STUDIES ON MIXTURES OF COTTON (*Gossypium hirsutum* L.) AND BEANS (*Phaseolus vulgaris* L.) WITH SPECIAL REFERENCE TO PLANTING ARRANGEMENT.

By

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DECLARATION

I declare that this thesis is my orignal work and has not been presented for examination in any other University.

Date ..14.-.1.-.87

E.O. Baraza

I declare that this thesis has been submitted for examination with my approval as University Supervisor.

Date ..14.1.87..........

R.W. Michieka

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ABSTRACT

Studies were conducted at Mwea Tebere Research Station and Wanguru Sunflower Research Centre to evaluate the effect of growing cotton (Gossypium hirsutum L.) in mixture with field beans (Phaseolus vulgaris L.) on their respective yields and on the combined yield from a unit area of land. The studies were also designed to test the effect of various patterns of planting on the yield of each of the two crops as well as evaluating the efficiency with which rainfall is utilized. The study further considered the effect of intercropping on weeds.

It was found that the yield of seed cotton was not influenced by the companion crop of beans, but, was significantly effected by the row to row spacing of cotton with closer rows producing more seed cotton than wider rows. The yield of dry beans was however slightly reduced by mixing the latter with cotton.

Results showed that huge advantages in land productivity and monetary earnings can be obtained by mixing cotton with beans compared to growing these crops separately. Such advantages varied with the planting patterns.

It was further observed that in a bimodal rainfall pattern such as in Central Kenya, rainfall is more efficiently utilized when cotton is mixed with beans than by growing either of the crops separately. Observations on weed problems indicated that weeds are suppressed a great deal through mixing cotton with beans and the return per unit labour used in weeding was greater in mixed stands than in pure-stand cotton.

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INTRODUCTION

Cotton (Gossypium hirsutum L.) is one of the most important cash crops in Kenya. It earns a sizeable share to total foreign exchange through direct lint exports as well as through exports of finished goods. Cotton based industries both at farm level such as Cotton Ginneries and Urban based Textile and Oil Mills provide employment to thousands of Kenyans. The oil extracted from cotton seed is utilized for vegetable ghee and many other preparations. The cotton seed-cake and meal are fed to livestock which is an important part of our Agricultural economy. Cotton is also utilized in making mattresses, bedding and in the manufacture of paper. Thus this crop has a significant role in bringing economic uplift thereby ameliorating the lot of our teeming millions.

The earliest cultivated cotton in Kenya dates as far back as 1906 (Munro, 1966). The development of cotton Industry in Kenya and indeed East Africa started at the beginning of the century when the crop was introduced. In 1921 the Cotton Research Corporation (CRC) was established by the Royal Charter to extend and promote growing of cotton through providing technical assistance in close liaison with Ministries of Agriculture of member countries and with Ministry of Overseas Development in United Kingdom. In addition to providing information and advice on all aspects of cotton growing the CRC was to supply specialists in those fields of cotton growing Research that overseas countries could not cover themselves. East African countries benefited from the CRS through the establishment of a number of Research Station as well as providing personnel to carry out research in these Institutions. Thus Bukalasa, Namulonge and Serere Research Stations were established in Uganda, Ukiriguru and Ilonga in Tanzania were also established.

The CRC concentrated the cotton Research in Tanzania and Uganda as these countries were regarded as having more potential for cotton production than Kenya. Kibos and Msabaha Research Stations were only used as testing sites for Research Programmes developed from adjacent countries. It was also believed that the Research Stations in Tanzania and Uganda could handle the potential cotton growing areas of Kenya (believed by that time to be Coastal Strip and areas around Lake Victoria).

Central Nyanza (now Siaya and Kisumu) and Busia District was handled by Bukalasa Research Station in Uganda as the climate of these areas are similar to that of the Lake shore region of Uganda. South Nyanza on the other hand was handled by Ukiriguru Research Station in Tanzania again because of climatic similarities. Coastal Strip was also handled by the two Research Stations in Tanzania. Siaya, Kisumu and Busia District had their varietal seed developed from Bukalasa (BP Series). South Nyanza and Coastal Strip were supplied by UK Series developed from Ukiriguru and IL Series for Taveta area from Ilonga. Little Research was thus carried by CRC in Kenya.

Cotton was introduced in Kitui, Machakos and parts of Central Province in 1933 but was abandoned in 1941 because of insect pests which could not be adequately controlled by the available control measures at that time. It was not until 1961 when cotton was reintroduced in this region following a break-through in better insect control methods (development of effective active ingredients). The Kenya Goverment has charged the Cotton Lint and Seed Marketing Board

(CLSMB) with the responsibility of buying seed cotton from farmers either directly or through farmers cooperatives. The CLSMB was created way back in 1955 through an Act of Parliament. Until 1963 the eight year average cotton production in Kenya was 14,000 bales. In November, 1963 the CLSMB embarked on a plan of tenfold increase in production by 1970. The target of 137,000 bales included 80,000 bales from Hola Irrigation Scheme. This was later revised to a modest 100,000 bales when it was realized that Hola would not have reached the stage of production by 1970 (Munro, 1966). Production had only risen to 30,000 bales by 1970. It staggered around this figure until 1977 when it started to rise. In 1980 there was a substantial increase to a record of 75,000 bales. The production has dropped to its 1970 level of about 30,000 bales over the last two years. Many factors have attributed to this drop including lack of facilities for adequate seedbed preparation, competition for labour between cotton and food crops at critical time of planting and weeding, poor cotton prices relative to the prices of other alternative crops, and delays in payments of produce by cotton cooperative societies, (Muturi. 1975) and mixing cotton with food crops.

Average yields of seed-cotton from rain-fed cotton growing areas in Kenya is only 220 - 450 kg/ha but with good husbandry and efficient pest control, yields of between 1,300 kg/ha to 1,600 kg/ha have been obtained from the important cotton growing areas (Acland, 1971). At Hola Irrigation Scheme where cotton crop is grown under irrigation average yields are upto 2,500 - 3,000 kg/ha underscoring the importance of moisture management on cotton production. Enhancing cotton production in Kenya is a major problem which has to be tackled properly. The variety and zoning hardly contribute 10% increase in yield, whereas irrigation increases yield by 50% and fertilizers hardly contribute 10% while the cultural practices can account to as much as 40% increase in yields (Fielding, 1983).

Before 1970, cotton production in the traditional cotton growing areas of East Africa was mainly in pure-stand farms. With the emergence of price increases of petroleum products (including pesticides) in the early 70s, and the encroaching land scarcity in cotton growing areas which had in the past enjoyed relatively low population densities, more and more farmers have over the last decade changed their farming systems to that of growing cotton in mixtures with maize (*Zea mays* L.), sorghum (*Sorghum vulgare* Pers.), beans (*Phaseolus vulgaris* L.) and pigeonpeas (*Cajanus cajan* (L.) millsp). A fast increase in population density in these areas calls for an equally fast increase in food production to sustain the population. In the cotton growing areas of Central and Eastern Province of Kenya, the population and high cost production factors are compounded with long cotton growing season of upto eleven months. It is thought that farmers may be growing cotton in mixtures so as to compensate a lost food crop season (Popay, 1972).

Mixed cropping of cotton with beans has become very popular in cotton growing areas of Central and Eastern Province of Kenya. Reasons for this are both technical and socio-economic. One of the reasons for instance is that with the outbreak of some common cotton diseases or pests the farmer would not loose both crops. Also in case of any early outbreak of drought cotton is more tolerant than beans. The farming system therefore provides a security for both food and cash to the small-scale farmer.

Higher total return from a unit area of land and per unit of labour are also some of the economic reasons for this system.

Over 70% of rainfed cotton in Kenya today is raised in some form of crop mixture. For these farmers to get higher yields, a great deal of research should be diverted to production through intercropping. This could greatly help the small-scale cotton farmers in Central Kenya. The objectives of this study were:-

1. to test the effect of mixed cropping on yields of cotton and beans,
2. to observe the influence of beans on growth and development of cotton,
3. to provide information relating to a favourable plant arrangement of cotton and beans that can be adopted by the farmers,
4. to give information on utilization of soil moisture under different planting pattersn, and
5. to investigate the effect of mixtures of cotton and beans on weed control.

LITERATURE REVIEW

Intercropping in the Tropics

Intercropping is the growing of two or more crops at the same time in the same field. It is one of the main crop production system in the tropics and sub-tropics (Willey, 1979, Pearce and Gilliver, 1978). When this system was started is not known but is is likely to have evolved through generations because of farmers environmental conditions. Norman (1972) listed 24 different crops grown in 174 different interprises in one sample region in Nigeria alone. Less than 17% of these enterprises consisted of sole crops. In Kenya Eignatten (1974) carried a survey on bean production in Eastern and Central Provinces and reported that only 31% of beans from this region was grown as a sole crop with 44% of the households in Eastern Province and 17% in Central Province growing beans as a monoculture. In Latin America upto 60% of maize and 80% of beans are produced in various associated cropping systems (Francis, 1978).

Although mixed cropping is predominantly the system of subsistence farmers in developing countries. Agricultural research in these countries has in the past concentrated on a monocrop situation. The most frequently quoted justification for this is that mixtures are more difficult to manage as agriculture develops particularly if mechanization is introduced.

But with realization that very limited mechanization is possible in the small scale farms, more and more research in mixed cropping is now being done. A notable example is the evaluation of varieties of beans suitable for mixture with maize in Kenya undertaken by National Horticultural Research Station and National Seed Quality Control Station (N.S.Q.C.S.). This is in order to issue the farmers with bean seed that can be able to do well in mixture with maize. This is done because it has been established that maize-beans mixtures have advantages over their pure-stands.

Previous Work on Mixed Cropping

Literature on various aspects of intercropping is accumulating fast. Leakey (1934) in his book

"Science and the African", points at possible advantages of mixed cropping among the small scale farmers in the Kenya highlands. He expressed his opposition to those Agriculturalists who advocated for pure-stand crops among small-scale farmers. Experiments on mixtures involving legumes and certain cash crops have reported advantages in mixtures.

Grimes (1963) cited the work comparing alternate row cropping of cotton and maize with pure-stands of each in Malawi. Yields of both cotton and maize were grown in alternate rows than in the pure-stands. The experiments also compared two planting dates with cotton and it was found that if the planting date of cotton is delayed by three weeks, yields of cotton were reduced and the yield of maize from alternate rows was not increased.

In his experiments conducted on intercropping of groundnuts with maize or sorhum in Tanzania, Evans (1960) reported an increase in total productivity from a unit area of land through intercropping. He found that about 12 - 49 more land under sole crop would be required to produce same amount of yields as one acre of mixture depending on site and season. Evans found increased returns from a mixture of castor beans (Ricinus communis Linn.) and groudnuts (Arachis hypogaea Linn.) compared to their pure-stands. In his fertilizer and manure responses in mixed crops in Tanzania, Evans (1963) found that maize in mixture with groundnuts gives a highly significant yield response to fertilizers and manure of the same order as response in pure-stands. Groundnuts on the other hand did not give yield response to fertilizers and manure when intercropped, although in pure-stand response of 250 and 300 kg/ha were obtained for manure and fertilizers respectively.

In Western Nigeria, preliminary trials carried by Agboola and Fayemi (1971) on maize mixtures with other legumes reported lower yields from mixture than from their pure-stands. Andrews (1972) on the other hand found yield advantages of upto 80% from sorghum/ millet mixture or sorghum/cowpeas (Vigna unguiculata Linn.) mixture in Northern Nigeria.

Baker and Yusuf (1976) reported findings on mixed cropping research at Samaru, Nigeria that the yield of sorghum or millet from a 1:1 ratio mixture was greater than yield from half hectare pure-stand of each crop. They also found from maize and groundnuts mixture that maize reduced groundnut yields, but, 30% more returns was still obtained from the mixtures compared to an equivalent area under sole crops. They also found large reduction of cotton yields when cotton is late sown under cereals.

In Uganda Osiru and Willey (1972) found an increase in yields of upto 55% from mixtures of dwarf sorghum and beans over the same crops in pure-stand. Willey and Osiru (1972) in a separate experiment found from their studies that mixtures of maize and beans produced 38% higher yields than could be achieved by growing these crops separately. The same authors in a separate study on mixtures of maize and beans found a decline in yield advantages with delayed planting beans from 20% advantage when beans are planted with maize at the same time, to only 2% when beans are planted four weeks later.

