The Inclusion of Time Factors in the Design of On-Station and On-Farm Trials: A Case Study from Kilosa District, Tanzania

Larry S. Lev

INTRODUCTION

It is perhaps the critical importance of time related elements which most clearly differentiates agricultural production from industrial production. Whereas production schedules within industry can be set by man, in agriculture these schedules can only be established within the parameters permitted by nature.

Within the field of agricultural research, much work in recent years has concentrated on studying production activities in a systems context. This may take the form of either formal mathematical models or less rigorous tools such as crop calendars and flow charts which serve the same purpose. In all cases it has been found that when the time elements are more carefully taken into account it becomes possible to better understand and predict farmer reaction to proposed innovations (Norman,1980; Crawford,1982; Delgado, 1979; Hankins, 1974).

Despite the demonstrated advantages of this holistic approach, much agricultural research is still based upon the reductionist approach of focusing on one or two elements while attempting to control all others. In this paper the experience which a farming systems team working in Tanzania has had in transforming the approach to research in a specific district will be discussed with the particular reference to the issue of timing.

The Tanzanian Agricultural Research Organization (TARO) is a parastatal that has a broad mandate to conduct both food and non-food crop research throughout most of Tanzania. Research within TARO is organized on a commodity basis with a single coordinator setting the research priorities for each crop on a nationwide basis. With limited resources (especially foreign exchange) these research programs have done a commendable job. In late 1983 in collaboration with USAID, a Farming Systems project was launched which has as its major thrust the attempt to ensure that the research carried out by TARO scientists would be more relevant to the client groups to be served. At that time, the personnel within TARO were virtually all biological and physical scientists with little training in the methodology of the farming systems approach.

The objective of the Farming Systems Research and Extension (FSR/E) approach is to transform the research process so that the farmer rather than the researcher is at the center. Specifically this requires taking into account farmer constraints, opportunities, and preferences. The achievement of these objectives requires a multi-stage research process which proceeds from system description and diagnosis, to experimental design and testing and finally to the extension of the new technologies (Byerlee, D. et al., 1980; Shaner et al., 1982).

In particular, the concept of time has been introduced as a key consideration in the re-orientation of the TARO commodity research programs. It is clear that the temporal dynamics of peasant decision making has been a if not the main focus of FSR/E work. This paper recounts the small yet significant steps which the FSR/E team within TARO has made towards the integration of previously ignored timing considerations into the on-going research programs.

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THEORETICAL FRAMEWORK

Specifically four time related elements should be taken into account:

1. The amount of farmers' time required to implement the proposed innovations;

2. The periods in which time is required;

3. The variability in the outcomes of the proposed innovations over time;

4. The sustainability of the proposed innovations over time.

The importance of timing considerations becomes apparent when the proposed innovations are put through the prescreening process As outlined in Anandajaysekram (1983), the solutions which researchers propose for the modification of existing production systems are screened for three criteria:

1. Economic viability

2. Riskiness

3. System compatibility

The first, economic viability, is in many respects the easiest for the agricultural researchers to comprehend and integrate into their analysis. Since most of them farm themselves they realize that it is the net return earned rather than the achievement of the biological potential of the individual crops which must be the goal of the technological packages which they design. Although the scientists understand the principle behind this change they still may not be well qualified to carry out the necessary economic analysis. Specifically they may not be well versed in assigning costs and prices to the changes in inputs and outputs which occur. As is detailed below, many of the pricing problems occur in determining the appropriate price at different points in time. The more complex issue of the opportunity costs associated with time related resources is considered under system compatibility below.

Risk is a somewhat more difficult concept for the biological and physical scientists to handle. All of them are certainly familiar with the concept of variability from their work in statistics but the existence of risk necessitates an understanding of its psychological complications. Another complication is that although some understanding of risk can be developed by examining the experiments on a commodity by commodity basis, in order to truly grasp the concept it is necessary to look at the whole system since ordinarily one would expect the farmer to consider the whole system in terms of riskiness rather than each individual part. The models which have been developed in the various disciplines range from the simple to the very complex (Hey, 1979). Still even relatively simple concepts such as "risk premiums" can go a long way towards explaining which proposals will be acceptable to farmers.

