EFFECT OF GENOTYPE x ENVIRONMENT INTERACTION ON YIELD PERFORMANCE OF COWPEA (*Vigna unguiculata*-L. Walp.) IN THE LAKE ZONE OF TANZANIA

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ABSTRACT

Cowpea (*Vigna unguiculata* L. Walp.) (2n=2x=22) is a member of the Phaseoleae tribe of the Leguminosae family. Cowpea is an important grain legume as well as fodder crop, especially in the dry regions of Africa. The production of this crop has been below average because of low genetic variation and cultivation of poor-yielding varieties which have not been improved. Genotype by environment interaction studies were conducted in Misungwi, Bariadi and Maswa locations on ten cowpea genotypes in a randomized complete block design under split plot experiment for grain yield and other growth characters. Significant mean values under combined analysis were observed with their mean range; germination percentage (83.61 to 99.44%), initial plant stand (34 to 40), days to 50% flowering (43 to 62 days) and final plant stand (34 to 40) in which the outstanding performance for the preceding characters was observed on IT99K-1122. Mean number of pods per plant ranged from 6 to 10 pods, whereby, VULI-1, VULI-2, TUMAINI, FAHARI, and IT99K-573-1 had better performance for this character, for the mean number of seeds per pod which ranged from 10 to 16 seeds, the outstanding performance was recorded on VULI-2, Mean weight of 100 seeds ranged from 10.68 to 20.22 g, IT99K-7-21-2-2 had the highest performance for this character. Moreover, the mean grain yield ranged from 1648 to 2379 kg/ha, TUMAINI revealed outstanding performance for this character and the LOCAL VARIETY was the lower performing genotype. Participatory variety selection was done at each location during flowering and at harvest. Farmers identified IT99K-1122 as the best genotype during flowering at Misungwi and Bariadi, while at Maswa IT99K-7-21-2-2 was recorded as the best. PVS at harvest recorded IT99K-1122, (LOCAL

VARIETY and IT00K-1263), and LOCAL VARIETY for Misungwi, Bariadi, and Maswa respectively. The partial (farm) budget revealed the net income of Tsh 2 537 200/= per hectare of land grown cowpea as the profit made.

DECLARATION

I, **JOSEPH SIMUDA JOACHIM,** do declare to the senate of Sokoine University of Agriculture that this dissertation is my own original work done within the period of registration and that it has neither been submitted nor being concurrently submitted in any other institution.

23/09/2013

Joseph Simuda Joachim **Date**

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The above declaration is confirmed

23/9/2013

Prof. R.N. Misangu **Date**

(Supervisor)

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LIST OF ABBREVIATIONS AND SYMBOLS

AFLP	Amplified Flagment Length Ploymorphism
BC	Before Christ
C.V	Coefficient of Variations
FAOSTAT	Food and Agriculture Organization Statistics
Fpr	F – probability
g	Genotype
G x E	Genotype by Environment interaction
GDP	Gross Domestic Product
gm	Grams
NBS	National Bureau of Statistics
NGOs	Non Government Organizations
P	Probability
PAA	Plant Affected Area
pH	Negative Logarithm of Hydrogen Ion Concentration
PVS	Participatory Variety Selection
R	Replication
RCBD	Randomized Complete Block Design
s.e	Standard Error
ssp	Specie
t	Tonne
Tsh	Tanzanian Shillings
Var	Variety

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background Information

Cowpea is a food and animal feed crop grown in the semi-arid tropics covering Africa, Asia, Europe, United States, Central and South America (Ehlers and Hall, 1997). It originated and domesticated in Southern Africa and was later moved to East and West Africa and Asia. The name "cowpea" probably derived from when it was an important livestock feed for cows in the United States (Ehlers and Hall, 1997).

The grains contain 25% protein, and several vitamins (vitamin A, B6 and C) and minerals (Fe, Zn, Ca, Mg, K, and P). The plant tolerates drought, performs well in a wide variety of soils, and being a legume replenishes low fertile soils when the roots are left to decay (Ehlers and Hall, 1997). In addition, cowpea contributes to the sustainability of cropping systems and soil fertility improvements in marginal lands by providing ground cover and plant residues, fixing nitrogen, and suppressing weeds. Some cowpea varieties also cause suicidal germination of *Striga hermonthica*, a devastating parasitic weed of cereals. Hence, cowpea is an ideal crop for the semiarid regions of the tropics, where other food legumes may not perform well. It is grown mainly by small-scale farmers in developing regions where it is often cultivated with other crops as it tolerates shade. It also grows and covers the ground quickly, preventing erosion. The crop is grown in warm to hot regions of the world (Ehlers and Hall, 1997). Most of the highlands (above 1500 m) in Tanzania grow common beans as a source of plant protein, while the lowlands (below 900 m) and coastal areas grow cowpea. About 50 – 60% of the country consists of semi-arid areas where cowpeas but not common bean can be grown (Price *et al.* 1982). According to Singh *et al.* (2001), the estimated area under cowpea production in Tanzania is 145 000 ha and the yield is apparently low (317 Kg/ha), compared with world average estimated at 4.2 t/ha. In any breeding program, emphasis is usually placed on developing cultivars which would perform well under varying environmental conditions. G × E interactions are reflected by changes in the relative performance ranking of genotypes in different test environments (Kang, 1998).

1.2 Problem Statement

According to data from NBS (2006), agriculture sector in Tanzania is the main contributor to the total GDP although its relative importance has been declining slightly in the past few years. Based on the data from the statistics unit, Ministry of Agriculture, Food Security and Cooperatives (2005), area under cowpea production in Mwanza, Shinyanga and Mara regions were 5500, 12 800 and 200 ha respectively, while cowpea productions in those regions were 3600, 6200 and 200 tons respectively, indicating an average of 0.65, 0.48 and 1 t/ha respectively compared with the world estimated average production at 4.2 t/ha according to Singh *et al.* (2001). This poor yield may be due to unavailability of high yielding and adaptable genotypes which are relevant to specific locations with potential for maximum production. This has made farmers to rely on low yielding local varieties.

1.3 Justification

Despite the slight decrease, yet the agriculture sector remains the mainstay of the Tanzanian economy and it is likely to continue to be vital for the Tanzanian economy in the foreseeable future. Thus, attempts to alleviate poverty in this country should put more emphasis on this sector. Genotype x Environment interaction is an important consideration in crop improvement since relative performance of genotype changes from one environment to another can be realized. Genotype x environment interaction reduces association between phenotypic and genotypic values. Plants that perform well in one environment may not necessarily perform well in another environment (Akande, 2007). Several cowpea genotypes have to be evaluated to study seed yield in different agro-ecological zones of the lake zone. The yielding ability of a genotype is the ultimate result of favorable interaction of genotype with the environment. Environmental factors such as moisture content, time of sowing, air temperature and photo-period length, soil characteristics and soil fertility differ across years and locations having significant influence at different developmental stages of crop growth (Bull, *et al.* 1992). Specific response of a genotype may be observed in a particular environment and its adaptable performance over different environment is a desirable characteristic.

This depends upon the magnitude of genotype x environment interaction (Ahmad, *et al.* 1996). A genotype is considered to have agronomic stability if it yields well with respect to the productive potential of the test environment (Romagosa, *et al.* 1996). Stable genotypes are defined as the cultivars that make the smallest contribution to the genotypes x environment interaction (G x E). A model according to Eberhart and Russell (1966), had been widely used to study stability parameters through Genotype x Environment interaction i.e. mean seed yield, regression coefficient and deviation from regression.

1.4 Overall Objective

To determine the effect of environment on the genotypic expression in cowpea;

1.5 Specific Objectives

(i) To determine the performance of ten cowpea genotypes in three different locations;

(ii) To conduct participatory evaluation based on farmers criteria in order to identify best cowpea genotypes in each location;

(iii) To generate farm budget (partial budget) for the production of the crop;

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Origin and distribution of cowpea

Cowpea (*Vigna unguicula ta* L. Walp.) (2n=2x=22) is a member of the Phaseoleae tribe of the Leguminosae family. Members of the Phaseoleae include many of the economically important warm season grain and oilseed legumes, such as soybean (*Glycine max*), common bean (*Phaseolus vulgaris* L.), and mungbean (*Vigna radiata*). The name cowpea probably originated from the fact that the plant was an important source of hay for cows in the southeastern United States and in other parts of the world. Some important local names for cowpea around the world include "niebe," "wake," and "ewa" in much of West Africa and "caupi" in Brazil. In the United States, other names used to describe cowpeas include "southern peas," "blackeyed peas," "field peas," "pinkeyes," and "crowders." These names reflect traditional seed and market classes that developed over time in the southern United States (Ehlers *et al.* 2002).

Cowpea plays a critical role in the lives of millions of people in Africa and other parts of the developing world, where it is a major source of dietary protein that nutritionally complements staple low-protein cereal and tuber crops, and is a valuable and dependable commodity that produces income for farmers and traders (Langyintuo *et al.* 2003). Cowpea is a valuable component of farming systems in many areas because of its ability to restore soil fertility for succeeding cereal crops grown in rotation with it (Carsky *et al.* 2002; Tarawali *et al.* 2002; Sanginga *et al.* 2003). Early maturing cowpea varieties can provide the first food from the current harvest sooner than any other crop (in as few as 55 d after planting), thereby shortening the "hungry period" that often occurs just prior to harvest of the current season's crop in farming communities in the developing world (Tarawali *et al.* 2002).

Cowpea has considerable adaptation to high temperatures and drought compared with other crop species (Hall *et al.* 2002; Hall, 2004). As much as 1000 kg/ha of dry grain has been produced in a Sahelian environment with only 181 mm of rainfall and high evaporative demand (Hall and Patel, 1985). Presently, available cultivars of other crop species cannot produce significant quantities of grain under these conditions. The crop is more tolerant to low soil fertility, due to its high rates of nitrogen fixation (Elawad and Hall, 1987), effective symbiosis with mycorrhizae and ability to better tolerate soils over a wide range of pH when compared with other popular grain legumes (Kwapata and Hall, 1985). Dry grain yields above 7000 kg/ha has been achieved in large field plots with guard rows in the southern San Joaquin Valley of California (Sanden, 1993), where growers often obtain yields above 4000 kg/ha. Clearly, cowpea is both responsive to favorable growing conditions and capable of growing under drought, heat, and other abiotic stresses.

Cowpea most certainly evolved in Africa, as wild cowpeas only exist in Africa and Madagascar. Interestingly, while west Africa appears to be the major center of diversity of cultivated forms of cowpea and was probably domesticated by farmers in this region (Ba *et al.* 2004), the center of diversity of wild *Vigna* species is southeastern Africa (Padulosi and Ng, 1997). Some evidence that domestication occurred in northeastern Africa, based on studies of amplified fragment length polymorphism (AFLP) analysis, has also been presented (Coulibaly *et al.* 2002).

The wild cowpea *Vigna unguiculata* ssp. *Unguiculata* var. *spontanea* is the likely progenitor of cultivated cowpea (Pasquet, 1999). It is likely that the crop was first introduced to India during the Neolithic period, and therefore India appears to be a secondary center of genetic diversity (Pant *et al.* 1982). "Yardlong beans," a unique cultivar group (Sesquipedialis) of cowpea that produces very long pods widely consumed in Asia as a fresh green or "snap" bean, apparently evolved in Asia and is rare in African landrace germplasm. Cowpea has been cultivated in southern Europe at least since the 8^{th} century BC and perhaps since prehistoric times (Tosti and Negri, 2002). Cowpea was introduced to the West Indies in the 16^{th} century by the Spanish and was taken to the USA about 1700 (Purseglove, 1968). Presumably it was introduced into South America at about the same time.

2.2 Morphological and phonological characteristics of cowpea

Cowpea is an herbaceous warm-season annual that is similar in appearance to common bean except that leaves are generally darker green, shinier, and less pubescent (Hall *et al.* 1997). Cowpeas also are generally more robust in appearance than common beans with better developed root systems and thicker stems and branches (Hall *et al.* 1997). Plant growth habit can be erect, semi-erect, prostrate (trailing), or climbing depending mostly on genotype, although photoperiod and growing conditions can also affects plant stature. Most cowpea accessions have indeterminate stem and branch apices. Early flowering cowpea genotypes can produce a crop of dry grain in 60 days, while longer season genotypes may require more than 150 days to mature depending on photoperiod. Flowers are borne on racemes on 15 to 40 mm peduncles that arise from the leaf axils (Hall *et al.* 2002). Two or three pods per peduncle are common, and often four or more pods are carried on a single peduncle if growing conditions are very favorable (Hall *et al.* 2002).

Cultivated cowpea seed weighs between 8 and 32 mg and ranges from round to kidney shaped. Pods are cylindrical and may be curved or straight, with between 8 and 15 seeds per pod (Ehlers and Hall 1997). The seed coat can be either smooth or wrinkled and of various colors including white, cream, green, buff, red, brown, and black. Seed may also be speckled or patterned. Seeds of well-known cowpea types, such as "blackeye pea" and "pinkeye," are white with a round irregular-shaped black or red pigmented area encircling the hilum, giving the seed the appearance of an eye (Ehlers, *et al.* 2002).

2.3 Cowpea Production and Yield in Tanzania

According to data from the statistics unit-Ministry of Agriculture Food Security and Cooperatives, by the year 2005, total area under cowpea production in Tanzania was 138 440 ha, while the total production was 8520 tones, thus the average production being 1.7 t/ha. According to FAOSTAT (1990-2007), cowpea production in Africa, Tanzania ranks number six after Nigeria, Niger, Burkina Faso, Mali and Senegal.

