GENOTYPIC COMPETITION IN FIELD BEANS (*Phaseolus vulgaris* L.) VARIETIES

by

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DECLARATION

This thesis is my original work and has not been presented for a degree in any other University.

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DEDICATION.

This piece of work is sincerely dedicated to my late father Dr. Yona Otsyula who cherished education.

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ABSTRACT

Beans in Kenya are normally grown by small scale farmers in mixtures for subsistence agriculture. These mixture often comprise landraces or improved cultivars. Farmers do not select the most suitable cultivars for the combination in this system of cultivation. There is also little information available on the effects of competitive interactions on the production of such mixtures. This study was designed to study genotype interactions and hence analyse the effect of competition on the performance of established bean cultivars. It was therefore to identify the varieties best suited to varietal mixture production systems in the peasant farming sector.

Four established bean cultivars namely Rosecoco, Canadian Wonder, Red Haricot and Mwezi Moja planted in Kenya were used in this study. The four varieties were used to develop six biblends and each biblend comprised of equal proportion of the component varieties. The biblends and uniblends formed a total of ten treatments which were planted in a randomised compete block design at Kabete, Kakamega and Bukura. Genotype competition analysis was done according to model presented by Federer et al., (1982).

It was evident from the study that there was genotypic interaction in the mixtures studied. Four forms of competition as described by Schutz et al., (1968) ,namely neutral effects, overcompesation (cooperative), undercompesation and complimentary were observed. Among these interaction forms overcompesation was considered as the most important interaction form as it clearly pointed at yield advantage. Competitive ability of various genotypes showed awider variability over seasons and locations. It is therefore recommended that the results from one location or season can not be used in another before it is tested. For Kabete short rains Canadian Wonder and Mwezi Moja would be considered favourable. For Kabete during the long rains, however none of the mixture combinations for yield was favourable. For long rains at Kakamega, mixture combination of Rosecoco and Red Haricot and Rosecoco and Canadian Wonder combination could be adapted. At Bukura Rosecoco and Red Haricot combination and Rosecoco and Mwezi Moja mixtures may be favourable combinations.

1 INTRODUCTION

Field beans (Phaseolus vulgaris L.) belongs to the genus Phaseolus of the tribe Phaseoleae and family Leguminaceae. Beans are believed to have originated from Central America and spread to Europe in the 16th Century from where they were introduced to East Africa.

Beans have been cultivated in Kenya for the last 300 years (Mukunya and Keya, 1975). Acland (1986) estimated that about half a million hectares of field beans were grown in Kenya annually. At present the total acreage in Kenya is about 1,000,000 hectares scattered over Eastern, Central, Rift Valley and Western Kenya. One of the reasons for increased acreage could be due to the progressive research on beans which has led to the release of improved varieties like Canadian Wonder adapted to medium rainfall areas, Mwezi Moja adapted to dry areas, Rosecoco adapted to medium rainfall areas and Red Haricot which is adapted to high rainfall areas.

Beans in Kenya are normally grown by small scale farmers who grow them for subsistence and commercial purposes to a lesser extent like in many ather developing countries (Pachico 1989). Bean yields from the small scale farms is generally low. Acland (1986) indicated that average yield from the farmers field was about 800kg/hectare or less. However, it has been reported from National Horticultural Research Center, Thika that with new varieties such as GLP.2 (Rosecoco) farmers should obtain 1500kg/hectare of beans under good management.

The importance of field beans as a food crop in Kenya is well documented (Acland, 1986, and De-Groot, 1979). Field bean is the most important leguminous crop in Kenya and is the leading source of plant protein and second to maize which is aprinciple stable food in Kenya. Beans are often cooked in a mixture with maize and has become a major dish easily affordable by majority of Kenyans. Most beans are grown in mixture with other crops. The small scale farmers grow the beans mixed with cereals, other legumes, vegetables and even tree crops (Njungunah etal., 1980)

Eijnatten (1974) carried out a survey on bean production in Eastern and Central province of Kenya and reported that only 31% of beans from these regions were grown as a sole crop. In Latin America, up to 60% of maize and 80% of beans are produced in various associated cropping systems (Francis,1978). Other studies on the performance of beans when intercropped with other crops are presently being conducted at the National Horticultural Research Station, Thika, with an objective of coming up with a package of information on the appropriate bean varieties to be grown in mixtures.

In Kenyan small scale farms, the bean fields are rarely of pure varieties. More often, a bean crop will be comprised of a mixture of different cultivars (Acland 1986). This is more so for the unimproved landrace bean cultivars which are often comprised of mixtures of different purelines. Some advantages of varietal mixing, according to a survey conducted in Western Kenya Agricultural Research Station (1987) included crop security, economic purpose and palatability.

Farmers do not generally select the most compatible crop varieties for mixed cropping. The varieties that are used are those that are easily available in the locality. Improvement of the intercropping system through the identification of suitable and compatible cultivars would be a step forward since it would be expected to give higher yields as suggested by Willey (1979). This is possible only if the intergenotypic competition is properly understood.

Agronomists in Kenya are presently involved in investigating crop arrangement patterns and advocating for intercropping instead of pure stands. Their argument has been more of having different types of crops growing at the same time for crop security rather than competitive aspects. However, it would be desirable to understand and quantify the competition aspects in crop mixtures. Competition may be as intraspecific genotypic interaction when different varieties of the same crop are grown together or interspecific genotypic interaction when different crop species are grown in the same field at the same time . The nature of interaction in crop mixtures influences crop yield of different genotypes in a mixed stand.

Evidence has accumulated from competition experiments with plants that the reproductive capacity of an individual frequently varies when it is in competition with other genotypes of the same species (Schultz and Brim, 1967; Sakai, 1961 and Harper, 1967). It has also been reported in plants that the reproductive success of a genotype sometimes changes with its frequency (Harding et al., 1966, Schultz et al., 1968).

This study was undertaken to investigate the performance of different bean cultivars grown in mixtures. The objectives were:-

1. Study the genotypic interaction and analyse the effects of competition on the performance of established bean cultivars.

2. To estimate change due to specific combinations and thereby establish the cultivars that are good competitors and good neighbours.

2. LITERATURE REVIEW

2.1 Concept of Genotype Interaction

Kan-inchi-sakai (1955) has defined genotype interaction, in broad sense as all biological interaction between co-existing organisms within a limited area. In a narrow sense he defined it as the effect of interaction operating between individuals genotypes within a population.

According to Schultz et al., (1968) intergenotypic interaction may result in any of the following conditions:

a) **Neutral effects-** This is a situation where none of the genotypes in the mixture is affected. Neutral effects have the same properties as Hardy-Weinberg model which assumes no selection and no interaction and leads to similar expectation.

b) **Under compensation interaction** - This is comparable to the genetic system involving the underdominance fitness. (heterozygote disadvantage). In this case the reproductive capacities are not equal and interactions not balanced. The poor competitors are eliminated rapidly. This is the reason why actual population contains so few genotypes which interact unfavourably. This system is less helpful than neutral system in explaining the great diversity of genotypes found in natural populations.

c) **Overcompensation interaction**. This is also a cooperative interaction and may also be compared to a genetic system involving the overdominance fitness which is a necessary condition for stable equilibrium In this form of interaction both genotypes benefit from each other in mixtures. Genotypes which show cooperative interaction appear to be common in populations with history of mutual selection. Such systems are balanced in that all the genotypes have equal reproductive values and interact favorably and equally in all combinations. They also have properties similar to those of genetic systems involving equal advantage of heterozygote over homogygote and it can be seen that they lead to same outcome convergence on stable equilibrium values.

d) **Complimentary interaction**. The loss in one direction is off-set by gain in the other direction. This is helpful because certain patterns of complimentary interactions can, in theory, allow more than one genotype to remain in the population permanently. In the light of yield, overcompensation is important and a desirable interaction and is capable of fitting in the cropping pattern and local conditions in which the Kenyan farmer operates with an idea of maximum output/acre. It is therefore important to study the interaction of genotypes used by farmers.

2.2 The Role of Competition in Evolution and Natural Selection

The hypothesis of Darwin according to which evolution of the new species is by accumulation of small changes "Natural selection" and "survival for the fittest" revolve around the competition among plants. In natural selection, some individuals leave more offsprings by out-competing others. Such individuals are fitter in the Darwinian sense. The important role of competition in natural selection was further recognised by Haldane (1932). He indicated that the fitness of plants in Darwinian sense must be tested with plants grown in competition. Gastafisson (1951) demonstrated that in barley, single gene mutants which were less productive in purestand that in mother strain became more productive when competing with each other in segregating progenies of the non-heterozygote. Moor (1952) also reported similar results with Drosophilla. He observed that genetic differences as a result of mutation would affect the competitive ability of individuals within species promoting natural selection.

Kan-inchi-sakai (1955), considered competitive ability as a genetic character and concluded that competition has played an important role in evolutionary changes of plant and animal population. He also concluded that a large genetic variation in competitive ability occurs even among the varieties of the same species. He however, found no association between the competitive ability and several morphological characters and vigorous growth. Kan-inchi-sakai (1955) demonstrated that the competitive pressure increased at an intensified rate as the density of the population became larger or interplanting spacing became smaller. It would be suggested that in natural conditions such competitive pressure would select individuals with higher competitive ability as plant community grows denser. Similarly, increment or decrement due to interplant competition in a population is determined by the frequency as well as the competitive ability of the competitors. This observation suggests that a few invading individuals with a stronger competitive ability than the base population would propagate at a faster rate even if their progression rate in pure stand were not high. This is in line with the colonization and adaptation process in evolution.

Natural selection resulting from competition between lines might increase or decrease the number of desirable segregates in a bulk population (Mumaw and Weber 1957). Mumaw and Weber (1957) reported that the effect of selection resulted in a marked change in varietal percentage in soyabean and that a variety with a branching growth habit increased in composites with a corresponding decrease in variety with a non-branching growth habit. Also the composites of branching varieties yield 1% more than the mean of their parents. This indicated that a variety with a branching growth habit was more efficient in utilizing the sunlight which seemed to be the main factor of competition in this particular case. Jennings and Aquino (1968) reported that light was a major factor of competition and any character associated with light such as leaf number, leaf length, spreading growth habit, leaf area index and height were greater in strong competitors. It would be obvious that close spacing, moisture and added nitrogen would increase competition. It would be expected that negative effects of competition on natural selection would restrict scope as it increases overall population adaptation and fitness. Competition seem to have played a negative roll in evolution of tropical agriculture hence the reason why dwarf wheat and rice do not exist under natural selection. Competition is therefore undesirable as it maltigates against realisation of major objectives of tropical breeding programms thus lodging resistance nitrogen responsiveness and high yield potential (Jennings and Herrera 1968).

