HAITI AGROFORESTRY RESEARCH PROJECT

SOUTH EAST CONSORTIUM FOR INTERNATIONAL DEVELOPMENT/

AUBURN UNIVERSITY

April 1991

THE EFFECTS OF ALLEY CROPPING AND FERTILIZER APPLICATION ON CONTINUOUSLY-CROPPED MAIZE

by

Dennis A. Shannon, Wolfgang O. Vogel
and
Kapinga N. Kabaluapa

SECID/AUBURN AGROFORESTRY REPORT No. 30

The views expressed herein are the views of the contractor and not necessarily the views of USAID.

NOTE

Although the research described in this report was accomplished in Zaire while the primary author was with the International Institute of Tropical Agriculture in the Applied Agronomic Research and Extension Project funded by USAID/Kinshasa, the results have application in many other regions and can be useful in the implementation of the Agroforestry II Project in Haiti.

Hedgerows have been accepted by many Haitian farmers for use as a barrier to erosion and as a forage for livestock, but are not generally managed as a soil amendment. Crops may benefit due to soil accumulation above the hedgerows and improved moisture retention within a restricted area, but little benefit to the crops may be expected throughout much of the alleys. In this paper, evidence is presented to show that higher crop yields may be possible by applying the prunings to the entire alley in order to improve the nutrient status of the soil. The trial reported herein was conducted on flat land, so no soil was accumulated by the hedgerows. Yield increases due to alley cropping may be attributed only to improved nutrient status or increased organic matter content in the soil.

Of major significance in this study is the evidence it provides to suggest that <u>the beneficial effects of alley cropping may be cumulative</u>. Farmers who practice alley cropping may actually increase the productivity of their land over time. Because of the significance of these results and the high probability that they would apply to Haiti, SECID/Auburn University is distributing this paper as part of its Haiti Agroforestry Research Report Series.

CONTENTS

THE EFFECTS OF ALLEY CROPPING AND FERTILIZER APPLICATION ON CONTINUOUSLY-CROPPED MAIZE

by

Dennis A. Shannon, Wolfgang O. Vogel
and
Kapinga N. Kabaluapa

EXECUTIVE SUMMARY

A trial was conducted to study the effect of alley cropping on maize under continuous cropping. Treatments consisted of alley cropping and control (no hedgerows), with and without fertilizer. Maize was planted twice a year for a total of eight crops. Alley cropping resulted in higher maize yields than no alley cropping from the fourth crop onward. Fertilizer application increased yield in all seasons. Highest yields averaged across seasons were obtained with a combination of alley cropping and fertilizer application. Time trends were estimated by multiple regression for grain yield over seasons. Account was taken in the regression equation of seasons where drought or other factors severely reduced yields. Without alley cropping, maize yields declined, while with alley cropping, maize yields increased over time.

REZIME

Nou fè yon ètid sou èfè ramp vivan genyen sou kilti mayi ki nan mitan yo pandan plizyè sèzon. Nou tè komparè mayi ki nan mitan ramp vivan ak mayi ki pa nan mitan yo kom tèmwen, tou dè (2) ak angrè è san angrè. Sou yon total de 8 rèkot, mayi yo tè plantè dè 2 fwa pa anè. Dèpi sou katrièm rèkot, nou tè konstatè mayi ki nan mitan ramp vivan bay plis randman kè mayi ki pa nan mitan ramp vivan. Angrè tè fè randman yo montè nan tout sèzon. Pandan sèzon yo, pi gwo randman tè soti nan mayi ki nan mitan ramp vivan ak ki jwen angrè. Pou nou tè èstimè chanjeman ki fèt pandan sèzon yo, nou fè yon règresyon miltip ak randman gren'n sou sèzon. Nan ekwasyon règresyon-an, nou tè konsidèrè sèzon ki pa bay lapli ak lot faktè ki rèdwi randman yo. San ramp vivan, randman mayi tè dèsan'n, ak ramp vivan, randman mayi tè ogmantè sèzon pa sèzon.

