Genetic Studies of Pearl Millet (*Pennisteum Glaucum L.*) Under Water Stress at Different Growth Stages

By

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DEDICATION

To My family who have always been hoping to see this work in light

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ABBREVIATIONS

ANOVA	Analysis of variance
bi	Coefficient of regression
Biomass	Biomass/plant
CV	Coefficient of variation
Dpleng	Dead part length / head (cm)
E	Environment
FTL	Number of fertile tillers / plant
G	Genotypes
GMP	Geometric mean of productivity (Fernandez, 1993).
GA	Genetic advance
GCV	Genotypic coefficient of variation
G × E	Genotypes × environments
G × T	Genotypes × Treatment
HI	Harvest index (%)
h^2	Heritability
LSD	Least significant difference
LAI	Leaf area index
Matur	Days to maturity
ME	Macro - environments
Pnlng	Panicle length / main head (cm)
PH	Plant height (cm)
r	Correlation coefficient
RW	Elrawakeeb location

SH	Shambat location
Sd/pn	Number of seeds / main head
SSI	Stress susceptibility index
S^2d	Deviation mean square from regression
T	Treatment
TL	Number of tillers / plant
Yd	Grain yield / plant (g) under dry conditions
Yd/Yw	Ratio of grain yield / plant (dry) to grain yield / plant (well watered)
Yw	Grain yield / plant (g) under well – watered conditions.
Yg/p	Grain yield / plant (g)
Yd t/h	Grain yield ton/ha
50%Flr	Days to 50 % flowering
1000-sd	1000- seeds weight (g)
σ^2g	Genotypic variance
σ^2ph	Phenotypic variance
σ^2e	Environmental variance

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Abstract

Fifteen pearl millet genotypes were tested under four levels of water treatments at two locations (ELRawakeeb 2003/04 and Shambat 2004/05), to estimate the genetic variability and heritability for drought tolerance in pearl millet and to determine the correlation between yield, its components and other traits as well as to identify the most yield stable genotype under drought stress condition. Split – plot design with three replications was used. Four levels of water stress were used in the main – plot, namely; normal irrigation every 7 days (W_0), irrigation every 14 days during vegetative stage (W_1), irrigation every 14 days during filling stage (W_2) and irrigation every 14 days throughout the vegetative and grain filling stage (W_3).The genotypes were used in sub plots.

At all locations, significant differences among the evaluated genotypes were detected for all studied characters. The combined analysis revealed highly significant variation due to genotypes and genotypes x location interaction for most of the studied characters. A wide range of genetic variability was detected among genotypes for drought tolerance. Yield and yield components were significantly reduced by water stress. Whereas, the water stress during grain filling stage had small effect on yield and its components.

Estimates of genotypic coefficient of variation exhibited narrow range while the estimates of heritability exhibited wide range of variation. Grain yield/ plant exhibited strong positive phenotypic and genotypic correlation with some yield components and it has negative correlation with days to 50 % flowering, date to maturity and dead part length.

There was positive and significant correlation between grain yield under drought condition (Yd) and grain yield under normal condition (Yw). Whereas, the association between drought tolerance (Yd/Yw) with Yw was negative. The path analysis reflected that the fertile tillers per plant had highest positive direct effect on grain yield per plant, followed by number of seeds per head and 1000–seed weight. The genotypes exhibited significant variation for stability as measured by (regression coefficient (bi), deviation from regression line ($S^2đ$). The genotypes Madelkawiyia, JM36, and JM38 showed high yield and high stability therefore, these genotypes could be recommended for improvement of pearl millet under drought conditions.

بسم الله الرحمن الرحيم

ملخص الأطروحة

تم اختبار 15 طرازاً وراثياً من محصول الدخن تحت 4 معاملات مائية مختلفة وفى موقعين مختلفين (الرواكيب 2004/03 وشمبات 2005/04). وذلك بغرض دراسة مدى التباينات الوراثية، درجة التوريث والارتباطات المختلفة لمقاييس الإجهاد المائي. وكذلك تحديد درجة الارتباط بين الإنتاجية ومكوناتها والصفات الأخرى وتحديد مدى ثبات الإنتاجية لطرز الوراثية فى البيئات المختلفة. صممت التجربة باستخدام النظام ذو القطاعات المنشطرة بثلاثة مكررات حيث استخدمت فى القطع الرئيسية 4 معاملات مائية هى: الرى كل 7يوم (W_0)، التعطيش على فترات 14 يوم أثناء فترة النمو الخضرى فقط (W_1) وأثناء فترة امتلاء الحبوب فقط (W_2) والتعطيش كل 14 يوم أثناء فترة النمو الخضرى وامتلاء الحبوب (W_3). بينما استخدمت الطرز الوراثية فى القطع الفرعية.

فى كل البئيات اظهرت نتائج التحليل الفردى فروقات معنوية بين الطرز الوراثية موضع الدراسة. التحليل التجميعى اظهر وجود فروقات معنوية بين الطرز الوراثية والتداخل بين الطرز الوراثية × المواقع لمعظم الصفات. كذلك وجد ان هنالك مدى واسع للتباين بين الطرز الوراثية فى درجة تحملها للاجهاد المائى.وجد أن الانتاجية ومكوناتها قد تاثرت معنويا بمعاملات الإجهاد المائى الا ان الاجهاد المائى خلال فترة امتلاء الحبوب (W_2) كان اثرة قليلاً على الانتاجية ومكوناتها.

النتائج أوضحت ان هنالك مدى ضيق للمعامل التباين الوراثى (GCV) ومدى واسع لدرجة التوريث. كذلك وجد ان هنالك ارتباطا مظهرياً ووراثياً موجباً بين الإنتاجية وبعض مكوناتها.وارتباطا سالباً مع فترتى الأزهار وفترة نضج المحصول والجزء الميت من القندول.

أظهرت النتائج وجود ارتباط معنويا موجبا بين انتاجية الحبوب/ النبات تحت ظروف الرى العادى (Yw) و انتاجية الحبوب تحت ظروف الإجهاد المائى (Yd) وأرتباطاً سالباً بين أنتاجية النبات تحت ظروف الرى العادى (Yw) وصفة مقاومة الجفاف (Yd/Yw). مسار الارتباط (Path Analysis) اظهر أرتباطاً موجباً ومباشراً بين وزن البذور / النبات وكل من عدد الخلف المثمرة للنبات، عدد البذور / القندول الرئيسى ووزن الألف حبة . الطرز الوراثية اظهرت اختلافات معنوية لكل مقاييس ثبات الانتاجية (معامل الانحدار) (bi) والانحراف عن خط الانحدار($S^2đ$).أظهرت الطرز الوراثية (Madelkawiyia, JM36 JM38) انتاجية مرتفعة وثباتا في البيئات المختلفة.وهذه الطرز الوراثية يوصى باستخدامها لتطوير محصول الدخن في البيئات الجافة.

Taxonomically Pearl millet {*Pennisetum glaucum (L) R.Br*} belongs to family Poaceace sub family panicoideae section penicillarium and possesses 2 n = 2 x =14 chromosomes. It is across - pollinated annual C_4 crop species that originated in western Africa and was introduced to eastern Africa and Indian sub continent some years ago (Gill, 1991).

In terms of annual production, pearl millet is the sixth most important cereal crop in the world following wheat, rice, maize, barely and sorghum (Stoskopf, 1985). The world production is around 33.4 million metric. ton with an average grain yield of 699.0 Kg ha^{-1} (FAO, 2002). Generally, the crop is grown under the most difficult farming conditions, including those in drought – stricken areas where soil fertility is low and food supplies are dependent on rainfall (Gill, 1991 and Algan, 1994).

Pearl millet is adual-purpose crop, it's grain is used for human consumption, and its fodder serves as feed for cattle. In Asia and Africa, where more than 95% of the crop is produced, it is grown primarily as a grain crop .The grain of pearl millet is comparatively nutritive than grain of other cereals .

CHAPTER ONE

INTRODUCTION

The genus Pennisetum is distributed through out the tropics and sub tropics of the world. It includes about 140 species .One African species, *P. glaucum* (L.) was domesticated as the cereal pearl millet. The common names of pearl millet include pearl, bulrush, cattail or spiked millet and duckn (Gill, 1991).

In Sudan, pearl millet (*Pennisetum glaucum L.*) is the preferred staple food for the majority of the inhabitants in Western Sudan (Kordofan and Darfur regions). Among the cereals, it comes second to sorghum in area and total production (AOAD, 1992). The crop is mainly raised under traditional farming systems, where the rainfall ranging (200 – 800) mm / annum (Abu Elgasim, 1999). Yields are generally low, the average fluctuates between 185 to 618 kg ha^{-1} (FAO, 2002). The short rainy season

and the fluctuation in rainfall expose the crop to drought stress; there is a need to breed for drought tolerance and early maturity.

Although it is an important food crop in the Sudan, pearl millet did not receive much attention to improve it prior to 1974 when a proper millet-breeding program was started. This program was strengthened in 1977 through cooperation with ICRISAT. The program objectives were centered around developing high yielding, drought tolerant, early - maturity verities with acceptable grain quality and resistance to prevailing pests and disease (Abu Elgasim, 1989).

Pearl millet is sensitive to water stress, particularly during flowering and grain filling (Garrity *et al*., 1983; Hattendorf *et al*., 1988). There fore, genetic improvement of stress tolerance in pearl millet has concentrated on the flowering and grain filling stages (Mahalakshmi *et al*., 1987)

Usually, development of drought – tolerant cultivars is hindered by poor understanding of the mechanisms of drought tolerance and by inadequate selection techniques (Bruckner and Frohberg, 1987; Richards, 1996). Strategies for improving drought tolerance include selection in low – stress environments, high stress environments and a combination of stress and no stress environments (Byrne *et al*., 1995). Selection for high yield in an optimum environment is effective because genetic variation is usually maximized and genotype – by - environment interactions is low (Richards, 1996). On the other hand, selections is often complicated by low heritability of traits, non – uniform testing conditions and large genotype – by – environment interactions (Hamblin *et al*., 1980; Smith *et al*., 1990).

The main objectives of this study were:

1. To study the performance of some local pearl millet genotypes under different water treatments.

2. To estimate the amount of genetic variability and heritability for drought tolerance in pearl millet under different water stresses.

3. To determine the correlation of yield with its components and other traits.

4. To identify the most stable genotypes under different levels of drought.

CHAPTER TWO

LITERATURE REVIEW

2.1 Drought as a production limiting factor:

Drought is actually meteorological event which implies the absence of rainfall for a period of time, long enough to cause moisture – depletion in soil and water deficit with a decrease of water potential in plant tissues (Kramer, 1980). It acts as serious limiting factor in agricultural production by preventing a crop from reaching the genetically determined theoretical maximum yield (Begy, 1980). The effect of drought on crop production is well known (Singh, 1990). Most of the crops are sensitive to water deficits particularly during flowering to seed development stage (Salter, 1967). Even the crops grown in arid and semi arid regions such as pearl millet, sorghum and pigeon pea are affected by drought at the reproductive stage.

Plant adaptation to drought stress (as measured by grain yield) depends on different traits, response, the time and intensity of its occurrence. An attempt to breed for improved adaptation to stress makes sense only if the stress is reasonably well defined.

2.2 Mechanisms of drought resistance:

The crop grown under unfavorable environments withstands the stress through different modifications. These include developmental, morphological and biological

mechanisms (Turner and Begy, 1981). Plant adaptations mechanisms are classified into three major categories:

2.2.1 Drought escape:

Which is particularly an important strategy for phenological development with in the period of soil moisture availability to minimize the impact of drought stress on crop production in environments where the growing season is short and terminal drought stress predominates (Turner, 1986). Also later flowering can be beneficial in escaping early season drought when it is followed by rains (Ludlow and Muchow, 1990).

