Plant Population and Spatial Arrangement Study on the Intercropping of Maize and Beans (*Phaseolus vulgaris* L.) in Northeast Brazil

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Abstract

*In Northeast Brazil, the peasant farmers usually raise their crops in mixture, and the intercropping of maize and beans (*Phaseolus vulgaris *L.) is very frequent.*

In order to examine plant populations and spatial arrangements of maize and beans intercropped, an experiment was carried out at Filadelfia, Brazil, located at 10°45' S and 40°07' W at 550 m altitude. The average annual rainfall of the area is 811 mm.

The statistical design was a randomized complete block with a split-plot arrangement, with four replications. Four population levels of maize (25 000, 50 000, 75 000, and 100 000 plants/ha) and beans (150 000, 200 000, 250 000, and 300 000 plants/ha) formed the main plots. The subplots were composed of five spatial arrangements (sole maize; 1M:2B; 1M:3B; 1M:4B; and sole beans).

It was concluded that the best spatial arrangement was 1:3, comprising 12 500 plants/ha of maize and 150 000 plants/ha of beans.

Northeast Brazil occupies an area of 13% of the Brazilian territory and according to Hargreaves (1974), half of this land is classified as semi-arid tropics. The Brazilian semi-arid tropics are located between 3 and 18° south and 35 and 46° West, comprising an area of around 1 million km² including parts of the following states: Maranhao, Piaui, Ceara, Rio do Norte, Paraiba, Pernambuco, Alagoas, Sergipe, Bahia, and Minas Gerais.

According to Brasil. Sudene (1975), 73% of the holdings in Northeast Brazil are less than 50 ha and occupy 12% of the total area of the region. As shown in a survey carried out in the first 20 nuclei of the "Sertanejo" Project[1] by Brasil. Sudene (1977), the farmers can be classified as follows:

- 40% — farmers without land
- 56% — farmers having small properties
- 4% — farmers having medium and large properties

At the present time, the cultivated land accounts for only one-sixth of the total area of the agricultural holdings (Franco 1977).

In Northeast Brazil, the small farmers normally manage a farming system involving small areas planted in food crops such as maize, beans, cassava, squash, and fruits (banana or mango) and cash crops such as cotton and castor beans. Crop combinations vary with the region. Moreover, to complement their food or cash needs, they raise chickens, pigs, and goats. Until recently, the research programs devoted to semi-arid tropics had not sufficiently considered the farming systems, and most research objectives had been to improve production techniques only for single crops or animal species, independently of each other (Dillon et al. 1978). So it is urgent to spread the use of new technology emphasizing farming systems as a whole, and there is nobody better than farmers themselves to provide the basis for this goal.

Krantz (1974) reported that two important factors, namely climate and soils, have

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1. Government project to promote the development of typical holdings in the semi-arid tropics of Northeast Brazil, leading to the minimization of drought effects.

influenced farmers in developing their cropping patterns in the semi-arid tropics. The rainfall is erratic and undependable, so in a single cropping season, it is possible to have excessive rainfall and droughts of short duration. The soils have a very low content of organic matter and native fertility. Adding these factors to the erratic and undependable rainfall pattern makes crop production in the semi-arid tropics a hazardous enterprise.

Limited capital resources and risk aversion of small farmers associated with other characteristics caused the early farmers in the semi-arid tropics to develop special cropping patterns based on multiple cropping, where more than one crop is grown on the same land in one year. In Northeast Brazil the most common situation is intercropping, where two or more crops are grown simultaneously on the same land in rows in definite patterns.

In terms of cropping combinations, there are two clear situations in the semi-arid tropics of Northeast Brazil related to the rainfall regime. In regions with too erratic rainfall and limited suitability for rainfed agriculture, the most common combination is maize × beans [i.e., cowpea, (*Vigna unguiculata* L. Walp)] × perennial cotton (*Gossypium hirsutum* L. var. 'Maria Galante' Hutch.), with some variation for cassava, castor bean, or palma cactus (*Opuntia cochinellifera* Mill.) for forage. The second situation, occurring in those regions with less erratic rainfall and a higher moisture availability index (MAI) (Hargreaves 1974), is predominantly maize × beans (*Phaseolus vulgaris* L.), with variation for cotton (*Gossypium hirsutum* L.), cassava, or palma.

In Northeast Brazil, some studies have been carried out on intercropping involving cereals and legumes (Faris et al. 1976; Araujo et al. 1976; and Lopes et al. 1976), where the advantage of intercropping in relation to sole crops can be seen. However, in these studies, the different aspects of plant population, proportional population, and spatial arrangement have not been clearly distinguished.

This experiment was planned with the objective of studying these aspects in detail.

Materials and Methods

The experiment was carried out at Filadelfia county (State of Bahia), located at 10°45′ South and 40°07′ West, at 550 m altitude.

