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1) A breeding project aimed at producing major morphological changes required to fit a soybean "idiotype".

There is evidence that only small increases in yield have resulted from soybean breeding in the United States during the past 30 years and that some major limitations to yield have been reached (Frey, 1971). During this period the main advances have been in developing resistance to pests and diseases, and improving agronomic traits such as resistance to lodging and shattering.

Considerable increases in yield have been achieved during this period in programs conducted for the development of soybeans in the tropics and subtropics through adaptability to short days and high temperatures. These yield improvements are analogous to those obtained in the U.S.A. some decades ago when comparable advances were made. It can therefore be expected that yield improvement will decline once certain levels have been reached.

What factors limit yield? The physiological limitations to yield which have been reached probably relate to both the carbon and nitrogen metabolism of the crop. It is necessary to examine some information relevant to these limitations before considering how they may be overcome.

Carbon assimilation as a limitation of yield: The photosynthetic apparatus of this crop is not remarkable for its efficiency, and in the opinion of many researchers in this field, there is little prospect of large yield improvements (Duncan, personal communication). The plant has a C_3 metabolic pathway and therefore individual leaves become light saturated at relatively low light intensities. While there are variations in photosynthetic rate between varieties (Dornhoff and Shibles, 1970; and Shibles, personal communication), the relationship between yield and photosynthetic capabilities is apparently not great.

It would seem, therefore, that the problem of photosynthate supply may best be overcome by spreading the available light at a lesser flux density over a larger area of leaf. This would require modification of the existing canopy structure. The establishment of a powerful reproductive sink may also increase photosynthesis since increased demand has been shown to increase supply of assimilates. This phenomenon may exist for soybeans (Dornhoff and Shibles, 1970), although the extent and limit of this stimulation has not been defined. It may be a sizeable increase since a two week improvement of light into the lower regions of the canopy at the pod setting stage may increase yield by as much as 40% (Schou et al., 1978). The nutrient limitation to yield would therefore appear to be the one which is of greatest significance to yield.

Nitrogen as a limiting factor to yield: The role of nitrogen as a limiting factor in the determination of yield potential has been researched by a number of workers since Sinclair and de Wit (1975, 1976) concluded that the seeds accumulated nitrogen at a rate in excess of the crop's ability to achieve N accumulation and utilized N from the leaf to achieve this. This use of nitrogen from the leaves reduces photosynthesis and is associated with rapid senescence (Murata, 1969; Egli et al., 1978).

Attempts to overcome this by foliar applications of nutrients have been consistently successful only in greenhouse experiments (Hanway, personal communication).

This problem may also be overcome by increasing the supply of carbohydrates to the roots and nodules. Nodule activity is closely dependent on the supply of assimilates to the roots (Hardy and Havelka, 1976). Any change in photosynthate availability has a rapid effect on the nitrogen fixation by the nodules which is greatly reduced once the pods start to grow. The roots appear to be unable to compete with the pods for the carbon assimilates for the following reasons. First, the distribution of assimilation within the plant is usually from the leaves to the nearest sinks and the pods are nearer to the leaves than are the roots. Second, the lower leaves which are normally responsible for the carbon nutrition of the roots have either senesced or are in very poor radiation conditions and unable to support the roots with the amounts of carbohydrates that they need for active N fixation. The consequence of decreased root activity to the plant may extend beyond the reduced mineral assimilation since the roots also produce cytokinins which are involved in the senescence of the leaves (Torrey, 1976).

Plant morphology and competition: Individually soybean plants have a capacity to yield substantially more than they do in a crop community. The competition afforded by neighboring plants reduces the nitrogen fixation by the plants (Weil and Ohlrogge, 1975) and this becomes the yield limiting factor and results in hastened senescence (Egli et al., 1978). When the soybean plant is examined in the light of the above, the petioles and their development are a major disadvantage to the plant. The petioles of normally spaced plants are relatively short at the bottom of the plant and increase in size progressively up the plant until those near the top reach a maximum size in excess of 30 cm. These petioles spread the leaf away from the central axis of the plant and effectively shade the lower leaves. This has the undesirable consequence for the supply of carbohydrates to the nodules that has been described earlier.

The petioles also constitute about 33% of the growth prior to pod filling and potentially this material could be utilized elsewhere by the plant and could contribute to increased seed yield.

Is it possible to overcome these limitations? This question remains unanswered at present although it has been hypothesized that changed morphology may help to overcome these problems by improving light into the lower canopy. This will require changed petiole characteristics.

Plant breeding for improved morphology: No genotypes with sessile or near sessile leaves have been found among our collection. The possibility that such a type may arise through mutation led to an irradiation project. Air-dry seed of cv. 'Rhosa' were exposed to three levels of gamma radiation (6,000, 12,000 and 18,000 r) using a Cobalt 60 source. The irradiated seed was then planted in the field, and regularly inspected to find any mutant of interest to the program.

Among the plants from the 18,000 r treatment one was found with the petioles from the first nodes being normal in length and becoming progressively shorter up the stem until the top leaves are almost sessile, creating a 'pine tree' shaped canopy. This plant produced 15 seeds which have been grown as separate lines for three generations. No segregation occurred for the main abnormalities of the original selection which were, in addition to the smaller petioles, crinkled leaves and decreased plant height.

The mutant was undesirable from two aspects in that it was dwarfed and produced fewer seeds than normal plants. In order to improve these defects and also to establish the mode of inheritance of the mutation, three crosses were made to well-adapted prolific lines. In two of these crosses the mutant was used as the female parent and in the other it was the male parent. In all crosses the F_1 plants were normal and in the F_2 segregation was as shown in Table 1.

Table 1

Segregation ratios in the F_2 generation of progeny of crosses between mutant and normal parents

♀ parent	♂ parent	Normal	Sessile	Chi-square	Probability of ratio being 3:1
74/6/23	Mutant	165	13	29.73	p = 0.01
118/6/40	Mutant	41	37	13.64	p = 0.01
Mutant	20/6/25	280	89	0.14	p = 0.7-0.8

In one cross the mutant behaved as a simple recessive but not so in the other two crosses. At this stage it seems that the mutation is recessive and not cytoplasmic but just how many loci are involved is not clear and further investigation is indicated.

Of practical interest, however, is that the types of plants selected from these crosses appear to have considerable promise. Single plant selections were taken at the F_2 and further selections of their progeny in the F_3. These plants, selected for normal height and a 'pine tree' canopy at the early reproductive stage, have proved to be high yielding. This tends to confirm the importance of canopy modifications to future improvements of soybean yield. The improved light penetration associated with the canopy change has resulted in heavy podding in the middle and lower strata of the crop. Leaf area duration has been increased and the plant structure seems less likely to lodge. The height of the lower nodes appears to have been unaltered.

Further selection work must continue to stabilize these lines and the benefits of the mutant form must still be demonstrated in yield trials. However, it does appear that a single cross with the mutant onto a suitable genotype can produce desirable plant types which should have certain desirable physiological properties not normally found in the species. On the arguments presented in this note, and our own initial observations, this may well lead to increased seed yield.

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