Genetic Variability for Yield and Yield Components of Some Maize (*Zea mays* L.) Genotypes Determined Under Drought at Different Growth Stages

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DEDICATION

To my dear family
Father, mother, brothers and sisters
To my dear friends and colleagues

With love and respect

Elfadil

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ABSTRACT

This study was carried out during the 2003/04 season at two different locations, Shambat and Medani, Sudan, to determine the genetic variability for yield and yield components of 15 maize (*Zea mays* L.) genotypes under three water treatments at different growth stages. The design used was split plot design with three replications, in which the water treatments were allocated in the main plots and the genotypes in the sub-plots. Phenotypic and genotypic variance, phenotypic (*PCV*) and genotypic (*GCV*) coefficient of variation, heritability (h^2), genetic advance (*GA*), correlations coefficient between the different characters and the correlations between the drought tolerance parameters were determined. The results revealed that highly significant differences ($P \leq 0.01$) between water treatments were detected for most of the investigated traits. Significant differences ($P \leq 0.05$) between the evaluated genotypes were found for most of the traits. The greatest *GCV* (13.6%) was recorded for lodging percentage and the lowest one (0.77%) was recorded for ear length. The highest estimates of h^2 (69%) obtained for ear diameter and the lowest (11%) for ear length. Furthermore the largest (177.5%) *GA* was scored by grain yield/ha, while the lowest one (0.06%) was obtained for husk cover. Grain yield/plant exhibited significant positive associations with its components. The genotypes that possess drought tolerance were PR – 2 under drought at vegetative stage, Z – 2 under drought at reproductive stage and M – 45 at both vegetative and reproductive stages. These genotypes could be used further in breeding programs to improve drought tolerance in maize.

بسم الله الرحمن الرحيم

خلاصة الأطروحة

أجريت هذه الدرسة خلال موسم 2004/2003 م في موقعين مختلفين بالسودان (شمبات ومدني) ، لتحديد التباين الوراثي للإنتاجية ومكوناتها لخمسة عشر طرازاً وراثياً من محصول الذرة الشامية تحت الإجهاد المائي في مراحل النمو المختلفة. لقد أستخدم تصميم القطع المنشطرة بثلاثة مكررات، حيث وضعت معاملات الماء في الأحواض الرئيسية والطرز الوراثية في الأحواض الفرعية. تم تقدير التباين المظهري والوراثي ومعامل التباين المظهري والوراثي ودرجة التوريث والتقدم الوراثي ومعامل الإرتباط بين الصفات المختلفة ومعامل الإرتباط بين مقاييس درجة تحمل الإجهاد المائي. دلت النتائج علي وجود فروقات معنوية عالية ($P \leq 0.01$) بين المعاملات المائية لمعظم الصفات المدروسة. أظهرت النتائج أيضاً فروقات معنوية ($P \leq 0.05$) بين الطرز الوراثية المقيمة لمعظم الصفات المدروسة. أعلي تقدير(13.6%) لمعامل التباين الوراثي سجل لنسبة الرقاد بينما أقل تقدير (0.77%) سجل لطول الكوز. اعلي تقدير لدرجة التوريث (69%) سجل لقطر الكوز وأقل (11%) تقدير كان لطول الكوز. إضافة إلي ذلك وجد أن أكبر درجة تقدم وراثي (177.5%) سجلت لوزن البذور للهكتار بينما أقل قيمة (0.06%) سجلت لمستوي تغطية الغلاف. دلت النتائج أن إنتاجية البذور/ النبات أظهرت إرتباطاً معنوياً موجباً مع مكوناتها. وجد أن الطرز الوراثية ذات التحمل للإجهاد المائي هي PR–2 عند التعرض للإجهاد في فترة النمو الخضري و Z–2 عند التعرض للإجهاد المائي في فترة النمو الثمري وM–45 عند التعرض للإجهاد المائي في فترتي النمو الخضري والثمري. وهذه الطرز الوراثية يمكن إستخدامها مستقبلاً في برامج التربية لتحسين صفة تحمل الإجهاد المائي في الذرة الشامية.

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CHAPTER ONE

INTRODUCTION

Maize (*Zea mays* L.) is a member of the grass family Poaceae to which all the major cereals belong. Maize is considered as the third most important cereal food crops in the world after wheat and rice (Timothy *et al.,* 1988).

The origin of the maize and the history of its cultivation are still debatable, as no wild maize has been reported. However, most of the recent hypothesis refers to teosinte as appropriate close ancestor of maize (Hallauer, 1990; Gallinat, 1992).

Teosinte is like *Zea mays*, it has 10 pairs of chromosomes, which are cytogenetically similar to those of *Zea mays* (Dowswell, *et al.,* 1996). Although all types of maize belong to the same species, several thousand varieties are now grown throughout the world. These cultivated varieties belong to one of the following groups flint, dent, sweet, floury, pop and waxy corn (Dowswell, *et al.,* 1996).

Maize is used in many ways than any other cereals. It is used as human food, feed for livestock, fermentation and for industrial purposes. It is a crop of high grain yield potential, probably exceeds that of all other cereal crops. In 2001 season the total grown area was (139101) million hectares which gave (614234) million metric tons as total production. The average yield/hectare was (4416 kg/ha)(FAO, 2002).

Drought or water stress is a serious agronomic problem, being one of the most important factors causing substantial yield reduction in marginal lands and affecting yield stability in temperate areas. Drought is a multidimensional stress affecting plants at various stages of their growth. The major effect of drought on maize is the delay in silking, resulting in an increase in the anthesis silking interval (ASI) which is an important cause of yield failures (Bolanos and Edmeades 1993; Byrne *et al.,* 1995).

During the last 50 years, considerable effort has been devoted to improving genotypes yield performance through breeding, and to understand the mechanisms involved in drought tolerance (e.g. Jensen 1971; Edmeades *et al.,* 1992). Characterization of the drought environment in the target production region is the first and crucial step in undertaking any genetic program aiming at improving yield and yield stability in drought-prone environments (Campbell and Daiz, 1988; Robertson and Elsherbeeny 1988).

Drought is practically acute in developing countries where irrigation facilities are often lacking and where rainfall represents the main source of crop available water (Edmeades *et al.,* 1997). The risk of drought is highest at both vegetative and reproductive stages. Consequently, the development of maize genotypes that have greater adaptability to wide range of soil moisture conditions and ability to produce substantially higher grain yield in the presence of water stress is the most economic solution.

The objectives of this study were:

1. To study the performance of some different maize genotypes under different water managements.
2. To estimate the amount of genetic variability and heritability for drought tolerance in maize.
3. To determine the correlation between yield, yield components and other traits.

CHAPTER TWO

LITERATURE REVIEW

2.1 General:

Maize is considered as one of the most important crops for its many uses all over the world. However, many recent researches in physiology, agronomy and breeding have been focused on increasing maize productivity, and developing cultivars with improved adaptation to wide range of environmental conditions.

During the last 50 years, considerable efforts had been devoted to improving yield through breeding and to understanding the mechanism involved in drought tolerance (e.g. Jensen, 1971 and Edmeads *et al.,* 1992).

2.2 Effect of Drought on Maize:

Drought or water stress is a serious agronomic problem and one of the most important factors contributing to crop yield loss.

In most maize-growing areas drought is one of the main environmental factors causing substantial yield reductions, even through temperate and tropical zones, where it differs both in the intensity of the stress (higher in the tropics) and for its variability in different years (larger in temperate zones) (Passioura, 1996).

The magnitude of yield reduction due to stress as reported by Jurgens *et al.,* (1978) depends upon:

i. The growth stage at which the water deficiency occurs and,
ii. The severity and duration of the stress.

Many researches were carried out to determine the stage of growth that is sensitive to water stress, and they revealed that maize is vulnerable to drought which is particularly affects the ability of the maize plant to produce grain at three stages. These are: early in the growing season, at the flowering and during mid-to late grain filling, which results in great yield reduction (Johnson & Herrero, 1981; Westgate & Bassetti, 1990; Dowswell *et al.,* 1996 and Heisey and Edmeades, 1999).

Water stress also delays silking which results in an increase in anthesis silking interval (ASI), which is an important cause of yield failure (Bolanos & Edmeades, 1993; Byrne *et al.,* 1995).

Consequently tolerance to drought is largely determined by events that occur at or shortly after flowering (Laffitte and Edmeades, 1995; Sari-Grola *et al.,* 1999).

Chapman *et al.,* (1997) reported that drought had a strong effect on grain yield and ear per plant. Fischer *et al.,* (1996) studied the drought effect, using harvest index and found great losses in grain number and grain yield.

Ribaut *et al.,* (1997) reported that drought resulted in 60% decrease of grain yield under severe stress. In the tropics, annual yield losses due to drought about 17%, but depending on severity and time of drought, can reach 80% (Edmeades *et al.,* 1992).

2.3 Yield and yield components:

Several previous investigations have been carried out by many workers to study the influence of drought on yield and its components of different genotypes and at various growth stages.

Sallah *et al.,* (2002) studied drought tolerance / susceptibility in nine early maturing maize genotypes. They found that effects due to environment (E), genotype (G) and G × E interaction were highly significant for grain, lodging, ear per plant and ear rating in both environments.

Debelo *et al.,* (2001) on study of 18 wheat varieties under five moisture stresses found that there were significant differences among varieties for grain yield, days to maturity and 1000 kernel weight.

Elsheikh (1999) found that maize subjected to water stress at early and late season, water stress at late season had more severe effect on grain yield than the early one.

Grant *et al.,* (1989) studied the time at which water deficit affects yield in maize, and they found that the interval when kernel number was sensitive to water deficit began 2 – 7 days after silking and ended 16 – 22 days after silking and the kernel weight was sensitive to water stress during the grain filling period.

Vicente (1999) studied 49 early maize lines extracted from different CIMMYT population under three water regimes, normal irrigation, intermediate and severe stress. The reduction in grain yield was 70% and 90% in the intermediate and severe stress respectively.

Vilela and Bull (1999) found that in maize plant subjected to three levels of water stress 44 days after emergence, the highest water level in soil increased the dry matter of the all components and consequently the whole plant. Jama (1993) reported that grain yield and dry matter were decreased due to water stress.

Tulu *et al.,* (1998) stated that water stress at vegetative stage had least affect on grain yield, while yield reduction was greatest from stress applied at grain filling.

Song *et al.,* (2000) studied the effect of drought stress on growth and development of female inflorenscence and yield of maize, and found that stress at anthesis gave greatest yield reduction followed by stress at tesseling. Moreover, observation of Claassen & Show (1970) of the effect of time of water deficit on yield components of maize indicated that significant reduction in kernel number are connected with yield reduction due to water stress before and during silking and pollination and the kernel weight was significantly reduced by stress during or after silking.

Kirda *et al.,* (1999) reported that water stress imposed at vegetative and flowering stage of maize reduced yield significantly. Bari *et al.,* (1980); Mohamed (1984); Nadal & Agarwal (1989) reported beneficial effect of irrigation on the grain yield of maize, they found that irrigation with 7cm of water every 7 days gave the highest consistent yields, while extending the interval to 14 and 21 days gave a further reduction of 37% and 50%, respectively.

Ahmed (2002) and Rajender & Dahiya (1996) stated that water stress significantly reduced grain yield, number of grains per ear, seed weight, while number of ears/m^2 was not affected by water stress.

Juan *et al.,* (1999) reported that water deficit decreased yield components (number of ears/hectare and average ear weight). Whereas, dry matter, harvest index and ear diameter were negatively affected by lack of water. Water stress significantly reduces cobs/plant, 1000 seed weight and harvest index (Malhodra and Khehra, 1986; Mohmoud *et al.,* 1997).

Edmeades *et al.,* (1993) reported that grain yield under stress is normally more highly connected with kernel number per plant than with individual grain weight.

Water stress reduced grain weight as had been reported by many workers (Westgate and Boyer, 1989; Ahmed & El Hag, 1999).

Ahmed and El Hag (1999) showed that prolonging the watering interval significantly reduced the number of cobs/m^2, number of grains per cob, 100 grain weight and grain yield (ton/ha).

Poehlman (1987) suggested that yield of small grain can be visualized as a box, with its three dimensions representing the yield components, which are: the number of heads per unit area, the number of grains per head and the average weight per grain.

2.4 Drought:

2.4.1 Definition:

The term stress is used for any environmental factor potentially unfavorable to living organisms. On the other hand, the term stress resistance is used for the ability of the plant to survive the unfavorable factor. Water stress can be understood to arise either due to deficit or an excess of water. Since stress due to deficit is most common, the term water deficit is shortened to a "water stress" (Levitt, 1972).

Osmanzia *et al.,* (1987) defined drought resistance as the ability of plant to obtain and retain water as well as to continue its metabolic function during a period of low water potential in its tissue. In wild plant species drought tolerance is often defined as survival, but in crop species it is defined in terms of productivity (Passioura, 1983). Hall *et al.,* (1993); Wenzel (1997) quantified drought susceptibility as the relative yield loss of a genotype compared to other genotypes subjected to the same moisture stress. Others defined drought tolerance as minimization of the reduction in yield caused by stress compared to yield under non-stress environment (Fischer & Maurer, 1978; Langer *et al.,* 1979; Blum, 1983 and Blum, 1988).

Turner (1997) stated that drought resistance is mediated by the maintenance of the plant water potential brought about by roots ability for sustainable moisture uptake or the reduction of the moisture loss by the above soil plant and the maintenance of growth and production under reduced water potential.

Gupta (1986), cited by Ismail (1996) defined drought resistance as the ability of plant to live, grow and yield satisfactorily with limited water supply or under periodic water deficit. He divided drought resistance into:

i. Drought escape, which is the ability of a plant to mature before water stress becomes a serious limiting factor.
ii. Drought avoidance, which is the ability of a plant to maintain higher water status during a drought.
iii. Drought tolerance, which is the ability of a plant to withstand water deficit as measured by degree and duration of low plant water potential.
iv. Drought recovery, which is the ability of a plant to resume growth and yield after drought stress with minimum or irreversible yield loss.

2.4.2 Drought tolerance evaluation and improvement:

The improvement of drought tolerance of genotype is one of the main objectives of the breeder's program. Selection for drought tolerance to mid and late season drought was based in a combination of attributes, several of which are highly correlated with grain yield (Chapman *et al.*, 1997).

Many attempts have been made to define drought tolerance in terms of an index. Palmer (1965a, b) derived a drought index known as Palmer Drought Severity Index (PDSI). Meyer *et al.,* (1993) developed a Crop Specific Drought Index (CSDI) model specifically for corn. Fischer and Maurer (1978) suggested Stress Susceptibility Index (SSI), which is the ratio of relative reduction in yield of genotype due to drought compared to the mean relative reduction in yield of all tested genotypes. This SSI is found to be the ratio of yield under stress to yield under non-stress (yd/yw), (Link *et al.,* 1999; Frova, *et al.,* 1999).

Heringa *et al.,* (1984) considered the ratio of Absolute Reduction in yield (AR) to the yield under non-stress AR/yw, as a measure for water stress. Fernandez (1993) based geometric mean of productivity (GMP), which is the square root of the product of yield under stress time's yield under non-stress.

Genotypic differences for SSI have been demonstrated in faba bean (e.g. Stelling *et al.,* 1994; Abdelmula, 1996) and for GMP & SSI in common bean (e.g. White & Singh, 1991; Schneider *et al.,* 1997).

Pirayvatlou (2001), who estimated drought tolerance, attributes MP, SSI and GMP in wheat obtained less grain yield under water deficit before anthesis than under other water management cycles.

Sallah *et al.,* (2002) found positive association between grain yield under drought and non-stress environment, when he tested nine maize genotypes under ten drought treatments.

2.5 Phenotypic and Genotypic Variability:

The inconsistent performance of genotypes across range of environments is caused either by differential responses of the same set of genes to changes in environment or by expression of different sets of genes in different environments (Falconer, 1952; Robertson, 1959; Cockerham, 1963).

Larger estimates of variance components had been observed in non-stress than in stress environment (Fery, 1964; Mederski & Jeffers, 1973; Rumbaugh *et al.,* 1984). However, Guei & Wasson (1992, 1993) observed that genetic variances were larger under stress conditions.

Genetic variability in maize susceptibility to water stress had been demonstrated by many workers (e.g., Hall *et al.,* 1982; Yang *et al.,* 1994).