2.2.2 Drought avoidance:

Defined as the ability of plants to attain a relatively high level of hydration under conditions of soil and atmospheric water stress (Blum, 1988). Plant can exhibit dehydration avoidance through increasing water uptake and reducing water loss by means of morphological or physiological modifications.

2.2.3 Drought tolerance:

Plants tolerate drought by ability of their tissues to withstand water stress. The mechanism of drought tolerance is maintenance of turgor through osmotic adjustment, increase in elasticity in cell and decrease in cell size and desiccation tolerance by protoplasmic resistance (Ugherughe et al, 1986).

Unfortunately, most of these adaptations to drought have disadvantages. A genotype of short duration usually yields less compared to that of normal duration. The mechanisms that confer drought resistance by reducing water loss (such as stomata closure and reduced leaf area) usually result in reduced assimilation of carbon dioxide. Osmotic adjustment increases drought resistance by maintaining plant turgor,

but the increased solute concentration responsible for osmotic energy requirement may have detrimental effect in addition to energy requirement for osmotic adjustment (Turner, 1979). Consequently, crop adaptation must reflect a balance among escape, avoidance and tolerance while maintaining adequate productivity.

2.3 Effect of drought on growth and development of pearl millet:

Drought is one of the most common environmental stresses that affect growth and development of plants through alterations in metabolism and gene expression (Leopold et al., 1990) .The effect of water stress on crop growth and yield depends upon the degree, duration of the stress and the developmental stage at which the stress occurs (Hasio, et al. 1976; Sullivan and Eastin, 1974).

Most of the plant growth and development are sensitive to water stress (Turner and Kramer, 1980), and response of crop plants to drought periods is major factor influencing their adaptation to environments. Bunting and kassam (1988) reported that during the growth of many plants, there are periods during which plants are susceptible to drought stress. Moreover, Bunting and kassam (1988) indicated that the time of transition from the vegetative to reproductive phase in cereals is the most sensitive to water deficit.

Responses of pearl millet genotypes to drought during the period of seedling establishment to a point just prior to panicle initiation showed that drought has little effect on grain yield (Anon, 1984). However, Seetharama et al., (1984) reported that stress during seedling stage resulted primarily in poor crop establishment, and consequently grain yield reductions. On the contrary, (Farah, et al. 1987) reported that stress during vegetative stage (GS1) of sorghum growth affect yield through reduction in grain number. Drought stress during the panicle development stage was reported to have more severe effects on grain yield (Seetharama *et al*, 1984; Mahalakshmi and Bidinger, 1986). The main effect on grain yield was through the number of grains per

head and number of heads per unit area, but the loss was compensated for by increasing grain yield of tillers.

Mahalakshami and Bidinger (1986) claimed that a synchronous tillering of millet crop is an important productive mechanism conferring adaptation to low and erratic rainfall. Similarly, Eck and Musick (1979) showed that yield reductions from stress initiated at early boot stage resulted from reduced seed number; where as only seed size was reduced when stress was imposed at heading or later. Drought stress during the panicle development stage (GS2) affected the growth and development of the main shoot grain yield (Anon., 1984).

In green house pot trials, pearl millet (*P. glaucum*) plants were subjected to water stress at different phenological phases and different lengths of time (Maracchi *et al*., 1993). They concluded that yield reductions in the field resulting from water stress during the reproductive stage are linked to late development of un productive tillers. So, synchronized tillering appears to be the most effective mechanism for cropping with water stress during the vegetative stage.

2.3.1 Effect of drought on yield and yield components:

The effect of water deficit on yield and yield components have been the subject of many investigations. Moisture deficit was found to account for 65% of variation in grain yield of sorghum and pearl millet (Mahalkshmi and Rao, 1990).

Timing of water supply generally has a larger effect on grain yield than total quantity of water for many crops (Shaw, 1988). Both pearl millet and grain sorghum are most sensitive to water stress during flowering and grain filling (Garrity *et al*., 1983 and Hattendorf *et al*., 1988).

Grain yield of pearl millet genotypes was found to be linear with severity of stress (Mahalakshmi *et al*., 1988). Grain number per unit area and grain size were reduced by severity of water deficit, where as grain yield and grain number, were affected by the time of the stress onset at all intensities. Grain number per panicle was

found to be more affected by severe stress than panicle number. Grant *et al*. (1989) showed that moisture stress occurred during early grain development significantly reduced kernal number per ear.

Field trails with pearl millet, irrigated and rainfed, showed significant differences between those two moisture regimes in grain yield, time to 50% flowering, time to maturity, number of heads per unit area, head mass and grain mass (Osmanzai, 1992).

Studies of the response of pearl millet and sorghum to water deficit revealed that stress during the grain filling period had more drastic effect on yield. It reduced yield by 70% when the stress period was at or just before flowering (Seetharama *et al*. 1984). However, Anon (1985) reported that the time of onset of stress determined the extent of grain yield reductions (70-80%) when the stress was initiated prior to flowering, but the effect declined rapidly as the onset of stress was delayed. The timing of terminal stress (stress during GS3) together with intensity of stress was reported to have equal importance in their effects on yield. At mid intensities, time of onset stress had no serious effect on grain yield; whereas, it become critical as the stress intensity is increased. The effect of stress intensity on grain yield was expressed through reduction in both grain number and size.

Drought stress during grain filling in tall and dwarf pearl millet hybrids, reduced the number of grains per unit area and individual grain mass as well as biomass and harvest index (Mahalakshmi *et al*, 1991). The reduction in number of grains was attributed to the allocation of available carbohydrates to fill the remaining grain and to maintain a minimum grain mass.

2.3.2 Effect of drought on vegetative traits:

Despite its importance as a major cereal for drought and famine-prone areas of the world, there are very few growth analysis studies of pearl millet (Gregory and Squire, 1979). Faragalla, (1995) indicated that water stress during panicle initiation reduced plant height. Similar results were reported by Gruz and Ơ´ Toole. (1984). These reports showed that plant height decreases with water deficit imposed at different stages of plant growth, except after anthesis. Eldickery (1992) indicated that plant height was reduced as watering interval was increased. In field trails with rice, Gruz and Ó Toole (1984) showed that water stress resulted in reduction of leaf area, plant height and number of tillers per plant. Number of tillers per plant was progressively increased with plant age where as it was decreased with water deficit. These results were in accordance with those reported by Conover *et al*., (1989) who found that panicle number and tiller number decreased by water stress in pearl millet. Similar findings were shown by Unger (1991) and Vanderlip. (1991), who reported substantial tillers production as a result of water stress. Leaf area index increased with plant age but was reduced with water stress (Payne, et al. 1991).

The shoot dry weight increased with plant age, where as it was declined with water regime. Mahalakshmi *et al*., (1991) found that biomass was reduced due to water deficit in two experiments under dry and rainy season conditions. Also Conover *et al* (1989) reported that shoot dry weight decreased by water stress in pearl millet. Muchow (1989) reported that the decrease in biomass of pearl millet in response to

water deficit was associated more with reduction in radiation efficiency. Similarly, Ibrahim *et al*., (1985) found that dry weight was reduced significantly by water stress.

The effect of water stress on days to flowering reported by Anon. (1984) suggested that flowering of pearl millet was delayed by water stress, with the effect being more pronounced in the tillers. On the contrary, Mahalakshmi *et al*., (1991) reported that there was no difference between two groups of tall and dwarf hybrid pearl millet growing in dry and rainy season in the time to flowering. A synchronous tillering habit in pearl millet was reported by some workers as an adaptive feature to water stress, allowing for development plasticity during the early stages of growth (Seetharama *et al*., 1984).

Seetharama et al., (1984) found that physiological maturity is in variably hastened with increasing intensity of stress in pearl millet. Rao and Rao (1982) reported that physiological maturity was reached by pearl millet after 76 days from sowing under rainfed conditions.

2.4 Evaluation of drought tolerance:

Many yield – based parameters were suggested to evaluate drought tolerance. Many of them were constructed in form of indices, e.g., stress susceptibility index SSI suggested by Fisher and Maurer (1978). The stress susceptibility index is ratio of relative reduction in yield of genotypes due to drought compared to the mean relative reduction in yield of all tested genotypes. This SSI is found to be equivalent to the ratio of yield under stress to yield under non – stress, Yd/Yw (link *et al*., 1999). Heringa *et al*., (1984) considered the ratio of absolute reduction in yield due to stress (AR) to yield under non - stress (Yw), AR/Yw what is again equivalent to ranking of genotypes according to their ratios Yd / Yw. A further yield – based parameter of drought tolerance is geometric mean of productivity (GMP, Fernandez. 1993) which is the square root of the product of yield under stress times under non stress conditions. The geometric mean is often used by breeders, who are interested in performance

under favorable and stress condition, since drought stress can vary in severity in field environments over years.

2.5 Genetic Variability:

Genetic variability is essential to secure the success of any breeding programme. Selection is not effective unless considerable genetic variation is present in the population. Evidence for the existence of considerable amount of variability in pearl millet has been reported by investigators, and the germplasm resources are still largely un exploited (AbuElgasim, 1999).

Genetic variability found in over 140 species of genus Pennisteum offers a vast potential for improvement through breeding and selection (Gill, 1991). Berwal and khairwal (1997) found highly significant differences in plant height, number of tillers, stem diameter and leaf area of pearl millet. They predicated successful crosses between these accessions to improve each of these traits.

Forty-one genotypes of pearl millet were divided in to 14 clusters, based on geographical origin, and compared for genetic diversity in nine traits including grain (Savery and Prasad, 1995). Awide genetic diversity for all characters in pearl millet was observed. Some genotypes from different clusters were superior in grain yield and some yield components. These genotypes could be recommended for further breeding programme.

Pearl millet is grown in harsh environments and exposed to a variety of stresses such as drought, heat and low nutrient supply during the crop season. The cultivars targeted for these areas need to have a certain degree of adaptation to such stresses,

Berwal and Khairwal (1997), in their study of genetic divergence in pearl millet, where forty – two accessions were evaluated, indicated highly significant differences in plant height, number of tillers, stem diameter and leaf area. They predicted successful crosses between these accessions to improve each of these traits. and should have ability to take advantage of favorable growing seasons during better rainfall years (Yadav and Weltizein, 1997).

2. 6 Heritability and genetic advance:

Information on heritability and yield correlation is derived from data on 12 yield components in 20 fodder bajra (Pennisetum glaucum) genotypes grown at Vellayani, Kerala India. Dry matter showed the highest positive and negative genotypic correlations with crude protein content and internode length (Suresh and Bai, 1998).

Johnson *et al.* (1955) indicated that estimates of heritability along with genetic coefficient of variation are useful in predicting the resulting effects of sample size, environment, the character and population on heritability estimates. Moreover, heritability value indicates the confidence with which selection of genotypes can be based on phenotypic performance. However, estimation of heritability in broad sense has limitation, because it includes both additive and espistatic gene effects (Abraham *et al*, 1989). Therefore, estimates of heritability in broad sense would be of more meaning if accompanied by estimates of genetic coefficient of variation.

Abraham *et al*. (1989) studied seven quantitive characters in 20 diverse genotypes of finger millet (Eleusine coracana). They found that the estimates of heritability in broadsense ranged from 0.40 for productive tillers /plant to 0.99 for days to maturity. Grain yield /plant, 1000 grain weight and grains /ear had high estimates for heritability with low genetic advance indicating that non – additive (dominance and epistasis) gene effects were predominant. It was concluded that progress in the improvement of this character would be slow. Selection may be

Analysis of the interrelationship in 76 genotypes of pearl millet showed that grain yield possessed a high positive association with number of productive tillers, plant height, days to 50% flowering and ear length. There was positive correlation between ear length and thickness, 1000 –grain weight and number of productive tillers (Latha and Shanmugundarae, 1998).

effective for grain yield /plant, 1000 – grain weight and grains /ear, since these characters showed high value for heritability, genetic advance and genetic variation.