Table 1: Cowpea production in Tanzania from 2002/03 season to 2009/10 seasons

Year/season	2002/03	2003/04	2004/05	2005/06	2006/07	2007/08	2008/09	2009/10
Area under cowpea production. '000' hectares	73.17	159.00	150.40	155.93	177.61	88.44	128.29	258.16
Cowpea production in '000' tons	16.88	123.60	80.50	154.77	134.36	39.36	224.96	151.73
Yield (tons/ha)	0.23	0.78	0.540	0.99	0.76	0.45	1.75	0.59

Source: Statistics Unit-Ministry of Agriculture Food Security and Cooperatives

Table 2: Major cowpea growing countries in the world (1990-2007)

Country	Area under cowpea (ha)	Production (tons)	Yield (kg/ha)
Nigeria	6770 446	3 560 706	11 212
Niger	6 503 081	862 455	2 442
Burkina Faso	1 133 404	540 571	8 979
Mali	556 945	161 827	5 842
Senegal	318 604	70 541	5 685
Tanzania	277 684	85 526	5 821
Kenya	240 757	102 295	8 176
Malawi	148 105	100 353	12 939
Uganda	114 210	104 526	17 143
Mauritania	67 330	24 671	6 544
Cameroon	54 467	118 600	40 735
South Africa	25 000	12 440	9 446
Myanmar	158 167	119 062	12 977
Haiti	91 532	63 319	13 117
Sri Lanka	39 617	27 401	17 244
USA	12 065	16 301	22 669

Source: FAOSTAT (1990-2007)

2.4 Cowpea production constraints

According to Dugje, *et al.*. (2009), there are a number of factors that affect cowpea production, they include drought, weeds, heat, short rainfall (300 – 500 mm/year), pests and disease and lack of high yielding varieties. Drought and fluctuating rainfall are other important factors that will continue to affect the future production of cowpea. Cowpea is cultivated mainly in the drier areas. Most of the cowpea produce is dependent on rainfall. Short cycle varieties are best for these areas. Weeds are a serious problem in cowpea production and, if not well managed, can harbor pests and reduce both the yield and the quality of the grain. Fodder yield can also be reduced. Cowpea is not a strong competitor with weed, especially at the early stage of growth. Adipala, *et al.* (2000), reported that, cowpea plant is attacked by pests during every stage of its life cycle. Aphids extract juice from its leaves and stems while the crop is still a seedling and also spread the cowpea mosaic virus. Flower thrips feast on it during flowering, pod borers attack its pods during pod growth, and bruchid weevils attack the post-harvested seeds. The plants are also attacked by diseases caused by fungi, bacteria and viruses. Parasitic weeds (*Striga* and *Alectra)* choke the plants growth at all stages and nematodes prevent the roots from absorbing nutrients and water from the soil. Most cowpea crops are rain fed and although it is drought tolerant, cowpea farmers in the dry savanna areas of sub-Saharan Africa obtain low yields, estimated at about 350 kg/ha.

2.5 Genotype by Environment Interaction

In any breeding program, emphasis is usually placed on developing cultivars which would perform well under varying environmental conditions. The environment affects the expression of quantitative traits, and different environments can affect genotypes differently (Kang, 1998). In breeding programs, several genotypes are commonly evaluated in different environments. When genotypes tested differ in their relative performance across environments, there is G x E which can affect response to selection (Ribaut *et al.* 2007). Non-crossover interaction, i.e. where rank of genotypes does not change across environments, does not have any effect in selection as the best and worst genotypes are the same in all locations. Crossover interaction, where the rank of genotypes changes across environments, has strong consequences in breeding as best and worst genotypes in different environments are not the same (Romagosa and Fox, 1993).

Plant breeders aim at selecting genotypes with stable and high performing phenotypes across environments. However, the environment and genotype by environment interaction affect the phenotype of cultivars and breeding lines, especially if the target environments are not similar. This interaction also reduces the association between phenotypes and genotypes, thereby selected genotypes in one environment may exhibit a poor performance in another environment (Romagosa and Fox, 1993).

The G x E studies are somewhat complicated as they require integrated approaches which combine many fields including agriculture, biology, statistics, computer, and genetics. A genotype or the genetic makeup of an organism is defined by Falconer and Mackay (1996) as the combination of alleles at a single autosomal locus in a diploid organism. The physical or visible characteristics resulting from the interaction between the genetic makeup and the environment are referred to as phenotype. Phenotypes can be observed, measured, classified, or counted. Environmental factors (non-genetic factors) such as locations, growing seasons, years, rainfall, the amount of precipitation received in each season, temperature, etc. may have positive or negative impacts on genotypes. Mather and Jinks (1982), Mukai, (1988); Wu and OíMalley (1998) report on two types of environmental variations: Micro-environmental which cannot easily be identified or predicted (e.g. year to year variation in rainfall, drought conditions, extent of the insect damage) and macro-environmental variances which can be identified or predicted (e.g., soil type, management practices, and controlled temperatures). According to these investigators, the G x E interaction variance can only be estimated for the macro-environmental condition indicating that some variables that explain experiment differences are often unknown or can't be measured.

2.6 Most desired Characteristics in Cowpea

Observation by Coulibaly *et al.* (2010), from the baseline assessment of cowpea breeding and seed delivery efforts to enhance poverty impacts in sub-Saharan Africa including Tanzania in specific and the survey on most desired characteristics in cowpea in Tanzania revealed that about 16.3% of farmers prefer cowpea varieties which are high yielding, early maturing (17.1%) and drought tolerant (24.4%). The large proportion of farmers preferring drought tolerant varieties can be attributed to the fact that the survey covered semi arid areas.

In these areas, drought is among the most important limiting factors for crop production. Thus it is not surprising that farmers consider drought resistance to be a crucial attribute in an ideal cowpea variety. The nature of the study area, semi arid, can also explain the large proportion of farmers preferring early maturing varieties. Early maturity is a crop physiological mechanism to cope with drought. The attributes related to drought resistance, early maturity, yield (high and stable), and performance under poor soils (69% of respondents) provide the direction on the types of new cowpea germplasm to be targeted to this marginal area.

2.7 Partial budget

Partial budgeting is a method of organizing experimental data and information on the cost and benefits from change in the technologies being used on the farm. The aim is to estimate the change that will occur in farm profit or loss from some change in the farm (Turner and Taylor, 1998). A partial budget is mainly used to evaluate minor adjustments in the farming business by comparing a new activity with the present one (Kay and Edwards, 1994). Minor changes include those which do not have a major impact on farm structure or fixed costs of the business. Partial budgets only focus on the change in profit, although the manager also needs to consider other factors such as risks, taxation, physical and technical feasibility, cash flow differences and relative profitability (Dalsted, *et al.* 2007).

2.8 Farmers participatory evaluation

One way of increasing the speed of adoption of new varieties is for farmers to be given a wide range of modern varieties to test for themselves in their own field (Baidu-Forson, 1997). The method used is Participatory Variety Selection (PVS). PVS is becoming a more widely adopted method of making improved varieties available to farmers. It is a relatively simple, low-cost technique that can be used to overcome constraints that cause farmers to grow obsolete varieties (Rheenen, *et al.* 1984). The main players in this process are farmers, researchers, extension agents, and NGOs. On-farm pilot programs provide farmers with first hand information on the advantages of improved varieties and agronomic practices. These programs need to be replicated in other target areas in collaboration with partners who have established links with farming communities there (Baidu-Forson, 1997).

CHAPTER THREE

3.0 METHODOLOGY

This study was conducted in three locations within the lake zone of Tanzania in 2011/12 cropping season. The locations are, Ukiriguru-Misungwi, Maswa, and Bariadi with latitude/longitude 2°42' S/33°01' E, 3°25'00" S / 34°20'00" E, and S 2°45'00" S/ 34°30'00" E respectively. Ten cowpea genotypes were evaluated namely, VULI-1, VULI-2, TUMAINI, FAHARi, IT00K-1263, IT99K-1122, IT99K-7-21-2-2, IT99K-573-1, TZA 263-accession and local variety. All of them were obtained from ARI Ilonga, but local variety (checks) differed from one location to another. *Katigula*, *Sembe* and *Sembe mchele* were the local varities used at Misungwi, Bariadi and Maswa respectively.

3.1 Experimental Design

The experiment was laid out in a Randomize Complete Block Design (RCBD). Two factors were used, which include sites or locations (environments) and genotypes. Split plot experiment was used, in which the three locations (Misungwi, Maswa and Bariadi) were the main-plots, where as the ten cowpea genotypes were planted in three replications were the sub-plots (treatments). Cowpea genotypes were planted in a four-rows plot of 1.5 x 2 m, at a spacing of 50 cm between rows and 20 cm within rows. Seeding rate was three seeds per hole; thinning was done three weeks after planting to have two plants per stand. The trial was protected from insect attack by the application of Karate insecticide three weeks after seedling emergence and twice after anthesis to control insect attack. The field was kept clean through manual weeding.

3.2 Data Collection

In achieving objective one from the experiment above, the following data were collected:

(i) Germination percentage;

This was obtained by counting the number of plants germinated and divided by the expected total number of plants per plot.

(ii) Initial plant stand;

This was obtained by counting plant stands three weeks after emergence.

(iii) Days to 50% flowering;

This was obtained by counting the number of days from planting to the date when 50% of the plants in the plot had flowered.

(iv) Number of pods per plant;

This was obtained by counting randomly in S-shape, the number of pods per plant from the 2^{nd}, 5^{th}, and 9^{th} plant in a row. Therefore from the four rows the mean was computed and recorded for the plot.

(v) Final plant stand at harvest;

This was obtained by counting plant stands at harvesting period.

(vi) Number of seeds per pod;

This was obtained by counting the number of seeds from ten different pods picked randomly from the plot.

(vii) Weight of 100 seed;

100 seeds were randomly taken from the plot seed yield and weighed.

(viii) Yield per plot.

This was obtained by weighing the total seed yield from a plot

(ix) Disease scores;

Specifically for disease scores, between 6 and 7 weeks after planting, cowpea varieties were observed for disease incidence and severity under natural development of symptoms. Rating was done using a modified Horsfall and Barret scale (1945) scale of 0, 1, 5, 10, 25, 50, 75, and 100% plant area affected (PAA).

In achieving objective two, Participatory evaluation with Farmers' was done at flowering and at harvest in each location whereby pair-wise ranking approach was used. At least 10 farmers who are knowledgeable in cowpea farming were involved to evaluate cowpea genotypes based on their performance in the field and other farmer's criteria.

In performing partial budgeting for achieving objective three, the first step was identification of the costs and benefits. This involved:

(i) Careful quantification of the production parameters;

(ii) Careful elicitation of the inputs used, and outputs produced; and

(iii) Recording of the (farm-gate) prices of outputs and inputs.

3.3 Data Analysis

Based on the data which were obtained from this study, analysis of variance for the complete randomized block design under the split plot arrangement using the statistical model shown in appendix 1, to determine genotypes with wide adaptability, and to find out the path of influence for the yield character.

3.4 Identification of genotypes adaptability

Data on yield were analyzed by using a split plot statistical model as shown in appendix 1, to identify genotypes with wide adaptability.

Five variables which were included in the path-coefficient analysis include four independent variables;

(i) Final plant stand;

(ii) Number of pods per plant;

(iii) Number of seeds per pod;

(iv) 100 seed weight

Dependent variable;

(v) Seed yield;

The path coefficients were obtained by the simultaneous solution of the following equations arranged in matrix notation, while express the basic relationships between correlation and path coefficients.

1. $r_{15}=P_{15}+r_{12}P_{25}+r_{13}P_{35}+r_{14}P_{45}$ .... (1)

2. $r_{25}=r_{12}P_{15}+P_{25}+r_{23}P_{35}+r_{24}P_{45}$ .... (2)

3. $r_{35}=r_{13}P_{15}+r_{23}P_{25}+P_{35}+r_{34}P_{45}$ .... (3)

4. $r_{45}=r_{14}P_{15}+r_{24}P_{25}+r_{34}P_{35}+P_{45}$ .... (4)

The residual, P^2_{X5} was computed from the following equation:

$$1=P^2_{X5}+P^2_{15}+P^2_{25}+P^2_{35}+P^2_{45}+2P_{15}r_{12}P_{25}+2P_{15}r_{13}P_{35}+2P_{15}r_{14}P_{45}+2P_{25}r_{23}P_{35}+2P_{25}r_{24}P_{45}+2P_{35}r_{34}P_{45} \quad \text{.......... (5)}$$

Where, r_{ij} = simple correlation coefficient for measuring the mutual association of the two variables

P_{ij} = path coefficient for measuring direct effects of the variables on yield

$r_{ij}P_{ij}$ = indirect effects of variables upon another via other variables

P_x = the residual effect in the path analysis model; i and j = (1, 2..., 5)

Participatory evaluation during flowering was based on farmer's criteria which include earliness to flowering, plant vigor, and good plant stand. PVS at harvest was based on pod length, number of pods per plant, and anticipated high yielding genotype in order to identify best cowpea genotypes in each location. Pair wise ranking in which each item on a list was compared in a systematic way with each other as shown in Appendix 1.

To generate farm budget (partial budget) for the cowpea crop Data analysis was done by converting the identified quantities into costs and returns. All other non-cash costs (e.g. family labour) were valued based on market prices. Non-market inputs and costs were valued at their opportunity costs. On the input side, cash and non-cash cost were determined to include family labour, wages for hired labour and other non-market costs.