Osiru (1974) in his work on physiological studies of some annual crop mixtures in Uganda similarly found that in maize-beans mixture, yield advantages declined from 23.0% for simultaneous sowing to an average of 6.3% when the beans were sown one month after the maize. In sorghum-soyabeans (Glycine max (L.) Merr) mixture the comparable decline was from 33.1% to 10.6% with an early (80 days) or late (120 days) soyabeans variety.

The success of any crop mixture relative to pure-stands depend on the form and magnitude of the interaction that occur between the crops in these mixtures. Such a success may be determined by various agronomic practices which affect the nature of interaction between species and so affect their use of the limiting growth resources. Such practices include manipulating overall plant density, the relative density of component crops, the relative time of planting and the supplies of limiting resources (Martin and Snaydon, 1981). Previous studies of the effect of planting patterns on the performance of crop mixtures have given conflicting results.

Bodade (1964), using sorghum and groudnuts found that intimate mixtures give greater yields; Dalal (1974, 77) working on maize and pigeonpea found that alternate row mixtures yielded most. Singh (1979) working with sorghum and pigeonpeas found that less closer mixtures yielded most. Other workers such as Evans (1960) Pendleton and Seif (1962), Freyman and Venkateswarlu (1977), Osiru and Kibira (1979), have all failed to find significane yield differences between different planting patterns. Gajendra Giri and Rajat De (1978) found that a 1:1 ratio mixture does not significantly reduce grain yield of pigeonpea in mixture with sorghum but higher proportion of sorghum in mixture with pigeonpea reduced the yield of the latter.

<u>Intercropping of Crops other than Cotton in Kenya</u>

Kenyan research workers in the past have not shown much interest in mixed cropping. This may have been caused by the set-ups of the research institutions which were mainly single commodity stations with objectives of trying to improve on these single commodities.

Others on the other hand think the reluctance could have been caused by the research workers trying not to identify themselves with traditional farming methods. A few workers such as Wright (1955-56), and Grimes (1963) were the first to pioneer into mixed cropping studies in Kenya.

Leakey (1934) described the mixed cropping system as being quite traditional and contradicted those who advocated for sole cropping system. He observed that the system seems to have advantages for the small scale farmers.

Mixed cropping studies in Kenya has mainly concentrated on considering the two main staple food crops, namely maize and beans. However, some substantial studies have also been carried on mixture of maize and sorghum with cotton. Njeru (1973) in his preliminary studies to test the effect of interplanted beans on maize yield at Embu reported a 40% yield reduction relative to pure-stand. Makatiani (1974) in his summary of experiments on maize intercropped with beans conducted at Kakamega in Western Province of Kenya reported greater yield totals from mixtures (maize-beans) than from pure stands. Mbagaye (1975) from his maize-beans time of planting experiments in Kisii observed a decline in yield of beans as time of sowing of beans in maize is delayed. The same was true when maize was sown after beans. Marimi (1975) also observed in his preliminary findings on the system of mixed cropping in dry areas of Central and Eastern Provinces of Kenya during the long rains of 1974 that maize-beans mixtures gave advantages over pure-stands, and such advantages were greater at those sites where the pure stand yield levels were highest. Laycock et al, (1975) reported from their maize-beans mixtures in Kitale a slight increase in maize yields although this was not statistically significant.

Fisher et al (1976) in their studies on maize-beans intercropping in Kisii found no significant effect of beans on grain yield of maize from all the sites used for the experiment. Thus maize yields from mixed plots were not significantly different from the yields from pure-stand plots.

Yield of beans responded significantly to the relative time of planting giving reduced yields with delay in time of sowing beans under maize. At the University of Nairobi, Kabete, Fisher (1977) observed that a yield advantage is possible in maize-beans mixtures during long wet seasons, but in seasons with low rainfall, the yield from mixtures fell short of that from pure stands. His conclusions was that competition from beans for moisture during low rainfall season can adversely reduce the yields of companion maize crop.

Intercropping of Cotton in Kenya

The earliest documented intercropping experiments on cotton in Kenya were those of Wright (1955-56). He reported from his studies on intercropping of cotton with maize at the Coast Province that at one site used, pure-stand maize outyielded maize interplanted with cotton if both crops are planted together at the onset of the long rains. From another site he observed that pure-stand maize produced a yield not significantly different from the yield of maize interplanted with cotton.

He also observed a steady fall in maize yield with the delay in time of sowing maize under cotton after the onset of rains. Generally he did not find any significant differences in yields between pure-stand cotton and cotton interplanted with maize. He however, did not find any yield advantages from cotton/groundnuts mixture.

. His final remark was that relative yields of pure-stands and intercrops is a matter of site and season. Grimes (1963) from his experiments conducted on the effect of growing maize and cotton in alternate rows further reported slightly higher yields of both cotton and maize, but the yield of one crop was depressed. His experiments were also conducted at the Coast Province. He reported greater financial returns from alternate row intercropping.

Goldson (1969) also reported from a maize-cotton intercropping experiment at the Coast Province that interplanting of maize with cotton reduces maize yields no matter what spacing of maize is used, at all planting dates of maize relative to time of planting of cotton.

He also found that a delay in planting pure-stand of four weeks reduced cotton yields by 50% and maize yields by 24%. In his concluding remarks he reported that intercropping only gives favourable results where the ratio of plant densities and arrangements of the two crops are within certain limits.

Popay (1967-70) also carried out maize/cotton intercropping experiments in twenty farms in Malindi at the Coast Province where he observed that if the population of maize in the intercropping was not too high, yields of maize and cotton were not significantly different from yields from pure stands.

In a different experiment Popay (1972) showed that interplanting of cotton with beans in Eastern and Central Kenya had no effect on the yield of cotton, thus higher overall yields could be obtained provided that the associated crops were sown early and moisture is adequate. He went ahead and recommend that intercropping of cotton with beans be permitted in Meru District after establishing that beans did not have any adverse effects on cotton yields.

Brown (1971) in his experiments to test the effect of interplanted beans on the yields of associated cotton crop observed no yield reduction in cotton at Giaki in Meru District. The two crops were arranged in alternate rows. Further in his experiments at Kibos in Kisumu the same author found that two hectares of cotton and sorghum planted in alternate double rows gave an increase of 29% gross cash return and that of cotton and maize gave 7% increase compared to one hectare of cotton and one hectare of either crops in pure-stands. He observed that a satisfactory financial return from inter-cropping cotton with maize or sorghum depended on obtaining good prices for sorghum or maize.

In similar intercropping trials on mixtures of cotton with maize, and cotton with sorghum at Kibos in Kisumu, Nyaisawa (1976) found a marked decrease in total production per unit area of land from mixed stands compared to pure stands of the tested crops. He observed that through mixing these crops, the gross cash return per unit area was only 49% of the gross cash return from pure-stands. He also found that the land equivalent ratios for maize/cotton mixture varied from 0.49 to 0.60, and that for sorghum-cotton mixture from 0.49 to 0.67 for the period between 1973 and 1976. The same author however, observed in his intercropping trials involving cotton with grain legumes (beans, soyabeans, greengrams, and groundnuts) that there was very little depression on yield of cotton resulting from mixtures with the grain legumes.

Mixed cropping of cotton with other crops notably food crops such as maize, beans or pigeonpea has become a very popular farming system in cotton growing areas of Central and Eastern Provinces of Kenya. In an effort to make a follow up of the work done by Popay (1972) and Brown (1971) cited earlier, a programme was started at Mwea Tebere Agricultural Research Station to further investigate the importance of intercropping cotton with other crops, as it has become apparent that the majority of cotton farmers prefered cotton mixed with any of the mentioned food crops to growing cotton in pure-stands. In the programme investigation on the possibility of mixing of cotton with maize, beans and sunflower was conducted. The main objective was to observe any yield reductions on cotton that could be associated with the companion crop in mixture.

The experiment was designed to investigate the best time to sow any of these crops in cotton. Unpublished results indicated that sunflower and maize adversely affected cotton yields at all the three sites used namely Mwea Tebere, Giaki in Meru District and Taveta in Taita - Taveta District. It was also noted that a delay in sowing any of these crops in cotton drastically reduced their yields.

Limitations and Weaknesses of Previous Work

It is observed from the foregoing literature review that some work has been done on mixtures of cotton with other crops. Most of the work such as of Wright (1955-56), Grimes (1963), Goldson (1969), Brown (1969-70), Popay (1967-71), Nyaisawa (1973-76) and authors own unpublished work have all concentrated on considering alternate planting pattern. Thus although Popay (1972) recommended that intercropping of cotton with beans be allowed in Meru District, he did not give specific recommendations on how the planting can be done. No reported work has considered the effect of increasing the population of a second crop on cotton. No work has for instance considered growing two or more rows of beans between cotton rows.

Similarly no worker has considered increasing the cotton row distance so as to maximize yields of beans between wider cotton rows.

Farmers are already practicing cotton - beans intercropping and require detailed recommendations on which to base their farming practice. It is with these ideas in mind that work on cotton/beans mixtures was started in order to consolidate facts and information on the advantages of this system as well as to find out the best planting arrangement that can be adopted by the farmers.

MATERIALS AND METHOD

Field experiments were conducted under rainfed conditions at Mwea Tebere Research Farm and Wanguru Sunflower Research Centre. Both sites are in Central Province of Kenya. The Sites are two and half kilometres apart. Two sites were selected so that reliable results could be obtained for the area.

Description of Site:

Mwea Tebere Research Farm and Wanguru Sunflower Research Centre are both situated approximately 0^{o} 35'S latitude and 37^{o} 20'E longitude. The experiment was conducted on even land in the sites. The soils in these sites are dark brown clays with soil depths exceeding 150 cm. Field and Laboratory analysis reveal that the soils are derived from Livine Basalt parent material. These Soils form Coarse to medium structure with hard consistency when dry and firm when moist. The soil reaction was medium to slightly acid (pH 5.1 - 6.0). The clay fractions are dominated by metahaloysite with traces of 2:1 type of clay minerals. This soil is generally poor in Calcium and Manganese but rich in other minerals. No fertilizers are recommended for cotton in these soils (Michieka D. O. and Otieno Oswago 1970, Brown, 1971). (See appendices 11, 12, for the results of soil analysis).

Treatment Details

Cotton was sown at three different inter-row spacing viz: recommended close spacing (100 cm), medium inter-row spacing (150 cm) and wide inter-row spacing (200 cm) was intercropped with varying intensities of beans between cotton rows. The within row spacing of cotton was maintained at recommended spacing of 30 cm between hills. Double row (paired row) cotton both at medium spacing (150 cm) and wide spacing (200 cm) was also included in the planting pattern. Different number of rows of beans were sown between cotton rows at a spacing of 30 cm x 15 cm. Therefore the mixed stands consisted of a full stand of cotton with varying proportions of beans, three quarter cotton with varying proportions of beans and half cotton stand with varying proportions of beans. A total of twelve different planting arrangements were tested in a Randomized Complete Block Design replicated five times at Tebere and Wanguru as follows:

1. Pure stand cotton spacing 100 cm x 30 cm
2. Pure stand beans spacing 30 cm x 15 cm
3. Recommended cotton spacing 100 cm x 30 cm with 1 row of beans spaced at 50 cm from cotton.

4. Recommended cotton spacing 100 cm x 30 cm with two rows of beans spaced at 35 cm from cotton and 30 cm from each other.
5. Medium row cotton spacing 150 cm x 30 cm with two rows of beans spaced at 60 cm from cotton and 30 cm from each other.
6. Double row medium row cotton spacing (150 cm x 30 cm x 30 cm) with two rows of beans spaced 45 cm from cotton and 30 cm from each other.
7. Medium row cotton spacing 150 cm x 30 cm with three rows beans spaced 45 cm from cotton and 30 cm from each other.
8. Medium row cotton spacing 150 cm x 30 cm with four rows of beans spaced 30 cm from cotton and 30 cm from each other.
9. Wide row cotton (200 cm x 30 cm) intercropped with three rows of beans spaced at 60 cm from cotton and 30 cm from each other.
10. Double row wide row cotton (200 cm x 30 cm x 30 cm) with three rows of beans spaced 55 cm from cotton and 30 cm from each other.
11. Wide row cotton (200 cm x 30 cm) with four rows of beans spaced 55 cm from cotton and 30 cm from each other.
12. Wide row cotton (200 cm x 30 cm) with five rows beans spaced at 40 cm from cotton and 30 cm from each other.