The effects of alley cropping and fertilizer application on continuously-cropped maize

D.A. Shannon[1] and W.O. Vogel[2]

International Institute of Tropical Agriculture, Ibadan,Nigeria

K.N. Kabaluapa[3]

Programme National Légumineuses, Gandajika, Zaire

Present Addresses: [1] Haiti Agroforestry Research Project, c/o Lynx Air, P.O. Box 407139, Ft. Lauderdale, FL 33340, U.S.A.; [2] c/o International Agricultural Programs, University of Arkansas, 300 Holtz Hall, Fayetteville, AR. 72701, U.S.A.; [3] Centre de Recherche sur le Mais, B.P. 4983, Mbuji Mayi, Kasai Oriental, Zaire

A trial was conducted to study the effect of alley cropping on maize under continuous cropping. Treatments consisted of alley cropping and control (no hedgerows), with and without fertilizer. Maize was planted twice a year for a total of eight crops. Alley cropping resulted in higher yields than no alley cropping from the fourth crop onward. Fertilizer application increased yield in all seasons. Highest yields averaged across seasons were obtained with a combination of alley cropping and fertilizer application. Time trends were estimated by multiple regression for grain yield over seasons. Account was taken in the regression equations of seasons where drought or other factors severely reduced yields. Without alley cropping, maize yields declined, while with alley cropping, maize yields increased over time.

Key Words: Alley cropping, Leucaena leucocephala, Fertilizer, Maize, Time trends

Alley cropping, is an agroforestry system designed as an alternative to shifting cultivation, for continuous cultivation and sustained crop production (Kang et al., 1984). Continuous cultivation of tropical soils without fertilizer use is known to lead to a general decline in yields over time (Kang and Balasubramanian, 1990; Sanchez, 1976; and Stifel, 1989). Alley cropping in the forest/savanna transition zone of Nigeria resulted in stable yields over an eight-year period. When hedgerow prunings were removed from alley-cropped plots, yields declined over the same period (Kang, 1989).

No information was available on the long-term effects of this system on crop yield in the savanna regions of Zaire. The present trial was located at Gandajika in the "wooded Guinea savanna" (Fahem, 1978). In a survey conducted in a village near the Gandajika station, it was observed that fallow periods have decreased to 2-3 years following 3-4 years of cropping, while some farmers no longer fallow their land. Fertility is no longer restored and yields have declined. These are conditions where alley cropping would be most relevant to stabilize or even increase yields.

The objectives of this trial were to determine the effects of alley cropping and fertilizer use on continuous maize production.

Materials and methods

The trial was established on a sandy loam Alfisol on the Gandajika station (780 m altitude, 7° S. latitude). Rainfall averages 1400 mm between late August and mid May, permitting two maize crops a year. The first planting in September is designated Season A and the second planting in January or February is designated Season B. The trial site had previously been planted to cassava. The crop had been harvested three months previously and the site had been abandoned because of low productivity and termite damage. There was no record of fertilizer use in the trial plot.

The trial design was a 2 X 2 factorial in randomized complete block with four replications. Treatment factors were presence or absence of hedgerows and presence or absence of fertilizer. Maize variety, Salongo II, was planted in all plots for the four consecutive years (eight seasons). Leucaena leucocephala, giant Hawaiian variety, which grows well on slightly acid soils, was chosen for the hedgerows.

Plots measured 8 m X 11 m. Two hedgerows 4 m apart and 11 m long were planted in alley plots. In fertilized plots, 64 kg N and 46 kg P_2O_5 were applied to the maize crop in bands, as diammonium phosphate at planting and urea at 30-40 days after planting. After three seasons, the P rate was reduced to 30 kg/ha P_2O_5 to avoid nutrient imbalances associated with over-fertilization with P, and potassium sulfate, at a rate of 30 kg K_2O/ha, was added because K deficiency symptoms were observed on lower leaves of maize. These rates were maintained for the remaining five seasons.

The leucaena was planted together with maize on 28 January 1986. Maize was planted at a spacing of 80 cm X 23 cm, or a population of 53,333 plants/ha. Scarified leucaena seed was planted at 2 seeds/hill at 20 cm interval mid-way between maize rows, and later thinned. The harvest area was 4 m X 9 m in all plots. In subsequent seasons, the spacing of maize was changed to 75 X 25 cm. This maintained the density in plots without alleys at 53,333 plants/ha. In plots with alleys, this widened the spacing between the hedgerow and the adjacent maize row from 40 cm to 87.5 cm and reduced the maize density to 50,000 plants/ha. The harvest are was reduced to 3.75 m X 9 m in plots without alleys but was unchanged in plots with alleys. From the sixth season onward, the number of rows of maize between the hedgerows was reduced from five to four, to reduce competition between the hedgerows and the maize. The in-row spacing was not altered, so that the density was reduced to 40,000 plants/ha. In the eighth season, the number of rows harvested was increased to 7 rows in plots without alleys and 6 rows in plots with alleys, giving harvest areas of 5.25 m X 10.5 m and 6.55 m X 10.5 m, respectively.