Costs and benefits associated with each agronomic practice were determined. The costs and benefits were compared using partial budgeting, which included only costs and benefits that varied. These were added costs and added benefits. All values were based on those prevailing during the season at the time when the study was conducted.

CHAPTER FOUR

4.0 RESULTS

4.1 Effect of locations on the performance of Cowpea Genotypes

4.1.1 Cowpea germination

The results for germination percentage are shown in Table 3. Significant variations ($P \leq 0.05$) in cowpea germination were observed among genotypes within and across locations. Genotype TZA 263 gave the lowest mean germination (88%) at Misungwi, while genotype IT00K-1263 gave the highest mean germination (99%). At Bariadi, genotype IT99K-7-21-2-2 recorded the lowest mean germination (90%), while genotypes FAHARI and Local variety had the highest mean germination (100%). Moreover, the lowest mean germination (88%) at Maswa was recorded on IT99K-573-1, while at that site genotypes VULI-1 and TZA 263 recorded the highest mean germination (100%).

The overall mean germination at Misungwi, Bariadi and Maswa were 95, 97, and 95% respectively. Across the three locations, the mean germination ranged from 88% recorded on TZA 263 at Misungwi and IT99K-573-1 at Maswa to 100% recorded on FAHARI and Local variety at Bariadi and, VULI-1 and TZA 263 at Maswa.

Generally, under combined analysis cowpea germination revealed significant G x E as shown in Table 11.

Table 3 Means for germination percentage in cowpea genotypes at Misungwi, Bariadi, and Maswa locations

Genotypes	Misungwi	Bariadi	Maswa
VULI-1	96^{abcd}	98^{c}	100^{c}
VULI-2	98^{bcd}	97^{bc}	97^{c}
TUMAINI	98^{cd}	99^{c}	98^{b}
FAHARI	96^{abcd}	100^{c}	98^{b}
IT00K-1263	99^{d}	99^{c}	99^{c}
IT99K-1122	99^{d}	99^{c}	99^{c}
IT99K-7-21-2-2	89^{ab}	90^{a}	72^{a}
IT99K-573-1	96^{abcd}	93^{ab}	88^{b}
TZA 263	88^{a}	98^{c}	100^{c}
LOCAL VARIETY	90^{abc}	100^{c}	98^{c}
Overall Mean	95	97	95
S.E (±)	4.724	2.661	4.998
C.V (%)	5	2.7	5.3
F pr	0.049	0.002	< 0.001

Means with the same superscript letter(s) in the same column are not statistically different following Duncan's Multiple range Test ($P \leq 0.05$).

4.1.2 Initial plant stand

Table 4 presents the means for initial plant stand in cowpea at Misungwi, Bariadi and Maswa. Non Significant variations ($P \geq 0.05$) were observed among genotypes at Misungwi. TUMAINI, IT00K-1263, and IT99K-1122 were the genotypes which gave the highest initial mean plant stands (40 plant stands) at Misungwi, while the lowest initial mean plant stands (38 plant stands) was recorded on IT99K-7-21-2-2 and Local variety genotypes. Significant variations ($P \leq 0.05$) were observed among genotypes at Bariadi. The highest initial mean plant stand (40 plant stands) were observed on TUMAINI, FAHARI, IT00K-1263, IT99K-1122 genotypes at Bariadi and, at the same site the lowest initial mean plant stand (36 plant stands) was recorded on IT99K-7-21-2-2 genotype. At Maswa significant variations ($P \leq 0.05$) were observed among genotypes. The highest initial mean plant stands (40 plant stands) was recorded on VULI-1, IT00K-1263, IT99K-1122, TZA 263 genotypes at Maswa, while the genotype IT99K-7-21-2-2 recorded the lowest initial mean plant stand (29 plant stands) at the same site.

The overall means for initial plant stands at Misungwi, Bariadi, and Maswa were 39, 39, and 38 plant stands respectively. Maswa site showed the lowest overall mean, while Misungwi and Bariadi showed the highest overall mean at the same level. At Misungwi the minimum mean initial plant stand was 38 and the maximum was 40 plant stands. At Bariadi the minimum mean initial plant stand recorded was 36 and the maximum was 40 plant stands. On the other hand, the minimum mean initial plant stand recorded at Maswa was 29 and the maximum was 40 plant stands. Generally, under combined analysis cowpea initial plant stands revealed significant G x E as shown in Table 11.

Table 4: Means for initial plant stand in cowpea genotypes at Misungwi, Bariadi and Maswa locations

Genotypes	Misungwi	Bariadi	Maswa
VULI-1	39	39^{bc}	40^{c}
VULI-2	39	39^{bc}	39^{c}
TUMAINI	40	40^{d}	39^{c}
FAHARI	39	40^{d}	39^{c}
IT00K-1263	40	40^{d}	40^{c}
IT99K-1122	40	40^{d}	40^{c}
IT99K-7-21-2-2	38	36^{a}	29^{a}
IT99K-573-1	39	37^{ab}	35^{b}
TZA 263	39	39^{bc}	40^{c}
LOCAL VARIETY	38	40^{d}	39^{c}
Overall Mean	39	39	38
S.E (±)	0.873	1.065	1.999
C.V (%)	2.2	2.7	5.3
F pr	0.19	0.002	< 0.001

Means with the same superscript letter(s) in the same column are not statistically different following Duncan's Multiple range Test ($P \leq 0.05$).

4.1.3 Days to 50% flowering in cowpea genotypes

Significant variations ($P \leq 0.05$) in days to 50% flowering were observed among genotypes across all locations (Table 5). The lowest mean number of days to 50% flowering was 51 days recorded on IT99K-1122 genotype at Misungwi, while at the same site the Local variety (Katigula) gave the highest mean number of days to 50% flowering (72 days). At Bariadi, the lowest mean number of days to 50% flowering (36 days) was also recorded on genotype IT99K-1122, while the highest mean number of days to 50% flowering (52 days) was recorded on the Local variety (Sembe). Genotype IT99K-1122 recorded the lowest mean for number of days to 50% flowering (42 days) at Maswa, while at the same location the latest (62 days) genotype in 50% flowering was TZA 263. Overall means for number of days to 50% flowering across locations were 63, 48 and 55 days for Misungwi, Bariadi and Maswa respectively. Across locations, the lowest mean number of days to 50% flowering (36 days) was recorded at Bariadi on genotype IT99K-1122, while the highest means number of days to 50% flowering was 72 days recorded at Misungwi on Local variety (Katigula). Generally, under combined analysis days to 50% flowering on cowpea genotypes revealed significant G x E as shown in Table 11.

Table 5: Means for number of days to 50% flowering in cowpea genotypes at Misungwi, Bariadi and Maswa locations

Genotypes	Misungwi	Bariadi	Maswa
VULI-1	64^{c}	49^{cd}	57^{d}
VULI-2	65^{c}	50^{cd}	56^{cd}
TUMAINI	66^{cd}	50^{cd}	57^{d}
FAHARI	69^{de}	48^{c}	58^{d}
IT00K-1263	55^{a}	49^{cd}	52^{b}
IT99K-1122	51^{a}	36^{a}	42^{a}
IT99K-7-21-2-2	60^{b}	44^{b}	52^{b}
IT99K-573-1	58^{b}	50^{cd}	54^{bc}
TZA 263	71^{e}	54^{e}	62^{e}
LOCAL VARIETY	72^{e}	52^{de}	61^{e}
Overall Mean	63	48	55
S.E (±)	1.901	1.84	1.507
C.V (%)	3	3.8	2.7
F pr	< 0.001	< 0.001	< 0.001

Means with the same superscript letter(s) in the same column are not statistically different following Duncan's Multiple range Test ($P \leq 0.05$).

4.1.4 Final plant stands at harvest

The results for final plant stands did not vary significantly ($P \geq 0.05$) among genotypes at Misungwi, while at Bariadi and Maswa varied significantly ($P \leq 0.05$) (Table 6). Genotypes IT00K-1263 and IT99K-1122 had the highest mean final plant stands (40) at Misungwi, while the lowest final plant stands (37) was recorded on the Local variety (Katigula). At Bariadi, the highest mean final plant stand was observed on genotype IT99K-1122 and the LOCAL VARIETY, but the lowest mean final plant stands (36) was recorded on genotypes IT99K-7-21-2-2 and IT99K-573-1. Genotype TZA 263 recorded the highest mean final plant stand (40) at Maswa, while genotype IT99K-7-21-2-2 recorded the lowest (29). Misungwi recorded the highest overall mean final plant stands (39) across locations, followed by Bariadi

(38) and Maswa (37) as the last. Generally, under combined analysis final plant stand in cowpea revealed significant G x E as shown in Table 11.

Table 6: Means for final plant stands at harvest in cowpea genotypes at Misungwi, Bariadi and Maswa locations

Genotypes	Misungwi	Bariadi	Maswa
VULI-1	39	39^{c}	39^{c}
VULI-2	39	38^{bc}	39^{c}
TUMAINI	40	39^{c}	39^{c}
FAHARI	39	39^{c}	38^{bc}
IT00K-1263	40	39^{c}	39^{c}
IT99K-1122	40	40^{c}	39^{c}
IT99K-7-21-2-2	38	36^{a}	29^{a}
IT99K-573-1	39	36^{a}	35^{b}
TZA 263	39	38^{bc}	40^{c}
LOCAL VARIETY	37	40^{c}	37^{bc}
Overall Mean	39	38	37
S.E (±)	1.015	1.225	2.099
C.V (%)	2.6	3.2	5.6
F pr	0.086	0.006	< 0.001

Means with the same superscript letter(s) in the same column are not statistically different following Duncan's Multiple range Test ($P \leq 0.05$).

4.1.5 Number of pods per plant

Mean number of pods per plant varied significantly ($P \leq 0.05$) among genotypes within and across locations (Table 7). At Misungwi, the results showed large mean number of pods per plant of 14 pods on VULI-2, TUMAINI, and FAHARI genotypes, while the LOCAL VARIETY had few mean number of pods per plant (8). At Bariadi, genotype VULI-1 out-performed the rest of genotypes in the mean number of pods per plant by recording 8 pods; LOCAL VARIETY gave the lowest mean number of pods per plant (4) at the same location. Genotypes VULI-1, VULI-2, TUMAINI, FAHARI, and IT99K-573-1 gave the highest mean number of pods per plant (10) at Maswa, while the LOCAL VARIETY had the lowest mean number of pods per plant (6).

Misungwi gave the highest overall mean number of pods per plant (12) compared with Bariadi and Maswa which gave the overall mean number of pods per plant 6 and 9 pods per plant respectively. Across locations the highest mean number of pods per plant (14) was recorded at Misungwi from genotypes VULI-1, VULI-2, TUMAINI, FAHARI, and IT99K-573-1 while the lowest mean number of pods per plant (4) across locations was recorded at Bariadi on the Local variety. Moreover, under combined analysis number of pods per plant in cowpea revealed non significant G x E as shown in Table 11.

Table 7: Means for number of pods per plant in cowpea genotypes at Misungwi, Bariadi and Maswa locations

Genotypes	Misungwi	Bariadi	Maswa
VULI-1	12^{bcd}	8^{c}	10^{cd}
VULI-2	14^{d}	6^{ab}	10^{cd}
TUMAINI	14^{d}	6^{ab}	10^{cd}
FAHARI	14^{d}	7^{bc}	10^{cd}
IT00K-1263	13^{cd}	5^{ab}	7^{ab}
IT99K-1122	11^{bc}	5^{ab}	8^{bc}
IT99K-7-21-2-2	10^{ab}	5^{ab}	7^{ab}
IT99K-573-1	13^{cd}	7^{bc}	10^{cd}
TZA 263	10^{ab}	6^{ab}	7^{ab}
LOCAL VARIETY	8^{a}	4^{a}	6^{a}
Overall Mean	12	6	9
S.E (±)	1.525	1.389	0.964
C.V (%)	12.9	24.1	11.3
F pr	< 0.001	0.028	< 0.001

Means with the same superscript letter(s) in the same column are not statistically different following Duncan's Multiple range Test ($P \leq 0.05$).

4.1.6 Number of seeds per pod

The means for number of seeds per pods in cowpea varied significantly ($P \leq 0.05$) within and across locations (Table 8). The study showed that genotypes VULI-1, and VULI-2, gave the highest mean number of seeds per pod (16 seeds per pod) at Misungwi, while the lowest mean number of seeds per pod was 9 seeds per pod recorded on genotype IT00K-1263. The variation among mean number of seeds per pod was also observed at Bariadi, whereby the highest mean number of seeds per pod (17) was recorded on genotype VULI-2 and the Local variety. The lowest number of seeds per pod was 11 recorded on genotype IT00K-1263. At Maswa, the genotypes which out-performed the rest in the mean number of seeds per pod were VULI-2 and TUMAINI with 14 seeds per pod. Overall mean number of seeds per pod at Misungwi, Bariadi, and Maswa were 14, 15 and 11 seeds per pod respectively. Generally, under combined analysis number of seeds per pod in cowpea revealed significant G x E as shown in Table 11.

