VARIABILITY FOR DROUGHT TOLERANCE IN FINGER MILLET [*Eleusine coracana* (L.) Gaertn.] ACCESSIONS FROM ZAMBIA

By

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DECLARATION

I, **Saul Mubaiwa Neshamba**, do hereby declare that this dissertation represents my own work and that it has not previously been submitted for the degree at this or any other university.

Signed: ....

Date: AUGUST 4, 2010

APPROVAL

The University of Zambia approves this dissertation of **Saul Mubaiwa Neshamba** as fulfilling the requirement for the award of the degree of Master of Science in Plant Breeding and Seed Systems

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ABSTRACT

Finger millet [*Eleusine coracana* (L.) Gaertn.] is an important traditional food security crop in 2 remote and dry areas of northern Zambia. Its several major uses include porridge, bread, malt, beverages, fodder and popped products. Yields in these areas are severely limited by drought. Drought is expected to occur with increased frequency and intensity in future with climate change. Development of tolerant varieties is a more sustainable way to cope with recurrent drought for small scale growers. Limited research on tolerance to drought in finger millet in Zambia has been done. As a result only a few varieties adapted to the high rainfall region have been developed and promoted. Two hundred and fifteen accessions in the national collection have not been evaluated for the trait. As a result very little is known about their variability in the trait. Assessment of variability is important for effective selection. Variation in 12 putative morphological and agronomic traits of drought tolerance in 203 accessions was studied in a wooden box Randomized Complete Block Design off-season in 2 environments, one with and the other without stress, on an Acrisol in northern Zambia. One sample T-test of differences in attributes of traits showed no significant difference between test environments in grain weight (GW, $p = 0.744$). The test, however, showed significant differences in spike length (SL, $p = 0.027$); highly significant differences in biomass (BW, $p < 0.001$) and chaff weight (CW, $p < 0.001$), days to 50 % flowering (DTF, $p < 0.001$), pest and disease susceptibility (PDS, $p < 0.007$), plant height (PH, $p < 0.001$), number of productive tillers (NPT, $p < 0.001$), spike weight per plot (SY, $p < 0.001$) and stay-green characteristic (SGC, $p < 0.001$). Withholding water for 5 days during flowering reduced SL by 3.4 %, BW by 3.1 %, SGC by , CW by, PDS by 10.5 %, NPT by 40.0 %), and SY by 48.5 % and increased PH and DTF by 3.1 and 4.3 %, respectively. One-way analysis of variance detected significant differences among accessions in SY ($p = 0.032$) under optimal conditions. The same analysis detected significant differences in number of spikes per panicle (SN, $p = 0.014$) and SGC; and highly significant differences in PDS ($p = 0.001$) under stress. Eighty-three accessions outweighed the best check (FMM 165 = 2.500 $\pm$ 1.000 kg/plot) in SY under optimal conditions. Accession ZM 3813 had the highest SY (6.450$\pm$1.000 kg/plot) and ZM 203 (0.200 $\pm$ 1.000 kg/plot) the lowest in the environment. Under stress 92 accessions exceeded the best check (Nyika = 5.923 $\pm$ 1.3825 – same and 1.5457 – different block) in SN. ZM 3825 had the largest attribute (8.706 $\pm$ 1.3825, 1.5457) and ZM 193 the smallest (2.631). In SGC 77 accessions were scored better than the best check, FMM 165. ZM 225 (5.222 $\pm$ 0.7643, 0.8545), ZM 245 (5.222 $\pm$ 0.7643, 0.8545), and ZM 112 (4.972 $\pm$ 0.7643, 0.8545) were scored the best and 37 others the poorest in the trait. And in PDS 31 accessions had better scores than the best check (Senga = 3.000 $\pm$ 0.0151, 0.01689). The least susceptible accession was ZM 3860 (Score = 0.406 $\pm$ 0.0151, 0.01689) and the most susceptible was ZM 3652 (6.031 $\pm$ 0.0151, 0.01689). Overall ranking of accessions according to tolerance to stress in 9 traits showed 16 accessions namely, ZM 3825, ZM 3920 ZM 1459, ZM 3906, ZM 3819, ZM 3834, ZM 3834, ZM 203, ZM 40122, ZM 3816, ZM 229, ZM 3685, ZM 154, ZM 153, and ZM 3824, to be more tolerant to stress than the best check, Nyika. These accessions occurred across a wide range of clusters. Six of them were collected from the high, and 5 from the low rainfall region. Five were collected from Kawambwa showing the district to be an important source of tolerance. Nearest neighbour analysis using the dissimilarity coefficient, Euclidean Distance, generated 3 dendrograms depicting relationships among the accessions based on the traits evaluated 1 dendrogram for each of the test environments and 1 for the most tolerant accessions. Accessions could be consigned to several clusters. All clusters could be read between Euclidean Distance 0.84 and 1.00. The pattern of clustering in

the 2 environments was similar. Under optimal conditions ZM 153 and ZM 3813 were the most divergent. Under stress maximum cluster distance was between the most tolerant accession (ZM 3825) and the recently released mutant variety, FMM 175. Among the most tolerant accessions ZM 3834 and ZM 40 122 were the most closely related, and ZM 154 and ZM 203 the most divergent. There was obvious differentiation at both intercluster and intracluster levels. In the dendrogram of the most tolerant accessions ZM 3825, ZM 3824, ZM 3819, ZM 3834, ZM 3783 and ZM 3816 collected from Luapula did not occur in the same cluster at short distances indicating wide divergence among the most tolerant accessions. This also showed extensive divergence between the most and less tolerant accessions. The accession may be used to introgress drought tolerance in the mutant variety.

DEDICATION

This work is dedicated to the poor farmers of the dry and remote zones of northern Zambia who subsist on finger millet as a basic staple; advocates of a vegetarian and whole grain diet, people living with HIV/AIDS and Diabetes (*Diabetes mellitus*).

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CHAPTER ONE

1. INTRODUCTION

Finger millet [*Eleusine coracana* (L.) Gaertn.] is a strategic traditional food security crop in Zambia because of its adaptation to a wide array of growing conditions and uses (Vietmeyer 1996, Agrawal 1997). The small grain crop is also an important staple food in other East and Central African countries, and India. It is believed to be 'one of the few special species that supports the world's food supplies' (Vietmeyer, 1996). In 1980 the crop had risen little in terms of importance outside Africa and India (Hulse, Laing and Pearson, 1980). Annual world production has been estimated to be 4.5 million tons of grain with Africa contributing about 44 % to that production (Vietmeyer, 1996). Millets are ranked fourth after maize, cassava and sorghum in terms of importance as staple food crops in Zambia (Mungoma and Mwambula, 1996; Ministry of Agriculture, Food and Fisheries, 1995). Both area under cultivation and production by province in the country have reduced considerably. Farmer yields are lower than yields under research. The reduction is attributable to drought.

Limited research on tolerance to drought in finger millet in Zambia has been done. As a result only a few varieties adapted to the high rainfall region have been developed and promoted. And yet Zambia has a long history of exposure to drought (Sichingabula, 1995). Severe drought causes substantial crop losses and chronic food insecurity through absolute and economic shortage of water (Ager, 2008). Zambia needs to adapt to variability in rainfall. Crop research to select varieties that are drought tolerant is a better way to cope with recurrent drought (Kajoba, 1995).

Finger Millet is not as drought tolerant as pearl millet or sorghum. However, it could play a complimentary role in the dry zones of north Zambia that get at least moderate rainfall (500 – 1 000 mm) (Vietmeyer, 1996). The crop has fair prospects for improvement in terms of drought tolerance. It is preferred to pearl millet and sorghum by farmers in the areas. However, productivity is severely limited by drought in these areas.

Drought tolerance could, in addition, increase areas of cultivation beyond the high rainfall regions. Finger millet is commonly grown in the high rainfall Region (III) (Agrawal, 1997). Possibilities for developing drought tolerant varieties exist through non-transgenic technologies to give a wider range of adaptation to the crop (Hittalmani *et al.*, 2006; Bennett, 2003).

The first step in any breeding programme is to estimate available genetic variation. Genetic variation provides scope for identification and isolation of plants with the desirable combination of characters. The efficiency of this process determines breeding success. Finally selection results in improved varieties.

At least two studies in the sub-region have shown significant variability in the crop in nine morphological and agronomic traits under rain-fed conditions (Mnyenyembe and Gupta, 1997). In India several studies have demonstrated considerable variability for drought and tolerance to water stress in a multiple of traits in finger millet (Viswanath, 1977; Reddy, 1977; Rao, 1978; Agalodia, *et al.,* 1979; Chandrasekharappa, 1979; Swaminath, 1979; Rao, *et al.,* 1981; Krishnasastry, *et al.,* 1982; Abraham, *et al., 1989;* Mehra, 1963; Hittalmani, *et al.,* 2006; Melse-Boonstra *et al.*, 2007; Reid *et al.*, 1986).

'It has been proposed that traditional agro-ecosystems maintain a high diversity of cultivated plants, both in terms of cultivated plants and genotypes within each species' (Zaldivar *et al.*, 2002) These agro-ecosystems are said, typically, to present opportunities for co-existence and inter-mating of crop species with their wild relatives. This is believed to be, especially true for centres of origin, domestication and diversity. The centre of origin of finger millet extends into north-eastern Zambia and typically should present considerable diversity.

The National Plant Genetic Resources Centre holds 215 accessions of finger millet in its gene bank at Mt. Makulu in Chilanga. The collection gathered between 1992 and 1999 in the country has not been evaluated for drought tolerance. As a result very little is known about the genetic variability for drought tolerance of the gene pool of the crop, especially local landraces being grown by smallholder farmers in the country.

The specific objectives of this study were:

1. To evaluation genetic variation for drought tolerance in finger millet from Zambia; and

2. To measure genetic relatedness among germplasm accessions collected in Zambia.

CHAPTER TWO

2. LITERATURE REVIEW

2.1. Origin

There is general consensus among authors (Chaugale et al, 1955; Mehra, 1963; Purseglove, 1972; Rachie and Peters, 1977) on the origin of the crop in East Africa. It is believed to be native to Africa. Its origin is deduced to be in the highlands of Uganda and Ethiopia on the basis of farmers' long tradition of cultivation and use.

Finger millet does not appear to have been adopted in ancient Egypt, and it is said to have reached Europe only about the beginning of the Christian era. However, it arrived in India much earlier, probably more than 3,000 years ago, and by 1977 when Rachie and Peters reviewed world literature about it, it had become an important staple food in some places, particularly in the hill country in the north and south of India.

2.2. Botany

Agrawal (1997) has described finger millet as 'a robust free tillering annual grass'. The plant is said to develop an extensive but shallow root system from the base of the main culm. The lower nodes have been described as semi-procumbent, and the upper part erect, stout, compressed, smooth, 30 – 120 cm in height, 4 – 12 cm thick and bearing numerous distichous leaves. The leaves have been portrayed as having a flattened leaf sheath, overlapping along the entire length and glabrous; the inflorescence as terminal and digitate with 3 – 9 sessile spikes. The inflorescence is known to often possess 1- 2 extra short spikes carried 2 – 4 cm below the terminal whorl. The shape of the head can be classed into 3 as top curved, incurved and open. The author has distinguished the shapes. He also describes the colour and form of the spike and grain.

2.3. Production

Estimates of world production figures are given by Vietmeyer (1996). Between 1987 and 2005 annual area cultivated and production in Zambia averaged 65 331 hectares (ha) and 43 367 metric tonnes respectively. Yields did not exceed 0.76 tonnes per ha in the period. They averaged 0.65 tonnes/ha.The same period also showed reduced yields. The low yields obtained in the period referred to could be attributable to drought as they coincided with the period of the worst occurrences of drought in the last century (Kajoba, 1995).

2.4. Utilisation

The significance of the crop lies in the wide array of uses. Rachie and Peters (1977) have enumerated various uses of the crop based on a review of world literature. Hulse *et al.* (1980) reviewed more than 1 700 original references to the nature, composition and nutritive value of finger millet among other cereals. The grain can be used in many types of foods, some of which are not quite common. Its several major uses include porridge, bread, malt, beverages, fodder and popped products (Vietmeyer, 1996). Finger millet is preferred to other grains as a food in difficult terrain and times of famine and fasting.

In more recent literature (2009) the National Food and Nutrition Commission of Zambia has published food composition tables that have specific amounts of nutrients contained in common foods consumed in the country including finger millet. Whole grain of finger millet has (0.6%) more protein than rice (6%) (National Food and Nutrition Commission, 2009).

However, it shows considerable variation, and at least one Indian cultivar contains as much as 14 percent protein. The main protein fraction (eleusinin) has high biological value, with good amounts of tryptophan, cystine, methionine, and total aromatic amino acids. All of these are vital to human health and growth and are deficient in most cereals. For this reason alone, finger millet is an important preventative against malnutrition. The methionine level is of special benefit, especially for those who depend on plant foods for their protein (Vietmeyer, 1996). Finger millet is also a rich source of minerals. Whole grain contains 0.27 percent calcium, 12-66 times more than most common cereals. The iron content of finger millet is among the highest in cereals (National Food and Nutrition Commission, 2009).

A finger millet diet may have therapeutic effect on arteriosclerosis and coronary heart disease by lowering blood cholesterol levels as the grain is normally consumed whole (Roger, 2004). Whole grain finger millet is useful for diabetics as it releases sugars slowly into the blood stream thereby stabilising blood sugar levels. Citing Novellie (1959) Hulse et al (1980) reported diastatic activity of finger millet. The grain is second only to barley in terms of malting quality. Selenium content of finger millet has been reported from Malawi and Mauritius by Melse-Boonstra et al. (May 2007). They have reported a concentration of 40mg Se/100g meal and also described the role of the element in the immune system. The element has been shown to be associated with proper functioning of antioxidant defence systems, thyroid hormone metabolism and the redox control of enzymes and proteins.

2.5. Finger Millet Adaptation

Numerous cultivars have been recognized in India and Africa, consisting of highland and lowland forms, dryland and irrigation types, grain and beer types, and early and late maturing cultivars. By and large, there are highland races and lowland races—each adapted to its own climate (Vietmeyer, 1996).

Vietmeyer (1996) has characterized finger millet as a short-day plant. A photoperiod of 12 hours is supposed to be optimum for the best-known types. It is mainly produced within 20°N and 20°S latitude. Day length-neutral types are believed to exist.

Finger millet requires moderate rainfall well distributed during the growing season with an absence of prolonged droughts. Dry weather is required for drying the grain at harvest. In drier areas with unreliable rainfall, sorghum and pearl millet are better suited. In wetter climates, rice or maize is preferable.

Most of the world's finger millet is grown at intermediate elevations, between 500 and 2 400 metres above sea level. Its actual altitude limits are unknown.

The crop tolerates a cooler climate than other millets. Paradoxically, finger millet is well adapted to the temperate zones. It thrives under hot conditions. It can grow where temperatures are as high as 35°C. Finger millet grows best where the average maximum temperature is not higher than 27°C and average minimum is not below 18°C.

Finger millet is grown on a variety of soils. It is frequently produced on reddish-brown lateritic soils with good drainage but reasonable water-holding capacity. It can tolerate some water-logging. It seems to have more ability to utilize rock phosphate than other cereals do.

2.6. Finger Millet Improvement

Agrawal *et al.* (1991) have reviewed finger millet improvement in Zambia up to 1983. They reported limited research on the crop in the country by that year. As a result, only four improved varieties were released. Although the research branch had access to global germplasm collections and support, and a framework within the national programme to develop drought tolerant varieties of finger millet, only a few varieties adapted to the high rainfall region were developed and promoted on-farm. During on-farm demonstrations farmers reported that none of the varieties developed by the Finger Millet Improvement programme were drought tolerant.

2.7. Characterisation of Drought-Prone Environments in Finger Millet Growing Regions of Northern Zambia

Two regions in the Northern Province of Zambia lying outside the high rainfall belt have been identified to face moderate to high risk to drought (Reid *et al.,* 1986). These are the Lakes Depression Area, northwest of the province around the lakes , and the Luangwa Valley, southeast in the Luangwa Valley, including part of Isoka District, against the Malawi/Tanzania borders around Muyombe. The climate of the two areas has been classed as tropical rainy, comprising a hot climate with no cool season with monthly average temperatures above 18^0C, with the exception of the north-western part of Isoka which experiences a longer cool season because of its altitude. The mean annual rainfall in these areas is below 1 000 mm. Rains start in the Lakes Depression Area around October 20 and progresses in a south-easterly direction to the Luangwa Valley where it starts around November 20. In the south of Mpika rains start declining around April 1. In the north around the lakes the rains stop a month later. The average number of days recording rain in the two areas is less than 80.

The two areas record more than two drought periods per year. The area around Lakes Mweru Wantipa and Tanganyika record an average 2-3 drought periods per season. A maximum of 5 dry times can be registered in a season in the valley. In Isoka east around Muyombe and Thendere an average 1-2 dry periods is experienced. The Luangwa Valley experiences frequent drought between January 10 and 20. The duration of the growing season ranges between 140 and 170 days.

