VARIATION AND YIELD PREDICTION ANALYSES OF SOME MORPHOLOGICAL TRAITS IN SIX KENYAN LANDRACE POPULATIONS OF SPIDERFLOWER (*Gynandropsis gynandra* (L) Briq)

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DECLARATION

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

Date 19.9.89 .....

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This thesis has been submitted for examination with my approval as the University supervisor.

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TO

MY PARENTS

CORNEL AND BENTA.

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Abstract

The objective of this study was to investigate the presence of heritable variation in Kenyan landrace populations of spiderflower (Gynandropsis gynandra (L) Briq) and assess the utility of yield components in the improvement of yield and duration of harvesting through the component breeding approach. Genetic components of variation and expected gain from selection as a percentage of the population mean were estimated from an S_1 family mating design. The experiment was conducted during the short rains of 1988 and the long rains of 1989 at the Field Station of the University of Nairobi, Kabete Campus and the National Horticultural Research Station, Thika. Twenty S_1 families from each population were planted in a three-replicate compact family block design at both sites. The data was collected for days to flowering, plant height, number of primary leaves, leaf length, leaf breadth, fresh leaf weight and dry leaf weight. The analysis was based on family means.

The results indicated that there was significant variation among populations for leaf length and dry leaf weight at Thika and number of primary leaves at Kabete. This reflected a variation in the yield potential of the populations. Significant variation was detected within population E for days to flowering and population M for

both fresh leaf yield and dry leaf yield. Yield prediction studies revealed that duration of harvesting could be prolonged by selecting late flowering genotypes in population E. Dry leaf yield and fresh yield could be improved by direct selection in population M. There was no inherent variation for any of the traits studied in populations P, Q, D and I. Therefore the improvement of these populations would necessitate the creation and maintenance of genetic variability by incorporation of genes from other populations and intermating within the populations.

1.0 INTRODUCTION

Gynandropsis gynandra, a member of the Capparidaceae family is geographically widely distributed, especially in parts of Africa and Asia (Holm *et al.*, 1976). It is a highly branched plant with pedate compound leaves, white or pinkish flowers and long capsules. The plant is viscid with glandular hairs and shows variable pigmentations on the stem and leaf petiole. It has a long primary root with numerous secondary roots that anchor it to the ground. Like other indigenous herbs and vegetables, *G. gynandra* comprises a large part of the diet of the people of East Africa. They are often collected in the field growing as weeds. Sometimes they are given some agronomic care by selective weeding. In a few cases they are grown and cultivated especially near homesteads (Watt and Breyer-Brandwick, 1962).

The young shoots of spiderflower are commonly used as a potherb throughout East Africa where they constitute a source of proteins, vitamins and mineral salts for a large sector of the population (Purseglove 1943, Imbamba *et al.*, 1977). Uncooked leaves are very bitter due to the presence of an oil similar to that of mustard. The seeds yield thick greenish oil. Tests for the presence of alkaloids in this oil have given doubtful results (Watt and Breyer-Brandwick, 1962).

Apart from nutritive value, medicinal uses of spiderflower have also been reported in many parts of the world. The sap from the leaves is used as a counter-irritant for local pains such as headache (Purseglove 1943). It can also be squeezed into aching ears in cases of epileptic fits. Roots are boiled and the decoction drunk to facilitate birth, for stomach-ache and for treatment of c njuctivities and severe infection by threadworms (Watt and Breyer-Brandwick 1962, Kokwaro 1976).

G. gynandra is a C_4 plant (Imbamba and Tieszen., 1977). The comparison of growth rates between C_4 and C_3 plant species have revealed that C_4 plants can produce three to five-fold more dry matter per unit leaf area and unit time than the C_3 plants (Joshi et al., 1965). The C_4 plants have a low CO_2 concentration point, require high temperature optima (30-40 ^{o}C) for attainment of maximum photosynthesis and also exhibit an unusually great capacity to fix CO_2. The combination of a high photosynthetic capacity at high temperatures and efficient water utilization may be important in East Africa especially in those areas possessing short periods of useful rainfall. Evans (1984) suggested that the fast growth rate of C_4 plants is due to more complete

translocation of assimilates from the mature leaves to the younger leaves and the growing tissues than to the higher rates of photosynthesis per se. The higher yields of C_4 plants are known to be associated with longer growing seasons and higher irradiation in which the crops are often grown and to which they are better adapted (Gifford, 1974).

It has been observed that there are some drawbacks on the use of spiderflower as a vegetable. The crop has a very short duration of vegetative growth. The plants tend to flower very early thus entering the reproductive phase of growth. As soon as the pods form the vegetative yield declines due to leaf senescence. The plants take a longer time producing flowers and forming pods upto the time they barely have any leaves. This is undesirable as a vegetable since the required ideotype would be a plant that maximizes vegetative growth at the expense of reproductive growth. The common practice to avert this problem is usually to cut off the flower buds and encourage branching and prolonged vegetative growth. The leaf yield per plant is also very low.

A large amount of variability seems to exist in spiderflower populations. Pigmentation, hairiness, degree of branching and other traits vary considerably. No genetic variation analysis have so far been conducted on the crop. It is for this reason that the present study was

undertaken to analyse the amount of heritable variation for some important agronomic traits in this crop. Although the specific mating system of this crop is not clear, there is likely to be a substantial rate of outcrossing owing to the diverse phenotypic variability and the phenomenon that anthers dehisce when the flowers have long been open and stigmas exposed to receive foreign pollen.

The objectives of the present study were in line with the problems of improving yield and duration of harvesting. These objectives were as follows:-

1. To study variation for yield and yield related traits within and among Kenyan landrace populations of spiderflower.

2. To identify leaf yield prediction characters in these landrace populations of spiderflower.

3. To predict the amount of genetic gain which can be obtained through simple mass selection.

2.0 LITERATURE REVIEW

2.1 Quantitative variation and estimation of variance components.

The success of breeding programmes depends mainly upon the amount of genetic variability in the populations to be improved and the breeding strategies. The total phenotypic variation of a character can be quantitatively partitioned into genetic and non-genetic variance components. Genetic variation can be manifested as distinctly different groups attributable to segregation of single or a few major genes or as a continuous variation arising from the presence of many polygenes. The two types of variations are known as qualitative and quantitative variations respectively. Quantitative variation is the variation of metric characters. Most breeding programmes are usually centred on the improvement of the metric traits. The genes controlling these traits are known to be complimentary and may be additive or multiplicative in their effects.

The ease with which a character can be improved is dependent upon the proportion of genetic variation as compared to the non-genetic variation. It is the genetic variation that is responsible for the genetic gain (Welsh, 1981). The genetic variation is often partitioned into additive, dominance and epistatic components. The additive

component measures the breeding value of an individual (Falconer, 1981). The genetic variance component also determines the degree to which a trait is inherited. Heritability of a character is the chief determinant of its response to selection.

Estimation of genetic variance components requires the use of appropriate mating and environmental designs. The systems of mating used to develop progenies have been classified by Cockerham (1963) as one, two, three or four-factor designs depending upon the number of ancestors per progeny over which controlis exercised. In choosing a mating design, the simplest design which provides the required information is prefered. Falconer (1981) pointed out that precision and bias are the two factors which govern the choice of relatives to use for estimation of heritability. Generally, the closer the relationship, the more precise the estimate. Bias in the heritability estimates is introduced by environmental sources of covariance and as in the case of full sibs, by dominance. Consequently, Falconer (1981) concluded that the correlation and the regression of the half-sibs on their male parents was more reliable since the estimates obtained were less affected by environmental component. The regression of offspring on female parent gives high estimate on account of maternal effects. The full sib correlation is the least reliable since the components due to the common environment is often present in large

amounts and is often difficult to overcome by an experimental design. The full sib covariance is further affected by dominance variance.

Depending upon the choice of the mating design, it was suggested by Kearsey (1965), Kearsey and Jinks (1968) and Dudley and Moll (1969) that some or all of the following assumptions are necessary for estimates of genetic variability:

1. The population should have a normal diploid and a mendelian inheritance.

2. The genetic population should be at random mating equilibrium.

3. There should be linkage equilibrium.

4. There should be no environmental correlation among progenies.

5. There should be no maternal effects.

6. There should be no non-allelic interaction.

7. There should be uncorrelated gene distribution.

8. The progenies should not be inbred and should be considered random members of some non-inbred population.

However, some designs have been developed that are not restricted to the above assumptions (Matzinger and Cockerham 1963, Martha and Jinks 1971). For example, an exception to the non-inbred progenies and non-inbred parental population was the mating design proposed by Matzinger and Cockerham (1963). In this design, self-pollinated progenies with gene frequencies of 0.5 or showing no dominance can be used. Similarly Martha and Jinks (1971) reported that where a species is capable of both easy self-fertilization and easy crossing, every member of any population may be treated as an F_1 between hypothetical parents. Self-fertilization will yield F_2 which may be used in turn to give both F_3 and biparental progenies. The components of variation may be estimated from such families even in the absence of a sufficiently large F_1 population from which a direct estimate of the environmental component can be obtained.

Kearsey and Jinks (1968) singled out three difficulties arising from the assumptions made when estimating additive, dominance and environmental components of variation. Firstly, most analyses assume the the absence of non-allelic interaction though they do not provide a valid test for this assumption. Secondly, the estimates of dominance components have larger standard errors as compared to the corresponding additive component. Thirdly, the additive and dominance components

are differentially affected by linkage and correlated gene distributions in the parents and are only comparable in the unlikely event of the population sample being in linkage equilibrium. The diallel analysis of Hayman (1954) and Jinks (1956) are exceptions to the first limitation since they provide a test for the adequacy of the additive-dominance model. Similar tests can be obtained from the designs of Martha and Vines (1952) and Opsahl (1956) which utilize crosses between single pairs of inbred lines and generations derived from them by selfing, back-crossing and sib-mating. The second limitation can be overcome by experiment III of Comstock and Robinson (1952) where the error variances used for testing the additive and dominance components are derived separately. Kearsey and Jinks (1968) described an extension of this design which provided an efficient estimate of the dominance component and an unambiguous test for epistasis. Jinks and Perkins (1970) used the extended design of Kearsey and Jinks (1968) to investigate the F_2 and backcross populations derived from two crosses between inbred varieties of Nicotiana rustica. This retained the advantage of the original design of Comstock and Robinson (1952) where dominance and additive components are tested against their respective error variances. It also made full use of the families in the triple test cross that had F_1 as one of the parents.

Jinks (1954, 1956) illustrated a method of analysis of generation means of parents, F_1, F_2 and backcross generations of diallel set of crosses between eight inbred lines of N. rustica. The analysis showed that genic interaction was responsible for all the apparent overdominance and heterosis in height and leaf length of N. rustica. The crosses were treated as independent. Jinks and Stevens (1959) considered their interaction and were able to estimate additive, dominance and non-allelic components.

