THE USE OF PLANT MAPPING FOR EVALUATING STRUCTURE AND YIELD OF SOYBEAN PLANTS

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Abstract. Several field situations and experiments were selected to provide examples of how soybean fruit mapping data could be used to more effectively delineate and understand responses. Field situations mapped included in-the-row subsoiling, severe drought, restricted soil rooting depths, variety tests, wheat residue test, and a representative production population. The methods of presentation used were mainstem nodes, nodes-above-ground, nodes-from-stem-end. Fruit mapping provided insight into the nature of some responses and was helpful in documenting morphological responses and characteristics. Future utility of fruit mapping depends upon identification of the most appropriate method for presenting the map data in order to illustrate the responses most clearly. These are only three of many possible ways to present the mapping data.

INTRODUCTION

Until its recent adaptation by cotton (*Gossypium hirsutum* L.) agronomists, plant mapping has not been used extensively for crop management (Bourland et al., 1990, 1992a, and 1994a; Klein et al., 1994; Oosterhuis et al., 1994; and Zhang et al., 1994). Cotton agronomists originally used plant maps (I) to evaluate the accuracy of computer predictions of plant development (Albers, 1990 and Smith et al., 1986) and (ii) to evaluate the effect of growth regulators on the cotton plant (Bourland and Watson 1990). The use of plant maps progressed rapidly to (i) determining which fruiting locations contribute most to yield (Bourland et al., 1990; Constable, 1991; and Jenkins et al., 1990ab) and (ii) using plant flowering, fruit set, and nodal characteristics to plan management practices such as end of season management for insect control and harvest aid applications (Bagwell and Tugwell, 1992; Bernhart et al., 1996; Bourland et al., 1992b and 1994b; Cochran et al., 1994; and Oosterhuis et al., 1992 and 1994). Plant mapping at the end of the season is a proposed tool for growers to identify production problems (Plant and Kerby, 1995.)

Keisling and Counce (1997) present a method to map fruit on a soybean (*Glycine max* L. Merr.) plant. The mapping procedure consists of recording the location and fruit characteristics in a numerical format. Soybean fruit mapping (if it parallels that of cotton) could become a powerful management tool. It may also be helpful in documenting and understanding soybean morphological responses to the environment.

The objectives of this paper were (i) to provide examples of potential applications of soybean fruit mapping and (ii) to show how fruit mapping aids understanding of soybean responses to the environment.

MATERIALS AND METHODS

Several diverse situations were selected to map fruit according to the method described by Keisling and Counce (1997). These situations were selected to show potential of the method for illustrating morphological differences. The selected situations included drought, row spacing, in-the-row subsoiling, variety testing, planting in wheat straw, population characteristics in a production field, and lodging. Location, soil type, cultivar, planting, and plant growth stage at sampling date are given in Table 1. Non-specified agronomic practices in each situation were commensurate with normal production practices used in the area.

Drought

A field exhibiting severe drought stress was selected. Plants in this field were dying. The seedbed was bedded in 38 in rows in the fall and remained a stale seedbed. Both live and dead plants from 1 m of row were selected for mapping.

Soil Depth

The field was planted in 6-in and 12-in drilled rows. Plant spacings were the same within each row spacing, giving plant populations of 612,000 plants per ha for 6-in row spacing and 306,000 plants per ha for 12-in row spacing. The field has a fragipan which varies in depth across the field: <12 in and 12-24 in. Plants were selected from 48 in row lengths per plot in five replications for mapping.

Wheat Straw

A split plot with main plots being fallow or cropped to wheat and subplots being soybean cultivar was sampled. The field was irrigated to eliminate water stress. Fifty varieties were planted no-till in 19-in rows. Certain varieties showed a dramatic response to the presence of wheat stubble. 'Hartz 5545' was chosen for mapping because height was reduced approximately 50% in the presence of wheat straw. One representative plant from each treatment was mapped.

In-the-row Sub-soiling

A tillage test received a conventional bedding treatment and in-the-row subsoiling system. Land preparation consisted of disking, chiseling and forming a crowned bed with disk bedders for seedling rows 30 in apart. The in-the-row subsoiling treatments were about 16 in deep immediately under the seedling row. The beds were dragged off just prior to planting. Plants from a 24 in length of row were mapped.

Growth Habit and In-season-progression

A cultivar test was chosen. In the fall of 1993, the field was disced, land-planed and bedded in 38-in rows. The beds were dragged off and bedded again in the spring immediately prior to planting. Plants for mapping were taken from 6 in length of row in each of four replications. Several determinate and indeterminate cultivars were mapped with similar results. 'Williams 82' and 'Hutcheson' were chosen as representatives of the two growth habits.

Population Dynamics

In the border of the cultivar test described above, soybean plants from 39 in of row were mapped with plant locations recorded. Yields per node on each plant were recorded to demonstrate potential utility of fruit mapping for delineating fruit distribution differences between high and low yielding plants.

Lodging

Locations with lodged plants in the same field as used for soil depth studies were selected. These plants lodged approximately at the V14 growth stage (last week in July.) The rows spaced at 6-in with 612,000 plants per ha were lodged, and the 12-in spaced rows at 306,000 plants per ha were upright.

