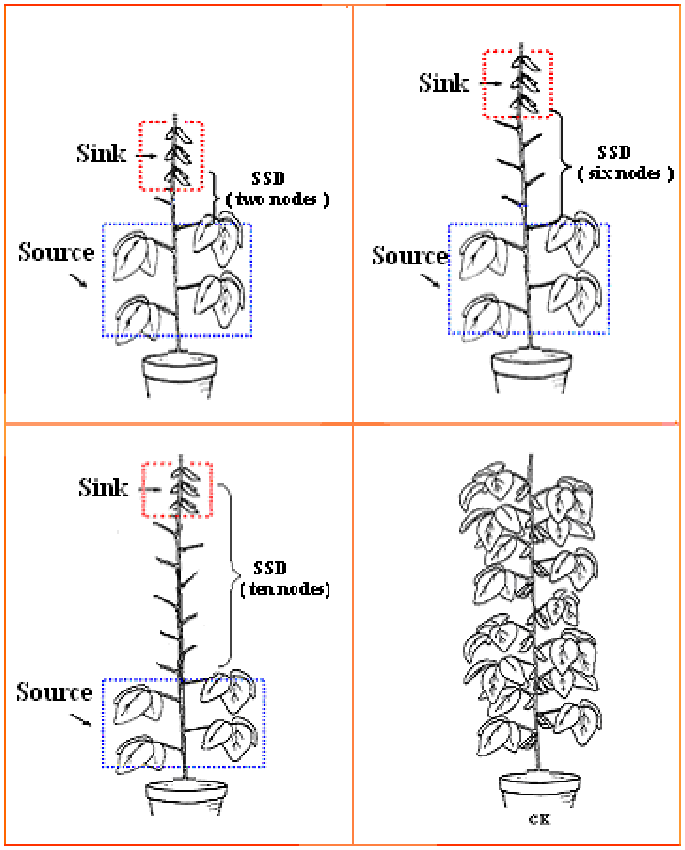

Figure 1. The diagram of source-sink distance (SSD) of leaves and pods-removed plants from two, six, ten nodes above the bottom four nodes with expanded trifoliate leaves and control plant in soybean.

axis with the change of source-sink intensity, and how long photo-assimilates could transport, in an attempt to maintain yield.

MATERIALS AND METHODS

Experiments were conducted at the greenhouse in Northeast institute of Geography and Agroecology, Chinese Academy of Sciences. Soybean cultivar, Heinong35, were grown in pots filled with a 2:1 (V: V) mixture of surface soil of a silt loam (typical Mollisol, black soil) and vermiculite. Eight seeds per pot were sown and germinated seedlings were thinned to one plant per pot when first trifoliate leave was expanded. Plants at the early pod formation stage were treated as follows: all pods at the bottom four nodes above the unifoliate node were removed, but expanded trifoliate leaves were remained as source, and then leaves and pods from the upper two, four, six, eight, and ten nodes above the bottom four nodes with expanded trifoliate leaves were removed, respectively, to form different source-sink distances with two nodes as a unit, while all young pods (>5 mm long) at the three nodes above all treated node were remained as sink, but trifoliate leaves of these three nodes were removed (Figure.1). Twenty nodes were formed when treatments were implemented. Fifteen soybeans were planted in each treatment. In order to obtain a detailed data of yield components, data were recorded for all the treated plants. Collected data included seed yield, pod number of remaining sink and seed size. Experimental data were analyzed statistically using PROC ANOVA, and least significant difference was calculated using SAS software.

RESULTS AND DISCUSSION

A reduction in the seed yield of remaining sink per plant occurred with the increase in the source-sink distance (Figure 2a). The seed yield of remaining sink in the two-node distance was not significantly different from the control plant although it was slightly reduced. In addition, no seed yield difference was observed between eight-node and ten-node distances (Figure 2a). Similarly, when the source-sink distance was two nodes, pod number per plant was not reduced compared with control plant, and no difference was observed in pod number between eight-node and ten-node distances (Figure 2b). Significant reduction of pod number started from four-node distance. On the other hand, a significant reduction of seed size occurred only for the two-node and ten-node distances from the source (Figure 2c). When source-sink distance was four, six, and eight-nodes, seed size was similar. It has been reported that soybean yield

