

# The Growth and Yields of Dent Corn Intercropped with Three Different Planting Densities of Soybean (*Glycine max* L. Merr. var. *Shirotae*)

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## Summary

A field experiment was carried out for two years to investigate the increase of dent corn yields when intercropped with 3 different planting densities of soybean. Dent corns planted at a spacing of 80 cm × 40 cm, intercropped with soybean planted at the densities of 6, 25 and 38 plants/m<sup>2</sup>, were observed in a completely randomized block design. The results were as follows. The Crop Growth Rate (CGR) and Net Assimilation Rate (NAR) of dent corn at 8 to 9 weeks after planting were the highest at the soybean density of 25 plants/m<sup>2</sup>. The Specific Leaf Area (SLA) significantly increased at 38 plants/m<sup>2</sup>, and the NAR decreased at the same density. The corn grain yields, harvest index of dent corn and percentage of nitrogen contents of corn grain, increased at the densities of 6 and 25 plants/m<sup>2</sup>. The highest grain yield and harvest index were obtained at 6 plants/m<sup>2</sup>, but the highest value of the Land Equivalent Ratio (LER) was obtained at 25 plants/m<sup>2</sup>.

The result of this experiment indicated an enhancement of growth and yields of dent corn intercropped with soybean. This was done by the balance between the relative advantage and the relative disadvantage caused by the intercropping.

## Introduction

The growth and grain yields of corn have significantly increased with increasing soil fertility<sup>3,5)</sup>. Soil fertility can be increased by the cropping of soybean because the root nodules of soybean are capable of fixing atmospheric nitrogen at rates which range from 84 kg N/ha<sup>6)</sup> to 160 kg N/ha<sup>7)</sup> depending on the environmental conditions. FRANCIS et. al.<sup>2)</sup> found that the yield of dent corn associated with legumes, such as bush beans or climbing beans, was higher than that in monoculture. However, FISHER<sup>1)</sup> found that the yield of dent corn decreased while the planting densities of dent corn and soybean increased from 2.73 to 4.62 plants/m<sup>2</sup>.

The senior author of this article has done some researches on an intercropping system in Indonesia, using cassava or corn as the main crops and soybean or *Stylosanthes* as the companion crops. This intercropping system has become popular and seems to be very important in increasing the agricultural productivity especially in the dry land area of Indonesia.

This study was designed to investigate physiological and morphological bases of the intercropping system and to find out whether a certain planting density of the intercropped soybean can be optimum for the growth and yield of dent corn at Okayama University in 1980 and 1981.

## Materials and Methods

The growth and grain yields of corn (*Zea mays indentata* Sturt.) intercropped with soybean

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(*Glycine max* L. Merr. var. *Shirotae*) planted at 3 different densities were studied. The dent corn, planted at the density of 3 plants/m<sup>2</sup> (80 cm×40 cm), was intercropped with soybean sown at the densities of 6, 25 and 38 plants/m<sup>2</sup> (80 cm×40 cm, 20 cm×40 cm and 13.3 cm×40 cm). The basal dressing, 45kg of N, P<sub>2</sub>O<sub>5</sub> and K<sub>2</sub>O/ha, was applied by a compound fertilizer on the day prior to planting corn. Ammonium sulfate, 100 kg N/ha, was topdressed on 25 days after planting. At their growing stage of 8 to 9 weeks after planting, 3 plants of dent corn were sampled from 4 repeated plots and measured for their growth analysis. In order to calculate the growth parameters<sup>41</sup>; Crop Growth Rate (CGR), Net Assimilation Rate (NAR), Leaf Area Ratio (LAR) and Specific Leaf Area (SLA); the leaf area was measured by an automatic area meter (Model AAM-5, HAYASHI DENKO Co.) and then the whole plant was dried in an oven and weighed. At the harvest the stalks, leaves, cobs, grains of dent corn and grains of soybean were weighed. The nitrogen contents of the grains for both dent corn and soybean were analysed by the kjeldahl methods. The results were analysed by the analysis of variance. The New Duncan Multiple Range Test was applied when significant differences were obtained between treatments.

### Results

The CGR and NAR of dent corn intercropped with soybean were higher than those in monoculture and the highest values attained were at the soybean planting density of 25 plants/m<sup>2</sup>. While the CGR of dent corn in monoculture was 14.2 g/m<sup>2</sup>/day, those of dent corn intercropped with soybean at the planting densities of 6, 25 and 38 plants/m<sup>2</sup> were 34.5, 38.7 and 20.5 g/m<sup>2</sup>/day (Table 1). They were 2.4, 2.7 and 1.4 times larger than CGR in monoculture (Fig. 1), re-