Yang *et al.,* (1994) reported considerable variation among maize genotypes in responses to environmental stress.

2.6 Heritability and Genetic Advance:

Heritability is the proportion of the total phenotypic variance that occurs due to gene effect (Stanfield, 1988). Johnson *et al.,* (1955) indicated that estimates of heritability together with genetic coefficient of variation are usually useful in predicting the resulting effect of selection than heritability value alone, this mainly because heritability estimate as a ratio of genetic to phenotypic variance, varies greatly, depending on the sample size, the environment, the character and the population. Heritability usually indicates the level of confidence on which selection of genotypes are made, based on the phenotypic performance.

Many investigators had carried out experiments to estimate heritability of some traits in maize (Struber, 1967; Kump *et al.,* 1979 Ordus *et al.,* 1987 and Singh *et al.,* 1989).

Singh *et al.,* (1989) reported high heritability estimates and expected genetic advance for 1000 seed weight. Phul *et al.,* (1986) reported that heritability estimates were high for maturity span, 100 grain weight and the expected genetic advance was high for grain yield.

High heritability estimates were observed for yield, number of ears per plant (Guei & Wasson, 1992), 100 seed weight and ear length. (Meseka *et al.,* 2003).

Frova *et al.,* (1999) reported that high heritability estimates were observed for ear length, kernel number and kernel weight as well as that observed by Veldboom & Lee (1996) for ear length and kernel weight and Ribuat *et al.,* (1997) for kernel number and kernel weight.

Yu-Haiqiu *et al.,* (2003) reported that cob length, weight per cob and grain yield per plant were mainly controlled by additive gene effects, while cob diameter and grain weight were controlled by non-additive gene effects.

In general, heritability (broad sense) was found to be slightly higher under favorable conditions than under drought–stress environment (Ud-Din *et al.,* 1992, in wheat; Bidinger *et al.,* 1994 in millet; Singh, *et al.,* 1995, in common beans; Sneller & Dombek, 1997, in soy bean). Other workers (Ceccarelli, 1987; Ceccarelli, 1994 in barley, White *et al.,* 1994; Schneider *et al.,* 1997 in common bean) reported that heritability estimates for yield under drought and non-stress were generally similar, suggesting that selection should be equally effective under both water regimes.

Blum (1988) reported that a decrease in the genetic variance and heritability of yield components was parallel to an increase in environmental stress.

2.7 Interrelationship among Different Traits:

Several different reviews on correlation between different characters under drought have been written.

Sallah *et al.,* (2002) reported that grain yield in the stress environment was positively associated ($r = 0.71$, $P \leq 0.01$) with yield in the non-stress environment. Stone *et al.,* (1997) studied the water deficit effect on growth water use and yield of corn; they found that yield and yield components were highly correlated with maximum potential soil moisture deficit.

Gencoglan & Yazar (1999) studied the Crop Water Stress Index (CWSI) and irrigation scheduling in maize plant. They found that there was linear relationship between grain yield and CWSI. Jaradat (1992) reported that Stress Susceptibility Index (SSI) was positively correlated with potential yield in semi-arid environments and negatively correlated with yield under stress in arid environments; also SSI was significantly correlated with days to maturity in semi-arid environments.

Rubaut *et al.,* (1997) reported that correlation analysis of grain yield, ear number, grain number and 100 seed weight showed that they were not independent of each other. They also reported that positive correlation was observed between a drought tolerance index and yield under well-watered condition. Parh *et al.,* (1986) reported significant positive correlation between 100 seed weight, days to maturity and grain yield per plant.

Debelo *et al.,* (2001) reported that 1000 seed weight was positively and significantly associated with grain yield. Xu (1986) observed a high significant correlation between yield per plant, ear length, ear thickness and 1000 grain weight.

However, Frova *et al.,* (1999) stated that ear length, ear weight, grain weight and grain number were positively correlated and the magnitude of the linear correlation increased under water stress. Under control, grains weight showed a lower correlation generally decreased under water stress with other traits.

Undersander (1987) reported that when the yield components were regressed against yield, number of grains per ear and number of ears per plant were significant and ears per plant was found to be more important in determining final yield.

Guei and Wasson (1992) reported high genotypic and phenotypic correlation between yield and number of ears per plant. Also Fischer *et al.,* (1996) on his study found that harvest index and yield are well correlated. Moll & Stuber (1974) found that correlation among traits could be utilized to enhance the rate of selection response in the primary traits.

Although, a low genetic correlation between yields is often observed for many crops, this indicates that different sets of genes may be important in conditioning the yield under different environments (Johnson & Geadelmann, 1989; Atlin & Frey, 1990).

CHAPTER THREE

MATERIALS AND METHODS

3.1 Experiment Description:

Two field experiments were carried out during the rainy season 2003/04 at two different locations, to study the effect of water stress on different genotypes of maize. The first at Shambat in the experimental farm of Faculty of Agriculture, University of Khartoum (Lat. 15º 40' N, Long. 32º 32' E, 380m above sea level). The soil is fine montmorillonitic clay characterized by low permeability, low nitrogen content and high pH. The second at Gezira Research Station (Lat. 14º 24' N, Long. 33º 29' E, 407m above sea level) at Medani. The soil is characterized by heavy cracking clay (58%), pH of 8.3, low organic matter (0.6%) and nitrogen content (0.02%). Monthly rainfall, temperature and relative humidity during the season of the two experiments are shown in Table 3.1.

3.1.1 Genotypes:

Fifteen genotypes of maize were used in these experiments; these genotypes consisted of six open pollinated varieties (Mexico), one local variety, two Egyptian varieties and six land races. They are shown in Table 3.2.

3.1.2 Water treatments:

Maize genotypes were grown under different water regimes, normal irrigation and drought treatment induced during two various growth stages in both experiments.

- ◙ W_0 = well-watered (non stress, irrigation every 14 days.) optimum irrigation was applied throughout the growing season (control) i.e. No stress at all.

Table 3.1. Monthly mean of temperature (ºC), rainfall (mm)and relative humidity (RH%) at Shambat and Medani for the 2003/04 season.

Month	Shambat			Madeni		
	Temp.	Rainfall	RH%	Temp.	Rainfall	RH%
June	34	6	33	NA	NA	NA
July	31	40	65	30	92	75
August	31	74	73	28	147	84
September	31	124	61	29	51	76
October	30	43	39	31	12	53
Mean	31.4	57.4	54.2	29.5	75.5	72.0

NA = Not available

Table 3.2. The 15 maize genotypes tested for drought tolerance at two locations, Shambat and Medani during the 2003/04 season.

Serial No.	Code	Names & Pedigree
1.	G – 1	TL 98B – 6225 – 145 × TL97B – 6170
2.	G – 2	TL 98B – 6225 – 9 × TL97B – 6170
3.	G – 3	TL 98B – 6234 – 122 × 545
4.	G – 4	TL 98B – 6234 – 544 × 545
5.	V – 113	Var 113
6.	Z – 2	Geza – 2
7.	M – 45	Mugtama 45
8.	PR – 1	PR – 91A – 222E
9.	PR – 2	PR – 89B – 5655
10.	D – 2	TLATIZAPAN 9733 ×TLATIZAPAN 9745 F_2
11.	D – 3	(Celaya 9733 × Celaya 9745) F_2
12.	D – 6	BANSLADRE 9733
13.	D – 7	TALLZAPAN – 9733
14.	E – 7	SLR – 12
15.	C – 12	S97 – TEW – GH "AYB" (2)

* 1-4,8-9	are open pollinated varieties (from Mexico)
* 5	is local variety
* 6-7	are Egyptian varieties
* 10-15	are land races

◙ W_1 = stress during vegetative stage till end of flowering (irrigation every 21 days) followed by well-watering till harvesting i.e. stress during vegetative stage only.

◙ W_2 = well-watering (irrigation every 14 days) till end of flowering and then followed by stress (irrigation every 21days) till harvesting. i.e. stress during seed filling reproductive stage.

3.1.3 Experimental design:

Split-plot design with three replications was used to carry out the investigations of both experiments. The three treatments of water (W_0, W_1&W_2) were assigned as main plots. The fifteen genotypes were distributed randomly within the main plot as sub-plots.

3.1.4 Planting methods:

Each genotype was represented by two rows, 3 meters in length, with row-to-row spacing of 70cm and 80cm at Shambat and Medani, respectively. Hole-to-hole spacing within rows was 25cm.

The genotypes were planted at 7th of July 2003 manually with a rate of two seeds per hole, thinned to one plant per hole after two weeks. For initiation and establishment, the crop received three irrigations of seven days interval.

Weeding was carried out by hand hoeing two times for both experiments. Appropriate amounts of chemical fertilizer, urea (1N=40 kg/ha) were applied after three weeks from sowing. Before planting seeds were treated by a protective fungicide (thiram). A systemic insecticide (furidan) was used twice, one of them at sowing for protection against stem borer, which had more effect. In Shambat, the crop was sprayed with Durispan against termites.

3.2 Data Collection and Assessment:

A sample of ten randomly selected plants from each sub-plot throughout the two experiments was used to record data for reproductive traits as follows:

3.2.1 Yield traits:

- GY = grain yield (kg/ha) this was calculated by the following formula:

$$\text{GY (kg/ha)} = \frac{\text{grain weight (kg)/subplot}}{\text{Actual subplot area}(\text{m}^2)} \times \frac{1 \times 10^4\,\text{m}^2}{\text{ha}}$$

- Grain yield per plant (g).
- Dry forage yield per plant in kg/ha.
- HI = harvest index = $\frac{Grain\ yield / plant}{Bio\log ical\ yield / plant} \times 100$

3.2.2 Yield components:

- Number of ears per meter square (m^2)
- Number of seeds per ear = was calculated by multiplication of No. of seeds/row by No. of rows/ear.
- 100 seeds weight in g = HSW
- Ear length in cm. The average length in cm of ten ears.
- Ear diameter in mm, the average diameter of the ten ears at its maximum width, using vernear champer.

3.2.3 Phenological traits:

- DM= days to 75% maturity. It is the number of days from sowing, till 75% of the plants in each sub-plot reached maturity.
- Number of husks per ear.
- HC = husk cover, it was a range (1 to 5 scale) of the number of ears in each sample of 10 plants that have or haven’t any

portion of the ear exposed, which described below. CIMMYT (1994) as follows:

Rating scale	Husk cover
1. Excellent	Husk tightly covers ear tip and extends beyond it
2. Fair	Covers ear tip tightly
3. exposed tip	Loosely covers ear up to its tip
4. Grain exposed	Husk leaves do not cover the ear adequately, leaving its tip somewhat exposed
5. Completely unacceptable	Poor husk cover, tip, clearly exposed

◙ Root lodging: recorded as percentage of the number of plants, that are leaning 30º or more from perpendicular at the base of the plant where the root zone starts, to the total number of plants/plot.

3.2.4 Drought tolerance parameters:

To evaluate drought tolerance, different traits were used as parameters; these parameters were based on the collected data of grain yield/plant. The parameters which studied were:

Y_d = grain yield/plant (g) under dry condition.

Y_w = grain yield/plant (g) under well – watered condition.

Y_d/Y_w = ratio of grain yield/plant (dry) to grain yield per plant (well – watered) as percent.

SSI = stress susceptibility index: was used to characterize each genotype in the stress experiments by using the generalized formula of Fischer and Maurer (1978), in which.

$$\text{SSI} = \frac{\{Y_w - Y_d\}}{\{Y_w(1 - y_d / y_w)\}}$$

Where:

Y_w and Y_d as defined in other parameters

y_w and y_d are the mean of grain yield over all genotypes studied in well-watered and drought conditions, respectively.

$(Y_w-Y_d)/Y_w$ = relative yield reduction.

$1-y_d/y_w$ = drought intensity index.

Values of SSI < 1 denote below average drought susceptibility (= above average drought tolerance) and average reaction is defined by SSI = 1 and values of SSI > 1 describe above drought susceptibility (= below average drought tolerance).

GMP = geometric mean of productivity in g, it is measured as $\sqrt{Y_d \times Y_w}$ as described by Fernandez (1993).

STI = Stress tolerance index (Fernandez, 1993). It is measured as $(Yd)(Yw)/(yw)^2$, where yw is the mean yield under well-watered conditions over all genotypes.

3.3 Statistical Analysis:

The collected data were subjected to different statistical analyses as follows:

3.3.1 Analysis of variance:

The analysis was carried out for studied parameters in each location separately according to Gomez and Gomez (1984) procedure for split-plot design (Table 3.3).

- **Combined analysis of variance:**

It was done for the parameters in which the mean squares of errors were homogenous. It was carried out as such as the procedures described by Gomez and Gomez (1984) for split-plot design (Table 3.4). The drought tolerance parameters were studied using combined analysis of variance as in Table 3.5.

Table 3.3 Analysis of variance for different characters of 15 genotypes of maize evaluated under three water treatments with three replicates, for each location separately, during the 2003/04 season.

Source of variance	**DF**	**MS**	**EMS**
Replications	r-1 = 2		
Treatments	t-1 = 2		
Error (a)	(t-1)(r-1) = 4		
Genotypes	(g-1) = 14	M_3	$\sigma^2 e + r\,\sigma^2 gt + rt\,\sigma^2 g$
Gen. × Treat.	(g-1)(t-1) = 28	M_2	$\sigma^2 e + r\,\sigma^2 gt$
Error (b)	t(r-1)(g-1) = 84	M_1	$\sigma^2 e$
Total	**(rtg-1) = 134**		

r = replications, t = treatments (main factor), g = genotypes (sub factor), M1, M2, M3 = mean square for error (b), genotypes X treatments interaction and genotypes, respectively.

$\sigma^2 g$ = genotypic variance, $\sigma^2 e$ = error (b) variance

$\sigma^2 gt$ = variance due to interaction between genotypes X treatments.

Table 3.4 Combined analysis of variance for characters of 15 genotypes of *Zea mays* evaluated under three water treatments with three replications, at two locations Shambat and Medani, during the 2003/04 season.

Source of variance	DF	Expected mean square
Locations	(l-1) = 1	
Replications/Loc	L(r-1) = 4	
Treatments	(t-1) = 2	
Treat. × Loc.	(t-1)(l-1) = 2	
Rep. × Treat./Loc.	L(r-1)(t-1) = 8	
Genotypes	(g-1) = 14	$\sigma^2e+r\sigma^2gtl+rt\sigma^2gl+ rl\sigma^2gt+rtl\sigma^2g$
Gen. × Treat.	(g-1)(t-1) = 28	$\sigma^2e+r\sigma^2gtl+rt\sigma^2gl+ rl\sigma^2gt$
Gen. × Loc.	(g-1)(L-1) = 14	$\sigma^2e+r\sigma^2gtl+rt\sigma^2gl$
Gen. × Treat. × Loc.	(g-1)(t-1)(l-1) = 28	$\sigma^2e+r\sigma^2gtl$
Pooled error	Lr(g-1)(t-1) = 168	σ^2e
Total	(Lrtg-1) = 269	

L = locations

r = replications

t = treatments

g = genotypes

σ^2g = genotypic variance

σ^2e = pooled error variance

σ^2gt = variance due to interaction of genotypes × treatments

σ^2gl = variance due to interaction of genotypes × Locations

σ^2gtl = variance due to interaction of genotypes × treatments × locations

Table 3.5 Analysis of variance for drought tolerance parameters among 15 genotypes of maize with three replications, at two locations Shambat and Medani, during the season (2003/04).

Source of variance	DF	Expected mean square
Locations	(l-1) = 1	
Replications/Loc.	L(r-1) = 4	
Genotypes	(g-1) = 14	$\sigma^2e+r\sigma^2gl+rl\sigma^2g$
Gen. × Loc.	(g-1)(l-1) = 14	$\sigma^2e+r\sigma^2gl$
Gen. × Rep./Loc.	L(g-1)(r-1) = 56	σ^2e
Total	(Lrtg-1) = 89	

L = locations r = replications g = genotypes

σ^2g = genotypic variance

σ^2e = pooled error variance

σ^2gl = variance due to interaction of genotypes × Locations

- ◙ **Coefficient of variance (CV%):**

It was estimated for each parameter in both locations using the formula:

$$\text{CV\%} = \frac{\sqrt{\text{Mean square of error}}}{\text{Grand mean}} \text{X100\%}$$

- ◙ **Mean separation:**
  - For mean, Duncan's Multiple Range Test (DMRT) of 5% level of significance according to Gomez and Gomez (1984) procedure was used for separating the mean of water regime treatments using the formula:

$$R_p = \frac{(\text{rp}) \times (\text{Sd})}{\sqrt{2}}$$

Where:

rp (p = 2, 3, …t) = tabular values of significant standardized ranges at 5% level of significance.

