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Some Observations on the Effects of Plant Arrangements for Intercropping

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The spatial arrangement of plants within an intercropped plot is an aspect of intercropping that has received considerable attention in the literature. The reports have been concerned with the culture of intercropped species in: the same or alternate rows; one or more rows of one species followed by a variable number of rows of another species; various groupings or hills of each species and hills that include plants of both species; and various populations of the component crops. The vast majority of reports are concerned with cohabitation of the intercropped species, whereas the principles of intimate interplant association have not been as well described. The extensive review of intercropping literature by Willey (1979) mentioned a few reports that discussed interactions occurring as a result of intimate association of component species in intercropping.

The studies presented in this paper were undertaken to gain insight into the effects resulting from different spatial arrangements of cereal-legume mixtures, with particular reference to intimate interspecific plant association and the ease of interplant cultivation.

Materials and Methods

The research was carried out at Morogoro in 1977 and 1978. The treatments were arranged in a 4 × 3 factorial in 1977 and a 4 × 4 factorial in 1978. They consisted of four cropping systems and three or four plant groupings or hills. The treatment combinations are given in Table 1. The spacing between the hills was adjusted to maintain a constant population per hectare in each experiment. The format developed for planting is illustrated in Table 2 using the 1978 measurements. Four-row plots, each plot being 10 m long, were used in all trials. The large plot size was adopted to give a better estimation of the time required to weed each plot.

In all of the intercropped plots, a 1:1 ratio of maize:legume plants was maintained. The correct ratio would, of course, depend upon many factors (crops, varieties, environment, etc.). This information was not available and, consequently, a 1:1 ratio was accepted, with the understanding that it may not have been the best ratio for maximum production.

A list of the trials conducted in this series of experiments is given in Table 3. Each trial has been given a code designation to facilitate differentiation in the discussion of the results. A combination of a dry spell at planting, maize streak virus, and cowpea insects forced the abandonment of the 1978a M-C trial. The 1978a M-S trial was refilled and allowed to continue. The whole 1978 experiment was then replanted using a medium altitude selection (MAS) of maize in place of the shorter stature but more streak susceptible Katumani.

A factorial analysis of variance was used to detect significant treatment effects and separate these effects according to their source (cropping system or hilling). The parameters analyzed were: number of harvestable plants per plot; grain yield per plot per species; time required to weed each plot; and relative yield total (RYT), where

$$\mathrm{RYT} = \frac{\text{cereal yield intercropped}}{\text{cereal yield in monoculture}} + \frac{\text{legume yield intercropped}}{\text{legume yield in monoculture}}$$

Table 1. Treatments used in the factorial experiments in 1977 and 1978.

Cropping systems
- (1) Monoculture maize
- (2) Monoculture legume (soybean or cowpea)
- (3) Intercrop in alternate holes
- (4) Intercrop in the same hole

Plant groupings or hills
- One plant of each species per hole
- Two plants of each species per hole
- Three plants of each species per hole
- Four plants of each species per hole (1978 only)

Table 2. Intrarow spacing (cm) and the number of plants per hole in the intercropped treatments in 1978 experiments.

	Intrarow spacing between plants of		Number of plants per hole	
Type of intercropping	Same species	Different species	Each species	Both species
Alternate hole	15	7.5	1	1
	30	15.0	2	2
	45	22.5	3	3
	60	30.0	4	4
Same hole	15	15.0	1	2
	30	30.0	2	4
	45	45.0	3	6
	60	60.0	4	8

Results and Discussion

Monoculture vs Intercropping

Larger numerical differences exist in the harvestable plant stand between monoculture and intercropped plots of maize and legumes in trials 1978a M-S, 1978b M-S, and 1978b M-C (Table 4). However, if adjustments could be made for the different numbers of plants of each species established in monoculture and intercropping, most of the differences would probably disappear. This adjustment would not affect the 1977 M-C and 1977 M-S trials, in which no consistent difference in harvested plant population occurred between monoculture and intercropped plots.

The grain yields of each species (Table 5) were always greater in monoculture than intercropping. These differences were sufficient to be significant in all of the legume data and for maize in two trials (1977 M-C and 1978a M-S).

The majority of intercropping experiments reported in the literature indicate yield reductions of individual species (Finlay 1975; Osiru and Willey 1972; Willey and Osiru 1972), as was the case in the present experiments. The yield advantages lie in the combined yield, determined using a suitable calculation such as the relative yield total. The average relative yield totals from four of the five trials were considerably larger than 1.00, indicating a yield advantage for intercropping (Table 5).

Alternate-Hole vs Same-Hole Intercropping

The number of harvestable maize and legume plants in all five trials was larger in the same-hole intercropping system than in the alternate-hole intercropping system (Table 4). The differences in three of the five maize comparisons (1977 M-C, 1977 M-S, and 1978a M-S) and in three soybean comparisons (1977 M-S, 1978a M-S, and 1978b M-S) were large enough to be significantly different at the 5% level. Thus, both of the mixture components, in all five trials, contained a larger number of plants in the same-hole intercropping system than in the alternate-hole intercropping system. In addition, the crop yields in 8 of 10 comparisons (Table 5) were greater in the same-hole intercropping system than the alternate-hole intercropping system, but the differences were not significant. There were no significant comparisons between the two intercropping systems with respect to RYT and no consistent trends toward either intercropping system (Table 5).