Mumaw and Weber (1957) also noted that the high yielding ability of a variety was not an assurance of its ability to survive in a heterogenous population. This may have been because of variety like that would be eliminated in such populations if found uncompetitive in respect to other segregants. This imposes elimination of bulk hybrid method of plant breeding.

It was further noted that on the average, composites composed of two varieties yielded 2% higher than the mean of their pure lines. It was, however, not apparent whether in maturity, height or lodging were more important in expressing yield advantage. It was found that the branching types yielded 60% of total composite yield and non- branching types yielded 40% of total composite yield. Generally, seed weight was found to decrease slightly in biblends while seed number increased and this accounted for yield advantage in the composite.

Genotype competition within a mixed population of various genotype brings about competition variance which is brought about by the segregating genotypes but is not transmissible to the progeny. This is because the number of segregants has reduced and the progeny is not under the same competition (Sakai 1955). Infact the progeny is under lower competition pressure and may not simulate the base population. Variation of plant character due to competition must therefore be taken into account as they are affected by intergenotypic competition.

2.3 The Significance of Genotype Competition in Plant Breeding.

2.3.1. Mass Selection

Intergenotypic interaction has played a major role in mass selection. Competition leads to a stable feedback system, which promote the retention of a large number of different genotypes in population, setting the stage for release of variability as intercrosses among their diverse genotypes infuse a steady stream of F_1 into the population (Allard and Adams 1969). Of particular significance is evidence that reproductive capacity of a heterozygote will leave far more than their proportionate share of off-spring thus vastly increasing the genetic effectiveness of inter- mating(Allard and Adams 1969). Mass population provides a method of exploring variability on a scale not possible with conventional method and intergenotypic interaction is important to the success of the method because of the key role they play in maintaining the variability essential for continual recombination (Allard and Adams 1969). Simmonds (1962) recommended the formation of broadly based mass population as the single most effective additional measure that might be taken for preserving variability. Such variability for various quantitative characters affecting basic reproductive and competitive ability and such population also remain highly variable for various morphological polymorphism.

The major limitation which competition imposes on mass selection is the fact that competing genotypes do not necessarily perform well under purestand conditions. Secondly competition may sometimes eliminate some favorable genotypes. This is evident from the results reported by Kawano and Thung (1982). In cassava, good competitors gave low economic yield. The poor competitors yielded high when planted in pure stand. In this case mass selection would produce such population of low competitors which are high yielders. Such genotypes would be lost in the event of selection, retrieving would also be very difficult.

2.3.2. Bulk Method

Bulk method of breeding provides an opportunity for natural selection and to change the composition of the population. Natural selection identifies the superior genotypes whose competition is high and eliminates the inferior ones whose competition is low. Suneson and Weibe (1942) termed this evolutionary method of plant breeding. In mixed population, there is a chance for the genotypes to fully express their potentials. Usually in pure stand, it is assumed that the homozygous lines have reached a stable equilibrium.

Natural selection in bulk population is environment dependent. It only occurs when there is a suitable environment. For example, plants resistance to disease can only be selected when the disease has occurred. Similarly in mixed population the good yielders or vigorous plants may not be identified until such an environment of competition is created by putting the respective genotypes in mixtures. Also in breeding economic characters, environment or stress may allow the identification of desirable alleles or favorable genotypes. Introduction of competition between members of a population by restricting nutrients may be a form of stress. It is very likely that testing performances under stress will lead to modification in relative proportion of additive and non additive variability contributed by the loci already segregating in population. Mumaw and Weber (1957) pointed out that in soyabean, the relative high yield of a variety in purestand was not necessarily an indication of its ability to survive in a mixed population. Similar results were reported in small grain crop by Suneson and Wiebe (1942). Donald (1963) indicated that the ability to compete in mixtures does not necessary give maximum yields in purestands. Also certain desirable characters have poor survival in mixed stand,for example dwarf rice varieties perform poorly in mixtures than in pure stands (Kawano et al., 1974). Hinson and Hanson (1962) however observed that competition effects were most complimentary in nature among genotypes and therefore competition was always beneficial. Competition may be however a source of error in evaluation test imposing a limitation on bulk hybrid method of plant breeding. Competition is however important criteria for prediction of performance of genotypes in mixtures. Also the extent to which competition stress influences a plant character is an important consideration in selecting for that character in a breeding program.

2.3.3 Effect of Competition on Segregating Population

While examining the relationship between plant form competition and grain yield of barley using F_3 and F_5 plant, Hamblin and Donald (974), observed that in a segregating population, the yield of F_3 and F_5 were not correlated. The high leaf length and leaf height were however all positively and significantly correlated over generations. In F_3 grain was positively related to the above vegetative character while in F_5, the correlation were negative. This showed that short plants with short leaves in F_3 tended to give lines of greater yield in F_5. Further they found that plants with short leaves in F_3 tended to give high yield progenies under competition condition in F_4. This also indicated that weakly competitive plants are likely to be higher yielding in monoculture. Intergenotypic competition, which is evident in the early segregating generations and absent in later generations is accepted as a reason for ineffective single plant selection. Sakai (1955), Briggs et al (1974) and Roy (1976) also indicated that competition effects are of major significance for same plant characters when selecting single plant out of population consisting of genetic mixtures.

2.4. Competition Studies in Crop Plants

Competition studies have been done in many crop plants which include tuber crops like cassava, cereals like rice, small grains and legume crops. In Kenya,such studies have not been given much attention. This may have been due to the fact that intercropping and mixed cropping have been give much attention as an agronomic practice. Mixed cropping has been sufficiently investigated by agronomists such as crop arrangement, fertilizer use and suitable crop mixtures competition is a form of stress under which if an individual is subjected, then it tends to vary its reproductive capacity as a reaction to overcome the stress. Similar observation was made by Sakai (1961) and Harper(1967). Allard and Adams (1969), Harding et al., (1966) Schultz and Brim (1967) independently reported that the reproductive success of a genotype sometimes changes with its frequency. This could be due to the fact that competition within a species is sufficiently reduced and between species competition is increased.

Kojima and Yarboroough (1967), Tobari et al., (1967) also reported similar results for Drosophilla. Their interaction values are often larger and in many cases the interaction helps to maintain genetic variability within population. There is evidence that the number of segregating loci maintained in population is often greater than can be explained solely from consideration of known transmissional genetic parameters and population size (Allard and Adams 1969). It appears that intergenotypic interaction can be an appreciable force in maintaining variability in population.

Allard and Adams (1969) pointed out that intergenotypic interaction are a force of real consequence in determining the dynamic and equilibrium of population and has three aspects to plant breeding. Firstly, evidence supports the contention that selection theory which in the past has been cast within the frame work of a single population of non-interacting individual is inadequate. They also pointed that intergenotypic interaction has played an important role in the development of multiline varieties. If the full potential of mixtures is to be realised it would be necessary to set up breeding program specifically designed to develop groups of genotypes , capable of making maximum use of environmental space. They further indicated that intergenotypic interaction have significant implication in plant breeding in connection with the utilization and preservation of great stores of genetic variability which exist in the large germplasm collection now available in all established crop plants. Previously such sources are utilised as primary sources of major genes like disease resistance genes.

Kawano and Thung (1982) suggested that in cassava (Manihot esculanta crautz) tube yield would be improved through the plant efficiency at the expense of competitive ability. They concluded so because competitive ability was negatively correlated with the tuber yield. They also observed that the genotypes which were capable of utilizing more space had a high competing ability and depressed less competing genotypes. In this case it could be assumed that the factor of competition was light. The good competitors grew taller and had less tubers. Tuberation was suppressed at the expenses of vegetative growth. It becomes apparent that during competition ,there is less conversion of monossacharides and oligossacharides into polysaccharide sugars for storage. Most of the monossacharide sugars formed during photosynthesis seem to have been utilized directly • for the energy production to promote vegetative growth. The poor competitors are capable of storing most of the sugars in the tubers as they are less demanding in terms of energy. They are more efficient than the good competitors in terms of food utilization.

In another study of cassava intercropped with beans and soybean, Kawano and Thung (1982) demonstrated that the cassava depressed the soybean yields more than the bean yields. The genotypes of cassava which were more competitive had more depressing effects on soybean than the less vigorous beans. This again points to light as a main factor of competition.

Mumaw and Weber (1957) found out that in soybean, crop mixtures stabilise and maximise the production. This suggested additive plant effects which were responsible for high yields when grown in mixtures. They also identified branching growth habit as responsible for high yields in mixtures. This may imply that this character is important in photosynthesis and hence light was the major character for which plants compete. They also identified other characters for which plants competed nutrient and water. They however could not say how much of the competition was associated to each of these characters. In this study they seem to have considered only the above ground competition.

Underground competition however may have played a role in this.

Mumaw and Weber (1957) also demonstrated that environment played a major role in competition. They found that different levels of competition existed between like and unlike genotypes and that there would be little yield advantage in a composite of varieties differing in height, lodging and growth habit in a year of unfavorable condition.

2.5 Methods used for competition studies in plants

Genotype interaction has been investigated using different methods by ecologists. agronomists, genetists and plant breeders. For example Mumaw and Weber (1957) in their study of competition and natural selection in soybean varietal composites used latin square design for their analysis. In their method, they minimised interrow competition and increased intrarow competition. The variety were composited before planting and spacing maintained as in natural selection experiments. Single plants which showed vigour were harvested. The main short-coming in this method was that each variety was not surrounded by the other and they could not differentiate between intravarietal and intervarietal competition.

Fehr .(1973) working with soybean (Glycine max) used paired row techniques to evaluate intergenotypic competition and compared this to 1:1 blends grown in single rows. This methods seem more realistic than method of Mumaw and Weber (1957) because the interplant and interow spacing was reduced to a minimum. It has also the advantage of the ease of harvesting. In this method again like that of Mumaw and Weber (1957) method, it was difficult to distinguish the competition associated to intravarietal and intervarietal competition. Since one variety was planted in each row, there must have been intrarow competition which became very difficult to partition. It is also difficult to tell whether the interow competition (inter-varietal) is significant. The above method when tested against 1:1 blends of two cultivars method was found more useful in determining the good and poor competitors for every cultivar tested.

