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Proceedings of the
Second Symposium on
Intercropping in Semi-Arid Areas,
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Influence of Plant Combinations and Planting Configurations on Three Cereals (Maize, Sorghum, Millet) Intercropped with Two Legumes (Soybean, Green-Gram)

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Intercropping is a cropping system that involves the growing of two or more crops simultaneously on the same piece of land in different but proximate stands. It differs from monocropping, which entails the cultivation of one crop.

Intercropping is the dominant peasant farming system in the tropics, and in Tanzania it is a traditional cropping practice characterized by minimal utilization of inputs such as fertilizers and insecticides. In general, experience with intercropping in Africa has shown that the yield of one or all of the crops in the intercrop is lower than the yield of their respective pure stands, but the combined yield from the intercrop is higher than the yield of any of the crops as a pure stand. The types and choices of crops grown are normally governed by physical, economic, and social factors.

Although many intercrops contain a legume, such as groundnuts, beans, cowpeas, or green-grams, particularly in Tanzania, the increase in yield is not attributed solely to the presence of the legume. Most farmers in Tanzania are used to intercropping but quite often they have been encouraged to grow crops in pure stand.

In the past, because researchers had little interest in intercropping, very little research on intercropping was carried out. Intercropping was looked upon as backward and disadvantageous when compared with monocropping. The reason had been due to the lack of quantitative information on the competitive merits of intercropping versus pure-stand cropping. Emphasis on plant population and yield records was not considered important and as such yields of pure-stand crops versus those in intercrops were difficult to compare. It was noted that the high yields in pure stand were due to the plant population. For this reason, emphasis was always placed on growing crops in pure stand, although most farmers were interested in practicing mixed cropping. Because very little coordinated research has been conducted on intercropping in the past, information on efficient intercropping systems is not available to the peasant farmer.

Currently, considerable emphasis is being placed upon intercropping as a better method of crop production. This is a result of recently accumulated information supporting the practice.

In this study, the crops chosen for experimentation included three cereals (maize, sorghum, and millet) and two legumes (soybean and green-gram). Each cereal was intercropped with each of the legumes at different spacings. The objective of the experiment was to test the effect of combining these crops in different arrangements or configurations on growth and yield. The choice of crops used in the experiment was based on the fact that, except for soybean, they form a major food source.

Materials and Methods

Experimental Area

This experiment was carried out at Mafiga Farm, Morogoro (latitude, approximately 6°S;

altitude, 525 m), over three cropping seasons, 1976-1978. The soils are sandy clay oxisols with a pH ranging from 5.6-6.8. The cation exchange capacity is about 21.2 meq/100 g. The area receives an average rainfall of 1000 mm. Its distribution is erratic and unpredictable. The rainfall pattern is bimodal, the short rains occurring between November and January, followed by the long rains in March. A dry spell is usually experienced in February.

Design and Treatments

The design of the experiment was a split plot with six main treatments and three subplot treatments replicated three times. Each replicate or block was made up of 18 subplots. The main plot treatments consisted of crop combinations in which each of three cereals (maize, millet, and sorghum) were combined with each of two legumes (soybean and green-gram). In the subplot treatments, three different spacings were used: alternating cereal and legume within a row, alternate rows of cereal and legume, and paired rows of legumes. The pure stands were also replicated three times, in separate plots, giving a total of 18 plots. Together with the intercrop plots, there were 72 plots (Table 1).

Sowing

Both cereals and legumes were sown at the same time on two successive dates. Sowing was carried out in rows according to the type of spacing. Gap filling or thinning was carried out, subsequently, to achieve maximum plant stand.

Fertilizer Application and Weeding

Ammonium sulphate, at a rate of 500 g per plot (277.5 kg/ha), and triple superphosphate, at a rate of 360 g per plot (200 kg/ha), were applied as a band application. Weeding was accomplished by hoeing, but weeds close to the plant were removed by hand to avoid shaking off flowers or disturbing the root system.

