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# CORN AND BEAN INTERACTIONS IN MIXED CULTURE

QUARTERLY PROGRESS REPORT

to

AGENCY FOR INTERNATIONAL DEVELOPMENT

AID Grant No. AID/ta-G-1435
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and to

WORLD FOOD INSTITUTE
Iowa State University

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9p

This report concludes our discussion of the results of the second phase (7719) and presents an update on the third phase (7821) of our ongoing investigation into maize:bean interactions in mixed culture.

PHASE 2: (Trial 7719: Field Work Completed and Data Analyzed)

Theory, methodology and an overall systems analysis of this study have been presented in the preceding three reports. In this report we will concentrate on separation of maize root and shoot influences on bean yield, focusing on measurements of light energy taken within the crop canopies.

Recall that the factorial treatment array employed in this study (Dec. 1977 Progress Report) involved both a root variable (three maize populations) and a light variable (three canopy structures). We recognized that competition would not be related simply to canopy structure (light) but would depend also on the root variable (maize population), complicating simple treatment comparisons. Thus, to compare treatments honestly, we quantified the light environment (see Appendix for methodology) and assumed that root competition within a given maize population would be constant across canopy structures (would be unaffected by canopy structure).

Problems were encountered in quantifying both treatment components. Measured differences in light availability among treatments were small, and thus, difficult to interpret. Secondly, maize root competition, as inferred from resultant maize yields, was significantly affected by canopy structure, violating a crucial assumption. Our approach to reconciling these problems and interpreting the bean yield data is presented below.

I. Methodological aspects

A. Light Variable

Mechanical details of the light measurement procedure are discussed in the Appendix. Although light energy was measured in the lateral as well as the vertical directions, only the vertical readings will be discussed, as the lateral readings were effectively zero.

In the bush bean (P566, Type II) treatments, light energy data were read at the level of the uppermost leaves, and thus, reflect only the shading imposed by the maize. We were able to exploit the height difference between the bush bean and the maize to distinguish shading arising from intercrop competition (maize on bean) from that owing to intracrop (bean on bean) competition for light. However, that neat distinction is obscured in the climbing bean associations because the leaf area display of the two crops occupies the same vertical profile. Thus, measurements made in the mid-to-upper canopy of the climbing bean treatments (where most of the bean yield is borne) reflect shading arising from both maize and bean leaves. Recognizing this, the light

data from climbing bean treatments do not represent the same entity as those in the bush bean treatments -- notably, total light energy available for bean growth and yield after maize demands have been satisfied.

We could try to relate climbing bean yields to light data taken from comparable bush bean treatments, reasoning that since the treatments (of canopy structure and maize populations) were equally applied to both bean types, it is thus possible that the proportion of total light energy taken by the maize was similar in comparable treatments. However, this analogy fails on two counts: 1) the leaf area distribution in Type IV beans, being physically proximate to that of the maize, could actively interfere with penetrance of light to the maize, and thus, alter the proportion of total thereby received; and 2) maize yields in the climbing bean associations were significantly lower than those in comparable bush bean associations, implying that the maize in the former treatments was receiving more competition (likely including less light) than in the bush associations. We will, therefore, restrict our discussion of root:shoot influences to only the Type II treatments.

B. Root Variable

Recall that a fundamental assumption of this study was that root competition exerted by maize would be equal across light treatments, or that maize canopy manipulation would not affect root competition. It was intended that root competition would vary only with maize population. This assumption has not been validated by the data, as bending the maize (treatments 4-7, 5-8, and 6-9) apparently altered maize yield relative to that in erect maize (treatments 1, 2, and 3). It is, moreover, impossible to discount the potential of enhanced competitiveness of the beans in these treatments as an additional contribution in maize yield reduction.

Assuming that lowered maize yields reflect correspondingly, although not necessarily linearly, lower total nutrient demand exerted by the maize, we cannot separate and quantify root and shoot level competition as originally intended (1977 Progress Report). We propose, therefore, to make inductive comparisons among individual treatments, to indicate (non-quantitatively) either the presence or absence of root and light effects.