Dressed seed of UKA 59/240 variety of cotton and Mwezi moja (GLP 1004) variety of beans were dry planted at Tebere and Wanguru just before the onset of October short rains in 1981. UKA 59/240 is recommended in this area because it combines high yields with resistance to Bacterial Blight (Xanthomonas malvacearum Dowson.) and Cotton Jassids (Empoasca spp). Mwezi moja beans is popular because of its high yield and short maturity period. Sowing of both cotton and beans was done by hand in plots measuring 12 m x 6 m. Diammonium phosphate fertilizer was applied at an application rate of 100 kg/ha. Five cotton seeds were put in each planting hole and the seedlings were later thinned to one plant per hill.

This produced a population of 33,333 cotton plants per hectare for narrow (100) row planting patterns. In paired row pattern (200 cm) the plant population was similarly 33,333 plants per hectare. In medium row (150 cm) pattern a population of 44,444 cotton plants was obtained. In wide row (200 cm) single line pattern and medium row (150 cm) single line pattern population of 16,666 and 24,999 plants were obtained respectively. Paired rows were 30 cm apart. The population of beans in pure-stand was 222,222 plants per hectare.

In narrow row cotton (100 cm) intercropped with one row of beans, the population of beans was 66,666 plants per hectare, and 133,333 plants per hectare in narrow row cotton with two rows of beans. In the medium row patterns the beans population varied from 80,000 plants per hectare in patterns with two rows of beans to 120,000 plants per hectare in the pattern with three rows of beans and 160,000 in the pattern with four rows of beans. The wide row (200 cm) patterns had bean population of 100,000 plants per hectare in patterns with three rows of beans, 125,000 plants per hectare in patterns with four rows of beans and five rows of beans respectively.

Weed control was undertaken through hand weeding and the time spent in weeding each plot recorded. The time to weed was determined by the state of weeds in the field relative to the agronomic consideration. This meant that whenever any one plot in the trial harboured weeds as to pose a threat to the good crop husbandry all the plots were weeded.

Pest control consisted of nine insecticide applications using Cypermethrin, Dimethoate, Triazophos in various combinations depending on the prevalent pests.

Three out of the nine applications was meant to protect the beans from Heliothis and Red Spider mite attack early in the season. The remaining six insecticide applications were done after the onset of long rains at an interval of approximately two weeks.

The growth of cotton plants was monitored through physical measurements of stalk elongation done on five randomly predetermined plants in each plot at an interval of two weeks. This was later changed after the onset of long rains to one month interval.

A full list of the data collected in this study include the following:

1. Fortnightly measurements of height of cotton plants (later changed to monthly).
2. Measurement of time spent in hand weeding each plot.
3. Harvest yield of dry beans from a net plot of 10 m x 4 m.
4. Harvest yield of seed cotton from net plot of 10 m x 4 m.
5. Height of cotton plants at the end of picking time.
6. Rainfall received during the cropping period.

Each of these data was subjected to analysis of variance to test whether mixing the crops and the planting arrangement had influence in the parameters considered. An analysis of covariance was conducted for Tebere site to test whether the yield of beans had any correlation to the yield of cotton.

The yield data obtained was transformed into equivalents of pure stand yield of each crop on plot basis and the land equivalents and land equivalent ratio derived from the land equivalents were subjected to analysis of variance in each site.

The Water Use Efficiency defined as kilogramme of seed cotton and dry beans produced per centimetre of rain received was derived from the yield of seed cotton and dry beans, and, the rainfall data collected during the growing period according to the method used by Longenecker *et al* (1968).

The rainfall data recorded during the period was analysed against the confidence limits based on 15 year average at Tebere (see appendices 13 and 14 for weather data, and analysed rainfall data respectively).

RESULTS

Yield Aspects

Analysis of covariance was conducted to test whether the yield of seed cotton obtained from mixtures with beans had any correlation with the yield of the companion crop of beans. The covariable obtained was found to be statistically insignificant at 95% level of probability. The yield of seed cotton was thus considered independent of the yield of beans and analysis of variance on each crop carried separately according to Pearce and Gilliver (1979).

Yield of Seed Cotton

The mean seed cotton yields at Tebere and Wanguru are presented in table 1. The amount of seed cotton obtained at Tebere was comparable to quantities obtainable under research conditions in Central Kenya. These yields were however higher than the average yields from farmers plots estimated at 450 kg/ha.

The yield of seed cotton at Wanguru was low owing to crop damage by cotton pests. Spiny bollworm (Earias insulana Boisd.) attacked the crop early in the season and because of the feeding habits of this pest, much lateral vegetative growth was encouraged. Movement through the crop thereafter became difficult and subsequent pest control measures could not be done efficiently. Much of the damage was due to Pink bollworm (Pectinophora gossipiela Saund.) attack. The latter feeds on seeds inside the bolls. The infested bolls do not open properly and are seldom harvested.

Statistical analysis conducted on the yield of cotton at Tebere shows that significant difference in seed cotton yields exist between various planting patterns. The mean yield of cotton in planting patterns with cotton rows 100 cm apart was significantly greater than the mean for patterns where cotton rows are 150 cm and 200 cm apart. The latter produced the lowest mean yields although this was not significantly different from patterns with rows 150 cm apart.

TABLE 1 - SEED COTTON YIELDS AT TEBERE AND WANGURU

Spacing and Planting Pattern	Mean Seed-Cotton Kg per hectare		
	Tebere	Wanguru	Mean for the sites
Pure-stand cotton	1275 ab	492	884
Narrow row Intercrops			
1 row beans	1318 a	586	952
2 row beans	1248 abc	564	906
Medium row Intercrops			
2 row beans	1064 abcd	513	789
*2 row beans	1207 abcd	583	895
3 row beans	1120 abcd	611	866
4 row beans	934 d	510	722
Wide row Intercrops			
3 row beans	1004 bcd	453	729
*3 row beans	982 cd	440	711
4 row beans	998 bcd	387	693
5 row beans	954 d	545	750
S.e	±87	±77	
C.V.(%)	7.9	15.1	

Note: Legend
1. Means separated by DMRT (P = 0.05)
2. Test for Wanguru was significant (P = 0.05)
3. Indicate planting pattern with paired cotton rows.

Among the planting patterns with similar row spacing, the differences in yield was insignificant (P=0.05).

Pure-stand cotton whose row spacing is 100cm outyielded all the patterns with row spacing of 150cm but the difference in yield was significant only in medium row intercrop with four rows of beans. The yield of cotton from mixed patterns with row spacing of 100cm was however very comparable to the yield from pure-stand cotton.

Increasing intensity of beans between cotton rows did not produce any appreciable effect on the yield of cotton. Similarly growing cotton in paired rows did not have much influence on its yield.

At Wanguru no significant differences in yields was recorded between all the tested planting patterns. Pure-stand cotton however produced less mean yields than mixed patterns with row spacing of 100cm and 150cm. Most of the patterns with row spacing of 200cm however produced lower yields than pure-stand cotton.

Yield of Dry Beans

Table 2 gives the mean yields of dry beans at Tebere and Wanguru. Analysis of variance conducted on the yield of dry beans at Tebere shows that significant difference in the yield exist between various planting patterns. Pure stand beans outyielded all but one mixed planting pattern but the yield difference was only significant with planting patterns possessing paired cotton rows. The latter produced significantly less dry beans than most of the planting patterns. Generally narrow row intercrops where the row spacing for cotton is 100cm produced less beans than medium (150cm) and wide (200cm) row intercrops at Tebere.

At Wanguru the analysis of variance has indicated that there is no significant differences in yield of dry beans between all the planting patterns (P=0.05). Pure-stand beans has however outyielded beans in all other planting patterns. No other systematic observation was made on the yield of beans at Wanguru.

TABLE 2 - DRY BEAN YIELDS FOR TEBERE AND WANGURU

Planting Pattern	Mean Dry Bean Yields Kg/ha		
	Tebere	Wanguru	Mean for two sites
Pure-stand beans	1956 ab	1507	1732
Narrow row intercrops			
1 row beans	1545 bcd	1358	1452
2 row beans	1525 bcd	1083	1304
Medium row inter-crops			
2 row beans	1778abcd	1219	1498
*2 row beans	1392 d	1140	1266
3 row beans	1739abcd	1255	1497
4 row beans	2102 a	965	1534
Wide row intercrops			
3 row beans	1624 bcd	889	1257
*3 row beans	1418 cd	1052	1235
4 row beans	1856 abc	1207	1532
5 row beans	1786abcd	1141	1464
S.e	±132	±167	
C.V. %	7.7	14.3	

Note: 1. * Planting pattern with paired rows of cotton.

2. Means separated by DMRT (P = 0.05)

The yields at Wanguru were however lower than the yields obtained at Tebere possibly due to ineffective pest control at Wanguru (beans and cotton had common pests at this site). When the mean for the two sites was computed, pure-stand beans produced better average yields than mixed stands. Among the mixed patterns, stands with paired cotton rows produced lower yields of beans than their contemporaries with regular single rows of cotton. The remaining patterns produced yields which were very comparable to one another.

Land Equivalent Ratios

Land equivalent for each crop was calculated on plot basis and their means for the two experimental sites are presented in tables 3, and 4 for Tebere and Wanguru respectively. Land equivalent for a crop is the ratio of the yield of that crop produced from mixtures to the yield from an equal area of the same crop in monoculture (Oyeyola and Mead, 1982). Land equivalent ratio (L.E.R.) is the sum total of land equivalents of the crops involved in the mixture.

$$\text{L.E.R.} = \text{L.E.(C)} + \text{L.E.(B)}$$

$$= \frac{\text{YC(M)}}{\text{YC(P)}} + \frac{\text{YB(M)}}{\text{YB(P)}}$$

Where L.E.R. = Land equivalent ratio

L.E.(C) = Land equivalent for cotton

L.E.(B) = Land equivalent for beans

YC(M) = Yield of cotton in mixture

YC(P) = Yield of cotton in pure-stand

YB(M) = Yield of beans in mixture

YB(P) = Yield of beans in pure-stand

The L.E.(C) values at Tebere site range from 1.08 for narrow row intercrop with a single row of beans to 0.75 for medium row intercrop with four rows of beans (Table 3). Pure-stand cotton is by definition alloted a land equivalent value of 1.00.

The relatively high values of L.E(C) obtained in these studies indicate that beans did not have much adverse effect on the associated cotton, and in certain instances where L.E(C) values are greater than 1.00, beans may have contributed positively to the yield of seed-cotton. This is particularly so with the narrow row intercrops whose L.E(C) values are 1.08 and 1.03 for patterns with a single row of beans and two rows of beans respectivley.

The L.E(C) values systematically declined with increasing cotton row width so that patterns with narrow row cotton (100cm) produced better average L.E(C) than medium (150cm) and wide (200cm) patterns in a descending order.

TABLE 3 - MEAN YIELDS AND LAND EQUIVALENT RATIOS FOR TEBERE

Planting Pattern	L.E.(C)	L.E(B)	L.E.R.
Monocrops			
Cotton	1.0(1275)	-	1.0
Beans	-	1.0(1956)	1.0
Narrow row intercrops			
1 row beans	1.08(1318)	0.76(1545)	1.84
2 row beans	1.03(1248)	0.82(1525)	1.85
Medium row intercrops			
2 row beans	0.85(1064)	0.93(1778)	1.78
*2 row beans	1.02(1207)	0.72(1392)	1.74
3 row beans	0.91(1120)	0.93(1739)	1.84
4 row beans	0.75(934)	1.09(2102)	1.83
Wide row intercrops			
3 row beans	0.82(1004)	0.86(1624)	1.68
*3 row beans	0.82(982)	0.75(1418)	1.57
4 row beans	0.82(998)	0.97(1856)	1.77
5 row beans	0.78(954)	0.95(1786)	1.72
S.e	±0.07	±0.08	±0.12
C.V. %	7.9	8.4	6.1

Note: 1. *Indicate planting pattern with paired cotton rows.