Table 8: Means for number of seeds per pod in cowpea genotypes at Misungwi, Bariadi and Maswa locations

Genotypes	Misungwi	Bariadi	Maswa
VULI-1	16^{c}	16^{bc}	13^{cd}
VULI-2	16^{c}	17^{c}	14^{cd}
TUMAINI	15^{c}	16^{bc}	14^{cd}
FAHARI	15^{c}	16^{bc}	10^{ab}
IT00K-1263	9^{a}	11^{a}	11^{bc}
IT99K-1122	16^{c}	16^{bc}	14^{cd}
IT99K-7-21-2-2	12^{b}	12^{a}	9^{ab}
IT99K-573-1	10^{a}	12^{a}	8^{a}
TZA 263	13^{b}	15^{b}	8^{a}
LOCAL VARIETY	15^{c}	17^{c}	10^{ab}
Overall Mean	14	15	11
S.E (±)	0.678	0.941	1.54
C.V (%)	4.9	6.3	13.8
F pr	< 0.001	< 0.001	< 0.001

Means with the same superscript letter(s) in the same column are not statistically different following Duncan's Multiple range Test ($P \leq 0.05$)

4.1.7 Weight of 100 seeds (in gm) of cowpea genotypes

The means for weight of 100 seeds of cowpea showed significant variation ($P \leq 0.05$) within and across locations (Table 9). At Misungwi, genotype IT99K-7-21-2-2, TZA 263, and Local variety (Katigula) recorded the highest mean weight in grams of 100 seeds which were 20.5, 19.6, and 18.9 gm respectively, while the lowest mean weight in grams of 100 seeds was 9.7 grams recorded on genotype VULI-2. Genotypes, IT00K-1263, IT99K-7-21-2-2, IT99K-573-1, TZA 263, and Local variety recorded 20.2, 20.1, 18.9, 18.8, and 20.7 gm respectively as the highest mean weights of 100 seeds at Bariadi, in contrast to genotypes VULI-1, VULI-2, TUMAINI, FAHARI, and IT99K-1122 which recorded 14.5, 10.7, 10.9, 12.0, and 12.4 gm respectively as the lowest mean weights of 100 seeds. At Maswa, the results indicated that genotype IT00K-1263 out-performed the rest of the genotypes by recording the highest mean weight of 100 seeds (22.4 gm). On the other hand, five genotypes including VULI-1, VULI-2, TUMAINI, FAHARI, and IT99K-1122 recorded the lowest mean weights of 100 seeds which were 11.4, 11.6, 11.9, 11.9, and 12.9 gm respectively. Overall mean weights of 100 seeds of cowpea across locations were 14.6, 15.9, and 16.3 gm for Misungwi, Bariadi and Maswa respectively. Maswa location had the highest overall weight of 100 seeds. Generally, under combined analysis weight of 100 seeds in cowpea revealed significant G x E as shown in Table 11.

Table 9: Means for weight in grams of 100 seeds of cowpea genotypes at Misungwi, Bariadi and Maswa locations

Genotypes	Misungwi	Bariadi	Maswa
VULI-1	10.1^{a}	14.5^{a}	11.4^{a}
VULI-2	9.7^{a}	10.7^{a}	11.6^{a}
TUMAINI	10.9^{b}	10.9^{a}	11.9^{a}
FAHARI	11.3^{b}	12.0^{a}	11.9^{a}
IT00K-1263	16.5^{d}	20.2^{b}	22.4^{d}
IT99K-1122	12.8^{c}	12.4^{a}	12.9^{a}
IT99K-7-21-2-2	20.5^{e}	20.1^{b}	20.2^{bc}
IT99K-573-1	16.1^{d}	18.9^{b}	21.7^{cd}
TZA 263	19.6^{e}	18.8^{b}	19.4^{b}
LOCAL VARIETY	18.9^{e}	20.7^{b}	19.2^{b}
Overall Mean	14.6	15.9	16.3
S.E (±)	0.3988	2.205	0.949
C.V (%)	2.7	13.9	5.8
F pr	< 0.001	< 0.001	< 0.001

Means with the same superscript letter(s) in the same column are not statistically different following Duncan's Multiple range Test ($P \leq 0.05$).

4.1.8 Cowpea grain yield

The results showed significant variations ($P \leq 0.05$) among the genotypes in all locations (Table 10). At Misungwi, FAHARI variety out-performed the rest of the treatments by recording the highest mean cowpea grain yield (4695 kg/ha), while at the same location the lowest mean cowpea grain yield (3093 kg/ha) was obtained on the LOCAL VARIETY. The results indicated 1715 kg/ha as the highest mean yield recorded on genotype IT99K-7-21-2-2 at Bariadi, while the lowest mean yield was 1103 kg/ha recorded on IT00K-1263. Maswa recorded the highest mean yields on genotype VULI-2 with 1131 kg/ha, while the lowest mean yield (514 kg/ha) was recorded on the LOCAL VARIETY. Across locations, Misungwi gave the highest overall mean yield (3946 kg/ha), followed by Bariadi (1340 kg/ha) and the lowest yield was recorded at Maswa (909 kg/ha). Generally, under combined analysis cowpea grain yield revealed significant G x E as shown in Table 11.

Table 10: Means for grain yield of cowpea (kg/ha) at Misungwi, Bariadi and Maswa locations

Genotypes	Misungwi	Rank	Bariadi	Rank	Maswa	Rank
VULI-1	3898^{abcd}	6	1453^{ab}	2	850^{ab}	7
VULI-2	3999^{bcd}	5	1305^{ab}	6	1131^{b}	1
TUMAINI	4627^{cd}	2	1393^{ab}	3	1118^{b}	2
FAHARI	4695^{d}	1	1279^{ab}	8	799^{ab}	9
IT00K-1263	4243^{bcd}	3	1103^{a}	10	905^{b}	5
IT99K-1122	4117^{bcd}	4	1206^{a}	9	879^{ab}	6
IT99K-7-21-2-2	3658^{ab}	8	1715^{b}	1	1052^{b}	3
IT99K-573-1	3344^{ab}	9	1327^{ab}	5	1010^{b}	4
TZA 263	3785^{abc}	7	1280^{ab}	7	832^{ab}	8
LOCALVARIETY	3093^{a}	10	1338^{ab}	4	514^{a}	10
Overall Mean	3946		1340		909	
S.E (±)	467.8		235.2		194.5	
C.V (%)	11.9		17.6		21.4	
F pr	0.01		0.243		0.037	

Means with the same superscript letter(s) in the same column are not statistically different following Duncan's Multiple range Test ($P \leq 0.05$).

4.1.9 Combined analysis

Significant variation ($P \leq 0.05$) was observed among genotypes on the mean germination percentage of cowpea (Table 11). The highest mean germination percentage was observed on IT99K-1122 which had 99.4 %. However, this treatment did not differ significantly from treatments VULI-1, VULI-2, TUMAINI, FAHARI, and IT00K-1263. The lowest mean germination percentage (83.6) was recorded on genotype IT99K-7-21-2-2 and the overall mean being 95.7%. Germination percentage indicated significant G x E interaction.

The mean initial plant stands had significant variations ($P \leq 0.05$) which indicate the presence of G x E interaction. The highest value for the mean initial plant stands was

40, observed on TUMAINI, IT99K-1122, and IT00K-1263. However, these treatments did not differ significantly from treatments VULI-1, VULI-2, FAHARI, TZA 263, and the Local variety which all recorded 39 mean initial plant stands. On the other hand, the lowest mean initial plant stands 34 was observed on genotype IT99K-7-21-2-2, while the overall mean was 39 plant stands.

The mean number of days to 50% flowering had significant variations ($P \leq 0.05$) which indicate there is G x E. Genotype IT99K-1122 flowered early with 43 mean numbers of days to 50% flowering, while the late flowering genotypes had mean numbers of days to 50% flowering being 62, observed in both TZA 263 and Local variety. The overall mean number of days to 50% flowering was 56.

The lowest mean final plant stands 34 was recorded on genotype IT99K-7-21-2-2, while the highest mean final plant stand was observed on IT99K-1122 which had 40.

Non significant variations ($P \geq 0.05$) were observed among genotypes on the mean number of pods per plant, this shows that there is no G x E interaction for this trait. The mean number of pods per plant recorded the lowest value of 6 pods on the Local variety, followed by 7 pods recorded on IT99K-7-21-2-2, while genotypes IT00K-1263, IT99K-1122 and TZA 263 recorded 8 pods per plant and the highest mean number of pods per plant (10 pods) was observed on VULI-1, VULI-2, FAHARI, TUMAINI, and IT99K-573-1. The overall mean number of pods per plant under combined analysis was 9 pods.

A significant variability ($P \leq 0.05$) was observed on the mean number of seeds per pod among genotypes. VULI-2 recorded the highest mean number of seeds per pod (16). The lowest mean number of seeds per pod (10) was observed on IT99K-573-1, but this treatment did not differ significantly from IT00K-1263, and IT99K-7-21-2-2 which both recorded 11 seeds per pod. The results revealed the overall mean number of seeds per pod being 13. The results indicated there is G x E interaction for the number of seeds per pod.

Genotypes differed significantly ($P \leq 0.05$) in 100 seed weight. There is G x E interaction. Whereby the highest mean weight of 100 seeds was recorded on IT99K-7-21-2-2 which had 20.22 gm. However, the genotype did not differ significantly from treatments IT00K-1263, IT99K-573-1, TZA 263, and the Local variety which recorded 19.7, 18.9, 19.3, and 19.6 gm respectively. Genotype, VULI-2, recorded the lowest mean weights of 100 seeds (10.7 gm). The overall mean weight of 100 seeds was 15.6 gm.

Moreover, significant variations ($P \leq 0.05$) were observed among genotypes on grain yield. TUMAINI variety out-performed the rest of the treatments by recording the highest mean yield (2379 kg/ha). The Local variety gave the lowest mean yield being 1648 kg/ha. The overall mean yield was 2065 kg/ha. Also grain yield showed G x E interaction.

Table 11: Means for different variables in cowpea under combined analysis

Genotypes	Germination percentage	Initial plant stand	Days to 50% flowering	Final plant stand	Number of pods per plant	Number of seeds per pod	weight of 100 seed (g)	Grain Yield (Kg/ha)
VULI-1	97.8^{c}	39^{b}	57^{d}	39^{b}	10	15^{de}	12.0^{ab}	2067^{bcd}
VULI-2	96.9^{c}	39^{b}	57^{d}	38^{b}	10	16^{e}	10.7^{a}	2145^{bcd}
TUMAINI	98.6^{c}	40^{b}	58^{d}	39^{b}	10	15^{de}	11.2^{a}	2379^{d}
FAHARI	98.1^{c}	39^{b}	58^{d}	39^{b}	10	14^{c}	11.7^{ab}	2257^{cd}
IT00K-1263	99.2^{c}	40^{b}	52^{ab}	39^{b}	8	11^{a}	19.7^{c}	2084^{bcd}
IT99K-1122	99.4^{c}	40^{b}	43^{a}	40^{b}	8	15^{de}	12.7^{b}	2067^{bcd}
IT99K-7-21-2-2	83.6^{a}	34^{a}	52^{ab}	34^{a}	7	11^{a}	20.2^{c}	2142^{bcd}
IT99K-573-1	91.9^{b}	37^{a}	54^{c}	36^{a}	10	10^{a}	18.9^{c}	1894^{ab}
TZA 263	95.3^{bc}	39^{b}	62^{e}	39^{b}	8	12^{b}	19.3^{c}	1966^{abc}
LOCAL VARIETY	95.8^{bc}	39^{b}	62^{e}	38^{b}	6	14^{c}	19.6^{c}	1648^{a}
Overall Mean	95.67	39	56	38	9	13	15.6	2065
S.E (±)	4.257	1.401	1.758	1.52	1.315	1.113	1.405	322.4
C.V (%)	4.5	3.6	3.2	4	15.1	8.4	9	15.6
F pr	< 0.001	< 0.001	< 0.001	< 0.001	0.125	< 0.001	0.001	0.001

Means with the same superscript letter(s) in the same column are not statistically different following Duncan's Multiple range Test ($P \leq 0.05$).

4.1.10 Genotype with wide adaptability

The highest mean cowpea yield (2379kg/ha) was recorded on TUMAINI variety and thus being regarded as the genotype with wide adaptability because of its highest mean performance across locations. The mean yields of TUMAINI variety at Misungwi, Bariadi and Maswa were, 4627, 1393, and 1118 kg/ha respectively (Table 10).

4.2 Genetic Correlations Between Some Cowpea Traits at Misungwi, Maswa and Bariadi locations

4.2.1 Genetic correlation between some cowpea traits at Misungwi

The correlation coefficients of cowpea yield and yield components at Misungwi (Table 12). Very highly significant positive correlations were observed between yield and number of pods per plant (r = 0.646***); germination percentage and initial plant stands count (r = 0.745***); germination percentage and final plant stands (r = 0.744***); initial plant stands and final plant stands (r = 0.938***). On the other hand, Very highly significant negative correlation were observed between number of pods per plant and weight of 100 seeds (r = -0.689***); number of seeds per pod and weight of 100 seeds (r = -0.588***). Germination percentage was very significant and negatively correlated with weight of 100 seeds (r = -0.557**). Also germination percentage was very significant and positively correlated with number of pods per plant (r = 0.471**).

Moreover, significant and positive correlations were observed between yield and final plant stand (r = 0.418*); yield and germination percentage (r = 0.380*); yield and initial plant stand (r = 0.4319*); days to 50% flowering and number of seeds per pod (r = 0.373*); final plant stand and number of pods per plant (r = 0.373*); initial plant stand and number of pods per plant (r = 0.377*). On the other hand, significant and negative correlations were observed between yield and weight of 100 seeds (r = -0.454*); final plant stand and weight of 100 seeds (r = -0.370*); initial plant stand and weight of 100 seeds (r = -0.360*); initial plant stand and days to 50% flowering (r = -0.454*); germination percentage and days to 50% flowering (r = -0.434*); days to 50% flowering and final plant stand (r = -0.429*).

