Analysis of the Yield-determining Process of Field-Grown Soybeans in Relation to Canopy Structure

VI. Characteristics of grain production in relation to plant types as affected by planting patterns and planting densities

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Since the characteristics of soybean varieties are genetically diverse and vary greatly with the cultural conditions, the yield-determining process of soybeans should be analyzed taking into consideration the relation between the difference in the varietal characteristics and the cultural conditions. However, there have been few reports from the viewpoint.

As branching ability is a main factor in classifying soybean varieties, and is significantly influenced—morphologically and quantitatively—by the cultural conditions, such as planting patterns and planting densities, the significance of branches for grain production was evaluated by Oizumi. In previous papers, the relationship between the plant type and the grain production as affected by planting densities was examined. The objective of this experiment was to obtain further agronomic information on the characteristics of grain production in relation to plant types as affected by planting patterns and planting densities.

Materials and Methods

The study was done at the experiment field (volcanic ash soil) of the Tohoku National Agricultural Experiment Station. Soybean (Glycine max (L.) Merr.) cultivar, Nanbushirome was seeded on 16 May 1980. The amounts (kg/a) of barnyard manure, calcium carbonate, N, P₂O₅ and K₂O applied before planting were 200, 7, 0.3, 1, 1, respectively.

Plant types used were the main-stem type and the branch type. The main-stem type was made by removing branches whenever they emerged. The branch type was made by cutting the main stem at the stage of the second compound leaf expansion (nodes below the second compound leaf were left).

A split-plot design with sub-split-plot was used with three plant types (including control), two planting densities (5.6 and 11.1/m² for the branch type and control, 11.1 and 22.2/m² for the main-stem type) and three planting patterns (60 cm and 90 cm row widths, square planting). Each sub-sub-plot consisted of 28 m² with two replications. The dry weight of each plant organ and the leaf area were determined on July 1, July 22 and August 11. At maturity, plants on 8 m² of each sub-sub-plot were harvested to determine the yields, and 10 (low density plot) or 20 (high density plot) plants of medium-weight were sampled to determine the yield components. Yields and 100-seed weight were adjusted to 15% moisture basis.

Results

1. Plant growth and development

The growth stages of plant varied slightly with the plant types and the cultural conditions. The beginning of flowering was on July 21 and the flowering time was on July 25 in all plots. The duration of flowering tended to be longer in the branch type than
in the main-stem type. The maturing stage of the branch type at high planting density or at square planting tended to be a few days later than that of the main-stem type at low density or at stripe planting (60, 90 cm row). The branch type plant produced three or four primary branches at low density, and almost all plants produced two branches on higher nodes at high density.

2. Dry matter production

Fig. 1 shows the change in leaf area index (LAI) with time. There were significant differences between the plant types or the planting patterns in the increase in LAI, especially during the period of flowering (July 22~August 11). The LAI increment was greater for the main-stem type than for the branch type at high density, and vice versa at low density. The increase in LAI was greater in narrower row spacing.

Crop growth rates (CGR) obtained from two growth periods (three weeks before and after the beginning of flowering) at high density were greater in the main-stem type than in the branch type and control. Comparing the planting patterns, CGR was greater in narrower row spacing for three weeks before the beginning of flowering, however, in contrast it was greater in wider row spacing for three weeks after the beginning of flowering.
Table 1. Dry matter partitioning ratio (%) to leaf (L), petiole (P) and stem (S).

<table>
<thead>
<tr>
<th>Plant type</th>
<th>Low density</th>
<th>High density</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>J. 1~J. 22</td>
<td>J. 22~A. 11</td>
</tr>
<tr>
<td></td>
<td>L   P    S</td>
<td>L   P    S</td>
</tr>
<tr>
<td>Control</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Square</td>
<td>49</td>
<td>19</td>
</tr>
<tr>
<td>60 cm</td>
<td>47</td>
<td>19</td>
</tr>
<tr>
<td>90 cm</td>
<td>46</td>
<td>20</td>
</tr>
<tr>
<td>Average</td>
<td>47</td>
<td>19</td>
</tr>
<tr>
<td>Main-stem type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average*</td>
<td>44</td>
<td>19</td>
</tr>
<tr>
<td>Branch type</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Average*</td>
<td>46</td>
<td>20</td>
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</tbody>
</table>

J.; July, A.; August. *; Response to the planting pattern was similar to control.

Fig. 2 presents the relationships between LAI, net assimilation rate (NAR) and CGR for two growth stages. As for the main-stem type, although LAI became greater, the decrease in NAR with increasing LAI was less than the branch type and control. As a result, CGR of the main-stem type increased by increasing LAI. In contrast, with the branch type, the decrease in NAR with increasing LAI was greater, resulting in a decrease in CGR as LAI increased during the period of flowering.