Table 1 CGR, NAR, LAR and SLA of corn intercropped with soybean at different densities of both for corn and soybean (1981)

| Treatments                           | CGR                                     | NAR                                       | LAR                               | SLA                               |
|--------------------------------------|---|---|-----------------------------------|-----------------------------------|
|                                      | g · m <sup>-2</sup> · day <sup>-1</sup> | g · dm <sup>-2</sup> · week <sup>-1</sup> | cm <sup>2</sup> · g <sup>-1</sup> | dm <sup>2</sup> · g <sup>-1</sup> |
| Dent corn + Soybean                  |   |   |                                   |                                   |
| C (control)                          | 14.18                                   | 0.34                                      | 30.71                             | 1.86                              |
| C + S (density 6.3/m <sup>2</sup> )  | 34.46                                   | 0.80                                      | 32.57                             | 1.98                              |
| C + S (density 25/m <sup>2</sup> )   | 38.70                                   | 0.89                                      | 31.67                             | 2.01                              |
| C + S (density 37.5/m <sup>2</sup> ) | 20.53                                   | 0.48                                      | 31.53                             | 2.19                              |

spectively. The NAR of dent corn also changed in nearly the same manner as CGR at different soybean planting densities (Table 1 and Fig. 1), while the LAR of dent corn intercropped with soybean increased slightly. However, the SLA increased significantly with increasing soybean planting densities which were 1.08 and 1.15 times larger respectively at 25 plants/m<sup>2</sup> and 38 plants/m<sup>2</sup> than that in monoculture (Fig. 1).

The yields and plant characteristics of dent corn intercropped with soybean were almost the same for both years and the data for 1980 was shown in Table 2. When the planting density of soybean increased up to 25 plants/m<sup>2</sup>, the grain yields of dent corn were higher than that in monoculture, but it decreased at 38 plants/m<sup>2</sup>. Similarly, harvest index and nitrogen contents of dent corn grain increased at planting densities of 6 and 25 plants/m<sup>2</sup> but decreased at 38 plants/m<sup>2</sup> to

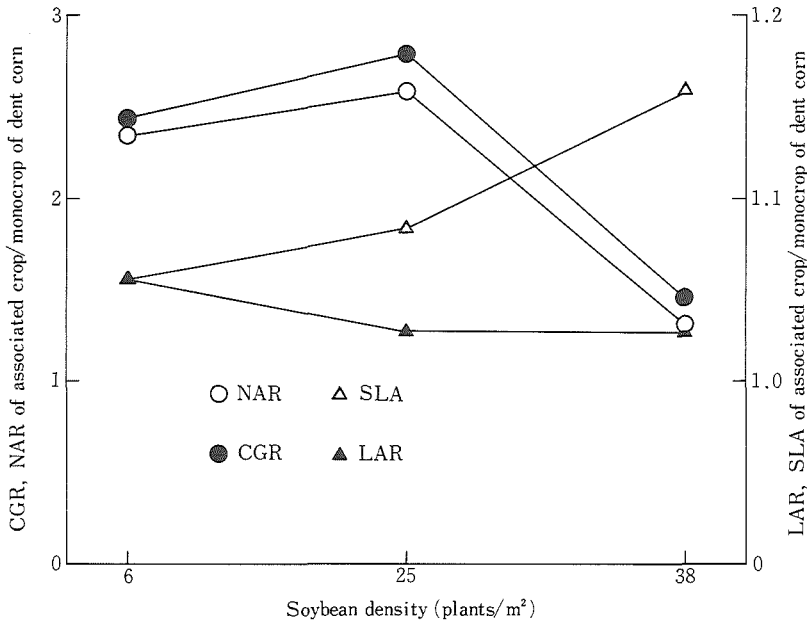


Fig. 1 The ratio (associated crop/monocrop) of CGR, NAR, LAR and SLA in dent corn intercropped with 3 different densities of soybean (1981).

Table 2 Yield components and plant characteristics of dent corn intercropped with various densities of soybean (1980)

| Treatment                    | Dent corn yield                |                                | Soybean yield<br>kg · ha <sup>-1</sup> | Harvest index*<br>of Corn | Ratio to Monocrop** |           | LER*** | Nitrogen content of Corn grain % |
|------------------------------|--------------------------------|--------------------------------|--|---------------------------|---------------------|-----------|--------|----------------------------------|
|                              | Total<br>kg · ha <sup>-1</sup> | Grain<br>kg · ha <sup>-1</sup> |  |                           | Corn %              | Soybean % |        |                                  |
| Dent corn + Soybean          |                                |                                |  |                           |                     |           |        |                                  |
| C (control)                  | 15405.9                        | 5511.3                         |  | 35.8                      | 100                 |           |        | 2.19                             |
| C + S (6.3/m <sup>2</sup> )  | 15113.2                        | 6059.1                         | 461.4                                  | 40.1                      | 109.9               | 28.7      | 1.39   | 2.29                             |
| C + S (25.0/m <sup>2</sup> ) | 14531.7                        | 5628.7                         | 1015.8                                 | 39.2                      | 102.1               | 54.3      | 1.56   | 2.43                             |
| C + S (37.5/m <sup>2</sup> ) | 14758.0                        | 5065.3                         | 2585.3                                 | 34.3                      | 91.9                | 62.1      | 1.54   | 2.21                             |

\* Harvest index: [grain yield/total yield] × 100.