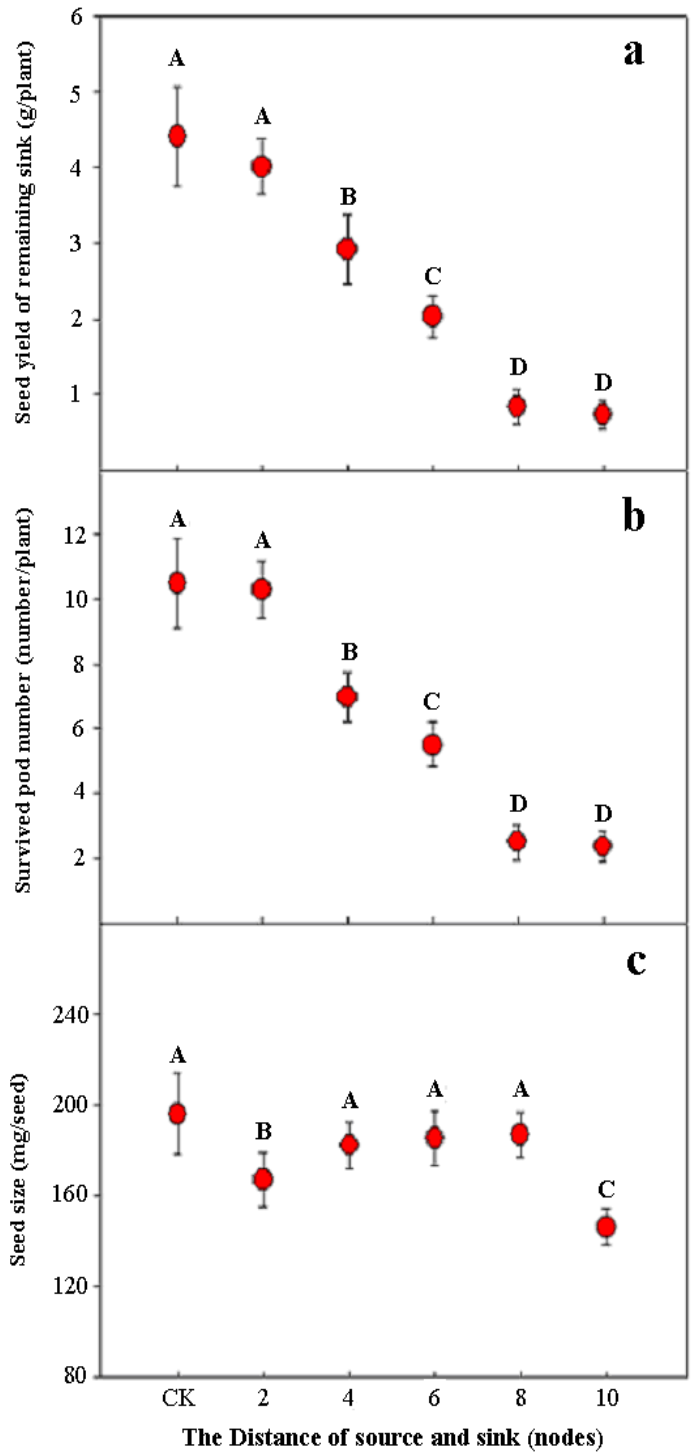

Figure 2. The effects of source-sink distance on seed yield, surviving pods and seed size. Different letters mean significant level (P<0.05).

was affected more by source strength rather than by sink activity, and was controlled by the availability of assimilates during the reproductive growth stage (Jiang and Egli, 1993). Results of this research suggest that source-sink distance is also a yield limiting factor, since the greater the distance of sink from the source, the fewer the pod number and smaller the seed yield. In this sense, it may not be appropriate to breed cultivars with excessive long internode distance. Board and Harville (1998) proposed that the relationship between source and sink in individual soybean plant was complicated, when source strength or sink activity was changed, direction and amount of assimilate distribution was influenced. Our research indicated that even if the source-sink distance was eight or ten-nodes, remained sink still had approximately two pods or four seeds (data not shown). The decreased seed yield of remained sink was mainly due to the reduction of pod number. Pod number per plant as the yield component was most influenced by changes in source-sink manipulation (Liu and Herbert 2006). However, this is not true when source-sink distance is two-nodes, because only seed size but not pod number was reduced. The reduction of seed size at two-node distance might be due to a self-compensation mechanism of maintaining enough pod number using the available assimilates. Seed size influences soybean yield (Morrison and Xue, 2007). Cotyledon cell number and cell volume or weight are two main components determining seed size (Egli et al., 1989). Our results suggested that seed size may also be modified by the source-sink distance. It must have some internal control moderating the final seed size. An increase of seed size compensating for the decreased pod load was reported by Board and Harville (1998). Our findings indicated that assimilates were used for pod and seed growth if the assimilates were relatively sufficient, and were used mostly to maintain seed size when they were too limited since only fewer pods survived from 4-node distance onward. Our data also showed that seed size at eight-node distance was similar to control plant, this suggests that soybean plants are able to transport and use assimilates as far as eight-node distance. It was indicated that assimilates translocated from lower leaves over a short distance are mainly used for pod formation and seed filling and those translocated over a long distance are used for growth of remaining seeds. Thus, long distance translocation of assimilates was shown to exist in soybean plant across the main axis to maintain yield.

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