Hedgerows were pruned at 50 cm height beginning on 11 September 1986, prior to seeding the second maize crop. A two-month pruning cycle was followed until the end of the third season. From then on, the hedgerows were pruned at 5-6 week intervals, with two or three prunings per season. The prunings were divided into leaves and branches and returned to the plots as mulch. Large hardwood branches were not returned to the plots.

The data from each season were analyzed by analysis of variance. Missing data estimates were calculated for one plot in Seasons 1 and two plots in Season 2.

Time trends for each treatment were estimated by regressing yield on seasons (McCleary and Hay, 1980). Rainfall records and field observations were used to identify seasons where environmental factors severely limited yields. Four seasons fell into this category. In 1986 Season B, drought occurred during grain filling; in 1986/87 Season A, drought occurred during and immediately following silking, and a storm caused lodging soon after silking; in 1987/88 Season B, downy mildew reduced stands, some drought occurred during the grain filling period and stem borers and termites caused injury and lodging; and in 1988/89 Season B, drought occurred during the grain filling period. A dummy variable for these seasons was included in the regression. Three dummies were included to account for block effects. Only in the treatments including fertilizer did the block effect improve $\bar{R}^2$.

The block-dummies were dropped from those regressions where they did not improve the fit.

The length of the analyzed time series differed between treatments. A beneficial effect from alley cropping was not expected to occur during the year when the hedgerows were established. Thus the first two seasons were excluded from the time series for alley-cropped plots. The mean of the first two seasons was used in the graph of these plots.

Results

Comparison within Seasons

Fertilizer application significantly increased yield in all seasons, as determined by analysis of variance procedures within seasons (Figure 1). During the first two seasons, the biomass from the hedgerows was not sufficient to increase maize yields. During the third season, the central rows of maize within the alleys produced more than the respective rows in plots without hedgerows (Table 1), but this gain was negated by poor yields of maize in the rows adjacent to the hedgerows.

This competition between the hedgerows and the adjacent maize led us to alter the pruning schedule from once every two months (except during the dry season) to a 5-6 week pruning cycle, with 3 and later 2 prunings per season. From the fourth season onward, maize in alley plots yielded consistently and significantly higher than without alley cropping (Figure 1).

There was no significant interaction between fertilizer and alley cropping treatments. Highest yields averaged over all seasons were obtained by combining alley cropping with the fertilizer application.

Biomass production averaged 10-11 t/ha of fresh biomass per year in the first two years of pruning, but increased to 25-26 t/ha per year in the last year and a half (Table 2). Fertilization had no significant effect on biomass production except for the prunings of 20 March 1987 and 15 January 1988, when higher biomass yields were obtained without fertilizer than with fertilizer. These dates correspond to the first pruning dates of Season B trials. The more vigorous growth of maize in fertilized plots in the preceding seasons may have suppressed growth of the hedgerows.

Time Trend Analysis

Maize yields showed significant downward trends over time in plots without alleys (Figures 2 and 3). Significant upward trends were obtained with alley cropping (Figures 4 and 5). The predicted values correspond closely to the real observations.

Discussion

Long-term yield trend

Two factors must be considered when examining the yields over the eight seasons: the long-term trend, associated with continuous cultivation of maize, and the seasonal fluctuations associated with the approximately bimodal rainfall pattern which occurs in Gandajika. In general, higher yields may be expected in Season A than in Season B because of more reliable rainfall and lower incidence of disease and insect pests, and the nutrient flush following the onset of rains after the long dry season (Semb and Robinson, 1960, cited in Sanchez, 1976).

The A Season of the 1986/87 cropping year was exceptional. A drought occurred during silking, a storm caused early lodging and downy mildew led to plant losses. In the subsequent Season

B, though some drought was experienced during grain filling, no drought occurred during the critical silking period and yields were better than usual for Season B. Thus the seasonal trends were reversed in the first three seasons (Figure 1).

From the third season onward, a decrease in yield over time was visible in B (odd) seasons in the control, no fertilization treatment (Figure 1), but not in A seasons. Yields appeared to recover in A seasons. This recovery might be attributed to nutrients released during the flush of microbial activity following the dry season.

By regression analysis, the loss in yield due to continuous cropping without fertilizer was estimated at 152 kg/season (Figure 2). Omission from the analysis of the last season did not change the slope. The downward trend was consistent with results reported by Kang and Balasubramanian (1990), Sanchez (1976) and Stifel (1989).