RESULTS AND DISCUSSION

Drought

The response of soybeans to inadequate water provide one set of examples of the potential value of the maps. Fruit maps (Fig. 1a and b) indicate that plants that had recently died had a much different fruit distribution along the mainstem nodes. The live plants tended to have more fruit at lower mainstem nodes than at upper mainstem nodes. The dead plants tended to have a reverse distribution of fruit along the mainstem. This fruiting pattern is dramatically depicted using cumulative graphs as in Fig. 1c and d. The fruit load on dead plants is approximately 30% higher than on live plants and is shown with the cumulative graphs. There is no apparent difference in the relative maturity of the fruit. The pods classified as R5 on the dead plants did not separate at the peduncle even if pulled until the pods split, but those classed as R4 easily separated at the peduncle. This indicates that pods in the R5 growth stage will not abort under drought stress even when severe enough to kill the plants. Severe drought damage leading to the death of some plants compared to survival for other plants provided us with an opportunity to illustrate plant characteristics of surviving versus dead plants.

Soil Depth

The narrow rows at the high populations resulted in a yield increase (p=0.01) compared to wide rows and low population on shallow soil but not on deeper soil. Mature fruit maps on a per plant basis indicated the following:

(1) On shallow soil (Fig 2a and c), plants in close rows and high population had some yield and branching characteristics similar to plants on wide rows and low population.

(2) On deeper soil (Fig 2e and g), the lower population on wide rows had dramatically higher yield and branching on a per plant basis than higher population on narrow rows.

Presenting the fruit mapping characteristics on an area basis (Fig 2b, d, f, and h) indicated that this yield increase was a result of more fruit per area. Plants in wider rows at lower populations on shallow soil do not produce fruit on branches as they did on deeper soil.

Wheat Straw

The maps of the representative plants are for one sampling date only. Checking the number and accumulation of fruit classified as R2, R3, R4, and R5 (Fig. 3a through e) shows the plant without wheat straw to have substantially more fruit in each of these categories. The fruit classification methods are described in Keisling and Counce (1997). However, fruit classified as R6 (Fig. 3e) indicates that the plant with straw has essentially twice as many pods. This indicates that the wheat straw plots had a more mature fruit load than those plots without wheat straw.

In-the-row Subsoil

Fruit mapping indicated that plants from subsoil treatments (Fig. 4a) had a dramatic increase in the number of fruit located at mainstem nodes 4 through 8 with some increase occurring until node 13. Twice as many mature pods per plant were on the subsoiled than on the non-subsoiled treatment (Fig. 4b). The pods on non-subsoiled plants began at mainstem node four and continued to node 22. For the sub-soiled treatments, pods continued for five additional nodes. The curve for the number of branch nodes with fruit is very similar to that obtained for fruit per mainstem node (Fig. 4a) indicating that the production of fruiting branches was the primary source of yield increase from subsoiling.

Growth Habit

The three methods of presenting fruit distribution for the soybean plant (mainstem nodes, nodes-from-stem-end, and nodes-above-ground) provide different perspectives of the plant. We exploit a well known growth habit and fruit set difference for determinate and indeterminate soybeans. A total of 15 determinate and indeterminate cultivars were mapped. We chose to present the maps for indeterminate cultivar 'Williams 82' and determinate cultivar 'Hutcheson' (Fig. 5). 'Williams 82' had few branches, and 'Hutcheson' had many branches. Weight of seed per plant was unrelated to the small amount of branching on 'Williams 82', but weight of seed per plant was directly related to branch number in 'Hutcheson' (Fig. 5a,b). Seed was distributed uniformly along nodes-from-stem-end for 'Williams 82' and was skewed to the first five nodes from the end of a stem for 'Hutcheson' (Fig. 5c,d). Weight of seed was distributed more uniformly along nodes-above-ground for 'Williams 82' compared to 'Hutcheson' (Fig. 5e,f). This example illustrates how the mapping procedure can be used to delineate differences in fruit location and branching patterns.

In-season-progression

Fruit maps illustrate the progression of the crop toward maturity (Fig. 6 a, b, and c). Since the time progression is for different plants at each sampling date, there is variation involved in the fruit load and classification with time of sampling. It is interesting to note that the number of fruit that was ultimately harvested was already on the plant in July. The peak on the August 18 curve (Fig. 6c) is a result of a flush of flowers that did not result in mature fruit (Fig. 6d). The curves of fruit number and weight of seed are essentially identical in shape (Fig. 6d). This was also true for many other varieties not shown. The correlation coefficient between weight of seed and seed number for plants treated the same from all studies was 0.99+ and highly significant statistically. This indicates that for many purposes fruit counts maybe as good as seed weights or with a subsample can be used to estimate seed weight.

Population Dynamics

The fruit mapping data can easily be used to produce useful interpretations. We illustrated how yields of plants vary (Fig. 7a and b). Using simple graphical techniques and cumulative percent showed that about 20% of the plants accounted for about 50% of the yield (Fig. 7b). About 70% of the seed yield for this set of data occurs in the first four nodes from stem end (Fig. 7c). About 70% of seed yield is distributed between nodes 7 and 14 above the ground (Fig. 7d). Fruit mapping indicated that higher yielding plants (Fig. 8a, b, and c) had characteristic yields distributions whichever mapping system was utilized. The node-from-stem-end (Fig. 8c) shows the most dramatic differences in fruiting patterns.

Lodging

Plants in narrow rows that lodged tended to have the same number of mainstem nodes as plants in wider rows that did not lodge (Fig. 9). However, there was a dramatic increase in fruit (Fig. 9a) and branch nodes (Fig. 9b) arising from about mainstem nodes 4 through 6. The lodged plants produced more branches nodes and fruit at these nodes.