II. Separation of Root and Shoot Effects

Starting with the light data first (Table 1), note that light energy transmission was not simply related to canopy structure, as maize population exerted an additional influence. However, specific combinations of factors were consistently associated with high light transmission:

a. Open canopy structure, regardless of maize population (treatments 4, 5, and 6).

b. Low maize populations, regardless of canopy structure (treatments 4, 1 and 7).

c. And of course, monoculture.

Conversely, lowest light transmissions were measured when canopy closure was increased (the erect and closed structures) at the higher maize populations (treatments 2, 3 and 8, 9). To simplify these relations the indices of Table 1 are represented below:

| Treatments | Canopy type | Maize Population Low | Med. | High | Range in Transmission | Range in Bean yield |
|---|---|---|---|---|---|---|
| 4,5,6 | Open | 27.8a | 21.5abc | 22.7ab | 6.3% | 383 kg/ha |
| 1,2,3 | Erect | 30.0a | 9.0cd | 12.6bcd | 21.0 | 523 |
| 7,8,9 | Closed | 14.6bc | 11.6bcd | 1.0d | 13.6 | 769 |

(Duncan's based on 2 reps. (12 error df)

(Monoculture (trt 10), 29.5% (a) transmission)

We may conclude then that, with some exceptions, the expected trends were observed, with light transmission generally decreasing with increasing canopy closure and with increasing maize population within each canopy type.

Note that light transmission in the monoculture bean plots was only 29.5%, compared to the 100% anticipated value (light available at top canopy). As mentioned in the previous report (p. 2), yield realized in monoculture P566 was adequate but not great. We suggest that the low light availability and lower than normal yield could well be attributed to the presence of tall maize plants in surrounding plots blocking out light from the lower angles. This supposition has been supported by readings taken in the current study (7821). Using larger plots (8.5 m x 21 m vs. 7.5 m x 6 m in 7719), the readings above monoculture P566 are nearly equal to 100%.

We have integrated the light transmission and nutrient demand data (as inferred from maize yields) from Table 1 and produced the information shown in Figure 1. A generally positive, slightly curvilinear relationship exists between yield and light transmission at 54 days. The shape of the yield response in the closed canopy is much sharper than in either the open or erect canopies (which are roughly parallel). Presuming that corresponding populations of the open and closed canopies are comparable in terms of nutrient demand (the associated maize was identical between the two canopy types), this suggests that when light is most limiting, increasing root competition has an increasingly negative effect on bean yield -- i.e., a root by shoot competition interaction.

Because of non-uniform root demands between comparable populations of the diverse canopy structures, we cannot quantify root demand as initially planned. We can, however, make individual treatment comparisons to ascertain the simple presence or absence of a root influence. As an example, compare treatments 10, 4, 5, 6, and 1, which did not differ significantly in light transmission, but which produced significatnly different yields over a range of 828 kg/ha. It is likely that bean yield differences within this group may be partly attributed to variation in maize nutrient demands, as inferred by associated maize yields which ranged from 0 (treatment 10) to 4874 kg/ha (trt 6).

Similarly, within the treatments 2, 3, 7, and 8, light transmission was not significantly different but bean yields differed significantly, over a range of 594 kg/ha. We may again suggest that variable maize nutrient demands (over a maize yield range of 3279 kg/ha) contributed to corresponding bean yield variation.

In conclusion then, both root and shoot levels of maize:bean competition, as well as a root-shoot interaction are evident in these data for bush beans. These data were obtained under optimal cultural practices, including irrigation and heavy fertilization. It is, therefore, suggested that under more marginal soil conditions, such as those of the subsistence level farmer, root level interaction may assume even greater importance in delimiting yield, and would thus, warrant more intensive study in the future.

PHASE 3: (Trial 7821: Field Work Completed)

Theory and methodology for this study were presented in the June 1978 Progress Report and will be supplemented but briefly here.