Falconer (1980) concluded that more variable conditions reduce heritability, where as uniform condition increase it. Faddlalla (1994), in bread wheat, showed that a wide range of variability in heritability estimates was observed over two seasons. Relatively, stable heritability estimates were detected for spike length, number of splikelets, spike and number of grains /spike over the two seasons. High heritability estimates ($h^2<0.70$) were recorded for morphological characters whereas, yield components showed low ($h^2 > 0.70$) heritability estimates.

Amar (1999) found a significant genetic advance in grain yield, in durum wheat under the semi – arid conditions. Selection pressure needs to be applied for this character, directly through number of grains /spike and number of spikes /m^2, and indirectly through days to heading, as selection criteria.

2.7 Interrelationship between characters:

Tolok *et al*. (1998) reported that genetic correlation between grain yield / plant and seed weight, panicle weight and productive panicle was 1.00, 0.89 and 0.75 respectively, suggesting that indirect selection through yield components will improve grain yield .Similar results were obtained by Harer and Karad (1998) who found that grain yield was highly and positively correlated with plant height, 100 grain weight, fodder yield (plant) ear length and flag leaf area, but was negatively correlated with days to maturity . Also Balakrishnan and Das (1995). Singh, (1995) reported similar results for different combinations of characters.

The analysis of the interrelationships among genotypes of pearl millet showed that grain yield possessed a high and positive association with number of productive tillers, plant height and 1000-grain weight . Plant biomass, days to 50% flowering and ear length were mutually correlated the thickness, and 1000 grain weight, which was positively correlated with yield .

In finger millet (*Eleusine coracana*), Abraham *et al* (1989) found that genotypic correlation coefficients were slightly higher than the respective phenotypic ones. Grain yield had positive phenotypic association with days to 50% flowering, productive tillers / plant, days to maturity and 1000 - grain weight.

2.8 Path analysis:

Path coefficient analysis specify the causes and measures their relative importance. It provides an effective mean for direct and indirect cause of association, then it gives an accurate idea about the most contributing characters to seed yield. Moreover, path analysis is an effective means of permitting a critical examination of specific factors that produce correlation since the breeder must apply different weights to various characters. The use of selection indices has proved its usefulness.

Direct effect of biological yield, harvest index, days to flowering, ear length, and ear girth and plant height on grain yield was reported by Godowat and Ghaudhry (1990), Harer and karad (1998), Kulkarni *et al*. (2000) and Sukhchain and Sindhu (1992).Muhammad and Shaheen (2003) found that grain yield /plot was positively and significantly correlated with above mention traits. Positive direct effect of biological yield /pot was observed. Path coefficient analysis revealed the importance of number of tillers per plants, stem weight and number of leaves per plant as major components contributing to green fodder yield (Jiban, *et al*. 1998).

2.9 Yield stability and adaptation:

Important genotypic differences in stability have been recognized but progress in breeding programmes has been slow because of the lack of satisfactory methods of measuring genotypic stability or complexities of natural environment. Finally and Wilkinson (1963) have developed statistical technique to compare the grain yield of varieties grown at several locations for several season. The mean yield of all varieties grown in each site and season was used as quantitative measure of environment. Eberhart and Russell (1966) used deviations from the regression as secondary measure of stability, and Henson, et al. (1982) proposed measures of genotypic stability combining information from analysis of regression and deviation from regression.

In proso millet (*Pennisteum miliaceum*), genotypes x enviroment interaction was assessed in twenty – two indigenous and exotic genotypes for grain yield and five yield components during the rainy seasons of 87-89 (Panwar *et al*., 1994) . Genotype x environment interaction was significant only for plant height and grain yield. Both linear and non-linear components of g x e interaction were presented for plant height, while only non-linear components were important for grain yield. Absence of association among stability parameters for grain yield and plant height indicated that grain yield may be increased without influencing stability across different environments.spacing affected plant height, panicle weight and grain yield . Season (T) affected mostly yield and its components. Spring sowing showed higher yield components values than fall sowing. Closer spacing increased grain yield. The number of productive panicles and panicles length were considered to be stable and useful characters for selection for higher yield.

An investigation conducted by Oosterom *et al.* (1995), about the effect of yield potential, drought escape and drought tolerance on grain yield of pearl millet (*P. glaucum*) in different stress environments, revealed that different types of drought and heat stress occurred. These findings indicated that, for stress environments, selection for yield potential is of limited use. The importance of escape and tolerance, however, depends on the timing and intensity of stress occurrence, and they concluded that if pearl millet growing regions can be characterized, based on occurrence of a biotic stress, Breeders, could select more efficiently for plant traits which enhance adaptation in specific target environment.

Gupta and Ndoye (1991) found that a large proportion of the g×e interaction, for number of pearl millet genotypes, evaluated over four locations and four years in Senegal, was accounted for by the non – linear regression on the environmental means. Although the linear component was significant, its magnitude was considerably smaller than that of the non – linear one. All genotypes were stable and their response to the change in environment could be predicted.In twenty genotypes of pearl millet evaluated in four different seasons, Karale *et al* (1997) found significant differences among genotypes and among environments. Linear regression and non-linear components were significant for seeds /m² of main ear. Significant pooled deviation was observed for other characters, suggesting that genotypes differed considerably with respect to their stability. Similar results were reported by Yadav et al. (1995), in nineteen indigenous and three exotic genotypes of pearl millets evaluated over three seasons. Similar results were also reported by Fadlalla, (2002).

CHAPTER THREE
MATERIALS AND METHODS

3.1 Experiment sites

Two field experiments were carried out to achieve the objectives of this study. The field experiments were conducted during the seasons of 2003 and 2004. At two sites namely; El Rawakeeb Dry land and Desertification Research station. National Center for Research (35 Km west of Omdurman, 32º 15´ E longitude, 15º 25 ´N latitude and 420 meters above the sea level). It is characterized by a short rainy season with hot - dry air during the summer and cold - dry air during winter. The soil particles size of El Rawakeeb follows the order: sand, silt and clay. Where the sand comprises the higher proportion. The other site was the Experimental Farm of the Faculty of Agriculture, University of Khartoum, at Shambat (32º 32´ E. Longitude, 15º 40´ N Latitude, and 380 meters above the sea level). The climate is characterized as a short - humid air during the summer and cold - dry during the winter. The soil of Shambat is highly saline – sodic clay. The soil particles proportions follow the order: clay, silt and sand. Where the clay comprises the higher proportion. Monthly mean maximum and minimum temperature and total rainfall were recorded for the two sides (Appendix .2).

3.1.1 Genotypes:

Fifteen genotypes of pearl millet (*Pennisetum glaucum L*) were used for this study. These genotypes were provided by Dr. Hashim Awadelkarim Fadlalla of Desertification Research Institute, the National for Centre Research (Table 3.1).

Table 3.1 Name and origin of pearl millet genotypes used to study the extent of variability under normal and water stress conditions during 2003/04 – 2004/05 .

Code	Name	Origin
1	JM 49	Darfur , Sudan
2	JM25	Darfur, Sudan
3	JM21	Darfur Sudan
4	JM44	Darfur Sudan
5	JM45	Darfur Sudan
6	JM48	Darfur Sudan
7	JM/97	Darfur Sudan
8	Madelkawiya	Kordofan. Sudan
9	JM3	Darfur Sudan
10	JM30	Darfur Sudan
11	JM23	Darfur Sudan
12	JM38	Darfur Sudan
13	BS/Sh94	Shambat
14	JM24	Darfur Sudan
15	Ugandi	Uganda, adapted

3.1.2 Watering treatment:

Water stress applied at different stages of growth as follows:

W_0: Watering every **7** days through out the growing season (control).

W_1: Watering every **14** days till end of flowering then watering every **7** days till physiological maturity.

W_2: Watering every **7** days till end of the flowering then watering every **14** days till maturity.

W_3: Watering every **14** days through out the growing season till the physiological maturity

The plant received equal quantities of water at **7** days interval for establishment, and then watering treatment was introduced four weeks after sowing.

3. 1. 3. Layout of experiments:

Split – plot design with three replications was used to layout the experiments in the field. The main – plots were assigned to watering treatments and the sub – plots to the genotypes. Each genotype was planted in 1 ridges, 5 meters long with 70 cm between ridges. Seed rate was three seeds per hole spaced at 20 cm between holes. Sowing was carried out in the first week of July in Elrawakeeb and in the second week of July in Shambat. Thinning was carried out one week after sowing to raise two plants / hill. Weeding was done twice at both sites using the hand hoeing.

3.2 Data collection:

Ten randomly selected plants per sub plot were used for data collection at Shambat and Elrawakeeb. Data were recorded on the following plant characters:

3.2.1 Yield and its components:

1/Grain yield (t /ha): The harvested heads from each genotype were air dried and threshed in bulk, then weighed and grain yield was calaculated by the following Formula:

$$\text{Grain yield (t/ha)} = \frac{\text{grain weight (g) /plot} \times 10000\ (m^2)}{\text{Plot area } (m^2) \times 1000 \times 1000}$$

2/ Grain yield /plant (g): the weight of grain yield produced by the main stem and tillers.

3/ Number of seeds /head: obtained by dividing the grain weight per main head by the corresponding weight of 1000-grain then multiply by 1000.

4/ Panicle length (cm): the length of the head beard on the main stem from the base to the tip of the panicle.

5/ 1000-grain weight (g): the weight of a random sample of 1000 grains taken from the grain yield of each ridge.

6/ Dead part length /head (cm): the average length of the non-developed part of main head.

7/ Number of fertile tillers /plant: average number of the panicle bearing tillers per plant at maturity.

8/ Harvest index (HI %): The harvest index was calculated according to the following formula :

$$\text{HI (\%)} = \frac{\text{grain yield plant} \times 100}{\text{Biological yield /plant}}$$

3.2.2 Vegetative traits:

These traits were collected on arandom sample of five plants

1/ Plant height (cm): It was measured from ground surface to the tip of the main panicle.

2/ Number of tillers/plant: Total number of head bearing tillers per plant**.**

3/ Days to 50%flowering: The number of days recorded from the date of sowing to the time when 50% of the genotypes had fully exerted head.

4/Days to maturity: It was computed (in days) from sowing to day when all the heads of genotypes had reached physiological ripening.

5/ Leaf area index (LAI): The leaf of the internodes number (4-6) of five plants /plot was selected to calculate LAI as follows:

Leaf area (LA) =length X width X 0.74 (cm)

Green area (Ga) =LA X number of leaves /plant (cm)

LAI = (Ga/plant)/ (occupied area/plant)

3.2.3 Drought tolerance measurements

Different traits were used as parameters to evaluate drought tolerance. These parameters were based on collected data of grain yield /plant. The parameters which computed in this study include:

Yw = Seed yield /plant (g) under well watered (W_0) conditions

Yd= Seed yield /plant (g) under drought conditions for W_1, W_2, W_3, treatments

Yd/Yw % = Ratio of grain yield /plant (under stress) to grain yield /plant (well watered) as percent.

SSI = stress susceptibility index of Fisher& Maurer (1978). It was determined using the formula:

$$SSI = \{Yw- Yd\} / \{Yw (1- yd /yw)\}$$

Where, Yd and Yw as defined in other parameters, then yd and yw are the mean yields over all genoypes evaluated under stress and well – watered conditions, respectively.