The methods of estimating variance components vary in their usefulness and efficiency. Kearsey (1965) did an experiment to evaluate five experimental designs which included Biparental progenies, North Carolina design I,The partial diallel cross, North Carolina design II and Half diallel cross. The criteria used to compare the methods were the estimates of variation obtained. The biparental progenies had the advantage of using the largest sample of parents from the population but had the disadvantage of yielding only two statistics, namely, variation within families and variation among families from which to estimate genetic and environmental components. The North Carolina designs I and II were well suited to certain breeding systems. The North Carolina design I was devised for situations in which the supply of female parents was in excess of males while the North Carolina design II was devised for cases where males and females were in equal

ratios. However, the two designs had the disadvantage of providing no test for non-allelic interaction. The partial diallel did not have any advantage over the other designs. The half diallel gave the most information about the small number of plants used in it. It demonstrated that additive and non-additive variation were mainly due to the non-allelic interaction. Apart from Biparental progenies, the other four designs are suited for analysing populations of known genetic composition such as inbred lines, backcross generations, F_1 and F_2 generations derived from crosses between inbred lines. They were not appropriate for the present study since the genetic composition of G. gynandra is still elusive. The S_1 family testing like biparental progenies is sufficient to partition phenotypic variance into genetic and environmental components. The S_1 progeny test as a means of estimating variance components have been used in sorghum by Eckebil et al. (1977) with great success. Selection based on S_1 families was found to be effective in improving traits with low heritability values such as grain yield by Dogget (1972) and Jan-Orn et al (1976) as compared to mass selection. Biparental progenies was not preferred in the present study due to the technicalities of making crosses rather than getting S_1 families used in this analysis.

2.2 Yield and Yield Components Interrelationships

Breeding for high yield is often difficult because the inheritance of yield is influenced by the interrelationships of many genetic and environmental factors. Yield is polygenically controlled and often exhibits low heritability values. Therefore, the strategy for crop yield improvement in most breeding programmes has been indirect selection via the yield components which are simpler in inheritance and often have higher heritability values (Moll et al. 1962, Johnson et al. 1966, Paroda and Joshi 1970, Grafius and Okoli 1974). Manipulation of plant morphological characters to the required architectural design leads to the development of varieties that are efficient in utilizing the environmental resources and partitioning of the photosynthates (Agwanda 1988). Yield can be predicted on the basis of relative contribution of the component characters. Such contributions can be revealed by undertaking studies on correlations, multiple regression and path analysis. The component breeding approach has been reported to result in substantial genetic gain (Rassmuson and Cannel 1970).

Although certain yield components that relate to vegetative yield are also determinants of seed yield, the required architectural design of a vegetative crop differs from that of a seed crop. This conclusion is reached from the observation that studies done on some species of amaranth for vegetative yield by Mohideen and

Muthukrishnan (1979) and grain yield by Ayiecho (1985) gave different results with some overlap. Mohideen and

Muthukrishnan (1979) found that stem weight, leaf length, leaf weight, stem diameter, plant height and leaf breadth were the important components of vegetative yield. Ayiecho (1985), however found that plant height, head weight, threshing percentage and yield: height ratio were the important components of grain yield. Many studies have been done that relate the yield of cereals to their yield components. For example, it has been found that the important components of yield in maize are ears per plant, number of kernel rows per ear, number of kernels per row and kernel weight (Adams 1967). The yield component traits in barley and wheat include spikes per plant, kernels per spike, kernel weight and kernel weight per spike (Puri et al. 1982 and Ayiecho and Onim 1983). Adams (1967) and Agwanda et al. (1989) also reported that the important yield components of field beans (Phaseolus vulgaris) included the average number of pods per plant, the average number of seeds per pod and the average seed weight.

Yield prediction studies done on vegetable crops, fodder crops and other vegetative crops like tobacco in which the important parts are vegetative rather than reproductive organs have been centred on traits like days to flowering, plant height, number of leaves per plant and

leaf size as some of the most important leaf yield components (Sastri and Gopinath 1968, Dangi and Paroda 1974, Sastri 1974, Paroda et al. 1975, Mohideen and Muthukrishnan 1979). Like seed yield vegetative yield improvement is enhanced by the understanding of the interrelationships between the vegetative yield and its components. It has been observed that selection using yield components is effective if there is no decrease in one of the components as selection is done on the other component (Kronstad and Foote 1964). Such a decrease could result if a direct or indirect negative association existed between the components and yield due to biological limitations.

The widely accepted fact that yield components are compensatory arises from the fact that the components compete for the same total amount of metabolic substrates produced by the plant (Kronstad and Foote 1964). The conditions which favour the development of one component could have adverse effects on the other components. Therefore, Kronstad and Foote (1964) concluded that a compromise as to the desired levels of each component have to be reached to obtain maximum yield. A similar argument was put forward by Grafius and Okoli (1974) that the ratio of yield components plays a vital role in the adaptation and subsequent yield of a crop. Their model assumed that for a given population and environment there was an optimum ratio of the yield components. They further noted

that the indefinite increase in any one component would inevitably be followed by a compensatory adjustment in the others. Similarly indefinite increase in yield destroys the original dimensional balance of the optimum shape. Adams (1967) and Grafius (1978) reported that the observed correlations between traits are due to genetic linkages, pleiotropy or physiological and developmental relations. Negative relationship when present indicate some form of competitive inhibition. Since the correlations between yield components are largely physiological, they change with the environment and the gene pool. However, a study reported by Adams (1967) on maize showed that the effect of years, locations, genotypes or levels of homozygosity did not alter the pattern of correlations.

Yield is said to be a product of several components which act multiplicatively. Therefore it can be inferred that multiplicative epistasis among genes controlling these traits affect yield *per se* (Ayiecho 1980). Kronstad and Foote (1964) reported that a large part of the total genetic variability for yield and its components in winter wheat was a result of additive gene action. Similarly Brown *et al* (1966) found that additive gene effects accounted for a major part of the genetic variation in hybrids of winter wheat for several traits including yield. Grafius *et al* (1952) reported contrasting results that additive genetic variance for yield was small compared to the non-additive fraction in bulked F_2

progenies of barley. Johnson and Askel (1959) also found a large amount of dominance variance relative to additive variance for yield of barley.

Variation analysis have also been done for flue-cured leaf yield of N. tobaccum (Matzinger et al. 1962) and vegetative yield of forage sorghum (Blum 1968) Matzinger et al (1962) found a relationship where the generally low values of heterosis and inbreeding depression in yield and yield components of N. tobaccum could be compared to the estimates of genetic variance. It was reported that the predominance of additive genetic variance and the general absence of appreciable amounts of heterosis or inbreeding depression suggested the use of breeding procedures which increase the gene frequencies of those genes showing primary additive effects. Blum (1968) found that general combining ability was more important in the determination of forage yield levels in sorghum compared to specific combining ability. This was an indication that additive genetic variance was important in the determination of forage yield within the materials and environmental conditions studied. Adams (1967) observed that the components of yield in beans were genetically independent. This conclusion was reached from the observation that in stress-free conditions, the component relationships were generally near zero. The predominantly negative correlations observed were believed to arise from developmentally induced relationships, such as competition

for limited nutrient supply. A review of the relationships among components of vegetative yield is given below:

2.2.1 Days to flowering.

Days to flowering has been studied extensively in both seed crops and vegetative crops. In seed crops it is important as a parameter of earliness but in leafy vegetables, early seed production is undesirable. Paroda et al. (1975) worked on fodder sorghum and found that days to flowering was positively and significantly correlated with green fodder yield as well as dry matter yield both at genotypic and phenotypic levels. They also found it to be positively and significantly correlated with stem girth and leaf characters such as leaflength and leaf breadth at genotypic level. Path analysis revealed that there was a low negative direct effect of days to flowering on both green and dry matter yield. Selection could therefore be done in favour of early genotypes with high production per unit time.

Dangi and Paroda (1974) demonstrated the effect of environment on correlation and path analysis results in fodder cowpeas (Vigna sinensis). Days to flowering showed negative correlation with other yield related characters under good fertility conditions. This reflected the fact that the early flowering plants were in general high yielding under those conditions. In a less fertile

environment, medium to late genotypes were high yielding and the correlations between days to flowering and yields of both green and dry matter were positive. In natu

tobacco, Sastri (1974) indicated that flowering time was negatively associated with cured leaf yield such that an early flowering plant that have a high leaf area index would give high yields. However, it was observed that early flowering plants had less leaf area index. In seed crops, flowering time has been reported to be positively associated with yield of grams and finger millets by Asawa and Tiwari (1976) and Patnaik (1968) respectively. Path analysis performed by Asawa and Tiwari (1976) showed that days to flowering had negative direct effect on yield in Panicum miliare. Yadav and Srivastava (1976) found no significant association between days to flowering and grain yield. Negative association was recently reported between seed yield and days to flowering in field beans (Agwanda et al. 1989).

Variation analysis in days to flowering revealed high estimates of broad sense heritability in Pennisetum typhoides (Gupta and Nanda 1971). Chandra (1968) and Sastri and Gopinath (1968) working on grams and natu tobacco respectively also reported high broad sense heritability in days to flowering and flowering duration of grams. Flowering time exhibited high heritability estimates and low values of genetic coefficient of

variation and genetic advance in natu tobacco. Sastri and Gopinath (1968) thus suggested that the expression of this character is conditioned by non-additive gene effects.

2.2.2 Plant height.

Vegetative yield of both leafy vegetables and fodder crops have been found to be significantly correlated with plant height by a number of workers. Paroda et al (1975) reported significant association of plant height with both green fodder yield and dry matter yield in fodder sorghum. They further reported that plant height was associated with leaf characters such as leaf length and leaf breadth. Path analysis results, however, gave a negative effect of plant height on forage yield of sorghum. Significant positive correlation between plant height and forage yield was also reported by Gupta and Nanda (1971) for inbred lines of Pennisetum typhoides. A high percentage contribution of plant height to the variation of fodder yield was reported by Gupta and Nanda (1971). A significant correlation between plant height and yield was also reported in natu tobacco (Sastri 1974). However, plant height had a low direct path effect on yield. The contribution of plant height to yield was mainly through the leaf area index.

Dangi and Paroda (1974) found that the effect of plant height on yield of fodder cowpea was influenced by

fertility status of the soil. There was a negative and significant genetic association between plant height and both green and dry matter yield of fodder cowpea under good fertility conditions. Under low fertility conditions there was a positive but non-significant genetic association. Therefore, it was concluded that plant height was a less important component in the improvement of yield in fodder cowpea. Studies on the association between plant height and seed yield have given contrasting results. Yadav and Srivastava (1976) found that plant height had no significant association with grain yield of Panicum miliare. In parental populations of grams, plant height was found to be correlated with seed yield at phenotypic level (Asawa and Tiwari 1976). However in segregating F_3 populations, seed yield was found to be negatively correlated with plant height at phenotypic level. The difference arose from the fact that parental populations had limited fixed genotypes whereas segregating generations like F_2 and F_3 had a large number of genotypes incorporated in the analysis. Giriraj and Vijuykuma (1974) reported positive association between plant height and seeds per pod in mungbean. Increased plant height resulted in more flowers through increased number of branches per plant. Path analysis data revealed that plant height had direct effect on seed yield.

