EVALUATION OF QUALITY PROTEIN MAIZE SYNTHETIC GERMPLASM FOR DROUGHT TOLERANCE

BY

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A DISSERTATION SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENTS FOR THE DEGREE OF MASTER OF SCIENCE IN CROP SCIENCE OF SOKOINE UNIVERSITY OF AGRICULTURE. MOROGORO, TANZANIA.

2008

ABSTRACT

Twenty one Open Pollinated Quality Protein Maize genotypes were evaluated for drought tolerance under three conditions of moisture regimes i.e. pre flowering stress, flowering moisture stress and optimal moisture to identify genotypes that maintained high yield under drought and well watered conditions. The experiment was conducted at Ilonga research station during rain free period of August to November, 2006, and Selian Arusha during rain season of 2006/07. Yield differences between moisture regimes were significantly ($p \leq 0.001$) different. Optimal moisture regime had the highest mean grain yield (1.49t/ha) followed by flowering stress (1.15t/ha) while pre flowering stress had the least mean grain yield (0.9t/ha). Correlation studies revealed that grain yield was related to number of days to anthesis, number of ears per plant, plant height, ear height, and leaf senescence. Of these, plant height, ear height, and number of ears per plant were consistently positively correlated with grain yield in all moisture regimes. Days to anthesis had varying correlations with grain yield depending on moisture conditions. Based on index values, entries 1 (EEQPMOPV-1-EA-#), 6 (EEQPM-13-EA-#), 10 (EEQPM-34 –EA-#), 13(EEQPM-45-EA-#), 14(EEQPM-49-EA-#), 19(POOL15QPM-SR-#-#) and 21 (Local check1) performed better in most traits associated with drought. Grain yield, numbers of ears per plant, days to anthesis and leaf senescence were important selection criteria under drought but only grain yield and leaf senescence were important under both stress and optimal moisture conditions. Nine entries had above average yield and out of these only 3 i.e. 13(EEQPM-45-EA-#), 19 (POOL15QPM-SR-#-#) and 21 (Local Check1) had stable performance across moisture regimes. Stable and high yielding genotypes should be evaluated under field conditions in the

target environments so that farmers can select suitable genotypes to be proposed for release. Molecular characterization should be carried out to ascertain the degree of diversity available among the entries identified as best in different moisture regimes.

DECLARATION

I ATUGONZA LUTA BILARO, do hereby declare to the Senate of Sokoine University of Agriculture that the work presented here is my own original work and has not been submitted or concurrently for higher degree award in any other university.

.... 26 . 09 . 2008

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The above declaration is confirmed

.... 07 . 11 . 2008

Prof. S.O.W.M Reuben

MSc Supervisor

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ACKNOWLEDGEMENT

I thank GOD for he kept me healthy throughout my studies resulting to this work being a reality. Sincerely I would first and fore most thank my employer (Ministry of Agriculture, Food Security and Cooperatives) for sponsoring me and granting me this opportunity to undertake my studies. Special thanks are due to Prof. Reuben, S.O.W.M my supervisor, for his wonderful guidance and assistance throughout this study. He was always available and willing to assist.

I also thank the Rockefeller Foundation for financial support that made this study possible. Special thanks are also due to Dr Alfred Moshi (Zonal Director for Ilonga Research Station) for supporting me and allowing me to use facilities at Ilonga. His facilitation is highly appreciated and to Mr Asenga, Mr A.B.C. Mbiza and Said Juma for providing me with technical assistance and logistical support.

My lovely wife Pendo Etami was always inspirational to my achievement because she always asked me to come out with first class but also sacrificed some of her moments for togetherness to allow me accomplish this work.

My heartfelt gratitude goes to Mr Kheri Kittenge of Selian for his profound support and facilitation during acquisition of germplasm and data analysis, his personal assistance that touched his own pockets will be remembered throughout my career. I also thank CIMMYT –staff in Nairobi, particularly Dr Diallo and Mr. Kassango for providing the germplasm that made my study possible.

My Classmates George Muhamba, Kudra Abdul, Lameck Makoye, Merry Ndimbo, Mr Mtenga, my friends Brown Anyelwisye and Cyprian Kilenzi your assistances are highly appreciated. Mr Nicholaus Musimu and his wife Schola who took care of my properties during my absence, their profound affection will always have a place in my heart, may the lord bless you abundantly.

DEDICATION

This work is dedicated to my parents, my father Mr Titus Mugisha Bilaro and my mother Mrs Levina T. Bilaro and Mr Wilbard Kilenzi - my role model and every member of the family for supporting me in my career.

TABLE OF CONTENTS

LIST OF TABLES

LIST OF FIGURES

LIST OF PLATES

ABBREVIATIONS

ABA = Absicic Acid

AD = Anthesis date (days to 50% male flowering)

ARI = Agricultural Research Institute

ASI = Anthesis – silking interval (50 % male flowering – 50% female flowering)

ASL = Above sea level

CIMMYT = Central International de Mejeromiento de Maiz y Trigor (International Wheat and Maize Improvement Centre)

EH = Ear height

EPP = Ears per plant (an ear must contain at least one fully developed grain)

ER = Ear rot

FEWS NET = Farmine early warning systems – network

GY = Grain yield

KARI = Kenya Agricultural Research Institute.

LR = Leaf rolling

MAFSC = Ministry of Agriculture Food Security and Cooperatives

MOI = Moisture [Grain moisture (%)]

MSV = Maize Streak Virus

N = Nitrogen

NARI = National Agricultural Research Institutes

NEPAD = New Partnership for African Development

NP = Number of plants (usually taken just before harvest)

NUE = Nitrogen Use Efficiency

OPV = Open Pollination Variety

PH = Plant height

QPM = Quality Protein Maize

Rel.GY = Relative Grain yield (it is expressed as the percentage of the mean Grain yield of the trial (which is taken to be 100%), Values above 100% indicate above average performance and values bellow 100% indicate below average performance

RUE = Radiation Use Efficiency

SADC = Southern African Development Countries

SADLF = Southern African Drought and Low Fertility Project

SEN = Senescence (Leaf senescence)

TOSCI = Tanzania Official Seed Certification Institute

URT = United Republic of Tanzania

WUE = Water Use Efficiency

CHAPTER ONE

1.0 INTRODUCTION

Maize is the main staple food in many Sub- Saharan African countries. East and Southern African countries have the highest per capita consumption of over 100 kg per year (Kaliba *et al.*, 1998; DeVries and Toenniessen, 2001; Mduruma *et al.*, 2004). Maize accounts for over 71% of the total land under cereals in the sub region; it is grown by small holder farmers feeding over 100 million people (Bänzinger and de Meyer, 2002).

In Tanzania, apart from being an important food crop, maize contributes substantial amount of cash income among small holders (Mduruma and Ngowi, 1997; Ponte, 2002). It is regarded as a national staple food contributing about 61 % of the dietary calories as well as up to 50% of the utilizable protein for the majority of the rural population. Maize is recognized as the most important food security crop in alleviating hunger. The crop is grown mainly by smallholder farmers on small plots (1-3 ha) in all 21 regions of mainland Tanzania and it accounts for more than 40 % of total land under cultivation. Smallholder farmer accounts for 85 % of the total maize produced. It is estimated that each year about 1.7 million hectares of land is cultivated with maize.

For the past few years, Tanzania was thought to be self sufficient in food with only isolated cases of food shortages at certain periods of the year (United Republic of Tanzania (URT, 2000; Isinika *et al.*, 2005). In recent years, this trend has however changed; recurrent problems of food shortage each year have become a common phenomenon. For example, the Rapid Vulnerability Assessment (RVA) carried out during the June/July months of 2003 by Multi-agency Food Security Information Team (MFSI), revealed that about 320 000 households (approximately two million people) in 47 districts were to become food insecure between October and March 2004 (FEWS NET, 2003).

At the same time national food production was expected to fall 10% below national requirement which was estimated at 8.4 million metric tonnes. Also it is reported that between 2005 and 2006 the proportion of districts facing shortage rose from 29 percent (34 districts) to 65 percent (77 districts) (URT, 2006). As a result, the government was forced to import food and also request assistance from donor communities or purchase food from surplus areas within the country.

At the same time, the cost of food insecurity remains unbearable. For example in 2004 the government spent over 2.8 billion shillings to purchase food from local producers and 2.1 billion to import food. The overall cost was even higher as the government had to incur transport costs of distributing the food to needy areas and sell at a subsidized price (Ministry of Agriculture Food Security and Cooperatives (MAFSC, 2004). In 2006 the country had experienced even more serious food shortages for the major grain cereals mainly maize and rice. It was estimated that over 3 million people were facing serious food shortages at that time caused by persistent drought which resulted into crop failure in many places. As a result about 18.7 billion shillings were used in the importation of food (Ministry of Finance, 2007).

Various strategies have been put forward by the government of Tanzania, Regional and International research organizations to try to tackle drought problems through breeding, promoting better farming practices and seed relief supply (World Development Report 2008 (WDR, 2007). Such efforts include the Southern Africa Drought and Low Soil Fertility (SADLF) Project initiated by National Agricultural Research Institutes (NARIs), Southern Africa Development Cooperation (SADC) and the International Wheat and Maize Improvement Centre (CIMMYT) with the aim of improving maize performance under conditions typical of poor resource farmers (CIMMYT, 2004).

1.1 Justification

Assuring food security remains the most important and biggest challenge for development and is set to expand even further. According to CIMMYT (1999), the challenge stems from two basic questions on where additional food production will come from. Will it be from increasing yield on favourable land or from increasing production on marginal land by increasing yield potential and actual area devoted to agriculture?

The main problem is the fact that, increasing food production and minimizing the effects of environmental degradation has become conflicting objectives (Bilaro, 2007). Also the increase in population limits cultural practices for soil improvement such as bush fallowing. Annual food demand has increased at the rate of 3 – 3.5 % due to population growth (Bänzinger and de Meyer, 2002). Increased food demand leads to continued use of land without nutrient replenishment; as a result, land is degraded further thus limiting crop production. In Tanzania, maize continues to be an important crop in maintaining the livelihood of many people both in rural and urban areas (Mduruma and Ngowi, 1997). This is due to the fact that the majority of the population depends on the crop for their livelihood thus justifying the need to focus on the crop with the aim of improving its productivity.

Currently, maize production is characterised by very low yield, nevertheless farmers have continued to grow the crop year after year signifying its importance to peoples' livelihood. One of the copping strategies adopted by farmers involves growing the crop on a large proportion of land which limits the proportion of land available for other crops. The fact that maize is produced under purely rain fed conditions aggravates the situation because the current drought incidences have intensified the problem. As a result, most of the food shortages are believed to be a result of drought rather than low acreage (Mduruma and Ngowi, 1997). According to DeVries and Toenniessen (2001), annual maize losses due to moisture stress account for 13% of the total production.

1.1.1 Previous work to address drought problems in maize

Various strategies have been developed to overcome drought problems in maize production, such innovative technologies in response to climatic variability include cultural practices like; (a) Intercropping with compatible legumes as cover crops to reduce the rate of evaporation and associated production risks through diversification (b) Breeding for drought escape using early maturing varieties (c) synchronization of planting dates and (d) use of adapted materials that entail the use of varieties tolerant to drought. With land becoming a limiting factor, farmers tend to use a large portion of land for maize cultivation, this minimizes the amount of land meant for other crops in the order of importance e.g. cassava, sweet potatoes and sorghum.

The first three options have not been very successful; intercropping per se is very limited and it is confined to areas with moderate to high moisture conditions. Timely planting and the use of early maturing varieties is limited by the unpredictable weather pattern especially when the dry spell comes at critical periods of crop phenological stage (Muasya and Diallo, 2002). That means in a situation where weather is highly unpredictable even early maturing varieties also become affected. With early maturing varieties there is also a problem of yield "penalty" when rainfall is higher than average (Edmeades *et al.*, 1997a). It is further stated in Bänzinger *et al.* (2000), that the yield of early maturing cultivars is limited by the amount of radiation the cultivar can capture which is normally less than that of later maturing cultivars. Also Mugo and Njoroge (1997) cite early maturity to result in reduced rate of photosynthesis. Thus, drought cannot be wholly avoided by going for early maturity or planting date because of unpredictable timing of drought (Mduruma and Ngowi, 1997).

On the other hand, mere survival with no grain yield is useless, thus successful maize cultivars must therefore be able to withstand some variation from year to year while increasing yield under drought. The best and viable option is the use of a combination of drought tolerant varieties with other cultural practices especially among resource poor farmers. This is termed as the use of genetic and non-genetic strategies (Mugo and Njoroge, 1997; Bilaro, 2007). However, the main setback is that currently there are only a small number of drought- tolerant varieties of maize that have been tested and released to farmers in Tanzania. This is further aggravated by lack of efficient seed supply system because reports indicate that supply of improved seed is only 10 % of the total demand (Mwaisela, 2000; MAFSC, 2006). As result, four out of five seeds currently acquired by farmers come through informal seed supply system (SPORE, 2001).

In order to avail farmers with a wider choice, especially in drought prone areas, new improved and suitable varieties must be developed. The strategy is crucial as it gives farmers a wider choice and enhances adoption. In this regard local crop production needs to be our initial focus because efforts to combat problems of drought under rain- fed conditions requires that maize varieties suited to wide range of constraining environments be developed.

According to Banzinger *et al.* (2000) best and appropriate germplasms are developed from experiments that seek to simulate a stress that has a high probability of occurring in farmers' fields. This is the best way of addressing the real needs for sustainable agriculture, biodiversity conservation and locally based food security. Such traditional agro – ecosystems which combine all the three should merit research and are fundamental to achieving one of the millennium development goals of halving hunger to half by the year 2015.

Nevertheless, with all the above mentioned efforts, very little has been achieved in terms of the number of varieties that are released, although there are over 12 released varieties (Mduruma *et al.*, 2004), only very few are known to be drought tolerant. This study was proposed with the view of improving maize production in drought prone areas through identification of additional better genotypes so that farmers can have many varieties from which to choose suitable ones.

1.2 Objectives

1.2.1 General objective

The over all objective is to identify maize genotypes with the potential to increase yield in drought prone areas of Tanzania

1.2.2 Specific objectives

(i) to evaluate maize genotypes for yield and drought tolerance under optimum and moisture stress conditions

(ii) to identify better sources of tolerance to drought among available genotypes

(iii) to identify at least eight best yielding genotypes under both optimal and moisture stress conditions

(iv) to asses stability characteristics on yield of the genotypes

1.3 Hypothesis

1. Certain genotypes perform better under both stressed and non-stress conditions
2. Certain plant characteristics are associated with drought tolerance and hence contribute to high yield under drought

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 The Importance of Agriculture to the Economies of Africa

Agriculture provides more than 85 percent of food in the African continent; it is also a major source of livelihood and generates employment for more than two thirds of the population. According to Byerlee and de Janvry (2007), agriculture has five functions: it is a source of national economic growth, an instrument for poverty reduction, a source of business opportunities, a source of natural resources and environmental services for the society and lastly a source on food security. Although food supply expanded faster than the human population in recent years, many households, in most developing countries particularly in Africa have fallen victims of food shortages (Bender and Smith, 1997).

According to DeVries and Toenniessen (2001), the continent has the highest percentage of agricultural population in the world and the second in terms of land under cultivation. Despite this huge dependence in agriculture as the mainstay of many economies, Africa is the only region in the world where per capital food production has declined during the past two decades (Jaeger, 1992; Berger, 2001; Ponte, 2002; Diouf, 2007) where the yield of maize and other staple cereals remain at 1.0 tonne per hectare. It is estimated that between 1961 and 2001 cereal per capita out put decreased by 13 percent (Djurfeldt *et al.*, 2005).

2.2 Maize as a Source of Income

Although crops inventories still classify maize as a food crop alone, the demand of maize within countries and beyond national borders has made maize the most traded commodity. Currently, many rural households earn their income through sale of maize especially in the major growing zones. Commercial production of maize though undocumented already exist in countries like Kenya, Zimbabwe, South Africa and it is starting to take shape in some parts of Tanzania. In South African commercial production is well developed and according to a report by Mduruma *et al.* (2004), about 50 percent of maize produced is used as animal feed.