Fertilization initially increased yields in the control treatment, but the long-term trend of 170 kg yield loss per season was not statistically different from that without fertilizer (Figure 3). Seasonal fluctuations in yield were greater with fertilizer application.

These results differ from Sanchez (1976). From his review of data from tropical soils he concluded that without fertilizer use yields declined with continuous cultivation, while with adequate fertilization, yields remained stable. It appeared that in the control treatment, even with NPK application, yield declined over time due to deficiency of other nutrients. Kang and Balasubramanian (1990) also reported that even with "adequate" NPK fertilization and crop residue retention, yields declined until the fifth year after forest clearing and stabilized at lower yields through the twelfth year of the trial.

Yields in alley plots without fertilizer application remained low but fluctuated little across the first seven seasons (Figure 1). This is particularly noticeable in seasons 5 and 7, where unfavorable environmental conditions greatly reduced yields. Perhaps improved moisture retention with higher soil organic matter levels in alley plots (Kang et al., 1984) enabled the maize to better withstand drought than in plots without alleys.

The increase in maize yield of 162 kg/ha per season was highly significant (Figure 4), confirming that alley cropping improved soil productivity. The higher yield in the eighth season may be attributed to a combination of favorable climatic conditions and a buildup in soil fertility due to alley cropping. When the data was analyzed without the eighth season, the slope was smaller (58 kg/ha/season) but still significant, indicating that the upward trend was not simply a function of high yields in the last season. The difference in slopes between the analysis of five and six seasons was highly significant.

The combined use of fertilizer and alley cropping resulted in the highest yields from the fourth season onward (Figure 1). Maize yields with alley cropping and fertilizer application fluctuated more than with alley cropping alone, but this was mainly because fertilizer allowed the maize to profit most from the best seasons (seasons 4, 6 and 8 in Figure 1). Maize in alley-cropped plots without fertilizer was not able to respond to favorable climatic conditions by producing high yields until the final season.

The upward trend was more visible in the more favorable A seasons (Figure 1) than in B seasons. Crops in A seasons also benefitted from larger quantities of biomass which accumulated during the dry season (Table 2). The increase in yield of 176 kg/ha per season was highly significant (Figure 5).

These results demonstrate the usefulness of regression analysis to interpret long-term trends. From visual observation of Figure 1, there appeared to be a downward trend for maize yields in plots without alleys, and an upward trend in plots with alleys. However, strong seasonal fluctuations owing to rainfall, disease incidence, particularly of downy mildew, stem borers and other environmental factors blurred the picture. Standard analysis of variance procedures did not help to clarify the long-term trends. By regression analysis procedures, it was possible to isolate the trend component.

By including in the analysis biomass applied at each pruning and estimates of N content, it should be possible to separate short and long-term benefits of alley cropping. The former would be yield increases owing primarily to N nutrition; the latter owing primarily to improvement in soil physical properties. We were not able to obtain dry weights of different plant parts, and thus could not adequately estimate these components of the time trend.

Benefit of alley cropping

Alley cropping is a system in which short-term losses are compensated by longer-term gains. Hedgerows compete with the crop for light, water and soil nutrients. In the long term, they benefit the crop through recycling nutrients, adding symbiotically fixed N, and adding organic matter which may improve structure and moisture retention properties of the soil (Kang et al., 1984). Crop yields may increase or decrease depending upon whether the beneficial effects are greater than the competitive effects. The relative importance of each of these factors changes over time as the hedgerows develop and are also influenced by husbandry of the hedgerows and the crop.

In the season of establishment, alley cropping decreased yields by 24%, though this reduction was not statistically significant. This season was characterized by drought stress during the grain-filling period of maize. Similar non-significant yield losses in the season of hedgerow establishment have been observed in other alley cropping trials (Kabaluapa and

Shannon, unpublished data). It is likely that competition for water between the leucaena and the maize reduced maize yields.

The first season in which a positive benefit from alley cropping occurred, as determined by analysis of variance, was in the fourth season (Figure 1). By the third season, it became apparent that the pruning frequency of hedgerows was inadequate to prevent competition from the hedgerows on the maize. Maize plants in rows adjacent to the hedgerows were etiolated, shorter and yielded less than maize plants in the center of the alleys. Had the pruning interval been shortened to minimize competition between the crop and hedgerow, a positive benefit might have been recorded as early as the third season (Table 1).

By the seventh season, yields in the control with fertilizer dropped below that of the alley cropping treatment with no fertilizer applied (Figure 1). In this case, it seems that the benefits from fertilization alone were short-term.