CONCLUSIONS

Soybean fruit mapping has the potential to be a useful tool. We demonstrated how it could be used to show cultivar differences, to delineate fruit distributions, and to define relative contributions of different nodal positions and plant structures. It may help the understanding of soybean yield responses to the environment. Perhaps this understanding will in turn help us to better manage the soybean crop. Future utility of fruit mapping depends upon identification of the most appropriate method for presenting the map data in order to illustrate the responses most clearly. These are only three of many possible ways to present the mapping data.

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Table 1. Name, location, soil type, cultivar and planting date for field experiments.

No.	Study Name	Nearest Arkansas Town	Soil Classification	Cultivar	1994 Planting Date	Growth[2] Stage When Sampled
1	Drought	Keiser	Sharkey silty clay[1]	Hutcheson	6 May	R6
2	Soil Depth	Colt	Calloway silt loam	Walters	28 May	R8
3	Wheat straw	Rowher	Herbert silt loam	Hartz 5545	10 June	R6
4	Subsoiling	Conway	Roxanna very fine sandy loam	NKRA452	23 April	R8
5	Growth habit	Keiser	Convent fine sandy loam	----	18 April	R8
6	Fruiting progress	Keiser	Convent fine sandy loam	Manokin	18 April	R4,R6,R8
7	Population	Keiser	Convent fine sandy loam	Manokin	18 April	R8
8	Lodging	Colt	Calloway silt loam	Walters	28 May	R8

[1] The soil was a small (4 m diameter) inclusion in a soil mapped as Sharkey silty clay.

[2] Growth stage is according to Fehr and Caviness (1977).

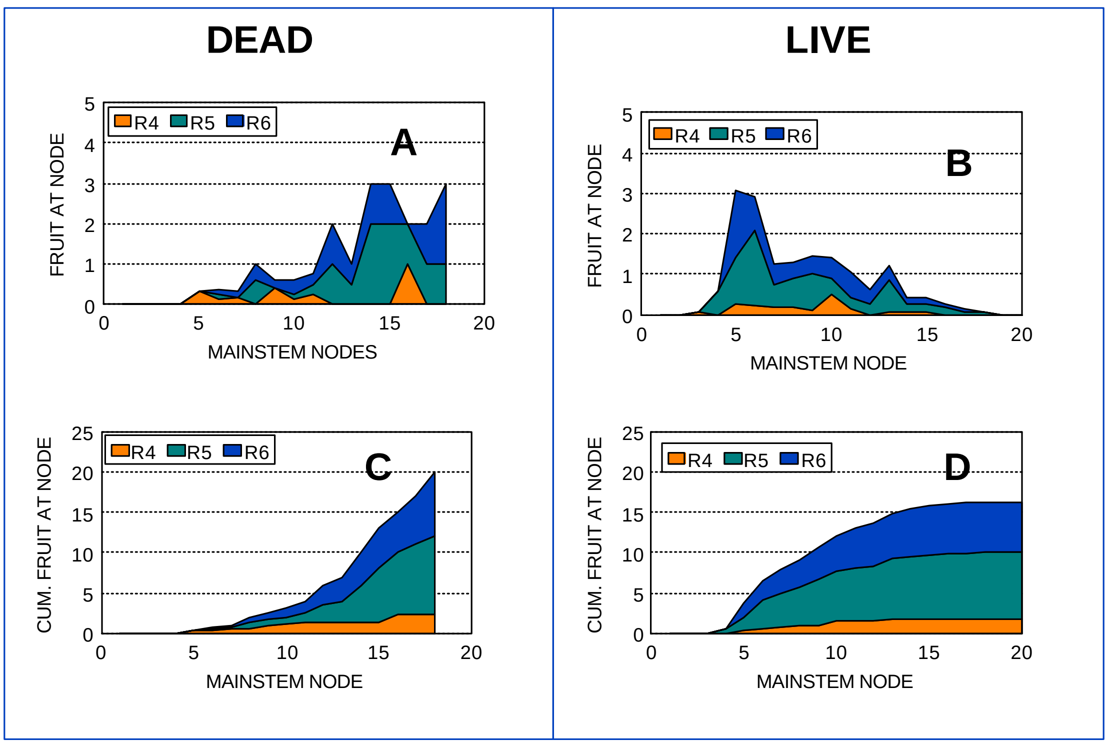


Fig. 1. Number of fruit versus mainstem node of plants under severe drought stress. A and C are for dead plants. B and D are for plants still living. Cumulative data is taken from the ground up.

