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CORN AND BEAN INTERACTIONS IN MIXED CULTURE

QUARTERLY PROGRESS REPORT

to

AGENCY FOR INTERNATIONAL DEVELOPMENT

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In the original plan for this work, we intended to use an anticipated genotype by cultural system interaction to select strong and weak bean competitors for subsequent definitive studies. However, the expected interaction did not materialize (Phase 1), and as a result, we have had to modify our approach somewhat. Our modified approach involves simply testing hypotheses concerning the effects of maize on associated beans with the aim being to elucidate the nature and temporal aspects of the competition as a necessary prerequisite to modifying it in a favorable direction.

These hypotheses are being tested in a four-part study, of which relevant details from the first three phases will be presented here.

PHASE 1. Status: fieldwork completed and data analyzed

This experiment was designed to quantify bean responses to associated maize. Details of the experimental design and cultural practices up to day 55 may be found in the Progress Report of October 1977. Proceeding on from there, an infestation of Heliothis sp. occurred around day 60. Attempts at chemical control were ineffective, and substantial green pod damage in the Type III and IV varieties occurred.

Heavy lodging of the associated maize (H207, which had reached 2.5 to 3 m in height) occurred on day 73 following a storm. The degree of damage to the associated beans was variable, depending on the then current state of maturity of each variety. Type II (bush) varieties were nearly mature and, hence, were little affected, whereas damage to the canopy structure and support system of Type III and IV varieties was serious. As a result, whereas the Type II varietal yield data may be considered representative of their potential, the performance of the Type III and IV varieties is confounded, reflecting both genetic yield potential and the damage inflicted by the Heliothis and the maize lodging. Thus, I will not be considering the final yield data from the Type III and IV varieties in this report. (An early infection of common mosaic virus in the Type I's previously had led us to eliminate them from further consideration in this experiment).

Summary of Results from Type IIs.

Green harvests at 47 and 62 days. These harvests were made during the early and middle stages of reproductive growth. Considering data from both harvest dates, maize appeared to elicit two generalizable responses from all bean varieties examined:

1. An acceleration of plant development, hastening the onset of reproductive growth, concurrent with,
2. A retardation of reproductive growth (dry matter accumulation), particularly at later stages.

This conclusion was drawn from the following observations:

a. In absolute terms, leaf weight decreased sharply and reproductive weight increased moderately in association, whereas in monoculture, leaf weights declined slightly and reproductive weight increased strongly in the 15-day interval between 47 and 62 days (Table 1). This may be interpreted as an early curtailment of vegetative growth, with depressed reproductive growth in associated beans, relative to the potential expressed in monoculture.

b. At 47 days, both pod number and percentage of total dry weight allocated to reproductive growth were higher in beans associated with maize than in those grown in monoculture (accelerated development, Table 2).

c. Whereas pod number increased sharply in monoculture beans between 47 and 62 days, it remained relatively static in associated beans (depresse reproductive growth) (Table 2).

d. Percentage reproductive dry weight allocation, while increasing with age in both cultural systems, remained substantially higher in associated beans between 47 and 62 days (Table 2).

From these data, we may hypothesize that associated beans are induced to shift from vegetative to reproductive development at an earlier age (smaller size and yield potential) than in monoculture. Realization of existing yield potential is further limited by subsequently depressed reproductive growth, assessed both in pod number and in absolute pod dry weight.

Final yield harvest. Final harvest occurred over the interval from 76 to 105 days from first irrigation. The hypothesis of accelerated reproductive development in associated beans was supported by harvest maturity dates in the two cultural systems. Associated varieties were ready to harvest from 10 to 30 days earlier than were their monoculture counterparts.

1. Dry weight partitioning: A primary effect of growth in associatio with maize was reduction in overall plant size, which is apparent in the data of Table 3. Within the context of this diminution in absolute plant size, the following trends appeared generalizable:

a. A wide range of phenotypic variability existed among varieties in monoculture in all partitioning aspects.

b. In associated culture, whereas varietal differences persisted in main stem characters, depression in branch dry weight parameters was so severe as to mask varietal differences.

c. A genotype by cultural system interaction was suggested in the main stem pod and seed weight responses, as well as in all measured branch parameters.

d. Branch components were relatively more penalized than were main stem components. This is supported by data in Table 4 showing percentage diminution in seed yield borne on main stem and branch sites.

e. In all varieties, seed yield relative to total dry matter yield (Harvest Index or HI) was lower in association than in monoculture (from 3 to 7% lower, Table 3). However, in relation to the large differences between systems in absolute plant size, differences in HI were small.

The central finding among the bean dry weight partitioning responses was the much greater effect of maize on branch components relative to main stem components.