Prospects for commercial production are expected to increase due to increasing need of alternative source of energy i.e. (bio fuel). Current improvement in nutritional quality (as Quality Protein Maize) and vitamin A enrichment means the prospects for maize becoming a major source of income are high due to increased demand for both animal feed and human consumption.

2.3 Livelihood (employment)

Population increase and falling food production have forced people to change eating habits by adjusting to limited alternatives of dishes available. *Green maize* is becoming popular. This has attracted off-season production under small-scale irrigation so that they can supply green maize at times when prices are likely to be high and competitive. This is providing employment among producers and traders contributing to peoples' livelihood.

2.4 Maize Production in Tanzania

Available statistics indicate that maize is the only crop grown throughout the country under all agro ecological conditions. Maize is regarded as a food security crop– meaning that the absence of maize at household level is regarded as a sign of hunger. The best testimony for this is the proportion of production (tonnage wise) it commands among major food crops as shown in Table 1.

Table 1: Production statistics of major food crops (metric tons) 1996 -2000

Crop	1996	1997	1998	1999	2000
Maize	1 879 000	1 835 000	2 685 000	2 451 750	2 128 000
Rice	528 000	550 000	676 000	576 190	576 000
Wheat	380 000	780 000	112 000	82 370	32 000
Sorghum	151 000	835 000	799 000	770 400	771 000
Beans	360 000	374 000	462 000	528 000	584 000
Cassava	1 425 000	1426 000	1758 000	1 795 380	1 440 000
Potatoes	653 000	372 000	644 000	569 590	587 000
Bananas	465 000	904 000	-	751 600	652 000

Source: Planning Commission, June 2001

However, despite the increased trend in maize consumption in the past few years, the production over the past 15 years has declined. DeVries and Toenniessen (2001) reported that between 1990 and 1997 maize production fell by 1.6 percent in East Africa. In Tanzania, maize production has been on the decline in recent years, (Fig 1).

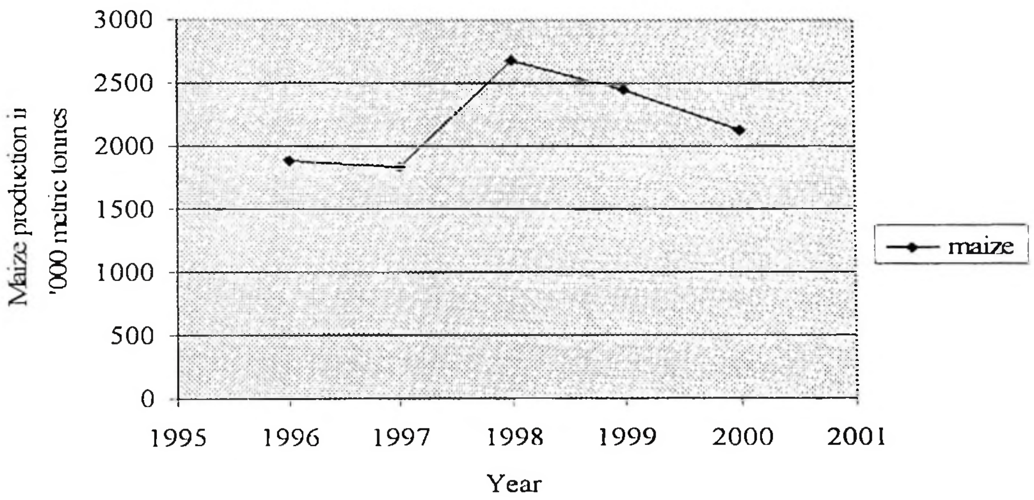

Fig. 1 : Maize production trend 1996 - 2000

Adapted from Table 1

2.5 Drought Problems

Although drought is a global phenomenon, the relative importance of water constraints appears to be highest in Africa (CIMMYT, 1999; Mduruma *et al.*, 2004). Estimates indicate that about 60 percent of the land in Sub Saharan Africa is vulnerable to drought, while 30% is highly vulnerable (Benson and Clay, 1998). This problem tends to subject agricultural production to sporadic periods of drought that affect yield of major crops (DeVries and Toenniessen, 2001). Decline in rainfall has had an adverse impact in agricultural production and other water intensive activities. The unpredictable weather pattern forces farmers to develop a complex mix of cropping systems to fit the environment with no single crop getting more attention due to weather uncertainties and persistent food shortages have become a symbol of inadequate agricultural performance. Significant yield losses due to drought incidences are expected to increase due to associated complications of global climate change resulting in altered temperature and rainfall pattern (Betran *et al.*, 2003b; Campos *et al.*, 2004).

As a result food security problem is said to be highest in Africa (NEPAD-New Partnership for African Development, 2003), where nearly over half of the countries in Africa today face serious food shortages. The continent has changed from net exporter of food to reliance on imports and food aid (NEPAD, 2003; Djurfeldt *et al.*, 2005). Countries like Seychelles relay entirely on food imports which have a negative impact to local agricultural production (SPORE, 2007). It is thus predictable that without taking concrete measures, Africa would continue to import food in the foreseeable future (Lofchie, 1987), and this poses a serious threat to attainment of higher rates of economic growth. Moreover, over reliance on imported food processed food pose health hazards.

2.6 The Extent of Drought in Tanzania

Food shortages due to drought in Tanzania have been reported for years (Rwehumbiza, 1987). However, from the year 2000, SADC countries including Tanzania have experienced successive years of drought-induced food deficit which eroded food reserves and copping strategies among the poor (Zambezi and Mwambula, 1997; FEWS NET, 2001). According to Mduruma and Ngowi (1997), almost all agro ecological zones of Tanzania are characterized by unpredictable dry spell of 1 to 3 weeks- exacerbated by relatively low water holding capacity soils. Maize production activities in Tanzania are divided into five agro ecological zones. The main production constraints for each zone are shown on Table 2.

Table 2: Incidences of moisture stress relative to other production constraints across major agro ecological zones in Tanzania

Zone	Production constraints
Eastern (Ilonga and Mlingano)	Moisture stress, field /storage pests, weeds Low soil fertility
Northern (Selian)	Low soil fertility, Moisture stress
Western (Tumbi)	Low soil fertility, moisture stress
Lake Zone (Ukiriguru)	Low soil fertility, moisture stress
Southern Highlands (Uyole)	Grey Leaf Spot, Maize Streak, Soil Fertility (K), Stalk borers and Storage Pests

Source: Temu, 2005

Moisture stress appears to be a common problem in almost all agricultural zones with exception of the Southern Highlands. During severe season, production losses of up to 50% percent are reported (Mduruma and Ngowi, 1997), serious loses are experienced when drought coincides with flowering and early grain filling period (Westgate, 1997). At the same time, the land under irrigation in Tanzania is very small.

According to the 2002/03 report, only 200 895 hectares of land were under irrigation (United Republic of Tanzania, 2004) and confined mainly to horticultural and cash crop plantations of coffee and tea with patches of rice fields scattered throughout the country. But with a large portion of the country facing moisture deficit problems and high dependence on maize as the main staple food, the need to develop drought tolerant varieties is inevitable.

2.7 Drought Tolerance in Maize

Inadequate water is a major cause of crop yield losses particularly in the tropics. Uncertainties in weather due to global warming are expected to increase the occurrence of inadequate water availability. At CIMMYT, various approaches to improve drought tolerance in maize have been explored. About three decades of work on drought tolerance in maize has resulted in improved source populations, open-pollinated and hybrid products that perform well under drought stress. Results from recent studies show the usefulness of this germplasm under severe drought stress conditions. Much of gains in genetic improvement have been a result of using secondary traits (Bänzinger *et al.*, 2000).

2.7.1 The mechanism for drought tolerance in maize

Yield is the primary trait for which all selections aim to achieve; however selecting for drought tolerance based on yield per se is not sustainable. Yield is the outcome of many phenological, physiological and biochemical phenomenon that take place in a very integrated fashion governed by genetic and environmental factors (Zaidi, 2002). Because grain yield is correlated with kernel number per plant under stress, it makes sense to focus on processes which determines this trait.

A plant experiences drought when demand from above ground plant parts for water exceeds the supply from root. Thus high yield is achieved when much water is passed through the plant as easy as possible and food assimilating leaf areas stay green as long as possible. Such efficacies arise from genetic factors; studies have revealed a wide variability in terms of water use efficiency suggesting genetic variation in several plant germplasms including maize. Cultivar differences that were observed among soybeans in response to abscission, growth and senescence are regarded as clear evidence suggesting genotypic differences with respect to drought in other crops (Nilsen and Orcutt, 1996).

In their study to identify genes behaviour under drought in maize, Sawkins *et al.* (2004) found out that gene responsible for different metabolic activities such as hormone metabolism for example ABA and Cytokinin or Carbohydrate metabolism such as Sucrose Phosphate Synthase (SPS) and Cell wall Invertase show differences in expression of gene under drought and well watered conditions. Plant growth regulators such as Abscisic Acid (ABA) help the plant to reduce water loss (Nilsen and Orcutt, 1996). Although the hormone has many varied effects on the plant, it is now considered to be one of the messengers which transmit root signals to the plant shoot resulting in closure of stomata without the usual reduction in leaf water potential. Other studies suggest that the hormone transmits signals which trigger cellular changes that confer ability to maintain cell tugor and withstand damaging forces associated with lowered water potential (Dass *et al.*, 1997).

Studies show that under conditions of drought very little ABA is passed into the leaves and grains where it causes leaf rolling, stomata closure, accelerates leaf senescence and contributes abortion of tip grains during grain filling (Nilsen and Orcutt, 1996; Bänzinger *et al.*, 2000). As a result, the hormone helps plants to survive drought stress. Further studies revealed that under mild to severe stress, both cell division and expansion are inhibited and is manifested in reduced leaf expansion, reduced silk growth and as stress intensifies stem elongation and root growth are reduced also.

2.7.2 The use of secondary traits in maize as selection indices for drought tolerance

High yield is the main target to which all selections are aiming at under drought. Therefore; drought tolerance alone has no meaning if the grain yield is zero especially when biomass production is not our intention. However yield is a function of many factors both genetic and environmental and because of this secondary traits are used as selection criteria. They are indicative of the performance of a genotype in the target environment. Secondary traits associated with grain yield provide a guide to specific mechanisms that contribute to grain yield under drought; for example leaf rolling is indicative of water extraction capacity, and chlorophyll concentration is a measure of functional stay green characteristics (Barker *et al.*, 2004) cited by Campos *et al.* (2004).

Selection for drought using secondary traits such as anthesis-silking interval (ASI), tassel size, leaf rolling and leaf senescence are reported to contribute about 20 percent gain when considered under low N conditions (Chapman and Edmeades,1999). Due to fairly high expression of the stress-adaptive traits under managed drought or excessive moisture stress conditions, they can be carefully selected and further improved.

However it is important to note at this stage that not all secondary traits are efficient to merit indirect selection but flower synchronization based on ASI data show more promising results (Bänzinger and Cooper, 2001). Also ASI and Number of Ears per Plant (EPP) are said to be strongly correlated with grain yield under stress (Vasal *et al.*, 1997).

In their study Chapman and Edmeades (1999), reported gains in larger grain sink arising from selection associated with reduced tassel size and stem near flowering. Tassel size has much to do with the partitioning of carbohydrates; one tassel branch contains millions of pollen enough to pollinate all potential grains in as many cobs. They confirmed that ASI was an important trait in the identification of stress tolerant genotype at flowering. Since maize is frequently exposed to both the extremes of water availability in many semi arid areas in Tanzania, our major focus is to develop robust germplasm with improved performance across the regimes of water availability. Other studies show that maize crop is most susceptible to drought at flowering (Campos *et al.*, 2004; Westgate, 1997). This is the time when silk growth, pollination and kernel set occurs, and water stress slows them down and widen ASI. Thus, the ideal variety described in Bänzinger *et al.* (2000) as drought tolerant is characterised by small or negative ASI, small tassel size, withstand senescence of leaves and stay green for longer periods under drought, and should have turgid /unrolled, erect leaves. Most important it should be able to maintain high grain yield under drought.

2.7.2.1 ASI and drought tolerance

Reduced ASI has been widely used as an evaluation criterion for drought tolerance in maize (DeVries and Toenniessen, 2001). Under moisture stress conditions, there is generally retarded growth due to reduced assimilate fluxes to growing organs. Reduced photosynthesis at flowering causes delay in silk emergence relative to pollen shed, which can result in lack of pollen for late-appearing silks on apical ears, reduced silk emergence from sub-apical ears, failure in ovary fertilization, and ultimately, reduced kernel set. Delayed silking increases ASI which in turn leads to ear and kernel abortion resulting into barrenness.

Consequently, close synchrony between pollen shed (i.e., anthesis) and silk emergence (i.e., silking, when the first silks emerge from the husks) is required for high kernel set in maize (Bolaños and Edmeades, 1997). A negative relationship exists between final kernel number and the extent of the anthesis-silking interval (ASI = date of silking – date of anthesis). It has been hypothesized that the lack of pollen for late-appearing silks is among the causes of kernel number reduction under water stress conditions in maize.

Research on kernel number determination demonstrated that kernel abortion still occurred when fresh pollen was added to late-exposed silks (Edmeades *et al.*, 1997b). Therefore, factors other than greater pollen availability must be involved in improving final kernel number in response to a shorter ASI.

2.7.2.2 Leaf rolling and drought tolerance

Drought stress reduces leaf area (Blum, 1997; Zaidi, 2002), hence the percentage of incident radiation that is intercepted by green leaves (or %RI), if the stress occurs before flowering. At any time of crop development, stress reduces crop photosynthesis rate (RUE, WUE or NUE) and consequently the total assimilates available to the crop.

During the pre-flowering stage, maize establishes many more ears and florets than can finally be filled. In the two weeks of bracketing flowering, the number of ears, kernels, and endosperm cells that are filled is determined, during this period the maize crop is very sensitive to stress. During grain filling, the supply of assimilates determines the extent to which ears, kernels, and endosperm cells established during flowering are filled. Thus, if crops are exposed to drought at this critical stage, certainly it is sink that will be a major limiting factor for higher yields.

2.7.2.3 Leaf senescence and drought tolerance

The effects of leaf senescence on grain yield have been investigated (Bänzinger *et al.*, 2000; Zaidi, 2002). Stress after flowering reduces green leaf duration. Senescence results in the loss of active leaf area, since maize cannot restore leaf area once it is lost. When drought occurs after flowering it causes the leaves to senesce early. The supply of assimilates will limit grain yield in this crop, as a result, the plant will have many small kernels due to limited supply of assimilate from source. Thus, under drought conditions source may be a key-limiting factor for grain yield. Grain yield is determined as well by the degree to which structures such as ears, kernels, and endosperm cells, which serve as sinks for assimilates, have been established. Thus selection for delayed leaf senescence is favoured.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Site

The experiment was carried out at Ilonga Research Station (Latitude 6^0 45'S, Longitude 37^0 E and 506m a.s.l) in Kilosa district of Morogoro region. The trial was conducted during rain free period under irrigated conditions with controlled moisture regimes. Soils were sandy loam with good drainage characteristics.

3.2 Germplasm

Twenty one Open Pollinated-Quality Protein Maize germplasm were evaluated for drought tolerance under different conditions of moisture regimes. The materials were collected from potential drought tolerant germplasm at CIMMYT- Kenya. Local check used was (SITUKA 1) a released variety that is also known to be drought tolerant. A description of genotypes used is presented in Table 3.