Reid *et al.* (1986) have ranked finger millet second after sorghum as an important staple crop in the Luangwa Valley. In the Lakes Depression area finger millet is considered a minor crop.

2.8. Drought

Below average rainfall lasting up to 10 years occurred in the period 1921 - 1987. Below average rainfall lasting 3 – 5 years occurred 12 % of the time. Drought is said to occur when rainfall is 70 % below average for 21 days or longer (Chiras, 1985). Sichingabula (1995) has catalogued three studies that have considered the history of occurrence of drought in Zambia. Two studies by Simango and Das (1977), and Sichingabula (1995) have defined drought as below thirty-year average rainfall. A third study by Muchinda (1988) has defined drought as less than 750 mm of rainfall. If rainfall does not meet crop water requirements it leads to stress. Severe water stress causes substantial crop losses and chronic food insecurity (Ager, 2008). There is need for Zambia to develop sustainable strategies to adapt to variability in rainfall.

Ager has presented the United Nations World Food Summit (1996) definition of food security. Food security is understood to exist when " all people at all times have physical and economic access to sufficient safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." The average food bill for Sub-Saharan Africa between 2000 and 2004 was estimated to be US$17 million per year. In 2008 FAO feared the region would not meet Millennium Development Goal Number One (MDG1): To 'eradicate extreme poverty and hunger by 2015'. Low food production for the region was partly blamed on erratic rainfall in time and space and drought was projected to get worse with climate change (Ager 2008, IUCN 2010).

2.9. Strategies to Cope With Recurrent Drought

Kajoba (1995) has dealt with Zambia's experience and identified several short-term copies strategies to cope with drought, including distress sale of household assets, retail trading, barter and distribution of food aid devised to deal with the 1991/2 drought. More recently IUCN has presented additional coping strategies. Kajoba has argued that while short-term measures worked well, they were not sufficient. As a result drought has contributed to deepening poverty and food insecurity. Deep and widespread poverty has left a great majority of communities in drought prone areas vulnerable to HIV and AIDS infection because of the pressure abject poverty and grinding hunger exerts on them to earn a living (FAO, 2003). Crop research to select varieties that are drought tolerant is a sustainable way to cope with recurrent drought (Kajoba, 1995).

Therefore, there was need to devise long term strategies based on the promotion of sustainable agriculture which incorporates and improves indigenous cultivation systems as a way of coping better with recurrent drought. An Agricultural and Forestry Development Plan including improvement of indigenous crops especially sorghum and millets had been formulated by 1945 but could not be implemented due to a shift in government policy which placed undue emphasis on maize at the expense of traditional crops. Nevertheless, in trying to work out a long-term strategy to cope with periodic drought in Zambia, crop research to select varieties that were early maturing and drought tolerant so as to respond better to partial drought was proposed (Kajoba, 1995). There is now a National Adaptation Policy operated by the Ministry of Tourism, Environment and Natural Resources. The National Adaptation Programmes of Action (NAPAs) are documents prepared by least developed countries (LDCs) identifying urgent and immediate needs for adapting to climate change. NAPAs are then presented to the international donor community for support. Agro-ecological Region I in Zambia has been identified in the National Adaptation Programme of Action for Zambia (NAPA) as a priority area for land and water management interventions.

Furthermore from the beginning of 2006, breeding finger millet for tolerance to drought was one of the activities to be implemented in the National Agricultural and Cooperatives Policy (NAP, 2003 - 2015). The policy is an instrument for the domestication of the Millennium Development Goals (MDGs) and other international development initiatives. The vision of the policy is 'to promote development of an efficient, competitive and sustainable agricultural sector, which assures food security and increased income'. The vision also strives to contribute to the overall goal to achieve 'poverty reduction and economic growth'. Sectoral strategies in the policy include encouraging farmer participation in research through participatory research methodologies, and applying new improved technologies to enhance the efficiency of crop improvement programmes in addressing the needs of farmers.

2.10. Assessment of Variability

Assessment of genetic variability is of utmost importance for effective selection. Total variation comes about because of genotypic and environmental effects. Phenotypic variation is the observed variation in a character of a population. It includes both genotypic and environmental components of variation. Its magnitude differs with environemental conditions. Genotypic variation, on the other hand, is the component of variation due to genotypic differences among individuals within a population, and is of concern to plant breeders.

2.11. Simple Measures of Variability

The variability present in a breeding population can be measured in the following three ways:

1. Using simple measures of variability,
2. By estimating the various components of variance, and
3. By studying genetic diversity (Singh, 1983).

Singh has gone on to enumerate and define simple measures of variability. They include range, variance, standard deviation, standard error and coefficient of variation. For the definitions of these measures reference is made to Singh (1983). Estimating components of total variance involves crossing of a number of genotypes or strains in a definite fashion and evaluation of the progeny in replicated trials. Two biometrical tools are used for assessing genetic diversity. The D^2 statistic of Mahalanobis (1936) cited by Singh (1983) measures forces of differentiation at two levels namely, intracluster and intercluster levels. The D^2 statistic helps in the selection of genetically divergent parents for exploitation in hybridisation. Metroglyph analysis is a semigraphic method and is used to study large numbers of genotypes taken at a time. For brief descriptions of the two tools reference is made to Singh (1983).

2.12. Traits for Measuring Drought Tolerance

Serraj *et al.* (2004)'s list of putative physiological traits that could be used to measure drought tolerance is endless. It includes emergence characteristics, nutrient acquisition, water-use efficiency, root development and architecture, canopy temperature, stomatal regulation, osmotic adjustment, hormonal control, stay-green or leaf senescence, grain number, grain fill duration and rate, harvest index, yield and components.

Mnyenyembe and Gupta (1998) have studied variability for grain yield and related traits in germplasm accessions of finger millet from Malawi. Days to flower, plant height, finger length, finger width, number of fingers, number of productive tillers, panicle yield, grain yield and finger blast incidence were used. The International Plant genetic Resources Centre (IPGRI) now Bioversity International Descriptor list has 37 traits that can be used to describe finger millet. The following have been shown to indicate drought tolerance:

1. High water-use efficiency, leaf elongation, proline accumulation, relative water content and carbondioxide fixation (Viswanath, 1977);

2. High chlorophyll fluorescence, leaf area, survival, dry matter accumulation and grain yield and components (Reddy, 1977); and

3. High tillering, days to 50% flowering and protein content (Chandrasekharappa, 1979).

Several other indices that make use of grain yields have been applied in assessing genotypes for drought tolerance. They take account of geometric and mean productivity, standard superiority measure, drought susceptibility index (DSI), drought intensity index (DII), sensitivity index and stress tolerance index (Saba *et al.,* 2001). The limitation with these measures is that reliable grain yields must be available. Reductions in putative traits of drought tolerance are the simplest and most commonly used in finger millet.

Other authors (Banziger *et al.*, 1997; Banziger *et al.*, 1999; Banziger *et al.,* 2000a & b; Banziger *et al.,*2001; Banziger *et al.*, 2002; Banziger *et al.*, 2006) dealing with maize have spoken highly of the value of secondary traits as an indirect way of selecting for drought tolerance. Due to limitation of resources plant breeders have to find a compromise on the ideal trait to use to measure stress tolerance (Bos, 2004). Finger Millet Descriptors also show how standard measurements can be taken on the traits.

CHAPTER THREE

3. MATERIALS AND METHODS

3.1. Location

The experiment was carried out at the Zambia College of Agriculture – Mpika on an Acrisols. Acrisols are one of the 30 major soil groups of the World Reference Base for Soil Resources. They are clay-rich, deep, weak, sub-angular blocky – massive, sandy-loam over clay, and are associated with humid, tropical climates. The soil colour is 2.5 – 7.5 yr. Available water holding capacity is 0.5 – 6.1 cm/dm. They have a tendency to dry out very quickly after wetting. They are friable with a pH of 4.5 – 5.5. The cation exchange capacity is low (6 – 15 me). Base saturation is 25 – 60 %. Al^{+} and Fe saturation are moderate. The clays are mainly kaolinite with traces of illite. Weatherable minerals are few or moderate (Reid *et al.*, 1986).

3.2. Materials

A total of 203 finger millet accessions held in the National Plant Genetic Resources Centre in Zambia were used for the study. Four current varieties developed by the Finger Millet Improvement Programme at Misamfu Regional Research Centre in Kasama, Zambia were used as checks. Two of the check varieties coded FMM 175 and FMM 165 are high yielding mutants and the other two named Nyika and Senga are older varieties. The complete list of the materials, including the four varieties and passport data is presented as Annexe I.

3.3. Field layout

3.3.1. Augmented Design

The experiment was arranged in a wooden box and an Augmented Randomised Complete Block Design with 4 blocks, each one with at least 50 accessions.

Augmented designs (Chandra, 2003) were chosen for off-setting disadvantages of unreplicated trials like not having control over field variability and estimates of error for comparing treatments. The principle of augmented designs was to include with a replicated design consisting of a few treatments in a larger unreplicated trial. The replicated sub-design was analysed and used to adjust effects of unreplicated treatments and to estimate supposed common error variance which is used to compare treatments statistically.

The basic layout of Augmented Design was a division of the experimental area into a number of blocks. The check treatments could be arranged in several other designs such as Randomised Complete Block, Lattice and etc designs. Checks were replicated in each block and accessions were not. They were assigned to plots at random throughout the blocks. Their effects were adjusted for block differences which are estimated through the checks. The checks were standard varieties developed by the Finger Millet Improvement Programme in Zambia. They could have been any some of the accessions. The assumption was that variability of checks was the same as that of the treatments and selected were chosen for homogeneity. Any difference, therefore, between any one check attributes would be considered error.

The following relationship holds:

The total number of plots, $N = bc + v = b(c + n), n = v/b$ where:

b = number of blocks,

c = number of checks,

v = number of test treatments, and

n = number of treatments.

The total number of blocks was determined by the need to have at least 12 degrees of freedom for error in the analysis of the data. Therefore, $b > [12/(c-1)] + 1$.

The first step in the analysis was to construct a two-way table of check effects and means. The next step consisted in computing a block effect, r_j, for each block where:

$r_j = B_j - M$ and B_j = mean of all checks in the j^{th} block; and

M = grand mean of the checks.

The values are annexed (Annexe V and IX).

The standard errors for the different comparisons were computed as follows:

Difference between

1. Two check means $= \sqrt{(2MSE)/b}$;
2. Adjusted effects of two accessions in the same block $= \sqrt{(2MSE)}$;
3. Adjusted effects of two accessions in different blocks $= \sqrt{[2MSE(1 + 1/c]}$; and
4. Adjusted accession effect and a check $= \sqrt{[MSE(b+1)(c+1)]/bc}$

The values are also annexed (Annexe VI and XI)

Two sets of experimental plots, each a single row, 0.3 metres apart and 2 metres long were drilled in 10 x 2 x 0.3 metre wooden boxes with 1 metre pathways between boxes of plots, one with and the other without water stress, at the same site. Water stress was induced by withholding water from one set for 5 days during flowering. The two sets were 2 metres apart.

3.3.2. Wooden Boxes

The wooden box procedure was a modified application of Singh's (1999) technique. Wooden boxes were constructed from seasoned wild wood. The wooden boxes were filled with ordinary top soil from the experimental site which was meant to simulate typical finger millet growing conditions in Zambia.

3.3.3. Randomisation

The randomisation of experimental material within the layout is shown in Table 1 on page 18.

3.4. Crop Management

All accessions were planted off-season on June 21, 2009 following construction of the wooden boxes. Planting was done by drilling seed thinly in rows 0.3 m apart in shallow furrows (1 – 2 cm) after basal dressing fertiliser. The furrows were opened using wooden pegs. They were covered and firmed around seed to stop insects carrying the seed away and to facilitate faster imbibitions of water and germination.

The crop was watered daily to maintain soil moisture at field capacity, except during 5 days at flowering in the water stressed experiment meant to induce stress. Irrigation was stopped after the start of rains in November.

One hundred (100) kilogrammes (kg) of "D" fertiliser compound were applied as basal dressing at planting to supply 10 kg of nitrogen, 20 kg potassium, 10 kg phosphorus and 6 kg sulphur per hectare (ha); and 75 kg Urea (46 % nitrogen)/hectares in two split doses, the first dose being half the amount one month after planting and the second at booting stage according to recommendation. The total amount of nitrogen applied, therefore, was 34.5 kg/ha.

Thinning was done 50 days from planting. Seedlings took longer than expected to reach the

15 cm height required for thinning because of low temperatures. Seedlings were left 10 cm apart within the row.

It was done to keep experimental fields clean to avoid competition between the crop and weeds which might have camouflaged accession effects.

There were no serious incidences of insect pests and diseases. No application of pesticides was necessary. However, stray animals and birds posed serious challenges. There was need to fence the experimental field and for bird scaring from grain filling until harvesting.

Harvesting was done in January 2010 by cutting heads using hand knives. Threshing was done by pounding dried heads in a mortar.

3.5. Data Collection

Data on 12 agronomic and morphological characteristics sensitive to water stress was gathered and these are presented in Table 1 overleaf.

Table 1: Field Layout and Randomisation

Blocks			
Replications			
I	II	III	IV
FMM 175	ZM 194	ZM 3696	ZM 3943
N 33	ZM 195	ZM 3702	ZM 3946
ZM 66	ZM 197	ZM 3703	ZM 3948
ZM 101	ZM 198	ZM 3706	ZM 3955
ZM 102	ZM 199	ZM 3710	FMM 165
ZM 103	ZM 200	ZM 3715	ZM 3958
ZM 106	ZM 203	ZM 3716	ZM 138
ZM 109	ZM 208	ZM 3717	ZM 3962
ZM 110	ZM 209	ZM 3718	ZM 3965
ZM 111	ZM 211	ZM 3720	ZM 3969
ZM 112	ZM 212	ZM 3735	ZM 3972
ZM 114		ZM 3736	ZM 3977
ZM 115	Senga	FMM 175	ZM 4639
ZM 118	ZM 214	ZM 3739	ZM 4732
Nyika	ZM 216	ZM 3741	ZM 6599
ZM 119	ZM 218	ZM 3753	ZM 6600
ZM 120	ZM 219	ZM 3765	ZM 6607
ZM 121	ZM 220	ZM 3771	ZM 6637
ZM 122	ZM 221	ZM 3775	ZM 6714
ZM 123	ZM 222	ZM 3783	FMM 175
ZM 124	ZM 223	ZM 3784	ZM 5061
ZM 125	ZM 224	ZM 3786	ZM 7024
ZM 126	ZM 225	ZM 3790	ZM 40122
ZM 127	ZM 226	ZM 3801	ZM 1459
ZM 128	ZM 227	ZM 3803	ZM 3919
ZM 129	ZM 229	ZM 3806	ZM 5051
ZM 130	ZM 235	ZM 3809	ZM 5052
ZM 131	ZM 238	ZM 3811	ZM 3834
ZM 132	ZM 240	ZM 3813	ZM 3839
FMM 165	ZM 241	Nyika	ZM 3841
ZM 133	ZM 245	ZM 3816	ZM 3842
ZM 137	ZM 246	ZM 3817	ZM 3844
ZM 140	ZM 252	ZM 3819	ZM 3847
ZM 143	ZM 254	ZM 3824	ZM 3847
ZM 144	ZM 257	ZM 3825	ZM 3849
ZM 146	ZM 263	ZM 3826	ZM 3853
ZM 147	ZM 266	ZM 3827	FMM 175
ZM 148	Nyika	ZM 3828	ZM 3854
ZM 149	ZM 269	ZM 3904	ZM 3860
ZM 152	ZM 3605	ZM 3906	ZM 3861
ZM 153	ZM 3607	ZM 3907	ZM 3863
ZM 154	ZM 3609	ZM 3911	ZM 3864
ZM 155	ZM 3614	Senga	ZM 3866
ZM 156	ZM 3650	ZM 3912	ZM 3875
ZM 157	ZM 3651	ZM 3914	ZM 3879
Senga	ZM 3652	ZM 3917	ZM 3880
ZM 159	ZM 3653	ZM 3918	ZM 3884
ZM 162	ZM 3655	ZM 3920	ZM 3885
ZM 168	ZM 3657	ZM 3922	ZM 3891
ZM 173	ZM 3658	ZM 3925	ZM 3895
ZM 175	ZM 3661	ZM 3930	ZM 3897
ZM 3834	ZM 3684	ZM 3932	Senga
ZM 186	FMM 165	ZM 3934	ZM 3899
ZM 187	ZM 3685	ZM 3937	
ZM 190	ZM 3686	ZM 3939	

Table 2: Agronomic and Morphological Traits and their Abbreviations

Trait	Abbreviation
1. Plant height (cm)	PH
2. Number of productive tillers	NPT
3. Days to 50 % flowering	DTF
4. Spike length (mm)	SL
5. Spike width (mm)	SW
6. Spike number per panicle	SN
7. Spike weight (kg) per plot	SY
8. Grain weight (kg) per plot	GW
9. Pest and disease susceptibility score (1-5)	PDS
10. Stay green characteristic score (1-5)	SGC
11. Biomass weight (kg) per plot	BW
12. Chaff weight (kg) per plot	CW

Data on chaff weight (kg) and threshing percentage was derived. See Annexe II for the complete set of data. Data on plant height, number of productive tillers, spike length and width, and number of spikes per panicle are means of observations taken on 10 plants per plot.