P = distance in rank between the pairs of treatment means to be compared

$$S_d = \frac{\sqrt{2 \times \sigma^2}}{r}$$

Where:

σ^2 = error mean square in analysis of variance and

r = number of replications.

Rp = the (t-1) value of the shortest significant range.

  - Comparison between genotypes: the means separated, using the least significant difference (LSD) at 5% level of significance according to the formula:

$$\text{LSD} = t_\alpha \times \frac{\sqrt{Average\ effective\ error\,(MS)}}{r}$$

Where:

r = number of replications.

MS = mean square.

α = level of significance for t – value.

- Means separation for drought tolerance parameters. The LSD at 5% level of significance was used

3.3.2 Phenotypic (σ^2ph) and Genotypic (σ^2g) Variance:

They were estimated using analysis of variance (Table 3.3) as follows:

Phenotypic variance (σ^2ph) = $\sigma^2 g + \sigma^2 e$

Genotypic variance (σ^2g) = $\frac{M_3 - M_2}{rt}$

Where:

r = number of replications.

t = number of treatments.

$\sigma^2 e$ = variance of experimental error.

M_3 = mean square of genotypes.

M_2 = mean square of genotypes X treatments interaction.

3.3.3 Phenotypic and genotypic coefficient of variation (%):

They were computed according to the formula suggested by Burton and Devane (1953) as follows:

Phenotypic coefficient of variation (PCV%) = $\frac{\sqrt{\sigma^2 ph}}{\text{grand mean}} \times 100\%$

Genotypic coefficient of variation (GCV%) = $\frac{\sqrt{\sigma^2 g}}{\text{grand mean}} \times 100\%$

3.3.4 Heritability (broad sense):

From the analysis of variance heritabilities were estimated for each location separately according to Johnson *et al.,* (1955) by the formula:

$$h^2 = \frac{\sigma^2 g}{\sigma^2 g + \sigma^2 gt / r + \sigma^2 e / rt} \times 100\%$$

where:

$\sigma^2 g$ = genotypic variance.

$\sigma^2 gt$ = genotypes X treatments interaction variance.

$\sigma^2 e$ = pooled error variance.

t = number of treatments.

r = number of replications.

Depending on the combined analysis of variance, broad sense heritabilities were estimated according to the formula:

$$h^2 = \frac{\sigma^2 g}{\sigma^2 g + \sigma^2 gt / rl + \sigma^2 gl / rt + \sigma^2 gtl / r + \sigma^2 e / rtl} \times 100\%$$

where:

$\sigma^2 g$ = genotypic variance.

$\sigma^2 gt$ = variance due to genotypes X treatments interaction.

$\sigma^2 gl$ = variance due to genotypes X locations interaction.

$\sigma^2 gtl$ = variance due to genotypes X locations X treatments interaction.

$\sigma^2 e$ = pooled error variance.

t = number of treatments.

r = number of replications.

l = number of locations.

3.3.5 Expected genetic advance (GA):

The formula of Robinson *et al.,* (1949) was used to estimate the genetic advance as follows:

$$GA = \frac{K\sigma^2 g}{\sigma ph}$$

Where:

K = selection differential and it was 2.06 as defined by Lush (1949) at selection intensity of 5%.

σph = square root of phenotypic variance.

CHAPTER FOUR

RESULTS

4.1 Performance of Genotypes over Environments:

Environmental means of 15 maize genotypes averaged over three water managements reflected significant differences for most of the investigated traits (Table 4.1). For instance the average grain yield per plant at Shambat was 59.4g, while at Medani was 72.8g, the coefficient of variation was 25%. Medani environment appeared to be more productive than Shambat for most traits, except total dry forage weight and number of husks per plant. However, the lodging percentage at Medani seems to be double than that at Shambat (Table 4.1).

4.2 Effect of Drought on The Reproductive Traits:

The analysis of variance (Table 4.2) for Shambat environment showed non-significant differences among water treatments for most of the traits under study, except, 100 seed weight, total dry forage weight which showed significant differences ($P \leq 0.05$) and days to maturity which showed highly significant differences ($P \leq 0.01$). While at Medani highly significant differences ($P \leq 0.01$) were obtained for most of the investigated traits. Non-significant differences were observed for number of seeds per ear, number of ears/m^2, ear length and number of husks/ear. Drought showed more obvious effect at Medani environment than at Shambat (Table 4.2).

Table 4.1. Means of locations (Shambat and Medani) of 15 maize genotypes for some characters under study. Means are averaged over 3 water treatments (W_0,W_1& W_2) in 2003/04 season.

Characters	Shambat	Medani	Means	CV%	LSD (5%)
Grain yield (kg/ha)	3561.77	3640.93	3601.35	25	815.15
Grain yield (g/plant)	59.37	72.82	66.10	25	14.94
No. of ears/m^2	6.35	6.71	6.53	7	0.39
No. of seeds/ear	393.56	392.90	393.23	19	64.65
100-seeds weight (g)	17.42	18.39	17.90	12	1.81
Ear length (cm)	13.80	15.48	144.61	11	0.97
Ear diameter (mm)	37.13	39.46	38.30	8	2.36
Dry forage weight/ha (kg/ha)	9182.51	8531.85	8857.18	17	827.03
Days to 75% maturity	73.19	84.67	78.93	1	0.70
No. of husks/ear	9.87	8.22	9.05	12	1.12
Harvest index	0.38	0.42	0.40	21	0.06
Lodging %	4.98	8.86	6.92	34	2.48
Husk cover (1-5)	1.84	1.90	1.87	26	0.27

W_0,W_1& W_2 refer to water treatments as in material and methods.

Table 4.2. Mean squares from ANOVA due to treatments (T), genotypes (G) and their interaction (G × T), for different characters in maize genotypes evaluated over three water treatments at two locations (Shambat and Medani) during the 2003/04 season.

Characters	Shambat			Medani		
	T	G	G × T	T	G	G × T
	d.f =2	d.f =14	d.f =28	d.f =2	d.f =14	d.f =28
Grain yield (kg/ha)	24553898.73 ns	990371.03 ns	1053324.48 ns	24370604.82**	1058968.95*	482235.81 ns
Grain yield (g/plant)	6830.19 ns	273.40 ns	292.43 ns	9874.41 **	428.90*	195.12 ns
No of ears/m^2	0.24 ns	0.52**	0.32 ns	0.71 ns	0.10 ns	0.16 ns
No of seeds/ear	48656.10ns	9122.16 ns	3866.08 ns	8765.05 ns	8459.96*	3087.89 ns
100-seeds weight (g)	140.48*	12.00**	7.14 ns	485.17 **	13.01**	4.71 ns
Ear length (cm)	20.77 ns	2.42 ns	2.05 ns	1.06 ns	4.41*	3.93*
Ear diameter (mm)	110.97 ns	22.75**	7.13 ns	77.70 *	19.45*	10.35 ns
Dry forage weight (kg/ha)	46121816.94*	3048253.06 ns	3291783.98 ns	73876380.36**	2588161.50	2046112.57
Days to 75% maturity	103.79 **	0.87 ns	0.90 ns	46.02**	2.92**	3.16**
No of husks/ear	0.50 ns	4.38**	1.82*	0.35 ns	1.76 ns	1.07 ns
Harvest index (%)	0.08 ns	0.02 ns	0.01 ns	0.03*	0.004 ns	0.002 ns
Lodging (%)	5.80 ns	4.05 ns	2.52 ns	80.31*	26.15**	13.00*
Husk cover (1-5)	2.09 ns	0.41	0.26 ns	1.69**	0.47*	0.24 ns

*, **: significant at probability of 0.05& 0.01, respectively, ns: non significant.

Combined analysis (Table 4.3) showed that most of the investigated traits reflect highly significant differences ($P \leq 0.01$) among water treatments except, number of ears/m^2, ear length, number of husks/ear, lodging percentage and harvest index which recorded non-significant differences (Table 4.3).

4.3 Effect of Drought During Vegetative and Reproductive Stages:

Drought stress during vegetative stage (W_1) appeared more severe for most of the investigated traits in both locations compared with W_0 and W_2 (Tables 4.4, 4.5 and 4.6) (Figs. 1-6). At Shambat, stress during vegetative stage till to end of flowering (W_1) resulted in reduction of the values of most of the characters under study (Table 4.4) (Fig.1-6). Non-significant differences among the three water treatments were recorded for most of the investigated characters except, 100 seed weight and dry weight (Table 4.4).

However, at Medani a greatest reduction and significant differences ($P \leq 0.05$) due to water treatments were observed for most of the traits under study (Table 4.5).

Drought stress during vegetative stage (W_1) reduced the values of some characters like number of seeds/ear and number of ears/m^2.

In general, W_2 treatment reduced the values of most investigated traits, while W_1 reflects greatest reduction for most of the same investigated traits. The reduction values due to W_1 treatment on number of seeds/ear was 15.2% at Shambat, 6.3% at Medani and the average was 10.7%. For W_2 the reduction for the same trait was 4.2% at Shambat, 5.2% at Medani and the average was 5% (Tables 4.4, 4.5 & 4.6).

W_2 treatment significantly reduced the 100 seeds weight by 17.1% at Shambat, by 30.1% at Medani and the average reduction was

24.1% (Tables 4.4, 4.5 & 4.6), while W_1 treatment non-significantly reduced the 100 seeds weight at Shambat and for the average, but significant reduction in Medani was observed (Tables 4.4, 4.5 & 4.6).

At Medani, W_1 treatment significantly reduced the total grain yield by 13.8%, whereas non-significant reduction was observed at Shambat and for the average (Tables 4.4, 4.5 & 4.6). However, W_2 treatment significantly reduced grain yield (kg/ha) by 33.9% at Medani and non-significantly by 25.8% and 29.8% at Shambat and for the average of both locations, respectively (Fig. 3).

For each location, W_1 treatment exhibited non-significant differences for most of the investigated traits as well as W_2 treatment (Tables 4.4, 4.5).

Husk cover, days to 75% maturity and harvest index were non-significantly decreased due to W_1 and W_2 treatments at Shambat, Medani and the average (Tables 4.4, 4.5 & 4.6).

Table 4.3. Mean squares from combined analysis due to locations (L) treatments (T), genotypes (G) and their interaction (G × T), for different characters in 15 maize genotypes evaluated over three water treatments at two locations (Shambat and Medani) during the 2003/04 season.

Characters	L	T	TL	G	GT	GL	GTL
	d.f =1	d.f =2	d.f =2	d.f =14	d.f=28	d.f =14	d.f =28
Grain yield (kg/ha)	423007.12ns	41492726.04**	7431777.52 ns	749286.95 ns	769118.37 ns	1300053.02*	766441.92 ns
Grain yield (g/plant)	12218.05**	14118.56**	2586.04 ns	265.79 ns	244.19 ns	436.51*	243.36 ns
No of ears/m^2	8.89**	0.84 ns	0.10 ns	0.33 ns	0.20 ns	0.30 ns	0.28 ns
No of seeds/ear	29.87 ns	46298.89*	11122.26 ns	9404.47*	3635.49 ns	8177.65 ns	3318.48 ns
100-seeds weight (g)	63.95*	536.47**	89.17*	18.63**	6.63*	6.38 ns	5.22 ns
Ear length (cm)	202.28**	13.39 ns	8.44 ns	4.97**	3.87*	1.86 ns	2.11 ns
Ear diameter (mm)	395.87**	174.81*	13.86 ns	31.32**	11.42 ns	10.88 ns	6.06 ns
Dry forage weight (kg/ha)	28576499.71*	103394290.75**	16603906.56*	4298207.07*	2646806.67 ns	1338207.49 ns	2305513.61 ns
Days to75% maturity (days)	8886.67**	139.39**	10.42 ns	2.82**	2.17**	0.96 ns	1.89**
No of husks/ear	184.35**	0.02 ns	0.83 ns	3.69**	1.59 ns	2.46*	1.29 ns
Harvest index (%)	0.12 ns	0.08 ns	0.06 ns	0.01 ns	0.01 ns	0.01 ns	0.01 ns
Lodging (%)	1015.78**	29.17 ns	56.95*	18.17**	5.73 ns	12.02**	9.79**
Husk cover (1-5)	0.26ns	3.69 ns	0.09 ns	0.74**	0.36*	0.14 ns	0.14 ns

*, **: significant at probability of 0.05& 0.01, respectively, ns: non significant.

Table 4.4 Means of some yield components and other vegetative traits, for 15 maize genotypes evaluated under three water treatments (W_0, W_1, W_2), at Shambat during the 2003/04 season.

Water treatment	Trait						
	No. of ears/m^2	Ear length (cm)	Ear diameter (mm)	100seeds weight (g)	Days to 75% maturity	Dry forage wt.(kg/ha)	No. of husks/ear
W_0	6.4a	14.4a	38.9a	19.4a	74.6a	10323a	9.9a
W_1	6.3a	13.1a	35.9a	16.8ab	71.6b	8389ab	9.9a
W_2	6.4a	13.8a	36.6a	16.1b	73.5a	8836b	9.8a
Mean	6.4	13.8	37.1	17.4	73.2	9183	9.9
CV(%)	8.2	22.3	17.2	27.6	4.0	30.5	17.1
LSD(5%)	0.3	1.8	3.8	2.8	1.7	1641	1.0

* Means followed by same letters are not significant at 5% level of probability.

Table 4.5 Means of some yield components and other vegetative traits, for 15 maize genotypes evaluated under three water treatments (W_0, W_1, W_2), at Medani during the 2003/04season.

Water treatment	Trait						
	No. of ears/m^2	Ear length (cm)	Ear diameter (mm)	100seeds weight (g)	Days to 75% maturity	Dry forage wt.(kg/ha)	No. of husks/ear
W_0	6.7a	15.5a	40.9a	21.2a	85. 8a	9823a	8.2a
W_1	6.6a	15.3a	39.1ab	19.2b	83.8b	8512b	8.2a
W_2	6.8a	15.6a	38.4b	14.8c	84.4c	7261c	8.3a
Mean	6.7	15.5	39.5	18.4	84. 7	8532	8.2
CV%	9.6	4.2	9.6	11.9	0. 5	7.4	8.3
LSD(5%)	0.4	0.4	2.2	1.3	0.2	367	0.4

* Means followed by same letters are not significant at 5% level of probability.

Table 4.6 Means of some yield components and other vegetative traits, for 15 maize genotypes evaluated under three water treatments (W_0, W_1, W_2) averaged over two locations (Shambat and Medani) during the 2003/04 season.

Water treatment	Trait						
	No. of ears/m^2	Ear length (cm)	Ear diameter (mm)	100seeds weight (g)	Days to 75% maturity	Dry forage wt.(kg/ha)	No. of husks/ear
W_0	6.5a	14.9a	39.9a	20.3a	80.2a	10073a	9.0a
W_1	6.4a	14.2a	37.5b	18.0a	77.7b	8450a	9.1a
W_2	6.6a	14.7a	37.5b	15.4a	78.9ab	8048a	9.0a
Mean	6.5	14.6	38.3	17.9	78.9	8857	9.1
CV(%)	8.9	15.2	13.7	20.9	2.6	22.9	14.2
LSD(5%)	0.00	1. 6	1.9	5.9	2.0	2633	0. 6

* Means followed by same letters are not significant at 5% level of probability.