Table 3: Description of 21 QPM – OPVs entries (genotypes) evaluated

Entry	Pedigree	Code	Origin
1	EEQPMOPV-1-EA-#	KB05B0B17-1	CIMMYT- KENYA
2	EEQPM-HT-#	KB05B0B17-2	CIMMYT- KENYA
3	EEQPM-6-EA-#	KB05B0B17-3	CIMMYT- KENYA
4	EEQPM-9-EA-#	KB05B0B17-4	CIMMYT- KENYA
5	EEQPM-8-EA-#	KB05B0B17-5	CIMMYT- KENYA
6	EEQPM-13-EA-#	KB05B0B17-6	CIMMYT- KENYA
7	EEQPM-16-EA-#	KB05B0B17-7	CIMMYT- KENYA
8	EEQPM-18-EA-#	KB05B0B17-8	CIMMYT- KENYA
9	EEQPM-29-EA-#	KB05B0B17-9	CIMMYT- KENYA
10	EEQPM-34-EA-#	KB05B0B17-10	CIMMYT- KENYA
11	EEQPM-36-EA-#	KB05B0B17-11	CIMMYT- KENYA
12	EEQPM-38-EA-#	KB05B0B17-12	CIMMYT- KENYA
13	EEQPM-45-EA-#	KB05B0B17-13	CIMMYT- KENYA
14	EEQPM-49-EA-#	KB05B0B17-14	CIMMYT- KENYA
15	EEQPM-21-EA-#	KB05B0B17-15	CIMMYT- KENYA
16	EEQPM-33-EA-#	KB05B0B17-16	CIMMYT- KENYA
17	EEQPM-42-EA-#	KB05B0B17-17	CIMMYT- KENYA
18	EEQPMS2-#GEASP-1-#	KB05B0B17-18	CIMMYT- KENYA
19	POOL15QPM-SR-#-#	KB05B0B17-19	CIMMYT- KENYA
20	KATUMANI (non QPM)	COMMERCIAL CHECK	KARI- KATUMANI
21	LOCAL CHECK1 (non QPM)	LOCAL CHECK1	ARI - SELIAN

3.3 Experimental Design

The experimental design was Alpha (0, 1) lattice with series of incomplete blocks each consisting of 3 plots. Alpha lattice designs are suitable tools in controlling random variation for evaluation trials especially when many genotypes are used. According to Gomez and Gomez (1984); Hassan and Meisner (2003), alpha lattice design is also suited to experiments evaluated under drought conditions, because it helps to control the within replicate variation and hence the experimental error. The entries were sown in two seeds per hill placed 30 cm apart and double row of metres in length spaced at 75 centimetres with a plot size of 7.56 square metres.

3.4 Experimental Procedure

Alpha Lattice experimental design with three replications was used and the experiment was set up during rain free period at Ilonga research station. Comparable data for random stress (rain fed conditions) for the same genotypes were collected from ARI- Selian (Arusha) (36^0.38' E, 03^0.22'S, 1390m a.s.l) where the experiment was established under rain fed conditions (i.e. random stress). Due to differences in climatic conditions between Ilonga and Arusha, data from random stress, have been evaluated separately. However the data are used to asses the behaviour of genotypes used under a different set of ecological conditions.

3.5 Evaluation of Genotypes and Stress Management

Two environments at Ilonga and Selian were used for evaluation. At Ilonga, the experiment was established during rain free period whereby the experimental site was divided in to three sets of water management regimes consisting of

(i) Pre- flowering drought stress

(ii) Flowering drought stress

(iii) Optimum moisture (well watered condition)

From Selian, data were collected from experiment established under rain fed conditions and were used to study the behaviour of genotypes when water supply in not controlled (random moisture). Both pre-flowering and flowering drought stress represents the most vulnerable stage in maize, thus selection at these stages improves drought tolerance (Magorokosho and Tongoona, 2003), and optimal moisture experiment was used as a control of the experiment as it serves to monitor the yield potential of genotypes (Bolaños and Edmeades, 1997).

3.5.1 Pre flowering drought stress

In this case, irrigation was designed so that by the time maize genotypes reach flowering stage drought is enough to delay silking and cause abortion. Water was applied to this block for a few weeks (about 4 weeks) in order to establish good plant stand. After four weeks, stress was applied by stopping irrigation. This stress is designed in such a way that by the time of maize flowering the plants are severely stressed. The purpose of this experiment was to delay silking thus resulting in a large positive ASI and induce rolling of leaves (plate1). Under this study, varieties showing small or negative ASI are considered better, because of the increased chances of fertilization by fresh pollen under moisture stress.

Plate 1: Maize genotypes under Pre flowering stress at Ilonga research Station (three weeks after stopping irrigation)

3.5.2 Flowering drought stress

This is where irrigation is designed so that drought develops directly at flowering and accelerates leaf senescence. This stress was applied at flowering stage where the partitioning of assimilates to the sink is considered highest. The aim of applying drought stress at flowering was to induce the senescence of leaves in which the selection criterion was to identify genotypes with the least percentage of leaf senescence. The ideal variety must stay green for a long time under conditions of moisture stress (plate 2)

Plate 2: Stress at grain filling (Flowering stress)

3.5.3 Optimum moisture condition (well watered, managed)

Irrigation was applied following normal routine so that maize plants had sufficient soil moisture to allow normal plant development. This was regarded as control of the experiment. It served to compare the performance of varieties under optimal conditions with performance under moisture stress. Thus water was applied based on water requirements by the plant (plate 3).

Plate 3: Maize genotypes under optimal moisture at Ilonga research station

3.5.4 Random moisture stress

In this experiment soil moisture was not controlled, thus the genotypes received moisture from natural rain fall. The experiment for random stress was conducted at ARI – Selian (Arusha). The objective of collecting such information was to determine the behaviour of genotypes evaluated under a different set of ecological conditions. Thus the data from this experiment were evaluated separately because they were meant to provide supplemental information especially when a wider recommendation is sought.

3.6 General Management

TSP was applied at planting as a starter material (50kg P/ha) to supply P needed for root development, while CAN was applied after 4 weeks (100kg N/ha) just before flowering to supply N for vegetative growth and plant development. Weeding followed routine management procedure which ensured clean field and pest control was ensured by applying Théoden dust to control stem borer (*Chilo partellus*) which is triggered by drought conditions.

3.7 Data Collection

The type of variables evaluated (data collected) under individual moisture regimes varied from one individual moisture regime to another. Apart from grain yield emphasis was placed on variables which are believed to be associated with yield during certain crop development stages (i.e. growth stage) (Table 4).

T able 4: Description of data collected under different moisture regimes

Regime	Main data	Reasons
Pre flowering stress	Anthesis – Silking interval , Leaf rolling, Grain yield, number of ears per plant (EPP), diseases and lodging	Stress at this stage seeks to identify genotypes with high yield but with unrolled leaves, small or negative ASI values, high EPP and resistant to diseases. The objective is to reveal genetic variation for ASI, EPP, LR and SEN.
Flowering stress	Leaf senescence scores, EPP, Grain yield, diseases and lodging	Stress at this stage seeks to accelerate senescence and induce kernel abortion. The aim is to identify genotypes that will remain green for a long time under drought and maintain reasonable number of ears /plant (less bareness). The objective is see genetic variability for grain yield and SEN
Optimal moisture	Grain yield, EPP, diseases and lodging	This is a control of the experiment where, all data are collected, but with emphasis on grain yield which is a trait of primary importance. The objective is to monitor the yield potential

Thus secondary traits were the main source of data. Such traits include; leaf rolling scores (LR), Anthesis- Silking Interval (ASI), leaf senescence (SEN), number of ears per plant (EPP), anthesis date (AD which were rated based on standard guidelines explained in Bänzinger *et al.* (2000) and CIMMYT Field book. At harvest, field cob weight was taken and from each plot, a sample of cobs was shelled for recording grain moisture by use of Grain Moisture meter. Grain yield was determined by shelling all cobs on a whole plot and weighing the grain weight. Other plant characteristics such as disease incidences, lodging characteristics were recorded. For secondary traits such as leaf rolling and leaf senescence data, two independent recordings (rating scores) were used and data were then averaged. Leaf rolling data were taken two times at an interval of 10 days before anthesis when leaves are still upright. The visual score of 1- 5 from each plot were used where (1 = turgid unrolled leaves and 5 = for leaves rolled like onion leaf). ASI was obtained by recording 50% anthesis and silking and subtracting days to anthesis from days to silking. Details of other variable rating are shown below

Leaf rolling (rating scale 1-5)

1 = unrolled, turgid

2 = leaf rim starts to roll

3 = leaf has the shape of a V

4 = rolled leaf rim covers part of leaf blade

5 = leaf is rolled like onion leaf

Leaf senescence (rating scale 1-10)

1 = 10% dead leaf area

2 = 20% dead leaf area

3 = 30% dead leaf area

4 = 40% dead leaf area

5 = 50% dead leaf area

6 = 60% dead leaf area

7 = 70% dead leaf area

8 = 80% dead leaf area

9 = 90% dead leaf area

10 = 100% dead leaf area

Maize Streak Virus (MSV) and other diseases

1 (= few, no infection) to 5 (severely diseased)

3.8 Data Analysis

Grain yield is of primary importance, therefore all evaluation were made including yield data. At harvest maize was shelled and weighed on full plot basis and grain moisture determined using Moisture meter. Using the Field book 8.4.1 with REML programme (Vivek *et al.*, 2005) all the varieties were analysed for grain yield and other agronomic traits from individual experiments (i.e. water regimes) and combined using across regimes analysis. In this case, entries (genotypes) were treated as fixed effects while incomplete blocks as random effects within replicates (Stern *et al.*, 2004). Response data was determined by comparing performance of genotypes under stress and non-stress plots. These were evaluated by average rank and per se performance to establish response of individual genotypes under different environments of moisture conditions.

3.8.1 Determination of better sources of tolerance

Genotypes that are good in most traits associated with drought were identified by use of selection index which determines the worth of genotypes by summarizing information on different traits such as grain yield, ASI and senescence (Bänzinger *et al.*, 2000). Thus the selection index for each genotype was calculated by use of the following formula:-

$I = b_1P_1 + b_2P_2 + \ldots.. b_nP_n$

Where P_i is the observed standardized value of the trait I and b_i is the weight given to that trait in the selection index which is normally based on economic value of each trait.

Selection indices were thus used to identify best genotypes (i.e. those with highest phenotypic value) with respect to drought and important traits under drought were assigned weights described in Bänzinger *et al.* (2000) as follows:-

Grain yield = 5 (selection for increased grain yield)

Ears per plant = 3 (selection for increased number of ears)

ASI = 2 (selection for decreased ASI)

Leaf senescence = 2 (selection in favour of decreased leaf senescence)

Leaf rolling = 1 (selection for decreased leaf rolling)

3.8.2 Selection of best genotypes across moisture regimes

From individual moisture management regimes best 8 ranked entries (genotypes) were selected based on yield data and associated variables such as ASI values, EPP, grain yield and leaf rolling during pre flowering moisture stress; grain yield, EPP and leaf senescence during flowering moisture stress; grain yield and EPP for optimal moisture The objective of this study was to identify genotypes that perform better by maintaining high yield under varying conditions of moisture. Thus stable genotypes have the advantage of wide adaptation with regard to evaluation criteria and are selected based on combined analysis of data from stress and non- stressed experiments. Across moisture regimes analysis was also conducted to identify genotypes with superior average rank for grain yield. The selection criteria used in the study was yield and stability of genotypes across conditions of moisture regimes using "Across moisture regimes" analysis tool on Fieldbook 8.4.2 software (Vivek *et al.*, 2005). In this case the mean yield of genotypes from individual yield averages across moisture regimes relative to the overall mean yield across moisture regimes gives the Relative grain yield (Rel GY). The consistency of rank of genotypes across all experiments is the ranked standard deviation (rank Stdv) and it is a measure of stability. The mean grain yield for across moisture regimes is taken to be 100 percent. Thus relative grain yield (Rel.GY) indicates the performance of a genotype relative to this mean. Relative grain yield values above 100% indicate above average performance and vice versa.

Further analysis-using SAS statistical programme for running ANOVA with the General Linear Model (GLM) as suggested in Stern *et al.* (2004) and mean separation was used, where the experiment was treated as CRBD without violation of any assumption for the statistical model as stated in CIMMYT instruction sheets for regional trials. Mean separation was done by using LSD and results declared at 5% level of significance. The ANOVA was based on the Viana and Regazzi (1999) statistical model:

$$\mathbf{Y_{il(j)(g)} = \mu + t_i + (r|a)_{l(g)} + (b|r|a)_{l(j)(g)} + a_g + (ta)_{ig} + e_{il(j)(g)}}$$

Where:

$Y_{il(j)(g)}$ is the observation of the i^{th} treatment ($i = 1,\ldots, v$) in the l^{th} block ($l=1,\ldots, k$) of j^{th} replication ($j = 1,\ldots, m$), in the g^{th} environment ($g = 1,\ldots, s$);

μ is the constant common to all observations;

$\mathbf{t_i}$ is the effect of the i^{th} treatment;

$\mathbf{(r|a)}_{l(g)}$ is the effect of the j^{th} replication in the g^{th} environment;

$\mathbf{(b|r|a)}_{l(j)(g)}$ is the effect of the l^{th} block of j^{th} replication in g^{th} environment;

$\mathbf{a_g}$ is the effect of the g^{th} environment;

$\mathbf{(ta)}_{ig}$ is the effect of the interaction between the i^{th} treatment and g^{th} environment;

$e_{il(j)(g)}$ is the error associated to the observation $Y_{il(j)(g)}$; $e_{il(j)(g)} \sim N(0,\delta^2)$, independent.

Correlation coefficients for various variables under the different regimes of moisture were calculated using Pearson correlation method under PROC CORR Data and were evaluated for significance.

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Analysis of Variance (ANOVA) Summary of Results

Variables under consideration except number of ears per plant (EPP) and number of plants (NP) indicated significant variation between moisture regimes (Table 5). This difference was evident for grain yield (GY), anthesis date (AD), anthesis – silking interval (ASI), plant height (PH), ear height (EH), ear rot (ER), leaf senescence (SEN) and maize streak virus (MSV). Only grain yield had a significant ($p \leq 0.05$) genotype x water regimes interaction.

Significant interaction observed between genotypes and water regimes have been reported by other researchers (Banzinger and de Meyer, 2002; Ngowi, 2002). Results in Table 5, suggest that besides the presence of genetic differences the variation in yield was also due to differences in duration of the effective grain filling period between water regimes. In this case shortest effective grain filling period (survival duration of plants during grain filling period) was expected under pre flowering while longest effective grain filling period was expected under optimal moisture because the plants stayed green for a longer time and were thus able to manufacture more assimilates. G x E implies differential response of genotypes in different environments and that the performance of genotypes depend on specific environments.

Table 5: ANOVA summary of selected variables across water regimes at Ilonga

S/f variation	df	GY (t/ha)	AD (days)	ASI (days)	PH (cm)	EH (cm)	EPP (#)	ER (%)	SEN (1-10)	NP (#)	MSV (1-5)
Rep	2	1.14*	58.8**	6.3*	86.4..	14.8	0.05	39.4	0.24***	22.4	0.4
W/ regimes (a)	2	5.64***	150.7***	9.6**	3580.5***	925.0***	0.04	543.8***	0.51***	113.2	3.7***
Genotypes (b)	20	0.92***	30.1***	3.7**	627.4***	191.2***	0.01	33.4	0.01	79.0***	0.9*
Interaction (axb)	40	0.34*	9.7..	1.4..	130.4..	72.6	0.02	55.7	0.02	39.9	0.4
Error	124	0.3	8.98	1.57	107.92	57.06	0.02	48.7	0.02	30.7	1.7
Total	188										

Source: Research data

Key

*** = significant at 0.001 probability level, ** = significant at 0.01 probability level, * = significant at 0.05 probability level

GY= Grain yield, AD= days form sowing to 50% anthesis, ASI= antheis silikng interval, PH= plant height, EH= ear height, EPP= number of ears per plant, ER=ear rot score, SEN=leaf senescence, NP= number of plants, MSV= maize streak virus

This differential response of genotypes under the three moisture regimes could be caused by variation in timing of moisture stress. The resulting effects were due to alteration of the order of genotypes based on yield from one water regime to another which results to change of the rank order Such interaction is very important in breeding programs because it gives a clue in developing genotypes adapted to specific conditions of moisture (Banzinger and de Meyer, 2002; Ngowi, 2002). On the other hand significant variation between genotypes for traits associated with drought such as AD, ASI and GY indicate that it is possible make selections of best genotypes by using these traits. Such variability between genotypes (genetic variability) shows that there is an opportunity for improvement by selecting for the right material (Edmeades *et al.*, 1997a)

4.2 The Effects of Moisture Regimes on Various Growth and Reproductive Variables

Moisture stress applied prior to flowering resulted to the least grain yield (GY) (0.9t/ha), delayed days to anthesis (AD) (62.2) and increased anthesis - silking interval (ASI) (2.2) days (Table 6). The mean values for similar variables under optimal moisture and flowering stress were significantly different ($p \leq 0.05$) from those recorded under pre-flowering stress. The mean values for grain yield were significantly different ($p \leq 0.05$) among individual moisture regimes.