Pests and Diseases

To control pests in the legumes, two sprayings using 30 cc of Dimecron 50 per 20 L of water were applied. The first application did not successfully control the pests but the second application wiped out the pests completely. Stalk borer *Busceola fusca* was noticed in maize but did not cause serious damage. A few plants, however, were infected with maize streak virus disease. The disease

Table 1. Treatment, spacing, plant population per plot, and plant population per hectare.

Combination	Arrangement	Spacing (cm)	Plant population per plot		Plant population per hectare	
			Cereal	Legume	Cereal	Legume
Sorghum alone	Rows	60 × 15	200	—	111112	—
Millet alone	Rows	60 × 15	200	—	111112	—
Maize alone	Rows	75 × 30	80	—	44444	—
Soybean alone	Rows	60 × 15	—	200	—	111112
Green-gram alone	Rows	60 × 15	—	200	—	111112
Sorghum and soybean	Paired rows	60 × 15	67	133	37222	73889
Millet and soybean	Paired rows	60 × 15	67	133	37222	73889
Maize and soybean	Paired rows	75 × 30	27	53	15000	29444
Sorghum and green-gram	Paired rows	60 × 15	67	133	37222	73889
Millet and green-gram	Paired rows	60 × 15	67	133	37222	73889
Maize and green-gram	Paired rows	60 × 15	27	53	15000	29444
Sorghum and soybean	Alternate rows	60 × 15	100	100	55556	55556
Millet and soybean	Alternate rows	60 × 15	100	100	55556	55556
Maize and soybean	Alternate rows	75 × 30	40	40	22222	22222
Sorghum and green-gram	Alternate rows	60 × 15	100	100	55556	55556
Millet and green-gram	Alternate rows	60 × 15	100	100	55556	55556
Maize and green-gram	Alternate rows	75 × 30	40	40	22222	22222
Sorghum and soybean	Alternate within row	60 × 15	100	100	55556	55556
Millet and soybean	Alternate within row	60 × 15	100	100	55556	55556
Maize and soybean	Alternate within row	75 × 30	40	40	22222	22222
Sorghum and green-gram	Alternate within row	60 × 15	100	100	55556	55556
Millet and green-gram	Alternate within row	60 × 15	100	100	55556	55556
Maize and green-gram	Alternate within row	75 × 30	40	40	22222	22222

did not spread to most of the plants, however, and the resulting damage was minor.

Varieties Used

A high-yielding, medium-altitude selection of maize, MAS (A), was used. This variety is one of the best yielding varieties in the Morogoro region. For sorghum, Dobb's Bora, commonly referred to as Red type, was used. The variety matures after a period of 4 months. Improved Pelican variety of soybean was also included in the experiment. For green-gram, IPA 5910 variety was used because it is recommended as one of the highest yielding and earliest maturing varieties in the Morogoro region.

Data Collection

The data collected were of two types, data on growth parameters and yield data, each of which were analyzed statistically. The yield data were collected after the plants were harvested. The samples were made up of 16 plants from each intercrop plot. They consisted of two legumes and two cereals taken from each corner of the plot. The samples were taken three rows from the top and bottom of the plot and after the fourth plant in from the side of the plot. Sixteen plants were sampled from each of the pure stands as well. The middle rows were left for harvest. The data collected differed from crop to crop according to the character of the plant.

Maize

Measurements included plant height and number of leaves at three successive periods after seeding. The yield data included the weight and length of the cob and the straw weight. It also included grain yield from the sample plants, the entire plot, and yield per hectare. All of the yields were expressed at a moisture content of 13.5%.

Millet and Sorghum

Measurements included plant height, number of leaves on three successive dates after planting, and a count of the effective tillers on the last date, when no more growth was expected. Measurements of panicle length, for millet, and head length, for sorghum, were also taken at harvest on the sample plants. Straw was also harvested and after threshing the grain yield from the sample plants was determined at a moisture content of 13.5%. The weights were used to calculate the yield per plot and per hectare.