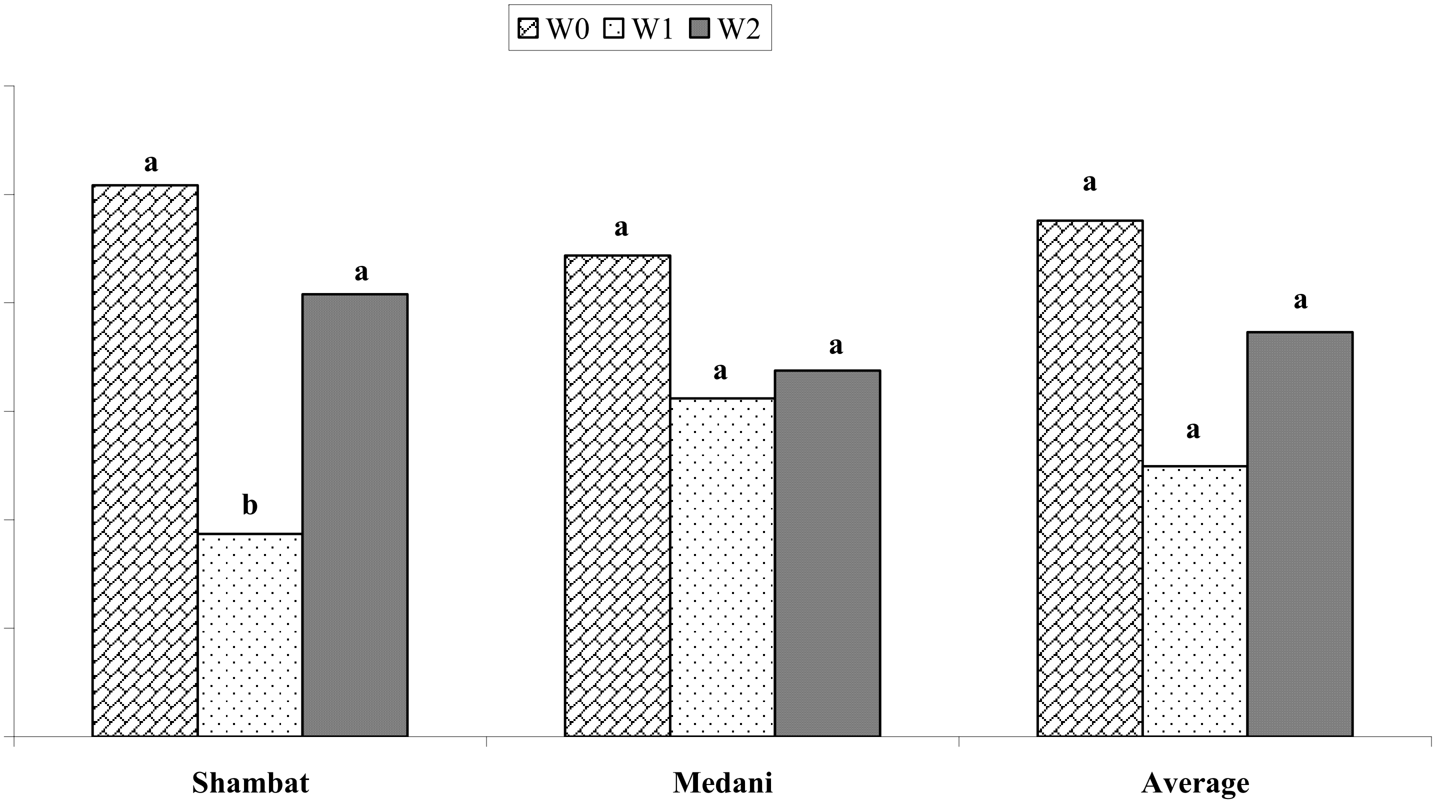

Fig. 4.1. Number of seeds/ear for 15 maize genotypes evaluated under three water treatments at two locations (Shambat and Medani) during the 2003/04 season

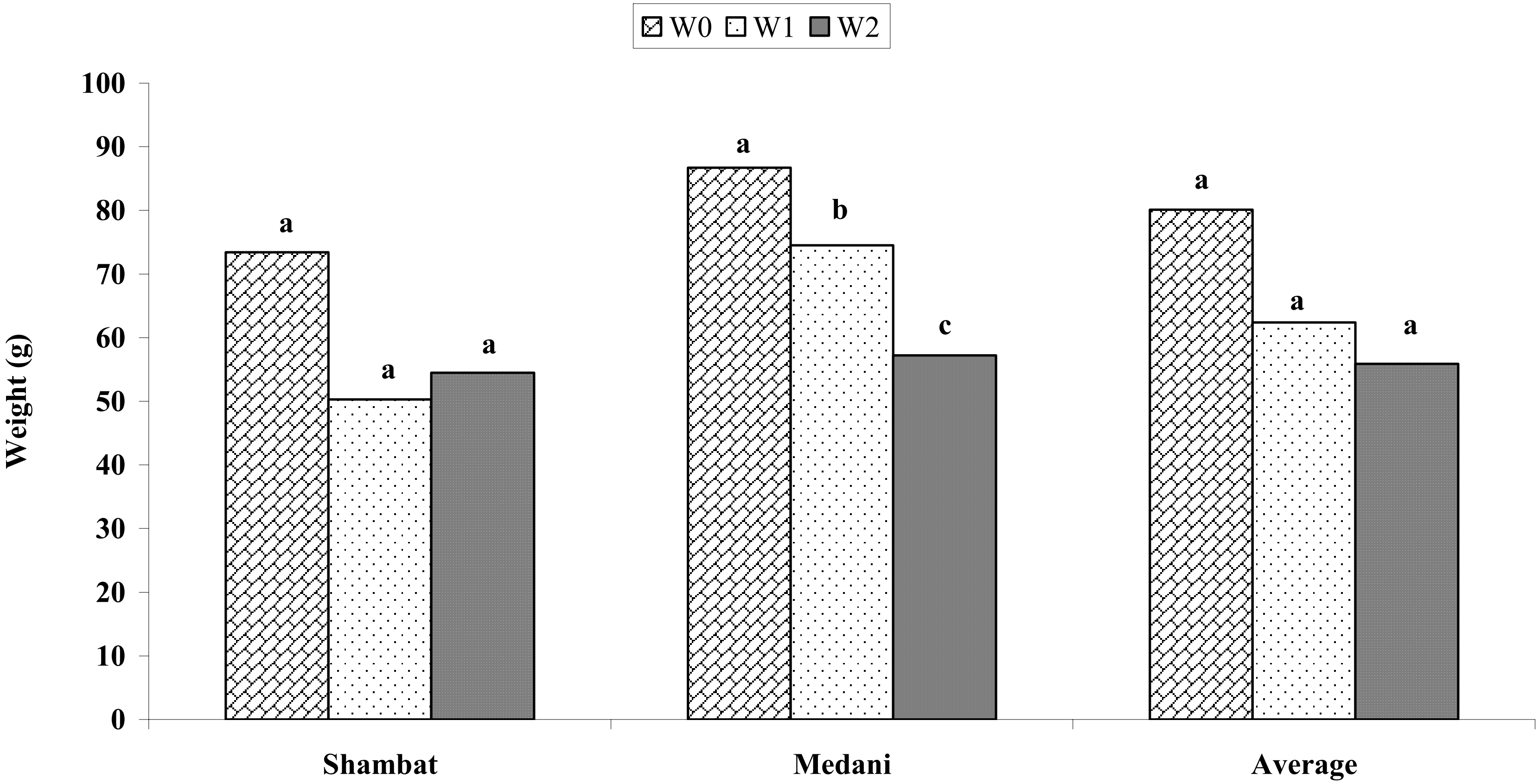

Fig. 4.2. Grain weight/plant (g) for 15 maize genotypes evaluated under three water treatments at two locations (Shambat and Medani) during the 2003/04 season

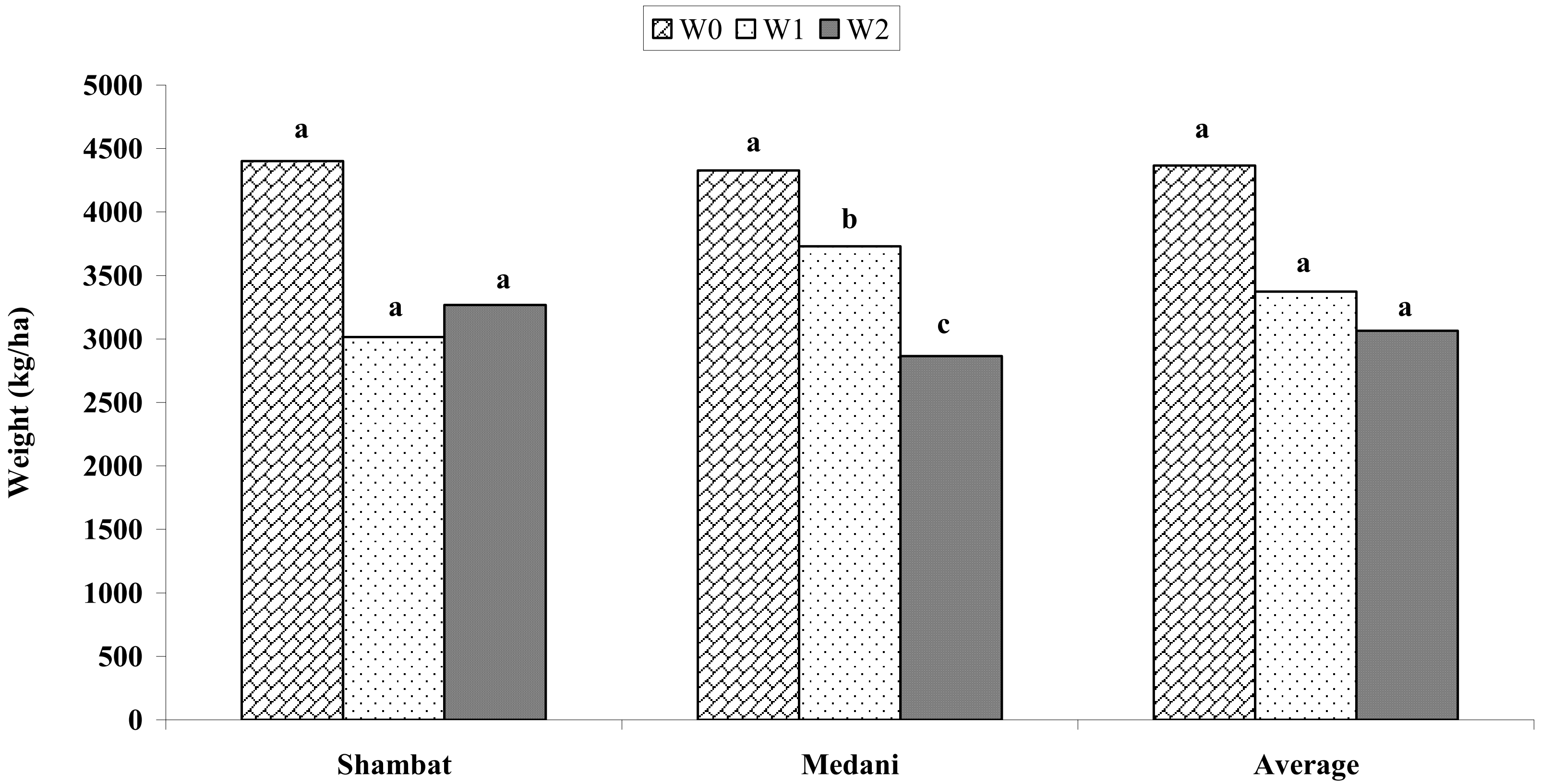

Fig. 4.3. Grain weight (kg/ha) for 15 maize genotypes evaluated under three water treatments at two locations (Shambat and Medani) during the 2003/04 season

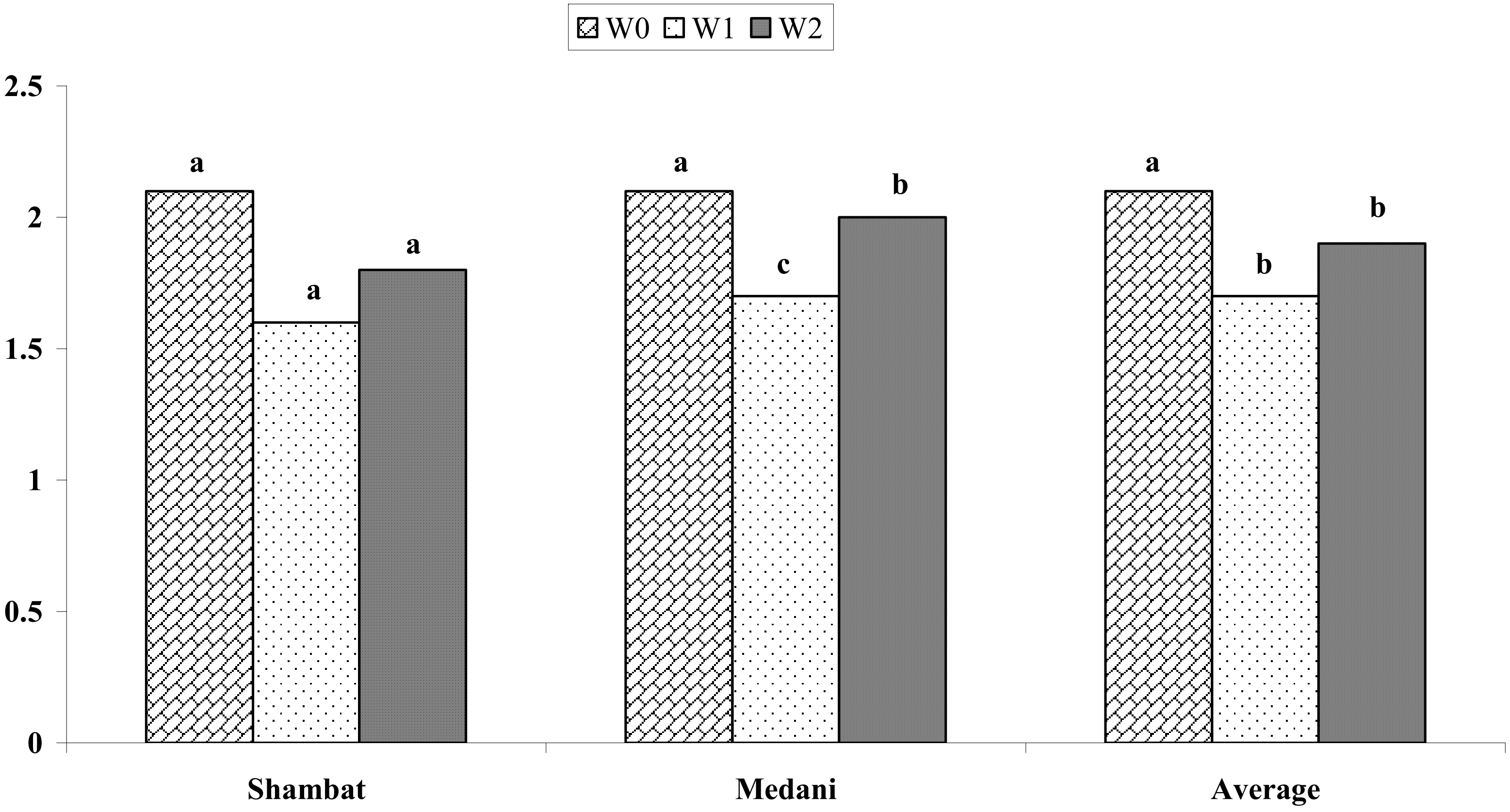

Fig. 4.4. Husk cover (1-5 scale) for 15 maize genotypes evaluated under three water treatments at two locations (Shambat and Medani) during the 2003/04 season