Moreover, SSI of a genotype can be given by a ratio of relative yield reduction under stress {(Yw-Yd)/Yw} to drought intensity index (relative yield reduction over all genotypes in the environment, it equal to 1-yd/yw). This drought intensity index (DI) range between 0 and 1 the larger value of it , the more severe is the stress intensity , i.e ., SSI = {(1-Yd/Yw) / (1-yd/yw)}.

Values of SSI < 1 denote. Below average drought susceptibility (above drought tolerance) as 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 $\sqrt{}$ (Yd ×Yw), as suggested by Fernandez (1993).

3.3 Statistical analysis

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

3.3.1. Analysis of variance

3.3.1.1. Individual analysis of variance:

It was carried out for all studied characters in each location separately according to the procedures described by Gomez and Gomez (1984) for split - plot design (Table 3.2).

3.3.1.2. Combined analysis of variance:

It was done for the characters in which the mean squares of errors were homogenous. It was carried out following the procedures described by Gomez and Gomez (1984) based on split plot design (Table 3.3).

3.3.1.3. Coefficient of variation: (CV %):

It was determined for each character in both locations using the formula

.

$$CV\% = \sqrt{\frac{\text{Mean square of error}}{\text{Grand mean}}} \times 100\%$$

Table 3.2 Analysis of variance for different characters of 15 genotypes of pearl millet, evaluated under four water treatments, for each location separately, during the season (2003/04).

Source of variation	D.F	M.S	F	Expected mean squares
Replications	(r-1) =2	MQ1	MQ1 / MQ3	
Treatments	(t-1) = 3	MQ2	MQ2/MQ3	
Error (a)	(t-1) (r-1) = 6	MQ3	-	
Genotypes	(g-1) = 14	MQ4	MQ/MQ6	σ^2e-rσ^2gt-rtσ^2g
Gen.× Treat.	(g-1) (t-1) = 42	MQ5	MQ/MQ6	σ^2e – rσ^2gt
Error (b)	t (r-1) (g-1) = 112	MQ6	-	σ^2e
Total	(rtg-1) =179			

r = Replications, t = Treatments (main factor), g = Genotypes (sub factor),

MQ1, MQ6, Mean squares for replication, factor (A), error (a), factor (B), A×B interaction and error (b), respectively.

σ^2g= genotype variance, σ^2e=error b variance,

σ^2gt= variance due to interaction between genotypes ×treatment.

After Gomez and Gomez,(1984)

Table 3.3 Combined analysis of variance for characters of 15 genotypes of pearl millet, evaluated under four water treatments, with three replications in two locations (Shambat and Elrawakeeb), during the season (2003/04).

Source of variation	D.F	MS	F	Expected mean squares
Locations	(1-1) =1	MQ1	MQ1/ MQ5	
Replications / loc.	L (r-1) = 4	MQ2	-	
Treatments	(t-1) = 3	MQ3	MQ3 / MQ5	
Treat × loc	(t-1) (1-1) = 3	MQ4	MQ4 / MQ5	
Pooled error (a)	L (r-1) (t-1) =12	MQ5	-	
Genotypes	(g-1) = 14	MQ6	MQ6 / MQ10	σ^2e-rσ^2gtl-rtσ^2gl-rl σ^2gt- rtlσ^2g
Gen. × Treat	(g-1)(t-1) = 42	MQ7	MQ7 / MQ10	σ^2e-rσ^2gtl-rlσ^2gt
Gen. ×Loc	(g-1) (1-1) = 14	MQ8	MQ8 / MQ10	σ^2e-rσ^2gtl-rtσ^2gl
Gen.× Treat× loc	(g-1) (t-1) (1-1) = 42	MQ9	MQ9 / MQ10	σ^2e-rσ^2gtl
Pooled error	lr (g-1) (t-1) = 224	MQ10	-	σ^2e
Total	(lrtg-1) = 359			

L = location, r = replication, t = treatment, g = genotype

MQ1,…..MQ10 = mean squares for locations , replications within locations , factor (A), L × A interaction , error (a) , factor (B) , L×B , A×B, L×A×B interactions and Error (b), respectively .

^{2}g = 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 genotype × treatments ×locations

After Gomez and Gomez, (1984)

3.3.2 - Mean separation:

3.3.2.1- Between water treatments:

Means of water treatments were separated using Duncan's Multiple Range Test (DMRT) at 5% level of significance according to procedure described by Gomez and Gomez (1984) as follows:

Step one: all treatment means were ranked in descending manner .

Step two: the adequate standard error of the differences (S d) was computed according to the following equations:

a) For means over all water treatment levels:

$$\mathbf{Sd_1 = \sqrt{\{2\,[(b-1)\,E_b + E\,a]\,/\,rb\}}}$$

b) For means over the two levels of water treatment: -

$$\mathbf{Sd_2 = \sqrt{(2\,E\,a)/\,rb}}$$

Where:

Ea and **E b** = Mean squares of error (a) and error (b), respectively.

r and **b** = number of replications and sub –plots, respectively

Step three: values of the shortest significant range at 0.05 level were calculated as:

$$\mathbf{R_p = [(r_p).\,(sd)]/\sqrt{2}\ for}\ p = 2, 3, \ldots, t$$

Where:

$\mathbf{R_p}$ = the (t-1) value.

t = the total number of treatment means under comparison.

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

$\mathbf{r_p}$ = the tabular values of significant studentized ranges at 0.05 level.

Step four: all treatment means which did not differ significantly from each other were then identified and grouped together.

Step five: alphabet notations were then used to indicate the non – significant difference between any two treatment means.

3.3.2.2. Comparison between genotypes:

The means were separated using the least significant difference (LSD) at 5% level of significant according to formula:

$$LSD = t\alpha \times \sqrt{\frac{2\ EMS}{r}}$$

Where

r = Number of replication's, EMS = mean squares.

α = level of significance for t – value (0.05)

3.3.2.3. Means separation for drought tolerance parameters:

It was separated using the least significant difference (LSD) at 5% level.

3.3.3.1. Phenotypic ($\sigma^2 ph$) and genotypic ($\sigma^2 g$) variances.

They were estimated from analysis of variance (Table 3.2) as follows.

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

Genotypic variance ($\sigma^2 g$) = (MQ4-MQ6)/r

Where:

MQ4, MQ6, Mean squares for genotypes and error (b), respectively.

$\sigma^2 e$ = MQ6

r =number of replications.

3.3.3.2 Phenotypic and genotypic coefficient of variation (%):

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

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

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

3.3.4 Broad sense heritability (h^2) :

It was estimated in each location separately, from the analysis of variance according to Johnson *et al*. (1955) by the formula:

$$h^2 = \sigma^2 g / \sigma^2 ph$$

$\sigma^2 g$ = genotypic variance

$\sigma^2 ph$ = phenotypic variance

3.3.5 Expected genetic advance (GA):

It was estimated by the formula of Robinson *et al*, (1949) as follows:

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

Where:

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

σ Ph = square root of Phenotypic variance

3.3.6. Interrelationships between characters:

3.3.5.1. Phenotypic and genotypic correlations:

The estimated genotypic and phenotypic covariance components between two traits (x and y) were used for computation of genotypic and phenotypic correlation between different characters, using the formula suggested by Miller *et al*., (1958).

$$\text{Genotypic correlation coefficient (rg)} = \frac{\sigma gxy}{\sqrt{(\sigma^2 g\, x).(\sigma^2 gy)}}$$

$$\text{Phenotypic correlation coefficient (r ph)} = \frac{\sigma phxy}{\sqrt{(\sigma^2 phx).(\sigma^2 phy)}}$$

Where:

σgxy = genotypic covariance between two traits (x and y)

$\sigma phxy$ = phenotypic covariance between two traits (x and y) ,

$\sigma^2 gx$ = genotypic variance for trait x, $\sigma^2 gy$ = genotypic variance for trait y ,

$\sigma^2 phx$ = phenotypic variance for traits x, $\sigma^2 phy$ = phenotypic variance for trait y

3.3.5.2. Path analysis:

Path analysis, as applied by Dewey and Lu (1959), was used to determine the direct and indirect effects of some characters on grain yield/plant.

For this objective, the characters included in the model were:

1. Number of fertile tillers /plant
2. Number of seeds/main head
3. 1000 – seed weight (g)
4. Panicle length /head (cm)
5. Dead part length (cm)
6. Grain yield /plant (g)

The path coefficients (direct effects) of the five characters on grain yield /plant (6), were determined. They were obtained by solving the following simultaneous equations:

r 16 = P16 + r12 P26 + r 13 P 36 + r14 P46 + r15 P 56

r26 = r12 P16 + P26 + r23 P36+ r24 P46 + r25 P 56

r 36 = r13 P 16 + r23 P26 + P 36 + r 34 P 46 + r 35 P56

r 46 = r 14 P 16 + r 24 P 26 + r 34 P36 + P 46 + r 45 P56

r 56 = r 15 P 16 + r 25 P26 + r 35 P 36 + r 45 P 46 + P56

Where:

r 16 , r 26 , ….and r 56 = genotypic correlation coefficients of characters involved in the model with grain yield /plant (6)

r12 …r16, r 23 ….r 26, r 34 …r 36, r 46….r 46 and r 56 = = genotypic correlation coefficients of the possible pair wise combinations of the six characters.

P16, P26 , ….P56 = Path coefficients (direct effects) of five characters on grain yield / plant (6) .

The residual effect was determined according to Singh and Chaudhary (1979) by substituting the estimated path coefficients and genotypic correlation coefficient in the following equation:

1 = P^2x 6 + P1 6 r 1 6 + P2 6 r2 6 + P 3 6 r3 6 + P 4 6 r 4 6 + P56 r56

Where:

= Px 6 = path coefficient of (x) variables, the excluded characters, on grain yield /plant (6).

3.3.7. Stability analysis:

The genotypes were tested under four water treatments at two locations. These factors (locations × water treatments) were combined to form eight macro – environments (ME) to carry out stability analysis .The stability analysis was

performed for grain yield /plant, as shown on Table (3.4), according to Eherhart and Russel (1966)

The stability parameters determined were based on regression approach. Genotype means in individual environments are regressed on environmental means, according to underlying statistical model (Singh and Chaudhary (1979) as follows

$$Yij = m + BiIj + \partial ij$$

$$i = 1 , 2, ….g$$

$$j = 1 , 2, …..s$$

Where:

Yij = the mean yield of the **i**th genotype in the jth environment,

m = the mean of all genotypes over all environments.

Bi = the regression coefficient of the **i** th genotypes on environments index, which measures the response of this genotype to varying environments.

Iij = the environmental index which is defined as the deviation of the mean of all genotypes at given environment from the over all mean,

∂ij = the deviation from regression of **i** th genotype at **j** th environment,

g = the number of genotypes, and s = the number of environment

3.3.7.1. Stability parameters:

The following two stability parameters were considered:

a) The regression coefficient (bi), which was the performance of each genotype under different environments on the environmental mean over all genotypes . This was estimated as :

$$bi = j\sum yij\ Ij\ /\sum I^2j$$

Where:

bi =regression coefficient of the **I** th genotype

yij =the performance of the I th genotype at the j th environment /

Ij = environmental index obtained as the mean of all genotypes at the j^{th} environment minus the grand mean.

Genotypes which have regression coefficient > 1 are regarded to be more adapted to favorable environments , and those who have regression coefficient < 1 are regarded to be more adapted to unfavorable environments .

b) Deviation from regression (σ^2d) in Eberhart and Russell (1966). Genotypes or environments which show small values of σ^2d are claimed to have high yield stability

$$\sigma^2d = £\ \partial^2ij\ /(S-2) - Se^2/r$$

Where:

$$\partial^2ij = \{£Y\ ij – Yi\ /g\} – \{£\ Yij\ I^2\}$$

Se = the pooled error

r = number of replications.