2. Mean of five replicates.

3. In brackets are the mean yields of cotton and beans in kg/ha.

The land equivalents for beans at Tebere were similarly very high. Varying from 0.72 for medium row pattern with paired cotton rows to 1.09 for medium row pattern with four rows of beans. The high value of L.E (B) is indicative of little influence of cotton on the yield of associated beans. Generally medium row (150cm) and wide row (200cm) patterns produced better L.E(B) values than narrow (100cm) patterns at Tebere. Planting patterns with paired cotton rows also produced lower L.E(B) values than their contemporaries with single cotton rows. These values were also lower than the values for all the tested planting patterns.

Land equivalent ratios were high in mixture at Tebere owing to high value of L.E(C) and L.E(B). Analysis of variance indicate significant advantages in land productivity of mixtures over monocultures (P = 0.05). The L.E.R. values varied from 1.00 for each of the monocultures to between 1.57 and 1.85 for mixtures at Tebere. Where cotton is planted in paired rows, there was a general decline in land productivity as demonstrated by the low L.E.R. values in these patterns.

At Wanguru, the land equivalents for cotton varied from 0.68 in wide row cotton (200cm) with four rows of beans to 1.37 for medium row cotton (150cm) with three rows of beans (table 4). These high values of L.E(C) were possible inspite of the relatively low yields of cotton in this site because they were calculated on the basis of the yields obtained during the cropping season and not the average annual yields.

Like Tebere, the L.E(C) for Wanguru also declined with increasing cotton row spacing. Narrow row (100cm) intercrops produced the highest mean L.E(C) followed by medium (150cm) row intercrops and lastly wide (200cm) row intercrops. The differences in land equivalents was however statistically insignificant (P=0.05) between all the tested planting patters.

The land equivalent for beans (L.E(B)) at Wanguru fell between 1.00 for pure-stand beans and 0.62 for wide row intercrop (single cotton rows) with three rows of beans. The differences in L.E(B) values among the tested planting patterns were however statistically insignificant (P=0.05).

TABLE 4 - MEAN YIELDS AND LAND EQUIVALENT RATIOS FOR WANGURU

Planting Pattern	L.E(C).	L.E(B).	L.E.R.
Monocrops:			
Cotton	1.00(492)	- ( )	1.00
Beans	-	1.00(1507)	1.00
Narrow row Intercrops			
1 row beans	1.19(586)	0.96(1358)	2.15
2 row beans	1.15(564)	0.81(1083)	1.96
Medium row Intercrops			
2 row beans	1.04(513)	0.84(1219)	1.88
* 2 row beans	1.20(583)	0.81(1140)	2.01
3 row beans	1.37(611)	0.83(1255)	2.20
4 row beans	1.04(510)	0.65(965)	1.69
Wide row Intercrops			
3 row beans	0.92(453)	0.62(889)	1.54
* 3 row beans	0.89(440)	0.71(1052)	1.60
4 row beans	0.68(387)	0.81(1207)	1.49
5 row beans	1.11(545)	0.79(1141)	1.90
S.e.	±0.05(±77).	±0.12(±167)	+0.12
C.V. %	4.7%(15.1)	15.5 (14.3)	7.33

Note: 1) * Indicate planting pattern with paired cotton rows.

2) In brackets are the mean yields in kg/ha.

Like in Tebere the L.E(B) values at Wanguru are also high indicating little influence of cotton on the yield of the associated beans. In contrast to Tebere, there was an indication of a general decline of L.E(B) with increasing cotton row spacing, with narrow row intercrops apparently giving better mean L.E(B) followed by medium row and lastly the wide row intercrops.

The land equivalent ratio (L.E.R) values for Wanguru ranged from 1.00 for the monocultures to between 1.49 for wide row cotton with four rows of beans and 2.20 for medium row cotton with three rows of beans. L.E.R. values greater than 1.00 indicate greater advantages in land productivity in mixtures compared to monocultures. Among the mixtures, significant differences were observed between various planting patterns. The narrow row intercrops produced better mean land equivalent ratio than medium and wide row intercrops.

When the mean L.E.R. for the two sites were considered, medium row intercrops (150cm) with three rows of beans produced the highest (2.02) L.E.R (Table 5) followed by the two narrow row intercrops with 2.00

TABLE 5: LAND EQUIVALENT RATIOS FOR TEBERE AND WANGURU

Planting Pattern	Land Equivalent Ratio		
	Tebere	Wanguru	Mean
Monocrops:			
cotton	1.00	1.00	1.00(11)
beans	1.00	1.00	1.00(11)
Narrow row intercrops:			
1 row beans	1.84	2.15	2.00(2)
2 rows beans	1.85	1.96	1.90(3)
Medium row intercrops:			
2 rows beans	1.78	1.88	1.83(5)
*2 rows beans	1.74	2.01	1.87(4)
3 rows beans	1.84	2.20	2.02(1)
4 rows beans	1.83	1.69	1.76(7)
Wide row intercrops:			
3 rows beans	1.68	1.54	1.61(9)
*3 rows beans	1.57	1.60	1.59(10)
4 rows beans	1.77	1.49	1.63(8)
5 rows beans	1.72	1.90	1.81(6)
S.E	±0.12	±0.12	-
C.V(%)	6.1	7.33	-

Note: In brackets are ranks of individual treatment from highest L.E.R (2.02) to lowest (1.00).

and 1.90 for narrow row (100cm) with single row of beans and two rows of beans respectively. Monocrops by definition were allotted the value of 1.00

Gross Cash Returns

The gross cash returns from an hectare obtained by multiplying the mean yields by the market price of each of the crop is presented in tables 6 and 7 for Tebere and Wanguru respectively. The Government producer price for seed cotton in 1982 was Kshs.3.80 per kilogram of grade A (AR) cotton. The price of beans paid by the area agents was Kshs.3.60 per kilogram.

The gross cash returns from Tebere ranged between Kshs.4,845.00 per hectare with pure-stand cotton to Kshs.11,116.40 for medium row intercrops with four rows of beans. This is an increase of 129.4% in gross cash returns over pure-stand cotton.

The gross cash return from pure-stand beans was Kshs.7,041.60 per hectare which amounts to 45.3% more than the gross cash return from pure-stand cotton.

TABLE 6: GROSS CASH RETURNS AT TEBERE (1982)

Planting Pattern	Produce Yields (Kg/ha) Seed-cotton	Dry beans	Gross Cash Return	Increase in Gross Cash over Pure-stand cotton (%)
Monocrops:				
Cotton	1275	-	4,845.00(12)	0
Beans	-	1956	7,041.60(11)	45.3
Narrow row Intercrops				
1 row beans	1318	1545	10,570.40(3)	118.2
2 row beans	1248	1525	10,232.40(5)	111.2
Medium row Intercrops				
2 row beans	1064	1778	10,799.60(2)	122.9
* 2 row beans	1207	1392	9,597.80(9)	98.1
3 row beans	1120	1739	10,516.40(4)	117.1
4 row beans	934	2102	11,116.40(1)	129.4
Wide row Intercrops				
3 row beans	1004	1625	9,665.20(8)	99.5
* 3 row beans	982	1418	8,836.40(10)	82.4
4 row beans	998	1856	10,474.00(5)	116.2
5 row beans	954	1786	10,054.80(7)	107.5
S.e	±87	±132	-	-

Note: 1) * Planting patterns with paired cotton.
2) means for five replicates
3) In brackets are ranks of gross cash returns for individual treatments from highest (1) to lowest (12).

TABLE 7: GROSS CASH RETURNS AT WANGURU (1982)

Planting Pattern	Produce Yields (Kg/ha) Seed Cotton	Dry Beans	Gross Cash Return (K.shs)	Gross Cash Return % Over Pure Cotton
Monocrops:				
Cotton	492	-	1,869.60(12)	-
Beans	-	1507	5,425.20(9)	190.2
Narrow row Intercrops				
1 row beans	586	1360	7,122.80(1)	281.0
2 row beans	564	1078	6,024.00(6)	222.2
Medium row Intercrops				
2 row beans	513	1219	6,337.80(4)	240.0
* 2 row beans	588	1140	6,338.40(3)	239.0
3 row beans	673	1250	7,057.40(2)	277.5
4 row beans	510	965	5,412.00(10)	189.5
Wide row Intercrops				
3 row beans	453	889	4,921.80(11)	163.3
* 3 row beans	440	1052	5,459.20(8)	192.0
4 row beans	387	1207	5,815.80(7)	211.1
5 row beans	545	1140	6,175.00(5)	230.3
S.e	±95	±167		

Note: In brackets are ranks for individual treatments from highest (1) to lowest (12).

* Inidate planting patterns with paired cotton rows.

The gross cash returns from cotton-beans mixtures are between 82.4% and 129.4% better than that of pure-stand cotton. On the average all the mixtures gave returns twice as much as pure-stand cotton. In only two occassions did the gross cash return from mixtures fall below 100% increase above pure-stand cotton. This occurred with paired row cotton intercrops at medium row (150 cm x 30 cm) and wide row (200 cm x 30 cm) spacings. This is probably due to the high reduction in the yield of dry beans observed in these two planting patterns. The mean gross returns from narrow row (100 cm x 30 cm) intercrops and medium row (150 cm x 30 cm) intercrops are 115% and 118% greater than the gross returns from pure-stand cotton respectively, while that for wide row intercrops (200 cm x 30 cm) is 101% better than pure-stand cotton. The relatively low returns from wide-row intercrops compared to narrow and medium intercrops is due to low returns from cotton component as a result of low yields of the latter. The low yields of beans observed among the narrow row intercrops were however compensated by the increased yields in cotton. Consequently the gross returns from narrow row intercrops are still high in comparison to medium or wide row intercrops.

Water Use Efficiency (WUE)

The efficiency by which crops utilize rainfall was calculated on the basis of Kilograms of marketable products per centimetre of rainfall received. (Longenecker et al 1969). Water use efficiency values for Tebere and Wanguru are given in tables 8 and 9 respectively. These values are based on 912.9mm (91.29cm) of rainfall recorded at Tebere site.

The results show pure-stand cotton to be less efficient in converting the available rainfall into marketable yield compared to pure-stand beans and cotton-beans mixtures. The water use efficiency at Tebere is 14.0kg/cm for pure-stand cotton, 21.4kg/cm for pure-stand beans. The values for mixed patterns varied from 26.3kg/cm to 33.3kg/cm. When these values were converted into percentages of pure-stand cotton, pure-stand beans had an efficiency advantage of 52.9% over pure-stand cotton at Tebere. The mixed patterns were better than pure-stand cotton by between 87.9% and 137.9% in water use efficiency.

TABLE 8: WATER USE EFFICIENCY VALUES FOR TEBERE (1981/82)

Planting Pattern	Marketable Yields Kg/ha Cotton	Beans	Total	WUE Kg/cm Rainfall	WUE % Over Pure Cotton
Monocrops:					
Cotton	1275	-	1275	14.0	-
Beans	-	1956	1956	21.4	52.9(10)
Narrow row Intercrops					
1 row beans	1318	1554	2872	31.5	125 (3)
2 row beans	1248	1525	2725	30.4	117.1(5)
Medium row Intercrops					
2 row beans	1064	1778	2842	31.1	122.1(4)
* 2 row beans	1207	1392	2599	28.5	103.6(8)
3 row beans	1120	1739	2859	31.3	123.6(2)
4 row beans	934	2102	3036	33.3	137.9(1)
Wide row Intercrops					
3 row beans	1004	1625	2629	28.8	105.7(7)
* 3 row beans	982	1418	2400	26.3	87.9(9)
4 row beans	998	1856	2854	31.3	123.6(2)
5 row beans	954	1786	2740	30.0	114.3(6)
S.e.	±87	±132	-	-	-

Note: 1) In brackets is the rank of individual treatment from highest (1) to lowest (10)

2) * Indicate patterns with paired cotton rows.