From these results, it can be concluded that alley cropping can be used as a substitute for fertilizer application. However, five seasons were required before alley cropping alone gave similar yields to fertilizer application alone. By combining the two practices, it was possible to benefit from fertilization in the short-term while increasing productivity in the long-term.

Based on 1989 prices of maize in Gandajika, fertilizer application would not be profitable in seasons where environmental conditions do not permit an adequate response to fertilizers. Since Season B is more prone to drought, disease and insect attacks, fertilizer should be applied in Season A, when the chances of favorable environmental conditions are greater.

Conclusions

While the role of alley cropping in stabilizing maize yields has been documented, this is the first case, to our knowledge, where alley cropping has been shown to increase maize yields over time. The combined advantages of maintaining land in food production for long periods, while improving soil productivity, make alley cropping an ideal solution for areas where population pressures have resulted in reduced fallow periods and declining productivity. Integrating alley cropping with moderate fertilizer use may be the best means to stabilize yield and to increase productivity for farmers in such conditions.

Acknowledgements: The contributions of M.L. Ngoyi and N. Mudiangombe in data collection are gratefully acknowledged. Thanks are due to the Government of Zaire for providing administrative support and facilities for this research and to the United States Agency for International Development, who funded this research in its entirety.

References

Fahem, A.K. 1978. Vegetation. pp. 20-21 In Laclavère, G., Atlas de la Republique de Zaire. Editions Jeune Afrique, Paris.

Kang, B.T. 1989. Alley cropping/farming: Background and general research issues. Paper presented at the AFNETA inaugural meeting, International Institute of Tropical Agriculture, Ibadan, Nigeria, 1-3 August 1989. 20 pp

Kang, B.T. and V. Balasubramanian. 1990. Long term fertilizer trials on Alfisols in West Africa. Transactions, 14'th International Congress of Soil Science, Kyoto, Japan. **4** 20-25

Kang, B.T., G.F. Wilson and T.L. Lawson. 1984. Alley cropping: a stable alternative to shifting cultivation. International Institute of Tropical Agriculture, P.M.B. 5320, Ibadan, Nigeria. 22 pp

McCleary, R. and R.A. Hay, Jr. 1980. Applied time series analysis. Beverley Hills, London. 331 pp

Sanchez, P.A. 1976. Properties and management of soils in the tropics. John Wiley & Sons, New York. 618 pp

Semb, G. and J.B.D. Robinson. 1969. The natural flush in different arable soils and climates in East Africa. East Afr. Agr. For. J. **34** 350-370

Stifel, L.D. 1989. IITA Research for Sustainable Agriculture in Africa. Presentation to the CGIAR at International Centers Week, Washington, D,C., U.S.A. 16 pp

Table 1. The effects of alley cropping and fertilizer application on the yield of maize in the central three rows of plots and on a whole-plot basis in the third season at Gandajika, Zaire.

	Maize Yield	
	Central Rows	Whole Plot
	kg/ha	
Control, no fertilizer	1490	1560
Alley cropped, no fertilizer	1690	1320
Control + fertilizer	2370	2570
Alley cropped + fertilizer	2840	2310
$LSD_{.05}$	490	347
CV %	15	11
Significance of Main Effects		
Alley Cropping	$P < 0.10$	$P < 0.05$
Fertilizer	$P < 0.005$	$P < 0.005$

Table 2. Fresh biomass production from <u>Leucaena leucocephala</u> hedgerows over seven seasons.

Season	Growing Season[a]	Fresh Biomass t/ha	Number of Cuttings
1	B	0	0
2	A	5.1	3
3	B	6.3	2
4	A	5.5	3
5	B	4.8	3
6	A	14.2	2
7	B	12.1	2
8	A	13.4	3

[a] Season A (September to January), Season B (January or February to May or June).