2. Yield and yield components: Seed yield varied widely among varieites in both cultural systems (Figure 1). In monoculture, the minimum yield was some 36% less than the maximum (1261 vs. 1974 kg ha^{-1}), while in association, minimum yield was some 48% below the maximum (427 vs. 824 kg ha^{-1}). Varietal rankings were quite consistent (although not identical) between cultural systems, indicating no genotype by cultural system interaction. In addition to large amplitude differences in absolute yield values among varieties within each system, differences in percentage yield reduction between systems were also observed (from 58% in P566 to 74% in P643). In general, the two high-yielding varieties in monoculture were less negatively affected by maize (58, 59%).

Based on varietal rankings in monoculture main stem vs. branch yield parameters (Table 4), we can designate varieties as being either main stem- or branch-dominated with respect to site of reproductive load. P566, P675, and P488 seem to be main stem-dominated, whereas the others exhibit branch-borne yield. Note that the main stem-dominated varieties consistently yielded highest in both cultural systems and generally manifested lesser percentage yield reduction in association than did branch-dominated varieties.

Summarizing now the yield data, the following trends were observed:

a. Wide ranges of varietal variability were observed in all characters, in both monoculture and associated systems.

b. A substantial genotype by cultural system interaction was suggested in most yield component characters, although varietal yield performance was remarkably consistent between systems.

c. Branch yield and yield components were more severely depressed by maize association than main-stem parameters.

The main conclusion then is that associated culture results in an overall depression in plant size with little change in harvest index.

Branch-related parameters were more severely depressed by associated maize than were main stem-related parameters. Branch-dominated varieties consistently yielded less than main stem-dominated varieties under both cultural systems. It would seem then that, in Type II varieties at least, branches represented an avenue of yield plasticity which was not useful under either the associated or monoculture growth conditions of CIAT.

PHASE 2. Status: field work completed, analysis of data initiated

This trial was designed to test the hypothesis of spatial competition for resources as the causal factor for bean yield depression in association with maize. We are attempting to separate and quantify root and shoot level competition between bean and maize using the approach outlined in the Progress Report of December 1977.

Seed was planted on 21 October 1977, using P566 as the Type II (bush) variety, P364 as the Type IV (climbing) variety and H210 (brachytic) as the associated maize. The treatments and experimental design were as reported in the December 1977 Progress Report, except that the artificial shading treatments had to be eliminated because of difficulties in obtaining the necessary materials.

Optimal cultural practices were applied in accordance with the system perfected at CIAT for the study of associated culture. Fertilizer (380 kg ha^{-1} of 10-30-10) was applied prior to planting, and supplemented by foliar applications of urea and micronutrients as needed during growth. Planting was on raised beds, one meter apart on centers, using a row of maize down the center, flanked by a row of beans on either side. The Type IV bean was artifically supported (both in association and in monoculture) to a height of 1.8 m (the mature height of the associated maize variety), using a system of wire and nylon twine strung between bamboo posts.

Irrigation was applied infrequently as needed to supplement the generally adequate rains. Chemical control of insects and diseases was rigorous, including applications of Sevin (to the maize), Pirimor, Derosal, Benlate, Azodrin, Thiodan metil, Plantvax, Elosal, Koccide, Daconil and Lannate during the first 75 days.

Due to difficulties in materials acquisitions, light measurement w delayed until 54 days from the first irrigation. Light energy was measured twice, once between 54 and 61 days (both Type II and Type IV treatments) and a second time between 82 and 89 days (Type IV treatments only), using

Green harvests of 2 m^2 samples were made at 66 days (P566) and 74 days (P364), from which leaf area, dry weight partitioning and canopy structure attributes were measured. Final yield (10 m^2) and yield component (2 m^2) harvests were made at 78 days (P566), 93 days (P364) and 128 days (H210, maize).

As data analysis has not yet been completed, results from this study will be reported in the next Progress Report.

PHASE 3. Status: to be planted in March 1978

This study will emphasize temporal aspects of resource competition between bean and maize. It is suggested that temporal overlap in the maximal resource demands of bean and maize critically limits bean growth and yield, with the extent of the damage depending on the extent of the overlap. In this context, it is of especial interest to contrast the Type II and IV growth habits, to learn how these two plant types, which exhibit such large differences in monoculture yields (2.5 vs. 4 t ha^{-1}) are reduced to a common low level (0.8-1.0 t ha^{-1}) in association with maize.

In accordance with the trends suggested in the first trial (Phase 1), it is hypothesized that varieties which normally exert resource demands early or which retain the capacity to accelerate their development and thus, to exert their resource demands prematurely, may minimize direct competition with the maize and suffer less yield depression. It is proposed to examine this hypothesis by constructing resource demand curves for a Type II and a Type IV variety, both in monoculture and in association, to contrast their responses to associated maize. Resource demand could be estimated by calculation of relative growth rates (RGR's) based on both dry matter and nutrient (nitrogen phosphorous and potassium) accumulation evaluated by weekly harvests taken throughout the growth cycle.