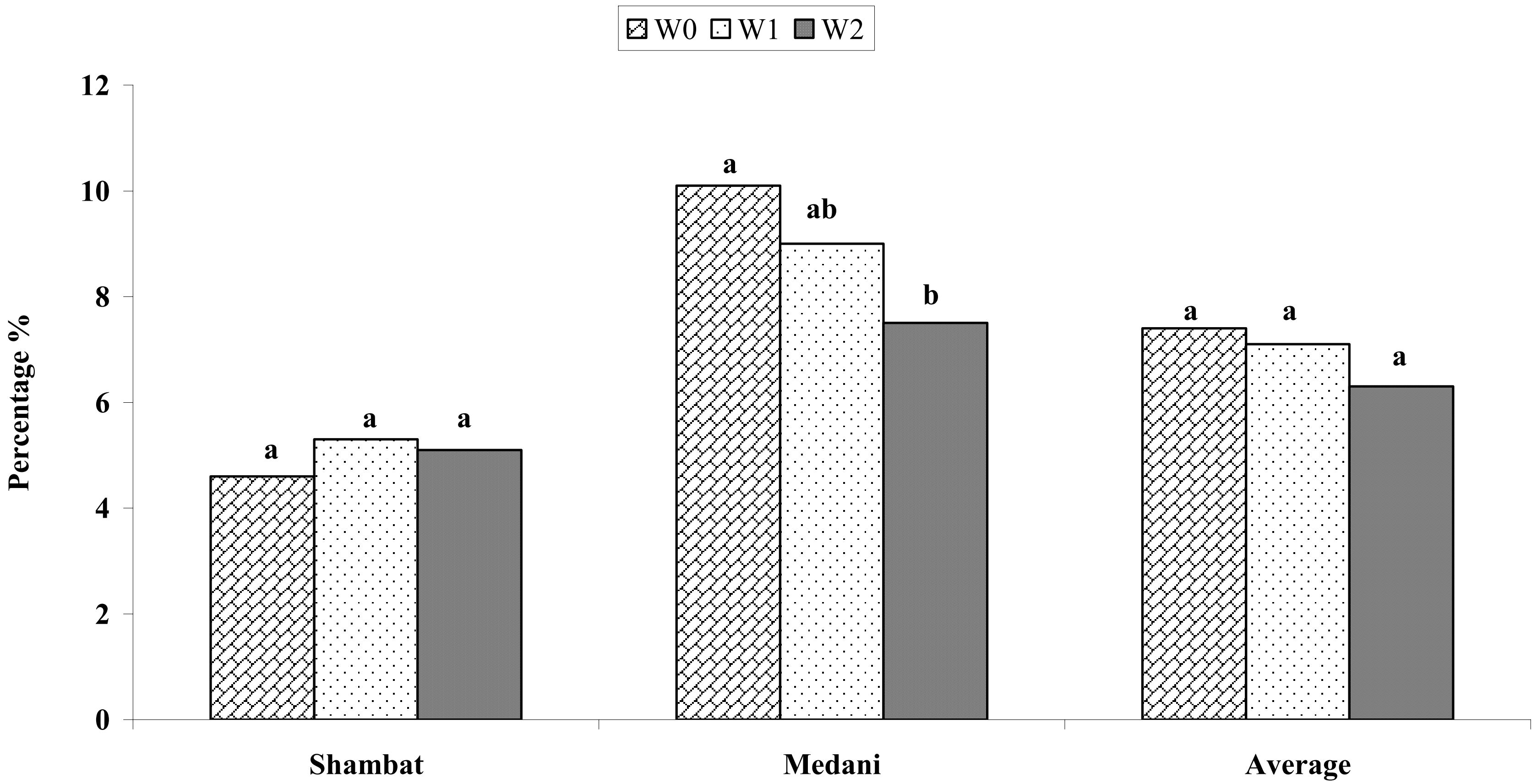

Fig. 4.5. Lodging percentage for 15 maize genotypes evaluated under three water treatments at two locations (Shambat and Medani) during the 2003/04 season

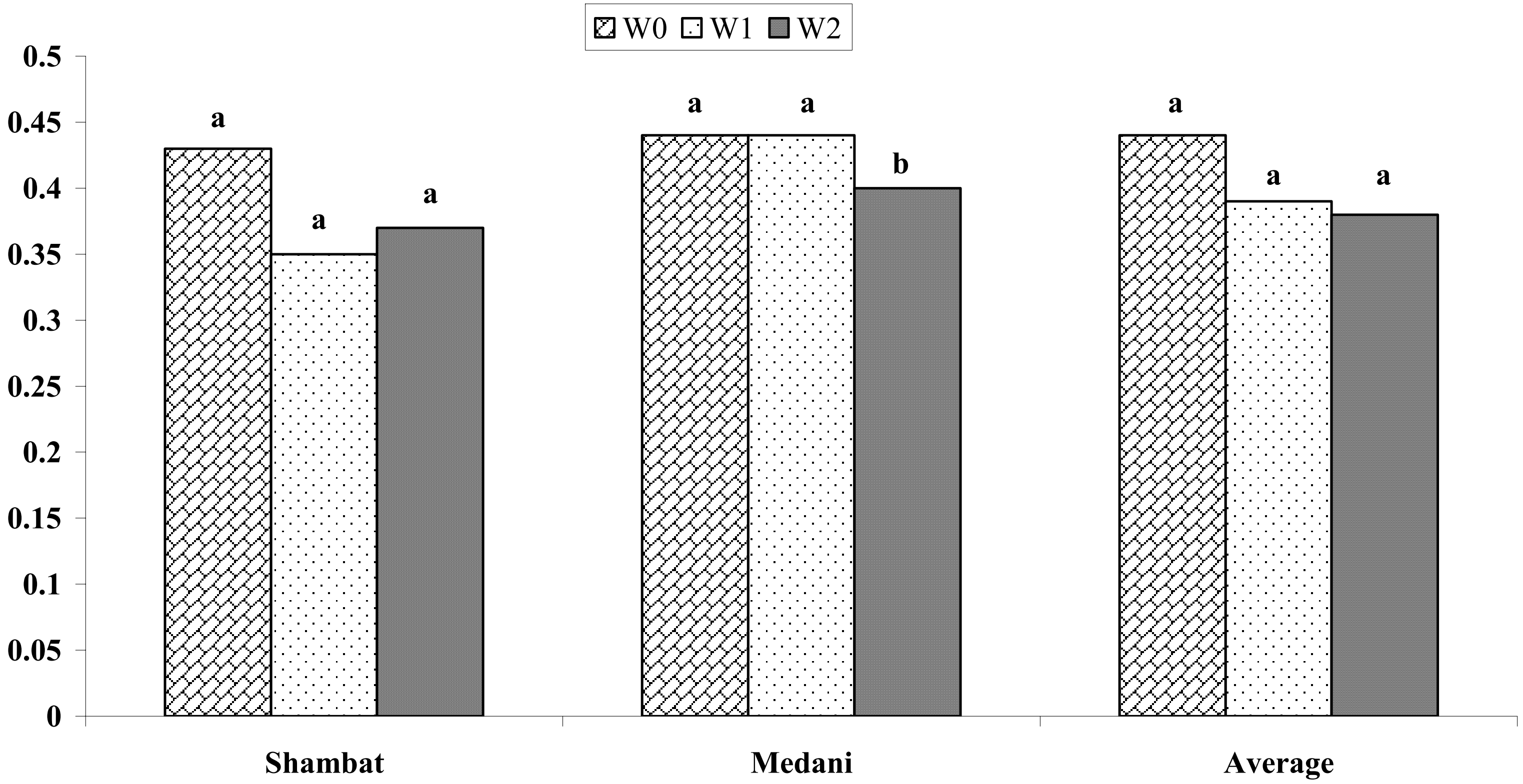

Fig. 4.6. Harvest index for 15 maize genotypes evaluated under three water treatments at two locations (Shambat and Medani) during the 2003/04 season

4.3 Drought Tolerance:

4.3.1 Genetic variability:

The genetic variability for different drought tolerance parameters was shown in Table 4.7. Non-significant differences among genotypes ($p \leq 0.05$) were recorded for all drought tolerance parameters, except GMP2 which exhibited highly significant difference (Table 4.7). The effect due to genotypes x locations interaction was highly significant for all drought tolerance parameters, except Yd1, Yd2 and GMP1 which were non-significant.

4.3.1.1 Means:

Table 4.8 illustrates the means of drought tolerance parameters of 15 maize genotypes. Most of the genotypes were more affected under W_2 drought than under W_1drought (Table 4.8). Each genotype achieved its maximum yield when grown under well-watered condition (W_0). The highest grain yield potential/plant (89.2 g) was produced by PR-1 whereas the lowest grain yield potential/plant (73.0 g) was given by D-3 (Table 4.8).

Under W_1 drought, the highest value (77.3 g/p) was produced by M-45, whereas the lowest value (50.0 g/p) was obtained by PR-1. Under W_2 the highest value (64.4 g/p) of yield/plant was produced by Z-2, while the lowest value (49.7 g/p) was given by D-3 (Table 4.8).

The ratio Y_d/Y_w expresses drought tolerance as shown in Table 4.8. The highest value of Y_d/Y_w (99.6%) under W1 was exhibited by PR-2, whereas the lowest value (56.1%) was exhibited by PR-1. However, under W_2 the highest value of Y_d/Y_w (82.7%) was given by G-2, while the lowest one (56.3%) was obtained by PR-1(Table 4.8).

Under W_1 the highest value of SSI (1.99) was given by PR-1, whereas the lowest value of SSI (0.02) was obtained by PR-2. When drought was induced during (W_2), the highest value of SSI (1.44) was given by PR-1, while the lowest value of SSI (0.68) was exhibited by Z-2.

The highest geometric mean of productivity (GMP) was produced by genotype M-45 under both W_1 and W_2. The values were 81.5 and 74.3, respectively. Whereas, the lowest GMP was obtained by genotype C-12 under both W_1 and W_2 and the values were 64.9 and 60.4 respectively.

Genotype M-45 exhibited the highest values of STI (1.04) and (0.86) under W_1 and W_2, respectively (Table 4.8). While, the lowest value of STI was given by genotype C-12 under both W_1 and W_2. The values were 0.66 and 0.57, respectively.

Table 4.7. Variance components due to genotypes (G) and their interaction with locations (G × L) among 15 maize genotypes for drought tolerance parameters.

Drought tolerance parameters	Water treatments	G	G × L
		DF =14	DF =14
Y_w	W_0	190.926 ns	435.859*
Y_d	W_1	399.546 ns	295.311 ns
	W_2	163.703 ns	192.061 ns
Y_d/Y_w (%)	W_1	0.074 ns	0.196**
	W_2	0.061 ns	0.180**
SSI	W_1	3.342 ns	5.949**
	W_2	0.892 ns	2.225**
GMP	W_1	166.760 ns	1108.840 ns
	W_2	116.796**	41.610**
STI	W_1	0.066 ns	0.228**
	W_2	0.048 ns	0.132**

*, **: Significant at probability of 0.05 and 0.01, respectively

ns: non significant.

Y_w, Y_d, Y_d/Y_w, SSI, GMP and STI: drought tolerance parameters.

W_0, W_1 and W_2: water treatments as in materials and methods.

Table 4.8 Means of drought tolerance parameters of 15 maize genotypes evaluated under 3 water treatments across two locations (Shambat and Medani) in 2003/04 season.

Genotypes	Yw	Yd		Yd/Yw%		SSI		GMP		STI	
	W_0	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2	W_1	W_2
G-1	83.6	65.9	50.7	78.8	60.7	0.96	1.30	74.2	65.1	0.86	0.66
G-2	73.7	60.3	60.9	81.8	82.7	0.83	0.57	66.6	67.0	0.69	0.70
G-3	84.9	54.3	59.0	64.0	69.6	1.63	1.01	67.9	70.8	0.72	0.78
G-4	86.6	53.3	61.2	61.6	70.7	1.74	0.97	68.0	72.8	0.72	0.83
V-113	74.0	69.6	56.7	94.1	76.6	0.27	0.77	71.7	64.7	0.80	0.65
Z-2	81.0	64.5	64.4	79.6	79.5	0.93	0.68	72.3	72.3	0.82	0.81
M-45	86.1	77.2	64.2	89.7	74.5	0.47	0.84	81.5	74.3	1.04	0.86
PR-1	89.2	50.0	50.2	56.1	56.3	1.99	1.44	66.8	66.9	0.7	0.7
PR-2	75.0	74.7	51.3	99.6	68.4	0.02	1.05	74.9	62.0	0.87	0.6
D-2	75.5	56.9	57.5	75.4	76.2	1.12	0.79	65.5	65.9	0.67	0.68
D-3	73.0	58.5	49.7	80.2	68.2	0.90	1.05	65.3	60.2	0.67	0.57
D-6	80.0	66.3	56.1	82.8	70.1	0.78	0.99	72.8	67.0	0.72	0.70
D-7	85.0	56.2	52.0	66.2	61.2	1.53	1.28	69.1	66.5	0.75	0.69
E-7	80.2	70.5	53.9	87.9	67.2	0.55	1.09	75.2	65.5	0.88	0.67
C-12	73.2	57.6	49.8	78.7	68.1	0.97	1.06	64.9	60.4	0.66	0.57
Mean	80.1	62.4	55.9	77.9	69.8	1.00	1.00	70.7	66.9	0.78	0.70
LSD(5%)	26.0	32.9	20.4	34.4	41.2	2.39	1.66	20.0	8.7	0.39	0.29

4.3.1.2 Variability of yield components:

For most of the yield components, highly significant differences ($P \leq 0.01$) under drought due to genotypes were found (Table 4.9) Non-significant differences for genotype × treatment interactions were observed for most of yield components (Table 4.9).

100 seeds weight:

Highly significant differences ($P \leq 0.01$) between genotypes for 100seeds weight were observed when drought was induced during reproductive stage W_2 and when there was no drought through W_0 (Table 4.9). The highest value of 100seeds weight was given by D-6 under W_0, by E-7 under W_1 and by D-2 under W_2 (Appendix 1).

Number of seeds per ear:

Non-significant differences between genotypes were observed for this trait when drought was during vegetative stage (W_1), and when there was no drought (W_0), whereas highly significant differences ($P \leq 0.01$) were observed under W_2 (Table 4.9). The highest number of seeds per ear were recorded by G-3 under both W_0 & W_2 and by M-45 under W_1 (Appendix 2).

Number of ears per plant:

Combined analysis showed non-significant differences among genotypes under W_0 and W_2 for this trait, while significant differences ($P \leq 0.05$) were recorded under W_1 (Table 4.9). Genotype C-12 exhibited the highest values (7.18) & (6.92) under W_1 and W_2, respectively. The highest value (6.77) under W_0 was shown by D-6 (Appendix 3).

Ear length:

Significant differences ($P \leq 0.05$) were recorded under W_1 (Table 4.9). The highest value under W_0 was obtained by G-3. However, the highest ear length under W_1 and W_2 were produced by D-3 and G-2, respectively (Appendix 4).

Ear diameter:

Combined analysis reflected highly significant differences ($P \leq 0.01$) among the genotypes for this character under W_2 treatment. and significant differences ($P \leq 0.05$) under W_0 (Table 4.9). The highest ear diameter under W_0 was obtained by D-7, under W_1 by V-113 and under W_2 by Z-2 (Appendix 5).

Grain yield (kg/ha):

Non-significant differences among the genotypes under all treatments were observed for this trait (Table 4.9). Genotype PR-2 produced the highest value under W_0. Under W_1 the highest value was obtained by M-45, while under W_2 the highest value was given by Z-2 (Appendix 6).

Table 4.9. Mean squares from combined analysis of variance due to genotypes (G) and genotype × location interaction (G×L) for different yield components, under different water treatments (W_0,W_1&W_2).

Traits		d.f	W_0	W_1	W_2
100seeds weight (g)	G	14	12.063**	8.329 ns	11.502**
	G × L	14	6.787 ns	5.749 ns	4.291 ns
No. of seeds/ear	G	14	4331.063 ns	6054.125 ns	6290.257**
	G × L	14	5508.045*	7055.564 ns	2251.010 ns
No. of ears/plant	G	14	0.099 ns	0.414*	0.214 ns
	G × L	14	0.260 ns	0.473*	0.128 ns
Ear length (cm)	G	14	3.248 ns	6.549*	2.912 ns
	G × L	14	1.220 ns	3.493 ns	1.366 ns
Ear diameter (mm)	G	14	10.326*	21.903 ns	21.926**
	G × L	14	5.015 ns	13.317 ns	4.666 ns
Grain yield (kg/ha)	G	14	600124.982 ns	1170231.212 ns	626140.412 ns
	G × L	14	1342551.067 ns	864245.389 ns	531851.514 ns

*, **: significant at probability of 0.05 & 0.01, respectively, ns: non significant.

4.3.2 Correlations between drought tolerance parameters:

Table 4.10 illustrates the coefficients of correlation between different drought tolerance parameters under different water treatments.

Non-significant and positive correlations were recorded between the yield values under different treatments except the correlation between Yw and Yd1 which was significant and positive (Table 4.10).

The correlation for Yw with Yd1/Yw, Yd2/Yw, SSI1, SSI2, GMP1, GMP2, STI1 and STI2 was highly significant. However, the correlation for Yd1 with Yd1/Yw (r = 0.687**) and GMP1 (r = 0.900**) was highly significant and positive, and negatively with SSI1 (r = -0.630**), but it was non-significant and negative with Yd2/Yw and SSI2 (Table 4.10).