Probst (1957) in studies on the performance of varietal blends in soybean used complete randomised block design and planted single row plot. The blends were made on the basis of germinable seed to give the desirable plant proportion of each variety in each blend. The disadvantages of this method is that no attempt was made to determine the proportion of each variety existing at maturity. Allard and Adams (1966) while carrying cut studies on intergenotypic competition and population structure in barley and heat, adapted the hill plot design. The center genotype in the test was surrounded by other competing genotypes. There was an additional interaction introduced. The interaction of one genotype when surrounded by all the others at the same time was determined. Federer (1964) used adjuscent row technique in wheat and was able to identify the intraspecific interaction. Kawano and Thung (1982) also used the bondered row method in the study of intergenotypic competition with associated crop in cassava. They were able to identify the interspecific interaction. The method was more suited for interspecific interaction with the two crops having very different characters. In intraspecific interaction, however this method may not be suitable because inter-varietal competitions are very low and difficult to detect.

3. MATERIALS AND METHOD

3.1 Materials

The following four field beans (*Phaseolus vulgaris* L.) varieties were used in this study.

a) Rosecoco (GLP-2)

This was developed by Grain Legume Project (GLP). It is an erect non bushy fast growing variety with determinate growth habit. It has white flowers and brown-white mosaic seed. It is medium maturity variety (86-90) days and is adapted to high rainfall areas.

b) Canadian Wonder (GLP24)

This cultivar was developed by Grain Legume Project. It is a bushy type variety with determinate growth habit and is non climbing . It has white flowers and purple seeds. It is adapted to high rainfall and is late maturing

c) Red Haricot (GLP 558)

Red Haricot was also developed by Grain Legume Project. It is semi-bush and semi-climbing. It has white flower colour and red seed colour. It is a medium maturity variety (86-95 days) and is adapted to high rainfall areas

d) Mwezi Moja (GLP-1004)

This is also a Grain Legume Project release. It also early maturity variety (76-80 days). It is erect with determinate growth habit. It flowers in 30 days.

It has white flowers and greyish white seeds. Mwezi Moja is drought tolerant and is well adapted to dry areas of Eastern Province

The four varieties were used to develop six biblends as follows-:

1) Rosecoco + Canadian Wonder
2) Rosecoco + Red Haricot
3) Rosecoco + Mwezi Moja
4) Canadian Wonder + Red Haricot
5) Canadian Wonder + Mwezi Moja
6) Red Haricot + Mwezi Moja

Each biblend comprised of equal proportions of the component varieties. The six biblends and each of the above varieties (uniblends), a total of ten treatments, were planted in a randomized complete block design, at Kabete, Bukura and Kakamega as described below .

3.2. Experimental Sites

The experiments were conducted at the following three sites:-

a) **Kabete Campus of University of Nairobi**. This falls under lower highland zone (LH) which is characterized as maize wheat and pyrethrum growing agro-ecological zone . It has annual rainfall of 1000mm. Kabete has an altitude of 1815m It has high agricultural potential.

b) **Western Agricultural Research Station at Kakamega**. This falls in upper mindland (UM1) agro-ecological zone , characterized as tea and coffee zone. The annual rainfall is 1985mm. The altitude of the station is 1550 m. It also has a high agricultural potential.

c) **Farmers Training Center at Bukura** - This is in low midland (LM1) agro-ecological zone characterised as the sugarcane growing zone. It has an annual rainfall of 1788mm, an altitude of 1463m. and is also of high agricultural potential.

3.3 Field Experiments

At Kabete the field experiments were conducted during the short rains of November 1988 - January 1989 and long rains of April-June 1989 . At Bukura and Kakamega the experiments were conducted during the long rains of April to June 1989. In each case conventional tillage practices were used for land preparation before planting. Triple supper phosphate fertilizer was used at the rate of 150 kg per hectare at planting.

The ten treatments (six biblends and four uniblends were planted in a four replicate randomised complete block design at each site. Each plot had a size of 3.0 m by 2.4m of 8 rows. The spacing between the rows and within the rows were 30 cm and 10 cm respectively. In the biblend, seed colour was used as markers to arrange the component varieties in alternate hills. There was one plant per hill.

3.4 Data Collection.

Data was collected on the following traits.

1) Days to 50% flowering.
2) The number of leaves per plant at the onset of podding stage.
3) Days to 50% maturity.
4) Number of pods per plant.
5) Number of seeds per pod.
6) Weight of 100 seeds in grams. This was done by weighing a sample of 100 seeds from each plot.
7) Seed yield in grams.

During harvesting, a sub-plot of 2.10 x 1.20 metres was sampled from each plot. The plants in each sub-plot were uprooted and threshed separately such that the individual cultivar yields were available from the biblends. The grain was separated from the chaff and weighed separately.

3.5 Methods of Data Analysis

The data from each location in a given season were subjected to analysis of variance following mixed effects model presented by Steel et al.,(1980) given in Table 1. All the main effects were treated as fixed with the exception of replicate (block) effects which were considered as random.

TABLE 1: Analysis of variance for the data obtained at each site in a given season.

Source	df	MSS	EMS
Total	rt-1	M5	
Replicates	r-1	M4	
Treatments	t-1	M3	$\sigma^2 e + r\sigma^2 t$
Error	(r-1)(t-1)	M2	$\sigma^2 e$.

Where;

$\sigma^2 e$ is error variance

$r\sigma^2 t$ is treatment variance

r is number of replicates

t is the number of treatments (biblends + uniblends)

The data from each location in a given season were further subjected to genotype competition analysis. The genotype competition analysis were done according to the model presented by Federer et. al., (1982). This assumes a fixed response model of the form;

$$Y_{hi(j)b} = (\mu + P_h + T_i + \sigma_i)/2 + \tau_{i(j)} + E_{hi(j)}$$

$$Y_{hj(i)b} = (\mu + P_h + T_j + \sigma_j)/2 + \tau_{(i)j} + E_{h(i)j}$$

For other traits other than yield, the above equation would be given as;

$$Y_{hi(j)b} = \mu + P_h + T_i + \sigma_i + \tau_{i(j)} + E_{hi(j)}$$

$$Y_{hi(j)b} = \mu + P_h + T_j + \sigma_j + \tau_{j(i)} + E_{hj(i)}$$

This is because the data taken for other traits is not based on half plot size.

Where;

$Y_{hi(j)}b$ = Observation of the ith genotype surrounded by the jth genotype inthe hthreplicate.

μ= General mean effect common to every observation.

P_h = Block effects

T_i = Uniblends effects. i = 1, 2, 3,--v

σ_j = Cultivar effects of the ith cultivar when grown in biblend

$\tau_{i(j)}$ = Specific mixing effects of the ith cultivar when grown with cultivar j (i= 1,2,---v,j=i) and Y_{ii}= 0. Here $Y_{i(j)}$ is not necessarily equal to $Y_{j(i)}$ since the effect of one cultivar on another does not require identical reciprocal effects and we have $Y_{i(j)}$ > 0 for a given i while $Y_{j(i)}$ may take any value.

$E_{hi(j)}$ = Random error term with distribution given as $E_{i(j)}$ and $E_{(i)j}$ -(0,σ2E/2). (This takes care of the fact that individual cultivar yield from biblends are obtained from one half the plot size for that of uniblends.) Under the model restriction the best linear unbiased estimates for the parameter as;

E_{rh} = 1 P_h= E_{vi} =1 T_i=0, E_{vi}=1, j=1 $Y_{i(j)}$=0

Table 2.Analysis of Variance for Genotype Competition.

Source	df	MSS	EMS
Total	rv^2		
Correction formula	1		
Blocks	r-1		
Treatment	n-1	m6	$\sigma 2e + r\sigma 2g$
Uniblends	v-1	m5	$\sigma 2e + r\sigma 2u$
Uniblends Vs. Biblends	1	m4	$\sigma 2e + r\sigma 2ub$
Cultivar effects	v-1	m3	$\sigma 2e + r\sigma 2c$
Specific mixing effects	v(v-2)	m2	$\sigma 2e + r\sigma 2s.m.e.$
Error	(v2-1)(r-1)	m1	$\sigma 2e$

LSD test with 0.05, was used to compare the treatment effects at in each site in each season.

The important parameter int he above model were estimated as follows;

a) Mean for uniblends = $\hat{\mu} = \frac{Y...y}{rv}$

b) Block effects = $\hat{Ph} = \frac{2}{r(v-1)}(Yh..u + Yh..b - \frac{Y...u + Y...b}{r}$

c) Uniblend effects = $\hat{T} = \frac{Y.iiu}{r} - \hat{\mu}$

d) Cultivars effect = $\sigma = Ti + \delta i - \delta = \frac{2}{r(v-1)}(Y.i (.)b - \frac{Y...b}{r}$

e) Specific mixing effect (SME) = $\hat{\tau i}(2) = \frac{Y.i(j)b}{r} - \frac{Y.i(.)b}{r(v-1)}$

f) Mean for biblends = $\mu + \sigma = \frac{2Y..(.)}{rv(v-1)}$

g) Uniblends Vs biblend = $\sigma = \hat{\mu} + \sigma - \hat{\mu}$

h) Error Term $\sigma i - \sigma = Ti + \sigma i - \sigma \hat{T}i$

Where;

$Y...y/rv$ = Grand mean

$Yh..u$ = block total for uniblends

$Yh..b$ = block totals for biblends

$Y...u$ = Grand total for uniblends

$Y...b$ = Grand total for biblends

$Y.ii\mu$ = Total for individual treatment for the uniblends

$Y.iih$ = Total for individual biblend treatments

$Y.i(.)$ = Single yield for individual biblends

$Y.i(.)b$ = Total yield for individual cultivar summed over the biblends in which it occurred

$Y...(.)b$ = Grand total for the biblends.

μ = estimate of general mean

ph = block effect estimate

t = treatment effect or g.m.e.

τ = estimates of specific mixing effects

δ = estimates of uniblends Vs biblends effects.

σ = estimate of cultivar effects

Changes in performance due to competition

$$\frac{\text{Yield in mixtures} - \text{Yield in Pure stand}}{\text{Yield in pure stand}} \times 100$$

4. RESULTS.

4.1 Experiments at Kabete during Short Rains of 1988/89.

4.1.1 Uniblend performances

The data obtained at Kabete during the short rains of 1988/89 are presented in Table 3, 4, 5 and 6. According to the analysis in Table 3 there were significant treatmemt effects for all the traits. The mean values presented in Table 4 indicate that uniblends (varieties) varied for most of the traits. The varieties were all significantly different with respect to days to 50% flowering, days to 50% maturity, pods per plant, seeds per pod and 100 seed weight.