Soybean and Green-Gram

Data collected included height measurements and number of pods at three different periods after seeding. Numbers of leaves and branch measurements were also taken at different periods. Both straw and pod were harvested, dried at a moisture content of 14.5%, and weighed. These weights were then used for calculating the yield per plot and estimating the yield per hectare.

Results and Discussion

Results from many intercropping experiments have shown that there is usually a reduction in yield of one or both crops compared with their pure stands, but the overall yields are generally higher in intercropping. Similarly, Andrews (1972) found that relay cropping and intercropping gave 59 and 80% more return per acre, respectively, than monocropping of sorghum, the increases coming mainly as a result of higher cereal yields. In the present experiments, results show that intercropping is superior to monocropping, with an increase in productivity of 5-61% (Tables 2-4). Intercropping also led to yield reductions per hectare for both crops, with higher reductions for legumes (33-82%) than for cereals (7-37%) (Table 2). However, the combined yields exceeded the monocrop yields, except in the cereal yields in both maize associations and the green-gram combinations of sorghum and millet when planted in alternate rows of cereal and legume and in paired rows in legumes. Agboola and Fayemi (1971) suggest that the yield of the legume is usually more depressed than that of the nonlegume, and that the decrease in yields can be reduced by growing crops of widely differing habits. Enyi (1973), in his experiments at the Faculty of Agriculture, Morogoro, indicated that although intercropping maize with either beans or cowpeas decreased the total yield of grain (legume and cereal) per hectare, intercropping sorghum with pigeon peas increased the total yield per hectare. Other researchers showed no advantage in intercropping, e.g., Grimes (1963) who reported that alternate-row cropping of cotton and maize may depress the yield of one crop but the overall cash returns are as high as those from growing cotton and maize in pure stand.

Several factors have contributed to the contrasting results obtained in the experiment in 1976. It is worth considering the different types of crops used in this experiment as well as the environmental factors. Osiru and Willey (1972) suggested that the advantages that can be said to be achieved from mixing two species must be partly dependent upon the requirements of the grower. For instance, if the requirements are simply to produce the maximum yield irrespective of how much comes from either species, then for a

Table 2. Effect of treatments on grain yields (kg/ha) and land equivalent ratio (LER) values (1976).

Plant combination	Alternate cereal and legume within row			Alternate rows of cereal and legume			Paired rows of legumes		
	Yield	Total	LER	Yield	Total	LER	Yield	Total	LER
Maize + soybean	2625.1 202.7	2827.8	1.10	2690.0 222.0	2912.0	1.15	2480.0 371.9	2851.9	1.23
Maize + green-gram	2740.0 74.9	2814.9	1.12	2722.7 68.9	2791.6	1.11	1942.5 152.0	2094.5	1.05
Sorghum + soybean	960.3 432.8	1393.1	1.23	877.8 450.0	1327.8	1.19	634.5 665.8	1300.3	1.21
Sorghum + green-gram	1050.0 176.2	1226.2	1.33	1003.4 204.8	1208.2	1.36	900.1 257.9	1158.0	1.41
Millet + soybean	1214.0 436.5	1650.5	1.24	1050.0 528.4	1578.4	1.22	968.8 639.7	1608.5	1.29
Millet + green-gram	1390.9 193.9	1584.8	1.40	1287.8 199.4	1487.2	1.35	1018.6 255.6	1274.2	1.32

NOTE: For comparison, the yields (kg/ha) of the monocrops were: maize, 2932.5; sorghum, 1208.3; millet, 1540.0; soybean, 972.9; and green-gram, 384.5.

Table 3. Effects of treatments on grain yields (kg/ha) and land equivalent ratio (LER) values (1977).