Table 6: The effects of moisture stress for pre –flowering, flowering and optimal moisture for various maize variables studied

Water regime	GY (t/ha)	AD (days)	ASI (days)	PH (cm)	EH (cm)	EPP (#)	ER (%)	MOI (%)	NP (#)	MSV (1-5)	SEN (1-10)
Pre flowering stress	0.90c	62.21a	2.23a	106.19c	42.78b	1.00a	13.66a	13.16b	16.32b	1.73a	0.25b
Flowering stress	1.15b	59.14b	1.55b	111.79b	45.33ab	1.05a	9.90b	14.25a	20.12a	1.34b	0.36a
Optimal moisture	1.49a	59.45b	1.54b	117.34a	46.18a	1.00a	5.23c	14.36a	18.91a	1.74a	0.28b
Mean	1.18	60.24	1.77	111.77	44.76	1.02	9.59	13.92	18.45	1.60	0.30
SE$_{\bar{x}}$ (±)	0.04	0.27	0.10	1.04	0.66	0.01	0.53	0.09	0.45	0.05	_
LSD $_{(0.05)}$	0.18	1.01	0.47	3.65	2.79	0.06	3.31	0.46	1.93	0.22	0.04
CV (%)	52.2	6.05	77.6	12.5	19.4	15.1	116.1	9.15	33.8	43.1	-

Means followed by same letters do not differ significantly (P=0.05)

This signifies the importance of water stress on maize at varying stages of development relative to optimal conditions because pre flowering stress affects fertilization where most pollen die before fertilization can take place due to delayed silk emergence. Also apart from its effect fertilization water stress is reported to have a negative effect on the size of the assimilatory structures thus reducing the green leaf area (Ngowi, 2002).

Stress at flowering affects assimilates distribution resulting to kernel abortion (Westgate, 1997). In this case fertilization may be successful but lack of assimilate to the growing embryo results into abortion of kernels. Thus, the least grain yield was observed in pre flowering stress followed by flowering stress while optimal moisture had the highest mean grain yield (Table 6).

With regard to ASI, water deficit increased the average ASI to 2.23 from 1.54 days under well watered conditions. Large ASI values under drought arise from the fact that silk growth and development is much slower compared to tassel growth in some maize genotypes (CIMMYT, 1999; Bolaños and Edmeades., 1997). One of the reasons for these differences in rates of growth under drought is that tassel growth is not sensitive to stress while silk development is very sensitive to moisture stress (Kling and Edmeades, 1997) and this is responsible for large ASI values.

On the other hand, the mean values for ASI did not differ significantly between optimal moisture (well watered) and stress applied at grain filling (flowering drought stress). This implies that silk development between the two regimes were similar. This is because at grain filling stage, stress develops only at a time when most silks have already started to emerge or about to emerge. As a result, the effect of drought on silk development and pollination due to large ASI is not felt much at this stage (Banziger *et al.*, 2000). Therefore ASI per se may not be an effective selection method for drought tolerance when stress is applied at grain filling stage thus the focus should be selection for more ears and delayed leaf senescence (CIMMYT, 1999; Bänzinger *et al.*, 2000).

4.2.1 Correlation of selected variables with grain yield

In this study Pearson correlation coefficients between growth variables and grain yield were calculated and results are as shown on Table 7 which combines results from (Tables 8, 9, 10 and 11). From this study, plant height (PH), ear height (EH) and number of plants (NP) had consistent positive correlation with grain yield across all moisture regimes except at random stress. This implies that as plant height increases, grain yield tended to increase under the respective conditions. Similar trend has been reported by (Ngowi, 2002). Under similar set of conditions, tall plants will usually reach flowering stage at later stage compared to shorter stature plants as indicated by a significant positive correlation ($r = 0.37^*$) between plant height and anthesis date (Table 8). This allows for more time to accumulate assimilates that contribute to grain yield and it accounts for the correlation trend observed between grain yield and PH. In addition tall plants tend to have more vigour which in turn gives rise to bigger cobs or larger grain hence larger grain weight. Plant height, ear height and yield can be selected for or improved simultaneously in breeding programmes because of positive correlations among themselves under certain conditions. However lack of significant positive correlation under random stress (rain fed) suggests that these relations are also dependent on environment (Ngowi, 2002). However it is important to note that enhanced tassel emergence under drought seems to widen ASI due to delayed silk emergence as shown by the negative and significant correlation($r = - 0.49^{***}$) between AD and ASI (Table 8).

Table 7: The correlation of selected growth variable with grain yield under different conditions of water regime

Regime	AD	ASI	PH	EH	EPP	ER	LR	SEN	NP	MSV
Pre flowering stress	-0.23	-0.001	0.49***	0.60***	0.21	0.07	-0.20	-0.30*	0.86***	-0.23
Flowering stress	-0.48***	-0.07	0.66***	0.68***	0.31*	-0.24	-	0.12	0.76***	-0.23
Well watered	0.16	-0.24	0.61***	0.61***	0.18	-0.08	-	-0.21	0.80***	-0.11
Random	0.62**	0.22	0.16	0.26	0.06	-0.02	-	-	0.89**	0.34

Key

*** = significant at 0.001 probability level, ** = significant at 0.01 probability level, * = significant at 0.05 probability level

- = data not collected (not available)

Table 8: Correlation coefficients of selected variables under pre flowering stress

	GY	AD	ASI	PH	EH	EPP	ER	LR	SEN	NP	MSV
GY	1.000	-0.23	-0.001	0.49***	0.60***	0.21	0.07	-0.20	-0.30*	0.86***	-0.23
AD		1.000	-0.49***	0.37**	0.08	-0.31*	-0.31*	0.004	0.13	-0.30*	0.35**
ASI			1.000	-0.28*	-0.19	0.18	0.18	0.06	-0.11	0.04	-0.19
PH				1.000	0.80***	-0.10*	-0.07	-0.26*	-0.16	0.31*	0.11
EH					1.000	-0.01	0.11	-0.24	-0.10	0.47***	-0.08
EPP						1.000	0.36**	0.11	0.08	0.004	-0.11
ER							1.000	0.001	0.09	-0.04	-0.18
LR								1.000	0.44***	-0.14	-0.03
SEN									1.000	-0.32*	-0.04
NP										1.000	-0.21
MSV											1.000

Key

*** = significant at 0.001 probability level, ** = significant at 0.01 probability level, * = significant at 0.05 probability level

Table 9: Correlation coefficients of selected variables under flowering stress

	GY	AD	ASI	PH	EH	EPP	ER	SEN	MOI	NP	MSV
GY	1.00	-0.48***	-0.07	0.66***	0.68***	0.31*	-0.24	0.12	0.003	0.76***	-0.23
AD		1.00	-0.28*	-0.003	-0.09	-0.28*	-0.04	-0.56***	0.41**	-0.41**	0.11
ASI			1.00	-0.14	-0.14	0.06	-0.02	0.26*	-0.23	0.00	-0.07
PH				1.00	0.89***	0.13	-0.21	0.01	0.12	0.57***	-0.19
EH					1.00	0.16	-0.15	0.09	0.12	0.60***	-0.11
EPP						1.00	-0.03	0.05	0.13	-0.06	0.03
ER							1.00	0.17	-0.05	-0.10	-0.12
SEN								1.00	-0.47***	0.30*	-0.20
MOI									1.00	-0.05	-0.04
NP										1.00	-0.33**
MSV											1.00

Key

*** = significant at 0.001 probability level, ** = significant at 0.01 probability level, * = significant at 0.05 probability level

Table 10: Correlation coefficients of selected variables well watered condition

	GY	AD	ASI	PH	EH	EPP	ER	SEN	MOI	NP	MSV
GY	1.000	0.16	-0.24	0.61***	0.61***	0.18	-0.08	-0.21	0.27*	0.80***	-0.11
AD		1.000	-0.21	0.37**	0.34**	-0.15	0.15	-0.36**	0.28*	0.14	0.30*
ASI			1.000	-0.10	-0.07	0.03	-0.02	0.06	0.03	-0.15	0.10
PH				1.000	0.85***	-0.03	0.15	-0.14	0.22	0.56***	0.08
EH					1.000	0.06	0.16	-0.13	0.18	0.51***	0.14
EPP						1.000	-0.12	-0.08	-0.07	-0.14	-0.09
ER							1.000	-0.08	0.01	-0.001	0.00
SEN								1.000	-0.11	0.004	-0.14
MOI									1.000	0.25	0.07
NP										1.000	-0.13
MSV											1.000

Key

*** = significant at 0.001 probability level, ** = significant at 0.01 probability level, * = significant at 0.05 probability level

Table 11: Correlation coefficients of selected variables under random stress (rain fed)

	GYG	AD	ASI	PH	EH	EPP	ER	RLG	SLG	MSV
GYG	1.00	0.62**	0.22	0.16	0.26	0.06	-0.02	-0.41	-0.57	0.34
AD		1.00	0.37	0.21	0.47*	-0.05	-0.09	-0.31	-0.65	0.21
ASI			1.00	-0.04	0.21	0.29	-0.15	0.00	-0.34	0.52*
PH				1.00	0.70***	-0.43	0.22	-0.01	-0.23	-0.18
EH					1.00	-0.23	0.40	-0.25	-0.41	-0.09
EPP						1.00	-0.20	0.16	-0.23	-0.06
ER							1.00	-0.10	0.05	0.32
RLG								1.00	0.15	-0.11
SLG									1.00	-0.11
MSV										1.00

Key: RLG = root lodging, SLG = stem lodging

*** = significant at 0.001 probability level, ** = significant at 0.01 probability level, * = significant at 0.05 probability level

Table 12: Correlation coefficients of selected variable across all conditions of moisture (combined analysis for experiment conducted at Ilonga)

TRAIT	GY	AD	ASI	PH	EH	EPP	ER	SEN	MOI	NP	MSV
GY	1.00	0.07	-0.43***	0.75***	0.73***	0.03	-0.07	0.07	0.60***	0.77***	-0.09
AD		1.00	-0.16	0.26*	0.25*	-0.22	0.23	-0.43***	-0.002	-0.02	0.17
ASI			1.00	-0.37**	-0.30*	-0.24	0.17	-0.17	-0.34**	-0.34**	0.15
PH				1.00	0.81***	-0.14	-0.26*	0.04	0.50***	0.57***	-0.09
EH					1.00	-0.09	-0.10	0.16	0.43***	0.63***	-0.09
EPP						1.00	-0.05	0.26*	0.003	-0.06	-0.05
ER							1.00	-0.21	-0.31*	-0.28*	0.25
SEN								1.00	0.08	0.30*	-0.37**
MOI									1.00	0.57***	-0.08
NP										1.00	-0.36**
MSV											1.00

Key * = significant at 0.05, ** = significant at 0.01; *** = significant at 0.001

Variations in tassel emergence relative to silk emergence arise from the fact that maize is a protandrous crop (i.e. male parts mature earlier than female parts) (Fischer and Palmer, 1984; Westgate, 1997). Studies by Kling and Edmeades (1997) revealed that ear-silk initiation in maize usually starts ten (10) days after tassel initiation. Thus tassel will usually tend to emerge first. More over tassel growth has been reported to be less sensitive to environmental factors than silking (Kling and Edmeades, 1997; Wastegate, 1997). This explains why drought delays silk emergence- resulting into wider ASI. There are exceptions where female parts mature earlier than male parts (i.e. protogny) but this occurs when there is vigorous growth and the plant is unstressed (Fischer and Palmer, 1984; Kling and Edmeades, 1997; Westgate, 1997).

Physiologically under normal conditions, plants with short anthesis date would reach pollen shedding early. But also early flowering has been cited as one of the survival mechanisms in plants under water stress (Nilsen and Orcutt, 1996). Early pollen shedding before stress intensifies increases the chances of fertilization and hence grain yield. However, in this study, shorter days to anthesis could not be associated with grain yield under pre flowering drought stress as had been reported by other workers (Chapman and Edmeades, 1999; Bänzinger *et al.*, 2000). Lack of significant correlation (Table 7) between grain yield and days to anthesis under pre flowering, well watered as well as combined moisture regimes contradicts findings reported by Ngowi (2002) and this could probably be due to the fact that genotypes used were from a population with a narrow genetic base. However, the correlations were positive and significant under random but negative and significant under flowering stress. In his study Ngowi (2002) reported positive correlations between grain yield and antheis date despite the variation in soil moisture conditions. From this study it shows that Ngowi (2002) agrees with some of these findings where the relationship between AD and GY seem to be under the influence of the environment rather than genetic. Grain yield seems to be negatively influenced by leaf senescence (SEN) and positively by number of plants harvested (NP) (Table 8) which had respectively significant positive and negative correlations with grain yield. Leaf senescence contributes negatively to grain yield because it results into death of the photosynthetic area (i.e. the proportion of green leaves). Leaves are responsible for feeding the growing ears thus senescence will reduce yield. Thus traits associated with drought tolerance in addition to drought escape become important selection criteria.

Under conditions of moisture stress, many growth variables often referred to as secondary traits tend to affect yield negatively. But the extent of individual effects differs depending on the timing and intensity of stress and also the genetic differences among maize genotypes. From this study, under conditions of moisture stress plant height (PH), ear height (EH) and ears per plant (EPP) had positive effects on grain yield. On the other hand anthesis dates (AD) had significant negative correlation with grain yield only under flowering stress while leaf senescence (SEN) had negative significant correlation under pre flowering stress. The two are associated with loss of photosynthetic area under stressful conditions because leaf senescence results in reduction of the proportion of green leaves as reported by Hoffer (1998). As a result, long AD allows time for senescence to intensify causing yield reduction.

The number of ears per plant (EPP) was also positively correlated with grain yield but significant correlation (r = 0.31*) was observed only under moisture stress applied at flowering (Table 7). Normally drought at flowering tends to affect grain formation and hence the grain yield; thus positive correlations indicate that grain yield is influenced by number of ears per plant (EPP) under such conditions which is in turn adversely affected by days to anthesis (r = - 0.28*) (Table 9) .That is why grain filling is regarded as a critical stage because of associated yield reduction under stressful conditions. Days to anthesis (AD) showed significant negative correlation with grain yield at flowering stress (r = - 0.48**) but positive at random stress (r = 0.62**). The sign has an implication on particular moisture regime, while negative correlation suggests that longer AD resulted in yield reduction as it allows stress to intensify and to cause abortion of kernels and reduced photosynthesis. Under random stress longer AD allows for accumulation of more food reserves for the growing embryo hence a positive correlation. Further analysis on ASI indicated consistent negative correlations (r = -0.001, r = -0.07 and r = -0.24) with grain yield (GY) under pre flowering stress, flowering stress and optimal moisture conditions respectively.

However, the association between ASI and grain yield were very weak and insignificant under all conditions of moisture, but the values observed were similar in sign to findings reported by CIMMYT (1999) and Diallo *et al.* (2002) where, significant and negative relationships were reported. Lack of significant correlations for the above variables could be due to differences in environments and sets of genotypes used.