3.6. Data Analysis

To check whether the amount of stress imposed on genotypes was adequate, one sample T-test of differences in genotype attributes between the two test environments was performed. First the differences were obtained. Subsequently, the differences were entered in a spreadsheet and saved in GenStat according to Buysse *et al.* (2007). Summary statistics, including the means and the standard errors required for a T-test, were then generated in the third edition of GenStat Discovery®. There was, however, need to show whether observed differences between accessions were significant. Therefore, separate individual one-way analysis of variance without blocking was conducted on the data.

3.6.1. Augmented Randomised Complete Block Design Analysis

Tables of check and block data and means of accessions were constructed (Annexe III, IV, VII and VIII). Block effects (Annexe V and IX) were then computed and used in adjusting accession data and in assembling the necessary tables. One-way analysis of variance in blocks in GenStat was used to generate error mean squares required to compute the standard errors for the different comparisons. The standard errors were used to construct rank orders in all traits considered.

3.6.2. *Calculation of Stress Tolerance*

The simple index, $Y_3 = Y_2 - Y_1$, where Y_1 = attribute of accession under optimum conditions, and Y_2 = attribute of accession under stress was used to measure tolerance to water stress. The values are in Table 13. The index was then employed to rank accessions in order of decreasing tolerance in the traits under consideration (Table 14).

3.6.3. *Cluster Analysis*

Hierarchical cluster analysis was performed in GenStat Discovery Edition 3 because of missing values in the data. Because available data had interval and ratio characteristics the dissimilarity coefficient, Euclidean Distance, $d_{(i,j)} = [^{p}\sum_{k=1}(X_{ik} - X_{jk}]^{1/2}$ was selected to perform nearest neighbour analysis.

The details on the basic steps followed in performing the procedure followed Subash Chandra's (2003) simplified outline.

CHAPTER FOUR

4. RESULTS

4.1. Summary Statistics

Summary statistics are shown in Table 3. On the basis of means alone they seemed to show a reduction in the number of productive tillers; spike length and number; grain, biomass and chaff weight; and pest and disease susceptibility with water stress. On the other hand, they gave the impression that there were increases in plant height, days to flowering, spike width and threshing percentage with stress. Grain weight per plot did not seem to change with stress.

The median values were the same for plant height, grain weight, pest and disease susceptibility, stay-green characteristic and biomass weight in the two growth environments. On the other hand days to 50 % flowering and spike width were higher, and number of productive tillers, spike length, spike number, spike weight and chaff weight lower in the stressed than in the optimal experiment.

The ranges of traits under study are also presented in Table 3 below. The values for range were the same in the stressed as in the optimal experiment for pest and disease susceptibility; higher for number of productive tillers, spike width, stay-green characteristic; and spike, grain and chaff weight; and lower for plant height, days to 50 % flowering, and spike length and number in the stressed than in the optimal. Higher values for range in number of productive tillers, spike width, stay-green characteristic; and spike, grain and chaff weight imply greater variability in these traits under stress.

Accessions exhibited the same pattern of variability with regards to interquartile range in the two sets as for simple range for most of the traits under study. The only exceptions were stay-green characteristic which had the same value in the two sets of environments; days to 50 % flowering which was higher; and spike and grain weight which was lower in stressed environment. Higher interquartile ranges meant greater data spread in days to 50 % flowering under stress.

Standard deviations were the same in the two sets for grain weight; larger for number of productive tillers, days to 50 % flowering, spike and biomass weight; and smaller for plant height, pest and disease susceptibility, stay-green characteristic, spike length, spike width and spike number in the stressed experiment. Larger standard deviations in number of productive tillers, days to 50 % flowering, spike and biomass weight showed that the measurements of the frequency distribution were widely spread out in these traits under stress.

Standard error of means were the same in the two experiments for number of productive tillers, days to 50 % flowering, spike length, spike width, grain width and pest and disease susceptibility; higher for spike number and stay-green characteristic; and lower for plant height, spike and chaff weight in the stressed experiment. Higher standard error of means implied greater chance variation in spike number and stay-green characteristic under stress.

Coefficient of variation was higher for number of productive tillers, days to 50 % flowering, stay-green characteristic, spike weight and number, and biomass and chaff weight; and lower for plant height, pest and disease susceptibility, and spike length and width in the stressed experiment. Higher coefficient of variation in number of productive tillers, days to 50 % flowering, stay-green characteristic, spike weight and number, and biomass and chaff weight pointed to greater relative variability of accessions under stress in these traits.

Table 3: Summary Statistics

Statistic	Trait							
	PH		NPT		DTF		SL	
Environment	1	2	1	2	1	2	1	2
Number of values	217	217	217	217	217	217	217	217
Number of observations	64	211	211	212	212	215	214	207
Number of missing values	153	6	6	5	5	2	3	10
Mean	70	73	5.9	5.3	131	135	59	57
Median	73	73	5.9	5.2	131	143	58	56
Minimum	0	45	2.4	1.6	82	82	22	32
Maximum	107	100	10.4	10.4	170	151	104	97
Range	107	54	8	8.8	88	69	82	66
Lower quartile	64	67	5	4.3	121	121	52	52
Upper quartile	82	79	6.8	6.2	140	147	66	62
Standard deviation	20	10	1.3	1.4	13	15	12	10
Standard error of mean	2	1	0.1	0.1	1	1	1	1
Variance	389	100	1.8	2	180	225	144	105
Coefficient of variation	28	14	22.3	26.9	10	11	20	18
Sum of values	4503	15404	1251.6	1119.1	27674	29015	12727	11853
Sum of squares	24510	21089	368.3	426.3	37963	48154	30726	21718
Uncorrected sum of squares	341367	1145712	7792.3	6333.8	3650464	3963829	787656	700442
Skewness	-2	0	0.3	0.4	4.13	4.96	1	1
Standard Error of Skewness	0	0	0.2	0.2	0	0	0	0
Kurtosis	5	0	0.3	0.5	1	0	1	2
Standard Error of Kurtosis	1	0	0.3	0.3	0	0	0	0

Table 3: Summary Statistics, Cont'd

Statistic	Trait							
	S W		SN		SY		GW	
Environment	1	2	1	2	1	2	1	2
Number of values	217	217	217	217	217	217	217	217
Number of observations	214	207	214	207	192	217	189	206
Number of missing values	3	10	3	10	25	0	28	11
Mean	7.2	7.4	11	5.9	2.6	1.34	0.011	0.011
Median	7.1	7.4	11	5.9	2.4	1.1	0.009	0.009
Minimum	4.9	4.9	4	2.6	0.4	-0.2	0.001	0
Maximum	9.3	9.5	14	8.7	6.6	6.5	0.046	0.057
Range	4.4	4.6	11	6.1	6.2	6.7	0.045	0.057
Lower quartile	6.5	6.8	10	5.4	2	0.6	0.005	0.004
Upper quartile	7.8	7.8	12	6.4	3	1.8	0.015	0.013
Standard deviation	0.9	0.8	2	0.9	0.9	1.05	0.009	0.009
Standard error of mean	0.1	0.1	0	0.1	0.1	0.07	0.001	0.001
Variance	0.7	0.7	2	0.9	0.8	1.1	0	0
Coefficient of variation	12	10.9	14	16	35.8	78.61	83.719	83.89
Sum of values	1533.4	1527.7	2354	1212.3	490.1	289.7	2.109	2.175
Sum of squares	157.7	134	525	180.2	159.7	237.89	0.016	0.016
Uncorrected sum of squares	11145	11408.1	26419	7280.1	1410.7	624.65	0.04	0.039
Skewness	0.1	0	-1	-0.4	0.8	1.45	1.482	2.126
Standard Error of Skewness	0.2	0.2	0	0.2	0.2	0.17	0.177	0.169
Kurtosis	-0.3	0.4	2	1.5	1.8	3.4	2.087	6.479
Standard Error of Kurtosis	0.3	0.3	0	0.3	0.3	0.33	0.352	0.337

Table 3: Summary Statistics, Cont'd

	PDS		SGC		BW	
Statistic Environment	1	2	1	2	1	2
Number of values	217	217	217	217	217	217
Number of observations	217	217	108	217	152	210
Number of missing values	0	0	109	0	65	7
Mean	4.2	3.8	3.13	2.8	2.27	2.2
Median	4	4	3	3	2	2
Minimum	0	0	1	0	0.5	0.3
Maximum	7	7	5	5	4.5	5.5
Range	7	7	4	5	4	5.2
Lower quartile	3	3	3	2	2	1.5
Upper quartile	5	5	4	3	3	3
Standard deviation	1.6	1.3	0.98	0.9	0.9	1
Standard error of mean	0.1	0.1	0.09	0.1	0.07	0.1
Variance	2.6	1.7	0.96	0.8	0.8	1.1
Coefficient of variation	38.2	34.3	31.23	32.5	39.45	46.9
Sum of values	908	832	338	606	345.5	469.7
Sum of squares	552.6	374	102.19	177.7	121.42	229.5
Uncorrected sum of squares	4352	3564	1160	1870	906.75	1280.1
Skewness	-0.3	-0.4	-0.56	-0.4	0.24	0.2
Standard Error of Skewness	0.2	0.2	0.23	0.2	0.2	0.2
Kurtosis	-0.9	0.2	-0.37	0	-0.31	-0.2
Standard Error of Kurtosis	0.3	0.3	0.46	0.3	0.39	0.3

Table 3: Summary Statistics, Cont'd

Statistic	Trait					
	T		C W		CGW	
Environment	1	2	1	2	1	2
Number of values	217	217	217	217	217	217
Number of observations	191	203	217	217	217	217
Number of missing values	26	14	0	0	0	0
Mean	0.44	0.94	2.2	1.32	6.7	4
Median	0.36	0.75	2.3	1.09	6.9	3.3
Minimum	0	-1	0	-0.2	-0.1	-0.6
Maximum	4	9.5	6.6	6.49	19.8	19.5
Range	4	10.5	6.6	6.69	19.8	20.1
Lower quartile	0.16	0.41	1.8	0.59	5.4	1.8
Upper quartile	0.56	1.2	2.9	1.79	8.7	5.4
Standard deviation	0.49	1.01	1.2	1.05	3.5	3.1
Standard error of mean	0.04	0.07	0.1	0.07	0.2	0.2
Variance	0.24	1.01	1.4	1.09	12.6	9.8
Coefficient of variation	111.67	107.38	52.6	78.89	52.6	78.9
Sum of values	83.82	190.35	488	287.53	1464	862.6
Sum of squares	45.63	204.81	301.7	236.01	2715.6	2124.1
Uncorrected sum of squares	82.41	383.3	1399.1	616.98	12592.2	5552.8
Skewness	4.13	4.96	-0.1	1.46	-0.1	1.5
Standard Error of Skewness	0.18	0.17	0.2	0.17	0.2	0.2
Kurtosis	24.49	35.88	0.6	3.47	0.6	3.5
Standard Error of Kurtosis	0.35	0.34	0.3	0.33	0.3	0.3

Environment 1 = Without Stress and 2 = With Stress, T = Threshing Percentage

Summary results of one sample T-test of differences in attributes of traits of accessions between the two sets of plots are in Table 4 below. They show significant differences in spike length ($p = 0.027$); highly significant differences in biomass ($p < 0.001$) and chaff weight ($p < 0.001$), days to 50 % flowering ($p < 0.001$), pest and disease susceptibility ($p < 0.007$), plant height ($p < 0.001$), number of productive tillers ($p < 0.001$), spike yield ($p < 0.001$) and stay-green characteristic ($p < 0.001$); and no significant difference in grain weight ($p = 0.744$) between test environments.

Table 4: Summary Statistics of One Sample T-Test of No Difference in Accession Attributes between the Two Environments.

Trait	Size	Mean	Variance	Standard deviation	Standard error of mean
BW	216	0.679	2.977**	1.725	0.117
CW	216	-0.927	2.098**	1.448	0.099
DTF	216	6.000	508.300**	22.550	1.534
GY	216	0.000	0.000	0.012	0.001
PDS	216	-0.335	3.318**	1.822	0.124
PH	210	51.990	1339.000**	36.590	2.525
NPT	207	-0.639	3.977**	1.994	0.139
SL	204	-2.194	197.000*	14.040	0.983
SN	206	-4.985	3.581**	1.892	0.132
SW	204	0.242	1.506**	1.227	0.086
SY	216	-0.938	2.196**	1.482	0.101
SG	216	0.806	3.708**	1.926	0.131

* = Significant at 5 % level, ** = Significant at 1 %

4.2 Formal statistical analysis

Details of separate test environment analysis of variance generated on the traits are presented in Annex XI and XII. Summaries of the analysis are contained in Tables 5 and 6.

In the optimal experiment one-way analysis of variance showed no significant difference in all traits studied except spike weight per plot ($p = 0.032$). Eighty-three accessions outweighed the best check (FMM 165 = 2.500kg/plot). The rank order is presented in Table 7

Table 5: Accessions and Error Mean Squares in Optimal Experiment

Source	Trait											
	PH	NPT	DTF	SL	SW	SN	SY	GW	PDS	SGC	BW	CW
Accessions	396.08	1.797^{ns}	183.2^{ns}	144.7^{ns}	0.715^{ns}	2.320^{ns}	0.8656^{*}	0.0000755^{ns}	2.597^{ns}	0.004337^{ns}	0.8160^{ns}	1.4131^{ns}
Error		1.021	114.3	116.1	1.308	4.944	0.2533	0.0001434	2.133	0.003028	0.4097	0.6931

^{ns} = not significant and * = significant at 5 % level

Table 6: Accessions and Error Mean Squares in Stressed Experiment

Source	Trait											
	PH	NPT	DTF	SL	SW	SN	SY	GW	PDS	SGC	BW	CW
Accessions	98.3^{ns}	2.063^{ns}	224.7^{ns}	107.57^{ns}	0.6376^{ns}	0.9107*	1.1296	0.0000755^{ns}	0.0014631^{**}	0.00014275^{*}	1.1215^{ns}	1.1209^{ns}
Error	148.9	1.304	239.1	66.74	0.9589	0.2517	0.4527	0.0001434	0.0002184	0.00005313	0.7417	0.4441

^{ns} = not significant, * = significant and ** = highly significant overleaf. Accession ZM 3813 had the highest spike yield (6.450 kg/plot) and significantly higher (SEs = 1.000 000 for comparing accessions in the same block and 1.000 000 for comparing accessions in different blocks, Annexe VI) than ZM 3811, the second highest spike yielding accession (5.150 kg/plot). ZM 203 was the least spike yielding accession (0.200 kg/plot).

In the stressed experiment the same analysis detected significant differences among accessions in spike number per panicle ($p = 0.014$) and the stay-green characteristic; and highly significant differences in pest and disease susceptibility ($p = 0.001$). The rank order of accessions according to decreasing number of spikes per panicle is given in Table 8. Ninety-two accessions exceeded the best check (Nyika = 5.923) in the attribute. The accession with the largest attribute (8.706 spikes) was ZM 3825, but was not significantly different (SEs for the different comparisons = 1.382534 and 1.54572, Annexe X) from 10 others, namely ZM 3828, ZM 153, ZM 3834, ZM 3715, ZM 3834, ZM 3816, ZM 154, ZM 3806, ZM 119 and ZM 121 with on average 8.306, 8.206, 8.131, 7.731, 7.706, 7.731, 7.606, 7.431, 7.406, 7.331 and 7.231 spikes respectively. ZM 193 had the smallest (2.631) average number of spikes.
The rank order of accessions according to increasing susceptibility to pests and diseases of accessions under stress is presented in Table 9. Thirty-one accessions had lower pest and disease susceptibility scores than the best check (Senga = 3.000). The least susceptible accession was ZM 3860 (Score = 0.406), significantly less (SEs = 0.015106 and 0.016889, Annexe X) than ZM 143, the next least susceptible accession with a score of 0.656. ZM 3652 with a score of 6.031 was the most susceptible accession.