Plant Groupings

The analysis of variance detected no significant differences among the number of harvestable plants per plot per species, grain yield per plot, or relative yield total that could be attributed to the

Table 3. Code designations for intercropping trials conducted in 1977 and 1978.

Year	Crop mixture	Type of intercropping	Designation	Remarks
1977	Maize-cowpea	Additive	1977 M-C	
1977	Maize-soybean	Additive	1977 M-S	
1978	Maize-cowpea	Replacement	1978a M-C	Discontinued
1978	Maize-soybean	Replacement	1978a M-S	Refilled
1978	Maize-cowpea	Replacement	1978b M-C	
1978	Maize-soybean	Replacement	1978b M-S	

Table 4. Mean number of harvestable plants per plot for maize and legume in monoculture and intercropping systems.

	1977 M-C	1977 M-S	1978a* M-S	1978b M-S	1978b M-C
Maize					
Alternate hole	32.0b	26.6b	30.0c	41.7b	35.2b
Same hole	35.3a	30.3a	43.5b	45.0b	38.5b
Monoculture	35.0a	29.7a	58.5a	74.0a	60.5a
Legume					
Alternate hole	61.0b	44.0b	28.0c	59.7c	25.5b
Same hole	65.6b	58.0a	32.0b	68.7b	32.2b
Monoculture	73.7a	62.0a	53.5a	121.0a	50.5a

*Calculated on a plot area of 15 m^2. The remaining figures are calculated on a plot area of 18 m^2. Means followed by different letters within each column of maize or legume differed (P = 0.05) from each other.

Table 5. Mean grain yield per plot (g/plot) for maize and legume in monoculture and intercropping systems and the relative yield total for the intercropping systems.

	1977 M-C	1977 M-S	1978a* M-S	1978b M-S	1978b M-C
Maize yield					
Alternate hole	2701b	2339	1319b	2665	2029
Same hole	2552b	2643	1481b	2920	2157
Monoculture	3409a	3020	1972a	3400	3004
Legume yield					
Alternate hole	654b	900b	267b	484b	39b
Same hole	680b	985b	224b	533b	263b
Monoculture	1819a	1746a	866a	1673a	488a
Relative yield total					
Alternate hole	1.21	1.34	1.09	1.37	1.33
Same hole	1.14	1.50	1.06	1.41	1.60

*Calculated on a plot area of 15 m^2. The remaining figures are calculated on a plot area of 18 m^2. Means followed by different letters within each column of maize or legume differed (P = 0.01) from each other.

plant groupings. The maize and soybean harvestable plant stands of the 1978a M-S trial were the only exception. Because this trial is the sole exception and it suffered considerable setbacks during plant establishment, no firm conclusions could be drawn from the results.

Weeding

The time required to weed each plot was not affected by the cropping system or hilling. The variability among the hoers and the uneven distribution of weeds probably contributed to the high experimental error and obscured any treatment effects that may have been present. The hoers, however, expressed a preference for intrarow spacings sufficiently wide to allow the passage of a hoe through the row. When the hoe can be passed both ways through the row, the physical effort associated with repeating the same motion all the time is decreased. Other results from Morogoro (Mongi et al. 1976) have also suggested a saving of time and labour as a result of hilling.

Intimate Interspecific Plant Association

The environment existing in a cereal-legume intercropped plot has received a considerable amount of attention in intercropping literature. Effort has been expended to gain an understanding of the features of an intercropped canopy that lead to an improved yield. Of the two intercropping systems being compared in the present experiment, the alternate-hole arrangement achieves a more uniform distribution of plants over the plot at each level of hilling, which should improve the interception of light. Better utilization of environmental resources, light in particular, have been considered responsible for yield increases due to intercropping (Baker and Yusuf 1976; Willey 1979; Willey and Osiru 1972). The monetary returns from a maize-soybean intercrop trial (Mongi et al. 1976) and the relative yield total from maize-soybean and sorghum-soybean trials (Finlay 1975) have all shown the alternate-row arrangement to be superior to the same-hole or same-row arrangement of intercropping. The alternate-hole arrangement of the present experiments produced more uniform plant spacing but, in contrast to these other reports, the grain yield per plot and the relative yield totals were not superior in the alternate-hole intercropping system in comparison with the same-hole intercropping system. In fact, the number of harvestable plants per plot and the grain yield per plot produced the opposite effect to that expected. Thus, factors other than light interception alone must be responsible for the superior performance of the cereal-legume mixture in the same-hole intercropping system.