At flowering Mwezi Moja flowered earlier than any other variety. Canadian Wonder and Red Haricot were not significantly different as relates to days to 50% flowering.

Mwezi Moja was early maturing but it did not differ significantly from Rosecoco and Red Haricot. These three uniblends differed significantly from Canadian Wonder which matured last.

Rosecoco did not differ significantly in number of seeds per pod from Canadian Wonder though it yielded more. Red Haricot had the highest number of seeds per pod and was significantly different from the

TABLE 3. Analysis of variance for various traits at Kabete during short rains of 1988-89

Source of variation	d.f.	Mean Squares						
		Leaves/ plant	Days to 50% flowering	Days to 50% maturity	Pods/ plant	Seeds/ pod	100 seed weight	Yield T/HA
Blocks	3	65.81	0.90	6.94	18.08	0.13	3.11	9312.13
Treatment	15	2218.37**	122.46**	34.33**	28.85**	3.99**	716.58**	31324.82**
Unibleds	3	44.72	72.23**	23.7**	6.57**	3.44**	1027.44**	8936.03
Uniblends vs. Biblend	1	25.52	0.19	9.19	9.59	0.36	5.03	5773.07
Cultivar effects	3	861.52**	412.35**	139.28**	118.22**	14.92**	2535.59**	36170.71*
*S.M.E.	8	70.52	47.88**	2.08	6.11	0.55	6.31**	41097.38**
Error	45	62.55	2.52	2.76	3	0.08	2.03	10407.70

F Values	5%	1%
F^{1}_{45}	4.06	7.23
F^{3}_{45}	2.83	4.25
F^{8}_{45}	2.15	2.93
F^{15}_{45}	1.92	2.51

*S.M.E. = Specific mixing effects

Table 4. Mean Values for uniblends and Biblends for various Traits at Kabete during the short Rains of 1988/89

Treatment*	Leaves/ Plant	Daysto 50% flowering	Daysto50% maturity	Pods/ plant	Seed/ pod	100 Seed weight (g)	Yield T/Ha
Rosecoco	37.0	48.5	88.3	7.3	4.7	60.1	1.35
Canadian wonder	37.8	52.0	93.0	10.1	4.5	36.4	1.47
Red Haricot	40.3	51.5	88.5	8.9	6.3	24.7	1.60
Mwezi moja	32.8	42.8	87.8	7.6	4.3	53.0	1.56
Rosecoco (CanadianWonder)	31.5	47.0	88.0	6.9	4.7	57.7	1.47
CanadianWonder (Rosecoco)	51.0	60.0	86.0	10.2	4.3	36.4	1.20
Rosecoco (Red Haricot)	33.0	44.8	88.8	7.8	4.4	60.6	1.67
RedHaricot (Rosecoco)	48.5	56.8	87.8	14.9	6.4	25.6	1.79
Rosecoco (MweziMoja)	29.8	48.8	89.3	4.7	4.6	56.2	1.33
Mwezi Moja (Rosecoco)	27.0	41.3	88.3	6.9	3.6	51.5	1.07
CanadianWonder (RedHaricot)	41.5	50.0	95.0	10.6	4.5	36.9	1.27
RedHaricot (CanadianWonder)	42.0	50.5	89.3	11.7	5.9	25.6	1.76
CanadianWonder (Mwezi Moja)	49.3	53.8	95.0	10.9	4.6	36.2	2.10
Mwezi Moja (CanadianWonder)	34.0	43.5	88.5	8.4	4.4	52.2	1.84
MweziMoja (Red Haricot)	29.0	39.8	87.5	6.5	3.4	50.1	0.11
Red Haricot (MweziMoja)	37.8	41.8	89.8	13.2	6.8	26.0	1.60
C.V	21.0	3.25	1.8	20.3	5.9	3.3	27.7
$LSD_{0.05}$ (Uniblends)	13.5	4.7	4.5	4.1	0.35	2.5	0.11
$LSD_{0.05}$ (Biblends)	11.3	8.5	1.2	2.7	0.4	20.9	0.37

* X (Y) - Means variety for X when surrounded by variety Y.

N.B.: Bushy type vareities are Canadian Wonder and Red Haricot.

Erect type varieties are Rosecoco and Mwezi Moja.

rest. Red Haricot yielded highest at Kabete during the short rains while Mwezi Moja yielded the least. The LSD test performed on the means however indicated that the four varieties did not have significant yield differences.

4.1.2 Cultivar Effects

The cultivar effect (average performance of varieties cultivar in mixtures) were highly variable for all the traits at Kabete during the short rains of 1988/89(Table 3). The mean for cultivar effects presented in Table 5 suggest that Canadian Wonder recorded the highest number of leaves on average in mixtures followed by Red Haricot. They differed significantly from Rosecoco and Mwezi Moja. The varieties tended to show distinct differences between bushy types (Canadian Wonder and Red Haricot) and erect types (Rosecoco and Mwezi Moja) unlike in pure stands where the difference among the varieties were not significant (Tables 4).

Mwezi Moja was the earliest flowering in mixed stand. However Rosecoco which was also fairly early flowering in pure stands turned out to be latest flowering in mixed stand. It averagely took almost the same time as Mwezi Moja to mature when grown in

TABLE 5. Means for cultivar effect values at Kabete during the short rains of 1988-89.

Variety	Leaves/ plant	Day to 50% flowering	Days to 50% maturity	Pods/ plant	Seeds/ pod	100 Seed weight (g)	Yield T/HA
Rosecoco	41.9	95.8	118.2	8.6	6.1	77.5	1.90
Canadian Wonder	63.0	72.8	127.1	14.1	5.9	48.6	2.03
Red Haricot	57.0	69.8	118.6	17.7	8.5	67.8	2.29
Mwezi Moja	40.0	45.3	117.4	9.6	5.0	68.3	1.59
$LSD_{0.05}$	12.0	8.3	2.1	6.8	1.1	2.8	1.17

mixtures(Table 5). Canadian Wonder, was on average, the latest maturing in the mixtures. Pods per plant were variable contrary to the results in pure stand where this trait did not show significant differences among the varieties. Red Haricot recorded the highest number of pods per plant followed by Canadian Wonder, Rosecoco and Mwezi moja. However Canadian Wonder did not differ significantly from Rosecoco. Mwezi Moja and Rococo also did not differ from each other for pods per plant.

Red Haricot had the highest number of seeds per pod when grown in mixtures. Though Canadian Wonder had the highest number of seeds per pod when grown in pure stand it was one of the varieties with the fewest seeds in pods when grown in mixtures (Table 5).It was the second highest yielding variety when grown in mixtures. Red Haricot gave the highest seed yield in mixtures while Mwezi Moja was the lowest yielder.

4.1.3. Mixing effects and percentage changes due to competition

Specific mixing effects interaction was significant for days to 50% flowering, 100 seed weight, and seed yield per plot as presented in Table 3. Percentage changes in the performance of varieties due to competition is given in Table 6. The flowering of Canadian Wonder was delayed by 15.4% when surrounded by Rosecoco. Similarly the flowering of Red Haricot was delayed by 10.3% when grown in mixture with Rosecoco. However this was not significantly different from other combinations. Canadian Wonder also matured latest when surrounded by other varieties. Its maturity dates was significantly delayed in all cases. Though there were same notable changes for the number of leaves, number of pods, seeds per pod (Table 6) the biblends did not have significant specific mixing effects among them (Table 3). The seed weight of Rosecoco were generally decreased as a result of competition with Canadian Wonder and Mwezi Moja. On the other hand Red Haricot gave heavier seeds when grown with any of the other three varieties (Table 6). The yield of Canadian Wonder was increased by 43.2% when surrounded by Mwezi Moja. Similarly the yield of Mwezi Moja was improved by 58.7% when surrounded by Canadian Wonder. Canadian Wonder was also favorable nieghbour to Rosecoco and Red Haricot. Canadian Wonder increased the yields of each of this two varieties by atleast 9%. On the other hand Rosecoco and Red Haricot suppressed the yields of Canadian Wonder. Red Haricot performed well when surrounded by Rosecoco (11.8% better) and Canadian Wonder (10% better)

TABLE 6. Percentage changes in cultivar performance due to competition at Kabete during the short rains 1988/89

		Surrounding Variety			
Trait	Variety	Rosecoco	Canadian Wonder	Red Haricot	Mwezi Moja
1.No. of leaves					
	Rosecoco		-14.9	-10.8	-19.6
	Canadian Wonder	34.9		9.8	30.4
	Red Haricot	20.3	4.2		-6.2
	Mwezi Moja	-17.7	3.7	-11.6	
2.Flowering					
	Rosecoco		-3.1	-7.7	0.6
	Canadian Wonder	15.4		-3.9	3.5
	Red Haricot	10.3	-1.9		-3.3
	Mwezi Moja	-3.5	1.6	-7.0	
3.Maturity					
	Rosecoco		0.3	0.6	1.1
	Canadian Wonder	3.2		2.2	2.2
	Red Haricot	-0.8	0.9		1.5
	Mwezi Moja	0.9	1.1	0.0	
4.No. of pods per plant					
	Rosecoco		-5.5	6.6	-35.6
	Canadian Wonder	1.2		5.2	7.6
	Red Haricot	66.3	30.7		47.5
	Mwezi Moja	-9.9	9.9	-14.5	
5.Seeds per pod					
	Rosecoco		8.5	-0.5	-6.9
	Canadian Wonder	-2.7		0.7	0.7
	Red Haricot	1.1	6.3		7.1
	Mwezi Moja	-16.1	1.2	-22.6	
6.Seed weight					
	Rosecoco		-4.1	0.8	-6.6
	Canadian Wonder	0.2		1.4	-0.7
	Red Haricot	3.6	3.8		5.1
	Mwezi Moja	-3.0	-1.6	-5.7	
7.Yield per plant					
	Rosecoco		9.2	23.6	-1.0
	Canadian Wonder	-17.9		-13.7	43.2
	Red Haricot	11.8	10.0		0.0
	Mwezi Moja	-7.4	58.7	-43.1	

4.2 Experiments at Kabete during the long rains

4.2.1 Uniblend performances

The data presented in Tables 7 and 8 show that there were significant differences among the uniblends for all the traits at Kabete during the long rains of 1989. The mean values in Table 8 indicate that in purestand Red Haricot recorded the highest number of leaves followed by Canadian Wonder, Rosecoco and Mwezi Moja. Mwezi Moja was the earliest flowering in purestand followed by Rosecoco and Red Haricot. The latter two did not differ significantly with respect to days to flowering. Days to maturity followed the same trend as days to flowering for the uniblends. The earliest maturing Mwezi Moja also had the lowest number of pods in purestand. The other uniblends did not differ with respect to pod number. For the number of seeds per pod, Rosecoco recorded the highest and Mwezi Moja the least. Mwezi Moja did not differ significantly from Canadian Wonder and Red Haricot. Rosecoco was however statistically different from the rest. Rosecoco and Mwezi Moja had the heaviest seeds and were significantly different from Canadian Wonder and Red Haricot. However Mwezi Moja gave the least seed yield. Rosecoco and Canadian. Wonder were the highest seed yielders. There was a noted significant difference between Rosecoco and Red Haricot and between Rosecoco and Mwezi Moja.