Table 7: Rank Order of Accessions in Optimal Experiment According to Spike Weight

S. #	Acc. #	SY	S. #	Acc.#	SY	S. #	Acc.#	SY	S. #	Acc. #	SY
1	3813	6.450	**38**	3875	3.200	**75**	40122	2.700	**112**	3720	2.250
2	3811	5.150	**39**	3899	3.200	**76**	123	2.600	**113**	140	2.200
3	3914	4.750	**40**	3686	3.150	**77**	156	2.600	**114**	216	2.200
4	3684	4.700	**41**	3904	3.150	**78**	225	2.600	**115**	222	2.200
5	3771	4.650	**42**	129	3.100	**79**	3651	2.600	**116**	3937	2.200
6	148	4.400	**43**	3860	3.100	**80**	3655	2.600	**117**	3710	2.150
7	153	4.300	**44**	3861	3.100	**81**	3853	2.600	**118**	3716	2.150
8	3739	4.250	**45**	3884	3.100	**82**	3946	2.600	**119**	219	2.100
9	3925	4.250	**46**	3891	3.100	**83**	3965	2.600	**120**	235	2.100
10	112	4.200	**47**	3943	3.100	**84**	211	2.500	**121**	3653	2.100
11	3609	4.100	**48**	3958	3.100	**85**	114	2.500	**122**	3696	2.050
12	3918	4.050	**49**	3717	3.050	**86**	159	2.500	**123**	3715	2.050
13	115	4.000	**50**	3801	3.050	**87**	3841	2.500	**124**	3736	2.050
14	3607	4.000	**51**	3917	3.050	**88**	3849	2.500	**125**	3790	2.050
15	131	3.900	**52**	238	3.000	**89**	3863	2.500	**126**	3816	2.050
16	147	3.900	**53**	257	3.000	**90**	3866	2.500	**127**	214	2.000
17	157	3.900	**54**	3955	3.000	**91**	3880	2.500	**128**	266	2.000
18	3775	3.850	**55**	6599	3.000	**92**	3885	2.500	**129**	3657	2.000
19	3828	3.850	**56**	3784	2.950	**93**	3972	2.500	**130**	66	2.000
20	269	3.800	**57**	3932	2.950	**94**	5051	2.500	**131**	119	2.000
21	3864	3.700	**58**	133	2.900	**95**	6607	2.500	**132**	138	2.000
22	3803	3.650	**59**	3969	2.900	**96**	3753	2.450	**133**	3834	2.000
23	3817	3.650	**60**	4639	2.900	**97**	137	2.400	**134**	3842	2.000
24	3930	3.650	**61**	3735	2.850	**98**	3614	2.400	**135**	3847	2.000
25	3806	3.550	**62**	124	2.800	**99**	3879	2.400	**136**	3897	2.000
26	3827	3.550	**63**	127	2.800	**100**	3895	2.400	**137**	3718	1.950
27	3911	3.550	**64**	168	2.800	**101**	3934	2.400	**138**	3906	1.950
28	3661	3.500	**65**	173	2.800	**102**	4732	2.400	**139**	3920	1.950
29	3977	3.500	**66**	3652	2.800	**103**	3702	2.350	**140**	220	1.900
30	3939	3.400	**67**	3844	2.800	**104**	3706	2.350	**141**	1459	1.900
31	6714	3.400	**68**	3854	2.800	**105**	3825	2.350	**142**	3919	1.900
32	3907	3.350	**69**	3765	2.750	**106**	3826	2.350	**143**	3703	1.850
33	130	3.300	**70**	120	2.700	**107**	101	2.300	**144**	3741	1.850
34	3650	3.300	**71**	241	2.700	**108**	218	2.300	**145**	3824	1.850
35	3809	3.250	**72**	3658	2.700	**109**	263	2.300	**146**	106	1.800
36	3912	3.250	**73**	5052	2.700	**110**	5061	2.300	**147**	128	1.800
37	122	3.200	**74**	7024	2.700	**111**	3685	2.250	**148**	208	1.800

Table 7: Rank Order of Accessions in Optimal Experiment According to Spike Weight, Cont'd

S. #	Acc.#	SY	S. #	Acc.#	SY
149	226	1.800	**186**	143	0.200
150	229	1.800	**187**	144	0.200
151	240	1.800	**188**	146	0.200
152	245	1.800	**189**	149	0.200
153	252	1.800	**190**	154	0.200
154	3962	1.800	**191**	162	0.200
155	6600	1.800	**192**	165	0.200
156	3922	1.750	**193**	175	0.200
157	111	1.700	**194**	186	0.200
158	246	1.700	**195**	187	0.200
159	254	1.700	**196**	3834	0.200
160	3819	1.650	**197**	190	-0.200
161	224	1.600	**198**	194	-0.200
162	109	1.600	**199**	195	-0.200
163	121	1.600	**200**	197	-0.200
164	152	1.600	**201**	198	-0.200
165	155	1.600	**202**	199	-0.200
166	3783	1.550	**203**	203	-0.200
167	3786	1.550	**FMM 175**		**2.21**
168	125	1.500	**FMM 165**		**2.50**
169	200	1.500	**Nyika**		**2.02**
170	223	1.400	**Senga**		**1.59**
171	3948	1.400			
172	110	1.200			
173	212	1.200			
174	221	1.200			
175	3605	0.900			
176	3839	0.900			
177	103	0.700			
178	209	0.600			
179	6637	0.600			
180	227	0.200			
181	33	0.200			
182	102	0.200			
183	118	0.200			
184	126	0.200			
185	132	0.200			

S. # = Serial Number
Acc. # = Accession Number

Table 8: Rank Order of Accessions in Stressed Experiment According to Spike Number per Panicle

S. #	Acc. #	SN	S. #	Acc. #	SN	S. #	Acc. #	SN	S. #	Acc. #	SN
1	3825	8.706	**38**	199	6.631	**75**	3899	6.131	**112**	6714	5.731
2	3801	8.306	**39**	3939	6.631	**76**	4639	6.131	**113**	3717	5.706
3	3828	8.206	**40**	3735	6.606	**77**	3904	6.106	**114**	3827	5.706
4	153	8.131	**41**	3784	6.606	**78**	131	6.031	**115**	101	5.631
5	3834	7.731	**42**	266	6.531	**79**	147	6.031	**116**	110	5.631
6	3715	7.706	**43**	3841	6.531	**80**	5052	6.031	**117**	146	5.631
7	3834	7.631	**44**	3919	6.531	**81**	3703	6.006	**118**	156	5.631
8	3816	7.606	**45**	3783	6.506	**82**	3790	6.006	**119**	186	5.631
9	154	7.431	**46**	3861	6.431	**83**	3826	6.006	**120**	224	5.631
10	3806	7.406	**47**	3864	6.431	**84**	3853	5.931	**121**	252	5.631
11	119	7.331	**48**	3880	6.431	**85**	3884	5.931	**122**	3661	5.631
12	3736	7.306	**49**	3897	6.431	**86**	7024	5.931	**123**	6600	5.631
13	3842	7.231	**50**	106	6.431	**87**	109	5.931	**124**	3786	5.606
14	121	7.231	**51**	123	6.431	**88**	120	5.931	**125**	3824	5.606
15	3817	7.206	**52**	129	6.431	**89**	125	5.931	**126**	3917	5.606
16	144	7.131	**53**	152	6.431	**90**	220	5.931	**127**	33	5.531
17	218	7.131	**54**	3609	6.431	**91**	240	5.931	**128**	148	5.531
18	3811	7.106	**55**	3720	6.406	**92**	3650	5.931	**129**	187	5.531
19	3839	7.031	**56**	3803	6.406	**93**	3706	5.906	**130**	219	5.531
20	3854	7.031	**57**	122	6.331	**94**	3718	5.906	**131**	225	5.531
21	3813	7.006	**58**	130	6.331	**95**	3741	5.906	**132**	3657	5.531
22	3885	6.931	**59**	226	6.331	**96**	66	5.831	**133**	3937	5.531
23	132	6.931	**60**	3844	6.331	**97**	127	5.831	**134**	3972	5.531
24	257	6.931	**61**	4732	6.331	**98**	165	5.831	**135**	5051	5.531
25	173	6.831	**62**	3775	6.306	**99**	194	5.831	**136**	40122	5.531
26	3614	6.831	**63**	190	6.231	**100**	269	5.831	**137**	3765	5.506
27	3948	6.831	**64**	3847	6.231	**101**	1459	5.831	**138**	3920	5.506
28	3739	6.806	**65**	3860	6.231	**102**	3652	5.831	**139**	3958	5.431
29	138	6.731	**66**	3710	6.206	**103**	3653	5.831	**140**	195	5.431
30	6637	6.731	**67**	3716	6.206	**104**	3866	5.831	**141**	198	5.431
31	114	6.731	**68**	3753	6.206	**105**	3891	5.831	**142**	235	5.431
32	124	6.731	**69**	3809	6.206	**106**	3685	5.806	**143**	238	5.431
33	157	6.731	**70**	168	6.131	**107**	221	5.731	**144**	3655	5.431
34	3906	6.706	**71**	175	6.131	**108**	254	5.731	**145**	3702	5.406
35	118	6.631	**72**	216	6.131	**109**	263	5.731	**146**	3771	5.406
36	128	6.631	**73**	3863	6.131	**110**	3658	5.731	**147**	3907	5.406
37	197	6.631	**74**	3895	6.131	**111**	6599	5.731	**148**	3911	5.406

Table 8: Rank Order of Accessions in Stressed Experiment According to Spike Number per Panicle, Cont'd

S. #	Acc. #	SN	S. #	Acc. #	SN
149	112	5.331	**186**	3962	3.931
150	115	5.331	**187**	3922	3.606
151	159	5.331	**188**	3930	3.506
152	3651	5.331	**189**	103	3.331
153	3849	5.331	**190**	155	3.331
154	5061	5.331	**191**	223	3.331
155	3686	5.306	**192**	3918	2.806
156	200	5.231	**193**	3879	2.631
157	3965	5.231		**FMM 175**	**5.750**
158	3977	5.231		**FMM 165**	**5.031**
159	102	5.131		**Nyika**	**5.923**
160	126	5.131		**Senga**	**5.650**
161	203	5.131			
162	246	5.131			
163	3943	5.131			
164	3955	5.131			
165	6607	5.131			
166	3819	5.106			
167	209	5.031			
168	229	5.031			
169	3912	5.006			
170	3969	4.931			
171	214	4.931			
172	143	4.831			
173	211	4.831			
174	245	4.831			
175	3875	4.731			
176	3946	4.731			
177	241	4.631			
178	222	4.531			
179	3914	4.506			
180	212	4.431			
181	227	4.331			
182	3934	4.331			
183	3684	4.231			
184	149	4.131			
185	3932	4.006			

Table 9: Rank Order of Accessions in Stressed Experiment According to Pest and Disease Susceptibility

S. #	Acc. #	PDS	S. #	Acc. #	PDS	S. #	Acc. #	PDS	S. #	Acc. #	PD
1	3860	0.406	38	212	3.031	75	140	3.656	112	222	4.0
2	143	0.656	39	223	3.031	76	148	3.656	113	225	4.0
3	3897	1.406	40	226	3.031	77	153	3.656	114	254	4.0
4	156	1.656	41	229	3.031	78	162	3.656	115	266	4.0
5	159	1.656	42	238	3.031	79	165	3.656	116	269	4.0
6	3911	1.906	43	240	3.031	80	168	3.656	117	3607	4.0
7	3932	1.906	44	241	3.031	81	173	3.656	118	3655	4.0
8	203	2.031	45	246	3.031	82	175	3.656	119	3657	4.0
9	224	2.031	46	252	3.031	83	186	3.656	120	3658	4.0
10	227	2.031	47	257	3.031	84	3834	3.656	121	3844	4.4
11	235	2.031	48	263	3.031	85	3686	3.906	122	3849	4.4
12	245	2.031	49	3661	3.031	86	3702	3.906	123	3863	4.4
13	3605	2.031	50	1459	3.406	87	3706	3.906	124	3864	4.4
14	3684	2.031	51	3839	3.406	88	3710	3.906	125	3879	4.4
15	138	2.406	52	3841	3.406	89	3715	3.906	126	3885	4.4
16	3834	2.406	53	3842	3.406	90	3718	3.906	127	3891	4.4
17	3880	2.406	54	3847	3.406	91	3720	3.906	128	3919	4.4
18	3958	2.406	55	3875	3.406	92	3739	3.906	129	3934	4.4
19	33	2.656	56	3899	3.406	93	3741	3.906	130	3939	4.4
20	103	2.656	57	3972	3.406	94	3753	3.906	131	3943	4.4
21	114	2.656	58	6607	3.406	95	3765	3.906	132	3955	4.4
22	121	2.656	59	6637	3.406	96	3801	3.906	133	3962	4.4
23	122	2.656	60	6714	3.406	97	3803	3.906	134	3969	4.4
24	152	2.656	61	66	3.656	98	3809	3.906	135	3977	4.4
25	3703	2.906	62	101	3.656	99	3811	3.906	136	4639	4.4
26	3735	2.906	63	102	3.656	100	3819	3.906	137	4732	4.4
27	3771	2.906	64	106	3.656	101	3826	3.906	138	5051	4.4
28	3813	2.906	65	109	3.656	102	3828	3.906	139	5061	4.4
29	3824	2.906	66	111	3.656	103	3912	3.906	140	40122	4.4
30	3906	2.906	67	112	3.656	104	3917	3.906	141	110	4.6
31	3914	2.906	68	115	3.656	105	3922	3.906	142	118	4.6
32	190	3.031	69	119	3.656	106	195	4.031	143	123	4.6
33	194	3.031	70	120	3.656	107	209	4.031	144	125	4.6
34	197	3.031	71	124	3.656	108	216	4.031	145	128	4.6
35	198	3.031	72	126	3.656	109	219	4.031	146	131	4.6
36	199	3.031	73	129	3.656	110	220	4.031	147	132	4.6
37	200	3.031	74	137	3.656	111	221	4.031	148	133	4.6

Table 9: Rank Order of Accessions in Stressed Experiment According to Pest and Disease Susceptibility

S. #	Acc. #	PDS	S.No	Acc. #	PDS
149	144	4.656	186	3895	5.406
150	146	4.656	187	3937	5.406
151	147	4.656	188	3946	5.406
152	149	4.656	189	3948	5.406
153	154	4.656	190	3965	5.406
154	157	4.656	191	5052	5.406
155	187	4.656	192	6599	5.406
156	3685	4.906	193	6600	5.406
157	3696	4.906	194	7024	5.406
158	3716	4.906	195	127	5.656
159	3717	4.906	196	130	5.656
160	3736	4.906	197	155	5.656
161	3775	4.906	198	3817	5.906
162	3783	4.906	199	3817	5.906
163	3784	4.906	200	3652	6.031
164	3786	4.906	**FMM 175**		3.594
165	3790	4.906	**FMM 165**		**5.219**
166	3806	4.906	**Nyika**		**4.198**
167	3816	4.906	**Senga**		**3.000**
168	3827	4.906			
169	3904	4.906			
170	3907	4.906			
171	3925	4.906			
172	3930	4.906			
173	208	5.031			
174	211	5.031			
175	214	5.031			
176	218	5.031			
177	3609	5.031			
178	3650	5.031			
179	3651	5.031			
180	3653	5.031			
181	3853	5.406			
182	3854	5.406			
183	3861	5.406			
184	3866	5.406			
185	3884	5.406			

Table 10: Rank order of accessions according to decreasing stay-green score

S. #	Acc. #	SN	S. #	Acc. #	SN	S. #	Acc. #	SN	S. #	Acc. #	SN
1	225	5.222	**38**	155	3.972	**75**	175	2.972	**112**	3866	2.2
2	245	5.222	**39**	156	3.972	**76**	186	2.972	**113**	3875	2.2
3	112	4.972	**40**	168	3.972	**77**	3834	2.972	**114**	3879	2.2
4	209	4.222	**41**	173	3.972	**78**	190	2.222	**115**	3880	2.2
5	211	4.222	**42**	194	3.222	**79**	195	2.222	**116**	3884	2.2
6	216	4.222	**43**	203	3.222	**80**	198	2.222	**117**	3885	2.2
7	218	4.222	**44**	214	3.222	**81**	208	2.222	**118**	3891	2.2
8	221	4.222	**45**	219	3.222	**82**	212	2.222	**119**	3895	2.2
9	229	4.222	**46**	220	3.222	**83**	223	2.222	**120**	3919	2.2
10	238	4.222	**47**	222	3.222	**84**	226	2.222	**121**	3946	2.2
11	241	4.222	**48**	235	3.222	**85**	3657	2.222	**122**	3948	2.2
12	252	4.222	**49**	240	3.222	**86**	3661	2.222	**123**	3955	2.2
13	257	4.222	**50**	246	3.222	**87**	3685	2.222	**124**	3958	2.2
14	263	4.222	**51**	254	3.222	**88**	3686	2.222	**125**	3962	2.2
15	266	4.222	**52**	3614	3.222	**89**	3702	2.222	**126**	3965	2.2
16	269	4.222	**53**	3650	3.222	**90**	3706	2.222	**127**	3969	2.2
17	3605	4.222	**54**	3653	3.222	**91**	3897	2.222	**128**	3972	2.2
18	3607	4.222	**55**	3655	3.222	**92**	3899	2.222	**129**	3977	2.2
19	3609	4.222	**56**	3658	3.222	**93**	3934	2.222	**130**	4639	2.2
20	3651	4.222	**57**	3696	3.222	**94**	3937	2.222	**131**	4732	2.2
21	3652	4.222	**58**	3710	3.222	**95**	3939	2.222	**132**	5051	2.2
22	3684	4.222	**59**	3715	3.222	**96**	3943	2.222	**133**	5052	2.2
23	106	3.972	**60**	3716	3.222	**97**	138	2.2	**134**	5061	2.2
24	109	3.972	**61**	66	2.972	**98**	1459	2.2	**135**	6599	2.2
25	111	3.972	**62**	101	2.972	**99**	3834	2.2	**136**	6600	2.2
26	115	3.972	**63**	102	2.972	**100**	3839	2.2	**137**	6607	2.2
27	123	3.972	**64**	110	2.972	**101**	3841	2.2	**138**	6637	2.2
28	124	3.972	**65**	118	2.972	**102**	3842	2.2	**139**	6714	2.2
29	125	3.972	**66**	119	2.972	**103**	3844	2.2	**140**	7024	2.2
30	126	3.972	**67**	120	2.972	**104**	3847	2.2	**141**	40122	2.2
31	127	3.972	**68**	121	2.972	**105**	3849	2.2	**142**	114	1.972
32	128	3.972	**69**	122	2.972	**106**	3853	2.2	**143**	133	1.972
33	129	3.972	**70**	137	2.972	**107**	3854	2.2	**144**	165	1.972
34	130	3.972	**71**	140	2.972	**108**	3860	2.2	**145**	187	1.972
35	131	3.972	**72**	157	2.972	**109**	3861	2.2	**146**	197	1.222
36	132	3.972	**73**	159	2.972	**110**	3863	2.2	**147**	199	1.222
37	143	3.972	**74**	162	2.972	**111**	3864	2.2	**148**	200	1.222