Stable genotypes: A variety with unit regression coefficient (b = 1) and deviation not significantly different from Zero ($\sigma^2d = 0$) is said to be stable.

3.3.7.2. Analysis of variance: Analysis of variance of the data was performed using randomized complete block design procedure, taking in account that each level of water treatment represented an individual environment.

3-3-7-3. Standard error: Standard error **(SE)** of regression coefficient

$$SE\ b = \sqrt{(M3)\ /j\sum l^2 j}$$

$$SE\ a = \sqrt{\{M3\ /\ S\text{-}1\}}$$

Table 3.4 ANOVA to show the sub division of genotype × environmental interaction in to its components with three replication and across eight macro-environments.

Source of variation	D.F	MS	F
Genotypes (G)	g-1 =14	MQ1	MQ1/MQ3
Environmental + (g×e)	g(s-1) = 105	-	
Environmental (linear)	=1	-	
(g×e (linear)	g-1 = 14	MQ2	MQ2/MQ3
Pooled deviation :-	g (s-2) = 90	MQ3	-
JM 49/97	s -2 = 6	MQ4	MQ4/MQ19
JM25/97	s -2 = 6	MQ5	MQ5/MQ19
JM21/97	, , ,,	MQ6	,, ,,
JM44/97	,, ,,	MQ7	,, ,,
JM45/97	,, ,,	MQ8	,, ,,
JM48/97	,, ,,	MQ9	
JM/97	,, ,,	MQ10	,, ,,
Model kawiya/97	,, ,,	MQ11	
JM3/97	,, ,,	MQ12	,, ,,
JM30/97	,, ,,	MQ13	,, ,,
Jm23/97	,, ,,	MQ14	,, ,,
JM38/97	,, ,,	MQ15	,, ,,
BS/Sh/94/97	,, ,,	MQ16	
JM24/97	,, ,,	MQ17	MQ18/MQ19
Ugandi/97	s-2 = 6	MQ18	
Pooled error	sg(r-2)	MQ19	,, ,,
Total	sg-1		

Where:

r = number of replications

g = number of genotypes

s = number of environments

MQ1 ,….MQ19 = Mean squares for genotypes (G) , g×e interaction , pooled deviation , Genotypes (JM49/97 ,……Ugandi /97) and pooled error respectively .

Singh and Chaudhary (1979), page

CHAPTER FOUR

RESULTS

4.1. Effect of environment and drought

4.1.1 Performance of genotypes over locations:

Significant differences ($P \leq 0.01$) were detected between environments for most characters under study (Table 4.2). The general mean of genotypes for grain yield / plant at ELRawakeeb was 46.14 g and 30.48 g at Shambat. The environment of ELrawakeeb was more productive than Shambat (Table 4.2). On the other hand, no significant difference between environments was detected for number of tillers / plant at 30 , 45 and 60 days after sowing date (DAS) and leaf area index at 30 , 45 and 60 (DAS). Variation due to genotypes × environments interaction was significant for all investigated traits , except leaf area index at 45 (DAS) (Table 4.2).

4.1.2. Effect of drought on performance of genotypes:

Significant ($P \leq 0.01$) effects due to water treatments were obtained for most of investigated traits, except plant height and leaf area index at first sampling occasions 30 (DAS**) (**Table 4.3). Further more, the relative response of the different genotypes to water stress was highly affected by the timing of stress and the development of the genotype tolerance to water stress. Genotypes × water treatments interactions were significant for grain yield /plant, number of seeds /head, biomass / plant, days to maturity, days to 50 % flowering. There was also non – significant difference for grain yield / plant, harvest index and panicle length/head (Table 4 .3).

Table 4.1 Enviromental means (Shambat and ELrawakeeb) of 15 pearl millet genotypes for some characters under study . Mean are average over four water treatments (W_0, W_1, W_2, W_3)

Characters	Shambat	ELrawakeeb	Mean	CV%	LSD (0.05)
Ph 30 (cm)	79.30	88.22	83.7	12.3	11.1
Ph 45 (cm)	126.7	144.7	135.7	10.9	16.7
Ph 60 (cm)	166.7	160.2	163.4	3.4	6.4
Ph 75 (cm)	176.5	162.9	169.8	7.2	13.8
TL 30	3.2	3.3	3.2	19.0	0.7
TL 45	3.7	4.2	4.0	14.1	0.6
TL 60	3.8	4.6	4.2	12.9	0.6
TL 75	4.2	5.0	4.6	11.9	0.6
50 % Flr (Days)	56.6	53.2	54.9	2.4	1.5
Matur (Days)	83.6	85.9	84.8	2.1	2.04
LAI 30	3.3	3.4	3.4	27.8	1.0
LAI 45	4.9	4.6	4.8	22.9	1.2
LAI 60	4.5	4.5	4.5	5.8	0.3
LAI 75	3.3	3.9	3.7	17.7	0.7
FTL	1.2	1.7	1.5	27.3	0.5
Deleng (cm)	2.1	3.1	2.7	19.0	0.6
Y(g)/p (g)	30.5	46.1	38.3	27.9	7.0
Yd(t)/h (ton/ha)	1.5	1.2	1.4	38.3	0.6
HI %	15.5	19.6	17.6	25.4	2.9
Biomass (g)	165.9	188.3	176.9	15.4	30.9
Pnlng (cm)	22.4	21.0	21.7	14.3	3.5
Sd /pn	1407.8	1719.0	1563.4	20.5	210.0
1000-sd (g)	6.8	7.4	7.1	16.5	0.6

Table 4.2 : Mean Squares from analysis of variance due to Treatments (T), Genotypes, and their Interactions (G×T), For different characters in pearl millet genotypes, evaluated over four water treatments, at two locations (Shambat and Elrawakeeb) in 2003/05

Characters	Shambat 2004/05	ELRawakeeb 2003/04

**,* = Significant of probability 0.01 and 0.05, respectively

	T	G	G ×T	T	G	G × T
	D.F = 3	**D.F = 14**	**D.F = 42**	**D.F = 3**	**D.F = 14**	**D.F = 42**
PH 30 (cm)	1585.84 ns	276.24 ns	126.19 ns	558.59 ns	215.16**	51.08 *
PH 45 (cm)	6578.39 ns	565.23 ns	266.13 ns	1390.75 **	981.35 **	159.09 **
PH 60 (cm)	645.44 ns	1113.87 **	218.95 ns	21305.50 **	881.97 **	181.34 **
PH 75 (cm)	1104.01 ns	1087.40 **	255.81 ns	19819.23 **	1210.96 **	297.76 **
TL 30	2.53 ns	0.89 **	0.27 ns	1.55 ns	0.46 ns	0.54 ns
TL 45	4.17 ns	1.04 **	0.31 ns	17.64 **	1.19 **	0.49 **
TL 60	3.54 ns	1.00 *	0.34 ns	15.18 **	0.94 **	0.41 **
TL 75	4.13 ns	1.15 **	0.43 ns	4.75 **	0.69 **	0.40 **
50%Flr (Days)	228.58 **	132.17 **	17.53 **	486.8 **	136.12 **	4.92 **
Matur (Days)	147.98 **	47.35 **	12.88 **	3774.13 **	375.22 **	57.94 **
LAI 30	2.12 ns	3.29 *	1.74 ns	1.65 ns	1.24 **	0.64 **
LAI 45	4.24 ns	3.83 *	1.43 ns	37.22 **	2.20 **	1.23 **
LAI 60	6.88 *	3.90*	1.70 ns	46.96 **	49.61 **	0.60 **
LAI 75	3.94*	1.45 *	098 ns	26.30 **	3.42 **	0.41 **
FTL	0.43 ns	1.30 **	0.35 ns	4.87 **	0.45 **	0.10 **
Dpleng (cm)	7.14 **	077 **	13.50 ns	30.88 **	3.29 **	0.86 **
Y(g)/p (g)	257.83 *	109.11 **	25.65 ns	2052.14 **	244.28 **	43.47 **
Yd(t)/h (ton/ha)	8.48 *	20.01 **	0.35 ns	10.15 **	0.69 **	0.22 ns
HI%	144.50 ns	85.48 **	25.58 ns	14.83 ns	12.07 **	3.65 ns
Biomass (g)	3459.18 *	1328.42 *	731.11 ns	39954.14 **	4538.49 **	2574.07 ns
Pnlng (cm)	222.32 *	66.67 **	52.01 ns	785.08 **	53.97 **	10.01 ns
Sd/pn	4.72 **	0.70 **	20.02 ns	8.60 **	0.62 **	0.25 **
1000 sd (g)	16.21 *	11.31 **	4.22 ns	24.15 **	8.13 **	4.68 **

Ns = non significant.

The combined analysis of variance (Table 4.3) releaved highly significant differences ($P \leq 0.01$) among water treatments for all characters under study, except plant height and number of tillers /plant at the first occasion (30 DAS). Genotypes × treatments interaction was significant for most of the investigated traits , except plant height at 30 and 45 DAS, number of tillers/plant at 30 and 60 DAS, Leaf area index at 60 and 75 DAS, harvest index and panicle length (Table 4.3) . Variation due to locations × treatments interaction was significantly for most characters except plant height at 30 DAS, leaf area index at 30 DAS, harvest index and 1000- seed weight (Table 4.3). Drought treatments W_1 and W_3 reduced most of the investigated traits (Fig 1–14). The treatments W_2 had no significant reduction on most of the characters during vegetative growth, although the reduction in traits obtained by W_3 was significant at both locations. On the other hand, the reduction percentages in grain yield and it components seem to be relatively high in comparison with other traits.

4.2 Effect of drought on vegetative and reproductive traits:

Drought stress reduced greatly and significantly the value of all investigated traits. However, the analysis of variance (Table 4.2) revealed significant variations ($P \leq 0.01$) between the four water treatments for most of the character under study, except plant height and number of tillers at first sampling occasion (30 DAS) at ELrawakeeb. where as , at Shambat there were no significant differences among water treatments for most of the investigated traits under study, expect 50 % flowering, days to maturity, leaf area index at 45 and 60 DAS, grain yield /plant, dead part length, biomass / plant , panicle length, number of seed / main head and 1000 seed weight (Table 4.2) .