\*\* Ratio to monocrop: [associated crop yield/monocrop yield] at the sample planting density.

\*\*\* LER (Land Equivalent Ratio):  $\sum$ [associated crop yield/monocrop yield].

the low levels as that in monoculture. The total amount of nitrogen contents in grain of dent corn, calculated by multiplying the grain yields and the percentage of nitrogen content, increased to 139 and 135 kg N/ha at soybean densities of 6 and 25 plants/m<sup>2</sup> respectively, being comparable to 121 kg N/ha in monoculture.

### Discussion

In these experiments, dent corn intercropped with soybean at the densities of 6 and 25 plants/m<sup>2</sup> grew well and yielded higher than which in monoculture. The higher content of nitrogen in grain of dent corn intercropped with soybean, implies the some extra productivity of dent corn is associated with the higher levels of nitrogen provided by intercropped soybean. When soybean

was intercropped at the densities of 6 to 25 plants/m<sup>2</sup>, the CGR and NAR of dent corn at 8 to 9 weeks after planting increased, though the grain yield did not increase much at the density of 25 plants/m<sup>2</sup>. The SLA increase of dent corn at 25 plants/m<sup>2</sup> and especially at 38 plants/m<sup>2</sup> indicate that the leaves of dent corn have become thinner at those planting densities. The fixation of atmospheric nitrogen by soybean aided the growth of dent corn up to the density of 25 plants/m<sup>2</sup>. At further high density in this experiment, dent corn might not be able to fix CO<sub>2</sub> at the same rates as at the densities of 6 or 25 plants/m<sup>2</sup>, because the CGR and NAR decreased significantly.

The productivity of dent corn intercropped with soybean is affected mutually by the balance between the relative advantage of competitive relations between dent corn and soybean for water, nutrient and light. In these experiments, at the highest planting density of soybean, the competitive effect of intercropped soybean seemed to overcome the advantage of their companionship because the growth rate, grain yield of corn fell down to about the lower level than in monoculture.

The result of these experiments shows that the productivity of dent corn, planted at a spacing of 80 cm × 40 cm, can be enhanced when intercropped with soybean planted at the densities of 6 to 25 plants/m<sup>2</sup>. The principal conclusion of these experiments may hold also for the other plant spacing of dent corn. However, the optimal planting density of intercropped soybean for different spacing of dent corn could be established theoretically and experimentally.

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#### 混作したダイズ播種密度の差がトウモロコシの生長と収量に及ぼす影響

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トウモロコシの生長ならびに子実収量の増大に適するダイズの播種密度を明らかにするため、トウモロコシ(イエローデントコーン)を条間80 cm, 株間40 cmで条播栽培し、その条間にダイズ(品種シロタエ)を3段階の播種密度で混作し、栄養生長末期に生長解析を、収穫期には収量調査をおこなった。

なお、ダイズの播種は株間をいずれも40 cmとし、条間を80, 20および13.3 cmとしたが、その密度はそれぞれ約6, 25および38株/m<sup>2</sup>に相当する。

I) 播種8~9週後、即ち、栄養生長末期の生長解析の結果、トウモロコシの生長速度(CGR)、純同化率(NAR)は、ダイズの混作によっていずれも増大し、25株/m<sup>2</sup>区で最大

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値を示し、葉面積比 (LAR) は 6 株/m<sup>2</sup> 区で最大となった。なお比葉面積 (SLA) は 38 株/m<sup>2</sup> 区で最大となったが、このことはダイズ播種密度の増大によって葉身が相対的に薄くなり、葉身光合成力の低下を通じて NAR が減少することを示唆した。

Ⅱ) トウモロコシの収量・収量指数および子実の N 含有% は混作によって 6 株/m<sup>2</sup> 区および 25 株/m<sup>2</sup> 区でそれぞれ増大した。収量・収量指数は 6 株/m<sup>2</sup> 区で最大となったが、トウモロコシおよびダイズの子実収量の総計については 25 株/m<sup>2</sup> 区が最大であった。

以上の結果から、ダイズの混作によるトウモロコシの生長と収量の向上は明らかであるが、ダイズの播種密度によって混作の効果には相違がみとめられた。その主要な原因は、混作によってダイズの空中窒素固定による有効態窒素供給量の増大や水の利用効率の改善など作物の生長にとって促進的な側面と、一方、水・栄養分および光に対する競合の増大という不利な側面の間のバランスが播種密度によって変化することによるものと考えられた。

本実験の結果、トウモロコシの子実収量はダイズを 6 株/m<sup>2</sup> で混作した区で最大となったが、トウモロコシの栽培条件がことなるばあいのダイズの最適播種密度については、さらに実験的に明らかにすることが必要である。