The planting date, 28 April 1977, was erroneously given as 28 May in the previous report. Apparently, as a result of prolonged heavy rains during the first 30 days of plant growth, the maize used in this study (Suwan-1) failed to develop an adequate root support system and was subject to lodging starting at 40 days. However, as extra land had been planted to each plot to allow for such contingencies, we were largely able to avoid the lodged areas and the green harvest data seem little affected. A total of nine Type II and ten Type IV harvests, including the final yield harvests, were made at weekly intervals, starting at 26 days from planting. From these harvests, we measured dry weight and leaf area, as well as analyzing for nitrogen, phosphorous and potassium in each of the several dry weight components. Final bean harvests were made at 80 days (Type II) and 92 days (Type IV), and at 126 days for the maize. Data are currently being analyzed. Results will be presented in the Dec. 1978 Progress Report.

Table 1. Treatment characteristics, yields, and percentage light energy transmission in P566 treatments, ranked by bean yield.

| Treatment | | | Yield | | Transmission |
|---|---|---|---|---|---|
| No. | Canopy[1] | Maize[2] | Bean[3] | Maize[4] | Vertical[5] |
| 10 | | 0 | 1809 a | 0 | 29.4 a |
| 4 | Open | 18.5 | 1392 b | 2622 f | 27.8 a |
| 5 | Open | 36.0 | 1104 c | 3880 de | 21.5 abc |
| 7 | Closed | 18.5 | 1047 c | 2622 f | 14.6 bc |
| 6 | Open | 48.0 | 1009 c | 4876 bc | 22.7 ab |
| 1 | Erect | 20.0 | 981 c | 3548 e | 30.0 a |
| 2 | Erect | 37.0 | 675 d | 4529 cd | 9.0 cd |
| 8 | Closed | 36.0 | 522 de | 3880 de | 11.6 bcd |
| 3 | Erect | 50.5 | 453 e | 5901 a | 12.6 bcd |
| 9 | Closed | 48.0 | 278 f | 4876 bc | 1.0 d |

[1]Defined as: Open (maize bent away from bean), Erect (normal erect maize) and Closed (maize bent over bean).

[2]By 1000, in plants/ha.

[3,4]In kg/ha, 14% moisture for the bean, 15.5% moisture for the maize.

[5]Duncan's values calculated from 2 reps., with 12 error df.