Systems compatibility is the third and most difficult concept to integrate into the traditional technology design process. This is the concept which most directly relates to the idea that the farmer is operating a system which has an internal logic over time and space. The breadth of this concept is difficult to

grasp for the commodity researcher who has been taught to view the world in a compartmentalized fashion. While the systems compatibility concept covers a variety of issues, it revolves primarily around the determination of the opportunity costs associated with the alternatives uses of the land, labor, and capital resources available to the farmer in specific time periods.

TIME CONSIDERATIONS

As a start it is useful to consider exactly which things vary over time and how many of them can and should be included in the analysis. First a distinction can be made between short and long term variations.

TIME CONSIDERATIONS WITHIN A SINGLE YEAR TIME HORIZON

1. Weather
   a. Rainfall
   b. Sunlight
   c. Temperature
2. Insects
3. Vermin
4. Crop diseases
5. Soil conditions
6. Availability of capital
7. Availability of inputs
8. Availability of food
9. Availability of household labor
10. Price of agricultural products (purchase and sale)
11. Price of hired labor
12. Use of land for double and/or intercropping
13. Flexibility of planning

TIME CONSIDERATIONS OVER A LONGER TIME HORIZON

1. Climate
2. Soil conditions

a. fertility

b. erosion

3. Availability of land

4. Political and economic changes

5. Flexibility of planning

Only a few of these time related considerations are commonly taken into account by commodity researchers who look at the world on an experiment by experiment basis. These are the time factors which directly influence yield (listed as 1-5 under the "single year" horizon). Since on-station conditions may differ greatly from on-farm conditions it is difficult to examine even these satisfactorily. The remaining issues listed under the "single year" horizon and all of the items under the "longer term horizon are even less likely to be taken into account during the process of evaluating new technologies on the research station.

RESEARCH PROCEDURES AND BACKGROUND TO THE STUDY AREA

FSR fieldwork was initiated in Kilosa District in late 1983 with a diagnostic survey carried out by a group of researchers under the direction of Dr. Alex Cunard (Cunard et. al., 1985). Subsequently, in July/August 1984 a verification survey was conducted in seven villages in Kilosa District (Lev, 1985). Based upon these activities and several subsequent planning sessions held at Ilonga A.R.I. in September and October of 1984 an experimental program was established for on-farm trials to be planted in November 1984, February 1985, and July, 1985. The experiments selected were intended to address major problems and opportunities in the existing farming system.

Figure 1 presents an overview of the study area. Kilosa District is located in the northwestern part of Morogoro region and has good road and train links to the important Dar es Salaam and Dodoma markets. It lies between six and eight degrees latitude and the majority of the land area is approximately 500m above sea level.

The FSR soils chemist, Mr. I.R.O. Mhando (1985), has characterized the area covered by the on-farm research as being divided into four land systems. These land systems depict soil and land form characteristics which differ and may influence crop growth. (1) The hilly region to the south possesses deep brightly colored and well drained soils which offer the possibility on crop production on its summits, midslopes, footslopes, and valley bottoms. Soil erosion is quite evident in this area. (2) The flat lowland plain (the Mkata Plain) is characterized by dark colored, moderately developed, poorly drained soils which are subject to waterlogging. (3) The undulating lowland plain (also part of the Mkata Plain) is characterized by deep well drained soils suitable for large scale mechanization. (4) A final, relatively smaller area consists of shallow depressions that are found on the undulating lowland plains and are characterized by dark colored poorly drained cracking clays which are difficult to cultivate when dry and are also subject to waterlogging.