Variation analysis done in P. typhoides revealed a high heritability estimate for plant height (Gupta and

Nanda 1971). Chandra (1968) reported that the estimates for the components of variation i.e. phenotypic variance, genotypic variance and environmental variance showed that there was a wide variation in plant height but variability was influenced by the environment. Sastri and Gopinath (1968) found that plant height showed high values of genetic coefficient of variation, genetic advance and heritability indicating high genetic variability which could be exploited by selection. Similar results were observed by Smith (1952) and Oka et al (1955) in N. rustica and N. tobaccum respectively.

High heritability estimates for plant height have also been reported in finger millet by Patnaik (1968). Jinks and Perkins (1970) found that variation for plant characters such as plant height and flowering time showed the relative importance of additive gene effects as compared to dominance and epistatic effects in one cross obtained from two inbred lines of N. rustica. The non-additive components were however, found to be important in another cross in all environments where it was tested.

2.2.3 Leaf length and leaf breadth.

Leaf length and leaf breadth are good indicators of leaf size. Studies have shown significant correlation between vegetative yield and leaf size parameters. In forage sorghum, Paroda et al. (1975) reported significant correlation between green fodder yield and both leaf-

length and leaf breadth. Similar results were obtained between dry matter yield and the leaf parameters. Path analysis revealed that the direct effect of leaf breadth on both green and dry matter yield were positive and high. The indirect effects of leaf breadth via leaf length were also high on green and dry matter yield. Paroda et al (1975) concluded that leaf length and leaf breadth were more reliable components of both dry and green fodder yield of sorghum.

Sastri (1974) singled out leaf area index as the most important component with profound influence on yield of cured tobacco. It was recommended that for higher yields to be realized, plants with higher leaf area index should be selected. Leaf area index was measured as the sum of the product of leaf-length and leaf-breadth of all cured leaves. Gupta and Nanda (1971) noted that the yield of green fodder in P. typhoides depended largely on leaf size and leaf number. Regression analysis results revealed that leaf size and leaf number accounted for 60.62 percent of the variation in green fodder yield. Contrasting results were obtained from studies done on fodder cowpea by Dangi and Paroda (1974). From their results, leaf length and leaf breadth were not considered as important parameters since they did not have a high direct effect. Sastri and Gopinath (1968) noted that the number of leaves per plant and leaf breadth in natu tobacco had high heritability estimates with medium values of genetic

coefficient of variation and genetic advance. This suggested that the two characters could be used as selection criteria. Robinson et al (1954) concluded on the basis of genetic coefficient of variation and genetic correlations that rapid progress would be expected by selecting for broad leaf types.

2.2.4 Number of leaves.

The number of leaves per plant have a high influence on the total vegetative yield of a crop. Numbers and sizes of organs tend to have inverse relationships (Porneleit and Egli 1979). This is because plants with smaller leaves can only compensate for total vegetative yield by having more leaves. In fodder cowpeas, Dangi and Paroda (1974) noted that leaves per plant was significantly correlated with both green and dry matter yield. Sastri (1974) found that number of leaves was the second most important yield component after leaf area in natu tobacco. However, direct and indirect effects via leaf area index was of a higher magnitude.

Variation studies by Gupta and Nanda (1971) revealed high heritability estimates for leaves per plant in all varieties of P. typhoides studied. Mohideen and Muthukrishnan (1979) found a positive correlation between the number of leaves and the weight of leaves in vegetable amaranth. However it was noted that the association between number of leaves and important parameters such as

leaf length, leaf breadth, plant height and stem diameter was not significant. Hence it had a negligible role as a criterion for selection in vegetable amaranth.

3. MATERIALS AND METHODS

3.1 Materials.

Six Kenyan landrace populations of spiderflower (Gynandropsis gynandra) given in Table 1 were used in the study. The populations were collected from different localities in the country by the Department of Crop Science of the University of Nairobi.

The plants within each population were highly variable for morphological traits like growth habits, hairiness and pigmentation . Some plants were short, highly branched and spreading in nature while others were tall, erect and less branched. Hairiness on the stem was a common trait for all plants in all populations. Hairy leaf margin was also observed in a few plants in each population. Pigmentation on the plants varied from red to green with variable intermediate colourations. There were plants with both stems and leaf petioles completely green or red. Other plants were either green on the stem and red on the leaf petiole or red on the stem and green on the leaf petiole (Plates 1 and 2). Variation in some plants was diffused between red and green while others had stems which had both red and green stripes. Such variations were observed in all the six populations.

Table 1: Collection sites for six populations of spiderflower (*G. gynandra*).

Population code	Site of collection
D	Kisii
E	Kisii
P	Kakamega (Mumias)
Q	Kakamega (Butere)
M	Bungoma
I	Kibwezi

Plate 1: Plant with red leaf petiole and green stem.

Plate 2:

Plant with red stem and green leaf petiole.

3.2 Field Experiments.

The field experiments were conducted at the Field Station of the University of Nairobi, Kabete Campus and National Horticultural Research Station, Thika, between June 1988 and May 1989. Seeds from each population were planted in June 1988 in two rows, 15 m long and 30 cm apart in a plot measuring 3.3 m x 15 m at Kabete. Diammonium phosphate was applied at planting at a rate of 100 kg/ha. Irrigation water was applied to supplement soil moisture during the entire growth season. Weeding and thinning was done after three weeks to a spacing of 15 cm within rows and 30 cm between rows.

Unopened flowers of 50 randomly selected plants from each population were bagged using glycine paper to prevent any cross pollination (Plate 3). The bagged plants were appropriately labelled for ease of identification. Selfing was allowed to continue and the plants regularly checked so that as the pods formed, they were uncovered to enhance photosynthesis and rapid pod maturation. The S_1 seed from each plant was harvested separately at maturity giving 50 S_1 family seedlots from each population.

Plate 3: Shows the selfing procedure. Pods are uncovered to enhance photosynthesis and rapid maturation after selfing is complete.

Out of 50 S_1 families, in each population, 20
e randomly selected and planted in a three-replicate
pact family block design at Kabete Campus and Thika
ing the short rains of October 1988. Each S_1 family was
nted in a three - meter row. Diammonium phosphate was
lied at planting at a rate of 100 kg/ha. Weeding and
nning was done after three weeks to a spacing of 15 cm
hin the rows. Spacing between the family rows was 30 cm
le spacing between the population plots within a block
50 cm. The experiment was repeated during the long
ns of March 1989 at both sites.

Data Collection.

The data was collected on eight randomly selected
nts from each family in each replicate at flowering
ge for days to flowering and 50 days after planting for
nt height (cm), Number of leaves, Leaf length (cm),
f breadth (cm), Fresh leaf weight (g) and Dry leaf
ght (g).

Days to flowering was scored as the number of days from the date of planting to the date the first flower-buds opened. Plant height was measured from ground level to the topmost flower bud. The number of leaves included leaves on the main stem and its branches. Leaf length was measured on the middle leaf-let of the largest leaf that was free from any damage. Leaf breadth was measured on the widest part of the same leaf-let that was used for leaf length measurement. The leaves were then harvested and weighed separately from the stem to obtain fresh leaf weight. Dry leaf weight was obtained by drying the fresh leaves at 100 ^{o}C to a constant weight. Yield was taken to be the weight of oven-dried leaves since this was free from fluctuation due to the presence of moisture as would be expected in the case of fresh leaf weight.

3.4 Statistical Analysis

3.4.1 Variation among populations

The analysis to compare the six populations was done according to the mixed model analysis of variance outlined by Hallauer and Miranda (1981), Steel and Torrie (1981) and Gomez and Gomez (1984). The population effects were treated as fixed while the season effects were treated as random. The analysis of variance was computed using individual family means as shown in Table 2.

Table 2: Analysis of variance for comparing populations of spiderflower (G. gynandra) at each site.

Source	df	MS	EMS
Seasons	y-1		
Replications within seasons	y(r-1)		
Populations	t-1	M_4	$\sigma^2 + s\sigma^2_e + rs\sigma^2_{ty} + sry\Sigma T_i^2/(t-1)$
Populations x season interraction	(t-1)(y-1)	M_3	$\sigma^2 + s\sigma^2_e + rs\sigma^2_{ty}$
Pooled experimental error	y(r-1)(t-1)	M_2	$\sigma^2 + s\sigma^2_e$
Pooled sampling error	ytr(s-1)	M_1	σ^2

Where r, y, t and s represent the number of replications per site, the number of seasons, the number of populations and the number of families per population, respectively.

T_i represent the effect of the i^{th} population.

σ^2, σ^2_e and σ^2_{ty} represent the variance components due to sampling error, experimental error and population x season interaction respectively. Duncan's multiple range test was used to compare the population means at $P = 0.05$.

3.4.2 Variation within populations.

The analysis for deriving genotypic variance components within each population was done for each site using a random model as outlined by Gomez and Gomez (1984) as in Table 3.

Table 3: Analysis of variance within each population at each site.

Source	df	MS	EMS
Replications within seasons	y(r-1)	M_5	
Seasons	y-1	M_4	$\sigma_e^2 + r\sigma_{gy}^2 + rg\sigma_y^2$
Families	g-1	M_3	$\sigma_e^2 + r\sigma_{gy}^2 + ry\sigma_g^2$
Family x season interraction	(g-1)(y-1)	M_2	$\sigma_e^2 + r\sigma_{gy}^2$
Pooled error	y(r-1)(g-1)	M_1	σ_e^2

Where: y, r and g represent the number of seasons, number or replications per site and number of families respectively.

σ^2_e, σ^2_y, σ^2_g and σ^2_{gy} are the variance components due to error, seasons, families and interaction between families and seasons respectively.

The variation analysis within each population was used to estimate the variance components by equating observed mean squares to their expectations.

Phenotypic variance within each population based on family means is given by:

$$\sigma^2_p = \sigma^2_g + \frac{\sigma^2_{gy}}{y} + \frac{\sigma^2_e}{ry} .$$

Where σ^2_g is the estimate of genotypic variance component obtained from the analysis as follows:

$$\sigma^2_g = \frac{M_3 - M_2}{ry}$$

σ^2_{gy} is the estimate of variance component due to interaction between families and the seasons and was obtained as

$$\sigma^2_{gy} = \frac{M_2 - M_1}{r}$$

σ^2_e is the estimate of variance component due to error and equals M_1.

The broad sense heritability estimate was obtained by:

$$h^2 = \frac{\sigma^2_g}{\sigma^2_p}$$

Predicted response to simple mass selection with a selection pressure of 10% was estimated as

$$\Delta G = ih^2_{BS}\sigma^2_p$$

Where i = selection intensity.

3.4.3 Phenotypic correlations and multiple regression

The S_1 family data was used to compute phenotypic correlation coefficients among the traits studied. Multiple regression was used to find out the best predictors of dry leaf yield per plant. MSTAT computer package was used in the analysis. The correlation and multiple regression coefficients were subjected to statistical tests at significance level of $P = 0.05$.