Table 10: Rank order of accessions according to decreasing stay-green score, Cont'd

S. #	Acc. #	SN	S. #	Acc. #	SN
149	224	1.222	**186**	3825	-0.778
150	227	1.222	**187**	3826	-0.778
151	3703	1.222	**188**	3827	-0.778
152	33	0.972	**189**	3828	-0.778
153	103	0.972	**190**	3904	-0.778
154	144	-0.028	**191**	3906	-0.778
155	146	-0.028	**192**	3907	-0.778
156	147	-0.028	**193**	3911	-0.778
157	148	-0.028	**194**	3912	-0.778
158	149	-0.028	**195**	3914	-0.778
159	152	-0.028	**196**	3917	-0.778
160	153	-0.028	**197**	3918	-0.778
161	154	-0.028	**198**	3920	-0.778
162	3717	-0.778	**199**	3922	-0.778
163	3718	-0.778	**200**	3925	-0.778
164	3720	-0.778	**201**	3930	-0.778
165	3735	-0.778		3932	-0.778
166	3736	-0.778		**FMM 175**	**1.399**
167	3739	-0.778		**FMM 165**	**2.711**
168	3741	-0.778		**Nyika**	**1.139**
169	3753	-0.778		**Senga**	**1.1595**
170	3765	-0.778			
171	3771	-0.778			
172	3775	-0.778			
173	3783	-0.778			
174	3784	-0.778			
175	3786	-0.778			
176	3790	-0.778			
177	3801	-0.778			
178	3803	-0.778			
179	3806	-0.778			
180	3809	-0.778			
181	3811	-0.778			
182	3816	-0.778			
183	3817	-0.778			
184	3819	-0.778			
185	3824	-0.778			

Error mean squares for computing the standard errors for the different comparisons in the traits of were obtained (Tables 11 and 12). The standard errors for the different comparisons are presented below adjusted and unadjusted accession data in Annexe X above.

The rank order of accessions according to decreasing stay-green score is in Table 10 on the next page. Accessions can be grouped into 6 classes according to this trait. Three accessions (ZM 225, 245 and 112) were scored excellent on the basis of the trait.

Table 11: Check and Error Mean Squares of Check Means in the Optimal Experiment

Source	df	PH	NPT	DTF	SL	SN	SY	GY	PDS	SGC	BW	T	CW	CGY
Checks	3	158.449	3.91^{ns}	73.5^{ns}	291.4^{ns}	3.535^{ns}	0.2617^{ns}	0.00010182^{ns}	2.879^{ns}	1.5815^{*}	0.9734^{ns}	0.13895^{ns}	$0.6291^{n}s$	5.662^{ns}
Error	6		5.41	66.94	177.1	1.632	0.1544	0.00003651	2.101	0.125	0.294	0.05086	0.3369	3.032
Total	12													

*= Significant and ^{ns}= Not significant at 5 %

Table 12: Accession and Error Mean Squares of Check Means in the Stressed Experiment

Source	df	PH	NPT	DTF	SL	SN	SY	SW	GY	PDS	SGC	BW	CW	CGY
Checks	3	34.3^{ns}	3.95^{ns}	106.6^{ns}	208.27^{ns}	0.439^{ns}	1.1738^{*}	0.8019^{ns}	0.0000514^{ns}	2.8073^{**}	1.2643^{*}	1.8958^{ns}	1.1594^{*}	10.434^{*}
Error	6	106.9	1.621	157.2	67.71	0.2667	0.1864	0.9557	0.0001141	0.3906	0.2921	0.5451	0.1811	1.63
Total	12													

** = Highly Significant, *= Significant and ^{ns}= Not Significant

The check and block data and means in the stressed experiment are presented in Annexes VII and VIII.

Differences in the attributes of accessions between the two sets of environments are presented in Table 13 overleaf. Accessions with 0 or positive values were tolerant to water stress while accessions with negative values were susceptible. The values were used to rank the accessions. The bigger the value or the more positive the difference, the greater was the tolerance and the higher the level of tolerance.

Table 13: Tolerance of Accessions to Water Stress

Acc. #	Trait											
	PH	NPT	DTF	SL	SW	SN	SY	GY	PDS	SGC	BW	CW
33	-11.8	0.1	2	0.7	1.7	-3.6	0.515	0.007	0.0	1.5	1.014	0.146
66	29.4	-0.4	10	-4.8	1.3	-4.5	-0.085	0.010	-3.0	0.5	1.714	-0.457
101	-8.2	-0.9	11	-35.3	0.8	-7.0	-1.486	0.003	-3.0	-0.5	1.214	-1.850
102	-0.8	-2.2	6	-19.3	0.6	-5.9	0.715	0.006	-3.0	-0.5	2.714	0.347
103	15.6	-2.9	2	-13.5	0.7	-3.7	-0.386	0.000	0.0	0.5	1.214	-0.747
106	25.1	0.1	-9	-9.5	-0.6	-5.2	-0.786	0.004	-3.0	-0.5	2.714	-1.151
109	12.2	1.8	1	-21.8	-0.7	-3.7	-0.486	0.005	-3.0	-0.5	2.714	-0.852
110	27.0	-1.5	-13	4.9	-1.4	-5.2	-0.386	-0.001	0.0	0.5	2.714	-0.746
111	12.6	-0.7	13	#DIV/0!	#DIV/0!	#DIV/0!	-1.386	-0.001	-3.0	-1.5	2.714	-1.746
112	10.7	0.6	18	-21.9	2.9	-7.3	-1.686	-0.001	-3.0	-2.5	2.714	-2.046
114	14.5	0.8	-20	-22.4	-3.8	-3.8	-1.486	-0.013	0.0	-0.5	1.714	-1.834
115	-3.3	1.9	-17	-8.1	-1.5	-6.4	-2.686	0.001	-3.0	-0.5	2.214	-3.048
118	7.1	2.7	16	-3.9	1.4	-7.0	1.315	0.006	-1.0	0.5	2.714	0.947
119	17.5	0.2	18	-2.6	-0.7	-7.2	-1.086	0.000	-1.0	0.5	2.714	-1.447
120	8.6	0.3	22	-10.2	0.4	-5.1	-1.686	0.009	-2.0	0.5	2.714	-2.056
121	19.8	0.5	2	-14.7	0.5	-2.5	-1.086	0.003	-3.0	-0.5	3.214	-1.450
122	-0.2	1.9	23	-16.0	0.3	-5.3	-1.886	-0.004	-3.0	-0.5	2.214	-2.243
123	-1.2	2.1	1	-15.3	-1.0	-3.0	-1.286	0.001	-1.0	0.5	3.714	-1.648
124	-12.7	0.0	-20	-13.8	-0.4	-5.0	-0.986	0.020	-3.0	-0.5	2.714	-1.367
125	-29.3	0.7	18	-7.0	-0.7	-3.1	-0.286	0.003	-1.0	-0.5	4.214	-0.650
126	-6.4	1.5	19	-18.6	-0.7	-5.5	0.915	0.008	-2.0	-0.5	3.214	0.545
127	-0.8	-3.3	7	-12.7	-0.9	-4.5	-1.186	-0.002	-1.0	0.5	4.714	-1.545
128	-8.4	1.1	20	4.9	0.2	-3.5	-0.686	0.002	-2.0	-0.5	3.714	-1.049
129	-11.8	-2.2	28	-12.3	-2.7	-4.4	-2.086	-0.036	-2.0	-1.5	0.714	-2.411
130	-1.4	-0.6	27	3.9	0.3	-3.3	-1.686	0.015	-1.0	-0.5	0.714	-2.062

Table 13: Tolerance of Accessions to Water Stress, Cont'd

Acc. #	Trait											
	PH	NPT	DTF	SL	SW	SN	SY	GY	PDS	SGC	BW	CW
131	-4.2	3.6	26	2.8	0.5	-5.9	-1.586	0.015	-1.0	-1.5	0.714	-1.962
132	2.4	0.1	22	-1.1	0.8	-5.7	1.115	0.000	-2.0	-1.5	0.714	0.753
133	-9.1	0.5	22	#DIV/0!	#DIV/0!	#DIV/0!	-2.586	-0.023	1.0	1.5	0.714	-2.924
137	-24.6	3.0	26	#DIV/0!	#DIV/0!	#DIV/0!	-2.086	-0.008	0.0	-0.5	3.714	-2.439
138	73.7	2.8	18	-0.4	-0.5	-2.3	-0.748	0.003	-0.9	-1.1	-0.673	-0.615
140	#DIV/0!	#DIV/0!	29	#DIV/0!	#DIV/0!	#DIV/0!	-1.886	-0.001	0.0	-0.5	3.214	-2.246
143	-28.0	-0.4	11	1.0	2.5	-7.7	1.915	0.013	-4.0	-0.5	2.714	1.540
144	-18.9	-1.7	17	-11.4	-0.2	-4.5	1.815	0.009	-1.0	3.5	3.714	1.444
146	-39.8	-1.4	26	-17.7	-0.4	-6.1	1.315	0.011	-2.0	2.5	3.714	0.942
147	-32.9	0.3	27	-11.8	1.1	-5.9	-1.686	0.034	-1.0	2.5	1.214	-2.081
148	-16.9	-1.1	30	-24.2	0.3	-5.5	-2.886	0.000	-3.0	3.5	1.714	-3.247
149	-10.8	-1.5	15	-31.5	-1.3	-7.6	-0.086	0.001	4.0	1.5	4.214	-0.448
152	-2.3	-0.4	21	-6.3	-0.4	-3.5	0.015	-0.009	-3.0	3.5	3.714	-0.338
153	69.1	0.8	23	#DIV/0!	#DIV/0!	7.5	-1.786	0.021	-3.0	3.5	1.014	-2.168
154	-0.6	1.6	0	-15.7	-0.6	-4.3	3.715	0.015	-1.0	4.5	4.714	3.338
155	11.6	-2.3	6	11.2	-0.9	-1.2	-1.486	0.000	0.0	-2.5	2.714	-1.847
156	-4.0	0.2	14	-11.4	0.5	-4.3	-0.586	-0.003	-5.0	-0.5	3.714	-0.944
157	62.3	-0.3	8	-13.2	0.8	-5.4	-1.286	0.010	1.0	-0.5	4.214	-1.657
159	2.0	-0.8	9	-13.5	-1.5	-5.7	-0.686	0.011	-1.0	-0.5	1.714	-1.058
162	69.8	0.4	15	#DIV/0!	#DIV/0!	#DIV/0!	0.115	-0.001	2.0	-0.5	2.714	-0.246
165	-0.2	0.6	-5	-8.6	0.6	-6.1	0.615	0.009	0.0	0.5	0.714	0.244
168	24.7	-1.5	19	-7.3	-0.8	-6.5	0.715	0.018	1.0	-1.5	1.714	0.335
173	5.1	-0.5	16	-32.2	-1.4	-4.8	-0.286	0.007	1.0	-1.5	1.714	-0.654

Table 13: Tolerance of Accessions to Water Stress, Cont'd

Acc. #	Trait											
	PH	NPT	DTF	SL	SW	SN	SY	GY	PDS	SGC	BW	CW
175	-10.5	-1.2	22	-13.0	-1.7	-6.0	0.815	0.007	1.0	-0.5	2.714	0.446
186	7.7	0.7	-7	-13.7	0.0	-9.2	1.815	0.000	1.0	0.5	2.714	1.453
187	-3.2	-1.8	22	-19.7	-0.8	-7.0	1.615	0.000	2.0	1.5	3.714	1.253
190	-20.6	1.3	22	12.7	-1.4	-5.2	2.171	0.005	1.3	-0.2	1.985	2.302
194	4.4	-2.5	-18	5.5	-0.6	-6.1	1.471	0.006	-2.7	-0.2	2.485	1.601
195	-23.7	-0.1	33	16.8	-1.5	-4.7	0.271	0.005	-0.7	-0.2	1.485	0.402
197	-14.2	-1.5	-6	32.7	1.1	-4.6	2.371	0.019	0.3	0.8	1.985	2.488
198	-14.9	1.8	25	-3.6	0.5	-8.2	1.571	0.022	0.3	-0.2	2.485	1.685
199	-21.9	-2.3	25	3.5	-1.6	-2.1	1.071	0.023	0.3	0.8	1.985	1.184
200	-16.5	1.2	-4	17.6	-2.4	-5.1	0.771	0.010	1.3	-0.2	2.485	0.897
203	-1.4	-0.1	-24	13.8	-0.8	-5.2	2.371	0.006	-1.7	-0.2	2.985	2.501
208	-20.7	-3.7	14	#DIV/0!	#DIV/0!	#DIV/0!	-2.129	0.007	3.3	1.8	-0.515	-2.000
209	0.6	-2.2	20	27.5	-0.7	-5.7	-0.929	0.009	2.3	-0.2	0.985	-0.802
211	61.6	-2.2	-15	#DIV/0!	#DIV/0!	5.2	2.771	0.002	0.3	-1.2	-0.015	2.905
212	60.6	-3.0	-4	-13.2	0.8	-7.0	1.771	-0.009	0.3	-0.2	1.485	1.916
214	71.3	1.5	8	11.9	-0.5	-6.5	-1.229	0.009	0.3	-0.2	-0.015	-1.102
216	75.5	-1.4	10	-0.5	0.6	-4.4	3.971	0.005	-1.7	-1.2	0.985	4.102
218	69.1	-0.9	13	2.9	-2.7	-3.0	-1.129	0.008	-0.7	-1.2	0.985	-1.001
219	54.2	-1.9	25	4.0	-0.8	-4.4	-0.629	0.013	-0.7	-0.2	0.985	-0.506
220	72.8	-1.2	18	13.9	0.9	-3.9	0.171	0.015	1.3	-0.2	0.485	0.292
221	61.7	1.1	11	6.6	1.0	-3.5	0.771	-0.005	-1.7	-2.2	0.485	0.912
222	56.7	-1.6	20	3.4	1.6	-8.2	-1.229	-0.010	-0.7	-2.2	0.985	-1.083