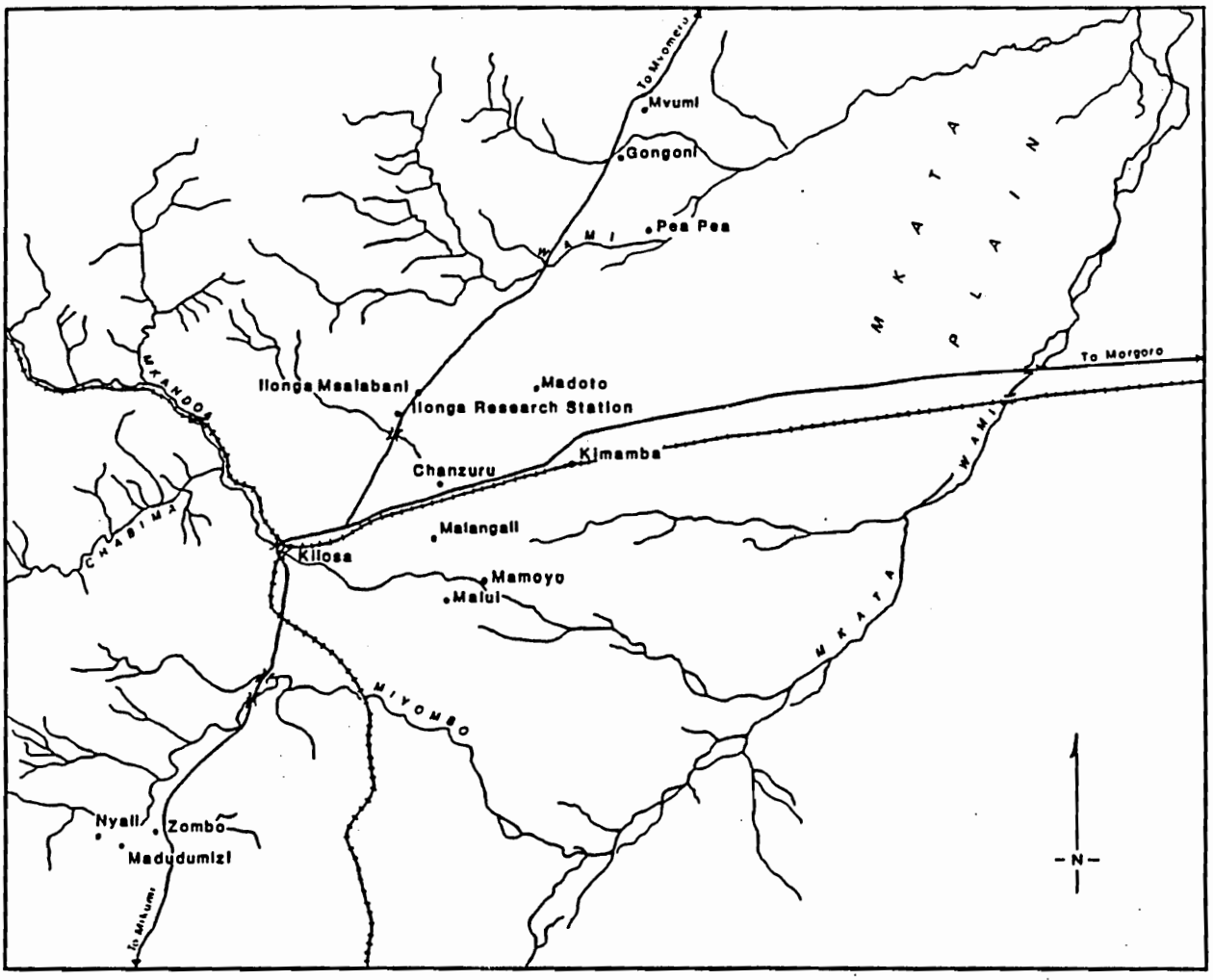

Figure I: Map of Kilosa District Experimental Sites (1984/1985)

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The soils found in all four classifications are generally fertile. They have relatively high levels of organic carbon (3.06%) and have ranges of ph that favor the availability of most soil nutrients to the plants.

Kilosa District is blessed with a long although somewhat unpredictable bimodal pattern of rainfall which stretches from November through May. In most sites the average annual rainfall surpasses 1000 mm per annum. Farmers commonly distinguish between the short rains (Vuli) which last from November through early February and the main rains (Masika) which extend from mid-February through the end of May. Over the last twenty seven years at the Ilonga Research Station the short rains have averaged 431 mm and the main rains 608 mm. In addition the greater reliability of the main rains is reflected in their coefficient of variation of 0.28 as compared to a figure of 0.45 for the short rains. their coefficient of variation of 0.45 versus the figure of 0.28 for the main rains. The reliability and amount of the short rains decreases as one moves from south to north in the District. Ordinarily a dry period of two to three weeks occurs during the month of February and separates the two rainy seasons. The average monthly rainfall and the 1984-1985 rainfall totals are presented in Figure 2.