Dry matter partitioning ratio (%) to each organ during two growth stages is shown in Table 1. With the main-stem type, the partitioning ratio to the leaves was less for three weeks before the beginning of flowering, while it was greater during the period of flowering. Comparing the planting patterns, the partitioning ratio to the leaves for three weeks before the beginning of flowering was greater in square planting, while it was greater in wider row spacing during the later growth stage.

3. Yield and yield components

Yields and yield components are shown in Table 2. The yield of the main-stem type increased with an increase in planting density, while that of the branch type did not increase. With all plant types, the yields increased in narrower row spacing at low planting density. In the main-stem type and control, the yields increased in wider row spacing at high density. The number of pods and the number of seeds per unit area varied significantly with the planting patterns and densities, while 100-seed weight varied only slightly.

4. Relationship between growth parameters and number of pods

Fig. 3 presents the relationships between growth parameters and number of pods per unit area which defined yields more critically than the other yield components. The relationship between CGR and number of pods varied considerably with plant types. The number of pods in the main-stem type significantly increased by increasing the CGR during the period of flowering, while in the branch type slightly decreased by increasing the CGR. In all plant types, the number of pods increased with increasing LAI up to about 5.5, but did not increase at LAI exceeding about 5.5 except in the main-stem type. NAR during the period of flowering for maximizing number of pods per unit area was about 20 (g/m²/week), in general, and the number of pods against the NAR was much more in the main-stem type than in the branch type and control.

5. Relationship between stem weight, seed-stem ratio and yield

The relationship between stem weight, seed-stem ratio and yield varied significantly with the plant type (Fig. 4). The yields of the main-stem type increased with an increase in stem weight, in spite of a slight decrease in seed-stem ratio. In contrast, the yields of the branch type barely increased with an increase in stem weight, resulting
Table 2. Yield components and yields of different plant types as affected by planting pattern and population density.

<table>
<thead>
<tr>
<th>Plant type</th>
<th>Low density</th>
<th></th>
<th>High density</th>
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<tbody>
<tr>
<td></td>
<td>No. of pods</td>
<td>No. of seeds/pod</td>
<td>No. of seeds</td>
<td>100-seed weight</td>
</tr>
<tr>
<td></td>
<td>m²/m²</td>
<td></td>
<td>g/m²</td>
<td></td>
</tr>
<tr>
<td>Control</td>
<td>/m²</td>
<td></td>
<td>/m²</td>
<td></td>
</tr>
<tr>
<td>Square</td>
<td>584</td>
<td>2.23</td>
<td>1,301</td>
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<tr>
<td>60 cm</td>
<td>579</td>
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<td>1,271</td>
<td>28.5</td>
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<td>90 cm</td>
<td>519</td>
<td>2.26</td>
<td>1,173</td>
<td>29.1</td>
</tr>
<tr>
<td>LSD. (5%)</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Main-stem type</td>
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<td></td>
<td></td>
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<tr>
<td>Square</td>
<td>492</td>
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<td>1,137</td>
<td>30.0</td>
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<tr>
<td>60 cm</td>
<td>456</td>
<td>2.35</td>
<td>1,066</td>
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<tr>
<td>90 cm</td>
<td>467</td>
<td>2.31</td>
<td>1,081</td>
<td>30.0</td>
</tr>
<tr>
<td>LSD. (5%)</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
<td>ns</td>
</tr>
<tr>
<td>Branch type</td>
<td></td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>Square</td>
<td>582</td>
<td>2.19</td>
<td>1,276</td>
<td>28.6</td>
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<td>60 cm</td>
<td>555</td>
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<td>1,207</td>
<td>29.1</td>
</tr>
<tr>
<td>90 cm</td>
<td>538</td>
<td>2.19</td>
<td>1,177</td>
<td>29.4</td>
</tr>
<tr>
<td>LSD. (5%)</td>
<td>26</td>
<td>ns</td>
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</table>

Fig. 3. Relationships between growth parameters (CGR, LAI, NAR) and the number of pods. Symbols are the same as in Fig. 1.

from a significant decrease in seed-stem ratio.

**Discussion**

Yield increment due to narrow row spacing has been reported by many workers\(^2\), \(^3\), \(^10\), \(^16\), and it has been known that the yield advantage changed with the variety used\(^2\), \(^3\), \(^5\). From the present experiment, the varietal differences in response to planting patterns may be explained by the different growing patterns caused by each plant type.

In soybeans, leaf area and dry weight increase rapidly during the period of flowering, attaining maximum LAI. This duration is a most critical stage to determine the number of pods and seeds which are important components of the yield\(^3\). \(Ojima\) and \(Fukui\)\(^4\) indicated that the number of seeds per unit area increased with an increase of dry matter distribution to the pods, rather than a weight increase in total plant, during about 4 weeks of flowering. In this experiment, with the main-stem type, the increase in CGR during the period of flowering distinctly lead to an increase in
the number of pods per unit area, whereas the relation was not clear in the branch type and control. Thus, the main-stem type partitioned dry matter to pods efficiently. Present results suggest that the efficiency of the main-stem type is mainly related to three growing characteristics; 1) a rapid vegetative growth at high planting density, 2) a high capability to expand the leaf area during the period of flowering even at high planting density, and 3) a decline of vegetative growth after the terminal leaf expansion stage*.