Table 4.3 .Mean Squares from combined analysis due to Locations (L). Treatments (T), Genotypes (G) , and their interaction for different characters in 15 pearl millet genotypes , evaluated over four water treatments at two locations (ELrawakeeb 2003/04 and Shambat 2004/05)

Traits	L	T	L×W	G	G×L	T×G	G×T×L
	d.f = 1	d.f =3	d.f =3	d.f = 14	d.f =14	d.f =42	d.f = 42
Ph 30 (cm)	6917.08 **	1211.19 ns	967.79 ns	274.69 **	217.90 *	108.59 ns	346.84 **
Ph 45 (cm)	29131.39 **	13277.93 **	7221.21**	744.06**	802.52 **	223.05 ns	1208.53 **
Ph 60 (cm)	3768.39 **	13651.60 **	8299.34 **	1007.27 **	988.57 **	179.75**	1322.62**
Ph 75 (cm)	16467.36 **	13647.91 **	7275.32 **	1091.05 **	1207.31 **	229.61*	1475.67 **
TL 30	2.10 ns	3.84 *	0.24 ns	0.72 *	0.63 ns	0.48 ns	1.04 **
TL 45	32.42 **	10.55 **	11.26**	1.37 **	0.86 **	0.49**	1.90*
TL 60	57.80 **	8.33 **	10.39**	1.10 **	0.84 **	0.41ns	1.77 **
TL 75	63.76 **	4.58 **	4.30**	1.05 **	0.78 **	0.44*	1.40**
50% Flr (Days)	1030.23 **	687.30 **	28.16 **	217.10 **	716.65 **	389.89 **	1744.17 **
Matur (Days)	462.40 **	2553.79 **	1368.32 **	308.59 **	113.98 **	44.80**	206.55**
LAI 30	0.34 ns	3.66 ns	0.11 ns	1.59 *	2.94 **	0.88 ns	3.36 **
LAI 45	4.81 **	21.40 **	20.06 **	4.17**	1.86 ns	1.02 ns	4.72 **
LAI 60	0.20 ns	10.95 **	42.89 **	4.35 **	3.10 **	1.25 **	6.40 **
LAI 75	53.74 **	20.55 **	9.69 **	2.54 **	2.33 **	0.83 **	2.86 **
FTL	18.99 **	3.83 **	1.47 **	0.95 **	0.80 **	0.23*	0.83**
Dpleng (cm)	87.015 **	32.140 **	5.89 **	2.113 **	1.94 **	0.76**	2.38**
Yd(g)/p (g)	22065.10 **	7624.12 **	1908.56 **	703.55**	684.71 **	133.14 ns	626.28 **
Yd(t)/h (Ton / ha)	8.52 **	8.37 **	4.60 **	1.42 **	0.70 **	0.55**	1.34**
HI%	1568.99 **	468.20 **	52.45 ns	63.23 **	63.57 **	24.33 ns	73.47 **
Biomg (g)	47335.78 **	33416.11 **	9997.22 **	3615.04 **	2251.87 **	1628.86 **	4769.89 **
Pnlng (cm)	182.40 *	907.34 **	100.05 *	72.70 **	42.60 **	13.22 ns	44.54 **
Sd/pn	8717334.44 **	11410418.15 **	1915498.15 **	973902.30 **	347068.97 **	314352.67 **	709410.58 **
1000 sd (g)	32.89**	38.56 **	1.80 ns	12.95 **	6.50 **	5.23 **	11.19 **

**,* = Significant of probability 0.01 and 0.05, respectively
ns = non significant.

4.2.1. Effect of drought during vegetative and flowering stages: Drought treatments W_1 and W_3 greatly significantly and reduced the value of most of the investigated traits except, plant height and leaf area index at 30 DAS at both locations (Fig 1 – 14 and Table 4.4 – 4.6). The reduction in many traits which caused by W1 was smaller at Shambat than at ELrawakeeb .More over, the reduction caused by W3 was significant in both locations (Fig 1- 14 and Table 4.1– 4.6). The reduction in grain yield (ton / ha) due to W_1 was 22.1, 25.2 and 23.3 % at ELrawakeeb, Shambat and for average of both locations respectively (Fig .1).At Elrawakeeb the reduction in the grain yield /plant due to W1 was 48.4 % , while at Shambat and for the average the reduction was 31.9 % and 42.9 % , respectively (Fig 2). Incidence of stress due to W_1 treatment significantly reduced the number of seeds /plant by 35.7 % and 39.1 % at Elrawakeeb and the average of both locations , respectively , and at Shambat the reduction was 43.5 % .(Fig 3) . Reduction in 1000 seed weight due to W_1 was 7.11 %, 7.11% and 9.02 % at Elrawakeeb, Shambat and for the average of both locations (Fig 4).At both locations , and for the average there was significants reduction in panicle length /head ,where as, the dead part length /head was significantly increased (Fig 5 and Fig 6) .

At Elrawakeeb and for the average of both locations , W_1 significantly reduced the biomass, plant height, days to 50 % flowering and harvest index , while it significantly increased days to maturity (Tables 4.4 and 4.6). On the other hand, the reduction due to W_1 was significant for the most of the investigated traits under studies at Shambat (Table 4.5).

4.2.2 Effect of drought during reproductive stage:

Drought stress during the reproductive stage (W_2 and W_3) reduced the values of most of the investigated traits (Fig 1—14 and Table 4.4 — 4.6). Non-significant differences between induction of stress during reproductive stage W_2 and control W_0 were observed for most of the investigated traits. More over, the reduction due to W_2 was smaller at Shambat than at ELrawakeeb although the reduction in values of traits due to W_3 was higher at both locations. (Fig 1-14 and Table 4.1 - 4.6).

The reduction in grain yield (ton /ha) due to W_2 was significant at ELRawakeeb and for the average of both locations, whereas, it was non – significant at Shambat (Fig 1). At ELrawakeeb, the grain yield /plant was decreased by 17.0 % due to effect of W_2, while at Shambat and for the average of both locations, the reduction was 11.04% and 9.3 % respectively (Fig 2). Reduction in number of seeds / plant due to W_2 was 6.0 %, 10.4 % and 16.4 % at Shambat, ELrawakeeb and the average of both locations, respectively (Fig 3). Treatment W_2 reduced the 1000- seed weight (g) by 10.9 % at Elrawakeeb and 12.7 % for the average of both locations while at Shambat the reduction was 10.9 % (Fig 4). Generally, the treatment W_2 had significant reduction in panicle length and dead part length / main head (Fig 5 and Fig 6).

At ELRawakeeb and for the average of both locations, W_2 significantly reduced the days to 50 % flowering; fertile tillers /plant and bio mass /plant (Table 4.4 and 4.6). At Shambat, W_2 non – significantly reduced the plant height and number of tillers /plant, whereas it significantly reduced fertile tillers, days to 50 % flowering and date to maturity (Table 4.5).

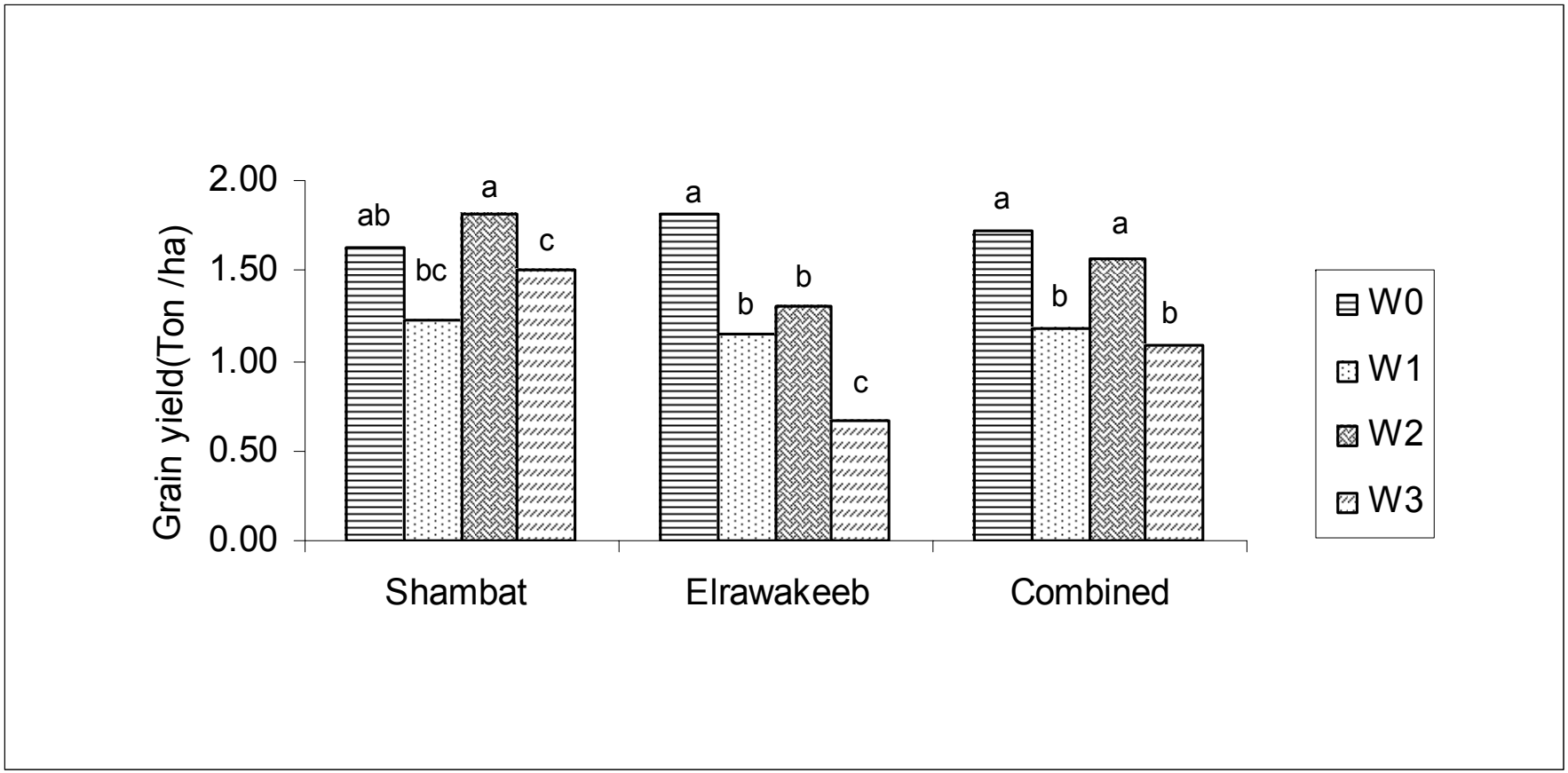

Fig .1. Effect of water treatments on the grain yield (ton / ha) of 15 genotypes of pearl millet at two different Locations (ELrawakeeb 2003/04 and Shambat 2004/05).