Evidence from literature support shorter ASI for improving yield under drought (Bänzinger *et al.*, 2000; Diallo *et al.*, 2002). This is because synchronization of anthesis and silk emergence in maize ensures maximum fertilization, a trait many breeders have been seeking to improve (Edmeades *et al.*, 1997a; Westgate, 1997). Thus negative correlation implies that genotypes with high and positive ASI values are associated with low grain yield hence not a good characteristic under drought. Combined analysis indicated negative but significant correlation between ASI and GY (r = - 0.43**), between leaf senescence and AD (r = -0.43***) (Table 12). Large ASI under drought cause yield reduction because of the resulting inefficiency in fertilization as more pollen grains die before silk emergence (Kling and Edmeades, 1997), causing grain abortion and hence grain yield.

With regard to senescence, shorter days to anthesis seem to increase senescence of lower leaves as evidenced by the significant negative correlations (r = - 0.43***) between AD and SEN because more assimilate will be directed to the developing grains (Fischer and Palmer, 1984). Similarly more number of ears per plant (EPP) accelerate senescence of leaves as shown by positive correlation with leaf senescence (r =0.26*). There is a possibility that at this stage more assimilate is diverted to the growing ears because of high source – sink gradient.

4.3 Performance of Maize Genotypes for Yield and Drought Tolerance under Moisture Stress and Well Watered Conditions

4.3.1 Evaluation of maize genotypes under pre flowering stress

The idea behind this type of experiment is to identify cultivars that are able to maintain high yield under drought, but also show favourable values of secondary traits that are associated with drought tolerance. Data from (Table 13) indicate that there were significant differences ($p \leq 0.05$) between genotypes for grain yield (GY), plant height (PH), ear height (EH), grain moisture (MOI),maize streak virus severity (MSV) antheis – silking interval (ASI) and leaf senescence (SEN).

Table 13. Grain yield (t/ha) and other important agronomic traits for QPM-OPV evaluated under managed stress at Ilonga – Tanzania (pre – flowering drought stress). ASI: ≤1 = very good, 2 = good, 3 = average, 4 = poor, 5 = very poor

Entry	Pedigree	GY		AD	ASI	PH	EH	EPP	ER	LR	SEN	MOI	NP	MSV
		t/ha	Rank	D	D	Cm	cm	#	%	1-5	1-10	%	#	1-5
1	EEQPMOPV-1-EA-#	1.14	4	61.1	3	104.4	42.6	1.01	8.4	2.1	0.2	12.5	19.9	1.0
2	EEQPM-HT-#	1.06	5	60.2	2	118.1	49.1	1.05	11.4	2.2	0.3	12.2	17.3	2.3
3	EEQPM-6-EA-#	0.88	11	62.9	5	112.9	42.9	0.86	15.7	1.8	0.2	10.8	13.6	1.3
4	EEQPM-9-EA-#	0.52	18	60.1	1	94.9	37.0	1.11	20.1	1.9	0.3	12.6	12.4	1.7
5	EEQPM-8-EA-#	0.39	19	61.4	3	105.9	41.6	0.94	10.6	2.2	0.2	13.6	13.2	1.5
6	EEQPM-13-EA-#	0.84	13	59.1	1	92.5	40.5	0.95	13.1	2.2	0.2	12.5	18.3	1.5
7	EEQPM-16-EA-#	0.84	14	60.2	3	107.1	41.7	0.89	8.9	2.1	0.2	12.0	17.1	2.3
8	EEQPM-18-EA-#	0.76	15	65.8	1	119.9	41.8	1.00	25.0	2.0	0.3	13.0	16.1	2.4
9	EEQPM-29-EA-#	1.00	9	61.2	1	113.8	43.1	0.98	10.9	2.5	0 3	14.1	20.9	1.3
10	EEQPM-34 –EA-#	1.43	2	62.8	3	111.4	47.9	0.90	9.5	2.4	0.1	15.9	22.4	2.1
11	EEQPM-36-EA-#	0.73	16	63.3	2	95.0	42.1	1.11	22.6	2.4	0.3	12.3	14.2	2.3
12	EEQPM-38-EA-#	0.54	17	60.4	3	97.0	38.4	1.09	13.4	2.6	0.3	12.7	13.9	1.5
13	EEQPM-45-EA-#	1.01	8	64.5	0	101.9	42.2	1.12	20.2	2.1	0.3	13.0	13.9	2.3
14	EEQPM-49-EA-#	1.01	7	62.4	3	100.1	37.5	1.13	31.5	1.8	0.2	14.0	17.1	2.1
15	EEQPM-21-EA-#	0.96	10	60.3	3	96.9	44.0	1.03	15.1	2.6	0.5	13.2	19.8	1.1
16	EEQPM-33-EA-#	0.36	20	63.9	1	109.0	45.7	1.09	12.7	2.0	0.3	12.5	11.1	1.8
17	EEQPM-42-EA-#	1.41	3	62.0	3	116.4	48.0	1.02	15.3	1.9	0.2	13.8	18.6	1.1
18	EEQPMS2-#-GEASP-1-#	0.86	12	64.9	2	108.8	48.3	0.74	13.0	1.9	0.3	14.1	16.1	1.5
19	POOL15QPM-SR-#-#	1.03	6	64.6	1	116.9	46.5	1.06	4.5	2.5	0.2	13.9	15.6	2.0
20	KATUMANI	0.07	21	57.3	5	85.1	32.3	1.01	12.7	2.3	0.2	13.1	7.1	2.3
21	Local check1	1.94	1	66.0	1	130.9	54.2	1.00	12.8	1.7	0.4	14.6	24.2	1.0
Mean		0.90	11	62.1	2.2	106.6	43.2	1.01	14.6	2.1	0.3	13.2	16.3	1.7
LSD (0.05)		0.51	6	4.9	2.4	14.6	8.1	0.24	18.8	0.8	0.2	2.4		1.0
P		***		-	**	***	**	-	-	-	*	*	-	*
CV		58.1		5.0	66.	8.1	11.1	15.23	79.7	22.8	46.	11.8	32.5	40.6

From this experiment, the mean yield was 0.9 t/ha an equivalent of 9 bags of maize for 100 kg bag. It has been reported that for a well managed drought experiment the average yield should range between 1 to 2 t/ha (Bänzinger *et al.*, 2000; Vivek *et al.*, 2005). Based on yield data, Local Check1, EEQPM-34-EA-#, and EEQPM-42-EA-# had higher yields compared to national averages estimated at 1.2 t/ha (Temu, 2005). Corresponding values of ASI, EPP and leaf rolling (LR) from the same genotypes above except for EEQPM-34-EA-# show favourable data with selection criteria stated in Bänzinger *et al.* (2000) in which small ASI values (≤3), more EPP (> 1.0) and small LR score (1-2) are preferable since they are characteristic of drought tolerant maize plants (Vasal *et al.*, 1997). It is important to note that entry 10 (EEQPM-34- EA-#) had exceptional performance in terms of yield despite its relatively poor EPP and LR values. At the same time some genotypes such as entries number 4(EEQPM-9-EA-#), 8(EEQPM-18-EA-#) and 16(EEQPM-33-EA-#) had exceptionally low yield despite being good in drought tolerance variables. These genotypes can be sources of genes of specific traits in improvement programmes

Studies have revealed that, under drought, genetic variability for ASI among maize germplasm increases (Bolaños and Edmeades, 1997). Thus it becomes easier to identify potential drought tolerant genotypes for use in production or in improvement programmes. From the current study there was no significant ($p > 0.05$) variation between genotypes in the number of ears per plant (EPP) under pre flowering moisture stress (Table 13). The mean value for EPP was 1.01 suggesting that the genotypes were good in this trait because this number has also been suggested by other workers as best selection criteria for drought tolerance (Banzinger *et al.*, 2000). Genotypes are considered barren when the mean EPP is less than one (Chapman and Edmeades, 1999). Entry 14 had the highest EPP value (1.13) and the fact that the mean EPP observed is 1.01 suggests that preliminary selection improved EPP such that most genotypes were good in this trait as 14 out of 21 entries had 1 or more ear per plant. However, since genotypes did not differ significantly on EPP, it is likely that the genetic base has been narrowed through cycles of selection for only few traits such as EPP and LR which did not show significant differences between genotypes. Efficient cultivars must maintain a reasonable number of grains for a given ear (i.e. an ear must contain at least one developed grain). Lower EPP values were observed for entries 18(EEQPMS2-#-GEASP-1#) and 3(EEQPM-6-EA-#) suggesting that these genotypes had relatively high degree of barren ears (Zaidi, 2002; Vivek *et al.*, 2005). The fact that some genotypes such as entries 4 (EEQPM-9-EA-#) and 6 (EEQPM-13-EA-#), had below average yields despite having good ASI values, suggests that there were inefficiencies in the ability to mobilize pre anthesis assimilate to the grain. But also under harsh weather the silks tend to dry up quickly such that fertilization does not take place so effectively (Kling and Edmeades, 1997). This explains the reasons why short ASI for some genotypes did not necessarily have corresponding high grain yield, as well as lack of significant correlation between ASI and grain yield for pre flowering stress (Table 7). Under this stress the best eight performing genotypes based on yield data and associated variables are presented on Table 14.

Table 14: Best eight selected entries under pre flowering drought stress based on grain yield (in ranked order) and number of ears per plant

Enter	Pedigree	Yield (t/ha)	ASI	EPP	LR	SEN
21	Local check1*	1.94	1	1.00	1.7	0.4
17	EEQPM-42-EA- #	1.41	3	1.02	1.9	0.2
1	EEQPMOPV-1-EA	1.14	3	1.01	2.1	0.2
2	EEQPM-HT-#	1.06	2	1.05	2.2	0.3
19	POOL15QPM-SR-#-#	1.03	1	1.06	2.5	0.2
14	EEQPM49-EA-#	1.01	3	1.13	1.8	1.8
13	EEQPM45-EA- #	1.01	0	1.12	2.1	0.3
9	EEQPM-29-EA-#	1.00	1	1.00	2.5	0.3

*SITUKA M1

4.3.2 Stress at grain filling (flowering drought stress)

Stress that is applied at flowering targets grain filling, and drought at this stage accelerates senescence of leaves. This minimizes the proportion (percentage) of green leaves hence the size of the source (amount of assimilates) available for the sinks leading to barrenness of cobs. In this experiment, the average yield was relatively higher at 1.12 t/ha (Table 15) compared to 0.9t/ha observed for pre flowering stress. Also the order of ranking for grain yield observed under pre flowering stress (Table 13) among genotypes was altered under flowering drought stress due to differential response of individual genotypes to drought under varying conditions of water stress (see also Tables 9 and 11).

Table 15: Grain yield (t/ha) and other important agronomic traits for QPM OPV evaluated under flowering drought stress at Ilonga Tanzania.

Entry	Pedigree	GY		AD	ASI	PH	EH	EPP	ER	SEN	MOI	NP	MSV
		t/ha	Rank	D	D	Cm	Cm	#	%	1-10	%	#	1-5
1	EEQPMOPV-1-EA-#	1.45	3	55.8	1.6	106.8	45.8	1.06	3.7	2.5	13.7	25.3	1.0
2	EEQPM-HT-#	1.07	13	59.7	1.3	117.4	48.6	1.05	1.8	1.9	14.1	16.7	1.5
3	EEQPM-6-EA-#	0.74	19	60.6	3.2	108.3	39.2	1.04	1.1	1.6	13.5	16.1	1.5
4	EEQPM-9-EA-#	0.77	18	60.3	2.0	108.6	40.0	0.91	3.6	1.7	14.6	18.7	1.6
5	EEQPM-8-EA-#	1.30	6	57.9	1.2	114.6	45.8	1.10	1.3	1.9	15.2	25.6	1.2
6	EEQPM-13-EA-#	1.20	11	58.5	1.2	109.4	44.2	1.17	7.4	1.9	15.2	18.9	1.4
7	EEQPM-16-EA-#	1.12	12	59.2	1.9	116.5	42.6	1.09	2.5	1.9	14.3	20.8	1.1
8	EEQPM-18-EA-#	1.23	8	60.4	1.0	112.6	48.5	0.95	4.1	1.6	14.2	23.8	1.2
9	EEQPM-29-EA-#	1.22	10	59.0	1.1	117.3	45.8	1.23	0.4	1.6	14.5	16.5	1.0
10	EEQPM-34 –EA-#	1.44	4	58.3	1.3	117.3	47.3	1.12	6.1	1.8	13.7	21.3	1.2
11	EEQPM-36-EA-#	0.63	21	61.8	0.9	105.5	37.3	0.99	11.3	1.5	14.2	14.2	1.7
12	EEQPM-38-EA-#	0.81	17	58.9	2.0	112.0	43.9	1.05	5.8	1.9	13.9	18.9	1.3
13	EEQPM-45-EA-#	1.25	7	58.5	0.5	102.0	40.9	1.08	7.7	2.4	13.9	18.6	1.5
14	EEQPM-49-EA-#	1.33	5	57.5	1.7	115.8	46.5	1.12	6.4	2.3	13.9	23.7	1.2
15	EEQPM-21-EA-#	1.23	9	62.1	1.8	109.6	41.4	1.13	1.5	1.7	14.7	21.1	1.5
16	EEQPM-33-EA-#	0.89	16	57.3	2.3	110.4	46.0	1.09	2.8	1.9	13.3	16.5	2.0
17	EEQPM-42-EA-#	1.03	14	58.8	1.8	114.6	43.6	0.84	4.8	1.4	14.4	18.8	1.3
18	EEQPMS2-#-GEASP-1-#	0.93	15	58.1	1.4	116.9	45.0	1.04	3.9	2.1	14.0	19.7	1.1
19	POOL15QPM-SR-#-#	1.63	1	61.2	1.9	128.8	57.2	1.06	11.7	2.2	15.7	27.9	1.4
20	KATUMANI	0.72	20	56.8	1.7	98.7	40.8	1.16	17.4	2.4	13.4	14.4	1.3
21	Local check1	1.58	2	62.0	0.9	130.8	58.6	1.01	4.3	1.7	15.2	25.2	1.1
Mean		1.12	11	59.2	1.6	113.1	45.2	1.06	5.2	1.9	14.3	20.1	1.3
LSD (0.05)		0.62	6	3.3	-	15.4	-	-	8.3	-	1.2	7.6	-
CV		50.7		4.3	73.2	8.4	16.2	11.04	95.8	47.2	5.4	28.2	32.9
P		**		**	Ns	*	Ns	Ns	*	Ns	**	**	Ns

Table 16: Yield data under flowering drought stress of best eight entries in ranked order

Entry	Pedigree	Yield (t/ha)	EPP	SEN	ASI
19	POOL15QPM-SR-#-#	1.63	1.06	0.4	1.9
21	LOCAL CHECK 1	1.58	1.01	0.3	0.9
1	EEQPMOPV-1-EA	1.45	1.06	0.5	1.6
10	EEQPM-34-EA-#	1.44	1.12	0.3	1.3
14	EEQPM-49-EA-#	1.33	1.12	0.5	1.7
5	EEQPM- 8- EA- #	1.30	1.10	0.4	1.2
13	EEQPM45-EA- #	1.25	1.08	0.5	0.5
15	EEQPM-21- EA- #	1.23	1.13	0.3	1.8

However, it is important to note that though some entries viz 1(EEQPMOPV-1-EA-#), 13(EEQPM-45-EA-#), 14(EEQPM-49-EA-#), 19(POOL15QPM-SR-#-#) and 21(Local check1) changed their ranks, are still within the best eight entries under both scenarios and can thus be recommended for areas suffering both pre flowering and terminal drought. Data from (Table 15) indicate no significant differences ($p > 0.05$) between genotypes for leaf senescence (SEN). This implies that no meaningful selection can be made by using the criterion of senescence although the experiment was meant to accelerate senescence. However, yield variations were significant ($p \leq 0.01$) among entries evaluated suggesting the presence of genetic variation for grain yield, Entry 19 had the highest grain yield (1.63 t/ha) and entry 11 had the least grain yield (0.63t/ha). The difference in yield between genotypes can be attributed to the number of plants harvested where entry 19 (27.9 plants) entry 11 were (14.2 plants) that survived to produce at least a single ear. Most of the maize genotypes had a good stay green characteristic which is essential for photosynthesis The highest leaf senescence recorded was 2.5 (entry 1), this means that at most 25 percent of leaves had senesced while at least 75 percent of leaves stayed green. High senescence level affects grain yield because kernel weight is also affected due to reduced photosynthesis (Bänzinger *et al.*, 2000) when stress occurs at flowering. Also when moisture stress is severe, plants tend to die earlier than normal due to senescence resulting in reduced effective grain filling period. The effect of drought variables on yield depend on the environmental stress prevailing. When stress is severe yield losses of up to 50 percent have been reported (Raj, 1987). However, under this experiment, ASI remained relatively less affected and the variation between genotypes for grain yield were relatively less compared to pre flowering stress.