TABLE 9: WATER USE EFFICIENCY FOR WANGURU 1981/82

Planting Pattern	Cotton	Beans	Total	WUE Kg/cm	WUE % Over Pure-Cotton
Monocrops:					
Cotton	492	-	492	5.4	-
Beans	-	1507	1507	16.5	205(8)
Narrow row Intercrops					
1 row beans	586	1360	1946	21.3	294(2)
2 row beans	564	1078	1642	18.0	233(6)
Medium row Intercrops					
2 row beans	573	1219	1732	19.0	252(3)
* 2 row beans	588	1140	1728	18.9	250(1)
3 row beans	611	1250	1861	20.4	378(1)
4 row beans	510	965	1475	16.2	200(10)
Wide row Intercrops					
3 row beans	453	889	1342	14.7	172(11)
* row beans	440	1052	1492	16.3	202(9)
4 row beans	387	1207	1594	16.9	212(7)
5 row beans	545	1140	1685	18.5	243(5)
S.e	±85	±162	-	-	

(1) * Patterns with paired cotton rows

(2) Means for 5 replicates

(3) In brackets are the rank for each treatment from highest (1) to lowest (11).

Water use efficiency values for Wanguru on the other hand were much lower than the values for Tebere due to low cotton yields at this site. Nevertheless pure-stand cotton still had the lowest water use efficiency value 5.4kg/cm compared to 16.5kg/cm for pure-stand beans and values ranging from 14.7kg/cm to 21.3kg/cm for mixed stands. When these values were converted into percentages of pure-stand cotton, enormous advantages were obtained. Pure-stand beans had an advantage of 205% over pure-stand cotton. The advantages of mixed patterns over pure-stand cotton varied from 172% to 294%. The values at Wanguru are much higher than at Tebere because of the poor yields of cotton at this site.

A common observation for all the sites is a general decline in water use efficiency with increasing cotton inter-row spacing from narrow row (100cm x 30cm) intercrops to wide row intercrops (200cm x 30cm).

Growth Characteristics

Plant height measurements taken on the cotton component in the mixture was plotted against time for Tebere (Figure 1).

The growth of cotton plants as measured through changes in plant height was fastest within the first six weeks following the emergence of cotton. During this period no significant differences in growth were observed between all the tested planting patterns. The next four weeks was characterized by a gradual decline in growth rates in all the planting patterns, but the decline in growth rate was greater in mixed stands compared to pure-stand cotton. This culminated in significantly taller plants in pure-stand cotton compared to cotton grown in mixtures with beans by the time beans were getting harvested. The period also coincided with the onset of the long dry season. Very little growth was recorded during the long dry period between January and April. A sharp rise in growth rate was again recorded with the onset of the long rains in April. Plots which had earlier been associated with beans apparently produced faster growth than pure-stand cotton. At the termination of cotton season there was no significant difference in plant heights between all the tested planting patterns both at Tebere and Wanguru. Plants at Wanguru were however shorter than those at Tebere (Table 10). This is possibly due to the effect of

FIG. 1. CHANGES IN HEIGHT OF COTTON MIXED WITH BEAN: NARROW ROW PLANTING PATTERNS.

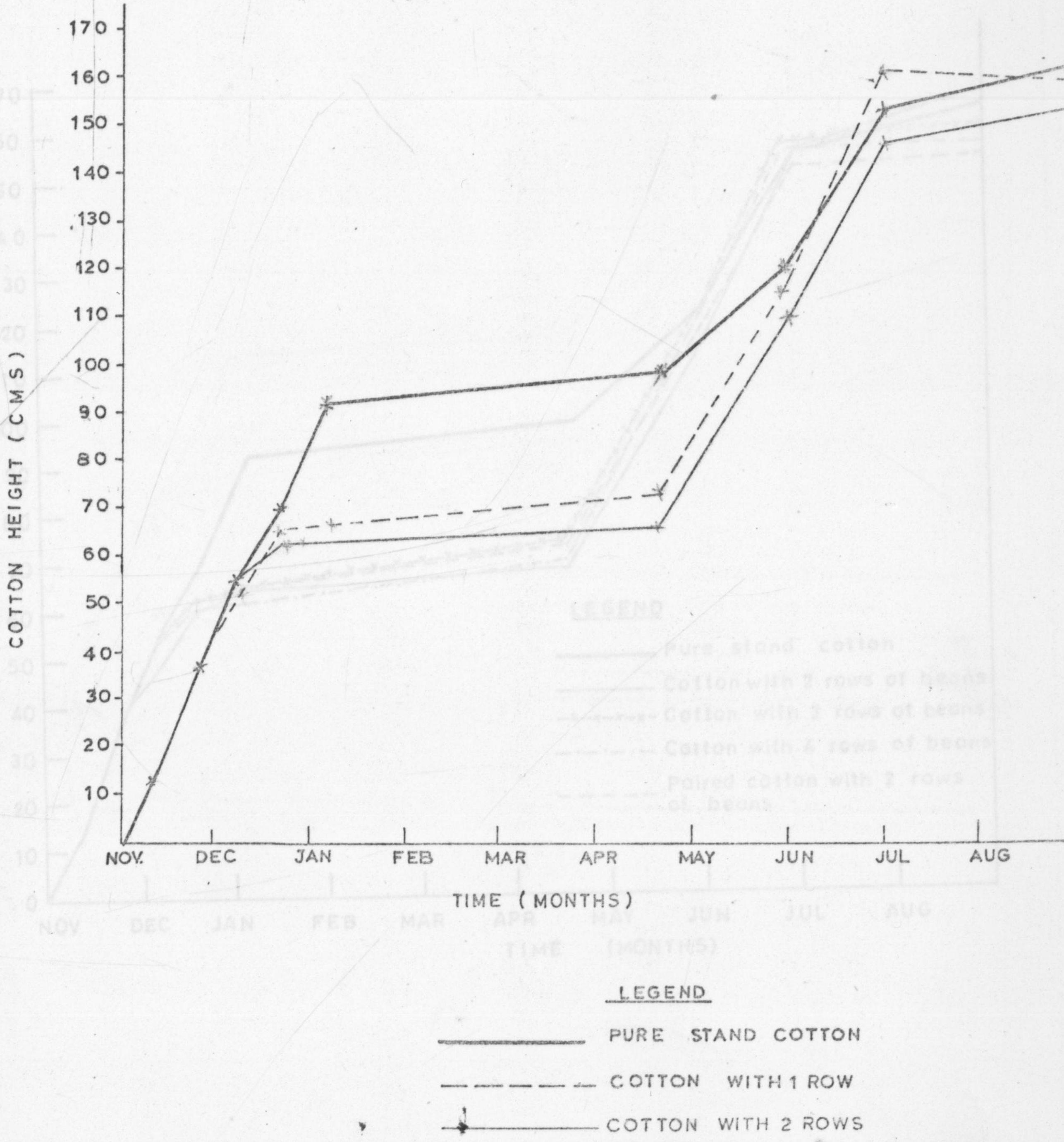

FIG. 2. CHANGES IN HEIGHT OF COTTON MIXED WITH BEANS: MEDIUM ROW PLANTING PATTERN.

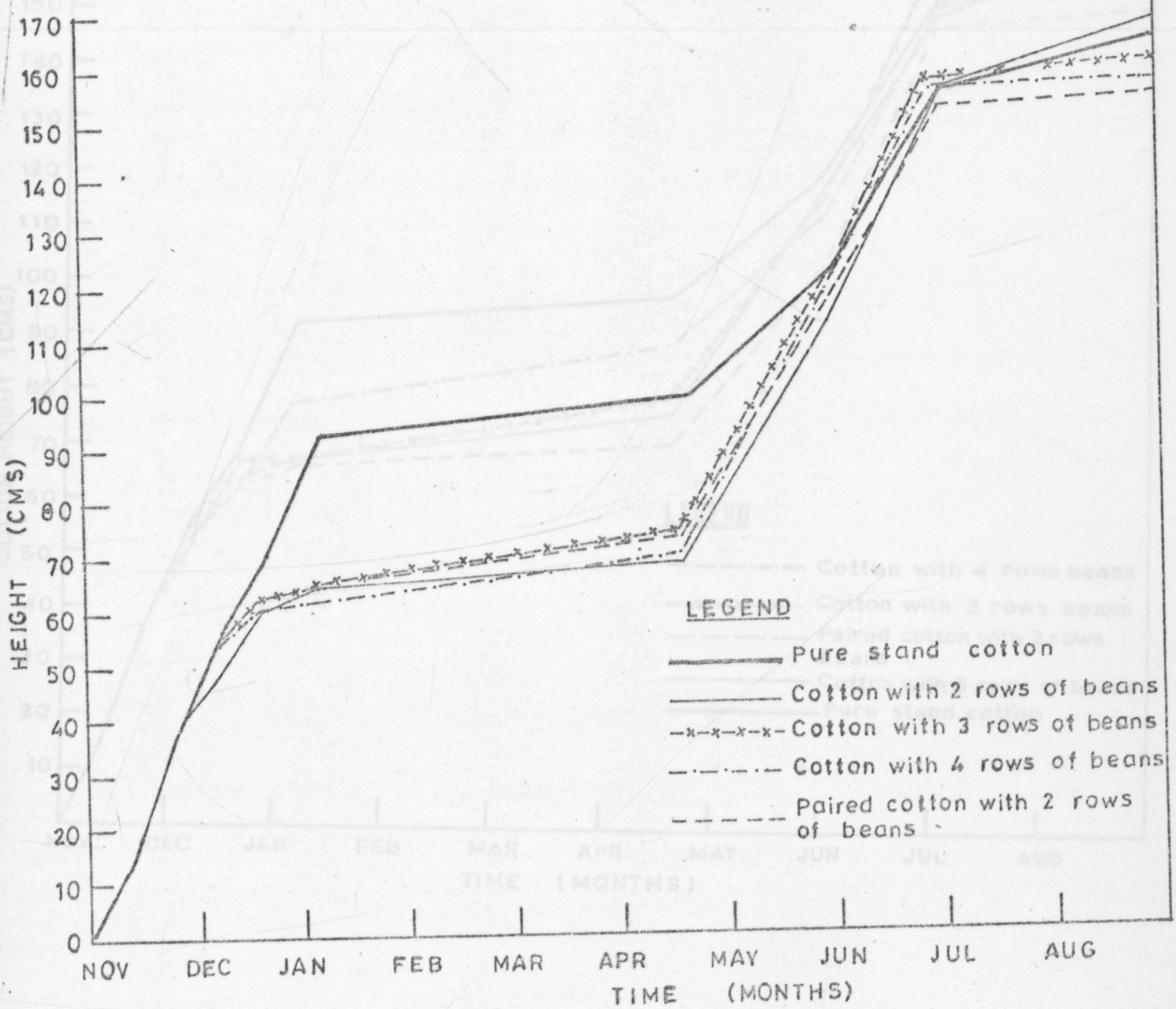

FIG 3. CHANGES IN HEIGHT OF COTTON MIXED WITH BEANS: WIDE ROWS PLANTING PATTERNS.