The soils of the area are deep eutrofic red yellow laterite with the following characteristics:

pH	6.5
P_2O_5	5.5 ppm
K_2O	0.2 meq/100 g
O.M.	0.8%
Al	0.05 meq/100 g

The average annual rainfall is 811 mm, concentrated from November to July. A rainfall gauge, set up at the experimental site, recorded 212.1 mm during the growing season.

The region has an average slope of 8% at the site of the experimental area. A system of ridges and furrows of 150 cm was prepared with three rows on the bed.

The statistical design was a randomized complete block with a split-plot arrangement, with four replications. Four population levels of maize and beans formed the main plots. Each main plot was divided into five subplots composed of three different spatial arrangements of maize and beans, sole maize, and sole beans.

The populations were distributed as follows:

Population	Maize	Beans
1	25 000	150 000
2	50 000	200 000
3	75 000	250 000
4	100 000	300 000

The populations were combined with the following spatial arrangements:

Sole maize (100%)

1 : 2 — 1 row of maize (33%) : 2 rows of beans (67%)

1 : 3 — 1 row of maize (25%) : 3 rows of beans (75%)

1 : 4 — 1 row of maize (20%) : 4 rows of beans (80%)

Sole beans (100%)

The distance between rows was 50 cm, except for sole maize, where it was 1 m. The different plant populations were obtained by using the row spacings of 80, 40, 26, and 20 cm for maize and 13, 10, 8, and 6.5 cm for beans, respectively. For sole maize, the spacings were 40, 20, 13, and 10 cm.

At planting time, 20 kg/ha of N, 60 kg/ha of P_2O_5, and 30 kg/ha of K_2O were banded near the seeds. Forty-five days after planting, 40 kg/ha of N was added as a top dressing to maize.

The experiment was sown on 19 May. Three seeds were placed in each planting hole, and plants were thinned to one plant per hill, 18 days after planting.

The variety of maize utilized was Centralmex, and the variety of beans was IPA 74–19, with growth cycles of 150 days and 90 days, respectively.

During the growing period, the crops were kept weed free, and regular chemical sprayings were applied to control *Spodoptera frugiperda* and *Heliothis zea* on maize and *Empoasca kraemeri* (1957) on beans.

Each subplot of sole maize was planted with five rows, and the subplots of sole beans or maize × beans were planted with nine rows, giving the following number of harvest rows for each crop:

Sole maize — Three central rows
1M : 2B — 1 row of maize and 2 rows of beans
1M : 3B — 1 row of maize and 3 rows of beans
1M : 4B — 1 row of maize and 4 rows of beans
Sole beans — Three central rows.

Results and Discussion

Grain Yields

Table 1 shows the grain yields for mixtures and sole crops at different population levels. The statistical analysis indicates significant differences for spatial arrangement.

Table 1 also shows significant differences for plant population in sole maize and mixture 1:3. There was no significant difference for population in the other mixtures.

The best yield advantages occurred at higher plant population levels (Table 1), which is in agreement with Willey and Osiru (1972). According to De Wit (1960), this situation takes place when the individual species utilize slightly different parts of the environment. For population 3, the best grain yields occurred in mixture 1:2, without significant difference for the mixture 1:3. In regard to population 4, the best grain yields occurred in mixture 1:2, differing statistically from the other combinations.

It can be observed in Table 1 that the yield of sole maize decreased with the increase of plant population. The difference between population 1 and population 4 reached 46.2%. This fact is explained by high competition within the same

Table 1. Yield (kg/ha) on the intercropping of maize and beans, Filadelfia (Brazil), 1978.[a]

	Crop	Sole maize	1:2	1:3	1:4	Sole beans
Population 1	Maize	3753	1940	1361	996	–
	Beans	–	1344	1449	1576	1890
	Total	3753 Aa	3284 Aab	2810 Bbc	2572 Acd	1890 Ad
Population 2	Maize	3494	2250	2184	1698	–
	Beans	–	1083	1421	1536	2019
	Total	3494 ABa	3333 Aa	3605 Aa	3234 Aa	2019 Ab
Population 3	Maize	2904	2768	2473	1527	–
	Beans	–	1060	1233	1294	1862
	Total	2904 Bb	3828 Aa	3706 Aa	2821 Ab	1862 Ac
Population 4	Maize	2021	2852	1852	1384	–
	Beans	–	1051	1220	1286	1881
	Total	2021 Bcd	3903 Aa	3073 Ab	2670 Abc	1881 Ad

a. Within each column, means not followed by the same capital letter, and within each row, means not followed by the same small letter, are significantly different at the 5% level of probability, as determined by TUKEY test.