Physiologically some maize plants tend to establish large leaf area, more kernels, and ears and genotypes exhibit variation in the amount of sink translocated. According to Bänzinger *et al.* (2000), efficient cultivars will yield higher than non-efficient ones when sink becomes a limiting factor because of differences in capacity to absorb more assimilate. However under terminal drought where the source becomes a limiting factor most genotypes may not be able to fully express their potential due to the fact that the supply of assimilates will limit grain yield. Moreover the rate of photosynthesis between cultivars does not differ significantly (Fischer and Palmer, 1984). This partly explains the trend observed in Table 15 relative to Table 13, where yield differences among genotypes is relatively high under pre flowering stress compared to stress at flowering. The trend can be fully explained by differential response of genotypes under different environments i.e. G x E interaction. The results indicate that pre flowering is more critical and that discrimination between genotypes is more pronounced under this condition. Thus selection for drought tolerance should be done under pre flowering stress. However it is also important to combine data from other moisture regimes because not all traits can be recorded under a single moisture regime (Table 4).

4.3.3 Optimal moisture / well watered (managed)

Water is applied so that soil moisture condition is enough to allow normal crop development. This experiment was conducted during rain free period, the objective was to determine the yield potential of genotypes under optimal moisture and establish a benchmark for comparing maize performance under stress and non stress conditions. Under this experiment the average grain yield was 1.48 t/ha (Table 12).

Table 17: Grain yield (t/ha) and other important agronomic traits QPM evaluated under optimal conditions of moisture (well watered) at Ilonga, Tanzania

Entry	Pedigree	GY		AD	ASI	PH	EH	EPO	EPP	TL	ER	SEN	G. moist	NP	MSV
		t/ha	Rank	D	D	Cm	Cm	0-1	#	Cm	%	1-10	%	#	1-5
1	EEQPMOPV-1-EA-#	0.85	20	58.9	1	108.5	36.1	0.35	0.98	35.3	15.5	0.2	14.0	15.2	1.2
2	EEQPM-HT-#	1.45	11	58.3	2	127.2	46.2	0.38	0.89	37.1	11.6	0.4	14.4	19.3	1.7
3	EEQPM-6-EA-#	0.97	19	61.7	2	109.8	38.2	0.37	1.08	37.2	4.6	0.2	15.3	11.5	2.3
4	EEQPM-9-EA-#	1.79	8	63.0	2	124.7	59.9	0.48	1.01	36.3	12.2	0.3	14.3	19.6	2.1
5	EEQPM-8-EA-#	1.01	17	56.8	2	102.1	38.7	0.38	1.13	36.5	2.2	0.2	13.4	15.1	1.4
6	EEQPM-13-EA-#	1.21	14	56.8	2	103.6	36.0	0.36	0.95	35.8	8.6	0.3	14.8	22.1	1.2
7	EEQPM-16-EA-#	1.50	10	60.0	1	132.8	49.5	0.40	1.05	32.7	6.5	0.3	14.6	22.1	1.6
8	EEQPM-18-EA-#	1.59	9	62.1	1	129.7	49.3	0.39	0.92	36.3	12.5	0.3	14.7	19.1	1.7
9	EEQPM-29-EA-#	2.04	4	61.1	1	126.1	47.4	0.39	1.03	34.0	10.8	0.2	15.1	21.0	1.6
10	EEQPM-34 –EA-#	2.08	2	63.1	0	127.0	51.4	0.40	1.01	32.4	6.6	0.3	14.8	24.8	2.2
11	EEQPM-36-EA-#	0.98	18	60.0	2	112.2	40.2	0.37	1.00	33.9	11.2	0.3	13.8	15.1	2.0
12	EEQPM-38-EA-#	1.08	16	56.2	2	111.9	46.0	0.41	1.02	34.7	15.9	0.3	13.6	14.4	2.3
13	EEQPM-45-EA-#	2.08	3	56.8	2	118.3	52.0	0.42	1.10	34.5	12.4	0.3	15.2	21.6	2.7
14	EEQPM-49-EA-#	1.30	13	57.7	2	113.6	45.5	0.41	0.91	36.8	15.3	0.3	15.2	18.8	1.6
15	EEQPM-21-EA-#	1.16	15	61.1	2	118.9	45.4	0.39	0.97	37.2	2.8	0.3	14.0	17.3	1.8
16	EEQPM-33-EA-#	1.94	5	59.8	2	118.8	51.2	0.42	1.00	35.2	7.7	0.2	14.1	23.2	2.1
17	EEQPM-42-EA-#	1.42	12	59.7	2	126.1	43.8	0.37	0.96	37.6	7.2	0.3	13.6	21.1	1.0
18	EEQPMS2-#-GEASP-1-#	1.87	6	58.4	1	118.4	45.8	0.41	1.20	36.1	12.2	0.3	14.1	18.8	1.7
19	POOL15QPM-SR-#-#	1.80	7	60.6	1	122.4	50.1	0.40	0.92	32.8	7.3	0.3	15.1	21.6	1.7
20	KATUMANI	0.78	21	53.5	2	107.1	45.8	0.42	0.99	35.5	5.7	0.4	12.7	14.0	1.4
21	Localcheck1	2.12	1	63.8	1	136.1	60.8	0.45	0.98	35.4	18.9	0.3	14.8	21.5	1.2
Mean		1.48	11	59.5	1.5	118.8	46.6	0.40	1.00	35.4	9.9	0.3	14.4	18.9	1.7
Lsd (0.05)		0.88	6	3.7	-	13.9	10.6	0.06	-	-	-	-	-	-	-
Cv		38.08		4.7	71.0	8.0	14.8	9.56	18.18	-	75.5	33.6	9.6	26.7	44.8
P		*		***	Ns	***	**	*	Ns	Ns	Ns	Ns	Ns	Ns	Ns

Thus the yield differences between optimal (well watered) and pre flowering moisture stress (0.9 t/ha) was 39 %, this is within the range reported in CIMMYT (1999); Bänzinger *et al.* (2000); Betran *et al.* (2003a) for a successful drought experiment that range between 20- 50 percent. Entry 21 (Local check1) had the highest grain yield (2.21 t /ha) under well watered conditions (Table 17). Data from experiment conducted under optimal (well watered) condition indicates that high grain yield is to some extent associated with long days to anthesis and has been reported by Ngowi (2002). Evidence from Table 17, shows that 2/3 (66 percent) of genotypes with above average AD under optimal moisture had corresponding above average grain yield, for example entries 4, 7, 8, 9, 10, 16, 19 and 21. The trend is more pronounced for genotypes evaluated under random stress (section 4.3.4) where 92.8% of the genotypes with above average days to anthesis also had corresponding above average grain yield. This partly explains for the significant positive correlation observed between GY and AD (Table 11). When moisture is not limiting, high grain yield tends to be associated with longer AD. This means the longer the maize plant is exposed to radiation, the higher the yield (Fischer and Palmer, 1984; Bänzinger *et al.*, 2000) because the plant is able to accumulate more food reserves for the developing seeds as shown in the following relationship:-

GY = RAD x %RI x GLD x RUE x HI, where:-

RAD = incident radiation per day (MJ/m^2 or MJ/ha)

%RI = fraction of incident radiation intercepted by green leaves (over the crop life cycle)

GLD = green leaf duration or number of days leaves stay green

RUE = radiation use efficiency (g per MJ)

HI = harvest index (proportion of shoot dry matter that is grain)

The above equation implies that the longer the maize plant stays green the higher the yield provided water and other nutrients such as Nitrogen are not limiting. This explains the contrasts for yield differences observed between water regimes as determined by days to anthesis (AD). Other workers also support yield advantage of later flowering maize cultivars over early flowering cultivars when moisture is not limiting (Edmeades *et al.*, 1997a; Mugo and Njoroge, 1997), because the effective grain filling period is extended. Based on yield data the best eight genotypes are shown in (Table 18).

Table 18: Grain yield with corresponding days to flowering for best eight ranked genotypes under optimal moisture regime

Entry	Pedigree	Yield (t/ha)	Days to anthesis
21	Local check1*	2.12	63.8
10	EEQPM-34-EA-#	2.08	63.1
13	EEQPM45-EA- #	2.08	56.8
9	EEQPM29- EA-#	2.04	61.1
16	EEQPM33-EA-#	1.94	59.8
18	EEQPMS2-# GEASP-1-#	1.87	58.4
19	POOL15QPM-SR-#-#	1.80	60.6
4	EEQPM9- EA-#	1.79	63.0

4.3.4 Random stress (rain fed moisture regime)

In well watered (managed) moisture regime, soil moisture is monitored and maintained at sufficient level to allow normal crop development. For the case of random moisture regime (rain fed), the soil moisture is not regulated because the experiment is entirely dependent on natural rain. Therefore random stress data represents data from field conditions where the entries were managed under rain fed conditions. The objective was to compare performance of same genotypes under both managed moisture and rain fed (which represents farmer condition because maize is still dominantly grown under rain fed conditions. This experiment had generally high average grain yield (2.27t/ha) taller plants (PH) with longer days to anthesis (AD) (Table 19).

Table 19: Grain yield (t/ha) and other important agronomic traits QPM evaluated under optimal conditions of moisture (random stress) at ARI – Selian, Arusha – Tanzania

Entry	Pedigree	GY		AD	ASI	PH	EH	EPP	ER	Root Lodge	Stem Lodge	P.sorg	MSV
		t/ha	Rank	D	D	Cm	Cm	#	%	%	%	1-5	1-5
1	EEQPMOPV-1-EA-#	2.3	19	80	3	148	65	1.0	0	2	3	3.0	1.1
2	EEQPM-HT-#	2.9	8	80	3	157	71	1.0	2	2	7	3.3	1.1
3	EEQPM-6-EA-#	2.2	20	84	3	157	77	1.0	3	1	6	3.6	1.3
4	EEQPM-9-EA-#	2.6	14	81	3	151	71	1.0	2	2	11	3.0	1.2
5	EEQPM-8-EA-#	2.6	13	85	3	145	66	1.0	4	2	5	3.0	1.5
6	EEQPM-13-EA-#	3.0	6	76	3	140	61	1.0	4	0	8	3.1	1.8
7	EEQPM-16-EA-#	3.6	2	84	3	152	76	1.0	3	0	2	3.0	1.3
8	EEQPM-18-EA-#	2.7	11	80	3	164	72	1.0	0	2	3	2.9	1.4
9	EEQPM-29-EA-#	3.1	3	85	3	147	66	1.0	0	0	9	3.5	1.3
10	EEQPM-34 -EA-#	2.3	17	83	3	142	77	1.0	4	1	5	3.2	1.2
11	EEQPM-36-EA-#	2.5	15	82	4	168	82	1.0	5	1	4	3.4	1.6
12	EEQPM-38-EA-#	2.4	16	82	4	145	65	1.0	1	4	7	2.7	1.7
13	EEQPM-45-EA-#	2.7	10	83	4	136	65	1.1	0	1	4	3.0	1.4
14	EEQPM-49-EA-#	2.3	18	82	3	148	68	1.0	0	1	6	3.8	1.2
15	EEQPM-21-EA-#	3.1	5	83	3	144	69	1.0	1	1	5	3.1	1.5
16	EEQPM-33-EA-#	2.8	9	82	4	137	69	1.1	1	2	2	2.6	1.4
17	EEQPM-42-EA-#	2.9	7	79	3	146	67	1.1	2	2	6	3.5	1.2
18	EEQPMS2-#-GEASP-1-#	2.7	12	84	4	141	66	1.0	0	0	6	3.6	1.5
19	POOL15QPM-SR-#-#	3.1	4	86	4	155	79	1.0	1	0	4	3.3	1.3
20	KATUMANI	1.2	21	70	3	140	64	1.0	2	2	16	2.7	1.2
21	Localcheck1	4.0	1	87	4	153	76	1.0	2	1	3	2.9	1.7
Mean		2.27	11	81.8	3.4	148.4	70.1	1.02	1.6	1.3	5.8	3.1	1.4
Lsd $_{(0.05)}$		0.63	6	3.6	-	-	-	-	-	-	6.3	-	-
Mse		014		4.5	0.7	113.1	58.5	0.00	6.1	2.9	13.9	0.2	0.0
Cv		13.71		2.6	24.1	7.2	10.9	2.90	153.4	131.9	64.4	15.4	7.3
P		***		***	Ns	Ns	Ns	Ns	Ns	Ns	*	Ns	Ns

Because the experiment was conducted under a different set of environment (Selian Arusha), with different weather and soil characteristics, long AD relative to those observed for experiments established at Ilonga, were mainly due differences in temperature between the two sites. Ilonga lies at 306m above sea level whereas Selian lies at 1390m a.s.l. Temperatures are generally higher at Ilonga by virtue of their elevations. High temperatures cause high metabolic rates in maize plants as a result of more heat units available at given time and hence faster growth and this account for the observed differences in AD between the two sites. In their studies on maize growth, Fischer and Palmer (1984) found that an increase in the mean temperature shortened the vegetative phase which is also associated with yield penalty (Banzinger *et al.*, 2000). More over grain- weight is product of growth rate and effective grain filling period thus given that the growth rate is small at Arusha the effective grain filling period becomes extended. This gives rise to high grain yield compared to fast growing plants at Ilonga where temperatures are likely to be relatively higher. Further evidence comes from the fact that AD is positively correlated with grain yield under random stress (Table 11) and support the effect of AD on yield when water is not limiting.

Other plant characteristics such as stem lodging were significantly different between genotypes ($p \leq 0.05$) but root lodging percentage did not show significant differences between genotypes (Table 19). Entry 20 (Katumani) had the highest percentage of stem lodged plants (16%) compared to other genotypes. This entry had consistent short AD across moisture regimes; this implies that it reaches maturity earlier than other entries and lodges because the stem becomes weak due to aging. More over Katumani seems to have poor adaptation because it had consistent poor performance across all moisture regimes (Tables 8, 10 and 12). Generally, both root lodging and stem lodging were not associated with any variables as shown by lack of significant correlation with other variables (Table 11). Also lack of comparable data for lodging from experiment at Ilonga due to effects of termites means no sufficient inferences can be derived. Table 20 present best eight (8) genotypes based on grain yield rank for random moisture management at Selian, Arusha with their corresponding days to anthesis (AD) in which only three entries viz 21, 9 and 19 remained among the best eight as it was for optimal moisture (Table 18)

Table 20: Yield data of best eight entries in ranked order from random moisture management at ARI- Selian

Entry	Pedigree	Yield (t/ha)	days to 50% flowering
21	Local Check1	4.0	87
7	EEQPM-16-EA-#	3.6	84
9	EEQPM-29-EA-#	3.1	85
19	POOL15QPM-SR-#-#	3.1	86
15	EEQPM-21-EA-#	3.1	83
6	EEQPM-13-EA-#	3.0	76
17	EEQPM-42-EA-#	2.9	79
2	EEQPM-HT-EA-#	2.9	80

4.4 Identification of Better Sources of Tolerance to Drought

As regards to drought tolerance best genotypes were identified by combining data on grain yield with secondary traits associated with drought tolerance by means of selection index. In this study genotypes were subjected to various conditions of moisture regimes and evaluated for strength of traits associated with drought tolerance. The idea behind is to find potential drought tolerant genotypes with the following characteristics; small ASI values, more number of ears per plant (EPP), unrolled (turgid) leaves(LR), less senescence (stay green) of leaves (SEN) all in the same background - when these genotypes are subjected to moisture stress. Based on the criteria stated above (i.e. selection index), the following are best eight entries with good sources of drought tolerance viz; 1(EEQPMOPV-1-E-A-#), 6 (EEQPM-13-EA-#), 10 (EEQPM-34-EA-#), 13 (EEQPM-45-EA-#), 14 (EEQPM-49-EA-#), 17 (EEQPM-42-EA-#), 19 (POOL15QPM-SR-#-3) and 21 (Local Check 1) (Table 21). It is important to note that an index value is the total sum of traits under consideration multiplied by the selection weight for each trait. A given genotype can have large index value despite being poor in certain traits because it was exceptionally good in few traits. This is the case with entry 6 which has high index value compared to entries 2, 9, 15. This is because these genotypes were poorer in one of the following traits, Plant height (PH), Leaf rolling (LR), Leaf senescence (SEN) and Anthesis date (AD) (Table 21). This implies that genotypes which are exceptionally good in few traits but poor grain yield can provide source material for breeding for specific traits in genetic improvement programmes.