Table 12: Genotypic correlation between some cowpea traits at Misungwi location

	1	2	3	4	5	6	7	8
1	_	-0.429*	-0.434*	-0.454*	-0.164	0.373*	0.054	-0.069
2		_	0.744***	0.938***	0.373*	-0.028	-0.370*	0.418*
3			_	0.745***	0.471**	0.054	-0.557**	0.380*
4				_	0.377*	0.003	-0.360*	0.432*
5					_	0.119	-0.689***	0.646***
6						_	-0.588***	0.198
7							_	-0.456*
8								_

* P ≤ 0.05; ** P ≤ 0.01; *** P ≤ 0.001

Whereby:

1 = Days to 50% flowering, 4 = Initial plant stand, 7 = Weight of 100 seeds

2 = Final plant stand, 5 = Number of pods per plant, 8 = Grain yield

3 = Germination percentage, 6 = Number of seeds per pod

4.2.2 Genetic correlation between some cowpea traits at Bariadi location

Table 13 shows the correlation coefficients between yield and yield components at Bariadi. Comparisons of the cowpea yield components showed very highly significant and positive correlation between germination percentage and initial plant stand (r = 1***); germination percentage and final plant stand (r = 0.876***); initial plant stand and final plant stand (r = 0.876***). Final plant stand was significant and positively correlated with number of seeds per pod (r = 0.424*). Also a significant and positive correlation was observed between germination percentage and number of seeds per pod (r = 0.440*). Initial plant stand had significant and positive correlation with number of seeds per pod (r = 0.440*). On the other hand, significant and negative correlation was observed between number of seeds per pod and weight of 100 seeds (r = -0.589*).

Table 13: Genotypic correlation between some cowpea traits at Bariadi location

	1	2	3	4	5	6	7	8
1	_	-0.142	-0.007	-0.007	0.101	-0.065	0.248	-0.146
2		_	0.876***	0.876***	-0.262	0.424*	-0.271	-0.236
3			_	1***	-0.166	0.441*	-0.264	-0.285
4				_	-0.166	0.441*	-0.264	-0.285
5					_	0.192	-0.326	0.244
6						_	-0.589*	0.123
7							_	0.152
8								

$*P \leq 0.05$; $** P \leq 0.01$; $*** P \leq 0.001$

Whereby;

1 = Days to 50% flowering, 4 = Initial plant stand, 7 = Weight of 100 seeds

2 = Final plant stand, 5 = Number of pods per plant, 8 = Grain yield

3 = Germination percentage, 6 = Number of seeds per pod

4.2.3 Genetic correlation between some cowpea traits at Maswa location.

In this location (Table 14), very highly significant and positive correlations were observed between germination percentage and initial plant stand (r = 1***); germination percentage and final plant stand (r = 0.972***); initial plant stand and final plant stand (r = 0.972***). Number of pods per plant was Very highly significant and negatively correlated with weight of 100 seeds (r = -0.604***), also number of seeds per pod showed extremely significant and negative correlation with weight of 100 seeds (r = -0.651***). Significant and positive correlation were observed between germination percentage and number of seeds per pod (r = 0.386*); initial plant stand and number of seeds per pod (r = 0.386*); final plant stand and number of seeds per pod (r = 0.395*), on the other hand, significant and negative correlations were observed between final plant stand and weight of 100 seeds (r = -0.363*); germination percentage and weight of 100 seeds (r = -0.371*); initial plant stand and weight of 100 seeds (r = -0.371*).

Table 14: Genotypic correlation between some cowpea traits at Maswa location

	1	2	3	4	5	6	7	8
1	_	0.175	0.203	0.203	-0.016	-0.239	0.016	-0.217
2		_	0.972***	0.972***	0.144	0.395*	-0.363*	-0.160
3			_	1***	1	0.386*	-0.371*	-0.264
4				_	0.089	0.386*	-0.371*	-0.264
5					_	0.278	-0.604***	0.351
6						_	-0.651***	0.009
7							_	-0.075
8								

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$

Whereby;

1 = Days to 50% flowering, 4 = Initial plant stand, 7 = Weight of 100 seeds

2 = Final plant stand, 5 = Number of pods per plant, 8 = Grain yield

3 = Germination percentage, 6 = Number of seeds per pod

4.2.4 Genetic correlation between some cowpea traits under combined analysis

In the combined analysis (Table 17), very highly significant and positive correlations were observed between days to 50 % flowering and grain yield ($r = 0.533^{***}$); number of pods per plant and yield ($r = 0.714^{***}$); final plant stand and number of seeds per pod ($r = 0.344^{***}$); initial plant stand and number of seeds per pod ($r = 0.346^{***}$); days to 50% flowering and number of pods per plant ($r = 0.537^{***}$); germination percentage and initial plant stand ($r = 0.918^{***}$); germination percentage and final plant stand ($r = 0.875^{***}$); initial plant stand and final plant stand ($r = 0.875^{***}$). On the other hand, very highly significant and negative correlations were observed between germination percentage and weight of 100 seeds ($r = -0.361^{***}$); number of pods per plant and weight of 100 seeds ($r = -0.429^{***}$); number of seeds per pod and weight of 100 seeds ($r = -0.539^{***}$). Germination percentage was found to be highly significant and positively correlated with number of seeds per pod ($r = 0.306^{**}$). Highly significant and negative correlations were observed between final plant stand and weight of 100 seeds ($r = -0.331^{**}$); initial plant stand and weight of 100 seeds ($r = -0.317^{**}$). Moreover, grain yield was found to be significant and negatively correlated with weight of 100 seeds ($r = -0.208^{*}$).

Table 15: Genotypic correlation between some cowpea traits under combined analysis

	1	2	3	4	5	6	7	8
1	_	0.054	-0.126	0.048	0.537***	-0.083	-0.020	0.533***
2		_	0.875***	0.875***	0.129	0.344***	-0.331**	0.493
3			_	0.918***	0.918	0.306**	-0.361***	-0.031
4				_	0.073	0.346***	-0.317**	0.126
5					_	-0.013	-0.429***	0.722***
6						_	-0.539***	0.205
7							_	-0.208*
8								_

* $P \leq 0.05$; ** $P \leq 0.01$; *** $P \leq 0.001$

Whereby;

1 = Days to 50% flowering, 4 = Initial plant stand, 7 = Weight of 100 seeds

2 = Final plant stand, 5 = Number of pods per plant, 8 = Grain yield

3 = Germination percentage, 6 = Number of seeds per pod

4.2.5 Association among cowpea grain yield influencing factors at Misungwi, Bariadi and Maswa locations

Results of associations among factors that influence cowpea grain yield at Misungwi as described using path coefficient analyses are shown in Fig. 1 and Table 16. The results showed significant variation in casual relationships among cowpea grain yield influencing factors. The highest genetic correlation on cowpea grain yield influencing factors was found on the effect of number of pods per plant (r = 0.645). At the same time, the direct effect of number of pods per plant (0.745) gave the highest effect on cowpea grain yield. On the other hand, its indirect effect via weight of 100 seeds was (-0.242). The effect of final plant stand on cowpea yield was positive (r = 0.417), while its indirect effect via number of seeds per pod and weight of 100 seeds (-0.009 and -0.130) were relatively very low and negative. The effect of number of seeds per pod (r = 198) was low. Generally, the direct effect of number of seeds per pod and its indirect effect via number of pods per plant were relatively low and positive as indicated in Table 16 and Figure 1.

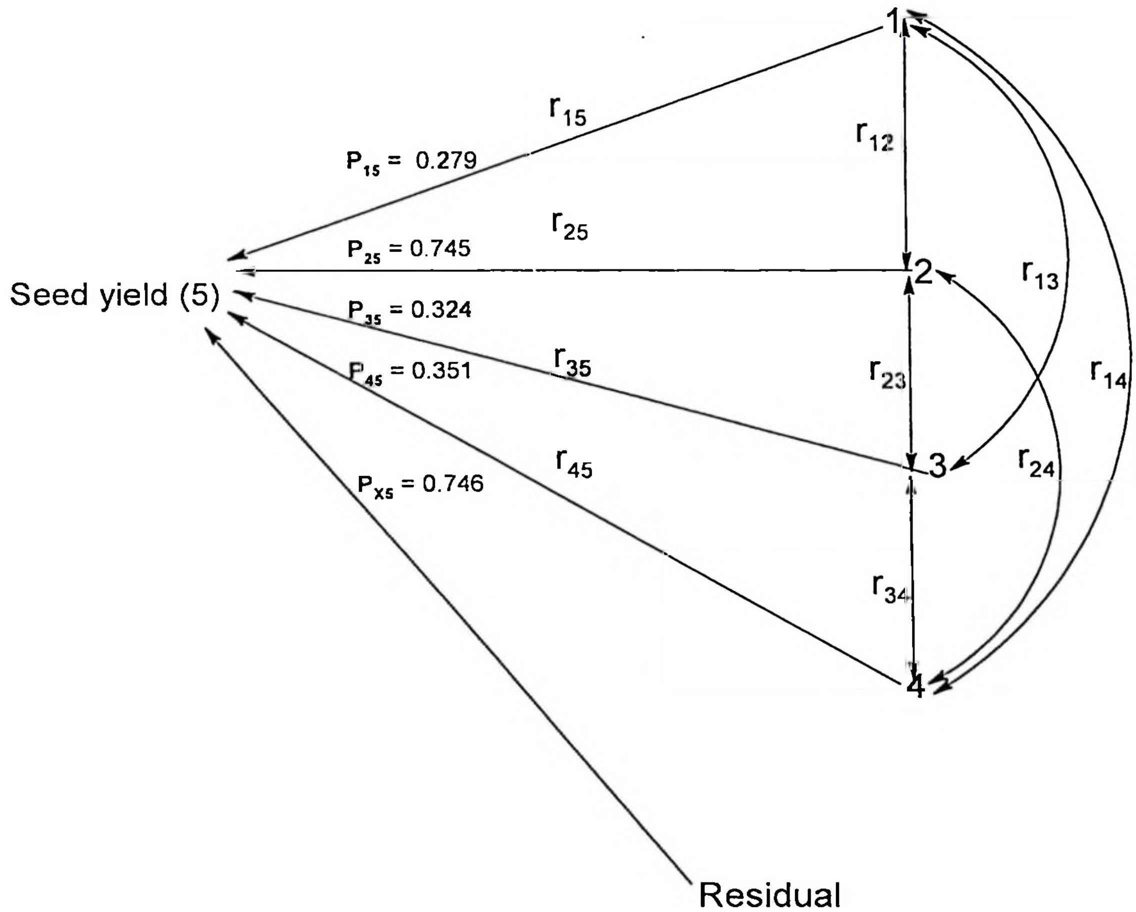

Figure 1: Path diagram showing the relationships between seed yield and seed yield influencing factors at Misungwi location.

Where,

P = Direct effect	P_{25} = effect of number of pods per plant	r_{45} = -0.456
r = correlation coefficient	P_{35} = effect of number of seeds per pod	r_{12} = 0.373
1 = final plant stand	P_{45} = effect of weight of 100 seeds	r_{13} = -0.028
2 = number of pods per plant	P_{X5} = residual effect	r_{14} = -0.370
3 = number of seeds per pod	r_{15} = 0.418	r_{23} = 0.119
4 = weight of 100 seeds	r_{25} = 0.646	r_{24} = -0.688
P_{15} = effect of final plant stand	r_{35} = 0.198	r_{34} = -0.588

Table 16: Path coefficients for cowpea grain yield influencing factors at Misungwi, Bariadi, and Maswa locations

	Effect	Mis	Bar	Mas
1	Effect of final plant stand on cowpea yield, r_{15}	0.418	-0.236	-0.160
	Direct effect of final plant stand, P_{15}	0.279	-0.243	-0.189
	Indirect effect via number of pods per plant, $r_{12}P_{25}$	0.278	-0.061	0.068
	Indirect effect via number of seeds per pod, $r_{13}P_{35}$	-0.009	0.180	0.031
	Indirect effect via weight of 100 seeds, $r_{14}P_{45}$	-0.130	-0.112	-0.070
	Total	0.418	-0.236	-0.160
2	Effect of number of pods per plant on cowpea yield, r_{25}	0.646	0.244	0.351
	Direct effect of number of pods per plant, P_{25}	0.745	0.233	0.473
	Indirect effect via final plant stand, $r_{21}P_{15}$	0.104	0.064	-0.027
	Indirect effect via number of seeds per pod, $r_{23}P_{35}$	0.039	0.082	0.022
	Indirect effect via weight of 100 seeds, $r_{24}P_{45}$	-0.242	-0.135	-0.117
	Total	0.646	0.244	0.351
3	Effect of number of seeds per pod on cowpea yield, r_{35}	0.198	0.123	0.009
	Direct effect of number of seeds per pod, P_{35}	0.324	0.425	0.079
	Indirect effect via final plant stand, $r_{31}P_{15}$	-0.008	-0.103	-0.075
	Indirect effect via number of pods per plant, $r_{32}P_{25}$	0.089	0.045	0.131
	Indirect effect via weight of 100 seeds, $r_{34}P_{45}$	-0.207	-0.244	-0.126
	Total	0.198	0.123	0.009
4	Effect of weight of 100 seeds on cowpea yield, r_{45}	-0.456	0.152	-0.075
	Direct effect of weight of 100 seeds, P_{45}	0.351	0.413	0.193
	Indirect effect via final plant stand, $r_{41}P_{15}$	-0.103	0.066	0.069
	Indirect effect via number of pods per plant, $r_{42}P_{25}$	-0.513	-0.076	-0.286
	Indirect effect via number of seeds per pod, $r_{43}P_{35}$	-0.191	-0.251	-0.051
	Total	-0.456	0.152	-0.075

Note: Mis = Misungwi; Bar = Bariadi; Mas = Maswa

At Bariadi, the highest genetic correlation of cowpea yield influencing factors was 0.321 and was found on number of pods per plant, while the direct effect of number of pods per plant had relatively low value of 0.265. The indirect effects of the number of pods per plant had either positive or negative value but generally they are relatively low as indicated in Table 16. The effect of final plant stand on cowpea yield was low and negative (r = -0.302). The highest direct effect (0.482) was found on the number of seeds per pod. The rest of the effects including the effect of the number of seeds per pod on cowpea grain yield and its indirect effects, and the effects of the weight of 100 seeds on cowpea grain yield and its indirect effect, were either positive or negative and relatively low as indicated in Table 16.