4.0 RESULTS

4.1 Quantitative Variation

4.1.1 Variation among populations

The analysis of variance for each of the seven traits at Thika and Kabete are presented in Tables 4 and 5 respectively. The results at Thika were combined over the two seasons. However, the results at Kabete are given for the long rain season of 1989 only since the short rain season of 1988 gave a very poor crop and therefore the results were excluded from the analysis. The results at Thika (Table 4) indicate that variation due to seasonal differences was significant for all the traits. There was no significant variation due to population x season interaction for all traits except fresh leaf weight and dry leaf weight. Significant difference among populations was observed for leaf length and dry leaf weight. The population means for these two traits were separated by Duncan's multiple range test indicating that population I had significantly shorter leaves than populations D and M (Table 6). The mean leaf length of populations E, P and Q were not significantly different from those of populations D, M and I. Duncan's multiple range test results also revealed that population I had significantly lower dry leaf yield than populations E, P, D and M.

Table 4: The mean squares for the analysis of variance for the six populations at Thika

Trait	Mean squares					
	Replications within seasons	Seasons	Populations	Population x Season Interaction	Experimental error	Sampling error
	df 4	1	5	5	20	684
Days to flowering	30.710	46507.302**	37.217	17.931	32.863	10.142
Plant height	241.755	6538.455**	40.166	280.198	148.734	24.049
Number of leaves	3.568	70.537**	14.951	28.151	13.476	1.943
Leaf length	1.780	274.985**	6.707*	2.468	1.995	0.276
Leaf breadth	0.390	42.691**	1.346	0.606	0.499	0.082
Fresh leaf weight	132.809	155.794*	58.932	98.245*	29.203	12.223
Dry leaf weight	1.660	3.281**	1.532**	0.964*	0.331	0.143

* Significant at P = 0.05
** Significant at P = 0.01

Table 5: The mean squares for the analysis of variance for the six populations at Kabete.

Trait	Mean Squares			
	Replications	Populations	Experimental error	Sampling error
	df 2	5	10	342
Days to flowering	76.889	3.683	51.414	48.848
Plant height	1267.143	121.548	699.494	62.840
Number of leaves	68.405	375.761*	81.794	10.376
Leaf length	25.188**	1.758	2.699	0.465
Leaf breadth	4.888	1.331	0.868	0.088
Fresh leaf weight	969.758	99.614	188.248	16.940
Dry leaf weight	13.091*	1.591	1.859	0.264

* Significant at P = 0.05

** Significant at P = 0.01

Table 6: The means standard errors and coefficients of variation (c.v) at Thika (1) and Kabete (2)

Trait		Mean						Standard error	Coefficeint of variation
		Population							
		E	P	Q	D	M	I		
Days to flower	(1)	43.675[a]	44.260[a]	44.301[a]	45.088[a]	45.005[a]	44.483[a]	0.523	12.891
	(2)	36.743[a]	36.560[a]	36.740[a]	36.507[a]	36.597[a]	36.070[a]	0.926	5.890
Plant height	(1)	29.244[a]	29.873[a]	30.411[a]	30.250[a]	30.866[a]	29.654[a]	1.113	40.584
	(2)	46.818[a]	44.515[a]	47.527[a]	46.944[a]	46.214[a]	44.004[a]	3.414	16.820
Number of leaves	(1)	9.940[a]	9.388[a]	9.899[a]	9.508[a]	9.468[a]	10.245[a]	0.335	37.716
	(2)	8.313[c]	12.053[abc]	10.393[bc]	12.814[ab]	13.460[ab]	15.519[a]	1.168	26.550
Leaf length	(1)	4.168[ab]	4.379[ab]	4.284[ab]	4.537[a]	4.545[a]	3.887[b]	0.129	32.843
	(2)	5.320[a]	5.356[a]	5.485[a]	4.990[a]	5.294[a]	5.415[a]	0.212	12.690
Leaf breadth	(1)	1.890[a]	1.845[a]	1.875[a]	1.910[a]	1.948[a]	1.662[a]	0.064	38.072
	(2)	2.179[a]	2.245[a]	2.395[a]	1.960[a]	2.102[a]	2.259[a]	0.120	13.480
Fresh leaf weight	(1)	5.933[a]	5.862[a]	5.717[a]	6.939[a]	4.885[a]	5.223[a]	0.493	93.803
	(2)	9.893[a]	8.480[a]	11.756[a]	9.288[a]	10.982[a]	11.402[a]	1.771	39.958
Dry leaf weight	(1)	1.137[a]	1.150[a]	1.110[ab]	1.239[a]	1.175[a]	0.867[b]	0.053	51.469
	(2)	1.428[a]	1.281[a]	1.708[a]	1.511[a]	1.669[a]	1.626[a]	0.176	32.900

Means followed by the same letter a, b or c on each row are not significantly different at P = 0.05 as determined by Duncan's multiple range test.

The results at Kabete (Table 5) indicate that there was no significant difference among populations for all the traits except the number of leaves. According to Duncan's multiple range test population I had more leaves than populations E and Q (Table 6) The coefficients of variation were lowest for days to flowering and highest for fresh leaf weight at both sites.

4.1.2 Variation within populations

Variation analysis results within populations are presented in a combined analysis of variance over seasons at Thika. Variation analysis at Kabete are given for the long rain season of 1989 only due to crop failure during the short rain season of 1988.

4.1.2.1 Variation in population E.

Variation analysis results for population E at Thika revealed significant difference among families for days to flowering only (Table 7). Variation due to seasonal differences was significant for all traits except number of leaves, fresh leaf weight and dry leaf weight. Apart from the number of leaves, all the characters studied did not have any significant variation due to family x season interaction. The components of variation heritability estimates and expected percentage gain for

Table 7: The mean squares for the analysis of variance for population E at Thika.

Trait	Mean squares				
	Replications within seasons	Season	Family	Family x season interaction	Error
	df 4	1	19	19	76
Days to flowering	71.231	6326.945**	15.878**	4.634	6.993
Plant height	471.319	15775.152**	60.362	48.190	49.064
Number of leaves	3.267	10.866	2.258	3.170*	1.607
Leaf length	4.743	111.535**	0.412	0.318	0.456
Leaf breadth	0.749	11.175**	0.084	0.122	0.112
Fresh leaf weight	225.015	804.402	6.215	16.306	5.995
Dry leaf weight	3.090	7.803	0.150	0.136	0.158

* Significant at P = 0.05

** Significant at P = 0.01

population E at Thika are presented in Table 8. Days to flowering had a fairly high heritability estimate (h^2 = 0.617). The other traits had no significant genetic variation hence low heritability values. The coefficients of variation for population E at Thika (Table 8) were low for days to flowering, intermediate for plant height, number of leaves, leaf length and leaf breadth but fairly high for fresh leaf weight and dry leaf weight.

Variation analysis at Kabete did not reveal any significant genetic variation for the traits studied (Table 9). The coefficients of variation were generally low for days to flowering, plant height and leaf length, intermediate for number of leaves, leaf breadth and dry leaf weight but high for fresh leaf weight.

4.1.2.2 Variation in population P.

Variation analysis for population P did not detect any significant difference among families for all the traits at Thika (Table 10). Variation due to seasonal differences was significant for days to flowering and leaf length only. There was also no significant variation due to family x season interaction for any of the traits. The components of variation, heritability estimates, expected selection gain and coefficients of variation for population P at Thika are presented in Table 11. The

Table 8: The components of variation, heritability estimates, expected selection gain as percent of the mean and C.V. in population E at Thika.

Trait	σ_p^{2*}	σ_g^{2*}	h^{2*}	Expected % gain	Coefficeint of variation
Days to flowering	3.040	1.874	0.617	4.330	6.01
Plant height	10.206	2.029	0.199	3.822	19.81
Number of leaves	0.528	0.000	0.000	0.000	14.72
Leaf length	0.092	0.016	0.174	2.226	15.50
Leaf breadth	0.020	0.000	0.000	0.000	17.87
Fresh leaf weight	2.718	0.000	0.000	0.000	33.50
Dry leaf weight	0.028	0.002	0.071	1.837	33.91

*σ_p^2, σ_g^2 and h^2 represent phenotypic variance, genotypic variance and heritability estimate respectively.

Table 9: The mean squares for the analysis of variance for population E at Kabete.

	Replications	Families	Error	Coefficient of variation
Trait	df 2	19	38	
Days to flowering	1.950**	0.565	0.502	1.95
Plant height	107.142**	8.940	9.360	8.84
Number of leaves	14.049**	2.182	1.757	12.09
Leaf length	3.158**	0.127	0.117	6.91
Leaf breadth	0.426	0.208	0.162	18.19
Fresh leaf weight	30.795**	3.256	2.252	20.98
Dry leaf weight	0.770**	0.072	0.044	16.22

** Significant at P = 0.01

Table 10: The mean squares for the analysis of variance for population P at Thika.

Trait	Mean squares				
	Replications within seasons	Seasons	Families	Family x season interaction	Error
df	4	1	19	19	76
Days to flowering	38.290	7061.309**	6.400	7.929	9.808
Plant height	254.723	491.670	17.168	16.477	26.917
Number of leaves	13.794	13.280	9.852	6.998	9.771
Leaf length	4.809	47.704*	0.543	0.552	0.651
Leaf breadth	1.195	7.808	0.135	0.097	0.097
Fresh leaf weight	122.907	310.537	4.879	3.125	4.635
Dry leaf weight	1.617	2.280	0.134	0.081	0.097

*Significant at P = 0.05

**Significant at P = 0.01.

Table 11: The components of variation, heritability estimates, expected gain as percent of the mean, and coefficient of variation in Population P at Thika.

Trait	σ_p^{2*}	σ_g^{2*}	h^{2*}	Expected % gain	Coefficient of variation
Days to flowering	1.635	0.000	0.000	0.000	7.08
Plant height	4.601	0.115	0.025	0.316	19.81
Number of leaves	2.105	0.476	0.226	6.140	32.14
Leaf length	0.109	0.000	0.000	0.000	18.07
Leaf breadth	0.022	0.006	0.273	3.858	16.60
Fresh leaf weight	1.065	0.292	0.274	8.480	6.96
Dry leaf weight	0.025	0.009	0.360	8.701	26.88

*σ_p^2, σ_g^2, and h^2 represent phenotypic variance, genotypic variance and heritability estimate respectively.

characters had low heritability values ranging from 0.000 for days to flowering and leaf length to 0.3600 for dry leaf weight due to lack of significant genetic variation. High coefficient of variation values of 26.88 percent and 32.14 percent were obtained for dry leaf weight and number of primary leaves respectively.

Variation analysis at Kabete also revealed no significant difference among families for all the traits studied (Table 12). The coefficients of variation for number of primary leaves, dry leaf weight and fresh leaf weight were fairly high with values of 25.23 percent, 35.80 percent and 41.09 percent respectively.

4.1.2.3 Variation in population Q.

The analysis of variance for population Q at Thika is presented in Table 13. There was no significant variation among families for all the traits studied. Variation due to seasonal differences was significant for days to flowering, plant height and leaf length. There was also no significant variation due to family x season interaction for all the traits. The components of variation, heritability estimates, expected selection gain and coefficient of variation values for this population at Thika are presented in Table 14. All the traits had low heritability values ranging from 0.000 for plant height

Table 12: The mean squares for the analysis of variance for population P at Kabete.