Table 21: Selection indices for the 21 genotypes evaluated for pre-flowering stress

Entry	Pedigree	Index	GY	Rank	AD	ASI	PH	EH	EPP	ER	LR	SEN	MOI	NP	MSV
			t/ha	#	D	D	Cm	cm	#	%	1-5	1-10	%	#	1-5
1	EEQPMOPV-1-EA-#	3.62	1.12	4	61.1	2.5	103.6	42.2	0.99	8.9	1.5	0.2	12.5	19.9	1.0
2	EEQPM-HT-#	0.62	1.05	5	60.2	2.4	117.5	48.8	1.01	7.5	1.6	0.3	12.2	17.3	2.3
3	EEQPM-6-EA-#	-3.69	0.86	12	62.9	4.6	112.1	42.4	0.86	22.4	1.4	0.2	10.8	13.6	1.3
4	EEQPM-9-EA-#	-0.10	0.55	18	60.1	1.1	94.2	36.4	1.09	19.4	1.5	0.3	12.6	12.4	1.7
5	EEQPM-8-EA-#	-5.44	0.41	19	61.4	2.7	105.7	41.0	0.94	7.6	1.6	0.2	13.6	13.2	1.5
6	EEQPM-13-EA-#	2.56	0.88	11	59.1	1.1	92.1	39.9	0.97	16.1	1.6	0.2	12.5	18.3	1.5
7	EEQPM-16-EA-#	-1.80	0.84	13	60.2	3.0	106.8	41.1	0.90	11.4	1.5	0.2	12.0	17.1	2.3
8	EEQPM-18-EA-#	-2.23	0.76	15	65.8	1.4	119.6	41.2	0.99	3.2	1.5	0.3	13.0	16.1	2.4
9	EEQPM-29-EA-#	0.74	0.98	10	61.2	1.2	113.7	42.6	0.98	12.6	1.7	0.3	14.1	20.9	1.3
10	EEQPM-34 –EA-#	3.71	1.39	2	62.8	2.7	110.9	47.9	0.86	6.5	1.7	0.1	15.9	22.4	2.1
11	EEQPM-36-EA-#	0.31	0.75	16	63.3	1.8	94.3	41.7	1.11	27.8	1.7	0.3	12.3	14.2	2.3
12	EEQPM-38-EA-#	-2.34	0.57	17	60.4	2.9	96.9	38.1	1.09	9.6	1.8	0.3	12.7	13.9	1.5
13	EEQPM-45-EA-#	4.30	1.02	7	64.5	0.1	101.9	41.7	1.13	18.2	1.6	0.3	13.0	13.9	2.3
14	EEQPM-49-EA-#	3.57	1.01	8	62.4	2.6	99.8	37.1	1.12	30.8	1.4	0.2	14.0	17.1	2.1
15	EEQPM-21-EA-#	-2.07	0.99	9	60.3	3.4	96.3	43.8	1.02	15.2	1.8	0.5	13.2	19.8	1.1
16	EEQPM-33-EA-#	-4.72	0.34	20	63.9	1.2	108.4	45.4	1.09	11.3	1.5	0.3	12.5	11.1	1.8
17	EEQPM-42-EA-#	4.91	1.39	3	62.0	2.7	116.1	47.8	1.04	17.2	1.5	0.2	13.8	18.6	1.1
18	EEQPMS2-#-GEASP-1-#	-4.68	0.83	14	64.9	2.3	108.6	47.9	0.77	13.3	1.5	0.3	14.1	16.1	1.5
19	POOL15QPM-SR-#-#	2.35	1.04	6	64.6	1.2	116.4	46.0	1.05	5.8	1.7	0.2	13.9	15.6	2.0
20	KATUMANI	-7.29	0.11	21	57.3	5.3	84.6	31.7	1.02	12.2	1.6	0.2	13.1	7.1	2.3
21	LOCAL CHECK1	7.66	1.92	1	66.0	0.6	130.4	53.8	0.99	9.6	1.3	0.4	14.6	24.2	1.0
Mean		5.50	0.90	11	62.1	2.2	106.2	42.8	1.00	13.7	1.6	0.3	13.2	16.3	1.7
LSD $_{(0.05)}$			0.51	6	-	2.4	14.5	8.2	-	14.0	-	0.2	2.4	-	1.0
CV			58.04		5.0	66.0	8.1	11.4	15.23	68.9	16.2	46.1	11.8	32.5	40.6
P			***		Ns	**	***	**	Ns	**	Ns	*	*	Ns	*
Selection direction			+	-	-	-	-	-	+	-	-	-	-	+	-

Colour legend

A	AB	BC	CD	D
Very good	Good	Average	Poor	Very poor

Colours that have no letter in common are different by at least one LSD

Thus, the above entries are good in most traits associated with drought tolerance. Larger selection index value means the genotype is superior in many variables under consideration. Most of the farmers' environment is dynamic but also very fragile in terms of rainfall availability and reliability. Similarly, drought prone areas of Tanzania where maize suffers pre flowering and terminal stress (flowering stress) are overlapping (Hodson *et al.*, 2002), thus forecasting drought and the timing of drought spell is still a big challenge. The difficulties in timing of drought spell has led breeders to find genotypes that increase yield under drought, because breeding for drought escape could not solve the problem. From this study entries 1(EEQPMOPV-1-EA), 10(EEQPM-34-EA-#), 13(EEQPM-45-EA-#) and 17(EEQPM-42-EA-#), are promising genotypes for production in drought prone areas while entries 6(EEQPM-13-EA-#) and 14(EEQPM-49-EA-#) can provide good genes for improving drought tolerance.

At this stage, it is important also to note that, not all genotypes with good selection indices are worth selection in this study because of poor grain yield - which is a primary focus (trait of interest). For example entry 11(EEQPM-36-EA-#) has better selection index compared to entries 8, 7 and 15 but has poor grain yield compared to the same entries (Table 21). This is because entry 11 had relatively good scores for leaf rolling, leaf senescence and ear per plants (EPP) which contributed to high index value. So the good traits observed in entry 11, can be used to make improvement through breeding to improve genotypes that are weaker in such traits with regard to drought tolerance as is the case of the above scenario. On the other hand stress applied at grain filling (Table 17), indicates that some genotypes lost certain level of tolerance while other genotypes improved. This implies that certain genotypes are efficient in ear formation and assimilate distribution than others (Banzinger *et al.*, 2000).

Table 17: Selection indices for the 21 genotypes evaluated for flowering stress

Entry	Pedigree	Index	GY	Rank	AD	ASI	PH	EH	EPP	ER	SEN	MOI	NP	MSV
			t/ha	Rank	D	D	Cm	Cm	#	%	1-10	%	#	1-5
1	EEQPMOPV-1-EA-#	3.08	1.47	3	55.7	1.5	105.6	45.5	1.06	3.8	0.3	13.7	25.1	1.0
2	EEQPM-HT-#	-0.09	1.12	13	59.5	1.2	116.3	48.4	1.05	1.5	0.2	14.0	16.3	1.6
3	EEQPM-6-EA-#	-4.12	0.79	19	60.4	3.3	106.8	39.3	1.03	1.4	0.2	13.5	16.2	2.0
4	EEQPM-9-EA-#	-5.17	0.81	17	60.2	2.0	107.1	41.1	0.91	3.4	0.2	14.5	18.6	1.8
5	EEQPM-8-EA-#	2.60	1.34	5	57.7	1.2	113.0	47.7	1.10	1.2	0.3	15.2	25.7	1.2
6	EEQPM-13-EA-#	2.91	1.21	11	58.4	1.3	108.5	44.5	1.17	7.1	0.3	15.2	18.7	1.4
7	EEQPM-16-EA-#	-0.25	1.15	12	58.9	1.9	115.5	42.7	1.09	2.7	0.3	14.2	20.5	0.8
8	EEQPM-18-EA-#	0.01	1.26	9	60.4	1.0	111.3	48.6	0.95	4.2	0.2	14.2	23.7	1.1
9	EEQPM-29-EA-#	3.99	1.24	10	59.1	1.1	116.1	45.0	1.23	0.4	0.2	14.5	16.7	0.6
10	EEQPM-34 –EA-#	3.78	1.45	4	58.5	1.3	116.2	47.1	1.12	5.7	0.3	13.7	21.3	1.1
11	EEQPM-36-EA-#	-4.07	0.66	21	61.8	0.9	104.3	37.9	0.99	11.1	0.2	14.2	14.2	1.7
12	EEQPM-38-EA-#	-2.55	0.94	16	58.6	1.9	107.2	42.0	1.04	2.2	0.3	14.0	20.1	1.1
13	EEQPM-45-EA-#	2.61	1.27	7	58.5	0.4	100.6	41.2	1.08	7.7	0.3	13.8	18.6	1.6
14	EEQPM-49-EA-#	2.03	1.33	6	57.5	1.7	115.2	46.5	1.12	5.9	0.3	13.9	23.7	1.2
15	EEQPM-21-EA-#	1.33	1.27	8	62.0	1.8	107.8	41.8	1.13	1.6	0.2	14.7	20.8	1.1
16	EEQPM-33-EA-#	-2.66	0.81	18	58.0	2.4	113.4	46.3	1.08	7.2	0.2	13.4	16.1	1.6
17	EEQPM-42-EA-#	-3.61	1.07	14	58.7	1.8	112.6	44.4	0.84	5.1	0.2	14.4	19.0	1.3
18	EEQPMS2-#-GEASP-1-#	-1.99	0.95	15	58.1	1.4	115.8	44.4	1.04	3.9	0.3	14.0	19.6	1.1
19	POOL15QPM-SR-#-#	2.48	1.70	1	61.0	1.9	126.8	57.1	1.06	12.5	0.3	15.7	27.9	1.4
20	KATUMANI	-1.71	0.74	20	56.8	1.7	97.6	40.8	1.16	17.3	0.3	13.3	14.5	1.5
21	LOCAL CHECK1	1.42	1.60	2	62.1	0.9	129.8	59.6	1.01	4.4	0.3	15.2	25.3	0.7
Mean		1.10	1.15	11	59.1	1.6	111.8	45.3	1.06	5.2	0.3	14.2	20.1	1.3
LSD (0.05)			0.61	6	3.3	-	15.4	-	-	8.1	-	1.1	7.6	0.8
CV			50.67		4.3	73.2	8.4	16.2	11.04	95.8	35.4	5.4	28.2	34.7
P			**		**	Ns	*	Ns	Ns	*	Ns	**	**	*

Under grain filling stress (flowering stress) entries 1(EEQPMOPV-1-EA-#), 5(EEQPM-8-EA-#), 6(EEQPM-13-EA-#), 9(EEQPM-29-EA-#), 10(EEQPM-34-EA-#), 13(EEQPM-45-EA-#), 14(EEQPM-49-EA-#), and 19(POOL15QPM-SR-#-#) had larger index values for drought tolerance traits (Table 17). On the other hand entry 21 (Local check1) which had performed better under all moisture regimes seems to be *relatively* poor in number of ears per plant (EPP) resulting in relatively lower index despite high yield. This selection index concept helps breeders to identify genotypes with good traits associated with drought tolerance so that these traits can be introgressed into genotypes lacking these traits but with good grain yield.

4.5 Selection of Best Genotypes across Moisture Regimes

Best genotypes are those which maintain high yield across moisture regimes, this is important in order to counteract the effect of moisture stress at different stages of crop development. From this study across moisture regimes, grain yield (GY) average was (1.56 t/ha) (Table 23). So genotypes with average yield equal to this value across moisture regimes are considered to have relative grain yield (Rel.GY) of 100 percent (Vivek *et al.*, 2005). With regard to relative grain yield, 42.9 % of genotypes under evaluation had above average yield, these include entries 2 (EEQPM-HT-#), 7 (EEQPM-16-EA-#), 9 (EEQPM-29-EA-#), 10 (EEQPM-34-EA-#), 13 (EEQPM-45-EA-#), 15 (EEQPM-21-EA-#), 17 (EEQPM-42-EA-#), 19 (POOL15QPM-SR-#-#) and 21(Local Check1). The Local Check1 had the highest yield of about 61% above the mean. Any genotype which performs above the mean is always considered better whereas those performing bellow the mean will be considered poor unless they are exceptionally good in certain traits of interest.

Table 23: Results of evaluation of maize genotypes for grain yield across four conditions of moisture regime at Ilonga and Selian

Entry	Pedigree	Across			Across		Pre flowering stress		Flowering stress		Well watered		Rain fed (random)	
		RelGY	Rank		GY	Rank	G Y	Rank	G Y	Rank	G Y	Rank	G Y	Rank
		%	Avg	StdDev	t/ha	#	t/ha	#	t/ha	#	t/ha	#	t/ha	#
1	EEQPMOPV-1-EA-#	100	11	9	1.45	12	1.12	4	1.47	3	0.91	20	2.30	19
2	EEQPM-HT-#	**105**	9	4	1.63	9	1.05	5	1.12	13	1.47	11	2.90	8
3	EEQPM-6-EA-#	78	17	4	1.20	17	0.86	12	0.79	19	0.97	18	2.20	20
4	EEQPM-9-EA-#	87	14	5	1.44	14	0.55	18	0.81	17	1.81	8	2.60	14
5	EEQPM-8-EA-#	81	14	6	1.34	14	0.41	19	1.34	5	1.00	17	2.60	13
6	EEQPM-13-EA-#	99	11	3	1.58	11	0.88	11	1.21	11	1.23	14	3.00	6
7	EEQPM-16-EA-#	**107**	9	5	1.78	9	0.84	13	1.15	12	1.51	10	3.60	2
8	EEQPM-18-EA-#	100	11	3	1.58	11	0.76	15	1.26	9	1.60	9	2.70	11
9	EEQPM-29-EA-#	**117**	7	4	1.84	7	0.98	10	1.24	10	2.05	4	3.10	3
10	EEQPM-34 –EA-#	**127**	6	7	1.81	6	1.39	2	1.45	4	2.09	2	2.30	17
11	EEQPM-36-EA-#	74	18	3	1.21	18	0.75	16	0.66	21	0.94	19	2.50	15
12	EEQPM-38-EA-#	76	16	1	1.24	16	0.57	17	0.94	16	1.05	16	2.40	16
13	EEQPM-45-EA-#	**116**	7	3	1.77	7	1.02	7	1.27	7	2.08	3	2.70	10
14	EEQPM-49-EA-#	100	11	5	1.48	11	1.01	8	1.33	6	1.27	13	2.30	18
15	EEQPM-21-EA-#	**103**	9	5	1.63	9	0.99	9	1.27	8	1.17	15	3.10	5
16	EEQPM-33-EA-#	87	13	7	1.49	13	0.34	20	0.81	18	2.03	5	2.80	9
17	EEQPM-42-EA-#	**113**	9	5	1.70	9	1.39	3	1.07	14	1.43	12	2.90	7
18	EEQPMS2-#-GEASP-1-#	100	11	4	1.59	12	0.83	14	0.95	15	1.87	6	2.70	12
19	POOL15QPM-SR-#-#	125	4	3	1.91	5	1.04	6	1.70	1	1.81	7	3.10	4
20	KATUMANI	43	21	1	0.71	21	0.11	21	0.74	20	0.77	21	1.20	21
21	LOCAL CHECK1)	**161**	**1**	1	2.41	1	1.92	1	1.60	2	2.11	1	4.00	1
Mean		100	11	4	1.56	11	0.90	11	1.15	11	1.48	11	2.71	11
LSD (0.05)		24	5	2	0.43	5	0.51	6	0.61	6	0.89	6	0.63	6
MSe					0.27	0	0.27		0.34		0.32		0.14	
CV							58.04		50.67		38.08		13.71	
P							***		**		*		***	

* Stdev = 1- 3 stable, 4 -5 = intermediate stability, >6 = unstable

All the above would normally perform above farmer average which is estimated to be less than 1.2t/ha (Mduruma and Ngowi, 1997). This superiority above farmer average is important in variety release procedures where a given variety must outperform farmer variety for all traits of interest. About 33.3 percent had below average yields (i.e. entries 3 (EEQPM-6-EA-#), 4 (EEQPM-9-EA-#), 5 (EEQPM-8-EA-#), 6 (EEQPM-13-EA-#),11(EEQPM-36-EA-#), 12 (EEQPM-38-EA-#), 16(EEQPM-33-EA-#) and 20 (KATUMANI); the rest (entries 1(QPMOPV-1-EA-#) 8 (EEQPM-18-EA-#), 14 (EEQPM-49-EA-#) and 18 (EEQPMS2-#-GEASP-1-#) had equal yields as the overall mean of all genotypes across moisture regimes.