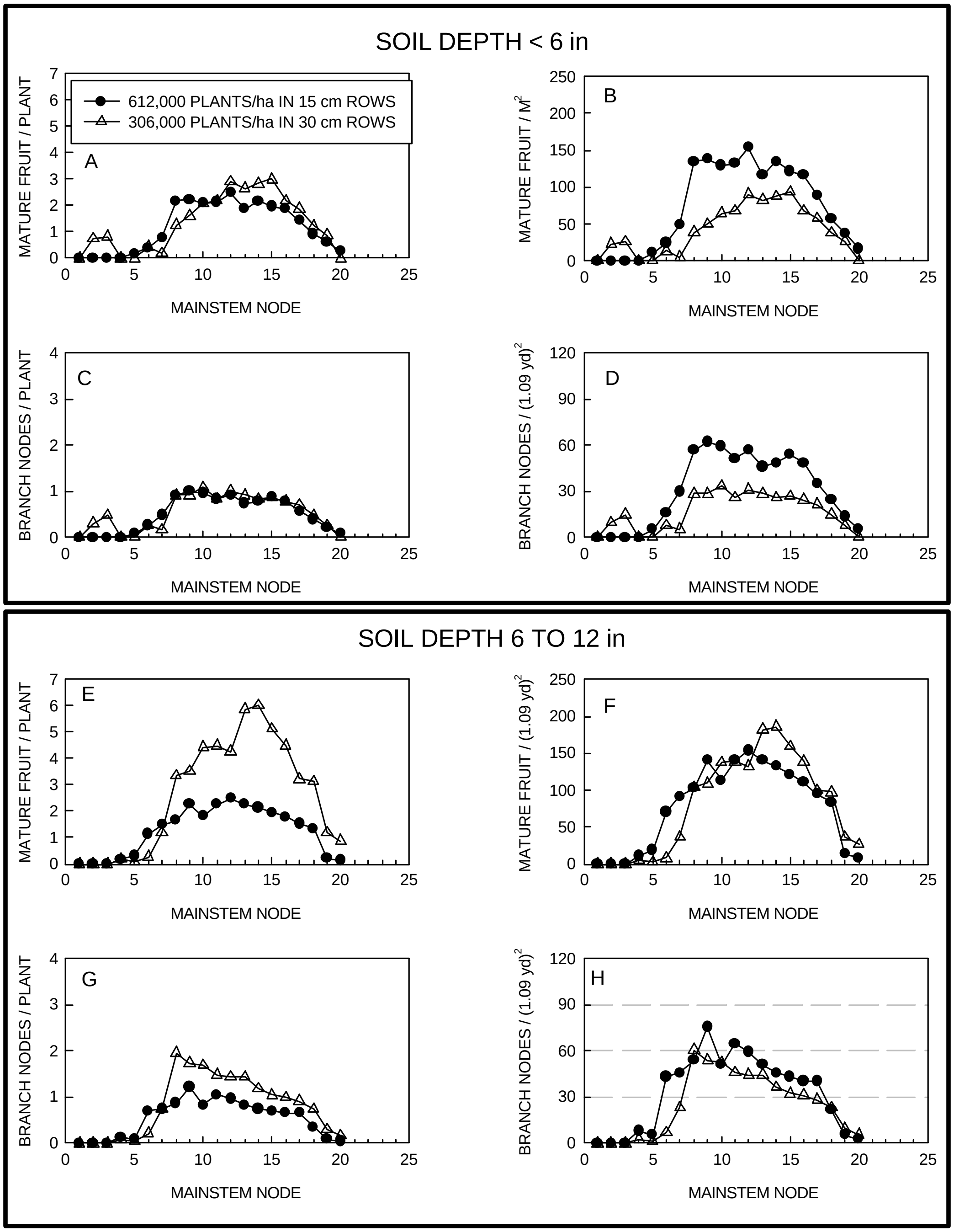


Fig. 2. Plant branching and fruiting response to varying soil rooting depths for two row spacings on a per plant and for an area basis. A thru D are for soil less than 6 in deep while E thru H are for soil 6 to 12 in deep.