Trait	df	Replications 2	Families 19	Error 38	Coefficient of variation
Days to flowering		220.934**	2.262	2.693	4.49
Plant height		3079.658**	58.382	45.361	15.13
Number of leaves		172.325**	12.665	9.249	25.23
Leaf length		8.188**	0.307	0.354	11.11
Leaf breadth		1.995**	0.080	0.079	12.51
Fresh leaf weight		173.935**	10.159	12.139	41.09
Dry leaf weight		1.523**	0.179	0.210	35.80

**Significant at P = 0.01

Table 13: The mean squares for the analysis of variance for population Q at Thika.

Trait	Mean squares				
	Replications within seasons	Sesons	Family	Family x season interraction	Error
df	4	1	19	19	76
Days to flowering	36.471	7634.627**	7.638	7.587	7.848
Plant height	202.170	13784.848**	57.591	64.845	46.995
Number of leaves	31.864	50.078	2.667	5.016	3.479
Leaf length	4.197	102.047**	0.417	0.390	0.326
Leaf breadth	4.283	29.008	1.009	0.749	0.967
Fresh leaf weight	394.331	1033.648	47.181	31.551	43.782
Dry leaf weight	4.667	12.352	0.245	0.224	0.216

** Significant at P = 0.01

Table 14: The components of variation, heritability estimates, expected gain as percent of the mean and C.V. in Population Q at Thika.

Trait	σ_p^{2*}	σ_g^{2*}	h^{2*}	Expected % gain	Coefficeint of variation
Days to flowering	1.317	0.009	0.007	0.032	6.26
Plant height	10.808	0.000	0.000	0.000	18.60
Number of leaves	0.836	0.000	0.000	0.000	19.14
Leaf length	0.070	0.005	0.071	0.771	12.51
Leaf breadth	0.204	0.043	0.211	8.935	47.52
Fresh leaf weight	9.902	2.605	0.263	25.449	75.04
Dry leaf weight	0.042	0.004	0.095	3.084	32.73

* σ_p^2, σ_g^2 and h^2 represent, phenotypic variance, genotypic variance and heritability estimate respectively.

and number of leaves to 0.263 for fresh leaf weight due to lack of significant genetic variation. The expected percentage gain from selection were generally low for all the traits except fresh leaf weight which had a value of 25.449 percent. High coefficient of variation values o f 47.52 percent, 75.04 percent and 32.73 percent were obtained for leaf breadth, fresh leaf weight and dry leaf weight respectively.

Variation analysis results at Kabete also gave no significant difference among families for all the traits studied (Table 15). High coefficient of variation values of 25.84 percent and 22.90 percent were obtained for fresh leaf weight and dry leaf weight respectively.

4.1.2.4 Variation in population D.

Variation analysis results for population D at Thika detected no significant difference among families for all the traits studied (Table 16). Variation due to seasonal differences was significant for days to flowering and leaf length only. Family x season interaction was not significant for any of the characters studied. The components of variation, heritability estimates, expected percentage gain from selection and coefficient of variation values for this population at Thika are presented in Table 17. The heritability values and

Table 15: The mean squares for the analysis of variance for population C

Trait	Replications	Families
Days to flowering	13.151**	0.356
Plant height	131.768**	11.918
Number of leaves	4.097	1.769
Leaf length	1.139**	0.310
Leaf breadth	0.034	0.153
Fresh leaf weight	9.482**	3.283
Dry leaf weight	0.114	0.105

**Significant at P = 0.01.

Table 16: The mean squares for the analysis of variance for population D at Thika.

Trait	Mean squares				
	Replications within seasons	Seasons	Family	Family x season	Error
	df 4	1	19	19	76
Days to flowering	41.181	8138.980**	9.494	7.898	6.335
Plant height	148.775	337.614	30.931	26.234	36.550
Number of leaves	6.217	0.112	2.003	0.728	1.907
Leaf length	3.764	45.141*	0.184	0.207	0.382
Leaf breadth	0.923	5.651	0.032	0.073	0.076
Fresh leaf weight	50.529	0.335	9.775	17.771	13.666
Dry leaf weight	0.497	0.077	0.174	0.242	0.274

*Significant at P = 0.05
**Significant at P = 0.01.

Table 17: The components of variation, heritability estimates, expected gain as a percent of the mean and coefficient of variation in population D at Thika.

Trait	σ_p^2*	σ_g^2*	h^2*	Expected % gain	Coefficient of variation
Days to flowering	1.582	0.266	0.168	0.825	5.59
Plant height	6.875	0.783	0.114	2.194	19.87
Number of leaves	0.531	0.213	0.401	5.403	14.57
Leaf length	0.064	0.000	0.000	0.000	13.68
Leaf breadth	0.013	0.000	0.000	0.000	14.45
Fresh leaf weight	2.962	0.000	0.000	0.000	52,38
Dry leaf weight	0.046	0.000	0.000	0.000	41.95

* σ_p^2 , σ_g^2 and h^2 respresent, phenotypic variance, genotypic variance and heritability estimate respectively.

expected percentage gain were generally low due to the lack of significant genetic variation. The coefficients of variation were relatively high for fresh leaf weight and dry leaf weight with values of 52.38 percent and 41.95 percent respectively.

The analysis of variance at Kabete also revealed no significant difference among families for all traits studied (Table 18). However, the coefficients of variation were fairly high for number of leaves, fresh leaf weight and dry leaf weight with values of 24.98 percent, 36.27 percent and 33.89 percent respectively.

4.1.2.5 Variation in population M.

Variation analysis at Thika for population M detected significant difference among families for fresh leaf weight and dry leaf weight (Table 19). Variation due to seasonal differences was significant for days to flowering and dry leaf weight. There was no significant variation due to family x season interaction for all the characters studied. The components of variation, heritability estimates, expected percentage gain from selection and coefficient of variation values for population M at Thika are presented in Table 20. Heritability estimates ranged from 0.000 for plant height and leaf length to 0.411 for days to flowering. The

Table 18:The mean squares for the analysis of variance for population D at Kabete.

Trait	Replications	Families	Error	Coefficient of variation
	df 2	19	38	
Days to flowering	40.073**	3.443	4.050	5.51
Plant height	501.868**	37.728	32.917	12.22
Number of leaves	1.318	10.733	10.243	24.98
Leaf length	0.843	0.470	0.387	12.46
Leaf breadth	0.366**	0.116	0.051	11.58
Fresh leaf weight	55.021*	11.566	11.347	36.27
Dry leaf weight	1.348**	0.287	0.262	33.89

* Significant at P = 0.05

** Significant at P = 0.01.

Table 19: The mean squares for the analysis of variance for population M at Thika.

Trait	Mean squares				
	Replication within season	Season	Family	Family x season interaction	Error
	df 4	1	19	19	76
Days to flowering	24.480	8497.467**	9.113	4.783	6.207
Plant height	138.072	267.712	15.233	26.230	27.932
Number of leaves	34.108	19.368	3.159	1.807	3.476
Plant length	0.676	2.346	0.586	0.646	0.377
Leaf breadth	0.240	0.075	0.121	0.073	0.059
Fresh leaf weight	24.137	80.001	11.580*	8.161	5.782
Dry leaf weight	0.172	2.083*	0.232**	0.148	0.099

* Significant at P = 0.05
**Significant at p = 0.01.

Table 20: The components of variation, heritability estimates, expected gain as percent of the mean and C.V in Population M at Thika.

Trait	σ_p^{2} *	σ_g^{2}*	h^{2} *	Expected % gain	Coefficient of variation
Days to flowering	1.757	0.722	0.411	2.129	5.53
Plant height	4.655	0.000	0.000	0.000	17.93
Number of leaves	0.804	0.225	0.280	4.662	18.58
Leaf length	0.108	0.000	0.000	0.000	14.51
Leaf breadth	0.020	0.008	0.400	5.105	13.57
Fresh leaf weight	1.930	0.570	0.295	14.749	49.20
Dry leaf weight	0.039	0.014	0.359	10.607	30.00

* σ_p^2 ,σ_g^2 and h^2 represent, phenotypic variance, genotypic variance and heritability estimate respectively.

expected gain from selection were relatively high for fresh leaf weight and dry leaf weight with values of 14.749 percent and 10.607 percent respectively. The coefficients of variation were also high for these traits with values of 49.20 percent and 30.00 percent respectively.

The analysis of variance at Kabete detected no significant difference among families for all traits except days to flowering (Table 21). High coefficients of variation were observed for number of leaves, fresh leaf weight and dry leaf weight with values of 30.42 percent, 42.73 percent and 34.60 percent respectively.

4.1.2.6 Variation in population I.

Variation analysis results for population I at Thika revealed no significant difference among families or due to family x season interaction for all the traits studied (Table 22). All the traits had significant variation due to seasonal differences except number of leaves and fresh leaf weight. The estimates of genetic variance components and heritability values for population I at Thika in Table 23 indicate that all the traits had low heritability estimates due to the lack of significant genetic variation. High coefficients of variation were observed, for fresh leaf weight and dry leaf weight with values of 47.32 percent and 34.18 percent respectively.

Table 21: The mean squares for the analysis of variance for population M at Kabete.

Trait	Mean squares			Coefficient of variation
	Replications df 2	Families 19	Error 38	
Days to flowering	6.529	10.026*	4.819	6.00
Plant height	63.479	139.500	81.119	19.49
Number of leaves	18.558	8.424	16.762	30.42
Leaf length	5.446**	0.801	0.458	12.78
Leaf breadth	1.049**	0.110	0.082	13.62
Fresh leaf weight	359.674**	21.489	23.757	42.73
Dry leaf weight	3.112*	0.349	0.333	34.60

* Significant at P = 0.05

** Significant at P = 0.01

Table 22: The mean squares for the analysis of variance for population I at Thika.

	Mean squares				
	Replications within seasons	Season	Family	FamilyxSeason	Error
df	4	1	19	19	76
Days to flowering	7.186	7717.004**	4.046	4.495	6.611
Plant height	43.890	781.933*	18.824	15.544	31.158
Number of leaves	11.789	18.299	1.313	1.728	1.416
Leaf length	0.134	76.592**	0.209	0.135	0.155
Leaf breadth	0.087	11.501**	0.059	0.055	0.052
Fresh leaf weight	13.689	71.185	6.194	7.384	6.127
Dry leaf weight	0.106	2.225**	0.075	0.112	0.124

* Significant at P = 0.05

**Significant at P = 0.01

Table 23: The components of variation, heritability estimates expected gain as a percent of the mean and C.V in population I at Thika.

Trait	σ_p^{2*}	σ_g^{2*}	h^{2*}	Expected % gain	Coefficient of variation
Days to flowering	1.102	0.000	0.000	0.000	5.79
Plant height	5.740	0.547	0.095	1.349	18.08
Number of leaves	0.236	0.000	0.000	0.000	12.32
Leaf length	0.038	0.012	0.316	2.786	9.38
Leaf breadth	0.010	0.001	0.100	1.058	12.60
Fresh leaf weight	0.210	0.000	0.000	0.000	47.32
Dry leaf weight	0.021	0.000	0.000	0.000	34.18

* σ_p^2 , σ_g^2 and h^2 represent phenotypic variacne, genotypic variance and heritability estimate respectively.

The other characters had low to medium coefficient of variation values of generally less than 20.00 percent.