Figure 2: Cowpea crop at Bariadi during early vegetative stage.

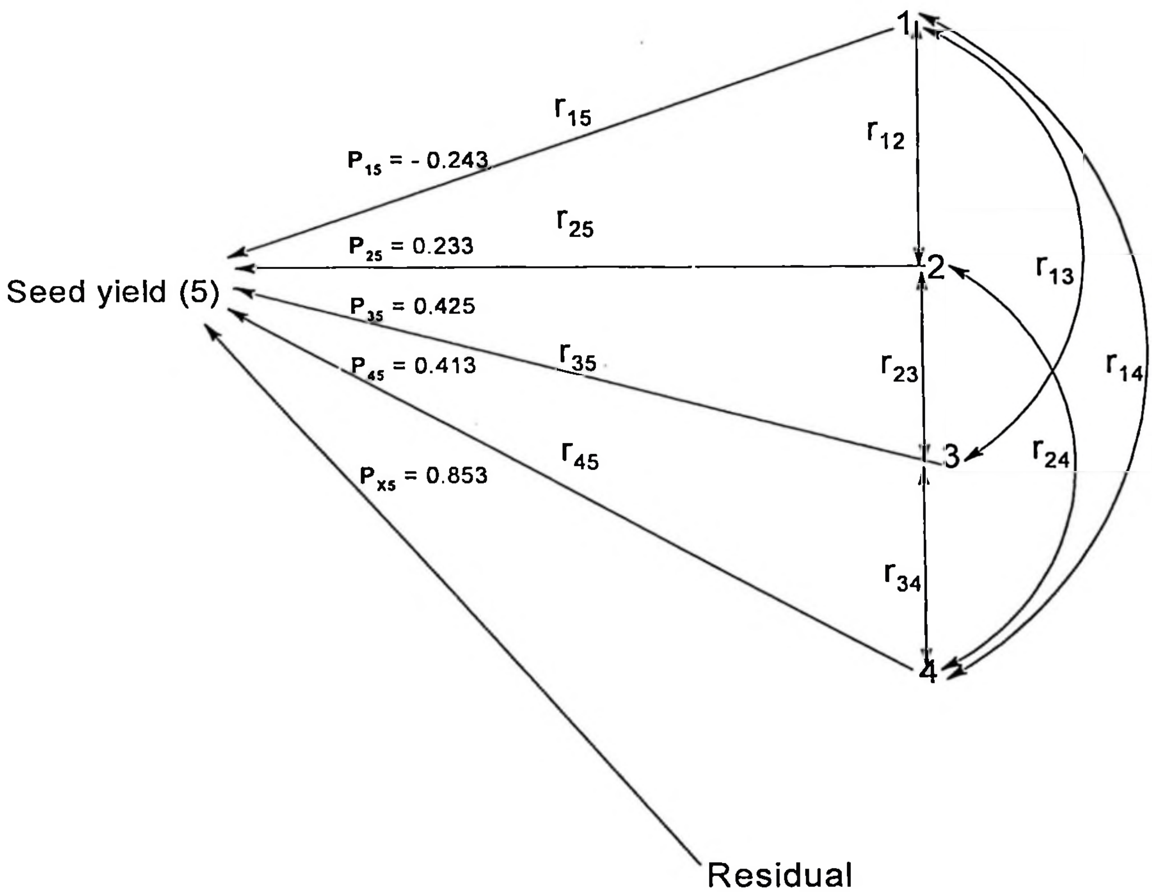

Figure 3: Path diagram showing the relationships between seed yield and seed yield influencing factors at Bariadi location

Where,

P = Direct effect	P_{25} = effect of number of pods per plant	$r_{45} = 0.152$
r = correlation coefficient	P_{35} = effect of number of seeds per pod	$r_{12} = -0.262$
1 = final plant stand	P_{45} = effect of weight of 100 seeds	$r_{13} = 0.424$
2 = number of pods per plant	P_{X5} = residual effect	$r_{14} = -0.271$
3 = number of seeds per pod	$r_{15} = -0.236$	$r_{23} = 0.192$
4 = weight of 100 seeds	$r_{25} = 0.244$	$r_{24} = -0.326$
P_{15} = effect of final plant stand	$r_{35} = 0.123$	$r_{34} = -0.589$

Table 16 and Fig 5 present the path analysis coefficients for Maswa location. The effect of the number of pods per plant (r = 0.351) was the highest effect obtained in this location despite of being low. Its direct effect was also relatively low (0.473). The other effects of the factors influencing cowpea yield together with their direct and indirect effects are relatively low despite of being either positive or negative as highlighted in the table.

Figure 4: Cowpea crop at Maswa during early vegetative stage

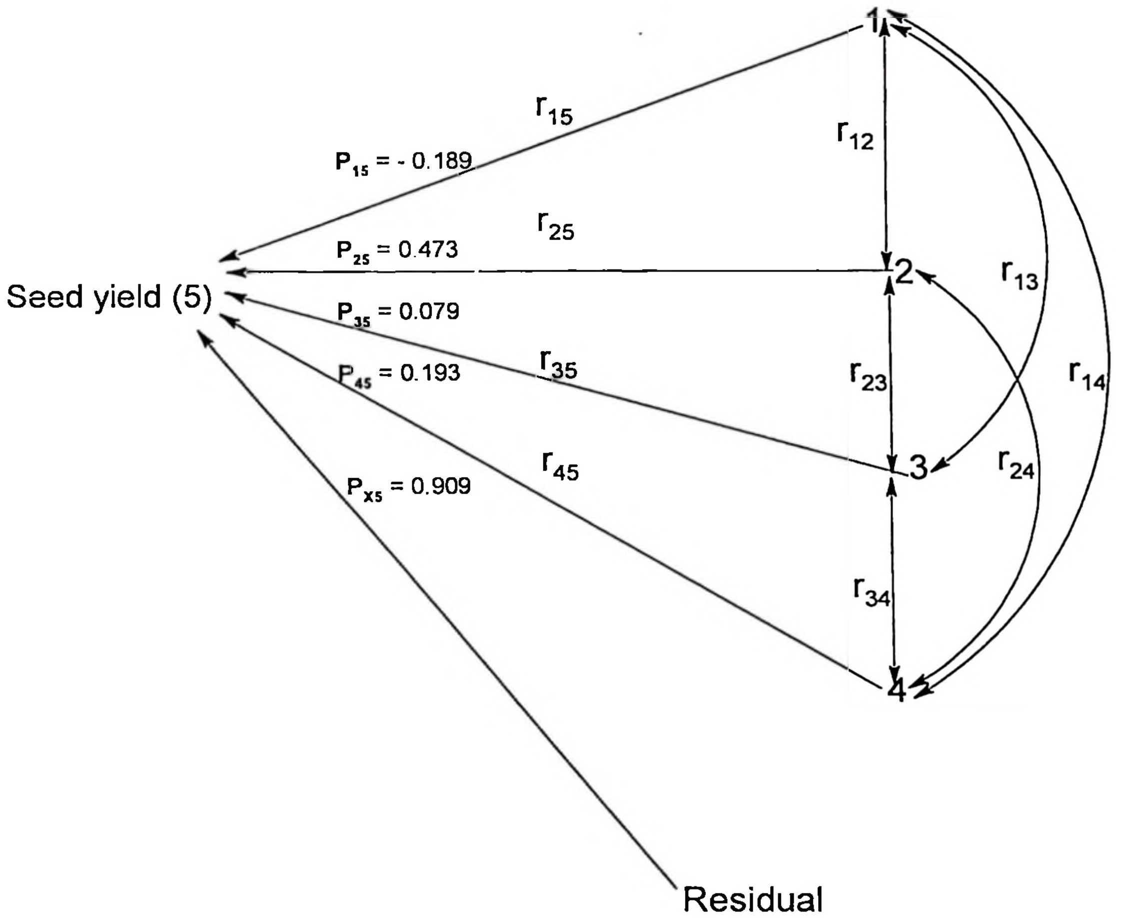

Figure 5: Path diagram showing the relationships between seed yield and seed yield influencing factors at Maswa location

Where,

P = Direct effect — P_{25} = effect of number of pods per plant — r_{45} = -0.075

r = correlation coefficient — P_{35} = effect of number of seeds per pod — r_{12} = -0.1435

1 = final plant stand — P_{45} = effect of weight of 100 seeds — r_{13} = 0.3954

2 = number of pods per plant — P_{X5} = residual effect — r_{14} = -0.3627

3 = number of seeds per pod — r_{15} = -0.160 — r_{23} = 0.2784

4 = weight of 100 seeds — r_{25} = 0.351 — r_{24} = -0.6040

P_{15} = effect of final plant stand — r_{35} = 0.009 — r_{34} = -0.6514

4.2.6 Association among cowpea yield influencing factors under combined analysis

Under combined analysis, the results revealed the highest and significant effect of the number of pods per plant (r = 0.722) and its direct effect being 0.871 (Fig. 7 and Table 17), therefore number of pods per plant was realized to be the most important parameter that influenced cowpea yield. Its indirect effect via final plant stand, number of seeds per pod and weight of 100 seeds were 0.055, 0.004, and -0.208 respectively. Generally the indirect effects were relatively low.

Figure 6: Cowpea crop at Misungwi during late vegetative stage

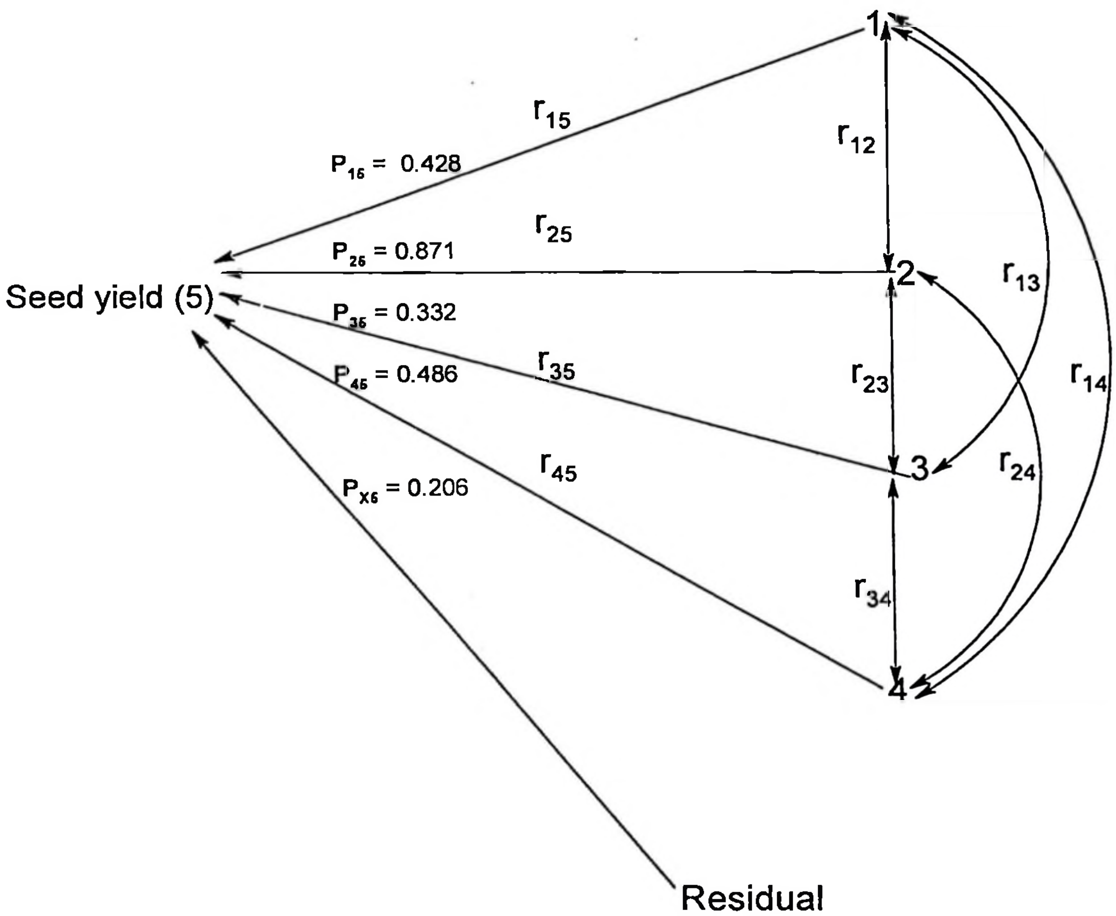

Figure 7: Path diagram showing the relationships between seed yield and seed yield influencing factors under combined analysis