Comparing the growing patterns caused by the different row spacing, narrow row plants produced more dry matter and reached higher LAI in the earlier stage than wide row plants. As the rates of dry matter production and leaf area expansion during flowering tend to be higher at narrower row spacings, the variety which distributes efficiently photosynthetic to pods may provide better yield in narrow row. Therefore, the main-stem type variety should have potential adaptability to attain consistently higher yield at high planting density in narrow row spacing. In recent years several types of "thin line" soybeans which have fewer branches and may have more open, erect canopies have been developed, and specific recommendations for narrower row spacings, when such cultivars are available, are being made in some leading soybean states in the U.S.A.141. The main-stem type used in this experiment may be characterized almost the same as "thin line" type. However, the main-stem type did not reveal yield advantage at narrow row. This may be due to a decreased amount of solar radiation in 1980 when decreased LAI with wide row might have been advantageous to grain production.

As mentioned above, with the main-stem type, the higher values of CGR during the period of flowering depended not only upon the higher LAI, but also upon a slight decrease in NAR as LAI increased. The difference in the change of NAR with LAI between the main-stem type and branch type may be due to the difference in photosynthetic potentiality of the leaves on the main stem and branches89, rather than in light-intercepting characteristics89. Therefore, the effect of plant type on grain production should be further evaluated taking into consideration the photosynthetic characteristics of the leaves at different positions on a plant.

**Summary**

The objective of this experiment was to obtain some agronomic information on the characteristics of grain production in different plant types as affected by the planting pattern and density. Different types of soybean plants, which were artificially made by removing branches (the main-stem type) or by cutting the main stem (the branch type), were compared in field trials.

In the main-stem type, LAI became greater at high planting density and the decrease in NAR with increasing LAI was less than the branch type (Fig. 1, 2). As a result, CGR of the main-stem type increased by increasing LAI, while CGR of the branch type did not increase by increasing LAI.

The number of pods per unit area signi-

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* Unpublished data.
significantly increased in the main-stem type by increasing CGR during the period of flowering, while did not increase in the branch type and control. The number of pods increased with increasing LAI up to about 5.5 in all plant types, but did not increase at LAI exceeding about 5.5 except in the main-stem type (Fig. 3).

The yields of low planting density plants tended to increase in narrower rows in all plant types, but yield response to row spacing varied with the plant type at high density (Table 2).

The yields of the main-stem type increased with an increase in stem weight, in spite of a slight decrease in the seed-stem ratio. In contrast, the yields of the branch type increased only slightly with an increase in the stem weight, resulting from a significant decrease in the seed-stem ratio (Fig. 4). Thus, the main-stem type appears to have a potentiality to partition dry matter to pods efficiently, consequently to attain consistently higher yield at high planting density in narrow row spacing.

References

1. Ariga, T. 1943. Classification of soybean varieties according to plant type. Agr. and Hort. 18: 669–670.**

* In Japanese with English summary.
** In Japanese.
大豆の群落構造と収量成立過程の解析
第6報 草型が異なる場合の子実生産特性と栽培様式、密度反応

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主茎あるいは分枝の有無による対照的な2つの草型一主茎型と分枝型一における子実生産特性を、異なる栽培様式および密度条件下で検討した。主茎型は分枝を切除することによって、分枝型は摘心することによって人为的に作成し、標準型（無処理）と比較した。

主茎型は分枝型や標準型に比べ、密植条件でも葉面積指数（LAI）が増大しやすく（第1図）、しかもLAIの増加に伴う純同化率（NAR）の低下程度が小さいかった（第2図）。その結果、LAIの増大に伴う個体群生長速度（CGR）の増加は主茎型において顕著であった（第2図）。

開花期間におけるCGRの増大は主茎型では単位面積当たりの葉数を著しく増大させた。単位面積当たりの葉数は草型にかかわらずLAIが約5.5まではLAIの増大に伴って増加したが、それ以上のLAIでは主茎型においてのみ増加した（第3図）。

高密度では草型にかかわらず狭植ほど多収であったが、密植では草型によって栽培様式に対する反応が異なり、草型に応じた栽培管理の方向性が示された（第2表）。

密植に伴う栄養生長量の増大は主茎型では効率良く子実収量を増大させたが、分枝型では粒集まりの低下が大きく収穫量は小さかった（第4図）。このように、主茎型の特性は密植、狭植栽培のような栄養生長量の増大しやすい条件で安定多収を示すものと思われた。