The analysis of variance at Kabete also detected no significant difference among families for all the characters (Table 24). High coefficients of variation were observed for number of leaves, fresh leaf weight and dry leaf weight with values of 27.60 percent, 45.17 percent and 35.02 percent respectively.

4.2 Phenotypic correlation and multiple linear regression analyses.

4.2.1 Correlation and multiple linear regression analysis in population E.

Table 25 shows that number ofleaves had the strongest association with dry leaf weight at Thika and Kabete for all the seasons. Leaf length and fresh leaf weight also had positive significant association with dry leaf weight during all the seasons at both sites. The other character associations during the 1988 season at Thika ranged from 0.015 for the correlation between plant height and dry leaf weight to 0.672 for the correlation between leaf breadth and fresh leaf weight. During the 1989 season at Thika, all the other character associations

Table 24: The mean squares for the analysis of variance for population I at Kabete.

	Mean squares			
	Replications	Families	Error	Coefficient of variation
Trait	df 2	19	38	
Days to flowering	18.600*	5.404	4.525	5.90
Plant height	327.860*	70.202	60.202	17.62
Number of leaves	220.926**	23.694	18.351	27.60
Leaf length	9.010**	0.461	0.699	15.44
Leaf breadth	1.247**	0.090	0.128	15.82
Fresh leaf weight	176.282**	31.722	24.603	45.17
Dry leaf weight	2.732	0.463	0.324	35.02

* Significant at P = 0.05

**Significant at P = 0.01

Table 25: Phenotypic correlation for population E at Thika 1988 and 1989 (lower half) and at Kabete 1989 (upper half)

Trait	1	2	3	4	5	6	7
1. Days to flowering		-0.170^{NS}	-0.023^{NS}	-0.031^{NS}	-0.151^{NS}	0.091^{NS}	0.052^{NS}
2. Plant height	a 0.271 b 0.870		0.015^{NS}	0.191^{NS}	0.456	0.002^{NS}	0.034^{NS}
3. Number of leaves	a 0.177^{NS} b 0.563	0.022^{NS} 0.702		0.311	0.317	0.777	0.938
4. Leaf length	a 0.226^{NS} b 0.540	0.348 0.656	0.385 0.677		0.592	0.304	0.366
5. Leaf breadth	a-0.082^{NS} b-0.534	0.122^{NS} 0.596	0.187^{NS} 0.651	0.206^{NS} 0.829		0.375	0.390
6. Fresh leaf weight	a-0.329 b 0.605	-0.234^{NS} 0.707	0.331 0.946	0.155^{NS} 0.720	0.672 0.723		0.845
7. Dry leaf weight	a 0.216^{NS} b 0.617	0.015^{NS} 0.724	0.974 0.976	0.485 0.719	0.147^{NS} 0.708	0.315 0.968	

a and b are for Thika, short rains (1988) and Thika long rains (1989) respectively.

NS = not significant, P = 0.05.

were positive and significant. The remaining character associations during the 1989 season at Kabete ranged from 0.002 for the correlation between plant height and fresh leaf weight to 0.777 for the association between number of leaves and fresh leaf weight.

The multiple linear regression analysis results also identified the number of leaves as the only trait having significant contribution to dry leaf weight at Thika and Kabete for all the seasons (Table 26). Leaf length had a significant contribution to dry leaf weight during the 1988 season at Thika. Fresh leaf weight had a significant contribution to dry leaf weight at both sites except during the 1988 season at Thika.

4.2.2 Correlation and multiple linear regression analysis in population P.

The phenotypic correlation results presented in Table 27 indicate that number of leaves had strong associations with both fresh leaf weight and dry leaf weight at both sites. During the 1988 season at Thika, days to flowering had weak negative association with number of leaves, leaf breadth and dry leaf weight. It had a significant positive association with plant height ($r = 0.548$) and a significant negative association with fresh leaf weight ($r = -0.362$).

Table 26: The multiple linear regression analysis results for populations E and P at Thika and Kabete.

High		POPULATION E			POPULATION P		
		Estimate	S.E.	t	Estimate	S.E.	t
1. Days to flowering	a	0.004	0.003	1.521	-0.009	0.007	-1.404
	b	0.019	0.011	1.794	-0.048	0.013	-3.691**
	c	0.020	0.014	1.369	-0.091	0.015	-5.972**
2. Plant height	a	-0.002	0.001	-1.753	0.007	0.005	1.297
	b	-0.003	0.003	-0.901	0.009	0.003	2.767**
	c	0.000	0.003	0.025	0.003	0.008	0.388
3. Number of leaves	a	0.213	0.007	31.818**	0.183	0.016	11.564**
	b	0.277	0.032	8.558**	0.080	0.007	11.418**
	c	0.129	0.011	11.460**	0.086	0.049	11.752**
4. Leaf length	a	0.078	0.015	5.261**	0.070	0.080	0.875
	b	0.020	0.032	0.643	0.105	0.042	2.486**
	c	0.015	0.022	0.709	-0.005	0.014	-0.388
5. Leaf breadth	a	-0.065	0.033	-1.979	-0.050	0.187	-0.266
	b	0.060	0.076	0.786	-0.238	0.075	-3.188**
	c	0.083	0.083	0.991	0.053	0.042	1.272
6. Fresh leaf weight	a	0.006	0.006	0.983	0.042	0.015	2.848**
	b	0.040	0.009	4.531**	0.051	0.010	5.309**
	c	0.035	0.009	3.961**	0.085	0.010	8.534**

** Significant, P = 0.01	POPULATION E		POPULATION P	
	a intercept= -1.338	R - square=0.969	a intercept= -0.753	R - Square= 0.885
	b intercept = -2.061	R - square =0.975	b intercept= 1.203	R - Square= 0.967
	c intercept = -1.361	R - square =0.922	c intercept= 3.366	R - square= 0.877

a, b, and c represent results for Thika short rains (1988), Thika long rains (1989) and Kabete long rains (1988) respectively.

Table 27: Phenotypic correlations for population P at Thika 1988 and 1989 (lower half) and at Kabete 1989 (upper half)

Trait	1	2	3	4	5	6	7
1. Days to flowering		0.469	0.317	0.100^{NS}	0.089^{NS}	0.425	0.087^{NS}
2. Plant height	a 0.548 b 0.949		0.647	0.364	0.364	0.711	0.590
3. Number of leaves	a-0.155^{NS} b 0.680	0.204^{NS} 0.694		0.489	0.567	0.811	0.784
4. Leaf length	a 0.313 b 0.765	0.646 0.677	0.323 0.690		0.338	0.572	0.540
5. Leaf breadth	a-0.102^{NS} b 0.613	0.366 0.601	0.418 0.604	0.747 0.893		0.492	0.552
6. Fresh leaf weight	a-0.362 b 0.749	0.031^{NS} 0.733	0.630 0.876	0.400 0.854	0.652 0.796		0.872
7. Dry leaf weight	a-0.208^{NS} b 0.662	0.239^{NS} 0.693	0.912 0.964	0.418 0.752	0.529 0.638	0.734 0.917	

a and b are for Thika short rains (1988) and Thika long rains (1989) respectively

NS = not significant, P = 0.05.

Plant height had weak positive association with number of leaves, fresh leaf weight and dry leaf weight during the same season. All the other character associations were positive and significant. During the 1989 season at Thika, there was positive and significant association among all the characters. Days to flowering had weak positive association with leaf length (r = 0.100), leaf breadth (r = 0.089) and dry leaf weight (r = 0.087) during the 1989 season at Kabete. The other character associations were positive and significant.

Multiple linear regression analysis revealed fresh leaf weight as having a consistent significant contribution to dry leaf weight at both sites (Table 26). Days to flowering was important during the 1989 season at Kabete and Thika. Plant height, leaf length and leaf breadth contributed significantly to dry leaf weight during the 1989 season at Thika. Number of leaves was important for the dry leaf yield at Thika for both seasons.

4.2.3 Correlation and multiple linear regression analysis in population Q.

Number of leaves had the strongest correlation with dry leaf weight in population Q during all the seasons at both sites (Table 28). Days to flowering had

Table 28: Phenotypic correlations for population Q at Thika 1988 and 1989 (lower half) and at Kabete 1989 (upper half)

Trait	1	2	3	4	5	6	7
1. Days to flowering		-0.360	-0.111^{NS}	0.130^{NS}	0.046^{NS}	0.307	-0.080^{NS}
2. Plant height	a 0.361 b 0.624		0.099^{NS}	-0.043^{NS}	0.120^{NS}	-0.082^{NS}	0.139^{NS}
3. Number of leaves	a 0.322^{NS} b 0.087	0.190^{NS} 0.120^{NS}		0.674	0.572	0.695	0.965
4. Leaf length	a 0.064^{NS} b 0.264	0.443 0.255	0.414 0.715		0.640	0.735	0.727
5. Leaf breadth	a-0.099^{NS} b 0.062^{NS}	-0.098^{NS} 0.062^{NS}	0.181^{NS} 0.685	0.233^{NS} 0.817		0.509	0.581
6. Fresh leaf weight	a-0.182^{NS} b 0.065^{NS}	-0.111^{NS} 0.074^{NS}	0.355 0.869	0.392 0.793	0.309 0.728		0.744
7. Dry leaf weight	a 0.318$_{NS}$ b 0.097^{NS}	0.204^{NS} 0.128^{NS}	0.991 0.942	0.427 0.778	0.172^{NS} 0.734	0.382 0.932	-

a and b are for Thika short rains (1988) and Thika long rains (1989) respectively.

NS = not significant, P = 0.05.

weak association with all characters except plant height (r = 0.361) number of leaves (r = 0.322) and dry leaf weight (r = 0.318) during the 1988 season at Thika. Plant height also had low non-significant correlation with all characters except leaf length (r = 0.443) and days to flowering (r = 0.361). Apart from the non-significant associations between leaf breadth and number of leaves (r = 0.181), leaf breadth and leaf length (r = 0.233) and leaf breadth and dry leaf weight (r = 0.172), all the other character associations during the 1988 season at Thika were positive and significant. During the 1989 season at Thika, days to flowering had low non-significant correlation with all characters except plant height (r = 0.624) and leaf length (r = 0.264). Plant height also had weak non-significant association with all characters except leaf length (r = 0.255) and days to flowering (r = 0.624). The other character associations during 1989 season at Thika were positive and significant. During the 1989 season at Kabete, days to flowering had weak non-significant correlations with all characters except plant height (r = -0.360) and fresh leaf weight (r = 0.307). Plant height also had low non-significant association with all traits except days to flowering (r = -0.360). The other character associations were positive and significant.