Table 13: Tolerance of Accessions to Water Stress, Cont'd

Acc. #	Trait											
	PH	NPT	DTF	SL	SW	SN	SY	GY	PDS	SGC	BW	CW
223	43.0	-0.8	-7	-10.4	-2.3	-6.5	-1.529	0.022	2.3	0.8	1.485	-1.415
187	-3.2	-1.8	22	-19.7	-0.8	-7.0	1.615	0.000	2.0	1.5	3.714	1.253
224	64.1	-0.5	-11	14.5	0.5	-5.3	1.871	0.001	1.3	0.8	1.485	2.006
225	63.9	-3.2	-36	20.4	-0.5	-6.4	-0.629	0.004	-2.7	-4.2	0.485	-0.497
227	71.6	-1.9	-13	19.8	0.6	-8.0	0.771	-0.003	1.3	0.8	0.985	0.910
229	84.7	-0.3	-13	33.6	-0.5	-3.3	-0.429	-0.018	-2.7	-1.2	-0.515	-0.275
235	72.6	-2.5	-3	6.8	-2.4	-6.2	-0.829	0.005	0.3	-0.2	0.985	-0.698
238	75.6	-2.1	-25	-0.5	-0.2	-6.4	0.271	0.007	0.3	-2.2	-0.015	0.400
240	63.0	-1.8	-12	30.4	-0.1	-6.2	-1.329	0.000	-0.7	-1.2	-2.515	-1.193
241	70.3	0.9	-5	12.5	-1.6	-7.9	-1.629	0.004	-1.7	-2.2	-2.015	-1.497
245	73.4	-0.2	23	-8.2	-1.4	-6.1	-0.929	0.006	-1.7	-3.2	-1.015	-0.799
246	67.1	-3.0	28	7.6	-0.4	-6.7	-0.429	0.006	-1.7	-0.2	0.485	-0.299
252	84.4	-2.8	2	17.3	-1.2	-3.3	-0.229	-0.007	-2.7	-1.2	-2.015	-0.086
254	73.9	-2.8	8	22.8	0.8	-4.2	0.871	-0.011	-0.7	-1.2	0.985	1.018
257	69.7	-4.5	-23	32.8	-0.1	-3.6	-1.629	0.023	-3.7	-1.2	0.485	-1.516
263	70.7	-1.4	-3	15.9	0.9	-5.7	-0.829	-0.001	-2.7	-2.2	-0.515	-0.692
266	81.1	-3.1	-21	4.0	-0.3	-5.8	1.671	-0.007	-2.7	-1.2	1.485	1.814
269	81.2	-2.1	13	3.1	-0.3	-6.9	-0.529	0.031	-2.7	-4.2	1.485	-0.424
1459	79.1	0.8	-1	4.0	-2.7	-2.1	-0.348	-0.011	-1.9	1.9	1.027	-0.201
3605	#DIV/0!	#DIV/0!	5	#DIV/0!	#DIV/0!	#DIV/0!	-1.229	-0.037	-3.7	-3.2	0.985	-1.056
3607	#DIV/0!	#DIV/0!	3	#DIV/0!	#DIV/0!	#DIV/0!	-4.329	-0.016	-0.7	-1.2	2.985	-4.177
3609	81.0	-4.7	-25	0.2	-1.7	-4.6	-2.729	-0.030	1.3	-1.2	-0.515	-2.563
3614	78.3	-0.8	117	19.0	-0.1	-7.1	-1.629	-0.002	2.3	-0.2	-0.515	-1.491
3650	78.4	-2.0	-6	1.3	-0.8	-5.9	-2.829	-0.021	1.3	0.8	-3.015	-2.672
3651	92.0	-3.2	-6	15.8	1.0	-5.9	-2.429	0.001	-0.7	-1.2	-3.015	-2.294

Table 13: Tolerance of Accessions to Water Stress, Cont'd

Acc. #	Trait											
	PH	NPT	DTF	SL	SW	SN	SY	GY	PDS	SGC	BW	CW
3652	77.9	-1.7	-3	11.6	-1.2	-4.9	-2.129	-0.008	-0.7	-1.2	-1.515	-1.985
3653	71.9	-1.5	-7	15.8	-0.9	-4.3	-2.029	-0.001	-0.7	-0.2	-0.015	-1.892
3655	83.7	-1.4	-7	-1.5	-1.5	-5.6	-2.229	-0.008	1.3	-0.2	-1.515	-2.085
3657	88.2	-0.9	-3	8.8	-1.0	-5.2	-1.829	0.001	-1.7	0.8	-0.015	-1.694
3658	76.3	-0.6	-2	4.0	-0.8	-6.2	-1.929	-0.010	-0.7	-0.2	-0.515	-1.783
229	84.7	-0.3	-13	33.6	-0.5	-3.3	-0.429	-0.018	-2.7	-1.2	-0.515	-0.275
3661	92.5	-1.5	-3	2.7	-1.7	-4.9	-3.429	-0.012	-2.7	-0.2	-1.015	-3.281
3684	83.5	-2.1	-30	0.3	0.1	-7.7	-3.729	-0.022	-2.7	-2.2	-2.015	-3.571
3685	78.9	-1.9	-17	12.7	-0.2	-5.9	-2.385	-0.006	0.5	1.2	2.215	-2.244
3686	79.8	-7.2	-24	-8.0	0.1	-5.0	-2.185	-0.014	-0.5	1.2	0.715	-2.036
3696	83.2	-3.9	1	#DIV/0!	#DIV/0!	#DIV/0!	-1.885	-0.012	1.5	0.2	0.715	-1.738
3702	68.2	-3.8	5	-7.7	0.4	-6.0	-2.685	-0.024	-0.5	1.2	1.215	-2.526
3703	94.1	-4.6	6	2.9	1.3	-4.5	-1.085	-0.009	0.5	1.2	1.715	-0.941
3706	78.6	-3.0	3	7.5	1.7	-6.4	-1.985	-0.014	-1.5	0.2	-0.785	-1.836
3710	73.8	-2.8	-4	-5.6	1.1	-3.7	-0.285	-0.004	-1.5	-0.8	1.215	-0.146
3715	92.3	-2.3	-3	7.6	0.0	-2.9	-1.285	-0.010	-1.5	-1.8	1.715	-1.140
3716	72.9	-5.7	2	6.2	1.4	-4.6	-1.485	-0.008	-0.5	0.2	-0.785	-1.342
3717	63.9	-3.9	-1	-4.3	1.1	-4.6	-2.585	-0.032	-0.5	4.2	-2.285	-2.418
3718	87.6	-1.2	-1	-2.4	2.4	-7.1	-1.685	-0.007	-0.5	3.2	-2.285	-1.543
3720	63.1	-3.7	12	1.9	1.1	-3.9	-1.585	-0.010	-1.5	3.2	-1.285	-1.440
3735	68.3	-0.4	-11	4.0	0.7	-4.0	-1.785	-0.005	-1.5	3.2	-0.785	-1.645
3736	77.4	0.9	3	-2.2	0.5	-4.3	-0.485	-0.012	0.5	4.2	1.215	-0.338
3739	69.9	-0.6	18	-7.9	0.0	-4.9	-3.085	-0.020	-1.5	3.2	0.215	-2.930
3741	69.1	-3.6	18	2.6	1.7	-4.8	0.015	-0.010	-1.5	3.2	1.715	0.160
3753	65.4	-2.5	21	-9.0	1.6	-4.6	-1.685	-0.012	-1.5	3.2	-0.785	-1.538

Table 13: Tolerance of Accessions to Water Stress, Cont'd

Acc. #	Trait											
	PH	NPT	DTF	SL	SW	SN	SY	GY	PDS	SGC	BW	CW
3765	77.7	-4.5	20	-10.2	0.8	-6.6	-2.185	-0.022	-1.5	4.2	0.215	-2.028
3771	63.1	#DIV/0!	33	-3.5	-0.3	-4.2	-3.185	-0.023	-1.5	2.2	3.715	-3.027
3775	71.3	#DIV/0!	25	2.5	1.6	-3.1	0.115	-0.014	0.5	4.2	1.215	0.264
3783	67.2	0.7	24	5.7	2.0	-2.5	-0.685	0.006	-0.5	4.2	3.215	-0.556
3786	68.3	-2.8	10	6.7	3.5	-2.7	1.115	0.007	2.5	4.2	2.215	1.243
3790	59.1	-0.4	12	11.2	2.9	-2.6	-0.985	0.012	0.5	2.2	-0.285	-0.862
3801	77.6	-3.3	7	-1.7	1.3	-4.5	-0.885	0.002	-1.5	4.2	-0.785	-0.752
3803	70.6	-1.6	-24	-2.0	2.4	-5.2	-3.385	-0.006	0.5	4.2	-0.285	-3.244
3806	69.3	-2.6	10	0.8	2.2	-5.2	-1.485	0.001	0.5	4.2	0.715	-1.351
3809	65.6	-0.3	16	13.2	1.7	-6.6	-1.985	-0.006	0.5	4.2	-0.285	-1.844
3811	61.2	-1.1	6	-26.5	1.9	-5.7	-3.285	-0.002	-0.5	3.2	-1.785	-3.148
3813	76.6	-1.0	148	-6.7	0.1	-5.3	-5.185	0.000	0.5	4.2	-0.785	-5.050
3816	86.6	0.8	147	1.5	0.4	-4.1	-0.185	0.002	-0.5	4.2	2.215	-0.052
3817	65.6	-2.2	-1	-11.0	2.1	-3.8	-1.385	0.000	3.5	3.2	-0.285	-1.250
3819	77.6	4.9	-4	4.0	1.3	-5.0	0.615	0.005	-0.5	2.2	0.215	0.745
3824	74.8	1.7	-1	-12.4	0.8	-7.4	-0.685	-0.001	-1.5	3.2	0.215	-0.549
3825	98.6	1.1	3	-8.2	1.3	-5.0	0.715	0.033	-5.5	5.2	1.215	0.817
3826	77.6	-3.1	8	-6.8	2.4	-6.6	0.215	0.014	-0.5	3.2	-0.285	0.336
3827	89.6	-0.7	8	-6.9	1.5	-7.7	0.915	-0.004	1.5	4.2	2.715	1.054
3828	85.4	1.7	3	18.6	1.4	-5.0	-0.585	-0.009	0.5	3.2	-2.285	-0.441
3834	-9.0	0.6	-1	-18.8	-1.9	-4.9	2.915	-0.001	1.0	-0.5	1.214	2.554
3834	80.7	3.9	-3	5.3	1.1	-5.4	-0.748	0.001	-0.9	-0.1	0.027	-0.613
3839	77.5	2.3	0	-1.2	0.3	-4.2	1.352	0.001	0.1	0.9	0.527	1.487
3841	68.2	0.8	3	-6.6	1.0	-5.3	-1.748	-0.003	0.1	-0.1	0.027	-1.609
3842	74.7	0.3	4	-1.2	0.9	-4.9	-1.148	0.001	0.1	1.9	-0.473	-1.013

Table 13: Tolerance of Accessions to Water Stress, Cont'd

Acc. #	Trait											
	PH	NPT	DTF	SL	SW	SN	SY	GY	PDS	SGC	BW	CW
3844	71.5	0.3	1	7.8	1.4	-4.6	-1.648	0.005	2.1	0.9	-0.473	-1.517
3847	72.7	2.6	2	0.7	0.5	-4.3	-0.448	-0.004	1.1	0.9	0.527	-0.308
3849	79.3	0.2	0	-9.1	0.9	-5.6	-1.848	0.001	2.1	0.9	1.527	-1.713
3853	67.9	-0.2	20	-12.1	0.4	-8.0	-1.548	-0.004	3.1	-0.1	0.527	-1.408
3854	86.6	#DIV/0!	3	-14.1	1.1	-2.8	-0.748	0.005	2.1	-2.1	0.527	-0.617
3860	#DIV/0!	0.4	20	20.5	0.1	-2.1	-1.848	0.003	-2.9	1.9	-0.973	-1.715
3861	77.2	0.0	-17	-4.1	-0.6	-5.7	-2.248	-0.001	2.1	0.9	-0.973	-2.111
3863	79.8	-0.7	-18	14.3	-1.9	-4.4	-1.948	0.002	1.1	0.9	-1.973	-1.814
3864	69.0	-0.8	-3	-12.8	-0.4	-2.6	-2.348	0.000	1.1	0.9	0.527	-2.212
3866	85.7	-2.8	4	34.2	0.2	-4.5	-1.748	-0.003	3.1	-0.1	0.027	-1.609
3875	82.5	1.6	-1	-45.7	-0.4	-6.5	-2.448	0.002	0.1	0.9	0.027	-2.314
3879	77.7	-1.3	9	-13.9	1.1	-7.9	-2.048	-0.001	0.1	-1.1	-1.473	-1.911
3880	82.5	1.4	22	8.9	1.5	-4.1	-1.348	0.000	-1.9	0.9	-1.473	-1.212
3884	73.7	-1.7	2	35.9	0.4	-4.6	-2.048	0.000	2.1	0.9	0.527	-1.912
3885	73.2	0.3	18	-38.3	0.7	-5.0	-1.548	0.002	0.1	0.9	-1.473	-1.414
3891	70.7	-0.2	-1	-28.7	0.2	-5.4	-2.448	0.001	0.1	0.9	-1.473	-2.313
3895	82.7	2.1	16	-15.8	1.3	-3.7	-1.648	0.000	1.1	-1.1	-2.973	-1.512
3897	83.7	2.5	-18	5.3	-0.9	-3.9	-1.548	-0.002	-0.9	-0.1	-0.973	-1.410
3899	#DIV/0!	#DIV/0!	19	1.4	2.2	-3.3	-2.448	0.009	-1.9	-0.1	-0.973	-2.321
3904	84.9	-0.7	10	-23.3	-0.4	-5.8	-1.085	-0.013	0.5	3.2	-1.785	-0.937
3906	87.6	2.5	-23	3.3	2.2	-2.9	-0.385	0.004	0.5	3.2	0.215	-0.254
3907	73.4	-1.8	11	-2.3	1.6	-6.2	-1.385	0.014	2.5	4.2	-2.285	-1.264
3911	96.7	-4.1	8	0.6	1.4	-6.5	-3.385	-0.010	-1.5	2.2	-0.785	-3.240
3912	77.8	1.4	5	-11.5	1.2	-6.7	-1.485	0.005	0.5	4.2	2.215	-1.355
3914	86.7	-1.6	-18	-25.3	1.2	-7.1	-4.885	-0.017	0.5	3.2	1.215	-4.733

Table 13: Tolerance of Accessions to Water Stress, Cont'd

Acc. #	Trait											
	PH	NPT	DTF	SL	SW	SN	SY	GY	PDS	SGC	BW	CW
3917	68.6	-0.9	6	-6.1	0.3	-4.7	-0.185	0.013	0.5	4.2	2.215	-0.063
3918	45.6	-2.9	9	-28.2	0.0	-7.1	-4.185	-0.037	-3.5	1.2	-0.285	-4.013
3919	63.9	-1.0	1	0.6	1.2	-4.9	-0.648	-0.001	-0.9	0.9	-0.973	-0.511
3920	83.8	-1.6	5	38.4	0.5	-2.2	-0.485	0.008	-3.5	1.2	2.715	-0.358
3922	67.3	-3.7	5	-12.2	0.1	-4.7	-1.885	-0.008	0.5	3.2	3.215	-1.742
3925	69.6	0.6	15	#DIV/0!	#DIV/0!	#DIV/0!	-4.585	-0.042	1.5	4.2	-1.785	-4.408
3930	67.6	#DIV/0!	15	2.5	1.1	-5.1	-2.185	-0.026	4.5	4.2	-1.285	-2.024
3932	66.8	#DIV/0!	12	-18.1	1.5	-6.3	-2.685	-0.006	1.5	3.2	-2.285	-2.544
3934	66.5	2.1	24	-4.7	0.9	-7.1	-1.148	0.003	-1.9	1.9	-0.473	-1.015
3937	74.0	0.8	-1	3.1	0.0	-4.8	-0.548	0.003	0.1	1.9	-0.473	-0.415
3939	71.1	-2.3	-1	2.8	0.9	-3.7	-1.248	0.012	-0.9	0.9	0.027	-1.124
3943	63.9	1.1	-1	-10.3	0.6	-5.8	-1.148	0.004	-0.9	0.9	0.527	-1.016
3946	62.1	-0.4	-1	-21.7	1.1	-4.5	-1.548	0.000	0.1	0.9	-0.973	-1.412
3948	63.5	3.8	-1	-2.5	0.6	-6.6	0.352	0.003	0.1	0.9	-0.973	0.485
3955	59.5	-0.8	0	-11.1	1.4	-5.6	-0.948	0.002	0.1	-0.1	-1.473	-0.814
3958	53.0	0.7	-1	-8.6	1.3	-2.5	-0.548	0.023	-0.9	-1.1	0.027	-0.435
3962	75.6	0.2	-1	-3.1	0.4	-3.9	-0.848	-0.003	1.1	1.9	-0.673	-0.709
3965	79.0	4.4	25	-2.2	0.9	-4.4	-1.448	0.002	1.1	2.9	-0.973	-1.314
3969	78.8	2.6	2	-2.8	0.4	-2.5	-1.448	0.001	3.1	1.9	-1.973	-1.313
3972	72.2	0.5	2	-1.7	0.1	-2.6	-1.348	0.000	2.1	0.9	0.027	-1.212
3977	71.2	0.5	-1	-2.2	-0.4	-5.7	-2.248	-0.002	2.1	1.9	-0.473	-2.110
4639	78.0	-0.4	13	-13.0	0.4	-5.5	-1.948	0.001	2.1	0.9	-1.973	-1.813
4732	82.1	-2.6	-1	-3.2	1.1	-3.5	-0.748	0.008	2.1	0.9	0.527	-0.620
5051	68.0	1.4	6	2.0	-0.5	-7.0	-1.048	-0.002	0.1	1.9	-0.473	-0.910
5052	77.3	0.9	-1	0.8	3.2	-6.5	-0.948	0.001	3.1	-0.1	-1.473	-0.813