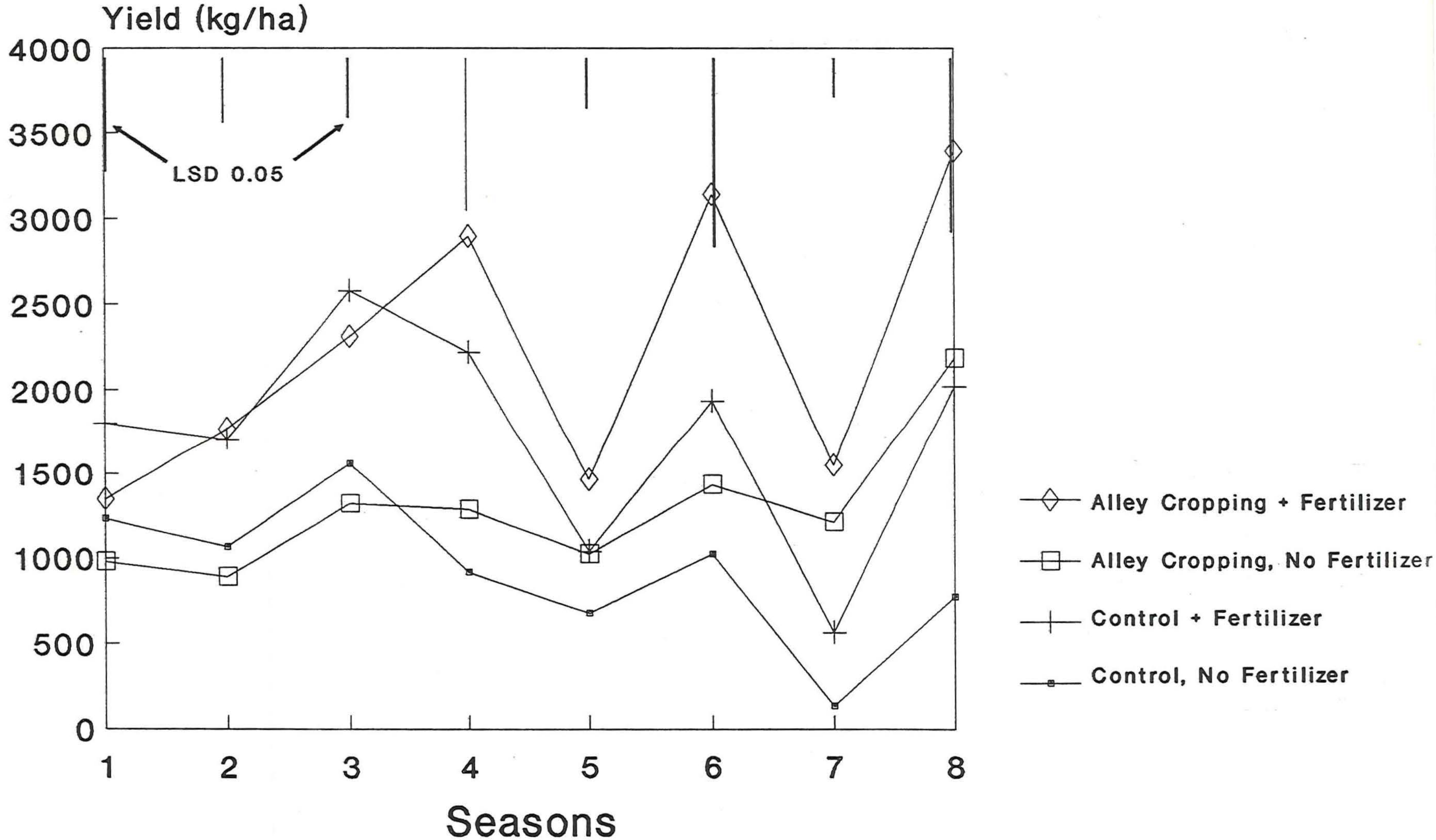
Figure 1. The effects of alley cropping and fertilizer application on maize yields during eight seasons at Gandajika, Zaire.