Main treatment	Alternate cereal and legume within row			Alternate rows of cereal and legume			Paired rows of legumes		
	Yield	Total	LER	Yield	Total	LER	Yield	Total	LER
Maize + soybean	2755.8 695.7	3451.5	1.50	2752.7 806.7	3559.4	1.7	2443.4 944.2	3387.6	1.61
Maize + green-gram	2906.5 447.5	3354.0	1.50	2849.5 558.1	3407.6	1.61	2373.1 524.4	2897.5	1.41
Sorghum + soybean	1483.9 864.1	2348.0	1.40	1346.3 879.6	2225.9	1.36	1371.9 1048.7	2420.6	1.51
Sorghum + green-gram	1655.1 440.1	2095.2	1.28	1443.6 493.3	1936.9	1.25	1282.6 624.6	1907.2	1.33
Millet + soybean	1387.4 747.1	2134.5	1.29	1538.2 850.2	2388.4	1.44	1381.4 918.2	2299.6	1.42
Millet + green-gram	1463.7 453.9	1917.6	1.23	1473.1 495.1	1968.2	1.28	1508.4 593.7	2102.1	1.41

NOTE: For comparison, the yields (kg/ha) of the monocrops were: maize, 2981.7; sorghum, 2152.6; millet, 2097.1; soybean, 1184.2; and green-gram, 840.5.

Table 4. Effects of treatments on grain yields (kg/ha) and land equivalent ratio (LER) values (1978).

Main treatment	Alternate cereal and legume within row			Alternate rows of cereal and legume			Paired rows of legumes		
	Yield	Total	LER	Yield	Total	LER	Yield	Total	LER
Maize + soybean	3615.56 501.11	4116.67	1.12	3470.56 926.11	4396.67	1.34	3043.33 953.33	3996.66	1.26
Maize + green-gram	2865.00 470.56	3335.56	1.19	2549.44 628.33	3177.77	1.30	2135.56 778.33	2913.89	1.37
Sorghum + soybean	3206.67 659.28	3865.95	1.27	3467.78 596.67	4064.45	1.32	2977.78 633.33	3611.11	1.19
Sorghum + green-gram	3271.67 498.89	3770.56	1.47	3601.67 345.56	3947.23	1.39	3018.33 636.11	3654.44	1.56
Millet + soybean	2994.44 535.00	3529.44	1.24	2466.67 611.11	3077.78	1.12	2505.56 777.72	3283.28	1.24
Millet + green-gram	3155.56 512.22	3667.78	1.57	2580.56 594.44	3175.00	1.48	2573.89 544.40	3118.29	1.42

NOTE: For comparison, the yields (kg/ha) of the monocrops were: maize, 4400.00; sorghum, 3611.11; millet, 3222.20; soybean, 1666.67; and green-gram, 870.56.

mixture to give a yield advantage, it must exceed the maximum yield of the higher yielding species. If it does not, it would be more advantageous to grow only the higher yielding species. This argument could apply, for example, where two cereals are being grown and are equally acceptable. When two species such as a cereal and a legume are grown, however, the situation is very different. These two species produce very different yields and at the peasant level the grower requires some yield from each species. In this instance, therefore, an advantage occurs if the mixture produces more yield from a given area of land than can be obtained by dividing the area into pure stands of the two species. On this basis, a yield advantage can occur without the mixture exceeding the yield of the maize associations because the yielding capacity of maize (118.1 g/plant) is very high in the 1976 experiment if compared with soybeans (7.8 g/plant) and green-grams (3.4 g/plant). In such a case, all of the combined yields of maize associations are lower than the maize monocrop yield. However, this is not the only factor because a different situation is shown in the millet and sorghum associations (Jana and Sekao 1976) and this can be attributed to environmental factors.