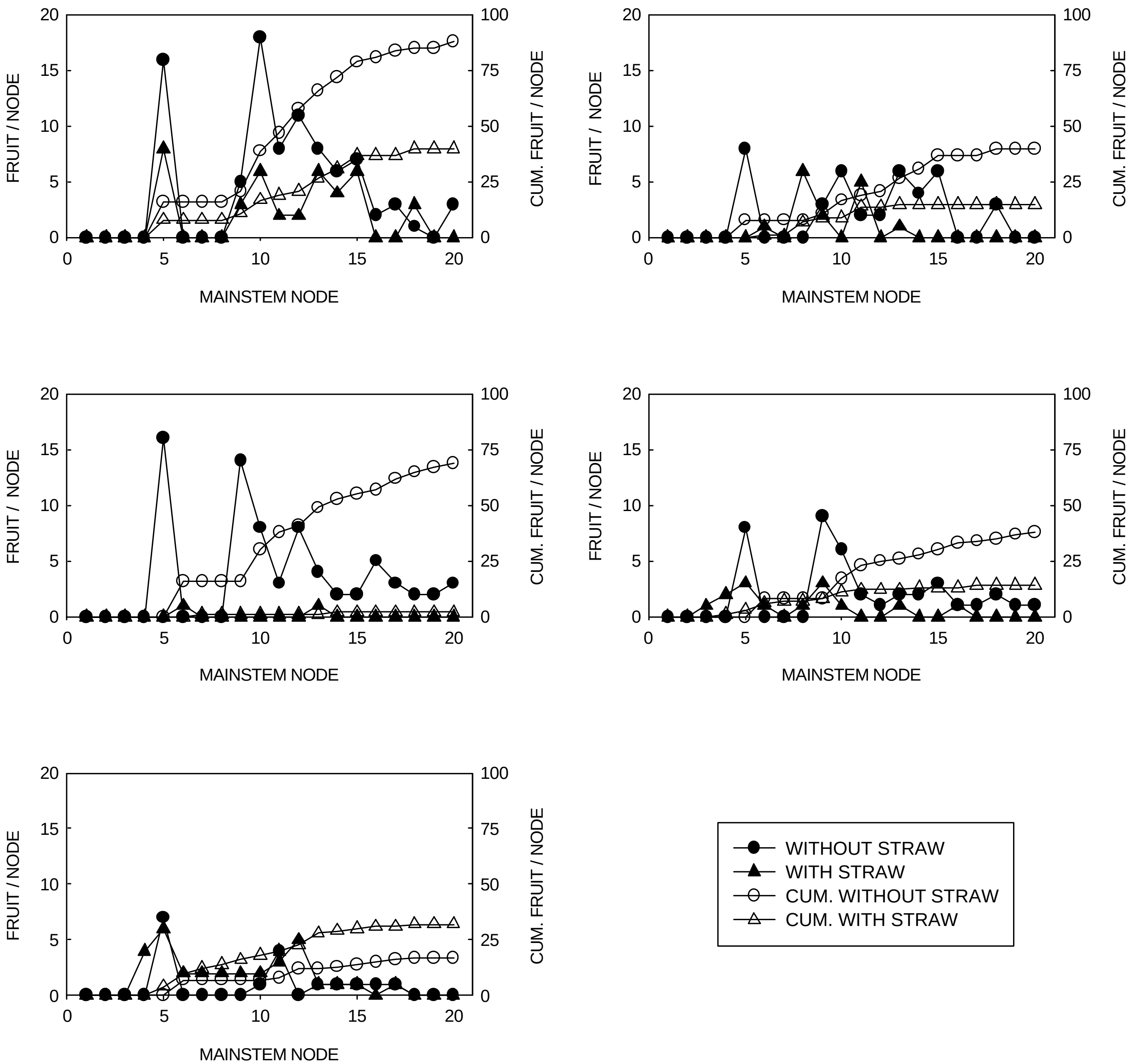
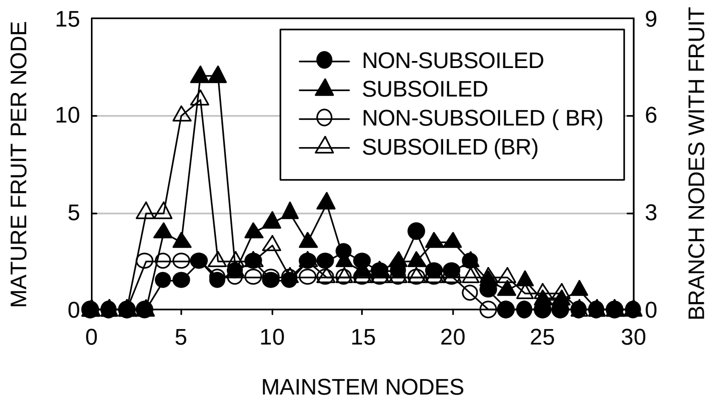


Fig. 3. Fruit classes versus mainstem node for soybeans grown with and without wheat straw residue. A, B, C, D, and E are for fruit classification of R2, R3, R4, R5, and R6, resp.



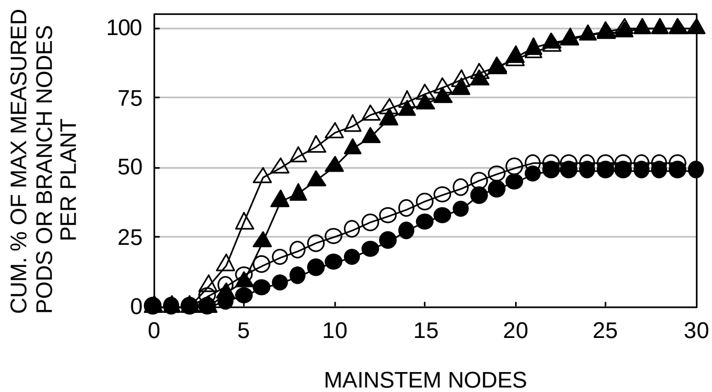


Fig. 4. Mature fruit (A), branch nodes (A), and cumulative percent of maximum fruits and pods per plant (B) versus mainstem node for in-the-row subsoiling and conventional planting.