Table 1. Dry weight (g pl^{-1}) of leaf blade, structural[1/] and reproductive[2/] components of Type II varieties, at 47 and 62 days[3/].

Variety		Dry weight Leaf blades		Dry weight Structural		Dry wei... Reproductive	
		47	62	47	62	47	62
P17	M	6.24	5.19	7.21	9.32	0.35	10.57
	A	3.18	1.03	3.90	3.87	0.91	3.94
P402	M	5.79	4.82	5.91	8.17	0.36	5.32
	A	2.69	0.91	2.92	2.80	0.71	2.50
P488	M	6.63	5.48	7.45	10.7	0.19	10.0
	A	4.07	1.79	5.49	4.90	0.83	4.61
P524	M	7.25	6.26	8.16	12.1	0.08	5.20
	A	4.71	3.34	5.86	5.90	0.33	5.74
P566	M	5.98	5.80	6.86	10.3	0.41	11.6
	A	3.03	0.76	3.73	3.31	0.76	4.19
P643	M	8.56	8.57	10.2	14.9	0.17	8.10
	A	2.96	1.77	3.98	4.18	0.37	3.10
P675	M	6.82	6.06	7.92	10.4	0.48	11.3
	A	3.26	1.26	4.09	4.09	4.01	3.67
P756	M	6.68	5.80	6.63	8.31	1.96	18.1
	A	3.83	0.49	4.17	3.21	2.05	4.94
Monoculture							
Mean		6.74	6.0	7.54	10.5	0.50	10.0
$2s_{\bar{x}}$		2.09	3.11	2.29	3.84	0.37	4.84
Association							
Mean		3.47	1.42	4.27	4.02	0.85	4.09
$2s_{\bar{x}}$		0.87	1.16	1.04	1.26	0.66	1.42

1/ Structural is defined as main stem, branch and petiolar material.
2/ Reproductive is defined as seeds and podwalls, pods > 5 cm long.
3/ Days from first irrigation.

Table 2. Pod number (pl^{-1}) and percentage dry weight distribution to reproductive material at 47 and 62 days

Variety		Pod number (pl^{-1})		Percentage reproductive dry weight	
		47	62	47	62
P17	Monoc.	4.6	19.6	2.3	41.6
	Assoc.	5.8	5.6	9.9	46.6
P402	Monoc	4.9	14.7	2.8	27.1
	Assoc	6.6	5.9	11.3	40.7
P488	Monoc	1.7	17.1	1.1	38.8
	Assoc	5.2	6.5	8.2	40.7
P524	Monoc	1.4	14.6	0.5	21.0
	Assoc	3.9	12.3	3.1	38.9
P566	Monoc	3.3	15.9	2.9	41.6
	Assoc	4.1	4.4	10.2	50.6
P643	Monoc	2.3	27.2	0.5	24.8
	Assoc	3.6	7.9	4.7	34.2
P675	Monoc	4.3	15.9	2.6	41.7
	Assoc	4.3	5.0	8.8	41.3
P756	Monoc	1.8	28.3	10.3	53.2
	Assoc	0.2	8.8	19.8	56.3
Monoculture					
	Mean	4.29	19.2	2.88	36.2
	$2s_{\bar{x}}$	4.09	8.23	2.97	9.0
Association					
	Mean	5.46	7.05	9.50	43.7
		2.64	2.34	5.60	6.80

Table 3. Dry weight partitioning measured at time of final harvest (g m^{-2}).

	Dry weight structural 1/		Dry weight reproductive 2/		Dry weight seeds		Harvest index 3/	
variety	Monoc.	Assoc.	onoc.	Assoc.	Monoc.	Assoc.	Monoc.	Assoc.
P17	89.3	38.2	221	71.4	161	53.5	.52	.49
P402	85.4	44.1	156	60.7	114	42.8	.47	.41
P488	77.9	37.9	185	69.5	136	50.0	.52	.47
P524	103	44.0	197	69.0	124	50.5	.42	.45
P566	98.0	54.5	237	100	173	74.1	.52	.48
P643	118	36.9	210	53.2	149	35.3	.45	.39
P675	104	53.6	211	81.0	153	56.3	.49	.42
P756	79.1	24.9	211	62.9	159	45.9	.55	.52

1/ Structural dry weight includes both main stem and branch material. Residual petiole and blade material were discarded.
2/ Reproductive dry weight includes podwall and seed weights of all pods which contained seeds. Main stem and branch pods were bulked.
3/ Harvest Index was calculated as seed dry weight/total dry weight.