The advantage of the same-hole intercropping system over the alternate-hole intercropping system may result from the often suggested transfer of nitrogen from a legume to a nonlegume (Agboola and Fayemi 1971; Finlay 1975). The precise interaction between intercropped legume and cereal species is not well understood. It has been observed that a reduction in soybean nodule formation and size occurred as a result of shading (Wahua and Miller 1978). Other authors (Thompson 1977; Willey 1979) have suggested that the depletion of nitrogen by the cereal caused an increase in nitrogen fixation that was observed as a stimulation of nodule number and weight. The present results coincide better with the latter theory because the response was from the intercropping system with the greater cereal and legume root contact. If the legumes were stimulated to greater nitrogen fixation in the same-hole intercropping system, then the results can be interpreted to indicate that the legume itself benefited from the additional nitrogen fixation. This conclusion is based on: (1) a larger number of legume plants at harvest in the same-hole intercropping system, and (2) maintenance of yield at or above that of the alternate-hole intercropping system.

The mingling of legume and cereal roots has been cited for its beneficial effects (Osiru and Willey 1972; Trenbath 1974) as well as its detrimental effects (Fisher 1979; Mongi et al. 1976). Other studies (e.g., Keswani et al. 1977) have reported a definite change in the rhizosphere environment with respect to the proportions of bacterial and fungal organisms as the cropping system changed from monoculture to soybean-maize intercrop. This study (Keswani et al. 1977) could not correlate rhizosphere changes with grain yield. Although rhizosphere measurement was not one of the variables in the present study, similar rhizosphere changes in the maize-soybean and maize-cowpea mixtures may have been responsible for the favourable effects produced by the same-hole intercropping system.

Conclusions

(1) The change from monoculture to intercropped conditions significantly lowered the yield of each component in the cereal-legume mixtures but did not significantly affect the number of harvestable plants per plot per species or the relative yield total.

(2) Intercropping both components of the mixtures in the same hole rather than in alternate holes was advantageous with respect to obtaining a significantly larger number of harvestable plants and a consistently larger, although not significantly larger, grain yield.

(3) Grouping the plants in hills of 1-4 plants/species/hill did not significantly affect any of the characters being measured.

(4) Interplant spacings wide enough to allow the passage of a hoe through the row were less tiring during weeding than narrower spacings.

(5) The improvement in grain yield in the same-hole intercropping system was not entirely due to the improved light interception that occurred as a result of intercropping. The intimate association of the components of the mixture below the soil surface probably resulted in the advantages expressed through mutually improved plant stands and grain yields. The advantages may have occurred through the stimulation of additional nitrogen fixation or the creation of a root environment more suited for the growth of the cereal-legume mixture.

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Discussion

Anandajayasekeram (question): The two workers have provided technical information based on plant density and different crop combinations. It would have been more useful if the economic viability, superiority, and suitability of these systems could be identified so that it would be of some direct use to the small holders of Tanzania in improving their productivity.

May (answer): The aim of the experiment was restricted to gaining information on the operation of the intercropping system. When we understand the interactions occurring between the intercropped components, then the relevant points can quickly and easily be extracted for extension workers.

Jana (comment): When economists talk about economic viability, they always forget to include some "invisible" benefits of the intercropping systems. For example, this system is giving reasonably good yield under farmers' field situations without such inputs on a sustained basis. In economic terms, the benefits may not be attractive, but it is important that this system maintains the quality of the ecosystem.

Wilson (question): Could you interpret the slight advantage in same-hole planting to better moisture usage due to storage in the wider interrow space?

May (answer): Moisture measurements were not taken during the experiment and may indeed be a determining factor. However, considering the lack of difference among the hilling treatments, I would not suspect that moisture usage is the major factor.

Monyo (question): The papers that have been presented cover a range of agronomic, environmental, and cropping situations. Interesting results have been obtained, but the conclusions and recommendations still give a vague picture of the utility or appropriateness of various cropping patterns and fertilizer placement methods to the peasant farmer. It might be more rewarding, in the future, to conduct trials at more than one location (though various seasons at one location might be just as useful) and attempt preextension trials in farmers' fields.

May (answer): More than one experimental site is very important. However, it must be ensured that good and reliable information can be acquired from these sites. Transportation and trained personnel are quite often in short supply.

Jana (comment): It is a good suggestion. In fact, we intend to go out into the farmers' fields in different locations to test our results in cooperation with our rapidly developing Departments of Extension and Continuing Education.

Nadar (question): You suggested that maize in same-hole intercropping benefited from the transference of nitrogen from the legume. Has maize been fertilized with nitrogen and how do you account for the reduction in maize yield in the intercropped system compared with the sole crop?

May (answer): The experiment received minimal fertilization in 1977 and none in 1978. The reduction in intercropping is due to competition of the species as well as reduced plant population.

Gunasena (question): In intercropping systems where alternate rows are used, root studies indicate their intermingling. Although your study is interesting from the point of view of high yield, the reason for such behaviour may not be the depletion of soil N enhancing nodulation. It may, perhaps, be due to differential depths of rooting.

Could you please comment?

May (answer): The root depths of the two species may indeed be different. However, there is nothing preventing root growth in the alternate-hole system and, indeed, there should be less competition. However, the same-hole system that has greater interspecific competition also has greater plant survival and grain yield.

Edje (question): Is there any reason why you prefer to report your yields in g/plot instead of the conventional method of g/m^2 or kg/ha?

May (answer): The importance of yield per unit area instead of per plot is that it allows for comparisons between or among different experiments even though plot sizes vary between or among experiments.