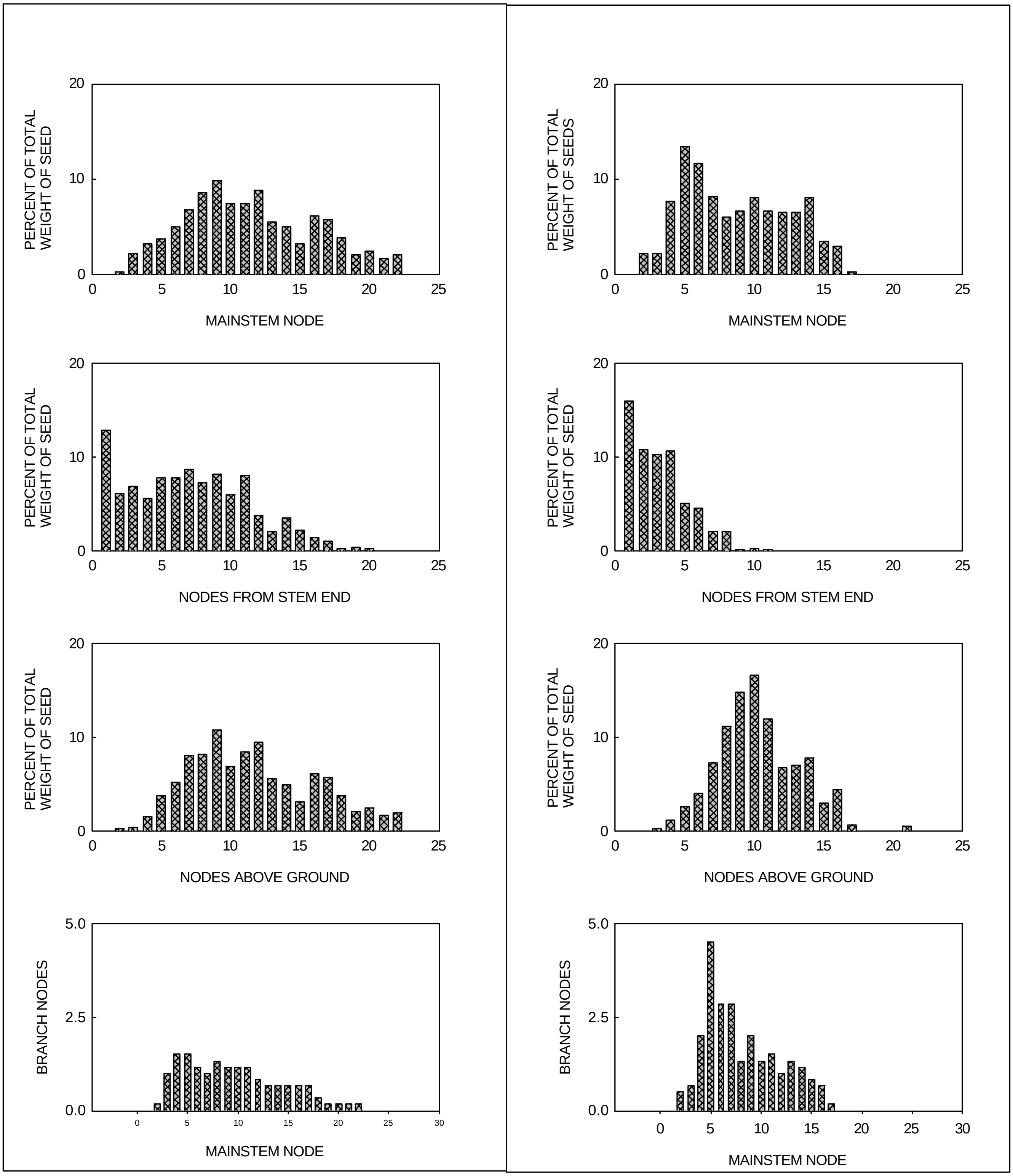


Fig. 5. Comparison of morphological characteristics for an indeterminate ('Williams 82') and a determinant ('Hutcheson') cultivar. Percent seed weight versus mainstem node (A and B), nodes-from-stem-end (C and D), and nodes-above-ground (E and F). Branch nodes versus mainstem nodes (G and H).