Table-7. Analysis of variance for various traits at Kabete during the long rains of 1989.

Source of variation	df	Mean squares						
		Leaves/ plant	Days to 50% flowering	Days to 50% maturity	Pods/ plant	seeds/ pod	100 seed weight (g)	Yield T/HA
Blocks	3	63.59	16.93	28.93	8.60	0.14	88.34	3632.89
Treatment	15	893.55**	280.93**	156.70**	44.95**	3.86**	839.46**	12287.31**
Uniblends	3	1969.14**	208.06**	129.23**	33.82**	1.08**	1189.17**	12976.92**
Uniblends vs. Biblend	1	445.30**	0.07	4.38	0.13	0.43	11.90	7051.24**
Cultivar effects	3	2060.51**	1080.83**	618.14**	182.24**	1.59**	053.90**	27745.79**
*S.M.E.	8	111.98**	43.40**	3.25	3.44	0.76*	6.82	6889.69**
Error	45	23.98	4.91	5.27	4.96	0.27	21.41	853.65

F Values	5%	1%
F^{1}_{45}	4.05	7.23
F^{3}_{45}	2.82	4.25
F^{8}_{45}	2.15	2.93
F^{15}_{45}	1.92	2.15

*S.M.E. = Specific mixing effects

TABLE 8. Mean values of uniblends and Biblends for various traits at Kabete during long rains of 1989.

Treatment*	Leaves/ plant	Days to 50% flowering	Days to 50% maturity	Pods/ plants	Seeds/ pod	100 Seeds weight (g)	Yield T/HA
Rosecoco	45.1	49.5	91.5	10.5	5.3	60.1	1.69
Canadian Wonder	56.8	60.0	102.0	11.2	4.6	39.8	1.55
Red Haricot	86.0	57.8	99.3	12.7	4.8	23.6	1.15
Mwezi Moja	34.5	44.5	90.5	6.1	4.0	58.4	1.07
Rosecoco (Canadian Wonder)	32.9	49.8	91.0	7.6	4.8	58.9	0.98
Canadian Wonder (Rosecoco)	51.6	70.0	106.0	12.5	4.4	41.8	1.03
Rosecoco (Red Haricot)	40.5	47.3	90.3	6.8	4.4	57.7	1.63
Red Haricot (Rosecoco)	56.4	56.8	97.8	14.9	4.6	24.2	0.87
Rosecoco (Mwezi Moja)	41.1	49.8	91.8	7.1	4.6	61.4	1.18
Mwezi Moja (Rosecoco)	40.6	41.3	88.3	6.4	4.2	84.9	1.22
Canadian Wonder (Red Haricot)	54.8	59.6	107.8	11.3	4.7	41.1	1.21
Red Haricot (Canadian Wonder)	67.7	59.3	99.3	14.9	5.1	23.3	0.75
Canadian Wonder (Mwezi Moja)	54.9	62.0	105.0	10.1	5.1	40.7	1.06
Mwezi Moja (Canadian Wonder)	37.8	44.3	89.5	4.6	3.6	49.2	0.32
Mwezi Moja (Red Haricot)	41.5	40.3	87.5	5.6	4.1	55.1	1.03
Red Haricot (Mwezi Moja)	74.5	54.0	93.5	12.9	4.3	23.0	0.99
CV	9.6	4.2	2.4	23.1	11.5	10.5	18.6
LSD $_{0.05}$ (uniblend)	7.6	4.9	5.1	3.7	1.2	6.4	0.52
LSD $_{0.05}$ (Biblends)	7.3	2.7	2.0	3.3	0.5	5.5	0.29

* X (Y) - Means varieties X when surrounded by varieties Y.

N.B.: Bushy types varieties are Canadian Wonder and Red Haricot.

Erect type varieties are Rosecoco and Mwezi Moja.

4.2.2. Cultivar Effects

Cultivar effects during the 1989 long rains at Kabete were quite variable and significant for all the traits studied (Table 7). From the estimates in Table 9 it is observed that Canadian Wonder and the Red Haricot were the most vigorous in mixtures in that they had the greatest number of leaves. These two varieties were also notably leafier than other varieties when planted in purestands (Table8). Mwezi Moja and Rosecoco were both earlier flowering and earlier maturing than the other varieties when grown in mixtures. However the two varieties had low pod number in mixed stands. This is in contrast to the data in Table 8 which suggest that all the varieties performed almost equally with respect to pod number when planted in pure stands. Though the data in Table 9 suggest that Mwezi Moja had the fewest seeds per pod in mixtures, there was very little variability among the varieties for this trait in mixtures. Mwezi Moja and Rosecoco maintained high seed weights as was observed in pure stand (Table 8). On the other hand Mwezi Moja had the lowest cultivar effect values for seed yield.

Table 9. Means for cultivar effect values at Kabete during long rains of 1989.

Variety	Leaves/ plant	Days to 50% flowering	Days to 50% maturity	Pods/ plant	Seed/ pod	100 Seed weight (g)	Yield T/HA
Rosecoco	50.9	65.2	121.3	9.5	6.1	79.1	1.69
Canadian Wonder	71.7	85.1	139.8	15.1	6.3	45.9	1.47
Red Haricot	88.1	75.6	129.1	18.8	6.2	31.3	1.16
Mwezi Moja	53.2	55.9	118.9	7.4	5.3	72.1	1.15
$LSD_{0.05}$	11.1	9.0	6.8	2.0	3.2	1.1	0.75

4.2.3 Mixing effects and percentage changes due to competition.

Specific mixing effects were highly variable and significant for number of leaves, days to flowering, seed per pod and yield per plot (Table 7).
The data in Tables 8 and 10 suggest that Mwezi Moja was fairly competitive and had mean leave number values that were higher than its the uniblends mean performance. The other varieties had their leaf number suppressed in mixed stand with other varieties. The varieties tended to flower earlier when subjected to competition. Exceptions which flowered later than their respective uniblends were Canadian Wonder when surrounded by Rosecoco (16.7% late) and Mwezi Moja (3.3%late) than in pure stand respectively, and Red Haricot when surrounded by Mwezi Moja (8.9% late). Similarly seed weight of most of the varieties was suppressed by competition. A notable consistent exception was Canadian Wonder whose seed weight was increased by 5% when surrounded by Rosecoco, 8.2% when surrounded by Red Haricot and 22.4% when surrounded by Mwezi Moja. Seed yield was significantly lowered in Rosecoco when surrounded by Canadian Wonder and Mwezi Moja (-41.9% and 30% respectively), in Canadian Wonder when surrounded by all the other tree varieties (-33%, -22% and -31% respectively), Red Haricot when surrounded by other varieties (-24%, -34% and -23.8%

TABLE 10. Percentage changes in varietal performance due to competition at Kabete during the long rains of 1989

Trait	Variety	Surrounding Variety: Rosecoco	Canadian Wonder	Red Haricots	Mwezi Moja
1. No of leaves					
	Rosecoco		- 27.3	10.4	-9.1
	Canadian Wonder	-9.0		-3.5	-3.3
	Red Haricot	-34.3	21.2		-13.3
	Mwezi Moja	18.6	9.6	20.3	
2. Flowering					
	Rosecoco		0.6	-4.6	0.6
	Canadian Wonder	16.7		-0.7	1.3
	Red Haricot	-1.7	2.6		28.9
	Mwezi Moja	-7.2	-0.5	-9.6	
3. 50% Maturity					
	Rosecoco		-0.5	-1.6	0.3
	Canadian Wonder	3.9		0.7	2.0
	Red Haricot	-1.5	0.0		-5.8
	Mwezi Moja	-2.5	-1.1	-3.3	
4. Pods per plant					
	Rosecoco		-27.3	-35.4	-38.5
	Canadian Wonder	11.8		16.1	-9.4
	Red Haricot	-17.3	17.3		2.0
	Mwezi Moja	5.4	24.6	-8.2	
5. Seeds per pod					
	Rosecoco		-9.4	-16.9	-12.9
	Canadian Wonder	-4.3		2.2	10.9
	Red Haricot	-4.2	6.3		-12.5
	Mwezi Moja	5.0	-10.0	2.3	
6. 100 Seed Weight					
	Rosecoco		-2.1	-4.0	2.0
	Canadian Wonder	5.0		8.2	22.4
	Red Haricot	2.3	-1.4		-2.9
	Mwezi moja	-6.1	-19.2	-5.8	
7. Yield per plot					
	Rosecoco		-41.9	-31.7	-30.0
	Canadian Wonder	-33.4		-22.0	-31.0
	Red Haricot	24.4	-34.4		-7.4
	Mwezi Moja	13.9	-69.4	-3.25	

respectively) and also in Mwezi Moja when surrounded by Canadian Wonder and Red Haricot (-69% and -3% respectively).

4.3 Experiments at Bukura during the long rains 1989

4.3.1. Uniblend performances

From the analysis of variance in Table 11 there were significant effects for treatments in all the traits studied. Further partitioning of the treatment effects indicated that uniblends showed significant variability for all the traits.