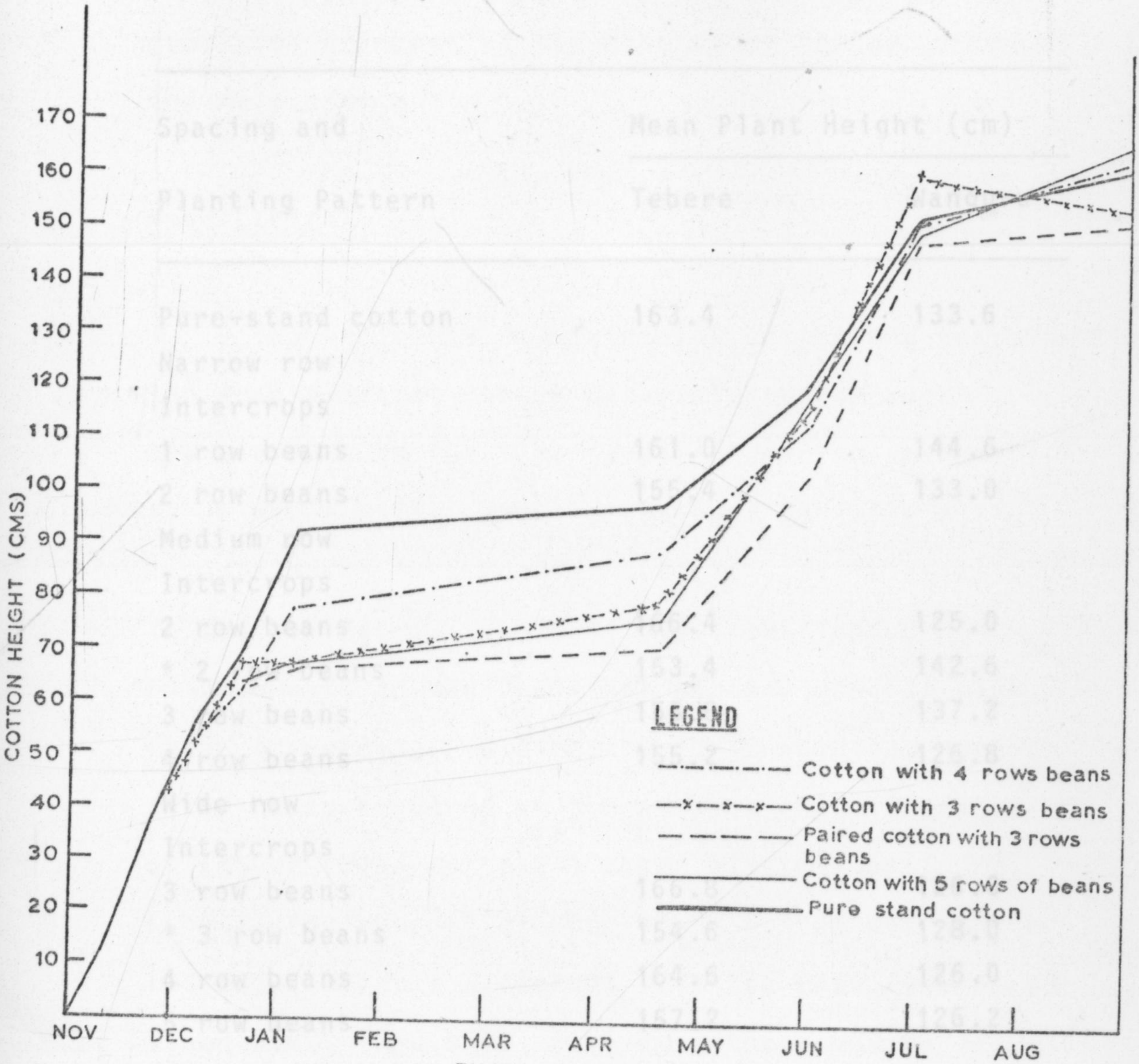

TABLE 10: PLANT HEIGHT MEASUREMENTS AT HARVEST

Spacing and Planting Pattern	Mean Plant Height (cm) Tebere	Wanguru
Pure-stand cotton	163.4	133.6
Narrow row Intercrops		
1 row beans	161.0	144.6
2 row beans	155.4	133.0
Medium row Intercrops		
2 row beans	166.4	125.0
* 2 row beans	153.4	142.6
3 row beans	156.8	137.2
4 row beans	155.2	126.8
Wide row Intercrops		
3 row beans	166.8	126.0
* 3 row beans	154.6	128.0
4 row beans	164.6	126.0
5 row beans	157.2	126.2
S.e	±6.4	±3.7
C.V. %	2.1	2.1

1) * Planting pattern with paired rows of cotton

2) Mean of five replicates.

Spiny bollworm whose feeding habit of boring the growing tip of the plant promoted a more lateral growth of branches at the expense of the growth of the main stem.

Weed Control

The influence of mixture of cotton and beans on the weed flora at Tebere was evaluated through measurements on the time spent in weeding each plot by an adult male. Weeding was done manually using a panga which is a popular tool for this operation in Central Kenya. Table 11 gives the labour requirements in man-hours per hectare used in each round of weeding. During the first weeding, pure-stand beans required on the average the highest amount of labour compared to all other planting patterns. Labour requirement for pure-stand cotton was however not significantly different from the requirements for mixed plots (P=0.05). Similarly there was no significant difference in labour requirements among the mixed patterns.

During the second weeding, pure-stand cotton required more labour compared to all the other planting patterns. Pure-stand beans on the other hand required the least amount of labour significantly lower than pure-stand cotton. Paired row (double row) cotton intercrops also required significantly more labour for second weeding than pure-stand beans and all the other mixed patterns. The labour requirement during the second weeding was generally lower than in first weeding.

The third weeding was a light operation because of the prevailing dry weather. Pure-stand cotton again required a significantly greater amount of labour than all mixed patterns. The operation was carried after beans had been harvested.

Fourth and fifth weeding operations were carried out after the onset of the long rains. The labour requirement for weeding during the fourth round was comparable to the requirements during the first weeding in the mixed stands. The requirement for pure-stand cotton during this round of weeding was however much lower than the requirements by pure-stand cotton during the first weeding.

TABLE 11: LABOUR INPUT FOR WEEDING IN HOURS/HA TEBERE 1981/82

	1st Weeding	2nd Weeding	3rd Weeding	4th Weeding	5th Weeding	Seasonal Total
Monocrops:						
Cotton	75	35	15	52	29	215 a (9)
Beans	85	10	-	-	-	95 d (1)
Narrow row Intercrops						
1 row beans	69	12	4	65	34	184 bc(3)
2 row beans	67	12	3	67	24	174 c (2)
Medium row Intercrops						
2 row beans	69	17	4	72	32	194 b (4)
* 2 row beans	65	20	5	75	37	202 ab(6)
3 row beans	76	12	7	68	38	201 ab(5)
4 row beans	67	13	6	84	43	213 a (8)
Wide row Intercrops						
3 row beans	76	12	6	76	47	217 a (11)
* 3 row beans	69	22	4	68	41	204 ab(7)
4 row beans	70	15	4	70	45	204 ab(7)
5 row beans	76	18	4	70	48	216 a (10)
S.e.	±3	±1	±1	±2	±2	±5
C.V. %	4.78	5.97	17.6	2.27	5.50	2.71

1) * Indicate planting pattern with paired rows of cotton.

2) Means separated by DMRT (P = 0.05).

In brackets are the ranks from least labour requirement (1) to highest (11).

Generally narrow row (100cm) spacing required less amount of labour compared to wide (200cm) and medium (150cm) spacing. During fifth weeding the labour requirements in all the tested patterns dropped below the levels required for fourth weeding. Pure-stand cotton again required the least amount of labour compared to all other patterns. Generally there was a systematic increase in labour requirement with increasing inter-row spacing of cotton during the fifth weeding operation. Wide rows (200cm) required more labour compared to medium (150cm) and narrow rows (100cm) planting patterns.

When the labour requirements for weeding during the whole cropping period was computed pure-stand beans turned out to be the least in requirement with most of the mixed patterns and pure-stand cotton requiring twice as much labour as pure-stand beans. This is because beans is a short season crop compared to cotton. The total labour requirement for pure-stand cotton was however very comparable to the requirement for most of the mixed patterns except narrow row intercrops which required significantly less labour than pure-stand cotton and most of the mixed patterns ($P=0.05$).

Table 12 gives the output per man-hour used for weeding. Pure-stand beans produced the best output because beans is a short season crop. Mixed patterns produced better output per man-hour used in weeding than cotton. Generally narrow row (100cm) cotton intercrops produced better output followed by medium row (150cm). Wide row intercrops gave lower returns to each man-hour used in weeding than the former two.

Summary of Results

From the studies conducted on cotton/bean intercropping in Central Kenya, the following results have been obtained:

1) Beans have no deterious effect on the yield of associated cotton although the rate of development early in the season is retarded by beans.

2) The yield of beans is slightly affected by growing the latter in association with cotton.

3) The productivity of land quantified by land equivalent ratio is much higher with cotton/ beans intercrops than when the two crops are

TABLE 12: LABOUR INPUT IN HRS/HA. CASH VALUE (SHS./HA) AND OUTPUT PER MANHOUR IN SHILLINGS.

Planting Pattern	Labour Input for weeding (Man-hours/ha)	Cash Value of crop (Sh./ha)	Output (Sh./Man-hour)
Monocrops:			
Cotton	215	4,845.00	22.50(12)
Beans	95	7,041.60	74.10(1)
Narrow row Intercrops			
1 row beans	184	10,570.40	57.45(3)
2 row beans	173	10,232.40	59.15(2)
Medium row Intercrops			
2 row beans	194	10,799.60	55.65(4)
* 2 row beans	202	9,597.80	47.50(8)
3 row beans	201	10,516.40	52.30(5)
4 row beans	213	11,116.40	52.20(6)
Wide row Intercrops			
3 row beans	217	9,665.20	44.55(10)
* 3 row beans	204	8,836.40	43.30(11)
4 row beans	204	10,474.00	51.35(7)
5 row beans	216	10,054.80	46.55(9)

Note: 1) In brackets are ranks of individual treatment from best output (1) to lowest (12).

2) Man-hour - work done by a male adult for one hour.

grown separately.

4) The efficiency with which rainfall is utilized is much higher when cotton and beans are mixed than when each of the crops is grown separately.

5) Growing cotton mixed with beans could save on the labour for weeding if the row width of cotton is not wide and the output for each man-hour used in weeding is higher with cotton/beans mixtures than cotton alone.

D I S C U S S I O N

The results obtained on the yield of cotton at Tebere and Wanguru indicate that the yield of cotton is not influenced by the companion crop of beans. This is demonstrated by seed cotton yields obtained from mixed plots which are not significantly different from the yields from pure stand cotton. The results corroborate similar observations by Wright (1956), in which maize did not influence the yield of a companion cotton in Coast Province Kenya. Similar results have also been obtained by Popay (1972), Brown (1971) and Nyaisawa (1976) on mixtures of cotton with beans at Giaki in Meru District Central Kenya, and cotton with beans, soyabeans, green-grams or groundnuts in Western Kenya respectively. The results also agree with the authors own unpublished observations on cotton-beans mixtures at Tebere, Central Kenya, and Taveta Coast Province Kenya, and Ithokwe Dryland Research Station, Kitui District Central Kenya in 1979/80 and 1980/81. Brown (1971) however found a decrease in yield of seed cotton when cotton was mixed with beans at Tebere. Nyaisawa (1976) also found large reduction in the yield of cotton as a result of mixing the latter with maize or sorghum in Western Kenya.

The yield data indicate that cotton is largely influenced by the planting pattern with the recommended narrow row (100cm) producing significantly higher yields than cotton widely spaced (200cm). Medium row (150cm) spacing also outyielded the wide row (200cm) cotton although not significantly. These results are however more pronounced at Tebere site than at Wanguru where the yield of cotton was very low. These results however could not conclusively associate the variation in seed cotton yield with cotton plant population. This is because double row planting patterns (paired cotton rows) with plant population similar to narrow row cotton at wide (200cm) spacing or higher population at medium (150 cm) spacing did not produce equally high yields as the narrow row (100cm) cotton. This is probably due to high infertility rate among crowded cotton plants in paired row cotton as observed by Taylor, Peacock, Reid and Hawkins and reported by Hawkins and Peacock (1973).

The results obtained in this experiment also indicate that growing cotton in paired rows has no effect on the yield of seed cotton. Similarly increasing the number of rows of beans between cotton rows does not have any effect on the yield of seed cotton.

The yield of bean component on the other hand was considerably influenced by the companion cotton crop. At both Tebere and Wanguru the yield of beans in all the mixed stands was generally lower than the yield of beans from pure-stands (Table 3). The yield reduction on beans as a result of mixing the latter with cotton varied between 3% to 27% at Tebere and 4% to 38% at Wanguru depending on the planting pattern. The number of rows of beans between cotton rows had an apparent influence on the yield of beans. The yield of beans increased with increasing number of rows of the latter between cotton for medium (150cm) and wide (200cm) cotton rows at Tebere. Increasing intensity of cotton produced a systematic reduction on the yield of beans with the planting patterns possessing higher cotton plant population producing relatively less dry bean yield compared to the patterns with fewer cotton plants. This is an indication of competition for the growth resources between cotton plants which are involved in the competition with one another and with beans for the growth resources the effect was transformed into low yield of beans. This is illustrated by the low yields of dry beans from paired row planting patterns (Double row cotton). The paired row patterns have higher plant population compared to single row patterns.