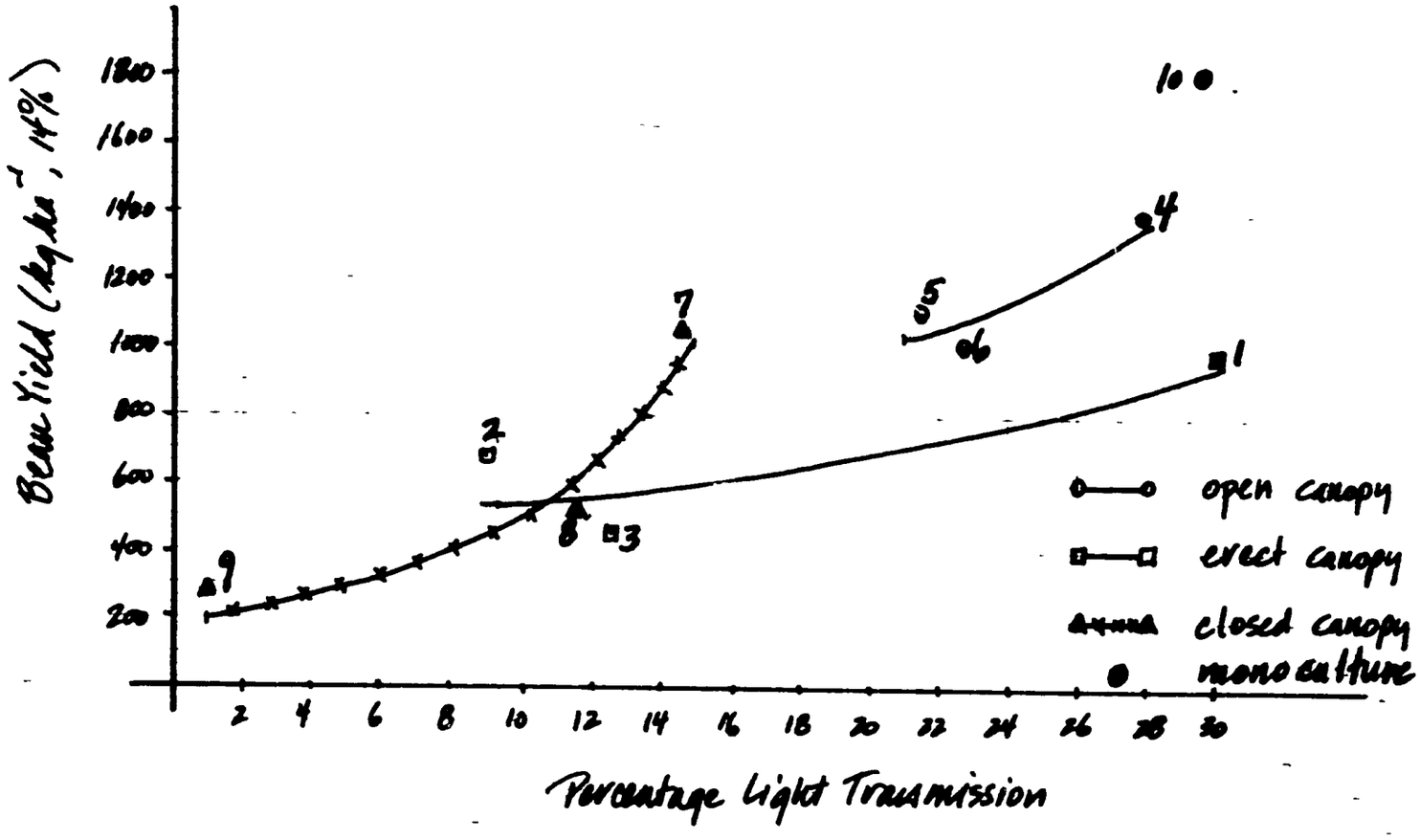


Figure 1. Relationship of bush bean (P566) yeild response to percentage light transmission at 54 days (maximum leaf area). (Numbers associated with each point are treatment designations).

## APPENDIX - METHODOLOGY OF LIGHT MEASUREMENT

Light energy was estimated using an adaptation of the method of Friend (1961). The light-sensing paper (OZALID) used by Friend (unavailable in Colombia) was replaced by a similar product (PAPEL INDHELIOS, Industrias Heliograficas, Ltd., Bogota, Colombia). The light-sensitive paper was exposed from within blackened plastic boxes (either 5 x 5 x 2.5 cm or 5 x 7 x 3 cm in size), fitted with foam rubber cushions which completely filled the interior. The paper was cut into 2 x 3 cm squares and stapled into multilayer packets which were inserted into the boxes opposite a 1 cm diameter window in one side. When the boxes were closed, the foam rubber acted to press the packet firmly against the window, preventing lateral penetration of light between the layers of paper.

These boxes were then strapped to 2.5 x 2.5 cm wooden bars which extended the full length (7.5 m) of the beds, supported at the desired height by lateral supports nailed to posts within and at either end of the beds. These posts were imbedded in the furrows (not within the beds) so that the boxes actually extended out over parts of two separate beds.

The boxes were sited at four positions on either side of the furrow, giving eight measured positions for each plot. Data presented (Table 1) are averages of all eight points, representing both sides of the furrow. Positions were spaced at 1.5 m intervals along the bed, starting at 1.5 m from either end. Exposure time was 24 hours on each of two days, 53 and 55 days after planting.

The support bars were located at 15 cm to either side of the furrow or 35 cm from the centers of the beds. The beans were planted at 25 cm from the bed centers, but due to lateral canopy expansion and lodging in P566, the measurement boxes were actually directly over (P566) or within (P364) the bean canopy. In the bent maize treatments, attempt was made to displace the maize canopy some 25 cm from the bed centers, or directly over the bean row. Thus, light readings in these treatments (7, 8, and 9, 17, 18 and 19) were taken from within the maize as well as the bean canopies.