The moisture content of the seeds was determined at harvest time, and correction was made to 13% on beans and 15.5% on maize on a wet basis. The number of plants of each crop was counted within the harvest area.

The bean crop was harvested on 22 August and the maize crop on 23 October.

species, causing a reduction of the cob index with an increase of the maize plant population, varying from 1.1 in a population of 25 000 plants/ha to 0.4 in a population of 100 000 plants/ha, as shown in Table 2. Table 2 also shows that the higher cob index occurred at lower population levels and in spatial arrangements with a lower proportion of maize.

Sole beans showed a stable yield with maximum variation of 7.8% (Table 1). It is supposed that this situation could be due to the use of high plant population levels maintaining all grain yield at a population plateau. This result can be explained by the significant compensation effect of the number of pods per plant. That is, on an average, the lower population treatments produced 62.5% more pods per plant than the higher plant population (Table 3). Also, it can be seen in the same table that there was no significant difference for number of pods per plant among spatial arrangements.

Table 4 shows the land equivalent ratio (LER)

Table 2. Cob index in maize intercropped with *Phaseolus vulgaris* L., Filadelfia (Brazil), 1978.[a]

Population	Sole Maize	1:2	1:3	1:4	Mean
1	1.1	1.5	1.6	1.6	1.4 a
2	0.8	1.2	1.4	1.5	1.2 b
3	0.7	1.0	1.1	1.2	1.0 b
4	0.4	0.8	1.0	1.1	0.8 c
Mean	0.7 c	1.1 b	1.3 a	1.3 a	

a. The figures followed by the same letters are not significantly different from one another at the 5% probability level, as determined by TUKEY test.

Table 3. Number of pods per plant of *Phaseolus vulgaris* L. intercropped with maize, Filadelfia (Brazil), 1978.[a]

Population	Sole Beans	1:2	1:3	1:4	Mean
1	16	17	15	15	16 a
2	14	11	13	12	12 b
3	12	12	11	11	11 c
4	11	10	10	10	10 d
Mean	13 a	12 a	12 a	12 a	

a. The figures followed by the same letters are not significantly different from one another at the 5% probability level, as determined by TUKEY test.

Table 4. Land equivalent ratio (LER) and percentage of lodging of maize plants on maize/beans intercropping, Filadelfia (Brazil), 1978.

	Sole maize	1:2			1:3			1:4		
Population	Lodging		LERs	Lodging		LERs	Lodging		LERs	Lodging
		Maize	0.52		Maize	0.36		Maize	0.26	
		Bean	0.67		Bean	0.72		Bean	0.78	
1	12	Total	1.19	3	Total	1.08	2	Total	1.04	17
		Maize	0.60		Maize	0.58		Maize	0.45	
		Bean	0.54		Bean	0.70		Bean	0.76	
2	56	Total	1.14	10	Total	1.28	12	Total	1.21	4
		Maize	0.74		Maize	0.66		Maize	0.41	
		Bean	0.52		Bean	0.61		Bean	0.64	
3	65	Total	1.26	23	Total	1.27	16	Total	1.05	15
		Maize	0.76		Maize	0.49		Maize	0.37	
		Bean	0.52		Bean	0.60		Bean	0.64	
4	97	Total	1.28	45	Total	1.09	25	Total	1.01	21

and percentage of lodging in maize. In comparing yield data of Table 1 with LER and lodging of maize contained in Table 4, it can be seen that the LER of mixture 1:2 in population 4 presents a yield advantage of 28%, with a lodging in maize of 45%. In population 2, of special note is the combination 1:3 where the LER indicates a yield advantage of 28% with a lodging in maize of 12%. In general, it can be seen that the percentage of lodging rose with the increase of plant population of maize, especially in sole maize treatments, that reached 97% at higher population level. This result is in accordance with Francis et al. (1976), in several experiments carried out at CIAT.

Competition between the Species

As shown in Table 1, in all population levels the bean yield increased as its proportion in the spatial arrangement increased. In the maize crop, the situation was the opposite. In regard to the different population levels within each spatial arrangement, the results show that the maize became increasingly competitive as population increased. These results are in agreement with those found by Willey and Osiru (1972) and Aidar (1978).

Conclusions

Considering the conditions in which the experiment was carried out, it can be concluded that:

1. Grain yield of sole maize decreased with an increase in plant population. However, bean yield remained unchanged with an increase in plant population.
2. Total grain yields in mixtures gave better advantage at higher plant population levels, especially in the spatial arrangement of 1:2 and 1:3.
3. Considering the LER and percentage of lodging in maize, it can be concluded for the conditions in which this experiment was carried out that the best spatial arrangement was 1:3, corresponding to 1 row of maize to 3 rows of beans, comprising 12 500 plants/ha of maize and 150 000 plants/ha of beans.

A further trial is suggested to confirm the results reported.

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