Table 4. Yield distribution among branch and main stem sites, as affected by association with maize (g m^{-2})

Variety	Dry weight Main stem seeds Monoc.	Dry weight Main stem seeds Assoc.	Percentage diminution	Dry weight Branch seeds Monoc.	Dry weight Branch seeds Assoc.	Percentage diminution	Percentage yield on branches Monoc.	Percentage yield on branches Assoc.
P17	62.8	42.5	32	98.0	11.0	89	61	21
P402	46.0	34.5	25	67.9	8.3	88	60	19
P488	85.3	46.2	46	50.6	3.8	92	37	8
P524	39.6	38.4	3	84.7	12.1	86	68	24
P566	139.0	73.1	47	34.2	1.0	97	20	1
P643	53.0	33.1	38	95.6	2.2	98	64	6
P675	95.4	52.9	45	57.6	3.4	94	38	6
P756	71.0	32.4	54	87.6	13.5	85	55	42
Mean	74.0	44.1	36.3	72.0	6.9	91	50	16
$s_{\bar{x}}$	8.11			8.02				

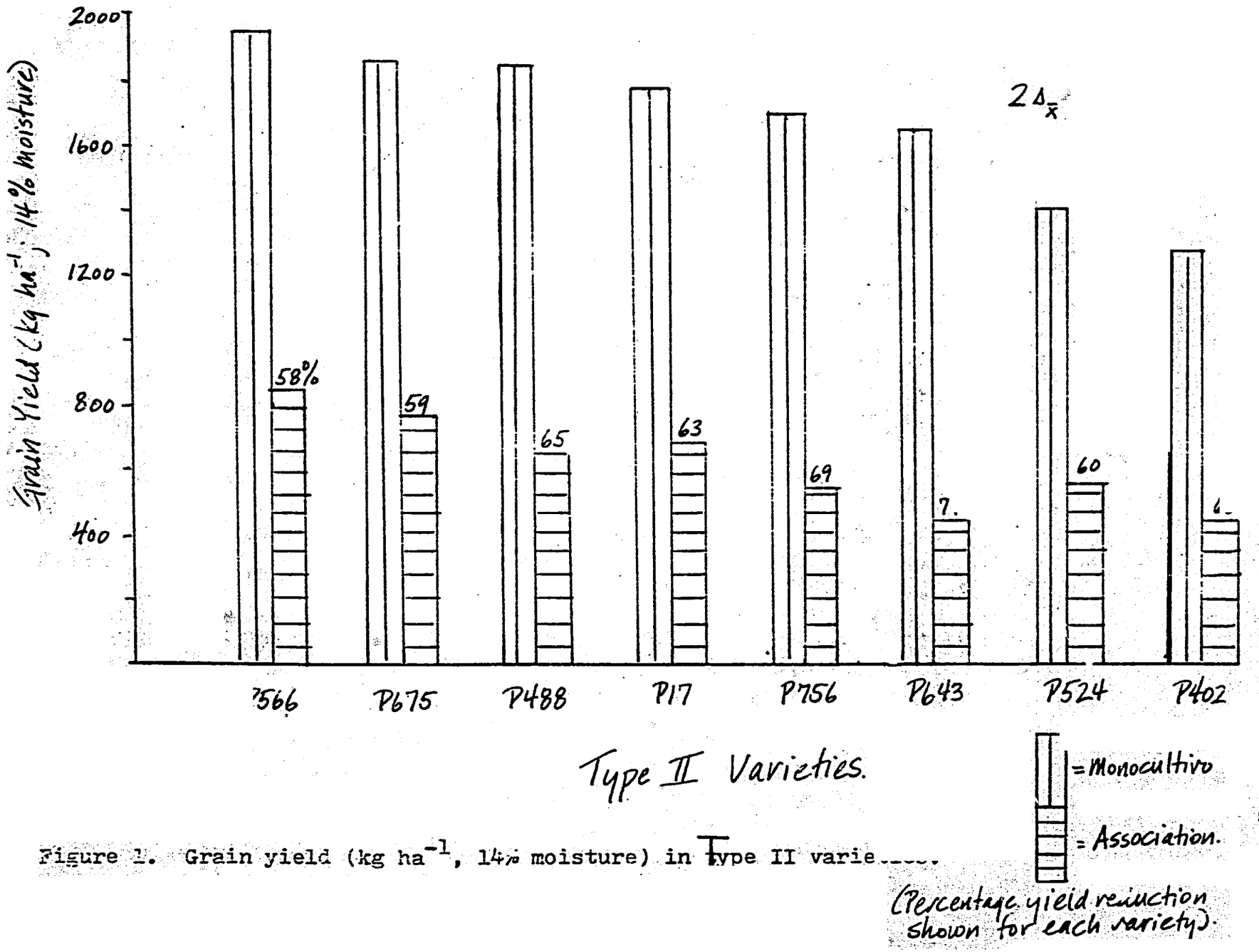

Figure 1. Grain yield (kg ha^{-1}, 14% moisture) in Type II varie.....