In Meru District Central Kenya where the short rains usually extend to the end of December, the crop formed from these rains is usually very substantial making about one third of the total crop. This cotton is usually picked before the onset of the long rains. Previous studies by Popay (1971) indicate that beans have no deleterious effect on cotton in Meru District. Infact he went a head and recommended that intercropping of cotton with beans be allowed in Meru District. Similar studies by Nyaisawa (1976) conducted in a completely different environment from that of Central Kenya produced same results. Western Kenya has a monomodal rainfall pattern where cotton and beans are sown at the beginning of rains in March and both crops mature within the same rainfall season as opposed to the bimodal rainfall pattern in Central Kenya. These results show that in Central Kenya, cotton is able to utilize the second rainfall season to rehabilitate from drought and competition effects suffered from mixing the latter with beans, and is able to fully attain its production potential.

The earlier results on the other hand further suggests that irrespective of the rainfall pattern, beans have no deleterious effect on the yield of cotton when the two crops are mixed.

The resumption in growth of cotton following the onset of long rains indicates that moisture is the most critical factor affecting the growth of cotton. It was further demonstrated that moisture was more limiting in mixed stands compared to pure-stand cotton. This is reflected in shorter plants in mixed stands compared to pure-stand cotton at the onset of the dry season.

The results obtained on the land equivalent ratios indicate huge advantages of growing cotton and beans in mixtures. Substantial advantages in production per unit area of land was recorded from mixed plots compared to monocultures.

These results are in agreement with earlier observations by Wright (1956), Grimes (1963), Brown (1971), Popay (1971), Nyaisawa (1976), all of whom have found advantages of intercropping cotton with certain crops. The advantage of intercropping cotton with beans (expressed by land equivalent ratio) over pure stand of each of the crops recorded in these studies varied from 57% to 85% for Tebere and 50% to 120% for Wanguru (Table 4 and Table 5). These values compare well with earlier findings by Andrews (1972) of 80% yield advantage in mixtures of sorghum with millet or cowpeas over monocultures.

They also compare well with findings of Willey and Osiru (1972) of 38% yield advantage obtained in maize/beans mixtures and 55% advantage obtained by Osiru and Willey (1972) on sorghum with finger-millet mixtures over monocultures.

Land equivalent ratios (L.E.R.) for Wanguru site were on the average greater than those for Tebere although the yield of individual crops were better at Tebere. This agrees with observations by Fisher (1977) that greater yield advantages are obtained from mixtures during years of low yields than during years when yields of individual crops are high. It can be added here that probably better advantages may be obtained from mixtures at sites with lower yields. Evans (1960) similarly observed that the advantages of mixed cropping groundnuts with maize or sorghum depends on site and season. Similar observations have also been made by Wright (1956) on cotton-maize mixtures at the coastal region, Kenya. The results have also shown that planting pattern has an apparent relationship with the land equivalent ratio. The L.E.R. values generally declined with increasing row width of cotton. The same relationship was observed on the yield of cotton suggesting that cotton yields has a very strong contribution to the L.E.R.

The results show that greater advantages in land productivity are obtained when cotton rows are closer to one another than when they are further apart.

The results have also indicated that alternate rows of cotton and beans produce a relatively very high mean Land Equivalent Ratio compared to other patterns. Similar results have also been obtained by Dalal (1974-77) on maize/pigeonpea mixtures.

Water use efficiency figures derived from this research have indicated better utilization of rainfall by mixed stands of cotton and beans than monocultures. When comparisons were made between mixtures and pure-stand cotton, mixtures excelled by between 87% and 137% and 172% and 278% for Tebere and Wanguru respectively. The huge difference in relative water use efficiency values between Tebere and Wanguru sites was due to low cotton yields at Wanguru.

These results support the theory that mixtures are able to utilize the resources more efficiently than monoculture as put forward by Andrews (1972), Remison (1978), Fisher (1978), Osiru and Willey (1972) and May (1982). The net rainfall after deep percolation runoff and evapotranspiration losses was transformed into marketable yields more efficiently in mixtures of cotton and beans than in the monocultures.

The growth cycle of cotton in Central Kenya consists of establishment of a crop stand during the short rains and flowering and boll development during the long rains. Beans on the other hand is a short season crop able to grow to maturity with the short rains. When cotton and beans are mixed, a good stand of cotton can be established with the short rains and a crop of beans produced from the same land at the same time. The rainfall pattern in this area thus favours growing cotton and beans together than pure-stand cotton.

Mixed stands were also able to cover the ground sooner than the slow growing pure-stand cotton. This could have helped in conserving the rainfall from evaporation losses. Studies thus suggest that mixtures may have used a larger proportion of the rain on the crop while evaporation losses in pure-stand cotton may have been enormous.

The gross cash earnings from the crops based on the 1982 government producer prices of Kshs.3.80 per kilogram of grade A cotton and Kshs.3.60 for a kilogram of beans indicate huge monetary advantages with cotton-bean mixtures compared to pure stands.

When the gross earnings from pure-stand cotton, advantages of between 66% and 99% was realized from mixture at Tebere. The advantages were much higher at Wanguru because of the low cotton yields. The gross cash earning from pure-stand beans were also better than the earning from cotton by 21% indicating that mixtures are able to realize better earnings than pure-stand beans.

The results also confirm findings by Baker (1978) of 27.7% cash gain overall in groundnut with cereals. Brown (1971) similarly recorded an increase of 29% gross cash earning on cotton/sorghum mixture and 7% on cotton/maize mixture compared to their pure-stands. These results have however fell short of confirming findings by Norman (1971) of profitability of upto 60% more than sole crops because no costing on management operations was done.

The huge monetary advantages realized in this experiment was due to two factors.

Firstly the prices of both the crops were equally competitive and not subject to market fluctuations because the producer price of both crops is fixed by the government. Secondly the yield of each crop is either not influenced by the companion crop as with cotton, or only slightly influenced as with beans. The results on gross earnings at Wanguru indicate that when cotton and beans are mixed, either crop is able to assume the role of an insurance crop if one of the two crops is adversely affected by weather or pests. For Wanguru, cotton was adversely affected by pests and the cotton yields and subsequent earnings were similarly very low. Beans acted as an insurance crop on cotton and was able to produce earnings very comparable to or better than a full cotton crop at Tebere. The gross earnings from pure-stand cotton at Wanguru was only Shs.1,869/60 per hectare compared to Shs.4,845/= per hectare at Tebere. The gross earnings from an hectare at Wanguru was however improved by beans component to between Shs.4,921.80 and Shs.6,122.80 depending on the planting pattern. These observations support the observation by Baker (1978) that crops grown in mixtures have the ability to maintain yields despite adverse weather, pest or disease attacks.

In Central Kenya the rainfall is extremely bimodal and the reliability of each rainfall peak is independent of the other. The maximum duration of either the short rains or the long is about ten weeks. The length of each rainfall season is enough to grow short term crop such as beans. Cotton can only grow if the two peaks are used.

Failure of the short rains may result in a crop failure of beans while cotton would have poor establishment. However with the present cotton cultivar which has the ability to make compensatory growth following a temporary check in growth during the dry period getting a crop is almost certain if long rains become reliable. Cotton would therefore act as an insurance crop in years when the short rains are insufficient for beans if the two crops are raised in mixtures. Conversely in years of insufficient long rains beans will have acted as an insurance crop to a cotton farmer if the short rains become reliable.

When the labour requirement for weeding was considered, results indicate that during the first weeding, pure-stand beans require more labour than pure-stand cotton and all the other mixed stands. This is probably due to the high population of beans per plot compared to the population of cotton or mixed stands. This is coupled with the delicate nature of beans which necessitates careful weeding operation in order to avoid any injuries to the plants as beans can hardly recover from physical injuries. On the other hand cotton plants are widely spaced between the rows and within the rows and in addition, five seeds are sown per hill and thinning to one plant per hill is not done until the first weeding is completed.

Mixed stands combine the delicate nature of beans at seedling stages with the wide spacing of cotton plants so that the labour requirements during the first weeding was not substantially different from that for pure-stand cotton. Beans to a large extent replaced weeds in mixed stands but this did not make weed control in mixed stands any easier.

The influence of growing cotton and beans in mixtures on the weeds became more apparent during the second and third weeding operations whereby mixed stands required significantly less labour input than pure-stand cotton. The advantage of mixing these two crops on weeds was however nullified in patterns with medium (150cm) and wide (200cm) rows by increased labour requirements in the subsequent fourth and fifth weeding operations. The increase in labour requirements was due largely to increased amount of weeds in the plots emanating from a more open crop compared to a relatively dense pure-stand cotton. Mixed stands had open canopy due to wide spacing in some of the planting patterns and more, so due to the effect of beans on cotton earlier in the growth cycle. Such open canopy encouraged weed growth and consequently high labour requirements for weeding. Pure-stand cotton on the other hand had a more closed canopy and weeds were controlled to some extent through shading effect of cotton crop. Only narrow row intercrops required a significantly lower amount of labour than pure-stand and nearly all the mixed stands. Narrow row intercrops combined the influence of beans on weeds early in the season with the effect of spacing on weeds later in the growth cycle.

These results generally indicate greater output per unit of labour used for weeding in mixed stands compared to pure-stand cotton.

This is largely due to increased gross returns obtained from mixed plots compared to pure-stand cotton while at the same time the labour requirements for mixed stands are generally comparable to that for pure-stand cotton. Narrow row intercrops with relatively low labour requirements gave the highest output per man-hour among the mixed patterns.

From the data obtained on variation of plant height with time it is apparent that the growth of cotton plants was influenced by the companion crop of beans. This is illustrated by a large difference in plant height between cotton plants from pure-stand cotton and cotton raised in mixture with beans at the onset of dry season in January. It is further demonstrated that moisture was the single most important factor influencing growth of cotton plants through the resumption of growth at the onset of the long rains in April.

These results show that cotton and beans probably compete for growth factors from the same rooting zone contrary to the hypothesis put forward by Osiru and Willey (1972) of crops in mixtures utilizing resources from different rooting zones.

The competition was however possibly not transformed into yield components because of the compensatory growth with the onset of long rains. The seed cotton production mainly stems from this compensatory growth put up after the long rains. A little amount of crop is usually formed with the short rains but this would open at the beginning of the long rains when picking is not possible.

CONCLUSIONS AND FURTHER RESEARCH

The total productivity per unit area of land has been one of the basic considerations in evaluating the performance of mixtures of cotton and beans in this experiment conducted in Central Kenya. The most obvious conclusion that can be drawn from the experiment is that the total productivity cotton-beans mixtures per unit area of land is considerably higher than that obtained if the two crops are grown in separate monocultures.

The huge yield advantages observed in these experiments can conclusively be related to little influence of the two companion crops on the yield of each other. The results have indicated that the yield of cotton is evidently not influenced by the interplanted beans, while the yield of beans is slightly reduced due to reduced population of beans in mixtures.

It has also been seen from the results obtained in these studies that planting pattern in general and cotton spacing in particular has much influence on the yield of cotton and consequently on the total productivity per unit area of land. Evidence gathered from the studies indicate that the current spacing recommendation for cotton in Central Kenya of 100cm x 30cm gives the best seed cotton yield. At the same time the yield of beans from mixed stands in which cotton is planted at the recommended spacing gave very high yields. Therefore it can be concluded that changing the recommendation for cotton spacing in order to interplant with beans may not be necessary and growing a single row of beans between cotton rows which are 100cm apart may suffice. This will also ensure that no extra extension service costs would be incurred in trying to change the recommended cotton spacing.

The evidence obtained from these studies have indicated huge monetary advantages from mixtures of cotton and beans compared to monocultures of either crop. Mixing cotton with beans, a practice evolved by farmers may have arisen from economic considerations beside other possible reasons.

Evidence obtained have also indicated that in a bimodal rainfall pattern such as in Central Kenya where cotton is not able to produce a crop with the short rains alone, growing cotton in mixtures with beans may not only improve the utilization of rainfall and land, but may also ensure that no food crop season is lost as a result of the long growth cycle of cotton.