The mean uniblend performance in Table 12 indicated that Red Haricot had the highest number of leaves followed by Canadian Wonder, then Rosecoco and Mwezi moja. However only Mwezi Moja and Red Haricot differed significantly. Uniblends had high variabilities and significant differences among themselves for days to 50% flowering. Mwezi Moja flowered earliest while Red Haricot was latest. Mwezi Moja was also the earliest maturing while Red Haricot was the latest (Table 12). The two uniblends apart from differing from each other, also differed significantly from the other cultivars as regards to days to maturity. Red Haricot registered the highest number of pods per plant followed by Canadian Wonder, Mwezi Moja and Rosecoco. Red Haricot differed significantly from Rosecoco and Mwezi Moja. Red Haricot again had the highest number of seeds per pod

Table-11. Analysis of variance for various traits Bukura during the long rains of 1989

Source of variation	d.f.	Mean squares						
		Leaves/ plant	Days to 50% flowering	Days to 50% maturity	Pods/ plant	Seeds/ pod	100Seed weight (g)	Yield T/HA
Blocks	3	1.49	3.02	1.21	1.19	0.05	38.05	628.08
Treatment	45	609.61**	202.03**	53.93**	9.10**	3.06**	434.38**	11877.45**
Uniblends	3	758.05**	168.27**	82.91**	7.68**	3.38**	649.73**	10503.98**
Uniblends vs Biblends	1	414.39**	5.67**	10.08**	4.90**	3.18**	18.37	104.01
Cultivar								
*S.M.E.	8	34.71	10.60**	10.94**	13.58**	0.23	84.36	9510.35*
effects	3	2151.89**	811.74**	154.47**	15.69**	10.26**	1342.81**	22306.89**
Error	45	23.22	1.27	1.30	1.41	0.22	40.78	1865.80

F values	5%	1%
F^{1}_{45}	4.06	7.23
F^{3}_{45}	2.82	4.25
F^{8}_{45}	2.15	2.93
F^{15}_{45}	1.92	2.51

*S.M.E.-- Specific mixing effects

Table 12. Mean values of uniblends and biblends for various traits at Bukura during long rains of 1989.

Treatment*	Leaves/ plant	Days to 50 flowering	Days to 50% maturity	Pods/ plant	Seeds/ pod	100 Seed weight (g)	Yield T/HA
Rosecoco	48.0	47.8	89.8	7.1	5.6	51.9	1.22
Canadian wonder	52.8	51.3	88.3	8.9	4.5	37.7	1.25
Red Haricot	66.6	54.3	95.3	10.7	6.5	21.3	1.30
Mwezi moja	33.7	39.3	84.3	8.5	4.7	41.6	1.27
Rosecoco (Canadian Wonder)	33.8	48.8	89.5	8.2	5.0	48.3	1.60
Canadian Wonder (Rosecoco)	49.4	56.3	92.3	6.4	4.2	41.7	1.37
Rosecoco (Red Haricot)	40.5	48.3	92.3	7.2	4.8	51.4	1.49
Red Haricot (Rosecoco)	61.8	53.0	94.0	11.2	5.8	23.8	1.02
Rosecoco (Mwezi Moja)	38.7	46.8	88.8	9.7	4.8	42.5	1.39
Mwezi Moja (Rosecoco)	31.2	35.0	85.3	7.7	4.1	48.1	1.11
Canadian Wonder (Red Haricot)	52.8	55.5	98.8	6.4	4.3	48.3	0.80
Red Haricot (Canadian Wonder)	56.1	56.0	96.0	9.9	6.1	21.2	1.16
Canadian Wonder (Mwezi Moja)	57.3	56.3	89.3	9.2	4.6	37.3	1.07
Mwezi Moja (Canadian Wonder)	31.5	39.5	85.0	7.2	4.0	44.5	1.10
Mwezi Moja (Red Haricot)	30.7	38.3	86.3	6.4	3.7	41.3	1.03
Red Haricot (Mwezi Moja)	61.1	52.3	92.3	11.2	6.4	97.5	1.25
CV	11.8	2.3	1.3	14.4	9.6	16.5	14.4
$LSD_{0.05}$ (Uniblends)	19.0	1.35	2.18	2.05	0.54	124.0	0.20
$LSD_{0.05}$ (Biblends)	7.85	1.56	1.57	1.73	0.67	9.25	0.26

* X (Y) - Means variety X when surrounded by variety Y.

N.B.: Bushy type varieties are Canadian Wonder and Red Haricot.

Erect type varieties are Rosecoco and Mwezi Moja.

when grown in purestand. It was followed by Canadian Wonder and Mwezi Moja. Mwezi Moja and Canadian Wonder were not significantly different in seed number. Rosecoco and Mwezi Moja had the heaviest seed in purestand. However the cultivar with the highest seed was Red Haricot. It was followed by Mwezi Moja, Rosecoco and Canadian Wonder in order of magnitude.

4.3.2 Cultivar Effects

The cultivar effects showed very high variability among the cultivars for the various traits studied (Table 11). The cultivar effect mean values in Table 13 indicate that Red Haricot seemed to be most vegetative followed by Canadian Wonder, Rosecoco and Mwezi moja when plated in mixtures. All the four cultivars differed significantly in leaf number.

Mwezi Moja had the lowest cultivar effect estimates for days to 50% flowering it was followed by Rosecoco. Canadian Wonder gave the highest estimate unlike in purestand where Red Haricot gave the highest cultivar effect estimates for days to flowering. However Canadian Wonder and Red Haricots did not differ significantly in the cultivar estimate for days to flowering.

Mwezi Moja again had the lowest cultivar effect estimates for days to maturity followed by Rosecoco, Canadian Wonder and Red Haricots.

Table 13. Means for cultivar effect values at Bukura during the long rains of 1989.

Variety	Leaves/ plant	Days to 50% flowering	Day to 50% maturity	Pods/ plant	Seeds/ pod	100 Seed weight (g)	Yield T/HA
Rosecoco	49.9	63.9	120.2	11.1	6.4	63.2	1.90
Canadian Wonder	70.7	74.6	121.9	9.8	5.9	56.6	1.39
Red Haricot	79.8	71.7	125.4	12.8	8.1	32.1	1.53
Mwezi moja	41.5	16.8	114.0	9.5	5.2	59.5	1.53
$LSD_{0.05}$	7.7	4.2	3.5	3.3	0.71	12.9	0.45

Rosecoco and Canadian Wonder also did not differ significantly.

Pods per plant cultivar effect estimates only showed significant differences between Red Haricot and Mwezi •moja. The later cultivar gave the lowest estimates. Similarly Mwezi Moja had the lowest cultivar effects for the number of seeds per pod. Red Haricot had seed number that was higher than than the rest of the other varieties. Rosecoco had the highest cultivar effects for seed weight followed by Mwezi Moja and Canadian Wonder. Red Haricot gave the lowest estimates. Rosecoco also had the cultivar effects estimates for seed yield. It was however the lowest yielding cultivar in purestand.

4.3.3. Mixing effects and percentage changes due to competition.

Flowering time, maturity period, pods per plant and the yield are the traits which were sigificantly affected by specific varietal interactions as shown on the Table 11. The percentage changes due to competition are shown on Table 14. During flowering, Rosecoco flowered earlier by 2.0% in mixtures when surrounded by Mwezi moja. In mixtures with Canadian Wonder and Red Haricot the flowering of Rosecoco was slightly delayed. Canadian Wonder was notably late in flowering in all the mixtures.

TABLE 14.Percentage changes in variety performance due to Competition at Bukura during the long rains of 1989.

		Surrounding variety			
Trait	Variety	Rosecoco	Canadian Wonder	Red Haricot	Mwezi Moja
1. No. of leaves					
	Rosecoco		-29.9	-15.3	19.5
	Canadian Wonder	-6.4		0.0	8.5
	Red Haricot	-7.3	-15.8		8.3
	Mwezi Moja	-7.6	-6.7	8.8	
2. Flowering					
	Rosecoco		2.1	1.1	-2.1
	Canadian Wonder	9.8		8.3	9.8
	Red Haricot	2.3	3.2		-3.7
	Mwezi moja	-10.8	0.6	-2.6	
3. Maturity					
	Rosecoco		0.3	2.8	-1.1
	Canadian Wonder	4.5		5.1	1.1
	Red haricot	-1.3	0.8		-3.2
	Mwezi Moja	1.2	0.9	2.4	
4. Pods per plant					
	Rosecoco		15.2	1.8	35.9
	Canadian Wonder	-27.1		-27.1	4.3
	Red Haricot	-4.4	-8.4		4.4
	Mwezi Moja	-9.7	-15.2	25.0	
5. Seeds per pod					
	Rosecoco		-11.1	-16.4	-15.2
	Canadian Wonder	-7.1		-3.8	2.9
	Red Haricot	-10.5	-6.6		-1.2
	Mwezi Moja	-12.8	16.0	20.6	
6. 100 Seed Weight					
	Rosecoco		-7.1	-1.0	-18.2
	Canadian Wonder	10.6		28.1	-0.9
	Red Haricot	11.8	0.3		29.0
	Mwezi Moja	0.2	6.8	-0.9	
7. Yield per plot					
	Rosecoco		31.4	14.3	14.3
	Canadian Wonder	58.9		-7.6	14.5
	Red Haricot	-21.0	10.3		-3.6
	Mwezi Moja	-12.4	-13.5	-19.0	

Red Haricot flowered significantly earlier in mixtures with Mwezi Moja than when grown in purestand. On the other hand its flowering was significantly delayed when planted in association with Canadian Wonder. Mwezi Moja, also flowered significantly late when planted with Rosecoco. The maturity period of Rosecoco in mixed stand was significantly delayed when surrounded by Red Haricot (2.8% late as compared to pure stand). Similarly maturity period of Canadian Wonder was delayed when Canadian Wonder was competing against Rosecoco and Red Haricots by (4.5%, and 5.1% respectively). Mwezi Moja is the only variety which had significant effects on maturity period of Red Haricot. Red Haricot matured earlier when planted in association with this variety. On the other hand Red Haricot delayed the maturity of Mwezi Moja by 2.4%. The number of pods in Rosecoco was significantly increased by 35.9% when surrounded by Mwezi Moja. On the other hand pods per plant in Canadian Wonder was significantly depressed when Canadian Wonder was competing with Rosecoco and Red Haricot by 27.9%. Mwezi Moja had no significant effects on the number of pods in Canadian Wonder. There was a general decrease in pods per plant when Mwezi Moja was put in mixtures with Rosecoco Canadian Wonder and Red Haricot by 9.7%, 15.2% and 24.9% respectively. However only Red Haricot had a significant effect on pod per plant of Mwezi

Moja (Table 14). The yield of Rosecoco was increased in the mixtures with Canadian Wonder and Red Haricots. On the other hand yield of Canadian Wonder was significantly depressed as result of competition with Red Haricot and Mwezi Moja. There were yield depressions of 36.7% and 14.6% when Canadian Wonder was grown in association with Red Haricot and Mwezi Moja respectively. The yield of Red Haricot was also decreased significantly in the mixture of Rosecoco. Other varieties had no significant effects on the yield of Rosecoco. The yield of Mwezi Moja also was not significantly affected when grown in mixed stand. However there was a general trend of slight reduction in its yields.