The correlation of Yd/Yw under different water stress treatments with Yw was negative and highly significant. Yd1/Yw showed non-significant correlation with Yd2 (r = 0.013), also Yd1/Yw showed highly significant negative correlations with SSI1, SSI2 and STI2. Highly significant positive correlations were recorded for Yd2/Yw with Yd2, Yd1/Yw and STI1 (Table 4.10).

Highly significant positive correlations were recorded for Yd1/Yw with Yd2/Yw, GMP1 and STI1. However, significant positive correlations were obtained for Yd1 with GMP1 and STI1 and for Yd2 with GMP2 and STI2.

GMP1 showed highly significant positive correlation with GMP2 and STI2. Also GMP2 exhibited highly significant positive correlation with STI under different water treatments (Table 4.10).

Table 4.10. Coefficient of correlation between the different drought tolerance parameters for maize genotypes under two locations across three water treatments.

Drought tolerance parameters		Yd		Yd/Yw%		SSI		GMP		STI	
	Yw	1	2	1	2	1	2	1	2	1	2
		0.241*	0.099	-0.397**	-0.606**	0.469**	0.544**	0.622**	0.668**	0.588**	0.486**
Yd	1		0.046	0.687**	-0.054	-0.630**	-0.014	0.900*	0.182	0.846**	-0.085
	2			0.013	0.617**	0.003	-0.640**	0.082	0.794**	0.029	0.793**
Yd/Yw%	1				0.491**	-0.917**	-0.517**	0.340**	-0.248*	0.311**	-0.342**
	2					-0.462**	-0.989**	-0.327**	0.062	-0.336**	0.170
SSI	1						0.453**	-0.270*	0.300**	-0281**	0.302**
	2							0.246*	-0.118	0.288	-0.167
GMP	1								0.437**	0.942**	0.145
	2									0.368**	0.870**
STI	1										0.209*
	2										

*1 and 2 = the water treatments W_1& W_2, respectively.

*, **: significant at probability of 0.05& 0.01, respectively.

4.4 Phenotypic Variability:

The analysis of variance at Shambat (Table 4.2) showed non-significant differences among the 15 maize genotypes for most of the studied characters, except number of ears/m^2, ear diameter, 100 seeds weight and number of husks/ear, which exhibited highly significant differences at $P \leq 0.01$, (Table 4.2). In Medani, significant differences ($P \leq 0.05$) between genotypes for most investigated traits were observed.

In the combined analysis, highly significant differences ($P \leq 0.01$) between genotypes were seen for most of the studied characters (Table 4.3). Furthermore, at the two environments, genotype × treatment interactions were non-significant for most of the characters under study (Table 4.2).

The overall means grain yield (kg/ha) were 3562 kg/ha, 3641 and 3601 kg/ha at Shambat, Medani and for the average of both locations, respectively. At Shambat the highest yield was produced by genotype D-6, whereas the lowest yield was obtained by genotype D-3 (Table 4.11). At Medani the highest yield was given by genotype E-7, while the lowest was obtained by genotype PR-1(Table 4.12). For the average of both locations the highest yield was obtained by genotype M-45 whereas the lowest was produced by genotype C-12 (Table 4.13).

4.4.1 100 seed weight:

The overall means were 17.4 g, 18.4 g and 17.9 g for Shambat, Medani and the average of the two locations, respectively. At Shambat the highest 100 seed weight (19.8g) was obtained by D-6, whereas the lowest 100 seed weight (15.2g) was produced by G-1 (Table 4.11). At Medani the highest 100 seed weight (20.4g) was produced by M-45 and the lowest (16.2g) by C-12 (Table 4.12). For the average of both locations the highest 100 seed weight (19.5g) was obtained by D-6, whereas the lowest weight (16.2g) was given by G-3 (Table 4.13).

4.4.2 Number of seeds per ear:

The overall means were 393.6, 392.9 and 393.2 for Shambat, Medani and the average of the two environments respectively (Table 4.11-4.13). At Shambat the highest number (442.2) was obtained by M-45 while the lowest (333.9) was produced by D-3 (Table 4.11). At Medani the highest number (440.3) was given by Z-2 whereas, the lowest (336.2) was developed by D-2 (Table 4.12). For the average of both locations the highest number (430.0) was obtained by M-45 while the lowest (352.9) was produced by D-2(Table 4.13).

4.4.3 Ear diameter:

The overall means of ear diameter were 37.1, 39.5 and 38.3 mm for Shambat, Medani and for the average of both locations, respectively (Tables 4.11-4.13). At Shambat the highest value (38.9mm) was obtained by M-45 whereas, the lowest value (34.1mm) was given by G-1 (Table 4.11). At Medani the highest diameter (42.3mm) was obtained by Z-2 while the lowest value (37.4mm) was recorded by G-4 (Table 4.12). For the average of both locations the highest ear diameter (40.5mm) was observed by Z-2 and the lowest diameter (36.6mm) was given by C-12 (Table 4.13).

4.4.4 Days to maturity:

The overall means were 73.2, 84.7 and 78.9 days for Shambat, Medani and the average of the two locations, respectively (Tables 4.11, 4.13). PR-2 was the earliest maturing genotype (72.7 days) at each location and the average of the two locations. The lately maturing (73.8 days) genotype at Shambat was D-6 whereas the genotype Z-2 was the late maturing (85.6 and 79.6 days)at Medani and at the average of both locations.

4.4.5 Other traits:

The overall means and coefficient of variation for other different characters at Shambat, Medani and for the average of both locations are presented in appendices (7, 8 and 9), respectively.

Table 4.11 Means of different characters of 15 maize genotypes averaged over the three water treatments at Shambat, during the 2003/04 season.

Serial No.	Genotypes	No. of seeds/ear	Ear diameter (mm)	100seeds weight (g)	Days to 75% mat.	Grain yield (kg/ha)
1	G – 1	393.6	34.1	15.2	73.0	3253
2	G – 2	428.3	36.71	16.6	73.0	3785
3	G – 3	439.4	36.6	15.9	73.6	3774
4	G – 4	427.0	38.6	18.0	73.0	3990
5	V – 113	375.9	38.2	16.5	73.0	3602
6	Z – 2	391.3	38.6	17.9	73.7	3356
7	M – 45	442.2	38.9	17.7	73.2	4014
8	PR – 1	406.5	37.2	17.3	73.0	3687
9	PR – 2	399.1	38.5	18.4	72.7	3674
10	D – 2	369.6	37.2	18.1	73.1	3529
11	D – 3	333.9	35.5	18.3	73.1	3057
12	D – 6	396.6	38.4	19.8	73.8	4029
13	D – 7	384.5	38.5	17.7	73.2	3452
14	E – 7	349.1	34.9	17.6	73.0	3107
15	C – 12	367.5	35.2	16.2	73.6	3118
Mean		393.6	37.1	17.4	73.2	3562
LSD (5%)		75.4	3.0	2.1	0.9	1006
CV%		21.5	8.6	12.9	1.3	30.1

Table 4.12 Means of different characters of 15 maize genotypes averaged over the three water treatments at Medani, among the 2003/04 season.

Serial No.	Genotypes	No. of seeds/ear	Ear diameter (mm)	100seeds weight (g)	Days to 75% mat.	Grain yield (kg/ha)
1	G – 1	423.7	39.2	18.4	84.6	3963
2	G – 2	396.9	38.0	16.9	84.0	3334
3	G – 3	407.2	37.5	16.5	84.0	3462
4	G – 4	367.9	37.4	17.9	84.3	3380
5	V – 113	395.4	40.0	18.6	84.0	3668
6	Z – 2	440.3	42.3	19.0	85.6	4198
7	M – 45	417.8	41.5	20.4	85.0	4230
8	PR – 1	349.7	38.7	18.3	84.8	3237
9	PR – 2	403.2	39.4	17.8	83.7	3534
10	D – 2	336.2	40.1	19.9	84.6	3388
11	D – 3	374.6	39.1	18.7	85.0	3516
12	D – 6	355.7	40.3	19.1	85.3	3387
13	D – 7	384.4	41.2	18.5	85.3	3558
14	E – 7	421.2	39.2	19.7	85.0	4220
15	C – 12	419.5	37.9	16.2	84.9	3439
Mean		392.9	39.5	18.4	84.7	3641
LSD (5%)		58.5	3.1	1.8	1.0	656
CV%		15.9	8.2	10.6	1.3	19.2

Table 4.13 Means of different characters of 15 maize genotypes averaged over the three water treatments and two locations (Shambat and Medani), during the season 2003/04.

Serial No.	Genotypes	No. of seeds/ear	Ear diameter (mm)	100seeds weight (g)	Days to 75% mat.	Grain yield (kg/ha)
1	G – 1	408.2	36.6	16.8	78.8	3608
2	G – 2	412.6	37.4	16.8	78.5	3560
3	G – 3	423.3	37.0	16.2	78.8	3618
4	G – 4	397.4	38.0	17.9	78.7	3685
5	V – 113	385.6	39.1	17.6	78.5	3635
6	Z – 2	415.8	40.5	18.4	79.6	3777
7	M – 45	430.0	40.2	19.0	79.1	4122
8	PR – 1	378.1	38.0	17.8	78.9	3462
9	PR – 2	401.1	38.9	18.1	78.2	3654
10	D – 2	352.9	38.6	19.0	78.8	3459
11	D – 3	354.2	37.3	18.5	79.1	3286
12	D – 6	376.1	39.4	19.5	79.6	3708
13	D – 7	384.46	39.9	18.1	79.3	3505
14	E – 7	385.2	37.0	18.6	79.0	3664
15	C – 12	393.5	36.6	16.2	79.2	3279
Mean		393.2	38.3	17.9	78.9	3601
LSD (5%)		64.7	2.4	1.8	0.7	815
CV%		18.9	8.4	11.8	1.3	25.2

4.5 Phenotypic (δ^2 ph), Genotypic (δ^2 g), Experimental (δ^2 e) and Genotypic × Treatment Interaction (δ^2 gt) Variances:

The phenotypic, genotypic, environmental and genotype × environment interaction variances for the investigated traits were presented in Table 4.14. Generally, it was found that higher phenotypic variances were exhibited at Shambat than at Medani for most of the studied traits. While lower estimation of genotypic and genotype × treatment interaction variances were exhibited at Shambat than at Medani (Table 4.14).

At both locations, the highest genotypic variance relatively to phenotypic variance was observed for number of husks/ear by 20% at Shambat and 5% at Medani, 100 seed weight by 19% at Medani and 9% at Shambat (Table 4.14). Most of the other traits reflected low genetic variance and this could be attributed to the fact that most of the variation is due to environment.

High genotype × treatment interaction variance relative to phenotypic one was recorded for lodging percentage by 18% and 100 seeds weight by 6% at Medani. While at Shambat it was observed for number of husks/ear by 16% and 100 seeds weight by 12%.

Table 4.14. Phenotypic (σ^2ph), genotypic (σ^2g), experimental (σ^2e), and genotypes × treatments interactions (σ^2gt) variances for different characters in 15 maize genotypes averaged over three water treatments, at two locations (Shambat and Medani) in 2003/04 season.

Traits	σ^2ph		σ^2g		σ^2e		σ^2gt	
	Shambat	Medani	Shambat	Medani	Shambat	Medani	Shambat	Medani
Grain yield (kg/ha)	1145018.540	601209.860	-6994.830	112304.790	1152013.366	488905.070	-328996.300	-2223.080
Grain yield (g/plant)	317.521	247.270	-2.114	25.975	319.635	221.296	-9.068	-8.724
No of ears/m2	0.252	0.234	0.023	-0.006	0.229	0.240	0.030	-0.027
No of seeds/ear	7752.424	4489.230	584.001	596.897	7168.423	3892.330	-1100.780	-268.150
100-seeds weight (g)	5.575	4.739	0.540	0.922	5.035	3.817	0.702	0.299
Ear length (cm)	0.525	2.456	0.011	0.054	2.514	2.402	-0.156	0.510
Ear diameter (mm)	11.824	11.568	1.735	1.012	10.089	10.556	-0.986	-0.070
Dry forage weight (kg/ha)	2772790.250	1871405.650	-27058.990	60227.660	2799849.243	1811177.988	163978.250	78311.530
Days to 75% maturity	0.871	1.162	-0.004	-0.026	0.875	1.188	0.001	0.656
No of husks/ear	1.411	1.460	0.285	0.079	1.126	1.381	0.232	-0.108
Harvest index (%)	0.013	0.003	0.001	0.0002	0.012	0.003	-0.001	-0.0003
Lodging (%)	3.578	9.333	0.170	1.461	3.408	7.872	-0.298	1.708
Husk cover (1-5)	0.280	0.240	0.016	0.026	0.264	0.214	-0.001	0.008

4.6 Phenotypic (PCV) and Genotypic (GCV) Coefficients of Variation, Heritability (h^2) and Genetic Advance (GA).

Table 4.15 illustrates the estimates of phenotypic and genotypic coefficient of variation, heritability and genetic advance for the characters under study. For all characters, phenotypic coefficient of variation was greater than genotypic coefficient of variation at both locations (Table 4.15).

Most of the traits showed high phenotypic coefficient of variation at Shambat than at Medani.

At both locations the highest value of phenotypic coefficient of variation (37.98%) was observed for lodging percent at Shambat, whereas the lowest value (1.27%) was recorded for days to 75% maturity at Medani (Table 4.15).

The highest value of genotypic coefficient of variation (13.6%) was observed for lodging percentage at Medani. However, the lowest one (0.77%) was observed for ear length at Shambat (Table 4.15).

A wide range of variation among the different characters was found for heritability estimates (Table 4.15). Most of the investigated traits showed greater values of heritability estimates at Medani than at Shambat, except for number of ears/m^2, ear diameter and number of husks per ear.

At both locations the greatest value (68.0%) was observed for ear diameter at Shambat, whereas the lowest value (4.7%) was observed for ear length at Shambat too.

Table (4.15) showed estimates of expected genetic advance. A greatest value of GA (177.5%) was recorded for grain yield (kg/ha) at Medani whereas, the lowest value (0.01) was observed for harvest index at Shambat.

Table 4.15. Estimates of phenotypic (PCV), and genotypic coefficient of variation (GCV), heritability (h^2) and expected genetic advance (GA) for different characters in 15 maize genotypes evaluated under three water treatments at two locations (Shambat and Medani) in 2003/04 season.

Traits	PCV%		GCV%		h^2		GA%	
	Shambat	Medani	Shambat	Medani	Shambat	Medani	Shambat	Medani
Grain yield (kg/ha)	30.04	21.29	#	9.20	#	67.70	#	177.5
Grain yield (g/plant)	30.01	21.59	#	7.00	#	54.51	#	3.4
No of ears/m2	7.91	7.21	2.37	#	39.04	#	0.09	#
No of seeds/plant	22.47	17.05	6.14	6.22	57.50	63.50	13.66	18.35
100-seeds weight (g)	13.56	11.86	4.22	5.22	40.50	63.77	0.47	0.87
Ear length (cm)	11.56	10.12	0.77	1.49	4.74	10.91	0.051	0.07
Ear diameter (mm)	9.26	8.62	3.55	2.55	68.65	46.82	1.04	0.61
Dry forage weight (kg/ha)	18.13	16.03	#	2.88	#	20.94	#	90.7
Days to 75% maturity	1.28	1.27	#	#	#	#	#	#
No of husks/ear	12.03	14.70	5.41	3.41	58.47	40.12	0.49	0.13
Harvest index (%)	29.23	13.34	6.16	3.34	33.53	46.15	0.01	7.28
Lodging (%)	37.98	34.48	8.27	13.64	37.83	50.25	0.19	0.99
Husk cover (1-5)	28.74	25.74	6.91	8.47	35.75	49.67	0.06	0.11

The values were not calculated because their variance was negative.

4.7 Interrelationships Between Characters:

The coefficients of correlation between different combinations of traits are presented in Tables (4.16, 4.17 & 4.18) for Shambat, Medani and the combination of the two locations.