Where,

P = Direct effect	P_{25} = effect of number of pods per plant	r_{45} = -0.208
r = correlation coefficient	P_{35} = effect of number of seeds per pod	r_{12} = 0.129
1 = final plant stand	P_{45} = effect of weight of 100 seeds	r_{13} = 0.344
2 = number of pods per plant	P_{X5} = residual effect	r_{14} = -0.331
3 = number of seeds per pod	r_{15} = 0.493	r_{23} = -0.013
4 = weight of 100 seeds	r_{25} = 0.722	r_{24} = -0.429
P_{15} = effect of final plant stand	r_{35} = 0.205	r_{34} = -0.539

Table 17: Path coefficients for cowpea yield influencing factors under combined analysis

	Effect	
1	Effect of final plant stand on cowpea yield, r_{15}	0.493
	Direct effect of final plant stand, P_{15}	0.428
	Indirect effect via number of pods per plant, $r_{12}P_{25}$	0.112
	Indirect effect via number of seeds per pod, $r_{13}P_{35}$	0.114
	Indirect effect via weight of 100 seeds, $r_{14}P_{45}$	-0.161
	Total	0.493
2	Effect of number of pods per plant on cowpea yield, r_{25}	0.722
	Direct effect of number of pods per plant, P_{25}	0.871
	Indirect effect via final plant stand, $r_{21}P_{15}$	0.055
	Indirect effect via number of seeds per pod, $r_{23}P_{35}$	0.004
	Indirect effect via weight of 100 seeds, $r_{24}P_{45}$	-0.208
	Total	0.722
3	Effect of number of seeds per pod on cowpea yield, r_{35}	0.205
	Direct effect of number of seeds per pod, P_{35}	0.332
	Indirect effect via final plant stand, $r_{31}P_{15}$	0.147
	Indirect effect via number of pods per plant, $r_{32}P_{25}$	-0.012
	Indirect effect via weight of 100 seeds, $r_{34}P_{45}$	-0.262
	Total	0.205
4	Effect of weight of 100 seeds on cowpea yield, r_{45}	-0.208
	Direct effect of weight of 100 seeds, P_{45}	0.486
	Indirect effect via final plant stand, $r_{41}P_{15}$	-0.142
	Indirect effect via number of pods per plant, $r_{42}P_{25}$	-0.373
	Indirect effect via number of seeds per pod, $r_{43}P_{35}$	-0.179
	Total	-0.208

4.3 Participatory Variety Selection (PVS) by Using Pair Wise Ranking Approach

4.3.1 PVS at Misungwi location

The results for participatory variety selection are as indicated in Table 18 and Table 19 for Misungwi during flowering and at harvest respectively. Based on the identified criteria, farmers were able to identify genotype labeled number 6 which is IT99K-1122 as the best genotype at flowering. Genotype labeled number 1 which is VULI-1 was ranked number 8 and thus become the last or poor performing one. At harvest, PVS by pair wise ranking approach ranked number one genotype labeled number 6 which is IT99K-1122, genotype which ranked last was the Local variety.

Table 18: Pair wise ranking during flowering at Misungwi location

Genotypes	1	2	3	4	5	6	7	8	9	10	Total	Rank
1		02	03	04	05	06	07	08	09	10	0	8
2			03	04	02	06	02	08	09	02	3	6
3				03	05	06	07	03	03	10	5	4
4					05	06	07	08	04	04	4	5
5						06	05	05	05	05	8	2
6							06	06	06	06	9	1
7								08	07	07	5	4
8									08	08	6	3
9										09	3	6
10											2	7

Table 19: Pair wise ranking during harvesting at Misungwi location

Genotypes	1	2	3	4	5	6	7	8	9	10	Total	Rank
1		02	03	04	05	06	07	08	01	01	2	6
2			02	02	02	06	02	02	09	02	7	2
3				03	05	06	03	08	03	03	5	4
4					05	06	04	04	04	04	5	4
5						06	05	08	05	05	6	3
6							06	06	06	06	9	1
7								08	09	07	2	6
8									08	08	6	3
9										09	3	5
10											0	7

4.3.2 PVS at Bariadi location

Tables 20 and 21 present the results for PVS at Bariadi during flowering and at harvest respectively. During flowering, genotype labeled number 6 which is IT99K-1122 appeared to be the best than the rest to the farmers followed by genotype labeled number 2 (VULI-2) which rank second. Genotype labeled number 1 (VULI-1) and number 9 (TZA 263) were both ranked last as poor performing genotypes during flowering. At harvest, PVS revealed genotypes labeled number 10 (Local variety) and number 5 (IT00K-1263) as the best one followed by genotype labeled number 7 (IT99K-7-21-2-2), the last one was genotype labeled number 3 (TUMAINI).

Table 20: Pair wise ranking during flowering at Bariadi location

Genotypes	1	2	3	4	5	6	7	8	9	10	Total	Rank
1		02	03	04	05	06	07	08	01	01	2	7
2			03	02	02	06	02	02	02	02	7	2
3				03	05	06	03	03	03	10	6	3
4					04	06	07	04	09	04	4	5
5						06	07	05	05	05	5	4
6							06	06	06	10	8	1
7								08	07	10	4	5
8									08	08	4	5
9										09	2	7
10											3	6

Table 21:Pair wise ranking during harvesting at Bariadi location

Genotypes	1	2	3	4	5	6	7	8	9	10	Total	Rank
1		01	01	01	05	01	07	08	09	10	4	4
2			02	04	05	02	07	08	09	10	2	5
3				04	05	06	07	08	09	10	0	6
4					05	06	07	08	09	10	2	5
5						05	07	05	05	05	8	1
6							06	08	06	10	4	4
7								07	07	10	7	2
8									08	10	6	3
9										10	4	4
10											8	1

4.3.3 PVS at Maswa location

Tables 22 and 23 present the result of PVS at Maswa during flowering and at harvest respectively. During flowering, farmers identified genotype labeled number 7 (IT99K-7-21-2-2) as the best performing genotype. This genotype was followed by genotype labeled number 8 (IT99K-573-1) in the rank and genotype labeled number 1 (VULI-1) was identified as a poor performing one. At harvest, PVS revealed the Local variety (Sembe mchele) genotype labeled number 10 as the best one out-performing the rest of the genotypes according to farmers, followed by genotype labeled number 9 (TZA 263) and number 8 (IT99K-573-1). While the poor performing genotype was the one labeled number 1 (VULI-1).

Table 22: Pair wise ranking during flowering at Maswa location

Genotypes	1	2	3	4	5	6	7	8	9	10	Total	Rank
1		02	03	04	05	06	07	08	09	10	0	8
2			02	04	05	02	07	08	02	10	3	6
3				04	03	03	07	08	03	10	4	5
4					05	06	07	08	04	10	4	5
5						05	07	08	05	10	5	4
6							07	08	09	10	2	7
7								07	07	07	9	1
8									08	08	8	2
9										10	2	7
10											7	3

Table 23: Pair wise ranking during harvesting at Maswa location

Genotypes	1	2	3	4	5	6	7	8	9	10	Total	Rank
1		02	03	04	05	06	07	08	09	10	0	8
2			02	02	05	06	07	02	09	10	4	5
3				03	05	06	03	08	09	10	3	6
4					05	04	07	08	09	10	2	7
5						05	07	08	09	10	5	4
6							07	08	09	10	3	6
7								08	09	10	5	4
8									09	10	6	3
9										10	8	2
10											9	1

4.4 The Partial Budget (Farm Budget) for Cowpea

Table 24 presents the farm budget for cowpea crop. The mean yield of TUMAINI (2379 kg/ha) under combined analysis was used to estimate total revenue when the market price for one kilo of cowpea was 1300 Tsh. Net income to the farmer was obtained after computing the difference between total revenue and total cost.

Table 24: Farm budget for cowpea

PARTICULARS			
REVENUE			
Yield (kg/ha)	2379		
Price (Tsh/kg)	1300		
Total revenue (Tsh/ha)	3 092 700		
COST	Amount (kg)	Unit Price (Tsh)	Total
Seeds (kg/ha)	20	2000	40 000
Fertilizer -Urea (kg/ha)	50	1420	71 000
-TSP (kg/ha)	150	1500	225 000
Insecticide (litres/ha)	1	14 000	14 000
Transportation (trip/ha)	2	4000	8 000
Subtotal (A)			358 000
LABOUR (personnel/ha)	Personnel	Cost/person	Total
Land preparation	15	2500	37 500
Planting	8	2500	20 000
Fertilizer application	5	2500	12 500
First weeding and thinning	15	2500	37 500
second weeding	8	2500	20 000
Insecticide application	3	2500	7 500
Harvesting	20	2500	50 000
Transportation and selling	5	2500	12 500
Subtotal (B)			197 500
Total cost = Subtotal (A) + Subtotal (B)			555 500
NET INCOME			2 537 200

CHAPTER FIVE

5.0 DISCUSSION

5.1 Performance of Cowpea Genotypes in three Different Locations

5.1.1 Cowpea germination and initial plant stand

The results from this study showed variations in cowpea germination percentage among genotypes within and across locations. Genotypes which germinated well at Misungwi were different from those at Bariadi and Maswa. The mean germination percentage across locations ranges from 88 to 100%. However genotypes IT99K-1122 and IT00K-1263 had highest and stable performance across locations compared with the rest. This implies that the two genotypes can be grown in any of the three locations with assured good germination, which in turn under good crop management and favorable growing conditions may give high yield. Asiedu *et al.* (2000) reported similar results on cowpea germination which was over 90%. Much variation among locations on germination was observed on IT99K-7-21-2-2 and thus regarded as unstable genotype. For location specific, genotypes IT99K-1122 and IT00K-1263 showed good performance at Misungwi, while FAHARI and the Local variety germinated well at Bariadi. At Maswa, VULI-1 and TZA 263 performed exceptionally well suggesting that they are suitable in this location for good germination. This implies that, different genotypes have different favorable moisture levels and temperature for good germination.

5.1.2 Days to 50% flowering

At Misungwi the plants reached 50% flowering late compared to other two locations. This could be due to the fact that Misungwi had good rainfall (appendix 3) which prolonged vegetative growth compared with Bariadi and Maswa. Genotype IT99K-1122 flowered early at Misungwi, Bariadi and Maswa compared with the other treatments. This observation suggests that, this genotype can perform well in areas with short and poor rainfall like Bariadi and Maswa as a drought escaping genotype because of its early flowering character. Being an early flowering genotype, this is indicative of early maturity as well.

The overall mean number of days to 50% flowering was 56. These results are in agreement with observations of Moalafi *et al.* (2010), Ngodi and Dauda (2010) and Akande and Balogun, (2009). Also the significant variations in days to 50% flowering observed suggest the opportunity in selecting for different maturity groups in cowpea. The Local variety generally flowered last in all of the three locations and thus being not suitable in areas with short rainfall. Differences in number of days to flowering were probably due to photoperiod sensitivity, thus indicating that the genotypes responded differently to photoperiod. The same findings of differences to flowering were reported by Amanullah and Hatam (2000), and Adeyanju *et al.* (2007) who reported similar transgressive segregation for flowering days which was due to the differences in photoperiod sensitivity.

5.1.3 Final plant stands

Non significant variation in final plant stand was observed at Misungwi, this was probably due to the ideal condition that was pertaining in the area during the whole period of crop development as it can be supported by rainfall data shown in Appendix 3. In this location, moisture was favorable for plant growth and development. Bariadi and Maswa locations had significant variations on final plant stands. TUMAINI, FAHARI, IT00K-1263 and IT99K-1122 had better and nearly consistent performance in all of the three locations compared with the rest of the genotypes; this suggests high yield because yield is proportional to the plant population at harvest. Genotype IT99K-7-21-2-2 had relatively poor performance across locations and thus gave relatively low yield compared with most of the genotypes. This variation was probably due to poor rainfall distribution in those locations.

5.1.4 Number of pods per plant

Based on the results of this study, it was observed that the mean number of pods per plant varied significantly within and across locations. Misungwi had plants with many pods compared to the other two locations. The differences observed so far from one location to another could be due to the differences in rainfall distribution between locations. There was prolonged rainfall at Misungwi which lengthened vegetative growth and thus gave enough time for setting good number of pods. Number of pods had great influence on yield; this suggests that cowpea yield high under good moisture condition. VULI-2, TUMAINI, and FAHARI gave better performance at Misungwi, indicating that, the three genotypes were very suitable in that location for good number of pods and ultimately high yield. Kombiok, *et al.* (2005), and Moalafi *et al.* (2010) also observed similar results. Padi (2008) stated that the results of poor set of pods could have been attributed to some genotypes that were late in flowering and end up setting few pods, this statement is in conformity with what was observed on the Local variety which gave few pods in all of the three locations. Due to the fact that neither of the genotypes showed consistent performance, it can be suggested that the character is highly influenced by environmental factors such as moisture and temperature.

5.1.5 Number of seeds per pod

This parameter showed significant variations within and across locations. Bariadi had plants with many seeds per pod compared to other locations. This was in contrast with what was observed by Cobbinah *et al.*(2011) who reported a range of 7 to 12 seeds per pod. Ashraf and Ahmad (2000) reported similar results to what was observed from the three locations. Genotypes VULI-1, VULI-2, TUMAINI, and IT99K-1122 showed better performance in terms of number of seeds in all of the three locations compared with the rest of the genotypes; this indicates that, the genotypes have an added advantage for high yield. Also they can be grown in variable locations for high yield because of being stable for this character. Few seeds per pod observed on IT99K-573-1 within and across locations, this could be due to genetic reasons that this genotype genetically has low number of seeds per pod. This indicates the unsuitability of the genotype for use with the aim of obtaining high yield unless grown in areas with good amount of rainfall.