4.4. Experiments at Kakamega During the Long Rains of 1989.

4.4.1. Uniblend performances

According to analysis of variance in Table 15 their were significant effects for treatments for all the traits at Kakamega during the long rains of 1989. Uniblends were also significantly different for all the traits.

Red Haricot was the most vegetative followed by Canadian Wonder. The two varieties differed significantly from each other and from the rest of the other cultivars (Table 16)

Mwezi moja flowered earliest and Haricot flowered latest. Similarly Mwezi Moja matured earliest while Red Haricot was again the latest maturing (Table 16). The two uniblends differ significantly from each with respect to flowering and days to maturity .

Red Haricot registered the highest number of pods per plant and differed significantly from Rosecoco and Mwezi Moja which gave the least number of pods per plant (Table 16). Red Haricot had the highest seeds per pod. This variety differed significantly from the rest of the uniblends.

Rosecoco had heaviest seeds and also was significantly different from the rest of the other

Table-15. Analysis of variance for the various traits at Kakamega during the long rains of 1989

Source of variation	d.f	Mean squares: Leaves/ plant	Days to 50% flowering	Days to 50% maturity	Pods/ plant	Seeds pod	100 Seed weight(g)	Yield T/HA
Blocks	3	21.62	14.54	4.18	0.75	0.06	0.63	2309.27
Treatment	15	643.62**	134.93**	45.94**	14.15**	1.89**	393.01**	11513.34**
Uniblends	3	792.14**	71.58**	35.75 **	21.30**	1.59*	537.61**	12978.69**
Uniblends vs Biblends	1	60.48**	22.63**	9.63**	0.15	0.09	0.59	7027.61**
Cultivar effects	3	2255.33**	539.33**	170.35**	30.92**	7.60**	1372.86**	27745.79**
*S.M.E.	8	57.00*	21.06**	7.66**	6.71**	0.35 *	9.95	6888.54**
Error	45	20.00	6.07	1.39	1.75	0.15	6.89	607.55

F values	5%	1%
F^{1}_{45}	4.06	7.23
F^{3}_{45}	2.82	4.25
F^{8}_{45}	1.15	2.93
F^{15}_{45}	1.92	2.51

*S.M.E.= Specific mixing effects

Table-16. Mean values of uniblends and biblends for various traits at Kakamega long rains of 1989.

Treatment *	Leaves/ plant	Days to 50% flowering	Days to 50% maturity	Pod/ plant	Seeds/ pod	100 seed weight(g) (g)	Yield T/HA
Rosecoco	34.0	49.3	91.3	6.8	4.4	47.6	0.80
Canadian Wonder	48.9	46.8	90.5	9.3	4.3	30.6	1.07
Red Haricot	65.5	52.3	95.0	11.7	5.1	19.2	0.76
Mwezi moja	31.5	42.3	87.8	6.8	4.1	32.1	0.51
Rosecoco (Canadian Wonder)	32.4	49.5	91.0	6.7	3.9	46.1	1.03
Canadian Wonder (Rosecoco)	47.0	56.0	92.0	10.3	4.4	31.2	1.07
Rosecoco (Red Haricot)	38.7	50.0	94.0	6.3	4.6	44.9	0.61
Red Haricot (Rosecoco)	63.8	55.0	96.0	10.6	5.6	19.5	1.13
Rosecoco (Mwezi moja)	38.2	48.5	90.0	9.6	4.7	43.5	0.93
Mwezi moja (Rosecoco)	30.4	38.8	86.3	6.4	4.2	36.1	0.64
Canadian Wonder (Red Haricot)	55.5	48.3	94.3	7.9	3.9	33.4	0.84
Red Haricot (Canadian Wonder)	54.7	56.8	97.0	8.9	6.2	19.2	0.81
Canadian Wonder (Mwezi moja)	55.1	48.8	91.0	10.5	4.3	35.3	1.03
Mwezi moja (Canadian Wonder)	31.0	40.5	86.3	7.2	4.0	33.4	0.55
Mwezi moja Moja (Red Haricot)	29.4	40.3	88.4	4.0	4.3	32.5	0.62
Red Haricot (Mwezi Moja)	60.5	55.8	96.0	11.1	5.7	17.8	1.06
CV	9.8	5.1	1.3	15.5	8.4	8.1	13.9
LSD $_{0.05}$ (uniblends)	6.62	8.4	2.28	2.5	0.72	12.0	0.18
LSD $_{0.05}$ (Biblends)	6.37	3.07	1.76	1.76	0.53	3.7	0.18

* X (Y) Means variety X when surrounded by variety Y.

N.B. Bushy types varieties are Canadian Wonder and Red Haricot.

Erect type varieties are Rosecoco and Mwezi Moja.

uniblends. Red Haricot had the lowest seed weight and also differed significantly from the other cultivars.

There was some variability in the grain yield of the four cultivars. Canadian Wonder yielded highest followed by Rosecoco, Red Haricot and Mwezi Moja Canadian Wonder was significantly different from the other uniblends.

4.2 Cultivar Effects:

Cultivar effects were significant for all the traits (Table 15). From the Table 17 it can be noted that Red Haricot had the highest estimates for leaf number followed by Canadian Wonder, Rosecoco and Mwezi Moja. The erect of cultivars differed significantly from the bushy types unlike in pure stand where this trend was not observed. The cultivar effects for days to flowering were again highest for Red Haricot and lowest for Mwezi Moja. They were significantly different from the rest of the cultivars and themselves.

Cultivar effect estimates for days to maturity was also variable among the cultivars with the highest estimates being Red Haricot and the lowest being Mwezi Moja (Table 17). Red Haricot also recorded the highest cultivar effects for number of pods per plant. This was significantly different from Rosecoco and Mwezi Moja. Like in pods per plant, Red Haricot registered the highest number of seeds per pod and was the only

Table-17. Mean for Cultivar effects values at Kakamega during the long rains of 1989.

Variety	Leaves/ plant	Days to 50% flowering	Days to 50% maturity	Pods/ plant	Seeds/ pod	100 seed weight (g)	Yield T/HA
Rosecoco	48.5	65.8	122.6	10.1	5.8	59.8	1.15
Canadian Wonder	70.0	68.0	123.6	12.7	5.6	44.4	1.35
Red Haricot	79.6	74.4	128.4	13.6	7.8	24.7	1.33
Mwezi Moja	40.3	53.1	116.2	9.1	5.6	35.3	0.80
$LSD_{0.05}$	21.3	5.4	7.7	2.5	0.9	63.5	0.20

Table 18. Percentage changes in varietal performance due to competition At Kakamega during the long rains 1989.

Trait	Variety	Surrounding Variety: Rosecoco	Canadian Wonder	Red Haricot	Mwezi Moja
1. No of leaves					
	Rosecoco		-26.3	-12.1	-13.2
	Canadian Wonder	0.1		18.4	17.6
	Red Haricot	-2.5	-16.5		-7.7
	Mwezi Moja	-3.5	-1.6	-6.7	
2. Flowering					
	Rosecoco		0.5	1.5	1.5
	Canadian Wonder	16.5		-3.2	4.3
	Red haricot	5.3	8.6		6.7
	Mwezi Moja	8.3	-4.2	-4.7	
3. Maturity					
	Rosecoco		0.3	3.1	-1.4
	Canadian Wonder	1.7		4.1	0.6
	Red Haricot	1.0	2.1		1.0
	Mwezi Moja	10.2	10.2	8.9	
4. Pods per plant.					
	Rosecoco		-1.2	-6.6	4.2
	Canadian Wonder	11.7		-14.6	12.9
	Red Haricot	-9.0	-23.1		-5.0
	Mwezi Moja	-6.2	5.6	3.4	
5. Seeds per pod					
	Rosecoco		- 10.7	4.1	6.8
	Canadian Wonder	3.0		-9.8	0.5
	Red Haricot	-9.6	20.5		11.1
	Mwezi Moja	4.4	-2.9	5.6	
6. 100 Seed weight					
	Rosecoco		-3.3	-5.7	-8.7
	Canadian Wonder	2.0		9.4	15.4
	Red Haricot	-3.8	0.0		-7.2
	Mwezi moja	12.4	4.1		1.1
7. Yield per plot					
	Rosecoco		29.4	23.6	16.3
	Canadian Wonder	0.9		-22.5	-4.2
	Red Haricot	58.6	12.5		47.2
	Mwezi Moja	23.8	7.5	20.8	

Likewise Canadian Wonder matured later when surrounded by Red Haricot (- 3.9%). Red Haricot was also found to delay in flowering in mixture with of Canadian Wonder. Mwezi moja matured about 4 days later when surrounded by Haricot.

Pods number in Rosecoco was increased as a result of competition with Red Haricot. Canadian Wonder also produced more pods when surrounded with Red Haricot. However only Canadian Wonder had a complimenting effect on Red Haricot in mixtures. It increased the yield of Red Haricot. Red Haricot is also the only variety which had beneficial effect on pod number of Mwezi Moja. Competition did not affect the seed number for specific mixing effects for Rosecoco and Mwezi Moja. While Red Haricot lowered the seed number in Canadian Wonder the latter increased seed number of Red Haricot in the mixtures (Table 18). Rosecoco recorded the highest values for specific mixing effects for yield when surrounded by Canadian Wonder. Red Haricot however depressed the yield of Rosecoco by 23%. These differences were significant. Likewise Canadian Wonder reduced in yield when in the biblend with Red Haricot. The yield of Red Haricot was generally improved when grown in mixtures. Similarly Mwezi Moja had an upward trend in yield performance when grown in was significantly different from yield in purestand.

variety which differed significantly from the rest.

There were no significant differences in seed weight among the cultivars in mixtures. Rosecoco however recorded the highest followed by Mwezi Moja, Canadian Wqnder and Red Haricot. Mwezi Moja had the least cultivar effect estimates for seed yield. It differed from the other cultivars when planted in mixtures. Rosecoco, Red Haricot and Canadian Wonder however, never differed significantly for seed yields at Kakamega during the long rains.

4.4.3. Mixing effects and percentage changes due to competition

Specific mixing effects were significant for days to flowering, days to maturity, pods per plant, seeds per pod, and yield as presented on Table 15. Percentage changes of varietal performance due to competition are presented in Table 18.

Flowering of Canadian Wonder was depressed by 9.15% when surrounded by Rosecoco. Red Haricot flowered significantly late in all its biblend combinations. Though Mwezi Moja and Canadian Wonder flowered early in biblends their performances were not significantly different when grown in pure stand. Rosecoco matured later when surrounded by Red Haricots 3.0%.