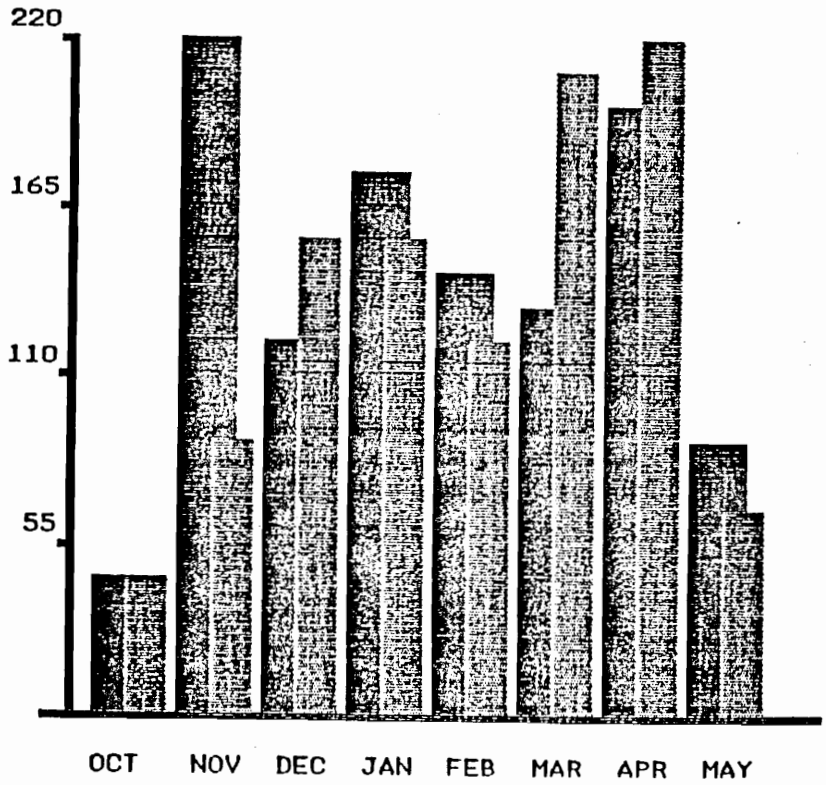
FIGURE 2: 1984-1985 & LONGTERM RAINFALL BY MONTH FOR ILONGA A.R.I. (in millimeters)

SHADING:

1984-1985 -- dark

longterm -- light

source: Ilonga A.R.I.



The lack of consistency in rainfall can be seen by examining the relationship between the short and main rains within individual years. In 14 of the last 27 years at Ilonga A.R.I.. the short rains have been above average. In six of those years (43%) the main rains were also above normal while in eight of those years the main rains were below normal. In eight of the thirteen years

for which the short rains were below normal the main rains were also substandard, while in the other five years the main rains were above average.

As one moves from south to north in Kilosa District the amount of rainfall decreases and the start of the rains is delayed. The FSR team at Ilonga defined three zones (southern, central, and northern) based upon the combined factors of soils and climate. As is described in greater detail below , in the southern zone there are three distinct growing seasons as a great deal of production takes place in valley bottoms during the dry season. In the central zone the farmers place a heavy dependence on food production in the short rains and produce cash crops during the long rains. Finally in the northern zone, neither rainy season is dependable so food crop production takes place equally in each of them.

Despite what the farmers are doing around them, all of the commodity research programs at Ilonga A.R.I. (which is located in Kilosa District) have focused their on-station experimental programs on crop production during the main rains. Little attention has been given to production practices during the short rains and no research effort has been devoted to crops grown during the dry season on residual moisture. A number of explanations for this tendency can be put forward. First, the greater and more reliable rainfall during the main rains makes it more likely that "optimal" yields will be achieved during that season. Secondly, if crops are planted during both seasons it becomes much more complicated to manage the overall research program. An additional reason may be that the current planning cycle for the on-station experiments revolves around a crop coordinators' conference which is held in late October or early November, and hence can not be used as a forum for the discussion of short season experiments.

Thus, the research programs have been motivated by the general goal of optimizing the production of individual crops rather than by specific objectives of farmers. As is demonstrated below this often causes them to work on issues which are not of particular interest to the farmers.

The farmers view their system and in particular the agricultural calendar in quite a different fashion and make full use of both rainy seasons as well as in many cases the opportunities to grow crops on residual moisture during the dry season. Farming in all parts of Kilosa District is quite diversified, with an average of eight crops grown per household, and fairly extensive, with the average household cultivating 2.42 ha. The cultivated area is split into an average of 7.6 separate fields. Although this poses management problems it also permits the majority of farmers to raise crops in a variety of environments.

The hand hoe is the principal work implement used although 20% of the fields are plowed with hired tractors and the demand for increased access to tractors ranks number one on farmers' lists of demands. The use of animal traction is exceedingly rare as is the keeping of cattle by the settled farmers. As a result there are few interactions between crop and livestock enterprises.