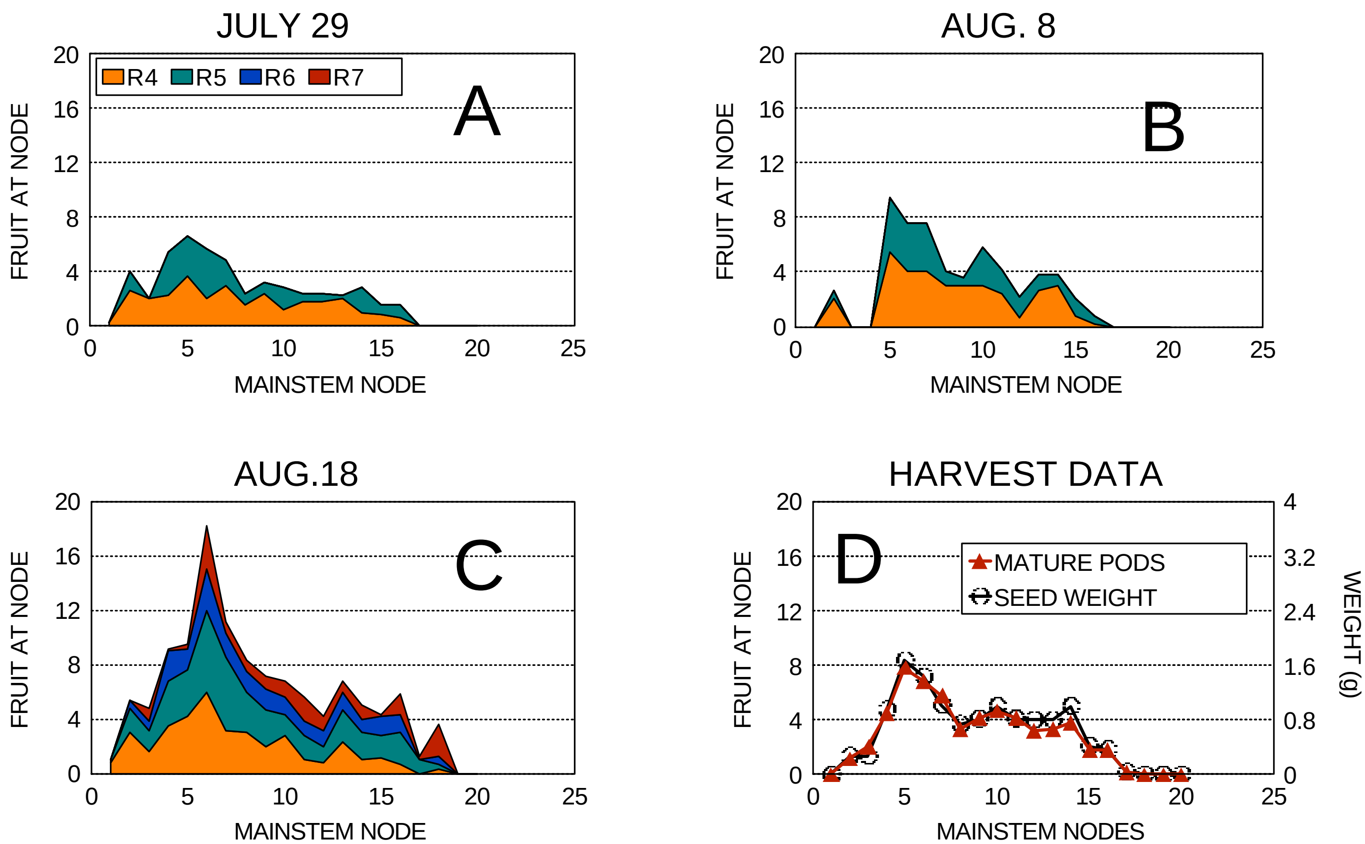


Fig. 6. Temporal progression of fruit toward maturity and at harvest. A, B, and C are stacked areas of R2, R3, R4, R5, and R6 fruit at the indicated dates. D is a line graph of fruit number and seed weight at harvest.

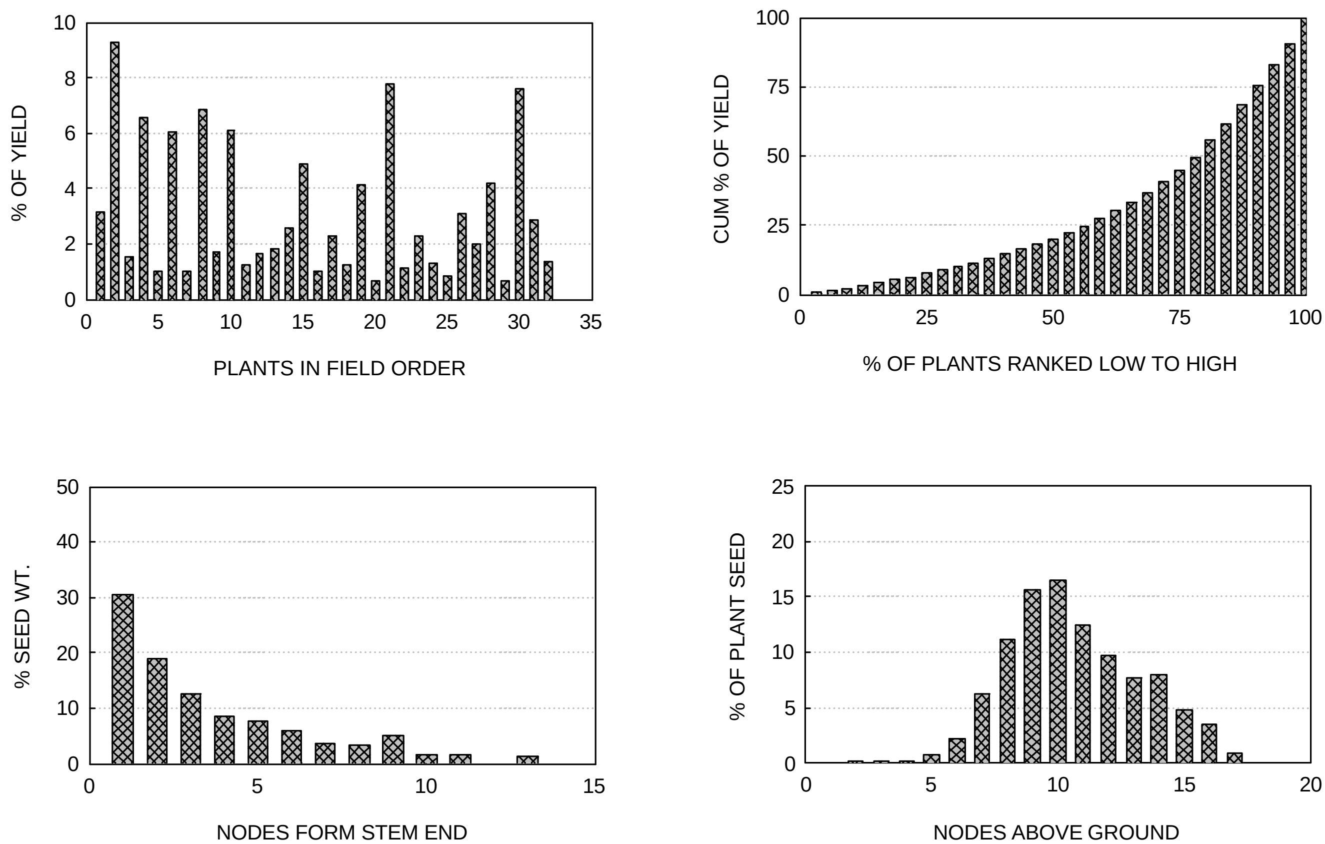


Fig. 7. Simple population characteristics of 'Manokin' soybean for locational effects on yield (A), cumulative yield (B), percent seed yield as a function of node-from-stem-end (C), and percent seed yield as a function of node-above-ground.