Stability studies were able to reveal that some genotypes consistently performed better across environments (varying conditions of moisture regimes). Stability studies are mainly conducted by use of rank standard deviation (rank Stdv) for across site (water regimes) analysis in the Field book 8.4.2 Software (Vivek *et al.*, 2005). Small rank standard deviation values imply stable performance and vice versa. In this study stable genotypes are those with rank standard deviation values of less than the mean Std dev. Rank Std dev.values above this mean are regarded as unstable while below this value are regarded as stable(Vivek *et al.*, 2005). From the current study it is evident that most entries (57.1%) indicated stable performance (i.e. Stdv $\leq$ 4) for grain yield and the rest (42.9%) had unstable performance (Table 23). Stable and high yielding genotypes, can be recommended for areas with unpredictable weather conditions because their performance is predictable. Genotypes that had unstable performance indicated variations in ranking grain yield under certain conditions of moisture, thus such genotypes can be recommended for conditions in which they are likely to perform better. Further analyses indicated that entries 19 (POOL15QPMS-SR-#-#) and 21 (Local Check 1) had above 100% Rel.GY and consistently fall within the best 8 genotypes across all moisture regimes. Entry 20 (KATUMANI) ranked poorly across all moisture regimes and had the lowest Rel.GY value (43 %). Highly stable and high yielding genotypes under varying moisture regimes suggest that the materials can be recommended for areas with unpredictable weather conditions because the genotypes will perform better regardless of moisture status compared to other varieties.

On the contrary, entry 1 (EEQPMOPV-1-EA-#) ranked better under moisture stress but poorly under optimal moisture and random stress relative to other genotypes. These alterations in ranking relative to other genotypes suggest genotype x environment interaction observed (Table 5). This kind of interaction has been described in Banzinger and Cooper (2001) as cross-over interaction where the ranking of genotypes is altered for genotypes evaluated under uniform management. Such genotypes can only be recommended for areas with similar pattern of moisture regimes in order to realize the expected yield. Based on yield advantage above the mean and stability data, eight genotypes have been identified as best (Table 24) are recommended for farmer evaluation under Mother – Baby trials in future studies.

However, among those, only entries 13(EEQPM-45-EA-#), 19(POOL15QPM-SR-#-#), and 21(Local ceck1) had stable / reliable response across moisture regimes.

Table 24: Best eight genotypes based on relative grain yield (best average rank) across all conditions of moisture regimes

Entry	Pedigree	Av.Grain yield (t/ha)	Rel. Grain yield (%)	Average stdv
21[a]	Local check1*	2.41	161	1
19	POOL15QPM-SR-#-#	1.91	125	3
10[b]	EEQPM-34 -EA-#	1.81	127	7
13	EEQPM-45-EA-#	1.77	116	3
9	EEQPM-29-EA-#	1.84	117	4
2	EEQPM-HT-#	1.63	105	4
7	EEQPM-16-EA-#	1.78	107	5
17	EEQPM-42-EA-#	1.70	113	5
15	EEQPM-21-EA-#	1.63	103	5

[a]- Local check1 is already released variety as SITUKA1

[b] Entry number 10 (EEQPM-34-EA-#) ranked poorly only under random stress which caused poor stability characteristics. Because its performance under moisture stress was good, it can be recommended for areas with consistently poor rainfall (i.e. site specific characteristics). When selecting genotypes to be recommended over a wide range of moisture regimes, it is important to take into consideration their consistency

in ranking across regimes. Thus a genotype that ranks better across conditions of moisture regimes is more reliable for wide recommendations than the one that performs exceptionally high under a single moisture regime thereby masking its poor performance in other regimes. Average rank gives data on ecological adaptation while per se performance is meant for specific ecology as is the case of entry 10 (EEQPM-34-EA-#) with Rel.GY 127% relative to entry 19 (POOL15QPMS-SR-#-#) Rel.GY 125%. Although entry 10 (EEQPM-34-EA-#) has high mean performance across regimes, its poor performance under random stress has been masked by high performance under pre flowering stress. This poor performance under random stress disqualifies it from being recommended for areas with such a pattern. Otherwise it could end being recommended in preference to entry 19 if average yield criteria were used.

4.6 Disease Incidences

For experiments established at Ilonga with exception of MSV no other diseases were observed to a significant level to warrant attention. Between water regimes MSV was relatively higher under pre flowering stress and optimal moisture (Table 6). The number of plants diseased per plot were high but the intensity (severity of the disease based on the 1-5 rating scale) was generally low. In all regimes of moisture, there were no significant correlations between grain yield and MSV (Table 7) however, the correlations were consistently negative. Because the experiment was carried out during off season the chances are that the diseases were not prevalent at that time which necessitates for the need to repeat the study in more locations and more years to ascertain both genotypes and environmental effects with regard to disease severity resistance.

Also the study revealed that under individual moisture regimes variation between genotypes for MSV was significant ($P \leq 0.05$) under pre flowering stress only (Table 13). In this study some maize genotypes that had low MSV incidences for example entries 1 (EEQPMOPV-1-EA-#), 17 (EEQPM-42-EA-EA-#) and the 21(Local check1) had good yield except entry 15 (EEQPM-21-EA-#) (Table 21). MSV and AD had significant correlations ($r = 0.35^{**}$) under pre flowering stress (Table 8) and ($r = 0.3^{*}$) under well watered conditions (Table 10). Positive correlations between MSV and AD occurred because the spread of MSV increases with time. Thus the longer it takes for maize plants to reach anthesis, the more time becomes available for population of vectors to build up hence spreading the disease. However in this study not all genotypes with longer days to anthesis had high incidences of MSV, which means that the genotypes used had varying degrees of resistance to MSV.

As regards to Ear rot (ER) there was significant variation between moisture regimes. The highest mean was observed under pre flowering stress while the least was observed under optimal moisture. Under individual moisture regimes variations between genotypes for Ear rot (ER) were more evident under pre flowering moisture stress ($P \leq 0.01$) and flowering stress ($P \leq 0.05$) only. The fact that variation for ER was observed under experiment in which stress was applied suggests that under stress the genetic variation between genotypes tends to become clearer thus selection for decreased ear rot incidences can be made at this stage.

CHAPTER FIVE

5.0 CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The issue of drought will continue to pose a big challenge to breeders and environmental scientists. Rapid population growth particularly in least developed countries of the world is responsible for decline in cultivable land leading to continual use without nutrient replenishment. Consequently food production is declining causing a serious threat to food security. Land degradation is the main cause of drought while its over use is responsible for many problems of salinity or acidity which in turn alters the soil structure leading to low water holding capacity.

At the same time maize will continue to be an important food and cash crop among small holder farmers who face many production constraints both biotic and abiotic. Therefore sustainable maize production efforts will require the development of robust genotypes which are able to withstand threats of weather uncertainties and soil variations. This can be achieved by utilizing the genetic potential observed in this study through breeding and careful selection to address specific constraints. Thus based on this study the following conclusions are made:-

Genetic variation exists: The germplasm used in this study exhibited different responses to specific moisture regimes, evidence from relative changes of performance of genotypes in different periods of moisture stress indicate the presence of genotype x environment interactions. Thus genotypes can be recommended to particular ecologies where best results are obtained. Good examples come from entries 10(EEQPM-34-EA-#), 19(POOL15QPM-SR-#-#), 21(Local check1) and (EEQPM-45-EA-#) for pre flowering and flowering moisture stress stages and 21(Local check1), 7(EEQPM-16-EA-#), 9 (EEQPM-29-EA-#) and 19(POOL15QPM-SR-#-#) for optimal and random stress. The selection of best genotypes that perform better under both stress (low input) and optimal (high input) conditions as a best approach has been suggested by many scientists. Best performing genotypes under drought may not necessarily perform better under optimal conditions and vice versa due to G x E. In the current study it was observed that certain high yielding genotypes under drought had relatively poor performance under optimal conditions as is the case for entry 1 (EEQPMOPV-1-EA-#) and 14 (EEQPM-49-EA-#). Such genotypes could be suited to areas that are persistently prone to drought like Tabora, Shinyanga, Singida, Dodoma some parts of Arusha and Kilimanjaro particularly Mwanga and Same districts. These areas have been demarcated in the Africa maize research atlas as areas prone to pre flowering and terminal (grain filling) stress.

Evaluation of genotypes across environments (regimes of soil moisture) helps to identify stable genotypes but which should merit selection. In this study, the following classes of yield stability with regard to moisture regime were identified

(i) stable and high yielding; for example entries 21(Local check1), 19 (POOL15QPM-SR-#-#) and 13 (EEQPM-45-EA)

(ii) unstable but high yielding example entry 1 (EEQPMOPV-1-EA-#), 10 (EEQPM-34-EA-#), 15 (EEQPM-21-EA)

(iii) stable and low yielding examples – entry 20 (Katumani) and 12 (EEQPM-38-EA-#)

(iv) unstable and low yielding e.g. entry 5 (EEQPM-8-EA-#) and 16 (EEQPMO-33-EA-#)

Understanding the knowledge of stability of genotypes across environments (ecologies) makes it easier for us to recommend which materials are to be grown under a particular situation. Stable and high yielding genotypes have a wide adaptation; these can be recommended in areas with lots of weather uncertainties. Such areas are those with erratic rainfall patterns for example Tabora, Shinyanga and large parts of central Tanzania regions. On the other hand stable genotypes but having low mean yield will not improve production even under favourable conditions, thus they are of little agronomic value. Genotypes such as entries 13 (EEQPM-45-EA-#), 19 (POOL15QPM-SR-#-#) and 21 (Local check1) can be recommended for all areas including those with erratic rainfall because of their high yield and stability. Also entries 1 (EEQPMOPV-1-EA-#), 7 (EEQPM-16-EA-#), 10 (EEQPM-34-EA-#), 15 (EEQPM-21-EA-#) and 17 (EEQPM-42-EA-#) are recommended for specific areas where they perform better.

The issue of using secondary traits as selection criteria is very complex as it is less likely to have a single variety that will have all desired values of secondary traits versus small ASI, unrolled leaves (turgid), stay green (less senescence) characteristic in the same background. Therefore progress can be made by either focusing on few traits that can have a positive impact on yield under drought, or have desirable optimum combinations levels of the traits for optimum agronomic performance. The latter can be done where as selection is based on small anthesis- silking interval (ASI), low senescence (SEN) and disease incidences also more ears per plant (EPP). This would include entries such as 10 (EEQPM-34-EA-#) (SEN), 1 (EEQPMOPV-1-EA-#) and 17 (EEQPM-42-EA-#) (MSV) and 1 (EEQPMOPV-1-EA-#), 9 (EEQPM-29-EA-#) (EPP, and SEN) and 13 (EEQPM-45-EA-#) (ASI) in which all traits have average to good values, whereas the rest of the entries were poor in one or more traits that control grain yield.

The correlation studies indicate how secondary traits are related to each other and to grain yield, which is a primary trait. Positive correlations between ears per plant (EPP) and grain yield will result to improved yield if selection for more ears per plant is done under all moisture conditions. while negative correlation between anthesis – silking interval (ASI), leaf rolling (LR), leaf senescence (SEN) and grain yield (GY) means selection for low levels of ASI, LR and SEN will improve selection for improved yield under stressful conditions. Lack of significant correlation as for some traits means materials come from a narrow genetic base population or other factors such as root architecture could have influenced the trend observed.

Depending on the prevailing conditions of soil moisture days to anthesis (AD) helps to identify which maize genotypes should be grown that will ensure farmers with yield. For example accessions with short AD viz entries, 6 (EEQPM-13-EA-#) and 17(EEQPM-42-EA-#) will be ideal for areas with short rains while those with long AD viz entries 2 (EEQPM-HT-#), 9 (EEQPM-29-EA-#), 15(EEQPM-45-EA-#), 19 (POOL15QPMS-SR-#-#) and 21 (Local Check 1) will be good in areas with enough rainfall because farmers who grow short anthesis date (AD) plant will suffer yield penalty.

5.2 Recommendations

1. Best genotypes are those that can be recommended over a wide range of moisture regimes. Thus the entries identified in Table 23 are recommended because they are likely to perform better under both sufficient and moisture stress. For specific moisture regimes, the following genotypes are recommended: consistently drought prone areas 1(EEQPMOPV-1-EA-#), 10(EEQPM-34-EA-#), 13(EEQPM-45-EA-#), 14(EEQPM-49-EA-#), 19(POOL15QPM-SR-#-#) and 21(Local check1) which performed better under both pre flowering and flowering stress. Entries 21(Local check1), 19(POOL15QPM-SR-#-#) and 9(EEQPM-29-EA-#) performed better under both random and optimal moisture

3. The eight genotypes selected from each individual moisture regime represents best entries that performed better under that particular regime based on yield data. However based on index values, other genotypes are exceptionally good in only few traits despite having relatively poor yield. Entries such as 9 (EEQPM-29-EA-#) and 6 (EEQPM-13-EA-#) seem to be good in number of ears per plant (EPP) and senescence scores despite ranking 10 and 11 for grain yield respectively. Thus, these genotypes can be used in genetic improvement programmes to introgress the good traits observed in these genotypes to those that had good yield but poor on traits associated with drought.

4. The success of plant breeding operations relies heavily on extent of genetic variability present in a crop species for a particular trait. In this study, the observed G x E implies differential response of genotypes in different environments and that the performance of genotypes depend on specific environments. Variations in index values for secondary traits score observed in this study, suggest the existence of genetic variation among genotypes (i.e. diversity). The suitability of a genotype to a particular regime depends on its interaction with the environment thus best selection can be made by identifying entries that gave optimum performance and good stability for example entries 19 (POOL15QPM-SR-#-#) and 21(Local check1)

5. Because the objective of this experiment was to identify maize genotypes with good drought tolerance characteristics, genotypes such as entry 4 (EEQPM-9-EA-#) and 16 (EEQPM-33-EA-#) with small anthesis – silking interval (ASI) values and low leaf rolling scores but poor grain yield can only be used for breeding purposes to improve drought tolerance in high yielding varieties that had poor tolerance characteristics to moisture stress at critical stages

6. Variation between genotypes seemed to be more pronounced under pre flowering stress compared to other kind of stress, thus it is possible to make useful selections under pre flowering moisture stress especially when the target is areas suffering this kind of stress.

7. The study was able to reveal that variations between genotypes for various traits associated with drought tolerance exist. However, the extent of genetic diversity can be established by undertaking molecular characterization that will complement phenotypic data. This is a useful tool as it helps to increase precision in estimation of chances for further genetic improvement or the need for introgression of new genes.

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