Aside from improved seeds (mostly maize) which are purchased by 20 to 30% of the farmers in a given year it is rare for farmers to purchase other inputs such as fertilizers or herbicides. One exception is the use of insecticides in cotton production.

Crop performance varies widely among farmers in a given year as well as from year to year. The within year variations can be attributed to variations in soil fertility, management levels (especially timely weeding), and hazards such as insect, disease, wild animal, and Maasai cattle attacks. Between years the most significant cause of variations in production is the level of rainfall.

Given all these sources of variation it is not surprising that the farmers choose to follow such a diversified pattern of production. The three main crops in the system are maize, rice, and cotton. The minor crops which are grown (cowpeas, sorghum, cassava, bananas, sugar cane, sesame, beans, and coconuts) fit in around the three main crops.

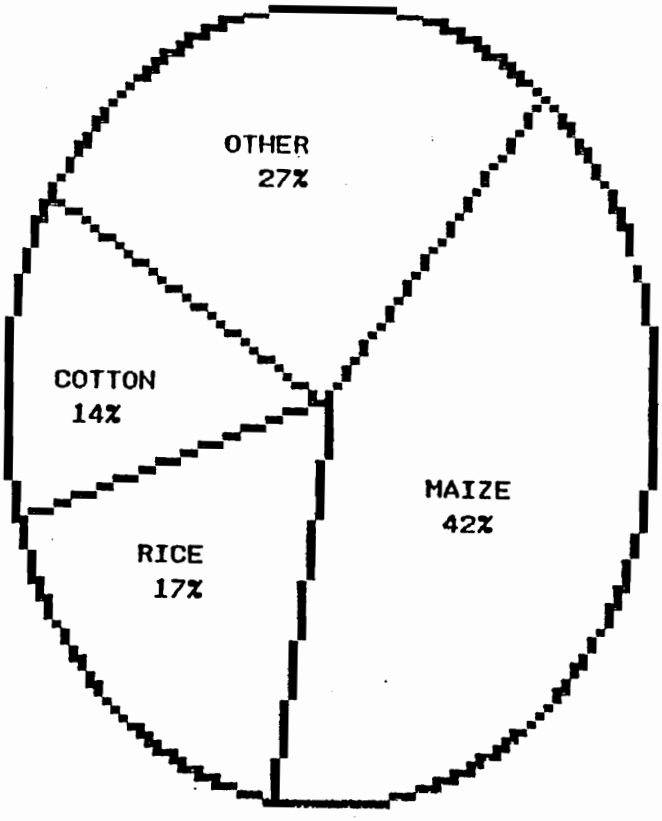


FIGURE 4:

LAND UTILIZATION BY CROP

KILOSA DISTRICT

A brief cropping calendar is provided below:

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     CROP    OPERATION OCT NOV DEC JAN FEB MAR APR MAY JUN JUL AUG SEP
-------------------------------------------------------------------------
     MAIZE   LAND PREP ###                                ######      ###
  (SOUTHERN) PLANTING    ****                                  ***
             WEEDING      +++++++++++                            ++++++++
             HARVEST   @@@@                   @@@@@@@@@@
-------------------------------------------------------------------------
     MAIZE   LAND PREP ##################
   (CENTRAL) PLANTING       ****************
             WEEDING           +++++++++++++++++++++
             HARVEST                           @@@@@@@@@@@@@@@@@@@@@@@@
-------------------------------------------------------------------------
     MAIZE   LAND PREP #######################
  (NORTHERN) PLANTING           **************
             WEEDING              +++++++++++++++++
             HARVEST                           @@@@@@@@@@@@@@
-------------------------------------------------------------------------
     COTTON  LAND PREP             #######
             PLANTING                    *****
             WEEDING                       ++++++++++++
             HARVEST                                       @@@@@@@@@@
-------------------------------------------------------------------------
      RICE   LAND PREP      #####
             PLANTING           *****
             WEEDING              +++++++++++++
             HARVEST                            @@@@@@@@@@@@
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As can be seen from the crop calendar the distinction among the three zones (southern, central, and northern) relates chiefly to the timing of maize production and is discussed below. In all of the areas the most important labor bottlenecks occur when all three crops require attention which is in the period from January through March. These bottlenecks are partially resolved through the hiring of labor which is the largest cash production expenditure.