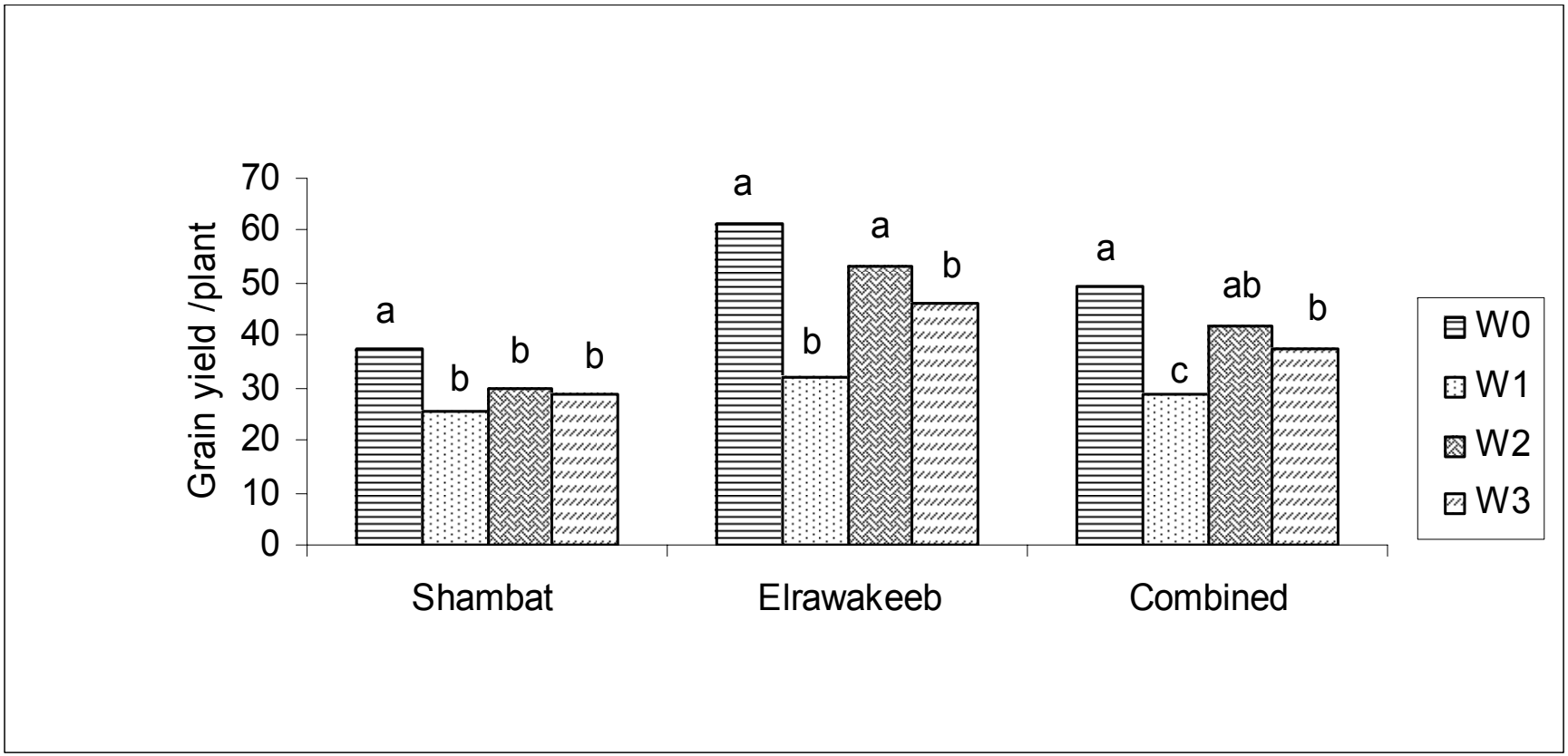

Fig .2. Effect of water treatments on the Grain yield /plant (g) of 15 genotypes of pearl millet evaluated at two different Locations (ELrawakeeb 2003/04 and Shambat 2004/05).

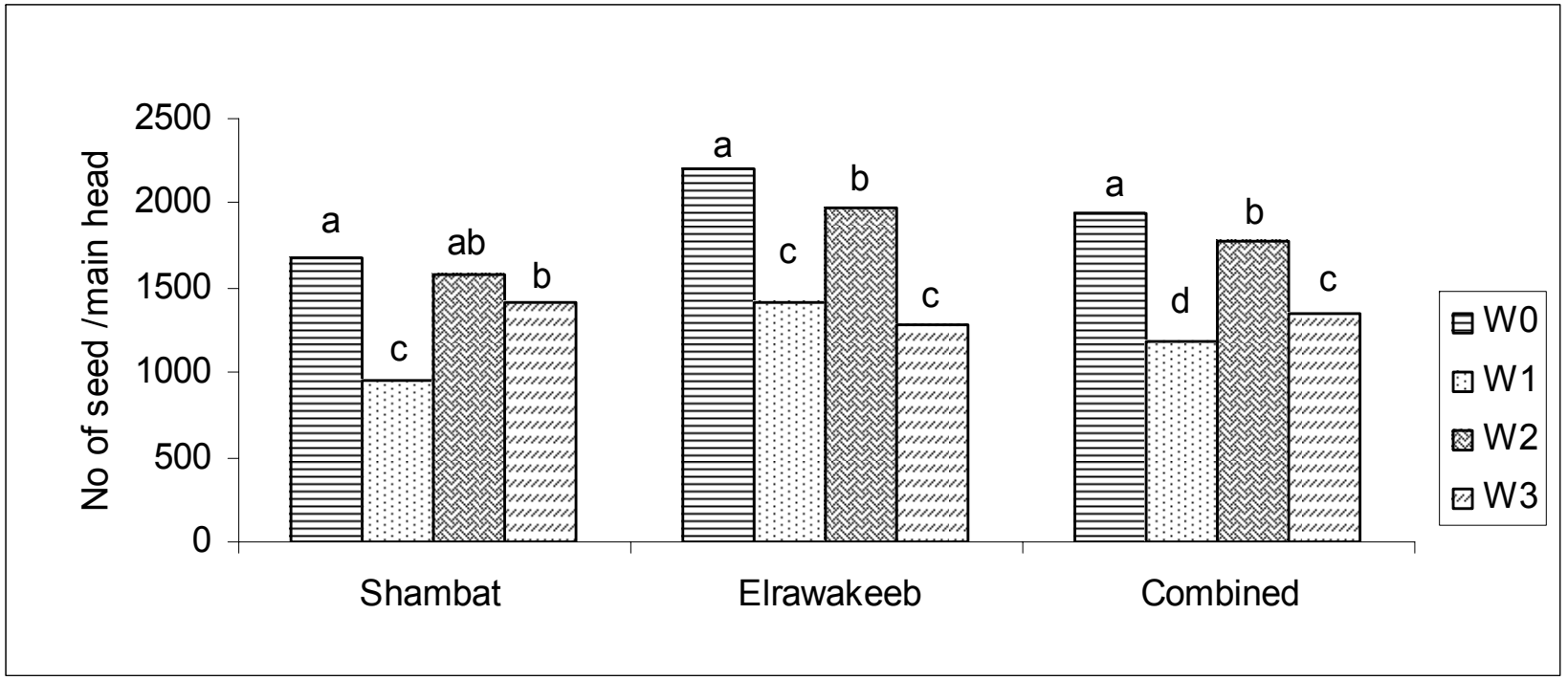

Fig .3 . Effect of water treatments on the Number of seeds / main head of 15 genotypes of pearl millet evaluated at two different Locations (ELrawakeeb 2003/04 and Shambat 2004/05).

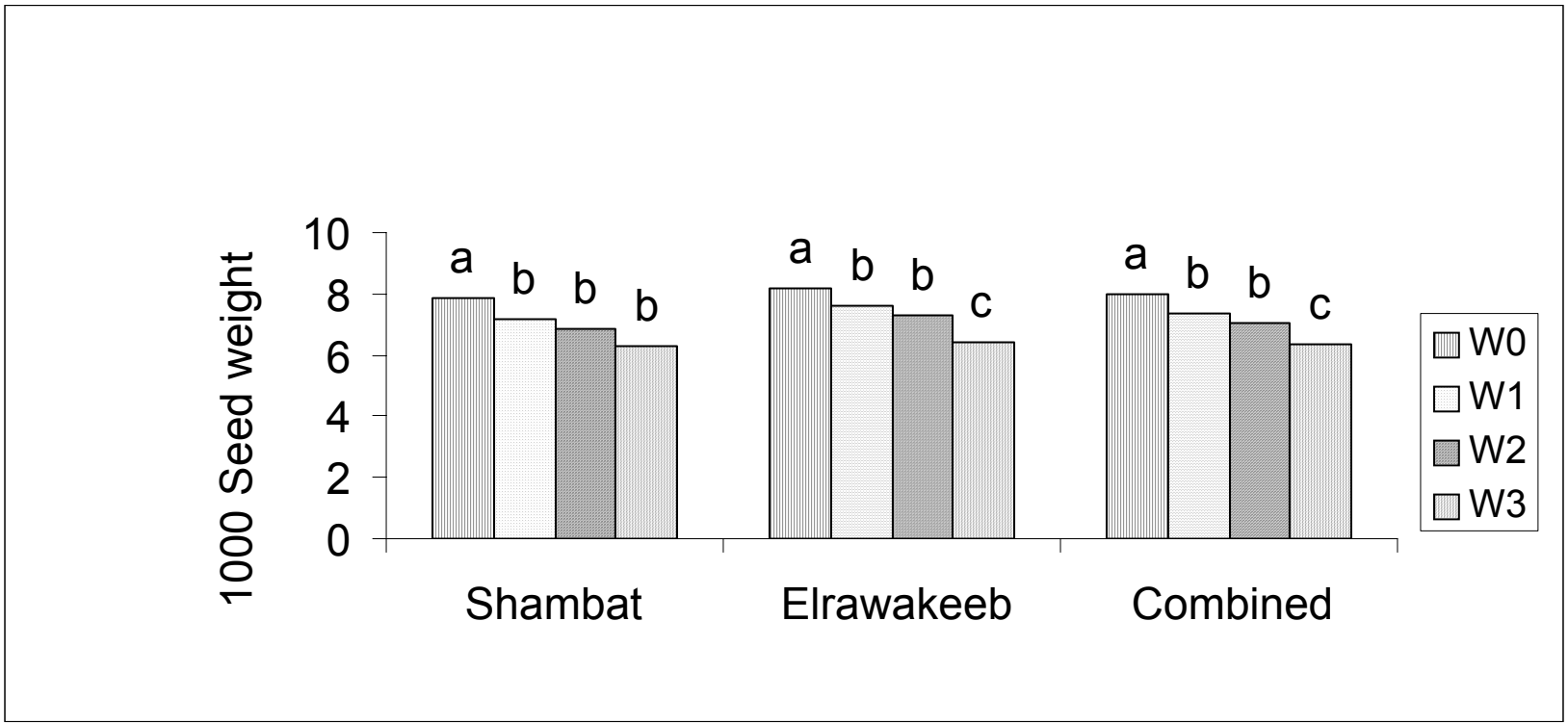

Fig .4. Effect of water treatments on the 1000 - Seed weight (g) of 15 genotypes of pearl millet evaluated at two different Locations (ELrawakeeb 2003/04 and Shambat 2004/05).

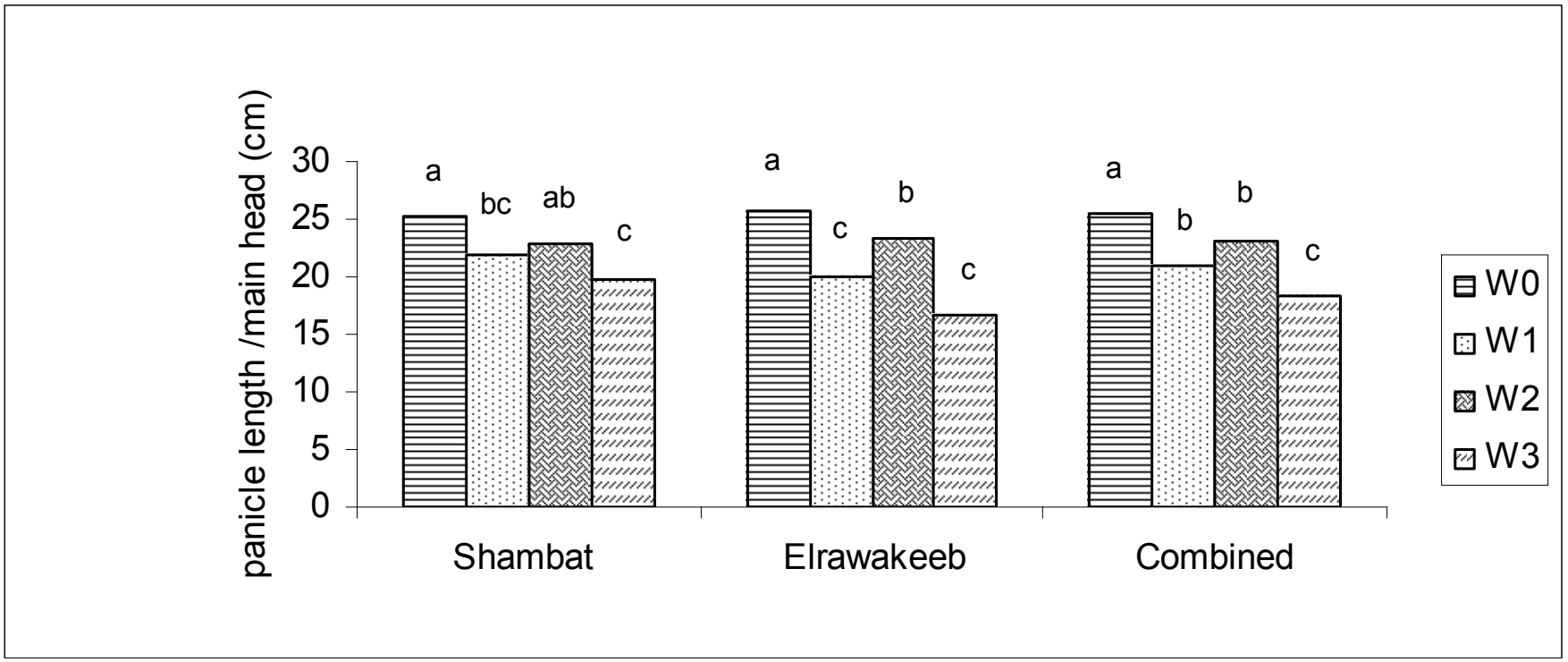

Fig .5. Effect of water treatments on the Panicle length (cm) of 15 genotypes of pearl millet evaluated at two different Locations (ELrawakeeb 2003/04 and Shambat 2004/05).