4.7.1 Association between yield and yield components:

Strong significant positive correlations at both locations and the average were observed for grain yield/plant, number of seeds/ear, ear diameter and grain yield (kg/ha) (Tables 4.16, 4.17 & 4.18)

At Shambat (Table 4.16) strong significant positive correlations were observed for grain yield/plant with number of seeds/ear (r = 0.818**), ear diameter (r = 0.701**) and grain yield (kg/ha) (r = 0.872**). Non-significant negative correlations were recorded for number of ears/m^2 with most of yield components (Table 4.16).

Strong significant positive correlations for grain yield/plant with number of seeds/ear (r = 0.737**) and grain yield (kg/ha) (r = 1.000**), while non-significant positive correlations were recorded for most of yield components with yield at Medani (Table 4.17).

For the average of both locations, highly significant positive correlations were observed for number of seeds/ear with grain yield (kg/ha) (r = 0.644**) and grain yield/plant (r = 0.643**).

4.7.2 Association of grain yield with vegetative traits:

Non-significant correlations were recorded for grain yield per plant with dry weight, days to 75% maturity, number of husks per ear, lodging percentage and husk cover at each location and their average. (Tables 4.16, 4.17 & 4.18)

At Shambat non-significant negative correlations were observed for grain yield (kg/ha) with dry forage weight (kg/ha) and number of husks per ear. However, strong positive correlation was found for grain yield per plant with harvest index (r =0.871**).

At Medani, non-significant positive correlations were observed for grain yield/plant with dry weight (kg/ha) (r = 0.330) and days to 75% maturity (r = 0.248). A strong positive correlation was found for grain yield/plant with harvest index (r = 0.778**). On the other hand, grain yield/plant showed non-significant negative correlation with lodging percentage (r = -0.248) and husk cover (r = -0.337) Table 4.17.

For the average of the two locations, grain yield (kg/ha) was correlated non-significantly and positively with dry weight (kg/ha), days to 75% maturity, number of husks/ear and lodging percentage (Table 4.18). Positive significant correlations were found for grain yield/plant with harvest index (r = 0.614*). Negative non-significant correlation was recorded for grain yield/plant with husk cover (Table 4.18).

Table 4.16. Coefficients of correlations between characters in 15 maize genotypes at Shambat averaged over three water treatments in the 2003/04 season.

Traits	No. seeds /ear	No. of ears /m^2	Ear length (cm)	Ear diameter (mm)	Grain yield/plant	100-Seed Wieght	Dry forage yield (kg/ha)	Days maturity	No. of husk/ear	Grain yield (kg/ha)	Harvest index %	Lodging (%)
No. of ears /m^2	-o.374											
Ear length (cm)	0.025	-0.314										
Ear diameter (mm)	0.450	-0.418	-0.093									
Grain yield/plant	0.818**	-0.407	0.172	0.701**								
100-Seed Wieght	-0.165	-0.205	0.447	0.557*	0.299							
Dry forage yield (kg/ha)	-0.268	-0.473	0.590*	-0.046	-0.070	0.418						
Days maturity	0.069	0.191	0.184	0.092	0.053	0.141	-0.291					
No. of husk/ear	0.110	0.201	-0.413	0.034	-0.057	-0.077	-0.436	0.098				
Grain yield (kg/ha)	0.820**	-0.404	0.171	0.701**	1.000**	0.297	-0.071	0.053	-0.060			
Harvest index %	0.845**	-0.119	-0.059	0.578*	0.871**	0.051	-0.518*	0.258	0.193	0.872**		
Lodging (%)	-0.194	-0.146	-0.015	0.488	0.100	0.536*	0.330	-0.194	0.147	0.097	-0.078	
Husk cover	0.177	0.245	0.208	-0.224	0.136	-0.068	-0.031	-0.233	0.051	0.136	0.204	0.123

*, **: significant at probability of 0.05 & 0.01, respectively.

Table 4.17. Coefficients of correlations between characters in 15 maize genotypes at Medani averaged over three water treatments in the 2003/04 season.

Traits	No. seeds /ear	No. of ears /m^2	Ear length (cm)	Ear diameter (mm)	Grain yield/plant	100-Seed Wieght	Dry forage yield (kg/ha)	Days maturity	No. of husk/ear	Grain yield (kg/ha)	Harvest index %	Lodging (%)
No. of ears /m^2	0.171											
Ear length (cm)	0.143	0.011										
Ear diameter (mm)	0157	0.013	0.169									
Grain yield/plant	0.737**	0.199	0.372	0.574*								
100-Seed Wieght	-0.162	0.054	0.395	0.712**	0.538*							
Dry forage yield (kg/ha)	0.632*	0.420	0.508	0.531*	0.889**	0.522*						
Days maturity	0.047	0.151	0.429	0.594*	0.330	0.463	0.372					
No. of husk/ear	0.483	0.305	0.050	0.109	0.248	-0.201	0.243	-0.205				
Grain yield (kg/ha)	0.741**	0.210	0.383	0.567*	1.000**	0.534*	0.894**	0.336	0.247			
Harvest index %	0.696**	-0.220	0.094	0.375	0.778**	0.254	0.419	0.120	0.164	0.773**		
Lodging (%)	-0.411	-0.038	-0.301	-0.136	-0.248	0.097	-0.457	0.034	-0.459	-0.253	0.049	
Husk cover	-0.285	-0.297	-0.277	-0.337	-0.341	-0.177	-0.502	-0.417	-0.043	-0.342	-0.013	0.090

*, **: significant at probability of 0.05 & 0.01, respectively.

Table 4.18. Coefficients of correlation between characters in 15 maize genotypes over two locations (Shambat and Medani) over three water treatments in the 2003/04 season.

Traits	No. seeds /ear	No. of ears /m^2	Ear length (cm)	Ear diameter (mm)	Grain yield/plant	100-Seed Wieght	Dry forage yield (kg/ha)	Days maturity	No. of husk/ear	Grain yield (kg/ha)	Harvest index %	Lodging (%)
No. of ears /m^2	-0.261											
Ear length (cm)	-0.288	-0.143										
Ear diameter (mm)	0.098	-0.414	-0.176									
Grain yield/plant	0.643**	-0.608*	0.052	0.562*								
100-Seed Wieght	-0.409	-0.353	0.439	0.638*	0.378							
Dry forage yield (kg/ha)	-0.038	-0.320	0.660**	0.179	0.422	0.530*						
Days maturity	-0.092	0.046	0.331	0.328	0.093	0.362	0.175					
No. of husk/ear	0.415	0.466	-0.485	0.082	0.210	-0.178	-0.065	-0.068				
Grain yield (kg/ha)	0.644**	-0.630*	0.023	0.5758	0.993**	0.376	0.351	0.066	0.178			
Harvest index %	0.694**	-0.307	-0.397	0.326	0.614*	-0.109	-0.433	-0.058	0.202	0.673**		
Lodging (%)	-0.051	-0.077	-0.073	0.319	0.333	0.437	-0.163	0.104	-0.004	0.394	0.467	
Husk cover	0.092	0.134	-0.041	-0.368	-0.056	-0.230	-0.358	-0.423	0.069	-0.020	0.313	0.072

*, **: significant at probability of 0.05 & 0.01, respectively,.

CHAPTER FIVE

DISCUSSION

5.1 Effect of Drought on Maize:

The artificial duration and intensity of drought induced in this study were simulated to those commonly encountered by rainfed in many semi-arid regions due to seasonal fluctuation in rainfall. Jurgens *et al.,* (1978) showed that the magnitude of yield reduction due to stress depends upon the growth stage at which the water deficiency occurs and the severity and duration of the deficiency.

In the present study the result revealed that reduction in yield reached 23% for the drought at vegetative stage and 30% for the drought at reproductive stage. This was in agreement with Edmeades *et al.,* (1992) and Ribaut *et al.,* (1997).

The yield reduction due to stress was greatest at Shambat than at Medani. This may be attributed to plentiful rainfall, high relative humidity as well as low temperature at Medani.

The critical stages of growth which particularly affects the ability of maize to produce grain are determined at the early growing season, at flowering and during mid-to-late grain filling (Johnson & Herrero, 1981; Westigate & Bassetti, 1990; Dowswell *et al.,* 1996 and Heisey & Edmeades, 1999). The results of this study revealed no significant differences for response of maize to drought at both vegetative and reproductive stages for most of the traits, but the degree of response is slightly high when drought occurred during vegetative stage than when it occurred during the reproductive one.

5.1.1 Yield:

At Shambat, Medani and the average of both locations, stress during vegetative stage and during reproductive stage, both reduced grain yield per plant and grain yield (kg/ha) compared with well watered. This may be due to the fact that each genotype achieved its maximum yield when grown under control treatment; this was in agreement with Bari *et al.*, (1980), Mohamed (1984) and Nadal & Agarwal, (1989).

Great reduction in yield was recorded when the drought treatments were applied at the reproductive stage for Medani and the average of both environments. This reduction in yield was consequently due to the decrease in number of seeds/ear and 100-seeds weight. This high reduction at reproductive stage due to drought was in accordance with that of Grand *et al.,* (1989).

At Shambat high reduction of yield was observed when the drought induced at vegetative stage than at reproductive stage, this can be attributed to low leaf area, which may lead to low leaf photosynthetic ability (El Tony, 1998) and/or to low biomass accumulation during the vegetative stages, also may be due to the small translocation rate as the plants were stressed at seed filling. This was in agreement with the finding of Claassen & Show (1970), El Tony, (1998) and Tulu *et al.,* (1998). Moreover, stress at vegetative stage, particularly at flowering stage, reduced maize grain yield and this was due to low number of seeds per ear. This finding was in line with reports of Claassen & Show (1970), Kirda & Kanber (1999) and Song *et al.,* (2000), that water stress at the pre-silking period was found to be important for both development of vegetative and reproductive structure.

5.1.2 Yield Components:

At Shambat the reduction of number of seeds per ear, ear length, ear diameter, grain yield/plant and 100-seeds weight, was during the drought at vegetative stage till to the end of flowering. This may be due to the fact that stress at growth and development of female inflorescence has great yield reduction (Song *et al.,* 2000). This fact indicated that stress at this period at any location tended to produce great effect, because this period is very critical to stress. Water stress also delayed silking, which resulted in an increase in anthesis silking interval (ASI), which is an important cause of yield failure (Bolanos & Edmeades, 1993; Byrne *et al.,* 1995).

The reduction in the same previous traits when drought was during vegetative stage, which observed at Medani and for the average of the two locations, may be due to the scientific fact that at this period flowers formation and development has taken place. These results could be confirmed with the finding of Kirda & Kanber (1999).

At Shambat, when drought was at vegetative stage the greatest reduction was observed for most of the yield components, while at Medani and for the average of both locations, the greatest reduction was observed when drought was imposed at reproductive stage. This was due to high relative humidity at Medani which led to low soil moisture stress.

The non-significant effect of water treatments for both locations and their average for most traits was mainly due to the fact that the severity of drought among these water treatments was not large enough. Also each genotype achieved its maximum yield when grown under control, and treatments in which water was limited were not severe enough to cause high reductions in the grain yield, similar results were also observed by Ahmed and Khalaf (1985).

For both water stress treatments, $W_1$and W_2, the reduction had been found for most of the yield components traits like 100-seeds weight, number of seeds/ear, harvest index, number of ears/plant. This indicated that soil moisture stress at any stage of growth decreased grain yield substantially. These results were in agreement with many workers

(Malhodra & Khehra (1986); Westgate & Boyer (1989); Edmeades *et al.,* (1993) Mohamed *et al.,* (1997); Ahmed & Elhag (1999); Juan *et al.,* (1999) and Ahmed (2000)).

Other traits like ear diameter and harvest index were not affected by water treatments; this was in agreement with Juan *et al.,* (1999). Also number of ears/m^2 was not affected with drought; this is in accordance with Ahmed and Elhag (1999).

Grain filling period was very sensitive to drought; therefore, the yield components are consequently affected according to their correlation together. Strong correlations between grain yield (kg/ha) and number of seeds per plant and 100-seeds weight were recorded by Parh *et al.,* (1986) Ribaut *et al.,* (1997) and Dibelo *et al.,* (2001).

In general, these results are in agreement with the fact that yield of small grain can be visualized as a box with its three dimensions, representing the yield components which are the number of heads per unit area, the number of grains per head and the average weight of grain, reduction of any one reduced the yield.

5.2. Drought Tolerance:

In the present study the drought treatments were capable enough to produce a drastic reduction in yield by 23% and 30%, during vegetative and reproductive stages till to maturity, respectively. However, the stress revealed a significant genotypes × treatments interaction variation for ear length, 100-seeds weight and husk cover, and highly significant for days to 75% maturity. Yang *et al.,* (1994) reported considerable variation among maize genotypes in response to water stress.

The grain yield of all genotypes was reduced under both water stress treatments during vegetative and reproductive stages.

When considering the relative yield reduction for the genotypes under study across water stress treatments, the least reduction was shown by M-45 under water stress during the vegetative stage and Z-2 under water stress during reproductive stage. Jurgens *et al.,* (1978) reported that the magnitude of yield reduction due to stress depends upon the growth stage at which the water deficiency occurs and the severity and duration of the deficiency.

5.3. Correlation Between Drought Tolerance Parameters:

The evaluation of maize genotypes in this study varied depending on the water stress treatments. According to the water stress intensity, the correlation degree between Yd and Yw are varied. Positive and non-significant correlations between yield under stress (Yd1 and Yd2) with that under non-stress (Yw) were recorded, these were in agreement with Sallah *et al.,* (2002) who reported that yield in the stress environment was positively associated with yield in the non-stress environment. However, Abdelmula (1999) recorded close correlation between Yd and Yw and attributed that to the large genetic variability among the genetic material used.

The positive and significant correlations were detected between Yd1 and Yw, this means that the performance of genotypes under both environments had the same ranking, and showed similar pattern.

Ceccarelli *et al.,* (1992) distinguished drought tolerance parameters into two groups, the first group is Yd/Yw and SSI which showed negative and significant association with Yw and Yd. Selection for improving these parameters decreases yield potential and increases yield under dry environments, similar results were obtained by (Fisher & Maurer, 1978; Riemer, 1995; Schneider *et al.,* 1997; Abdelmula & Link, 1998). Also, Abdelmula (1999) attributed the negative non-significant correlation for Yw and Yd/Yw to the close correlation between Yd and Yw. A positive significant correlation for Yd and Yd/Yw was recorded for F1- hybrids (Abdelmula 1999). That means selection for this parameter will increase Yd. The second groups of parameters are GMP and STI which exhibited positive and significant correlations with Yd and Yw. Therefore, selection for high values of these parameters improves yield under stress and non-stress environments. Based on the mathematical relationship between Yw, Yd and Yd/Yw, selection for high Yd/Yw should decrease yield under well-watered (Yw) and increase yield under drought (Yd) conditions (Hühn 1992).

In the present study, highly significant negative association between Yw with Yd/Yw and highly significant positive correlation with SSI, GMP and STI were found. Similar results were found by Jaradat (1992); Abdelmula (1999) and Mohammed (2002) in faba bean. The stress susceptibility index (SSI) has only advantage over the ratio Yd/Yw, when yield was evaluated in different environments with different drought intensities (Link *et al.,* 1999).

A drought-tolerant genotype, as identified by Yd/Yw, may not have a high yield potential. However, it should possess tolerance mechanism, which under severe stress might become more important yield potential (Bidinger *et al.,* 1994; Sadiq *et al.,* 1994).

5.4. Phenotypic Variability in Maize:

The amount of variation present in the material under study is of great importance for a successful application selection procedure for improving genotypes. This is because selection does not create variability but acts only on that already existing. The phenotypic variance is attributed to genotypic as well as environmental factors.

In this study, the 15 maize genotypes revealed significant differences for most of the investigated characters under stress and non-stress environments, at Medani and for few characters at Shambat. Similar observations were detected by many workers (Frey, 1964; Mederski & Jefferes, 1973 and Rumbough *et al.,* 1984).

At Shambat, non-significant variation was recorded for grain yield (kg/ha), this may be due to the great influence on yield by the environment which might mask the effect due to genetic factors. Also non-significant differences were observed in 100-seed weight, number of seeds per ear, ear length, harvest index and lodging percentage at Shambat. This was in agreement with Galeev *et al.,* (1987) who reported that the failure to detect any differences among the genotypes for such traits was due to the fact that the environmental variances were higher than the genotypic ones. So the effect on grain yield (kg/ha) due to the environment was great. This was in accordance with Falconer (1952), Robertson (1959) and Cockerham (1963).