Maize is the chief staple crop and dominates in terms of both land use and total crop production throughout the District. Area farm families cite self-sufficiency in maize as a primary production goal and most of them ordinarily neither sell nor buy any maize. Throughout the area addressed by the experimental program a substantial percentage of the maize fields are planted during the short rains (although since the traditional varieties require 120 days to mature they are harvested during the main rainy season). In the southern zone, the second most important maize production period is during the dry season, when maize is grown on residual moisture in low lying areas. In the northern zone, where the short rains are less reliable, a good deal of maize is in fact grown during the main rains. In the central zone there is really only one maize growing period, the short rains. Overall the survey data revealed that 90% of the maize fields are planted before January 15 in the southern and central zones and over half are planted before that date in the area to the north of Kilosa town.

Farmers in all three zones choose to plant their maize early for a number of reasons. The most important reason is that the earlier the maize is planted the earlier it can be harvested. Typically the farmers who plant in November

can begin to eat green maize in February and can harvest dried maize in March. Maize planted during the main rains will only be consumed from late May onward. Secondly, planting maize early is a risk reducing strategy since if the short rains are poor the farmers still have the opportunity to replant in time for the main rains. Thirdly, by planting maize early the farmer reduces the competition between maize and the other principal crops in the system -- rice and cotton. While the competition between maize and rice is solely in terms of labor, the competition between maize and cotton also involves land use. Of the three crops, maize is by far the most flexible in terms of timing. Whereas rice has to be planted after the rains are well established but still have a long way to go (hence a December planting date) and cotton must be planted so that it matures in dry weather (hence a February planting date), maize will produce adequately if not optimally when planted at a variety of times throughout the growing season. A final reason for the planting of maize in the short season is that the farmers thus avoid maize streak virus, a serious disease which is particularly destructive to late planted maize. Early planted maize escapes damage because the leaf hopper vector is not yet well established.

DESIGN OF THE EXPERIMENTAL PROGRAM

Initially the FSR team at Ilonga decided to focus on on-farm experiments of on the shelf technologies developed by the commodity programs. Thus timing issues were principally addressed in terms of when crops were to be grown. In the first year of the program 1984/1985 on-farm experiments were planted in the short and main rains as well as during the dry season. The results of these experiments are discussed briefly below. Relatively rapidly, however, the FSR program has moved towards the consideration of more complex timing issues both on and off the station. These issues are treated in a separate section.

INITIAL ON-FARM EXPERIMENTS

Based upon the analysis of the systems it was felt that labor bottlenecks in terms of weeding for all crops and land preparation for main season crops could be addressed through changes in crop sequencing and through increased intensification achieved by expanded intercropping. Furthermore it was felt that the National Maize Research Program had developed maize varieties (and the National Grain Legumes Program had cowpea and green gram) which would be readily accepted by farmers for both the short and main rains.

On-farm trials were planted in both the short and main rainy seasons in all three zones and in the dry season in the southern zone (these last trials are still in the field). The modifications proposed for the short rains consisted of the provision of Kito, a 90 day maize variety to be intercropped with cowpeas or green gram of very short maturity. The specific advantages to be attained are listed below:

1. The farmers would be provided with a short season maize variety which could be planted in November and harvested in February. By moving up the harvest by one month the farmers would obtain a supply of the preferred food, maize, during a period when it is ordinarily in short supply.

2. The yield performance of this short season variety would be compared

over time with full season varieties to see which performs better in terms of average yield as well as which has the lowest variability of yield.

3. The possibilities for increased intercropping, particularly with grain legumes, would be investigated based upon the recognition that Kito has a much smaller plant structure than the other common maize varieties and therefore would result in less shading. The National Grain Legumes Research Program had short maturity varieties (60 days) of both cowpeas and green gram available. varieties (60 days) are available.

4. Improved land use would be possible since an extra month of the growing season would be provided at the start of the main rains. This "head start" on the main season rains should result in increased production of cotton, maize or legumes in that season.

The researchers' expectations of the farmers evaluations of Kito were somewhat uncertain due to the lower yield potential of that variety under optimal conditions and the its relatively small cob size. Ordinarily yield and cob size are among the most important characteristics cited by farmers in rating new varieties.