In fact, the 1976 experiment was started in mid-April, toward the end of the rainy season. Rainfall was very low or nonexistent, whereas temperatures were high throughout the growing season. There was a heavy rainfall in the 2nd week of May that almost destroyed the plants. It was followed by a period during which little rainfall was received and the plants were again subjected to drought. This dry spell contributed greatly to yield decreases and low yields per plant. Normally, intercropping assumes that the two species used can exploit the environment better than one and the yields per plant of one or both intercrops are expected to be higher than those of the individual monocrops. This can be achieved through greater utilization of environmental resources such as differences in rooting depths and growth cycles. Such assumptions can be noticed in the cotton interplanting experiments carried out by Anthony and Willimot (1952) where they observed that a significant loss in cotton yield was compensated for in varying degrees by the yield of the legume crop. In the present experiment, the yielding capabilities of the plants were affected more by the plant character. Crops such as green-grams were significantly affected by drought and yields per plant were very low. Moreover, no difference exists in the legume yields between the intercrop and the same monocrop yield per plant, which indicates that intercropping had no beneficial effect on the individual legume plants and only contributed to higher yield reductions per hectare in the legume component. The cereal intercrop yields per plant, however, are higher than those of the same monocrops and the paired rows of legume configuration shows higher yields in all associations. Therefore, the yield reductions per hectare were lower in the cereals than in the legumes.

Another factor that contributed to the yield reductions per hectare is plant population. This applied particularly to the maize combinations in which the wider spacing used led to low plant population per hectare in the legume association and, hence, low yields per hectare. The legume yields per hectare of the maize contributions are lower than those of the millet or sorghum associations. With the additional factor of low plant population per hectare and low yields per plant, the yields per hectare were greatly reduced.

Different results could have been obtained if the above-mentioned factors were not present, but, in general, the yield of legumes was not affected by the different configurations used. Cereals, on the other hand, tended to have better chances of nutrient utilization due to the wider spacing used, resulting in higher yields per plant. With the paired rows of legumes intercropped between cereal rows, the spacing was still wider and, hence, the competition with the next cereal and associate was greatly lowered, contributing to even higher yields than in the other two planting arrangements. Similar inferences can be made from the results in which dry weights per plant in the legumes were more or less constant regardless of the spacing used, whereas cereal dry weights per plant are higher in intercrops than monocrops, with the paired rows of legumes arrangement showing the highest weights. High dry weights may indicate that a larger photosynthetic area was involved and, therefore, resulted in higher yields.

Relation of Yield and Growth Parameters

Tiller number in the three different planting arrangements did not differ within the intercrops, but the monocrops showed more tillers than the intercrops. This does not necessitate higher yields, however, because the effective tillers did not differ from monocrop to intercrops. Millet showed a larger number of effective tillers than sorghum, which also reflected higher yields per plant. The yielding capacity of millet is, probably, higher than that of sorghum.

The number of leaves in the legumes in the three different planting arrangements showed only a slight variation, indicating that photosynthetic activity was almost uniform, leading to only a slight variation in yields per plant. Similarly, the number of branches did not show any variation, except for the millet combination, which showed a slightly lower number of branches compared with the other combinations. This is also seen in the number of pods per plant, where the millet combination showed a slightly lower number of pods per plant than the other two combinations. This could be due to the fact that millet is fast growing and early maturing and, thus, could have deprived its associate of nutrients, leading to slightly lower branching capacity, which affected pod formation and, hence, yield. Of the legumes, the soybeans branched noticeably, but the green-grams did not. This is probably due to the effect of adverse moisture stress as well as the attack by bean fly, which necessitated replanting of the crop. The result was very low yields per plant (1976 experiment).

Intercropping systems used by farmers (cereals plus legumes) do not necessarily give the best returns in terms of yield because the farmers, generally, do not select the most compatible varieties for intercropping. It is only by chance that the cereals and legumes used in intercropping systems are ones that are common in a particular area. As shown in these experiments, different crops show different results under the same cropping systems and combinations, some giving better results than others. Improvement in the intercropping systems used by farmers could be a step forward because higher returns can be seen either in terms of yields or cash. This improvement could be achieved through selecting crops of widely different habits (for better utilization of moisture and nutrients with less competition), as well as appropriate spacing, which will produce a reasonable plant population and provide good yields per hectare.