On the other hand, a higher variability was recorded for most of the previously investigated traits. Similar results were obtained by Khalafalla (1993), Fadlalla (1994), Sarawathi *et al.,* (1995), Matsuura (1996), Sagar (1997), Debelo *et al.,* (2001) and Sallah *et al.,* (2002).

5.5 Genotypic Coefficient of Variation, Heritability and Genetic Advance:

Genetic coefficient of variation (GCV) determines the degree of genetic variability expressed by a character in the population, and the amount of genetic variability is a major determinant of the genetic gain from selection.

The studied characters showed a wide range of genetic variability among the evaluated genotypes. The high value of (GCV) was observed for grain yield/plant, a similar result was reported by Castro *et al.,* (1964) in maize, Harer & kard (1999) in pearl millet and Abdelmula (1992) in faba been.

Allard (1960) reported that genetic advance for any character depends mainly upon the genetic variability. The highest genetic advance was reported for grain yield (kg/ha), this was in accordance with Phul *et al.,* (1986).

Heritability estimates the proportion of the total phenotypic variance that occurs due to gene effects. The heritability values at Medani were greater than that at Shambat, this was due to the environmental differences. The result was in agreement with Falconer (1980) who indicated that more variable conditions reduce heritability and more stable conditions increase it.

In the present study the high values of heritability were recorded for number of seeds/ear, ear diameter, 100 seeds weight, grain yield/plant and number of husks/ear. This was in agreement with many workers, Ribuat *et al.,* (1997), Frova *et al.,* (1999) and Meseka *et al.,* (2003).

5.6. Correlation Coefficient Between Different Characters:

Yield is a complex character, which depends on many components and highly influenced by the environment. Correlation mainly indicates the degree of the association between different traits, also is useful to determine the characters which are highly associated with grain yield and consequently helpful in selection for yield.

The correlation coefficient of grain yield with the other related characters exhibited different patterns.

Grain yield/ha exhibited strong significant positive correlation at Shambat, Medani and the average of the two locations with number of seeds/ear, ear diameter and grain yield per plant, these results suggest that selection for these traits would be effective in the improvement of grain yield. Similar results were found by Xu (1986), Undersander (1987), Abdelmula (1992) and Ribuat *et al.,* (1997). These close associations could be refered to the effect of genes rather than the effect of the environmental factors.

The strong significant positive correlation for grain yield with harvest index at Shambat and Medani was also reported by many workers (Whan *et al.,* 1982; Fischer *et al.,* 1996). On the other hand, significant positive correlation was observed for 100seeds weight with days to maturity at Medani and the average of the two locations, which was in agreement with results obtained by Parh *et al.,* (1986). This indicates that drought has a great influence on these traits.

CONCLUSIONS

Based on the results obtained in this study that each genotype achieved its maximum yield potential when it was grown under fully irrigated treatment. Water stress at any stage of growth reduces grain yield and its components and the reduction was more pronounced under the treatment in which water stress was maintained during grain filling period.

A wide genetic variability was detected between the evaluated genotypes under well-watered and water-stress conditions. This variability can be used for improving this crop for drought tolerance.

Yield and yield components were more sensitive to drought stress.

The severe stress during the reproductive stage resulted in high reduction in seed yield per plant than at vegetative stage.

Grain yield per plant has positive correlation with some of its components and some agronomic characters, these were number of seeds/ear, ear diameter, harvest index and 100seeds weight. Thus, these components can be used as criteria in selection for the improvement of grain yield.

There was a highly significant negative correlation for Yd/Yw under the different water stress treatments with Yw. So selection for improving this parameter decreases yield potential and increases yield under dry environments.

There was a highly significant positive correlation for GMP and STI under the different water stress treatments with Yw. That means selection for high values of these parameters improves yield under stress and non-stress environments.

Some genotypes could be selected for drought tolerance at certain growth stages, eig. PR-2, M-45 and Z-2 i.e PR-2 When drought occur early, Z-2 when drought occurs late and M-45 was found to be for period of time.

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APPENDICES

Appendix: 1 Means of genotypes under the different water treatments (w_0, w_1 and w_2) for 100-seed weight averaged over two locations (Shambat and Medani) during the 2003/04 season.

Serial No.	Genotypes	W_0	W_1	W_2
1	G – 1	19.80	17.47	13.17
2	G – 2	17.75	17.38	15.12
3	G – 3	18.70	16.28	13.63
4	G – 4	20.88	17.23	15.72
5	V – 113	18.53	18.82	15.32
6	Z – 2	20.50	18.07	16.77
7	M – 45	20.28	19.60	17.15
8	PR – 1	21.60	17.40	14.48
9	PR – 2	20.10	19.02	15.18
10	D – 2	22.02	16.83	18.12
11	D – 3	21.87	18.45	15.28
12	D – 6	22.72	19.63	16.03
13	D – 7	21.12	17.63	15.45
14	E – 7	19.75	19.70	16.47
15	C – 12	19.02	16.17	13.47
MEAN		20.03	17.98	15.42
LSD (5%)		3.45	3.63	3.24

Appendix: 2 Means of genotypes under the different water treatments (w_0, w_1 and w_2) for No of seeds/ear averaged over two locations (Shambat and Medani) during the 2003/04 season.

Serial No.	Genotypes	W_0	W_1	W_2
1	G – 1	431.7	395.6	397.2
2	G – 2	432.7	377.6	427.5
3	G – 3	457.9	354.8	457.3
4	G – 4	436.5	342.5	413.2
5	V – 113	417.9	342.9	396.0
6	Z – 2	403.0	418.3	426.1
7	M – 45	434.6	419.9	435.4
8	PR – 1	431.9	327.8	374.6
9	PR – 2	391.1	413.2	399.1
10	D – 2	385.4	323.6	349.6
11	D – 3	360.8	342.3	359.6
12	D – 6	374.7	384.2	369.6
13	D – 7	418.5	361.5	373.4
14	E – 7	434.1	370.1	351.3
15	C – 12	417.5	374.3	388.7
MEAN		415.2	369.9	394.6
LSD (5%)		84.5	172.1	84.6

Appendix: 3 Means of genotypes under the different water treatments (w_0, w_1 and w_2) for No of ears/m2 averaged over two locations (Shambat and Medani) during the 2003/04 season.

Serial No.	Genotypes	W_0	W_1	W_2
1	G – 1	6.60	6.40	6.55
2	G – 2	6.40	6.23	6.68
3	G – 3	6.45	6.48	6.45
4	G – 4	6.65	6.13	6.68
5	V – 113	6.52	6.23	6.80
6	Z – 2	6.43	6.30	6.65
7	M – 45	6.43	6.33	6.18
8	PR – 1	6.67	6.30	6.42
9	PR – 2	6.50	6.75	6.72
10	D – 2	6.32	6.55	6.52
11	D – 3	6.50	5.48	6.78
12	D – 6	6.77	6.38	6.50
13	D – 7	6.67	6.18	6.73
14	E – 7	6.43	6.48	6.72
15	C – 12	6.67	7.18	6.92
MEAN		6.53	6.43	6.62
LSD (5%)		0.71	0.78	0.88

Appendix: 4 Means of genotypes under the different water treatments (w_0, w_1 and w_2) for Ear length averaged over two locations (Shambat and Medani) during the 2003/04 season.

Serial No.	Genotypes	W_0	W_1	W_2
1	G – 1	15.03	15.44	14.10
2	G – 2	14.11	14.37	15.61
3	G – 3	16.20	12.42	14.64
4	G – 4	15.02	13.79	14.66
5	V – 113	14.36	13.93	13.91
6	Z – 2	14.32	14.39	14.88
7	M – 45	14.57	14.38	15.36
8	PR – 1	15.23	12.69	13.82
9	PR – 2	13.97	14.64	13.58
10	D – 2	15.86	12.69	15.51
11	D – 3	16.11	15.93	15.25
12	D – 6	15.60	14.85	15.34
13	D – 7	14.23	14.41	14.09
14	E – 7	15.01	15.44	15.52
15	C – 12	14.46	13.48	14.44
MEAN		14.94	14.19	14.71
LSD (5%)		2.35	3.02	2.26

Appendix: 5 Means of genotypes under the different water treatments (w_0, w_1 and w_2) for Ear diameter averaged over two locations (Shambat and Medani) during the 2003/04 season.

Serial No.	Genotypes	W_0	W_1	W_2
1	G – 1	38.33	37.57	33.98
2	G – 2	38.90	36.78	36.45
3	G – 3	39.18	35.37	36.38
4	G – 4	41.33	34.45	38.25
5	V – 113	39.85	40.48	37.27
6	Z – 2	40.28	39.87	41.25
7	M – 45	41.48	39.75	39.32
8	PR – 1	41.00	35.97	36.95
9	PR – 2	40.00	40.23	36.60
10	D – 2	40.68	36.65	38.60
11	D – 3	37.98	37.47	36.43
12	D – 6	41.10	38.63	38.22
13	D – 7	41.73	37.35	40.60
14	E – 7	38.82	36.90	35.42
15	C – 12	37.92	35.02	36.72
MEAN		39.91	37.49	37.49
LSD (5%)		3.69	7.33	3.95

Appendix: 6 Means of genotypes under the different water treatments (w_0, w_1 and w_2) for Grain yield kg/ha averaged over two locations (Shambat and Medani) during the 2003/04 season.

Serial No.	Genotypes	W_0	W_1	W_2
1	G – 1	4524.8	3542.7	2757.4
2	G – 2	4010.7	3285.4	3383.2
3	G – 3	4601.6	2977.8	3275.5
4	G – 4	4762.6	2938.7	3354.2
5	V – 113	4058.0	3754.5	3091.5
6	Z – 2	4323.9	3451.5	3555.5
7	M – 45	4681.6	4165.8	3518.3
8	PR – 1	4916.3	2705.9	2762.7
9	PR – 2	4077.1	4096.5	2788.5
10	D – 2	4146.6	3089.7	3139.3
11	D – 3	3972.7	3148.9	2736.7
12	D – 6	4424.8	3603.9	3095.0
13	D – 7	4679.7	2981.8	2853.2
14	E – 7	4310.7	3786.7	2893.1
15	C – 12	3984.3.	3068.9	2782.7
MEAN		4365.0	3373.2	3065.8
LSD (5%)		1454.7	1743.9	1193.3

Appendix: 7 Means of different traits of 15 maize genotypes evaluated under three water treatments at Shambat in 2003/04 season.

Serial No.	Genotypes	No. of ears/m^2	Ear length	Grain weight/pl	Dry weight kg/ha	No. of husks/ear	Husk cover (1-5)	Lod. %	Harvest index
1	G – 1	6.4	13.4	54.2	9267	9.6	2.14	3.98	0.351
2	G – 2	6.3	13.9	63.0	9491	9.1	1.67	3.97	0.395
3	G – 3	6.3	14.1	26.9	8180	9.8	2.02	3.93	0.452
4	G – 4	6.2	13.8	66.5	9404	9.4	2.08	6.08	0.420
5	V – 113	6.3	12.9	60.0	9053	9.4	1.63	5.56	0.384
6	Z – 2	6.1	13.5	55.9	9225	10.3	1.52	5.27	0.370
7	M – 45	6.0	14.2	66.9	9748	10.4	1.88	5.62	0.416
8	PR – 1	6.1	13.4	61.5	8762	10.6	1.58	4.37	0.398
9	PR – 2	6.5	13.4	61.2	8970	10.8	2.22	5.72	0.406
10	D – 2	6.3	14.0	58.8	9119	9.4	1.86	5.09	0.379
11	D – 3	6.4	14.7	50.9	10225	8.7	1.89	5.25	0.256
12	D – 6	6.5	14.4	67.2	9387	9.6	1.88	4.88	0.431
13	D – 7	6.5	13.2	57.5	8797	9.4	1.62	4.76	0.374
14	E – 7	6.3	14.1	51.9	9981	10.4	1.74	5.22	0.318
15	C – 12	7.0	13.1	52.0	8131	11.2	1.89	5.01	0.374
Mean		6.3	13.7	59.4	9183	9.9	1.84	4.98	0.384
LSD (5%)		0.5	1.5	16.8	1569	1.0	0.48	1.73	0.103
CV%		7.5	11.5	30.1	18.2	10.8	27.9	37.1	28.0

Appendix: 8 Means of different traits of 15 maize genotypes evaluated under three water treatments at Medani in 2003/04 season.

Serial No.	Genotypes	No. of ears/m^2	Ear length	Grain weight/pl	Dry weight kg/ha	No. of husks/ear	Husk cover (1-5)	Lod. %	Harvest index
1	G – 1	6.6	16.3	79.3	8847	8.8	2.33	6.22	0.447
2	G – 2	6.5	15.5	66.9	8168	8.5	1.78	7.00	0.409
3	G – 3	6.6	14.7	69.2	8025	7.5	2.11	10.11	0.438
4	G – 4	6.8	15.1	67.6	8044	8.3	1.99	11.44	0.411
5	V – 113	6.7	15.2	73.4	8693	8.4	1.74	8.94	0.421
6	Z – 2	6.9	15.4	84.0	9660	8.6	1.60	7.06	0.431
7	M – 45	6.6	15.3	84.8	8964	8.0	1.89	10.38	0.47
8	PR – 1	6.8	14.4	64.8	8103	7.8	1.96	9.94	0.391
9	PR – 2	6.8	14.7	72.8	8454	9.1	2.04	8.28	0.427
10	D – 2	6.7	15.3	67.8	8259	7.6	2.26	8.61	0.404
11	D – 3	6.8	16.8	69.8	8893	8.1	1.73	6.94	0.392
12	D – 6	6.6	16.2	67.8	7978	8.0	1.93	12.10	0.422
13	D – 7	6.6	15.3	71.3	8222	8.2	1.70	8.11	0.431
14	E – 7	6.8	16.6	84.4	9480	8.0	1.52	9.00	0.443
15	C – 12	6.8	15.2	68.4	8188	8.4	1.97	8.72	0.419
Mean		6.7	15.5	72.8	8532	8.2	1.90	8.86	0.424
LSD (5%)		0.6	1.5	14.0	1.3	1.1	0.43	2.63	0.051
CV%		7.3	10.0	20.4	15.8	14.3	24.3	31.7	11.8

Appendix: 9 Means of different traits of 15 maize genotypes evaluated under three water treatments over two locations (Shambat and Medani) in 2003/04 season.

Serial No.	Genotypes	No. of ears/m^2	Ear length	Grain weight/pl	Dry weight kg/ha	No. of husks/ear	Husk cover (1-5)	Lod. %	Harvest index
1	G – 1	6.5	14.9	66.8	9057	9.2	2.24	5.10	0.399
2	G – 2	6.4	14.7	65.0	8830	8.8	1.72	5.48	0.402
3	G – 3	6.5	14.4	66.1	8102	8.6	2.07	7.02	0.445
4	G – 4	6.5	14.5	67.0	8724	8.8	2.03	8.76	0.416
5	V – 113	6.5	14.1	66.7	8873	8.9	1.69	7.25	0.402
6	Z – 2	6.5	14.5	70.0	9442	9.4	1.56	6.16	0.401
7	M – 45	6.3	14.8	75.8	9356	9.2	1.88	8.01	0.443
8	PR – 1	6.5	13.9	63.1	8433	9.2	1.77	7.16	0.395
9	PR – 2	6.7	14.1	67.0	8712	10.0	2.13	7.00	0.416
10	D – 2	6.5	14.7	63.3	8689	8.5	2.06	6.85	0.391
11	D – 3	6.6	15.8	60.4	9559	8.4	1.81	6.10	0.344
12	D – 6	6.6	15.3	67.5	8683	8.8	1.91	8.49	0.426
13	D – 7	6.5	14.2	64.4	8509	8.8	1.66	6.43	0.403
14	E – 7	6.5	15.3	68.2	9730	9.2	1.63	7.11	0.380
15	C – 12	6.9	14.1	60.2	8160	9.8	1.92	6.87	0.397
Mean		6.5	14.61	66.1	8857	9.1	1.87	6.92	0.404
LSD (5%)		0.39	0.97	14.9	827.0	1.12	0.27	2.48	0.06
CV%		7.4	10.7	24.9	17.1	12.4	26.1	34.3	20.8