The same farmers were also asked to participate in the main season experimental program. The advantages to be offered the farmer during the main rains were more straightforward. The variety to be introduced, Staha, has similar characteristics to the traditional varieties but exhibits a much higher tolerance to maize streak disease than do the existing varieties. The objective of the research program for the main rains was to demonstrate the improvement in yields which would be possible during the "optimum" maize growing period. It should be noted that in terms of yield potential Kito is assessed at 3.5 tons ha-1 and Staha at 5.0 tons ha-1.

RESULTS

A total of 34 farmers in twelve villages participated in the short season trials. In the main season it was more difficult to maintain farmer interest (they were busy with other crops) and only 15 continued to participate through to harvest time. It is instructive to compare the results as well as farmer reaction to these two sets of experiments. Although Kito performed fairly well (it yielded just over 1.5 tons ha-1 with no fertilizer) it was outyielded by traditional maize varieties by 15%. The intercropped grain legumes were in contrast devastated by elegant grasshopper attacks early in the cropping season and were largely lost. In spite of the poor main season rains (Figure 2) Staha provided a more striking contrast with the local variety control plots. It also averaged just over 1.5 tons ha-1 and outyielded the local check by more than two to one. The increase appeared to be due to better germination and greater streak tolerance.

In the light of these yield figures it might seem somewhat surprising that the farmers in all three areas were nearly unanimous in declaring themselves more interested in the Kito introduction. Their reasons were almost entirely timing related. Most of the participating farmers choose not to plant maize during the long rains (when Staha produces best) because they concentrate on cotton and rice production at that time. Even the potential for increased yields

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provided by Staha may not change this pattern drastically. In contrast, the farmers recognize that the planting of Kito during the short rains permits them to better achieve their primary family production goals. First, their maize harvest is hastened to a period when family supplies are low and market prices are high. Second, family labor is freed from February onward when the rice and cotton crops require much attention. Additionally the farmers felt that Kito's shorter maturity would allow it to provide a more stable yield in years in which the short rains were poor. Thus, while the results achieved by Staha during the long rains are statistically more impressive than the Kito results, they do not represent the same sort of major advancement for the farmer's production system as a whole. Many would in fact prefer to devote their labor during the main rains to rice and cotton.

During the main rains, experimental work which may ultimately be of more interest to the farmers was initiated on the station. Currently in Kilosa District there are by-laws which prohibit the interplanting of cotton with other crops. Area farmers, however, follow a traditional system of relay cropping the cotton in the drying maize fields which is an effective mechanism of minimizing land preparation and weeding time. Because of the political sensitivity of the work these experiments were only placed on the research station. Based upon a single season's data, the results were quite promising as they showed that in intercropping situations the maize yields (using the new smaller Kito variety) can be maintained at their sole cropped levels and the cotton yields only reduced by 30%. Overall the total return per hectare is increased by 44%. From the farmer's perspective this intercrop is undoubtably quite attractive. Subsequent research will also branch out to consider to the intercropping of cotton and cowpeas in which both crops should be able to benefit from the same insecticide. Once again the impetus for initiating this trial came from observations on farmers' fields.

THE INCLUSION OF OTHER TIMING ISSUES

Based upon the credibility which the FSR program gained from the successes achieved in the initial year of experimentation, the FSR has in the current year moved towards the consideration of more complex issues. In collaboration with the commodity programs a full slate of on-station and on-farm experiments have been planned. The on-station experiments in particular provide two fundamental innovations in the way in which research has traditionally been carried out at Ilonga. First the majority of trials are what may be termed "linked trials in that the experiments consider the production on a given plot of land during both the short and long rains. Secondly many of the trials require for the first time that permanent plots be established since the effects of the treatments must be evaluated over time. Both of these innovations represent important steps toward the more accurate simulation of farmer circumstances and hence should contribute to the formulation of more acceptable recommendations. Long term experimentation is one area in which the researcher, who does not face the challenge of ensuring the year to year welfare of the family, may be in a better position to carry out far ranging experimentation than the individual farmer. The chief areas which will be considered include long term fertility studies including the influence of crop rotations (within and between years) and the possibilities of integrating green manure crops as well as soil conservation measures (principally biological ones) into the existing farming systems.

SUMMARY

Overall the farming systems program in Kilosa District has made good progress in its initial year of trials. As a result of the dramatic comparison of farmer reactions to the introduction of the Kito and Staha varieties the commodity program researchers are now much more conscious of the factors which enter into farmer evaluations of proposed new technologies. It is to be hoped that the other timing issues discussed in this paper will yield the same sort of positive reactions from farmers and researchers alike.

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