Table 29: The multiple linear regression analysis results for population Q and D at Thika and Kabete

Trait		Population Q			Population D		
		Estimate	S.E.	t	Estimate	S.E.	t
1. Days to flowering	a	0.000	0.002	0.182	0.001	0.011	-0.098
	b	-0.017	0.026	-0.642	0.006	0.018	0.299
	c	-0.005	0.012	-0.408	0.000	0.007	0.046
2. Plant height	a	0.001	0.001	0.980	-0.005	0.007	-0.757
	b	0.007	0.008	0.855	0.003	0.006	0.542
	c	0.003	0.002	2.146*	0.003	0.002	1.062
3. Number of leaves	a	0.291	0.006	46.203**	0.408	0.033	12.540**
	b	0.126	0.017	7.538**	0.104	0.016	6.682**
	c	0.178	0.011	15.677**	0.280	0.016	17.020**
4. Leaf length	a	0.001	0.016	0.060	0.024	0.097	0.246
	b	0.031	0.063	0.489	0.065	0.052	1.253
	c	0.067	0.030	2.200*	0.023	0.033	0.668
5. Leaf breadth	a	-0.003	0.003	-0.821	-0.083	0.200	-0.412
	b	0.066	0.094	0.702	-0.229	0.113	-2.029*
	c	0.031	0.051	-0.597	-0.049	0.055	-0.894
6. Fresh leaf weight	a	0.006	0.003	2.058*	0.013	0.008	1.484
	b	0.044	0.082	5.332**	0.054	0.148	3.682**
	c	0.021	0.010	2.161*	0.006	0.006	1.057

* Significant at P = 0.05
** Significant at P = 0.01

POPULATION Q

a Intercept = -1.611 R - square = 0.985
b Intercept = 0.198 R - square = 0.942
c Intercept = -1.109 R - square = 0.951

POPULATION D

a Intercept = -2.569 R - square = 0.885
b Intercept = -0.506 R - square = 0.939
c Intercept = -1.523 R - square = 0.970

a, b and c represent results for Thika short rains (1988) Thika long rains (1989) and Kabete long rains (1989) respectively.

Table 30: Phenotypic correlations for population D at Thika 1988 and 1989 (lower half) and at Kabete 1989 (upper half).

Trait	1	2	3	4	5	6	7
1. Days to flowering		0.180^{NS}	0.055^{NS}	0.193^{NS}	0.239^{NS}	0.513	0.088^{NS}
2. Plant height	a 0.459 b 0.887		0.577	0.599	0.559	0.568	0.597
3. Number of leaves	a-0.034^{NS} b 0.346	0.351 0.431		0.808	0.772	0.782	0.983
4. Leaf length	a 0.239^{NS} b 0.067^{NS}	0.485$_{NS}$ 0.072^{NS}	0.615 0.416		0.910	0.793	0.810
5. Leaf breadth	a-0.080^{NS} b 0.059^{NS}	0.138^{NS} 0.097^{NS}	0.631 0.391	0.760 0.823		0.785	0.766
6. Fresh leaf weight	a 0.135^{NS} b 0.253	0.022^{NS} 0.357	0.523 0.918	0.472 0.546	0.431 0.509		0.797
7. Dry leaf weight	a-0.040^{NS} b 0.362	0.274^{NS} 0.450	0.936 0.957	0.575 0.436	0.592 0.373	0.564 0.927	-

a and b are for Thika short rains (1988) and Thika long rains (1989) respectively.

NS = not significant, P = 0.05.

characters except fresh leaf weight (r = 0.513). The other character associations were positive and significant.

Multiple linear regression identified number of leaves as having a consistent significant contribution to dry leaf weight at both sites (Table 29). Leaf breadth and fresh leaf weight were only important during the 1989 season at Thika.

4.2.5 Correlation and multiple linear regression analysis in population M.

Correlation analysis results in population M indicate that number of leaves had the strongest association with dry leaf weight during all the seasons at both sites (Table 31). During the 1988 season at Thika, days to flowering had weak association with all characters. Plant height also had low non-significant association with all characters except dry leaf weight (r = 0.342). The other character associations were positive and significant. During the 1989 season at Thika, days to flowering had significant positive association with all characters except fresh leaf weight (r = 0.190). Plant height had low non-significant correlation with number of leaves (r = 0.230), fresh leaf weight (r = 0.166) and dry leaf weight (r = 0.236). The other character associations were positive and significant.

Table 31: Phenotypic correlations for population M at Thika 1988 and 1989 (lower half) and at Kabete 1989 (upper half)

Trait		1	2	3	4	5	6	7
1. Days to flowering			-0.264	-0.179^{NS}	0.046^{NS}	0.130^{NS}	0.005^{NS}	-0.163^{NS}
2. Plant height	a	-0.108^{NS}		0.358	0.219^{NS}	-0.027^{NS}	0.299	0.447
	b	0.607						
3. Number of leaves	a	-0.040^{NS}	-0.181^{NS}		0.587	0.287	0.770	0.898
	b	0.257	0.230^{NS}					
4. Leaf length	a	0.127^{NS}	-0.001^{NS}	0.286		0.689	0.592	0.662
	b	0.371	0.414	0.741				
5. Leaf breadth	a	-0.022^{NS}	0.140^{NS}	0.350	0.612		0.370	0.351
	b	0.273	0.318	0.663	0.875			
6. Fresh leaf weight	a	-0.138^{NS}	-0.027^{NS}	0.600	0.303	0.402		0.787
	b	0.190^{NS}	0.166^{NS}	0.890	0.717	0.690		
7. Dry leaf weight	a	0.053^{NS}	0.342^{NS}	0.941	0.709	0.510	0.848	-
	b	0.269	0.236^{NS}	0.985	0.756	0.669	0.907	

a and b represent Thika short rains (1988) and Thika long rains (1989) respectively.

NS = not significant, P = 0.05.

Correlation results during the 1989 season at Kabete indicate that days to flowering had low non-significant association with all traits except plant height (r = -0.264). Apart from the association between plant height and leaf length (r = 0.219) and between plant height and leaf breadth (r = -0.027), the other character associations were positive and significant.

According to multiple linear regression analysis in Table 32, number of leaves had a significant contribution to dry leaf weight during all the seasons at both sites. Leaf length was important during the 1989 season at Kabete while fresh leaf weight contributed significantly to dry leaf weight during 1989 season at Thika and Kabete.

4.2.6 Correlation and multiple linear regression analysis in population I.

Correlation results for population I revealed that days to flowering had low non-significant correlation with all characters except plant height (r = 0.262) during 1988 season at Thika (Table 33). Plant height had non-significant association with both leaf breadth (r = 0.076) and fresh leaf weight (r = 0.052). Number of leaves had non-significant association with leaf breadth (r = 0.189). The other character associations were positive and significant. During the 1989 season at Thika, all the

Table 32: The multiple linear regression analysis results for populations M and I at Thika and Kabete.

Trait		Population M			Population I		
		Estimate	S.E.	t	Estimate	S.E.	t
1. Days to flowering	a	-0.048	0.193	-0.247	0.000	0.010	-0.033
	b	-0.012	0.013	0.953	-0.017	0.014	-1.206
	c	-0.007	0.014	-0.515	0.004	0.007	0.560
2. Plant height	a	0.000	0.004	-0.043	0.010	0.007	1.480
	b	0.003	0.003	-0.758	0.004	0.004	0.998
	c	0.007	0.003	2.286*	-0.001	0.003	-0.521
3. Number of leaves	a	0.105	0.010	11.736**	0.077	0.016	4.685**
	b	0.143	0.009	16.605**	0.105	0.005	20.463**
	c	0.066	0.010	6.866**	0.208	0.011	18.938**
4. Leaf length	a	-0.483	1.559	-0.310	0.049	0.107	0.459
	b	0.065	0.039	1.675	-0.005	0.030	-0.176
	c	0.093	0.046	2.003*	-0.031	0.031	-1.001
5. Leaf breadth	a	-4.409	4.241	-1.040	0.069	0.134	0.459
	b	0.099	0.083	-1.186	0.124	0.067	1.833
	c	-0.002	0.081	-0.019	0.074	0.073	1.018
6. Fresh leaf weight	a	0.111	0.365	3.303**	0.070	0.013	5.440**
	b	0.017	0.005	3.050**	0.019	0.004	4.491**
	c	0.028	0.013	2.105*	0.004	0.006	0.667

	POPULATION M		POPULATION I	
* Significant at P = 0.05	a Intercept = 13.513	R - square = 0.459	a Intercept = -0.699	R - square = 0.712
**Significant at P = 0.01	b Intercept = -0.940	R - square = 0.977	b Intercept = -0.059	R - square = 0.984
	c Intercept = -0.236	R - square = 0.848	c Intercept = -0.886	R - square = 0.933

a,b, and c represent results for Thiks short rains (1988), Thika long rains (1989) and Kabete long rains (1989) respectively.

Table 33: Phenotypic correlations for population I at Thika 1988 and 1989 (lower half) and at Kabete 1989 (upper half)

Trait		1	2	3	4	5	6	7
1. Days to flowering			0.197^{NS}	-0.064^{NS}	-0.089^{NS}	-0.129^{NS}	0.248^{NS}	-0.036^{NS}
2. Plant height	a	-0.262		0.240^{NS}	0.432	0.342	0.348	0.218^{NS}
	b	0.635						
3. Number of leaves	a	-0.106^{NS}	0.415		0.590	0.578	0.605	0.964
	b	0.369	0.409					
4. Leaf length	a	0.229^{NS}	0.438	0.362		0.756	0.517	0.554
	b	0.497	0.557	0.758				
5. Leaf breadth	a	-0.204^{NS}	0.076^{NS}	0.189^{NS}	0.306		0.580	0.574
	b	0.448	0.524	0.724	0.893			
6. Fresh leaf weight	a	-0.085^{NS}	0.052^{NS}	0.353	0.348	0.472		0.612
	b	0.411	0.441	0.871	0.725	0.686		
7. Dry leaf weight	a	-0.054^{NS}	0.358	0.679	0.440	0.382	0.687	
	b	0.379	0.429	0.987	0.780	0.756	0.902	-

a and b are for Thika short rains (1988) and Thika long rains (1989) respectively.

NS = not significant, P = 0.05.

other character associations were positive and significant. There was no significant correlation between days to flowering and the other characters during the 1989 season at Kabete. Plant height also had no significant association with all the characters except leaf length (r = 0.432), leaf breadth (r = 0.342) and fresh leaf weight (r = 0.348). The other character associations were positive and signif cant.

Multiple regression analysis results identified number of leaves as having a consistent significant contribution to dry leaf weight (Table 32). Fresh leaf weight was important during the 1988 season and 1989 season at Thika.

DISCUSSION

5.1 Variation among populations.

Variation analysis results at Thika detected no significant difference among the populations for all traits except leaf length and dry leaf weight (Table 4). Duncan's multiple range test for leaf length revealed that population I had significantly shorter leaves than populations D and M (Table 6). However, the mean leaf lengths of populations E, P and Q were not significantly different from the two groups. Populations D, E, P, Q and M were collected from the high rainfall parts of Western Kenya. Population I was obtained from the hot, semi-arid Kibwezi area in Eastern Kenya. Therefore population I might have been adapted to shorter growing periods which is often accompanied by lower biomass production. Under conditions of high irradiation, Donald (1968) found that plants with shorter leaves perform better than those with longer leaves. This was in consideration of the fact that shorter leaves tend to be erect thus trapping more light and resulting in faster growth rate. Smaller leaves also permit closer spacing thus increasing yield per unit area. Dry leaf yield of population I was also significantly lower than the dry leaf yield of populations E, P, D and M as indicated by Duncan's multiple range test. The lower yields of population I could be attributed to lower

genetic yield potential or to its adaptation to poor ecological conditions of Eastern Kenya that made it lack the potential to exploit favourable growth conditions. Owing to the significant positive association between leaf length and dry leaf weight (Table 31), the shorter leaves in population I, may have resulted in lower dry leaf yield. Paroda et al. (1975) reached a similar conclusion after finding a significant positive association between leaf length and dry matter yield of forage sorghum. Population Q did not yield significantly different from either population I or the other Western populations. This overlap is an indication that population Q might have lacked the genetic diversity possessed by the other Western populations that differentiated them from population I. The environment might have also influenced the dry leaf yield of population Q. Variation analysis data support the latter conclusion because of the significant population x season interaction and the high coefficient of variation values of 93.803 percent and 51.469 percent for fresh leaf weight and dry leaf weight respectively. Yield is often highly influenced by the environment. Evans (1983) pointed out that the yield determining factors are interrelated, hence, the full expression of the genetic yield potential of a population is dependent upon favourable conditions and good agronomic practices.