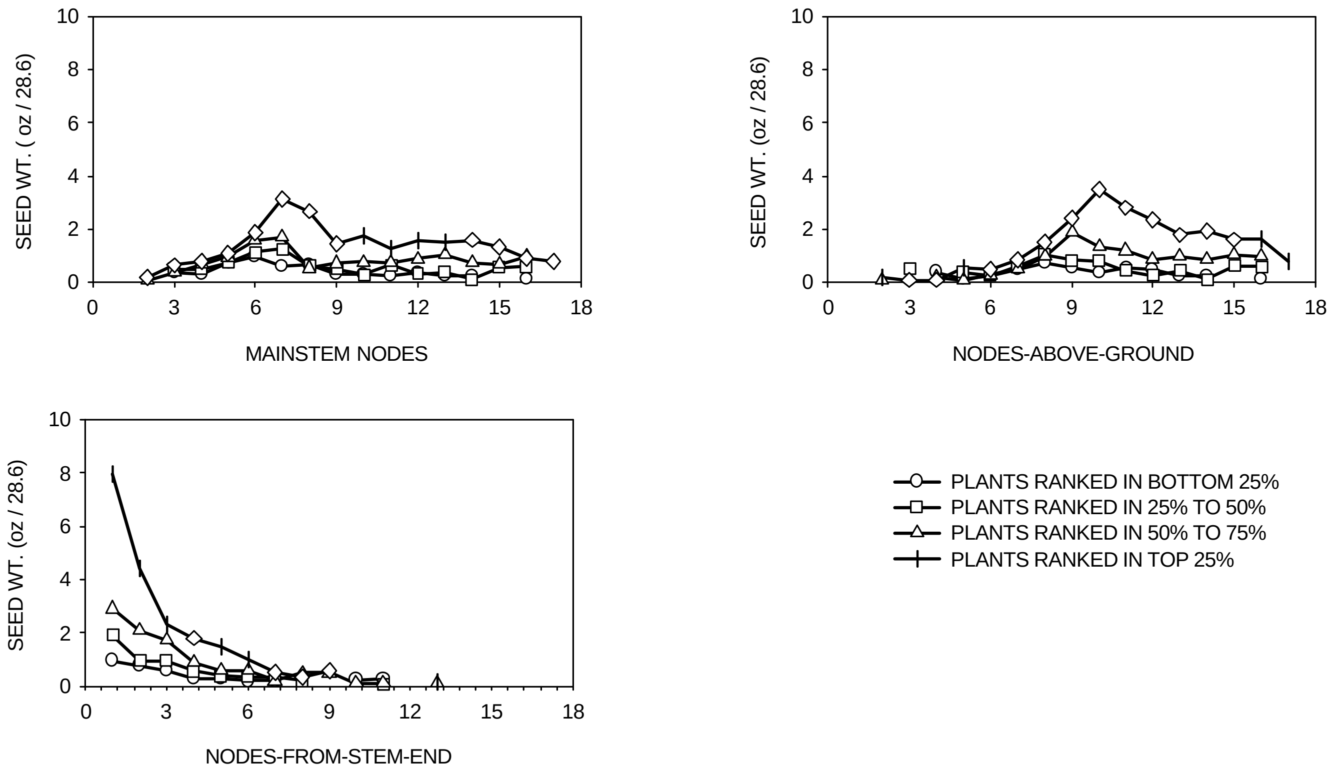


Fig. 8. Seed weight distribution at mainstem nodes (A), nodes-above-ground (B), and nodes-from-stem-end (C) for low to high yielding quartiles of 'Manokin' soybean.

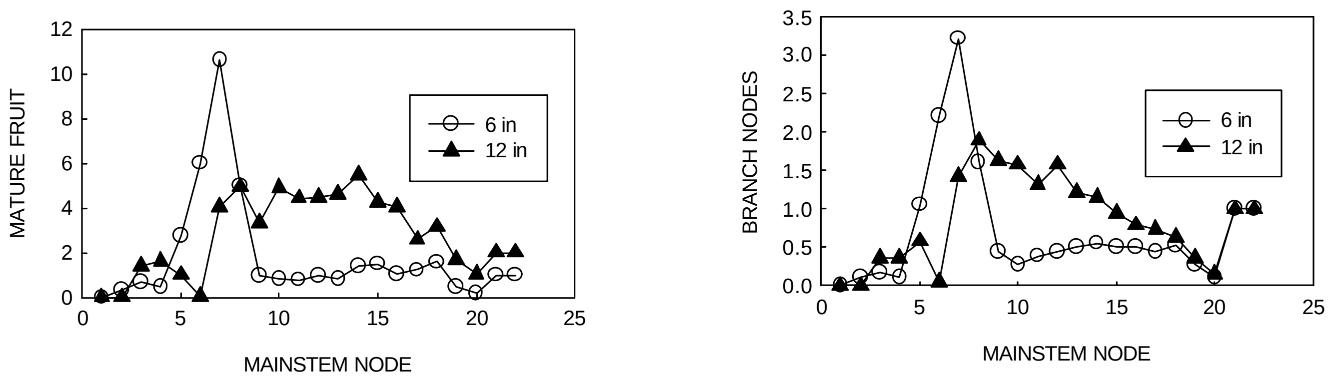


Fig. 9. Fruiting (A) and plant branching (B) response to lodging.