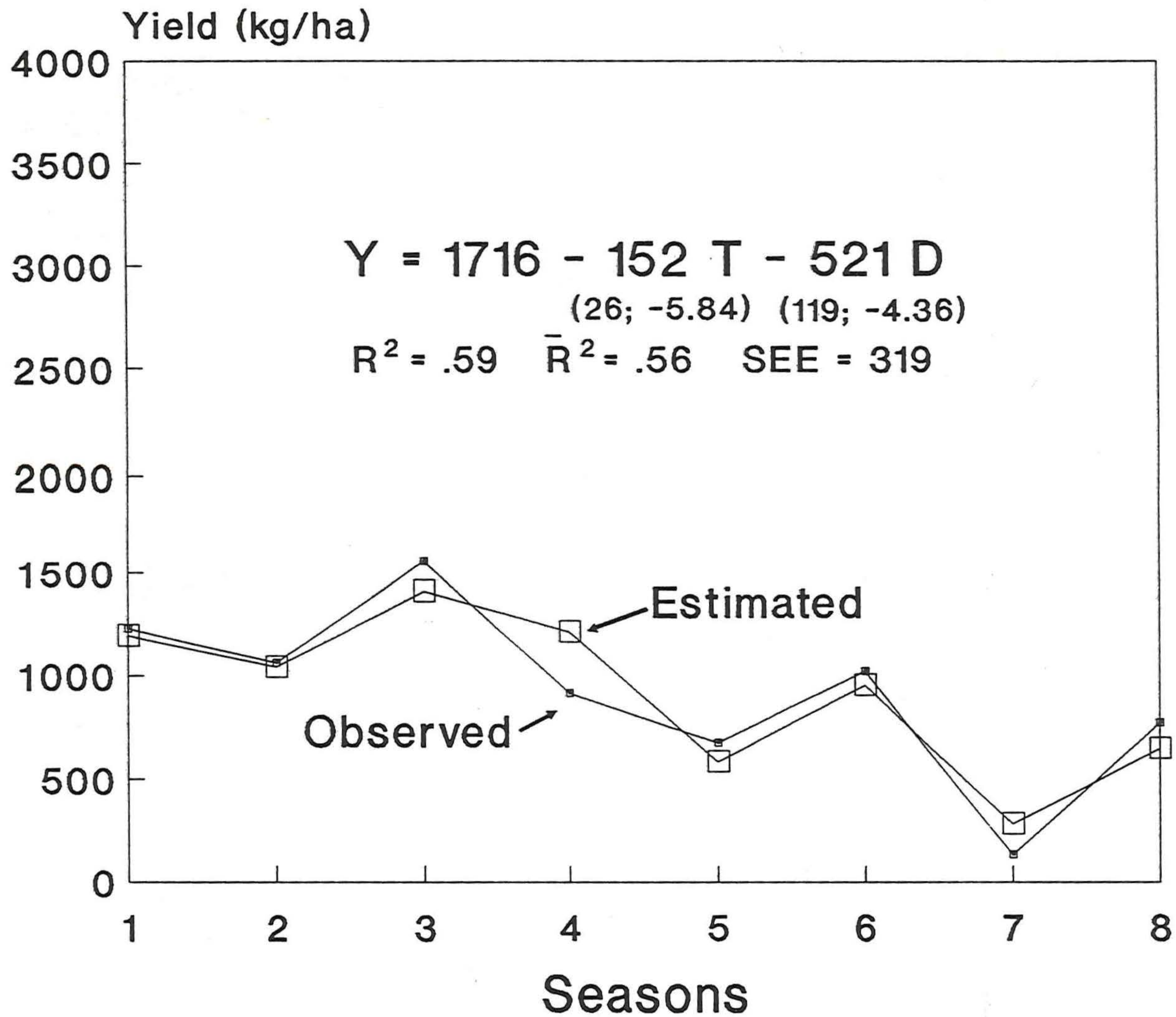
Figure 2. Estimated and observed maize yields in control treatments without fertilizer application over eight seasons at Gandajika, Zaire. [Y = yield (kg/ha); T = season, where T = 0 for base season; D = dummy for adverse environment. Numbers in parentheses represent standard errors and t values, respectively, for regression coefficients. (df = 29).]