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Discussion

Sengoba (question): What was the relationship between pest and disease incidence or severity and the plant groupings?

Jana (answer): We did observe the incidence of pests and diseases under different treatments. Visual observations indicated that sole cropping treatments, particularly green-gram, were more affected than intercropping treatments.

Shayo-Ngowi (comment): The terms available moisture, upper limit, and lower limit have been used very loosely by most agronomists. When you talk of upper limit, you have to define moisture at exactly (metric potential) 0.1, 0.2, 0.3, or some other level. Apparently, earlier work in Rhodesia (now Zimbabwe) has shown that for tropical soils field capacity should be taken as 0.1 bar rather than the conventional 0.33 bar.

Jana (comment): Agronomists are also well aware that the past concept of available moisture between 0.33 bar and 15 bars does not hold for all soils. In fact, some work was carried out on the subject during the 1960s (Ghildyal, B. P. and Jana, R. K. 1966. Influence of soil water potential on rice germination and seedling emergence. RISO, 15,3, 211-217). In this particular case, when moisture was determined by conventional methods, it is safe to express it in terms of upper and lower limits for easy understanding by most of the readers because actual metric potential of this soil at field capacity and permanent wilting point was not measured.

Kayumbo (comment): The papers presented by Dr May and Professor Jana, in addition to being interesting and well presented, show the complexity of the intercropping systems. Although both researchers worked on planting arrangements — planting two species in the same hole, planting in alternate holes, planting in alternate rows, etc. — the results obtained do not necessarily complement each other. In the light of these results, how should we proceed with future research regarding spatial arrangement trials? Could we extrapolate and draw up tentative recommendations, or would further research be required? If so, along what lines?

May (comment): The various papers presented here and elsewhere should be compared in detail. The similar aspects should be considered as truths and those that are different should form the basis for future research.

Jana (comment): Our results on the experimental site for 3 years are conclusive. On the basis of rainfall patterns and other environmental parameters, results can be extrapolated to some extent, but there is a need to test these in more locations.

Gathee (question): The plant combinations do not include maize and beans, which in my view should be given priority being the most common food crop combination. Why was this combination excluded?

Jana (answer): At Morogoro, we tried several cereals and several legumes in intercropping. In other experiments, maize/bean combinations were tried by my colleagues and the results will be presented later at this symposium.

Mongi (comment): Work done at Morogoro, Mogadishu, and several locations in Kenya shows that intercropping in semi-arid areas results in serious moisture competition among intercrops and, therefore, reduces the overall land equivalent ratio or yields of both crops. In this case, however, intercropping would still have to be considered for socioeconomic reasons because weather changes are unpredictable.

May (comment): I believe intercropping advantages lie in greater production per unit area. This is very important where land is limited for various reasons.

Jana (comment): Our results clearly indicate that during a relatively dry year maize/legume combinations do not perform well, whereas sorghum/bulrush millet/legume combinations give better yields. Hence, crop competition for moisture can be reduced by selecting proper crop combinations, and this is one of the objectives of the exercise.

Reddy (question): This is a general question to all of the speakers who presented papers this morning and also to other intercropping scientists. We have been hearing for several years that such and such an intercropping combination gives much higher yields, and the reasons may be due to better use of light or better use of moisture, or due to transfer of nitrogen from legume to cereal. All of these advantages are location specific. It is time for us, the intercropping scientists, to try to understand the reasons for obtaining intercropping advantages and how these results could be transferable to other areas by conducting some basic research.

May (answer): I agree completely. My studies are based more on the assumption that yield advantages are possible with intercropping and are aimed at determining why this advantage occurs.

Jana (answer): All agricultural field research is essentially site specific. In other fields (other than intercropping), lots of basic information is known; even in those cases, the results are location specific.