Table 13: Tolerance of Accessions to Water Stress, Cont'd

Acc. #	Trait											
	PH	NPT	DTF	SL	SW	SN	SY	GY	PDS	SGC	BW	CW
5061	77.1	1.1	-1	-4.2	1.3	-3.9	-0.748	-0.005	2.1	1.9	0.027	-0.607
6599	79.4	0.4	0	-3.3	-1.2	-4.8	-1.748	0.009	3.1	0.9	0.027	-1.621
6600	#DIV/0!	0.3	0	9.2	0.6	-2.0	0.752	-0.005	2.1	1.9	0.027	0.893
6607	76.3	2.3	-2	-13.0	-0.3	-6.3	-1.648	0.001	-3.9	-0.1	-0.973	-1.513
6637	76.7	0.3	-1	-1.5	-0.8	-2.9	0.352	0.004	-3.9	0.9	-0.973	0.484
6714	71.4	-1.0	-1	5.7	0.6	-5.7	-2.248	0.003	1.1	-0.1	-0.473	-2.115
7024	80.1	0.0	-1	-0.4	-0.7	-4.1	-1.748	0.002	0.1	0.9	-0.973	-1.614
40122	87.7	4.6	1	9.1	-1.3	-4.3	-1.648	0.001	0.1	-0.1	0.527	-1.513
FMM 175	**56.3**	**-1.6**	**-23**	**-13.1**	**0.7**	**-5.8**	**-1.517**	**-0.006**	**-0.8**	**1.9**	**0.871**	**-1.499**
FMM 165	**69.6**	**-1.5**	**-12**	**-21.7**	**-0.6**	**-5.5**	**-1.539**	**-0.002**	**-0.3**	**0.5**	**-1.494**	**-1.400**
Nyika	**49.2**	**-2.0**	**0**	**-2.5**	**0.7**	**-4.6**	**-0.733**	**0.003**	**0.3**	**2.2**	**1.971**	**-0.766**
Senga	**59.7**	**0.3**	**3**	**-1.6**	**1.1**	**-5.8**	**0.263**	**0.012**	**-1.3**	**1.1**	**1.360**	**0.263**

Rank numbers of accessions and check varieties in 10 traits are contained in Table 14 below. Genotypes maintained and changed positions in different traits. ZM 3825 was ranked highest in 3 traits, namely plant height, pest and disease susceptibility and stay-green characteristic. On the other hand, ZM 3819, FMM 175, ZM 3920 and ZM 154 were graded highest in number of productive tillers, days to 50 % flowering, spike length and biomass weight, respectively. These genotypes showed the least effect of stress in the relevant traits. ZM 146, ZM 3716, ZM 3875, ZM 3930, ZM 225, ZM 3651 and ZM 211 were positioned the lowest in plant height, number of productive tillers, spike length, pest and disease susceptibility, stay-green characteristic, biomass and chaff weight, respectively. ZM 3813 was the least in 2 traits, namely days to 50 % flowering and spike yield. These accessions, which were ranked the least, were therefore the most adversely affected by stress.

Table 14: Accession Ranks in Different Traits

Acc. #	Trait								
	PH	NPT	DTF	SL	SY	PDS	SGC	BW	CW	Mean
3825	1	37	107	138	32	1	1	76	188	65
3920	21	141	117	1	67	8	72	25	155	67
1459	42	44	62	58	60	42	53	84	163	68
3906	11	12	12	64	61	144	38	123	161	70
3819	56	1	44	60	35	98	50	126	186	73
3834	35	4	52	52	83	81	127	135	141	79
203	180	85	7	24	6	47	139	22	212	80
3897	22	13	17	51	136	83	128	185	92	81
3657	8	118	46	37	163	54	103	138	66	81
40122	9	2	85	35	145	131	131	115	80	81
3816	14	47	215	78	53	107	7	44	169	82
229	18	89	24	4	65	28	186	163	160	82
3685	44	151	21	28	191	158	77	48	28	83
154	175	26	84	176	2	71	2	1	215	84
153	105	48	193		161	20	25	85	32	84
3824	70	23	74	160	80	58	29	124	144	85
3783	117	52	195	48	79	108	8	16	143	85
6637	63	67	67	99	38	4	78	177	183	86
3828	16	24	105	14	73	145	39	210	151	86
3912	52	31	115	154	130	147	11	46	95	87
3736	59	41	108	105	68	154	16	74	156	87
3839	58	14	79	97	18	121	84	107	203	87
3735	109	96	29	59	160	63	32	171	69	88
266	32	187	13	56	13	32	187	71	207	89
3715	5	163	53	40	117	60	203	57	106	89
106	153	78	30	144	89	14	159	34	105	90
3937	73	45	63	66	71	126	56	155	154	90
115	183	20	22	136	201	22	164	50	12	90
3880	29	29	184	36	121	43	79	190	103	90
3860		63	177	10	164	25	52	176	63	91
3828	16	24	105	14	73	145	39	210	151	86

Table 14: Accession Ranks in Different Traits, Cont'd

Acc. #	Trait									
	PH	NPT	DTF	SL	SY	PDS	SGC	BW	CW	Mean
3827	7	108	130	130	24	185	18	24	196	91
110	152	136	26	53	62	119	117	29	131	92
194	169	167	16	49	17	26	137	41	205	92
3661	4	134	48	71	210	30	138	186	7	92
152	181	98	182	126	49	11	24	8	157	93
6607	65	15	55	165	147	5	124	183	81	93
224	126	101	28	21	9	176	106	67	209	94
257	101	202	10	5	144	7	184	118	78	94
3914	12	140	19	194	215	151	41	77	2	95
123	178	18	89	175	118	76	120	12	68	95
109	162	22	90	189	69	13	158	33	122	95
227	87	149	25	12	28	177	107	87	191	96
3847	83	11	95	86	66	166	91	108	158	96
3943	127	35	56	147	110	85	82	113	113	96
124	196	83	14	171	101	15	160	35	94	97
3875	28	25	59	204	196	124	85	129	24	97
3803	97	142	8	102	208	150	13	146	9	97
3653	86	135	33	19	175	94	144	139	50	97
128	188	38	180	54	82	41	166	14	112	97
121	155	62	98	174	106	16	161	19	85	97
3863	38	106	18	22	171	173	93	202	56	98
200	199	33	42	15	29	178	150	43	190	98
6600		66	81	34	31	191	60	131	189	98
197	197	137	35	6	5	135	104	51	211	98
118	167	9	161	117	19	73	114	28	194	98
5061	62	34	60	119	87	193	61	127	142	98
3718	10	126	75	107	150	101	36	209	75	99
3917	108	117	120	125	54	143	10	45	168	99
3686	39	207	9	135	184	102	74	100	41	99
241	98	40	38	29	143	51	207	206	83	99
66	151	100	141	122	50	12	111	59	149	99
3703	3	204	122	68	103	146	76	56	118	100
3741	106	194	168	72	47	56	28	55	172	100
5051	113	30	119	75	102	128	57	156	120	100
3658	66	103	54	55	170	93	143	161	58	100
3842	71	70	111	96	109	122	55	154	115	100
3771	134		213	115	206	67	48	7	13	100
7024	37	81	69	92	159	132	89	181	71	101
119	156	77	171	110	105	70	113	27	86	102
263	96	131	47	18	91	29	205	165	134	102
3948	131	5	58	109	39	125	86	179	184	102
3939	94	164	72	70	116	86	83	128	107	102
3801	55	191	125	101	93	59	3	168	129	103
225	129	190	2	11	76	34	216	120	147	103

Table 14: Accession Ranks in Different Traits, Cont'd

Acc. #	Trait									
	PH	NPT	DTF	SL	SY	PDS	SGC	BW	CW	Mean
5061	62	34	60	119	87	193	61	127	142	98
156	184	76	154	151	74	2	155	13	117	103
3809	122	90	160	25	173	149	12	144	53	103
3849	41	74	82	143	165	196	98	65	64	103
3684	24	154	3	89	211	31	206	205	6	103
214	91	28	127	30	115	142	148	140	108	103
143	207	95	144	81	8	3	156	31	204	103
3934	120	17	194	121	111	46	54	153	114	103
3775	92		201	74	45	153	15	73	174	103
3911	2	201	132	88	209	68	49	172	10	103
33	195	79	99	85	37	113	67	86	171	104
120	165	72	186	145	153	37	112	26	39	104
252	19	174	91	16	55	27	185	204	166	104
3962	67	75	68	112	92	169	58	166	132	104
186	166	51	34	170	11	160	118	30	202	105
269	31	155	150	65	70	33	215	72	153	105
235	84	168	50	43	90	140	147	90	133	105
114	158	46	15	191	133	116	171	61	55	105
3607			102		213	97	192	23	4	105
3739	99	104	167	134	205	66	33	125	14	105
3884	77	143	93	2	176	198	100	110	48	105
165	174	55	41	140	36	112	115	102	173	105
3977	93	59	65	103	188	199	62	151	35	106
3844	89	69	86	38	146	195	97	158	77	106
3710	75	178	45	124	56	57	179	78	165	106
3969	45	10	94	111	128	209	63	201	99	107
221	138	36	142	45	30	53	208	119	192	107
3706	46	186	106	42	174	64	121	173	54	107
3965	43	3	200	104	127	171	45	175	98	107
3786	110	180	140	44	21	205	20	47	199	107
111	161	110	152		126	17	197	38	59	108
6599	40	64	80	114	157	212	102	134	70	108
3651	6	189	37	20	193	96	191	216	26	108
216	69	129	137	94	1	52	188	91	216	109
3605			114		114	6	213	95	111	109
144	201	145	163	152	10	72	27	9	201	109
3972	85	58	96	100	122	190	95	133	102	109
3652	51	144	49	31	181	95	190	197	46	109
254	74	176	128	9	26	88	196	93	195	109
3861	61	82	20	118	189	200	101	182	34	110
3919	128	121	87	87	78	84	81	178	145	110
122	173	19	192	178	169	21	163	49	29	110
138	76	8	165	91	84	82	181	167	139	110
3806	103	172	139	84	131	157	17	98	96	111
3977	93	59	65	103	188	199	62	151	35	106

Table 14: Accession Ranks in Different Traits, Cont'd

Acc. #	Trait									
	PH	NPT	DTF	SL	SY	PDS	SGC	BW	CW	Mean
3790	144	97	147	33	100	155	51	149	121	111
3765	54	203	179	146	185	65	4	121	42	111
126	186	27	173	183	25	35	165	20	185	111
6714	90	120	71	47	187	168	132	152	33	111
5052	60	39	61	83	99	208	133	194	124	111
125	208	53	169	131	58	74	168	4	136	111
3826	57	188	131	129	42	99	34	145	178	111
3841	111	43	104	127	158	123	129	136	73	112
3866	15	173	110	3	156	211	135	130	72	112
4732	30	170	73	113	86	192	96	109	137	112
3922	116	196	118	157	166	148	40	17	61	113
3958	148	49	64	141	72	80	180	137	152	114
3702	112	198	116	133	199	104	75	75	19	115
218	104	116	149	67	108	91	189	92	116	115
131	185	6	202	69	141	77	200	106	47	115
3864	107	111	51	162	190	174	94	114	31	115
3655	23	130	32	98	186	181	152	196	36	115
238	68	156	5	93	41	139	209	143	180	115
240	135	147	27	7	120	87	195	213	104	115
146	210	132	204	181	20	39	46	10	193	115
137	206	7	203		179	118	173	15	20	115
147	209	73	205	155	154	79	47	79	37	115
195	205	84	212	17	40	89	141	69	181	115
127	177	193	126	161	112	75	119	2	74	115
190	202	32	183	27	7	175	149	54	210	115
155	163	166	124	32	132	120	212	40	52	116
112	164	54	170	190	155	19	211	39	40	116
3650	48	153	36	80	203	183	109	215	16	116
223	150	113	31	148	135	201	110	68	89	116
148	200	124	211	193	204	23	26	58	8	116
162	100	65	157		46	188	177	37	162	117
3925	102	57	156		214	187	19	198	3	117
102	176	162	123	185	33	10	157	32	179	117
3899			172	79	194	45	126	184	23	118
157	136	91	133	167	119	164	176	6	67	118
220	82	125	164	23	44	179	151	117	175	118
3716	81	206	97	46	129	109	122	174	97	118
3720	133	197	148	77	140	61	30	189	88	118
3696	26	199	88		167	186	123	99	62	119
3717	130	200	77	120	197	110	9	207	21	119
140			209		168	117	172	21	27	119
246	118	184	207	39	64	49	140	116	159	120
3904	17	109	138	192	104	156	42	200	119	120
159	171	115	136	169	81	69	167	60	110	120
198	198	21	196	116	16	137	146	42	206	120

Table 14: Accession Ranks in Different Traits, Cont'd

Acc. #	Trait									
	PH	NPT	DTF	SL	SY	PDS	SGC	BW	CW	Mean
3813	64	122	216	128	216	152	14	169	1	120
3891	95	86	70	198	195	134	90	192	25	121
132	170	80	187	95	22	40	199	105	187	121
130	179	105	206	61	152	78	169	103	38	121
3609	33	205	6	90	202	182	194	164	17	121
219	147	150	198	57	75	90	142	89	146	122
101	187	119	145	202	134	18	162	82	51	122
3946	137	94	57	188	138	129	87	180	91	122
3753	124	169	181	142	151	62	31	170	76	123
212	141	185	43	166	12	136	145	70	208	123
133	191	61	185		198	165	69	101	15	123
3918	149	182	135	197	212	9	73	150	5	124
103	157	183	101	168	63	114	116	81	130	124
3930	115		155	73	183	216	23	188	43	125
3614	49	114	214	13	142	204	154	162	84	126
3907	79	148	143	106	124	207	22	208	100	126
3811	140	123	121	195	207	105	37	199	11	126
3817	123	160	76	149	123	214	44	148	101	126
222	145	139	175	63	113	92	210	94	109	127
3834	190	56	78	184	3	159	174	83	213	127
211	139	158	23		4	141	193	142	214	127
199	204	165	199	62	23	138	105	52	197	127
3784	72	192	210	82	57	206	21	147	164	128
3854	13		103	173	88	194	204	112	138	128
3885	80	68	166	203	139	130	88	191	90	128
3955	143	112	83	150	96	127	130	193	123	129
209	172	159	176	8	94	203	136	88	127	129
245	78	88	190	137	95	50	214	187	128	130
3895	27	16	159	177	149	172	183	214	82	131
149	193	138	158	200	51	215	71	3	150	131
4639	50	93	151	164	172	197	99	203	57	132
187	182	146	189	187	15	189	70	11	200	132
3853	114	87	178	156	137	210	134	111	93	136
3879	53	128	134	172	177	133	182	195	49	136
168	154	133	174	132	34	162	201	62	177	137
3932	119		146	182	200	184	43	211	18	138
226	146	181	39	153	162	202	153	141	65	138
175	192	127	188	163	27	161	175	36	182	139
173	168	102	162	201	59	163	202	63	135	139

Table 14: Accession Ranks in Different Traits, Cont'd

c. #	Trait									
	PH	NPT	DTF	SL	SY	PDS	SGC	BW	CW	Mean
129	194	161	208	158	178	38	198	104	22	140
208	203	195	153		180	213	65	160	44	152
MM 175	**121.0**	**177.0**	**109.0**	**199.0**	**192.0**	**103.0**	**5.0**	**96.0**	**30.0**	**115.0**
MM 165	**94.5**	**131.5**	**58.0**	**188.0**	**139.5**	**112.5**	**118.5**	**184.5**	**85.5**	**124.0**
ika	**99.0**	**151.0**	**77.3**	**102.7**	**84.7**	**133.7**	**60.7**	**56.0**	**125.0**	**99.0**
nga	**88.5**	**67.5**	**112.5**	**97.0**	**47.5**	**70.8**	**98.5**	**88.0**	**171.0**	**93.3**

Table 15 is overall rank order of accessions based on the mean of rank numbers in 10 traits (Table 14). The highest ranking accession, ZM 3825, had the smallest mean (65). The lowest ranking was ZM 208 with the mean rank number of 152.