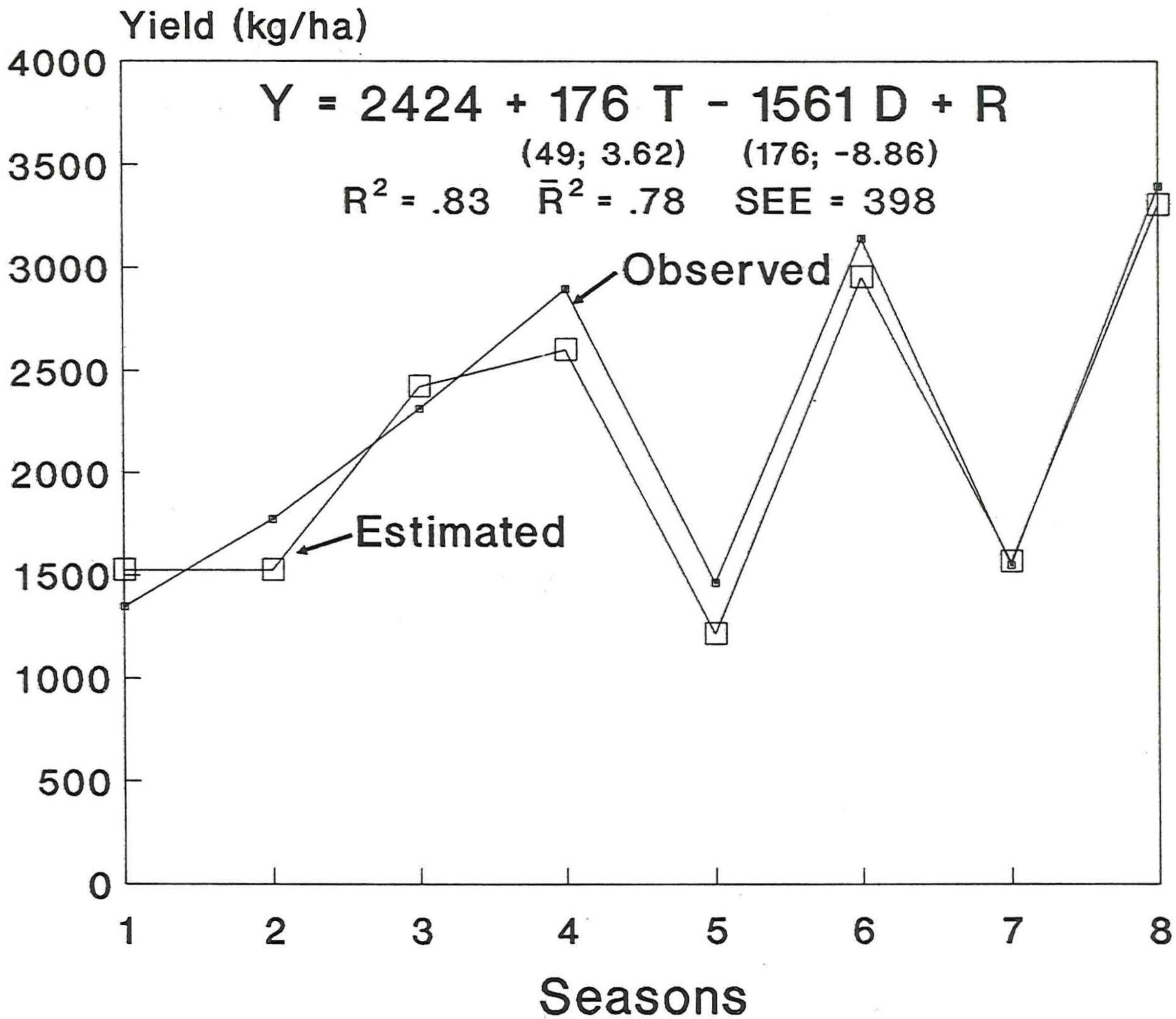
Figure 3. Estimated and observed maize yields in control treatment with fertilizer application but without alley cropping over eight seasons at Gandajika, Zaire. [Y = yield (kg/ha); T = season, where T = 0 for base season; D = dummy for adverse environment; R = dummy for replicates. Numbers in parentheses represent standard errors and t values, respectively, for regression coefficients. (df = 26).]

Figure 4. Estimated and observed maize yields with alley cropping without fertilizer over eight seasons at Gandajika, Zaire. [Y = yield (kg/ha); T = season, where T = 0 for base season; D = dummy for adverse environment. Numbers in parentheses represent standard errors and t values, respectively, for regression coefficients. (df = 21).]

Figure 5. Estimated and observed maize yields with alley cropping and fertilizer application over eight seasons at Gandajika, Zaire. [Y = yield (kg/ha); T = season, where T = 0 for base season; D = dummy for adverse environment; R = dummy for replicates. Numbers in parentheses represent standard errors and t values, respectively, for regression coefficients. (df = 18).]


Yield (kg/ha)
4000
3500
3000
2500
2000
1500
1000
500
0
LSD 0.05
1
2
3
4
5
6
7
8
Seasons
Alley Cropping + Fertilizer
Alley Cropping, No Fertilizer
Control + Fertilizer
Control, No Fertilizer


Yield (kg/ha)
4000
3500
3000
2500
2000
1500
1000
500
0
Y = 1716 - 152 T - 521 D
(26; -5.84) (119; -4.36)
R² = .59 R̄² = .56 SEE = 319
Estimated
Observed
1
2
3
4
5
6
7
8
Seasons


Yield (kg/ha)
4000
3500
3000
2500
2000
1500
1000
500
0
Y = 2424 + 176 T - 1561 D + R
(49; 3.62)
(176; -8.86)
R² = .83 R̄² = .78 SEE = 398
Observed
Estimated
1
2
3
4
5
6
7
8
Seasons