5. DISCUSSION

Genotypic interaction as defined by Sakai (1955) was evident from this study Various genotypes interacted differently in mixtures at different stages of growth. At Kabete during the long rains, Mwezi Moja was less leafy but on average in mixtures Rosecoco turned out to be least vegetative. Further when Rosecoco was surrounded by Canadian Wonder the number of leaves of both Rosecoco and Canadian Wonder were reduced significantly (Table-9). The relationship between Rosecoco and Canadian Wonder could be described as undercompesation. It would appear that they reduced the number of leaves because they seem to have been escaping some form of competition stress. Though they did not seem to flower early in mixtures the number of pods in both cases was depressed and ultimately there was significant reduction in yield in both varieties. Mwezi Moja which had least number of leaves increased significantly when surrounded by Red Haricot. This relationship could be described as complimentary because Red Haricot in turn decreased in number of leaves. Mwezi Moja which is adapted to conditions of low moisture, would be expected to be more vigorous under no moisture stress. Since it is a fast growing variety it is likely that it can compete for moisture at the expense of Red Haricot.

The number of seeds per pod increased slightly in Mwezi Moja as it decreased in Red Haricot but the yield decreased in both cases. Kawano et al., (1974) reported that early growth vigour was one of the major factors that contributed to competitive ability. Jennings and de Jesus (1968) however indicated that competitive ability was inversely proportional to yield. Perhaps this could be the case with Mwezi Moja at Kabete during the long rains.

At Bukura the variation in number of leaves was not significant for the mixtures. The flowering of Rosecoco and Canadian Wonder was delayed when the varieties were planted in mixtures. Lack of early vigorous growth in this mixture for both varieties may be responsible for late flowering and late maturity which would be described here as overcompensation. This is because these two varieties are favoured by long growth periods. Pods per plant on the contrary increased in Rosecoco as it decreased in Canadian Wonder and the relationship is complimentary. Though these two varieties did not show high competition between them, it is possible that some form of competition for space might have existed. It could be noted from flowering that though the two varieties did not seem to compete they flowered at different times. Rosecoco may have then outcompeted Canadian Wonder which formed the pods later. Harrer

(1979) indicated that a successful genotype in a mixture of competitors is one which is capable of establishing itself very fast before its neighbours enabling it to pre-empt resources. It is notable in this case that Rosecoco may have formed more pods at the expense of Canadian Wonder. It is however difficult to identify which factors were responsible for this kind of competition at this stage of growth. Moisture stress at fruit setting is known to reduce the number of pods in beans (Leakey, 1979). It is therefore likely that during fruit setting Rosecoco was more efficient in utilizing the moisture that was available at the expense of Canadian Wonder. The evidence from this study is however inadequate for confirmation of this. There was a general yield increase for both the biblends although relatively Rosecoco yielded more in mixture than Canadian Wonder. This may be because the number of pods formed in the latter cultivar were low. At Kakamega during the long rains like at Bukura there was no noted form of competition for number of leaves. However Red Haricot and Canadian Wonder in mixtures flowered and matured later than in pure stand. These two cultivars seem to be slow early growth. The number of pods per plant were in both cases decreased confirming that the two cultivars were closely related to each other in plant character. Seeds per pod were decreased in Canadian

Wonder by 9.8% while it increased in Red Haricot by 20.5% (Table 17). Red Haricot is a bushy and semi-climbing variety while Canadian Wonder is a bush non-climbing variety. It is therefore possible that during seed setting reciprocal shading between the two varieties could have taken place. Harrer (1979) pointed out that there was significant reduction in the photosynthetic rate of a leaf even if only half centimeter of it was shaded by another leaf. Red Haricot in the process of trying to find a support on Canadian Wonder may have had a shading effect which was responsible for poor seed setting in Canadian Wonder. This poor seed setting may have resulted in low seed yield (22.5% lower than purestand) in Canadian Wonder. The relationship between Red Haricot and Canadian Wonder could be described as complimentary for yield.

The competition interaction forms identified varied over the seasons and locations and only in very rare occasions did the same mixtures give the same interaction forms over seasons and locations. This suggest effect of environment on interactions between genotype grown in mixtures. Though Schultz et al., (1968) pointed out very clearly that environmental stress did not necessarily increase competition but competition was environment dependent. Jensen and Federer (1965) established that in wheat varietal competition was also affected by environment. They argued that since certain factors like soil types affected competitive ability of genotypes then there were gene-environment interactions. More evidence of gene environmental interaction is from the identification of more factors of competition such as vegetative vigour, a high rate of nitrogen absorption in early growth stages, and plant height as most significant characters. (Kawano et al., (1974). Jennings and de Jesus (1968) disassociated early growth vigour with high yields while Rao and Mitra (1987) reported that early maturity and early vigour increased the yields of groundnuts under competition in mixtures.

Throughout the study it could be noted that same varieties combinations were not significantly different for same traits. This could be because the varieties used in this study were improved types and therefore homogenous. Donald (1963) pointed out that if the genotypes were stable they would show very little competition effects. In barley Briggs et al., (1978) indicated that competition among the improved types of cultivars were stable and that competition effects would be higher if the the unimproved types were involved. This is because such population would have a wide population variance which would provide competitive ability. In another study Allard and Adams

(1969) while studying competition in barley also reported that the yield changes of the genotypes grown in mixtures were often low if the genotypes used were pure or improved types. Similarly Gastafisson (1951) demonstrated that in barley, single gene mutants became more productive when in competition with each other in segregating progenies of the monoheterozygote, while in purestand such mutants were unproductive. This evidence suggest that competition seem to depend on the population concerned. If the population was more variable then the competition pressure increased because the number of lines involved were generally large. Usually in purestand it is assumed that the homozygous lines have reached a stable equilibrium. In mixed stand it should therefore be expected that if unimproved types of field beans were to be used then there would be a higher interaction or competition pressure as suggested by Sakai (1955) and hence identify more important interaction forms. Hence larger competition effect values would be obtained if the four genotypes studied here were all mixed and subjected to competition. Such a mixture would be a form of changed environment to which the population would respond by changing overall phenotypic appearance. This is because genetic characters were susceptible to changing environment condition such as those induced by competition in mixtures and responded by showing an increase in phenotypic variability (Rao and Mitra 1987). Such changes based on the phenotype would be used as criteria for selection of some important plant characters which might not have been definite in pure stand. Competition in beans may also be used as a criteria for both direct selection (where the cultivars perform well in mixtures than in pure stand) or indirect selection (where the cultivars perform well in pure stand than in mixtures) as described by Kawano and Thung (1982) for cassava.

Almost all the traits studied were affected by competition except for the seed weight. This suggest that plant character is affected by competition and similar results were reported by Sakai (1955) while studying some barley crosses, Smith et al., (1970) in oat varietal mixtures and Khalifa and Qualset (1974) in wheat mixtures. In all the seasons and locations it could be noticed that the effects of competition were more pronounced in yield than in other characters. The same form of relationship between trait and competition was reported by Smith et al., (1970) and Roy (1976). There is no clear evidence from this study to explain why competition in yield was more pronounced. Work done by Jensen and Federer (1965), Roy (1976) on wheat and Smith et al., (1970) on oat suggest that competition in mixtures starts very early in growth stages as early as seedling stage, and this could have a cumulative effect on yield. This can explain the case in this study though the early growth data was not taken. Seed weight may be pointed out as one character that competition in field beans does not seem to favour. The other characters of field beans are considered as favourable and could be used as criteria for selection under competition.

Apart from the number of leaves the varieties studied though of different growth habits could not be definitely categorized in relation to competition. The erect types (Rosecoco and Mwezi moja) and bushy types (Canadian Wonder and Red Haricots) were not definitely affected by competition in specific forms. This is contrary to what was reported on soyabean where branching growth habit was definitely associated with high yields in mixtures (Mumaw and Weber 1957).

6. CONCLUSION

The results of this study shows that there was significant genotypic interaction in the different bean mixtures. It also suggest that all forms of interactions occurred in every trait studied.
Since genotype competition seem to be very dependent on environment, the results obtained in this study are location and season specific. From the discussion it is however indicated that for the two seasons and two locations those mixtures which showed over compensation interaction would be considered as important interaction forms and could influence production in the peasant farming systems. Peasant farmers often grow mixtures of bean varieties or landraces which are always mixtures of purelines. The superiority of this system for beans has not been ascertained. The data obtained from this study suggest that a few specific combinations may favour this system of cultivation. That means for Kabete short rains, Canadian Wonder and Mwezi Moja would be considered favorable. For Kabete during the long rains, however none of the mixture combinations for yield was fovarable. For long rains at Kakamega, Rosecoco and Canadian Wonder would be adapted. While at Bukura Rosecoco and Red Haricot and Rosecoco and Mwezi Moja may be favourable combination.

Under the conditions of the experiment, those mixture combination found to be significant should be subjected to further testing using paired row technique suggested by Fehr (1973) before they are recommended to the farmers. Every significant interaction in this study should therefore be proved under visible method of planting with view of commercial purpose. The significant combinations may also be tested under broadcast method, though it is a traditional method recommendation would however still be made if same biblends were found to interact favourably.

It is difficult to definitely classify the form of competition interaction in flowering and maturity observed in this study. This is because it will depend on whether early flowering or late flowering is considered desirable. In case of Mwezi Moja which is adapted to marginal dry land areas early flowering and early maturity would be considered as favourable because it is a form of drought escape, but in case of Canadian Wonder and Red Haricot late flowering may be considered as fovourable because of long growth period in areas where these varieties are adapted

Further studies on the frequence of individual component or ratios in mixtures could be computed for mixture combinations that were significant. It is possible that certain combination which were not significant at 1:1 ratio used in this study could be significant at certain ratios.

The study was based on only one set of data per season and location. A study replicated over years would be necessary for making more reliable conclusions. on varieties that peasant farmers can safely cultivate in varietal mixtures. Further studies on this subject is therefore recommended.

Studies on correlations among the various morphological traits and regression analyses for yield prediction under competition are important to consider as this will help identify significant genotypic interactions of traits which directly or indirectly affect the yield. These characters would also help in selection programs for bean improvement.

Stability studies of the various biblends would be necessary as it would confirm whether or not the differences between the interactions in the biblends in different locations were location specific.

There is still a wide scope for the competition studies in beans as there are a good number of bean landraces cultivated in this country. Most of them are mixtures of purelines. Beans are also widely grown in various combination or mixtures with other crops. Interspecific interaction would be necessary for such mixtures as it would identify the most suitable interaction forms and frequencies which would be recommended to the farmers.

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