Table 15: Overall Rank Order of Accessions According to Tolerance to Water Stress

Rank	Acc. #	Rank	Acc. #	Rank	Acc. #	Rank	Acc. #	Rank	Acc. #
1	3825	**47**	3847	**89**	3911	**134**	3826	**178**	130
2	3920	**48**	3943	**90**	33	**135**	3841	**179**	FMM 165
3	1459	**49**	124	**92**	120	**136**	3866	**179**	3609
4	3906	**50**	3875	**93**	252	**137**	4732	**180**	219
5	3819	**51**	3803	**94**	FMM 175	**138**	3922	**181**	101
6	3834	**52**	3653	**94**	3962	**139**	3958	**182**	3946
7	203	**53**	128	**96**	186	**140**	3702	**183**	3753
8	3897	**54**	121	**97**	269	**142**	218	**184**	212
9	3657	**55**	3863	**98**	235	**143**	131	**185**	133
10	40122	**56**	200	**99**	114	**144**	3864	**186**	3918
11	3816	**56**	Senga	**100**	3607	**145**	3655	**187**	103
12	229	**58**	6600	**101**	3739	**146**	238	**188**	3930
13	3685	**59**	197	**102**	3884	**147**	240	**189**	3614
14	154	**60**	118	**103**	165	**148**	146	**190**	3907
15	153	**61**	5061	**105**	3977	**149**	137	**191**	3811
16	3824	**62**	3718	**106**	3844	**150**	147	**192**	3817
17	3783	**63**	3917	**107**	3710	**151**	195	**193**	222
19	6637	**64**	3686	**108**	3969	**152**	127	**194**	3834
20	3828	**65**	241	**110**	221	**153**	190	**195**	211
21	3912	**66**	66	**111**	3706	**155**	155	**196**	199
22	3736	**67**	3703	**112**	3965	**156**	112	**197**	3784
23	3839	**68**	3741	**113**	3786	**157**	3650	**198**	3854
25	3735	**69**	5051	**114**	111	**158**	223	**199**	3885
27	266	**70**	3658	**115**	6599	**159**	148	**200**	3955
28	3715	**71**	3842	**116**	3651	**160**	162	**201**	209
29	106	**72**	3771	**117**	216	**161**	3925	**202**	245
30	3937	**73**	Nyika	**118**	3605	**162**	102	**203**	3895
31	115	**73**	7024	**119**	144	**163**	3899	**204**	149
32	3880	**74**	119	**120**	3972	**164**	157	**206**	4639
33	3860	**75**	263	**121**	3652	**165**	220	**207**	187
34	3827	**76**	3948	**122**	254	**166**	3716	**208**	3853
35	110	**78**	3939	**123**	3861	**167**	3720	**209**	3879
36	194	**79**	3801	**124**	3919	**168**	3696	**210**	168
37	3661	**80**	225	**125**	122	**169**	3717	**211**	3932
39	152	**81**	156	**126**	138	**170**	140	**212**	226
40	6607	**82**	3809	**127**	3806	**171**	246	**213**	175
41	224	**83**	3849	**128**	3790	**172**	3904	**214**	173
42	257	**84**	3684	**129**	3765	**173**	159	**215**	129
43	3914	**85**	214	**130**	126	**174**	198	**216**	208
44	123	**86**	143	**131**	6714	**175**	3813		
45	109	**87**	3934	**132**	5052	**176**	3891		
46	227	**88**	3775	**133**	125	**177**	132		

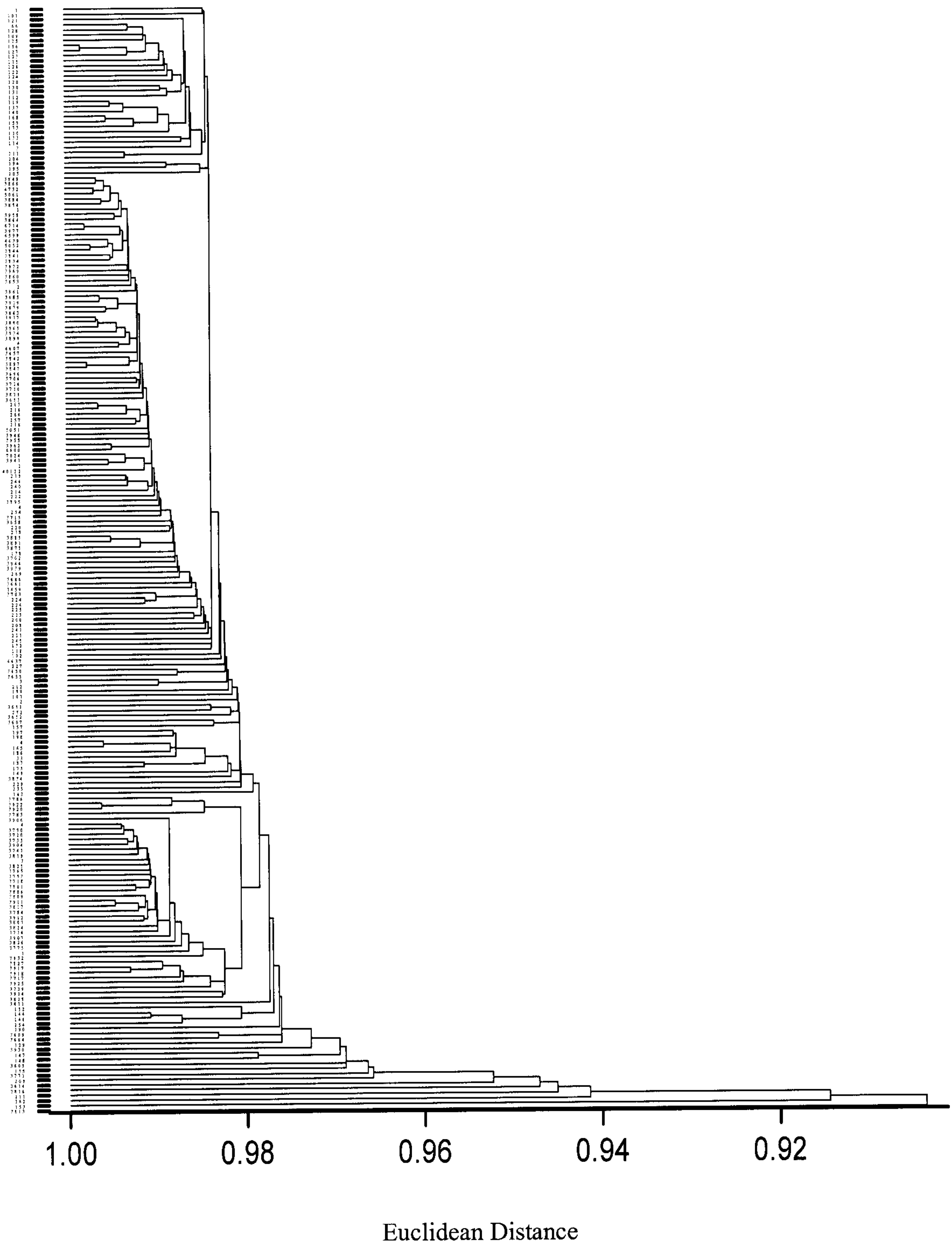
Sixteen accessions were ranked higher than the most tolerant check, Nyika. Passport data of the 17 accessions is given in Table 3 on the next page. Five of the accessions were obtained from Kawambwa District and 1 from Nchelenge in the Luapula Province, 1 from Isoka District in the Northern Province, and 2 from Chama District in the Eastern Province. The remaining 7 accessions had no passport data.

Table 16: Passport Data of the Most Tolerant Accessions

Serial #	Acc. #	SPGRC #	Collector's #	District	New Latitude	New Longitude	Province	Source	Collection Date	Village	Collector
1	3825	1171	NKD 93	Kawambwa			Luapula	Farm Store	15/6/92	Shinode	G.M. Kaula
2	3920	1209	NKK 27	Chama			Eastern	Farm Store	11/7/92	Malaonga	G.M. Kaula
3	1459										
4	3906	1201	NKK 13	Chama			Eastern	Farm Store	10/7/92	Mumaka	G.M. Kaula
5	3819	1168	NKD 87	Kawambwa			Luapula	Farm Store	14/6/92	Lumande	G.M. Kaula
6	3834										
7	3834	1175	NKD 102	Kawambwa			Luapula	Farm Store	15/6/92	Kambobe	G.M. Kaula
8	ZM 203										
9	40122										
10	3816	1166	NKD 84	Kawambwa			Luapula	Farm Store	14/6/92	Mushota	G.M. Kaula
11	ZM 229										
12	3685		MKN 82	Isoka			Northern	Farm Store	23/5/92	Mwenelema	H. Kasalu
13	ZM 154										
14	ZM 153										
15	3824	1170	NKD 92	Kawambwa			Luapula	Farm Store	15/6/92	Kantondi	G.M. Kaula
16	3783	1158	NKD 51	Nchelenge	-9.05	29.05	Luapula	Farm Store	12/6/92	Kanchinkwe	G.M. Kaula
	Nyika			Kasama			Northern	FMIP		Misamfu	

Results of clustering are displayed in Figures 1 and 2. Each genotype is located at the end of a branch of the tree on the extreme left of the 2 figures. The horizontal distance travelled by the branch, before it fuses with another, is proportional to the squared Euclidean distance between the 2 genotypes represented by the concerned branches. Figure 1 shows relationships among 203 accessions from Zambia and 4 check varieties based on 13 attributes of putative traits of drought tolerance. See a magnified copy of the figure in the back pocket. In the figure, accessions ZM

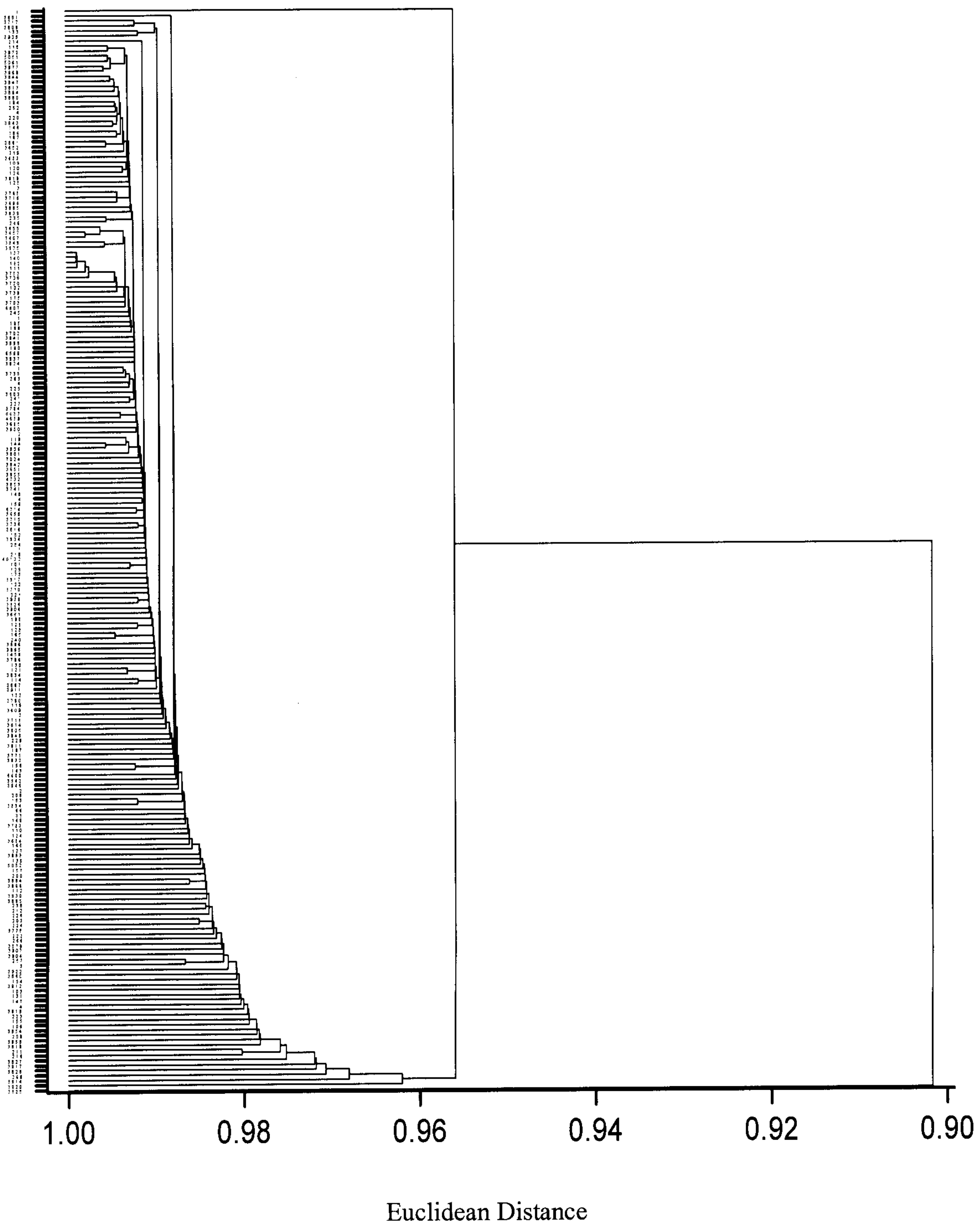
Figure 1: Dendrogram of Accessions under Optimum Conditions



122 and ZM 156 were the closest followed by ZM 6714 and ZM 3977. Furthest apart were

FMM 175 and ZM 3813. In contrast in Figure 15 below, ZM 111, ZM 137, ZM 140 and ZM 162 were the closest and FMM 175 and ZM 3825 furthermost apart. The figure shows

Figure 2: Dendrogram of Accessions under Stress



relationships among the same number of accessions and check varieties under stress. The dendrogram shows a similar pattern to the one observed under optimum conditions in Figure 2 above. The most tolerant accessions are widely dispersed among clusters. See a magnified copy of the dendrogram in the back pocket.

Figure 3: Dendrogram of Most Tolerant Accessions

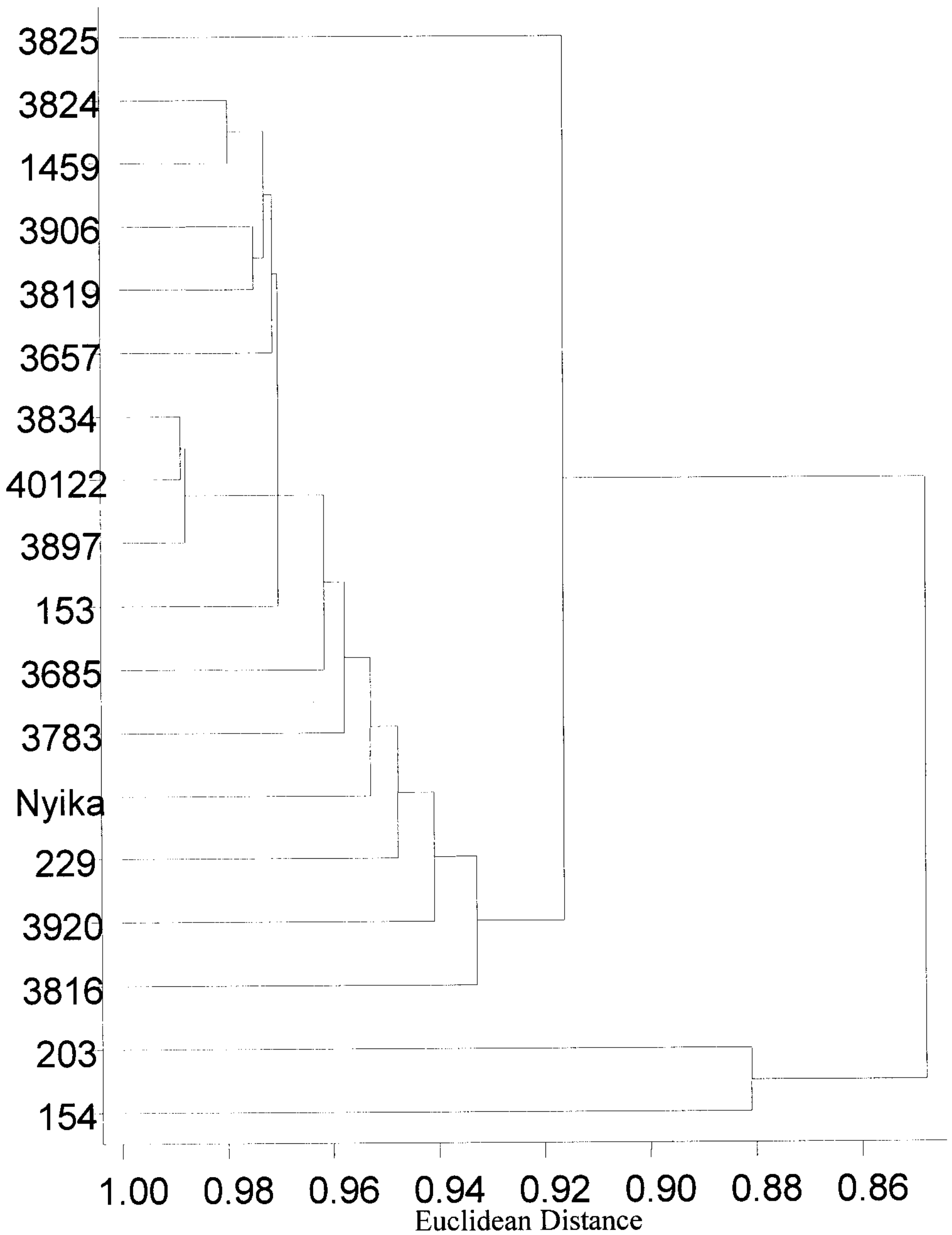


Figure 3 depicts relationships among 17 most tolerant accessions to water stress and the best check Nyika based on attributes of 9 putative traits of drought tolerance. The accessions can be grouped into 33 clusters representing 83 % clustering. At Euclidean distance 0.85 the most drought tolerant accession ZM 3825 belongs together with the rest of the most tolerant accessions, including Nyika. Above 0.92 it belongs to its own cluster. Accession ZM 154 and ZM 203 are more closely related with each other than any other accession in the diagram. They are most remotely related with ZM 3825.