5.1.6 Weight of 100 seeds in grams

Mean weight in grams of 100 seeds revealed significant variations within and across locations. Maswa had the highest mean weight of 100 seeds compared to the other two locations. The ranges observed are in conformity with what was observed by Moalafi *et al.* (2010) and Cobbinah *et al.* (2011). Genotypes TZA 263 and IT99K-7-21-2-2 appeared to be stable in terms of performance with respect to this character and gave the highest values. This reveals the potential for these genotypes for high yield. Also, it suggests the suitability of these genotypes in areas with erratic rainfall and other agro-climatic constraints. In each location, VULI-2 gave lowest weight of 100 seeds, as a yield influencing factor it indicates its minor contribution on yield and thus for VULI-2 to yield high it will depend mostly on other yield influencing factors like final plant stands, number of pods per plant and number of seeds per pod. IT99K-573-1 appeared to be unstable with inconsistent performance from one location to another; this indicates its unsuitability for high yield if 100 seed weight is among the main yield influencing factors.

5.1.7 Cowpea grain yield

Significant variations were observed among the treatments at Misungwi and Maswa locations, but on the other hand, no significant variation was observed at Bariadi location. Misungwi had the highest mean grain yield compared to the other two locations. Higher yields obtained at Misungwi were supported by good moisture condition during the whole period of crop development contrary to Bariadi and Maswa locations where moisture stress was experienced during crop development and this can be justified by earliness to flowering recorded at Bariadi and Maswa which were 36 and 42 days respectively, both recorded on IT99K-1122. This study agrees with the earlier views of (Ofori and Djagbletey 1995; Okeleye *et al.* (1999); and Ndon and Ndaeyo, 2001) who reported that early maturing cowpea genotypes have been shown to yield as much as or more than the late maturing varieties. Such genotypes have an added advantage of being suitable in areas with unreliable rainfall in terms of total amount, distribution and duration where crop failure is often attributed to early cessation of rains. Thereby making it adaptive to different agro-ecological environments. On the other hand, the results for yield confirms on what was observed by Akande and Balogun (2009). Neither of the genotypes showed consistent performance from one location to another, generally TUMAINI and FAHARI gave the best performance across locations which could be due to the strong influence of the number of seeds per pod, final plant stand, and the number of pods per plant, on which they all showed stable performance for these yield influencing characters. The Local varieties which were specific at each location they all showed poor performance. This is in contrast with their weight of 100 seeds and number of seeds per pod (yield influencing factors) and thus indicates insignificant contribution on yield for the local varieties. On the other hand, low yield of the Local varieties is possible due to low number of pods per plant recorded at each location. From this study, the number of pods per plant has been indicated as a major yield influencing factor.

The yields obtained in this study was much lower compared to what was reported by FAOSTAT (1990-2007) which is 5821 kg/ha in Tanzania. In connection to that, based on the yield data from the Statistics Unit-Ministry of Agriculture Food Security and Cooperatives as presented in Table 1, mean yields observed in the three locations are higher than the national average recorded from 2002/03 season to 2009/10 season. This big difference could be due to the fact that most of the farmers do not have an access to improved varieties of cowpea and instead they solely rely on the use of local varieties and poor crop management. Also most of the farmers do not use fertilizers and insecticides.

5.1.8 Genetic correlations between some cowpea traits in three different locations

This study revealed that, the correlations for an assortment of parameters varied with locations. At Misungwi, very highly significant ($P \leq 0.001$) positive correlations were observed between yield and number of pods per plant (r = 0.646***), this is in agreement with yield obtained in genotypes like VULI-1 (3898 kg/ha), VULI-2 (3999 kg/ha), TUMAINI (4627 kg/ha), and FAHARI (4695 kg/ha) while their number of pods per plant were 12 pods per plant for VULI-1 and 14 pods per plant for the last three genotypes. On the other hand, low yielding genotypes like the Local variety (3093 kg/ha) and IT99K-7-21-2-2 (3658 kg/ha) had relatively low numbers of pods per plant being 8 and 10 pods per plant respectively. This indicates an increase in yield as the number of pods increases and vice versa. Germination percentage and initial plant stands count (r = 0.745***), germination percentage and final plant stands (r = 0.744***). These very highly significant and positive correlations are in conformity with what was observed on IT00K-1263, where by germination was 99% and initial plant stands count taken three weeks later gave 40 plant stands while final plant stands was 40; initial plant stands and final plant stands correlation (r = 0.938***).

Contrary to Misungwi, the relationship between yield and number of pods per plant at Bariadi was not significant but the correlation was positive (r = 0.244), this suggests an increase in number of pods leads to a relatively small increase in yield and vice versa. At this location, VULI-1 gave 8 pods per plant and grain yield was 1453 kg/ha, while IT00K-1263 gave 5 pods per plant with a grain yield of 1103 kg/ha. Also very highly significant and positive correlation between germination percentage and initial plant stand (r = 1***); germination percentage and final plant stand (r = 0.876***); initial plant stand and final plant stand (r = 0.876***) were observed. This is in agreement with what was observed on FAHARI which germinated 100%, and recorded 40 initial plant stands and 39 final plant stands, while IT99K-7-21-2-2 gave 90% germination, and recorded 36 initial and final plant stands. In connection to these very highly significant and positive correlations were observed between germination percentage and initial plant stand (r = 1***); germination percentage and final plant stand (r = 0.972***); initial plant stand and final plant stand (r = 0.972***) at Maswa. But non significant and positive correlation (r = 0.351) was observed between yield and number of pods per plant. VULI-2 gave 10 pods per plant with grain yield of 1131 kg/ha. Positive correlations show that, the two variables tend to increase or decrease together and thus they are important in crop improvement. For instance, yield can be improved by improving the number of seeds per pod and number of pods per plant. The positive correlation observed between yield and most of the characters at Misungwi, Bariadi and Maswa are in agreement with the work of Tenebe *et al.* (1995) who also reported positive correlation between cowpea seed yield and growth characters such as number of pods per plant. Atuhene-Amankwa and Hossian (1991) suggested the use of number of pods per plant as an indirect selection criterion in increasing grain yield. On the other hand, the negative correlations observed at Misungwi, Bariadi and Maswa indicate that one variable increases as the other decreases. This suggests that precaution should be taken when improving a certain variable so that it will not have a negative effect on yield.

5.1.9 Association among cowpea yield influencing factors at Misungwi, Bariadi and Maswa locations.

The path analysis was carried out in order to comprehend more on the fundamental effects contributing to increased cowpea yield. At Misungwi, significant direct effects on cowpea yield were observed on number of pods per plant (0.745). This is in line with the range of 8 to 14 pods per plant observed in this location with a genetic correlation of 0.646. This correlation was slightly offset by the indirect effect of number of pods per plant via weight of 100 seeds (-0.242). Unless otherwise it could have been greater than it is, this indicates the negative influence of 100 seed weight on yield. The highest seed weight recorded on TZA 263 (19.6 gm), yielded 3785 kg/ha, while the lowest 100 seed weight of 9.7 gm recorded on VULI-2, yielded 3999 kg/ha. The effect of number of pods per plant at Bariadi and Maswa was non significant with weak positive correlation being 0.244 and 0.351 respectively. This is in line with the range (4 to 8 pods per plant) and (6 to 10 pods per plant) observed in these locations respectively. Also yield ranged from 1103 to 1715 kg/ha and from 514 to 1131 kg/ha respectively. This could have been attributed by moisture stress in the study areas during crop development which resulted into poor pod setting. Generally, these results suggest that, in order to improve cowpea seed yield more attention should be drawn in improving the number of pods per plant.

5.2 Participatory Variety Selection by Using Pair Wise Ranking Approach at Misungwi, Bariadi and Maswa locations

Different results obtained location-wise on participatory variety selection indicate differences in farmer's perception from one location to another. Also the results infer differences in genotype performance from one location to another that compelled farmers to identify what they found as more superior genotypes. For example, genotype IT99K-1122 was identified as the best during flowering at Misungwi and Bariadi, while at Maswa it was IT99K-7-21-2-2. On the other hand, VULI-1 was identified as the poor performing genotype during flowering at Misungwi, while at Bariadi VULI-1 and TZA 263 were identified as poor performing genotypes and only VULI-1 at Maswa performed poorly during flowering. Farmers came to a particular identification because it seems they were sensitive to characters like earliness to flowering, good plant stands and plant vigor. IT99K-1122, IT00K-1263, and the Local variety were identified as the highest performing genotypes during harvesting at Misungwi, Bariadi and Maswa locations respectively. Nevertheless, Local variety, TUMAINI, and VULI-1 were identified as poor performing genotypes at Misungwi, Bariadi and Maswa respectively. Moreover, PVS was based on physical observation by farmers in the field that is why most of the genotypes which were identified as the highest performing are in contrast with what was revealed on their yield. This implies that farmers are sensitive with attributes other than yield or even these farmers were not used to this kind of exercise. The traits like earliness to maturity and number of pods per plant had major influence on varietal selection by farmers.

5.3 The partial Budget (Farm Budget) for Cowpea

The farm budget presented in the results chapter presents the cost-benefit analysis that should be considered when someone wants to venture in a cowpea production enterprise.

Based on the overall mean yield under combined analysis, total revenue of Tsh 3 092 700/= could be obtained with the current market price (Tsh 1300/=) per kilogram observed from one hectare grown cowpea. Total cost from inputs purchasing and labour costs for various farm operations were Tsh 555 500/=. Under this condition, a farmer is assured of Tsh 2 537 200/= as net income from a hectare of land grown cowpea. Therefore, engaging in an enterprise is worthwhile for farmers and farmers abiding on appropriate agronomic practices for cowpea production will make it even more beneficial.

CHAPTER SIX

6.0 CONCLUSIONS AND RECOMMENDATIONS

6.1 Conclusions

(i) Cowpea genotype IT99K-1122 flowered early in all of the three locations and matured early as well. VULI-1, VULI-2, TUMAINI, FAHARI, and IT99K-573-1 gave the highest number of pods per plant but the preceding first four genotypes despite of having highest number of pods per plant and highest number of seeds per pod; they all gave the lowest weight of 100 seeds.

(ii) There was G x E interaction for germination percentage, initial plant stands, days to 50% flowering, final plant stand, number of seeds per pod, weight of 100 seeds and yield traits but not for number of pods per plant because the cowpea genotypes evaluated were variable for most traits.

(iii) Participatory variety selection done with farmers aimed at identifying superior genotypes. However the results showed that genotypes selected by farmers did not perform well in terms grain yield.

(iv) The partial budget prepared from this study showed the benefit that could be obtained on growing cowpea (TUMAINI genotype) in a hectare of land being Tsh 2 537 200/=.

6.2 Recommendations

(i) For the early maturing genotype, it is recommended to grow IT99K-1122 in all of the three locations and in drought prone areas because it can escape drought due to its early maturing character.

(ii) It is recommended that, genotypes with heavier seeds (few pods per plant and low yielding) and genotypes with large number of pods per plant (high yielding genotypes) to be used as parents in hybridization, so that the desirable traits are incorporated into the new varieties. A positive and linear correlation was observed between number of pods per plant and yield. This means that these two characters tend to increase or decrease together. Therefore it is recommended that breeders can improve the number of pods per plant in order to improve cowpea seed yield.

(iii) In terms of yield, FAHARI out-performed the rest of the genotypes at Misungwi, while IT99K-7-21-2-2 gave the highest yield at Bariadi. VULI-2 was the best genotype at Maswa. Generally, TUMAINI was found to be the highest yielding genotype across all locations and being recommended to be grown in any of those locations for high yield because of its wide adaptation and good return as highlighted on the farm budget.

(iv) Finally, it is recommended that similar research should be done and takes into account the analysis of nutrient contents in cowpea and that will involve more locations and several growing seasons in order to obtain more reliable information.

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APPENDICES

Appendix 1: Pair wise ranking table

Genotypes	1	2	3	4	5	6	7	8	9	10	Total	Rank
1												
2												
3												
4												
5												
6												
7												
8												
9												
10												

Appendix 2: Analytical model

Statistical model was: $Y_{ijk} = \mu + \beta_i + \alpha_j + \omega_{ij} + \gamma_k + (\alpha\gamma)_{jk} + \varepsilon_{ijk}$,

Where:

- Y_{ijk} = is the response for the K^{th} replicate of the i^{th} level of factor A and the j^{th} level of factor B (where i= 1 to a, j= 1 to b and K= 1 to r)
- μ= the overall mean,
- β_i = Replication/block effect for the K^{th} block,
- α_j = Main plot effect,
- ω_{ij} = Main plot random error effect
- γ_k = Subplot factor effect,
- $(\alpha\gamma)_{jk}$ = Interaction effect between treatments and locations.
- ε_{ijk} = Subplot random error effect

GenStat statistical tool was used for analysis and for the treatments showing significant F-statistics, the means will be separated using Duncan Multiple Range Test at a probability level of 5%, and comparisons.

Appendix 3: Rainfall data (mm) for 2011/12 season

Month	Misungwi	Bariadi	Maswa
Jan	94.7	47	98.8
Feb	42.8	65	69.8
March	190.5	89.5	101.5
April	96.8	49.5	77.01
May	44.4	34.5	40
June	15.6	25.5	8.5
July	0.5	Nil	Nil
Aug	90.2	64.5	1.2
Sept	86.4	25	29.4
Oct	84.3	38	93.7
Nov	131.3	85.4	75.2
Dec	171.9	40.1	88.4
Jan	6.1	4.6	5.8
Feb	73.3	54.5	30.6
March	36.5	58.5	32.3