The results at Kabete revealed no significant difference among populations for all traits except the number of leaves. The favourable climate at Kabete (Appendix 1) might have provided good growth conditions for all the populations thus making it difficult to detect differences in other traits. Duncan's multiple range test revealed that the number of leaves for populations D, M and I were significantly higher than populations E, P and Q. Although number of leaves had strong positive associations with fresh leaf weight and dry leaf weight in populations D, M and I (Tables 30, 31 and 33), the greater number of leaves did not result in a significantly high fresh leaf yield or dry leaf yield in these populations. Donald (1968) attributed this anomaly to the consideration that greater number of leaves only increase yield if each additional leaf permits a more complete exploitation of the environment. For example, additional leaves may shade lower leaves and lead to their early senescence and defoliation. These results indicate that, variation among populations for number of leaves, leaf length and dry leaf weight varied depending upon the environments where they were evaluated. Under Thika conditions, population I had shorter leaves and reduced leaf yield than the Western populations. At Kabete population I had the highest number of leaves per plant than populations E, P, Q, D and M. Therefore a wider range of environments would have been

ideal for their evaluation. Lack of significant variation among the populations for the other traits suggest that the populations were probably having similar sets of genes influencing those traits.

5.2 Variation within the populations.

The six populations of spiderflower used in the study showed a lot of variability especially for plant pigmentation. However the S_1 analysis only revealed limited genetic variation for the morphological traits studied. For example, the experiment at Thika revealed significant genetic variation for days to flowering in population E and for fresh leaf weight and dry leaf weight in population M (Tables 7 and 19). The analysis at Kabete revealed significant genetic variation for days to flowering in population M (Table 21). The remaining traits and populations had no significant genetic variation. The failure to detect genetic variation may be due in part to the presence of genetic linkages. Eckebil *et al.* (1977) found out that coupling-phase linkages were responsible for the low genetic variances for yield, plant height and days to bloom in grain sorghum. Hallauer and Miranda (1981) also singled out linkages as a possible source of biasing estimates of components of variance. The presence of dominance is another possible source of bias when using S_1 progeny means in the estimation of variance components. Eckebil *et al* (1977) found out that biases in either

direction may occur if dominance is involved in the genes controlling the quantitative trait. The magnitude and direction of the bias depends upon the gene frequencies and the degree of dominance. The presence of negative estimates were also interpreted to mean the absence of genetic variance. Searle (1971) suggested that competition among progenies, inadequate sampling and inadequate models were possible sources of this occurrence. The S_1 family testing is an adequate model if dominance is not an important genetic component. This model was used successfully by Dogget (1972) to improve an African population of sorghum with a progress of 25 percent increase over the base population after three cycles of selection. In the presence of dominance, designs which require less restrictions like North Carolina design I, half diallel, North Carolina design II, partial diallel among others might be more appropriate. The negative estimates may have also arisen due to competition among progenies, inadequate sampling or lack of adequate local control of the experimental error by the field design. Hallauer and Miranda (1981) estimated an adequate sample size to contain about 196 families entered in a 14 x 14 lattice field design. The populations might also have lacked the intrinsic genetic variability. Therefore the observed phenotypic variation might have arisen due to environmental influence. This is in support of the observation that the coefficients of variation for all

traits except days to flowering were either intermediate (10-20 percent) or high (more than 20 percent). High coefficient of variation with little or no genetic variation implies that the environment plays a major role in the expression of a character. Environmental effect, however, is not genetically fixable. The improvement of these populations cannot be based on variation analysis alone.

5.3 Correlations, multiple linear regression and yield prediction.

Correlation results for population E indicated that all traits had a positive association with dry leaf weight at both sites (Table 25). The association between days to flowering and dry leaf weight was significant during the long rains of 1989 at Thika but non-significant during the short rains of 1988 at Kabete and Thika. Therefore selection in favour of late flowering genotypes when moisture is not limiting would increase the duration of vegetative growth and thus increase the leaf yield per plant. Under short moisture regimes, the plants tend to enter the reproductive phase early, hence the duration of vegetative growth is not significantly prolonged. Variation analysis in Table 7 revealed a significant genetic variation for days to flowering in population E. The trait had a high heritability estimate of 0.617, an expected gain of 4.330 percent and low coefficient of

variation value of 6.01 percent (Table 8). This suggests that the inheritance of days to flowering was mainly conditioned by genetic effects. It was suggested by Moll et al (1962), Johnson et al (1966), Paroda and Joshi (1970) and Grafius and Okoli (1974) that improvement of yield when it has a low heritability value can be undertaken by indirect selection via the yield components which have higher heritability values. Therefore the yield of population E can be improved by indirect selection based on days to flowering. Number of leaves had the strongest association with dry leaf weight of population E at both sites. Multiple regression analysis results in Table 26 also identified number of leaves as having a significant contribution to dry leaf weight in support of the correlation results. However, there was no significant genetic variation for number of leaves (Table 7) hence it was not important in the improvement of vegetative yield in population E. Lack of adequate genetic variability and low heritability values for the other traits rendered them unsuitable for yield improvement in population E.

Phenotypic correlation results for populations P, Q, D and I revealed a strong positive association between number of leaves and both fresh leaf weight and dry leaf weight (Tables 27, 28, 30 and 33). Multiple regression analysis results also revealed a significant contribution of number of leaves to dry leaf yield for these populations except during the 1989 season at Kabete for

population P (Tables 26, 29 and 32). These results agree with the findings of Dangi and Paroda (1974) and Sastri (1974). Their studies reported a preponderant effect of number of leaves on leaf yield of fodder cowpeas and natu tobacco respectively. With the exception of days to flowering, all the other traits had positive association with dry leaf weight in populations P, Q, D and I for all the seasons at both sites. However, in the initial phase of a selection programme, an evaluation procedure to determine suitable populations for further improvement is usually necessary. Those populations which lack fixable genetic variation can only be improved by creating more variability. Variation analysis for populations P, Q, D and I did not detect any significant genetic variation for all traits studied (Tables 10, 12, 13, 15, 16, 18, 22 and 24). The heritability values and expected gain from selection were also low (Tables 11, 14, 17 and 23). Therefore, for further improvement of these populations there would be need to incorporate genes from other populations by crossing. This procedure widens the genetic base of the crossed population by introducing a wide range of gene action and interaction.

In population M, the strongest association was noted between number of leaves and dry leaf weight at both sites (Table 31). Multiple regression analysis also revealed a significant contribution of number of leaves to dry leaf weight for all the seasons at both sites

(Table 32). Leaf length, leaf breadth and fresh leaf weight also had a significant positive association with dry leaf weight. This shows that high yielding genotypes in population M would have more leaves that are large in size since there was no compensatory relationship between numbers and sizes as is often expected. These results are not in conformity with the findings of Porneleit and Egli (1979) that the numbers of organs are usually inversely related to their sizes. The positive relationship can be explained by the fact that the conditions which favoured the production of more leaves also favoured their expansion. Variation analysis for population M detected significant genetic variation for fresh leaf weight and dry leaf weight at Thika (Table 19). Significant genetic variation was also detected for days to flowering at Kabete (Table 21). Due to the lack of significant genetic variability for the yield components at Thika whereas direct selection on yield would result in a high expected progress of 14.749 percent for fresh leaf weight and 10.607 for dry leaf weight, it would be recommended that direct selection for yield be done at Thika rather than use of components. Although days to flowering had a significant genetic variation at Kabete, its association with both fresh leaf weight and dry leaf weight were low and statistically non-significant. Therefore it would not be necessary to select for late flowering genotypes to increase the duration of harvesting since even early

flowering genotypes would produce high vegetative yield due to more leaves that are large in size.

5.4 Concluding remarks and suggestions for further studies.

This study provided a useful evaluation to determine the populations that were suitable for the improvement of yield and duration of harvesting of *G. gynandra* through a selection programme. Variation analysis results and yield prediction data using morphological traits showed that the efficiency of yield predictors varied from one population to another. Therefore a single selection criterion would not be appropriate for the improvement of all the populations. This is in conformity with the findings of Grafius (1978) that correlations among yield components are largely physiological and tend to change with the environment and the population.

The results of this study revealed that duration of harvesting could be prolonged by selecting late flowering genotypes in population E. The yield of population M could be improved by direct selection on fresh leaf yield or dry leaf yield. Selection for other traits in population M would necessitate the creation of genetic variability by intermating to break genetic linkages or incorporating genes from other populations. Populations P, Q,D and I had no significant genetic variability for all the traits studied. There is need to

create variability in these populations before entering them into a selection programme. Based on these findings, a selection programme can be initiated on populations E and M to prolong the duration of harvesting and improve yield of G. gynandra. The results presented here are not exhaustive hence more genetic studies on variability of morphological traits can be undertaken by incorporating more populations and using designs that provide more information. Prior to initiating a breeding programme for this crop, more information is also required on the mating system, number of chromosomes and ploidy level, linkage, degree of dominance and ratio of additive to non-additive genetic effects among others. This information would provide a more complete description of the populations to be improved.

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Appendix 1: The 1988/1989 Climatic data at Thika and Kabete.

Year	Month	Thika			Kabete		
		Total Rainfall (mm)	Mean maximum temperature (°C)	Mean Minimum temperature (°C)	Total rainfall (mm)	Mean maximum temperature (°C)	Mean Minimum temperature (°C)
1988	June	46.4	23.5	14.0	50.9	21.3	12.6
	July	13.1	22.8	13.2	18.7	20.7	11.6
	August	8.6	23.1	13.6	46.9	20.9	11.9
	September	35.2	24.7	13.4	85.7	22.6	12.1
	October	56.6	26.8	13.5	16.7	24.5	14.9
	November	136.4	23.9	14.6	105.3	22.1	13.5
	December	189.8	23.8	13.7	139.1	22.0	13.0
1989	January	165.6	24.9	14.0	134.6	23.3	13.0
	February	34.1	25.9	12.1	45.1	23.9	12.2
	March	116.8	27.3	14.3	93.1	24.9	13.7
	April	314.9	24.3	15.2	210.5	22.0	13.8
	May	78.9	24.8	14.9	497.0	22.0	13.6

Source: Thika and Kabete Agrometerological stations.