When the labour requirements for weeding was considered, it was indicated from these experiments that weeds are to a large extent controlled through intercropping cotton with beans. These studies also pointed to planting pattern as a single factor which largely influence weed infestation. It was found that cotton sown in rows 100 cm apart and intercropped with beans required the least amount of labour for weeding. This provides indication that the narrow row intercropping patterns are the best possible pattern of growing cotton and beans in mixtures. The narrow row patterns furthermore produced the highest output per man-hour needed for weeding.

It can be concluded from these studies that intercropping cotton with beans such as practised by many farmers in Central Kenya by no way constitute a constraint in cotton production. However, yield reductions of cotton is possible if farmers will not adopt the current spacing recommendation for cotton of 100cm between the rows and instead go for a wider spacing in trying to maximize the production of beans in cotton. These studies thus prove that farmers are right in growing cotton in mixture with beans on the basis of monetary returns. The system also ensures that a farmer is able to get a staple food crop beside cotton. Similarly, if uncertainty involved in the production of crops are considered, these studies have further indicated better prospects with cotton-beans mixtures than raising either of the crops in monoculture.

Because these conclusions are based on results obtained from a single season they should be interpreted with caution as changes in growing conditions are likely to change from season to season, it is thus suggested that although these studies have identified the viability of growing cotton and beans together and indicating the best possible planting pattern, they should be followed with more studies in various other sites before any recommendations can be made to the farmers. These studies should include the following:-

(a) The influence of various varieties of each of the two crops on the yield of a companion crop. This will help in identifying varieties of each crop which are able to do best in mixed situations.

(b) The effect of mixing cotton with beans on the dynamics of certain pests common to both crops. Such a study would help in verifying the time to carry out appropriate pest control measures.

(c) The effect of climate on the yield of cotton and beans when the two crops are mixed-cropped. This will involve using various sites with different patterns of rainfall and soil types.

(d) The profitability of growing cotton in mixture with beans. Costing of all the inputs and the returns would be necessary for this.

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APPENDIX I

ANALYSIS OF COVARIANCE FOR COTTON AND BEANS YIELDS AT TEBERE

Source of Variation	Degree of freedom	Sum of Squares (Cotton)	Sum product of (Beans/Cotton)	Sum of Squares (Beans)
Total	49	44.7620	-27.1386	96.1085
Replication	4	11.7361	9.3840	15.5727
Spacing/ Pattern	9	13.0225	12.0872	34.2511
Covariable	1	0.6939 NS		
	36	20.0033	- 5.6673	46.2846
Error	35	19.3093		

APPENDIX 2:

ANALYSIS OF VARIANCE TABLE FOR SEED COTTON AT TEBERE

Source of Variation	df	Sum of Squares	Mean Sum of Squares	F.cal	F. Tabular 5%	1%
Total	54	53.6906				
Block	4	13.9437	5.7996806	5.80**	2.61	3.83
Planting Pattern	10	15.7045	1.5704	2.61*	2.08	2.80
Between groups	2	12.4630	6.2315	10.37**	4.75	9.33
Within groups	8	3.5099	0.4387	0.73NS	2.85	4.50
Error	40	24.0424	0.6011			

APPENDIX 3:

ANALYSIS OF VARIANCE TABLE FOR SEED COTTON YIELD AT WANGURU

Source of Variation	df	Sum of Squares	Mean sum of Squares	F.cal	F. Critical 5%	1%
Total	54	24.9714				
Block	4	1.12531	0.2813	0.59NS	2.61	3.83
Planting Pattern	10	4.6756	0.4675	0.98NS	2.07	2.80
Error	40	19.1705	0.4792			

Note: ** - Significant at 1% level of probability

* - Significant at 5% level of probability.

APPENDIX 4

ANALYSIS OF VARIANCE TABLE ON YIELD OF DRY BEANS AT TEBERE

Source of variation	df	Sum of squares	Mean sum of squares	F cal	F. Tabular	
					5%	1%
Total	54	106.9091				
Block	4	11.5528	1.8882	2.08NS	2.61	3.83
Planting pattern	10	39.8819	3.9882	2.88**	2.08	2.80
Error	40	55.4744	1.3869			

APPENDIX 5

ANALYSIS OF VARIANCE TABLE ON YIELD OF DRY BEANS AT WANGURU

Source of variation	df	Sum of squares	Mean sum of squares	F cal	F. Tabular	
					5%	1%
Total	54	118.9020				
Block	4	5.0843	1.2711	0.57NS	2.61	3.83
Planting pattern	10	24.3993	2.4399	1.09NS	2.08	2.80
Erro	40	89.4184	2.2355			

APPENDIX 6

ANALYSIS OF VARIATION TABLE FOR LAND EQUIVALENT RATION AT TEBERE

Source of variation	df	Sum of squares	Mean Sum of squares	F cal	F. Tabula	
					5%	1%
Total	59	8.7232				
Block	4	1.4839	0.3709	8.08**	2.58	3.78
Spacing/ pattern	11	5.2177	0.4743	10.33**	2.01	2.63
Error	44	2.0216	0.0459			

APPENDIX 7

ANALYSIS OF VARIANCE TABLE ON LAND EQUIVALENT FOR WANGURU

Source of variation	df	Sum of squares	Mean Sum of squares	F cal	F. Critical	
					5%	1%
Total	59	8.2625				
Block	4	0.1417	0.03543	0.51**	2.58	3.78
Planting/ pattern	11	5.0691	0.4608	6.64**	2.01	2.68
Error	44	3.0517	0.0694			

APPENDIX 8

PLANTS HEIGHT MEASUREMENTS AT TEBERE

(MEAN OF 5 PLANTS)

	Sampling Dates and Plant Height (cm)								
Planting pattern	11/11	24/11	6/12	20/12	5/1	19/4	30/5	30/6	30/8
Pure stand cotton	13.5	38.5	55.55	70.0	92.5	99.0	122.0	154.6	163.4
<u>Narrow row Intercrops</u>									
1 row beans	13.0	36.0	53.0	66.0	67.5	74.5	118.5	162.5	161.0
2 row beans	13.0	36.5	55.5	63.5	63.5	67.0	110.5	147.0	155.4
<u>Medium row Intercrops</u>									
2 row beans	13.5	39.5	48.0	61.0	65.0	69.0	112.0	155.0	166.4
* 2 row beans	12.0	38.5	53.0	63.0	65.5	73.5	115.0	151.5	153.4
3 row beans	13.0	39.5	54.5	63.0	65.0	74.0	117.5	157.0	159.8
4 row beans	12.5	39.0	54.0	61.5	63.0	70.5	118.5	155.5	156.2
<u>Wide row Intercrops</u>									
3 row beans	11.5	40.0	54.0	64.0	68.5	77.5	119.0	151.5	166.8
* 3 row beans	12.0	40.0	56.5	63.5	67.0	72.5	105.5	150.0	154.6
4 row beans	13.0	37.5	53.5	63.0	78.0	89.5	114.0	152.5	164.6
5 row beans	13.0	37.5	52.0	66.0	66.0	74.5	118.5	162.5	157.2

* Indicate planting patterns with paired cotton rows.

APPENDIX 9

ANALYSIS OF VARIANCE TABLE ON FINAL PLANT HEIGHT AT TEBERE

Source of variation	df	Sum of squares	Mean Sum of squares	F cal	F. Tabular 5%	F. Tabular 1%
Total	54	950043				
Block	4	641388.18	160347.0450	23.16*	2.61	3.83
Spacing/ pattern	10	31682.73	3168.2730	0.46NS	2.08	2.80
Error	40	276972.09	69243.0225			

APPENDIX 10

ANALYSIS OF VARIANCE TABLE ON FINAL PLANT HEIGHT AT WANGURU

Source of variation	Degree of freedom	Sum of squares	Mean Sum of squares	F cal	F. Tabular 5%	F. Tabular 1%
Total	54	12602.4400				
Block	4	1883.5273	470.8818	2.29NS	2.61	3.83
Spacing/ pattern	10	2485.6364	280.5636	1.21NS	2.08	2.80
Error	40	8233.2763	205.8319			

APPENDIX TABLE 11: SOIL ANALYSIS RESULTS AT MWEA TEBERE FARM

Depth	% C	% Sand	% Silt	% Clay	m.e % CEC	Exchangeable Bases Ca	Mg	K	Ng	ESP
0 30	1.14	16	16	68	38.8	10.9	5.7	1.8	0.10	0.26
30 - 106	-	20	10	70	27.8	4.8	5.0	0.6	0.20	0.72
106 +	-	16	16	68	26.4	5.8	8.4	0.7	0.10	0.39

Depth (cm)	pH 1:5 H_2O	Kcl	EC 1:5	m e Hp	Hv	Mn	Available Nutrients m.e % Na	K	Ca	Mg	PPm	% N
0 - 30	6.1	4.9	0.04	-	-	0.26	0.08	0.96	5.2	4.5	166	0.15
30 - 106	5.4	4.8	0.27	0.3	-	0.18	0.10	0.25	1.0	3.4	35	-
106	5.7	4.9	0.12	-	-	0.19	0.08	0.36	1.8	3.4	73	-

For % Organic Matter multiply % C by 1.73.

APPENDIX TABLE 12:

SOIL ANALYSIS RESULTS FOR WANGURU SITE

CMS DEPTH	% C	% Sand	% Silt	% Clay	m.e % C.E.C	EXCHANGEABLE BASES m.e %				ESP
						Ca	Mg	K	Na	
0 - 30	1.55	14	22	64	32.4	13.6	6.5	2.1	0.30	0.93
30 - 60	-	14	16	70	27.0	9.4	5.5	0.7	0.40	1.48
60 +	-	16	12	72	26.0	9.6	5.4	0.5	0.50	1.54

CMS DEPTH	pH 1:5		m.mhos/cm	m.e %		AVAILABLE NUTRIENTS m.e %					P ppm	% N
	H_2O	Kcl		Hp	Hv	Mn	Na	K	Ca	Mg		
0 - 30	6.0	4.7	0.04	-	17.5 -	0.18	0.02	0.76	6.8	4.8	268	0.14
30 - 60	5.8	4.7	0.08	0.2	16.1 -	0.10	0.10	0.20	4.0	3.8	148	-
60 +	5.8	4.8	0.08	-	-	0.18	0.10	0.14	3.8	4.4	81	-

For % Organic Matter, Multiply % C by 1.73

APPENDIX TABLE 13: SUMMARY OF METEOROLOGICAL DATA, TEBERE FARM, OCTOBER 1981 TO SEPTEMBER 1982

Latitude 00^{o} 37'S, Longitude 37' 20'E, Altitude 1,158 Metres

	Rainfall mm	Temperature in screen Mean max oC	Mean min oC	Dewpoint 0900 hours oC	1500 hours oC	Sunshine Campbell -stokes Hours/ days	Radiation gunn Bellani cal/sq cm/ day	Evaporation piche mm/month
1981								
October	102.0	29.0	16.7	17.4	15.0	6.7	623	229.9
November	133.0	N/A	16.4	17.3	16.7	6.8	N/A	147.3
December	51.0	N/A	15.0	17.1	17.7	7.5	597	149.5
1982								
January	7.1	28.5	13.9	16.6	16.0	9.0	643	228.5
February	0.0	31.0	14.6	16.0	14.6	9.0	642	304.0
March	135.6	N/A	15.4	18.4	13.6	8.6	688	375.6
April	260.4	N/A	17.5	18.5	18.1	5.7	516	131.4
May	176.6	N/A	17.8	18.1	18.3	5.6	532	92.5
June	8.5	26.2	16.1	16.4	17.1	6.0	530	122.6
July	13.2	25.8	16.2	15.1	15.1	N/A	467	161.5
August	0.4	25.1	15.7	15.2	14.3	3.4	417	182.8
September	32.2	27.6	16.7	15.4	N/A	4.7	556	196.7
Total	920.0							2322.3
Mean			16.0	16.8				

N/A denotes not available

Appendix Table 14: Rainfall confidence limits for Tebere in 20 days moving totals at 10 days interval (P = 0.5).