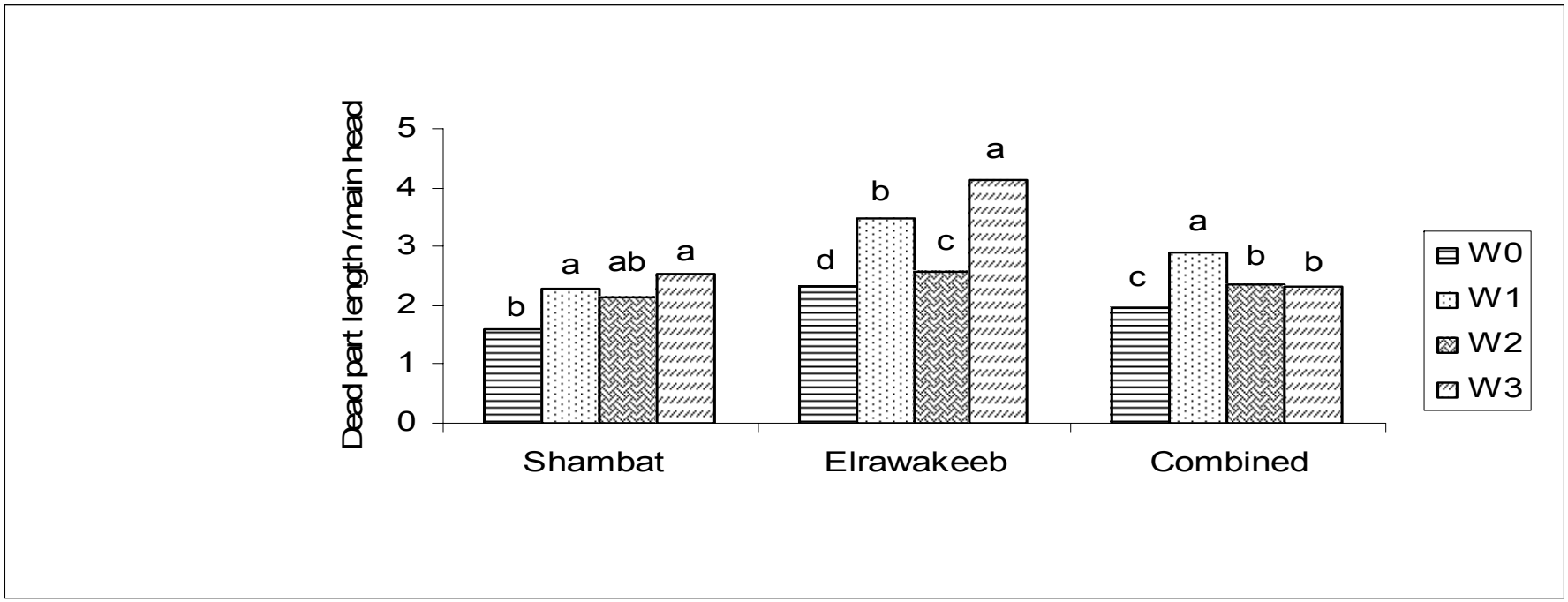

Fig .6. Effect of water treatments on the dead part length /main head (cm) of 15 genotypes of pearl millet evaluated at two different Locations (ELrawakeeb 2003/04 and Shambat 2004/05).

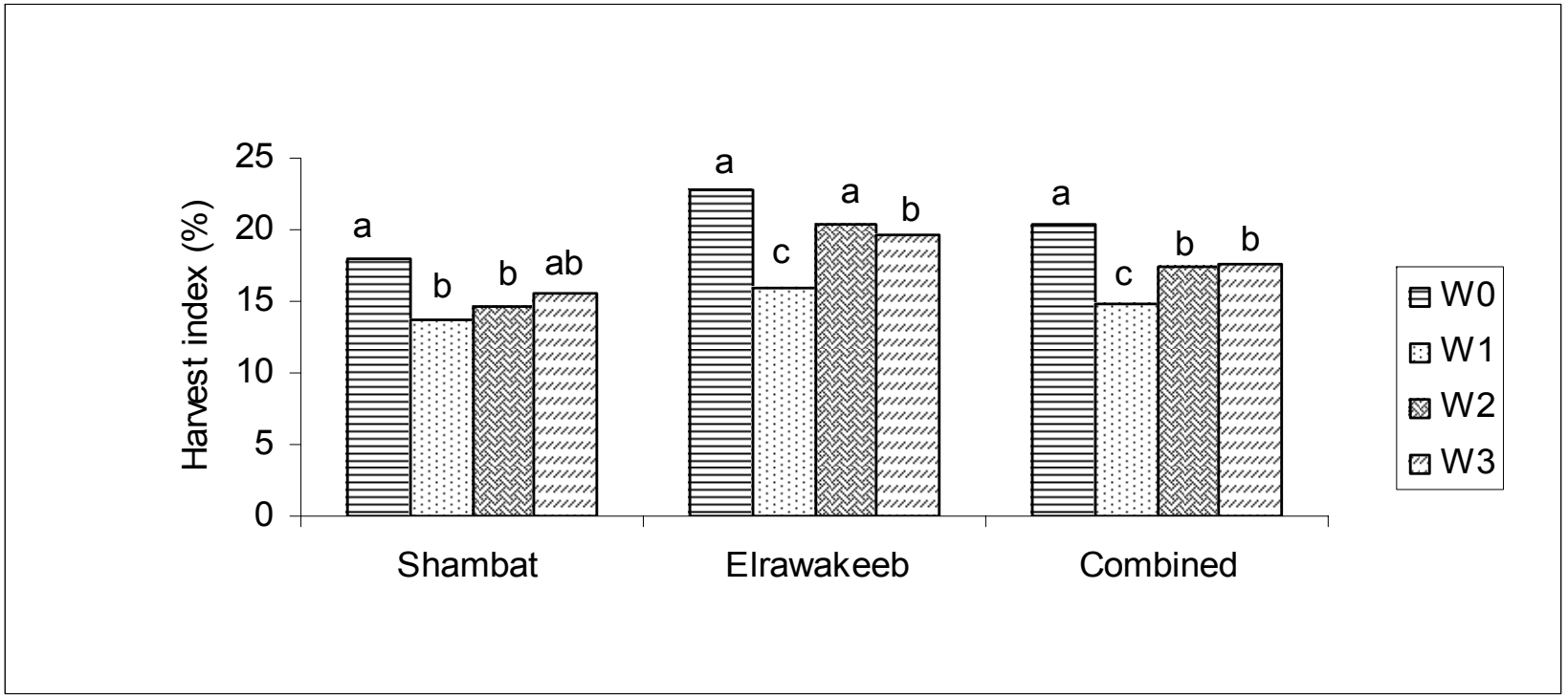

Fig .7. Effect of water treatments on the harvest index (%) of 15 genotypes of pearl millet evaluated at two different Locations (ELrawakeeb 2003/04 and Shambat 2004/05).

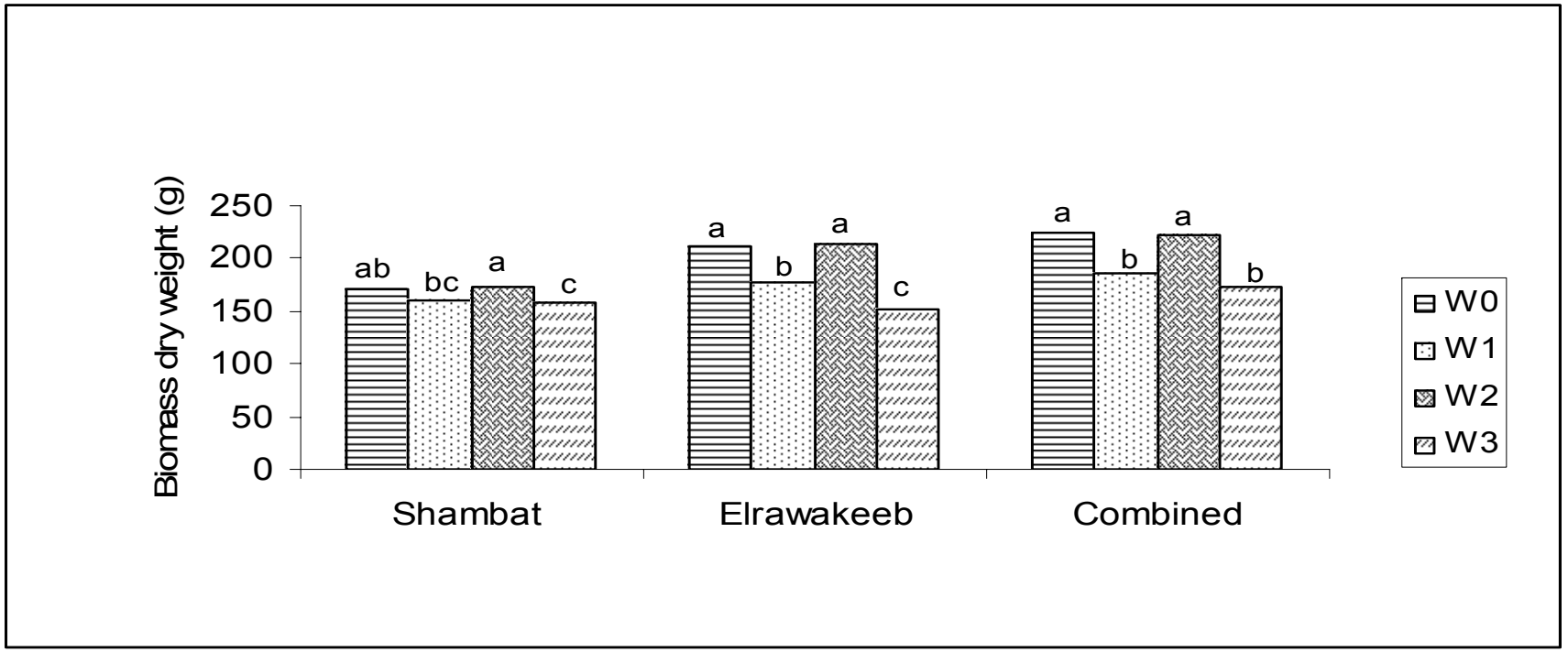

Fig .8. Effect of water treatments on Biomass/plant (g) of 15 genotypes of pearl millet evaluated at two different Locations (ELrawakeeb 2003/04 and Shambat 2004/05).

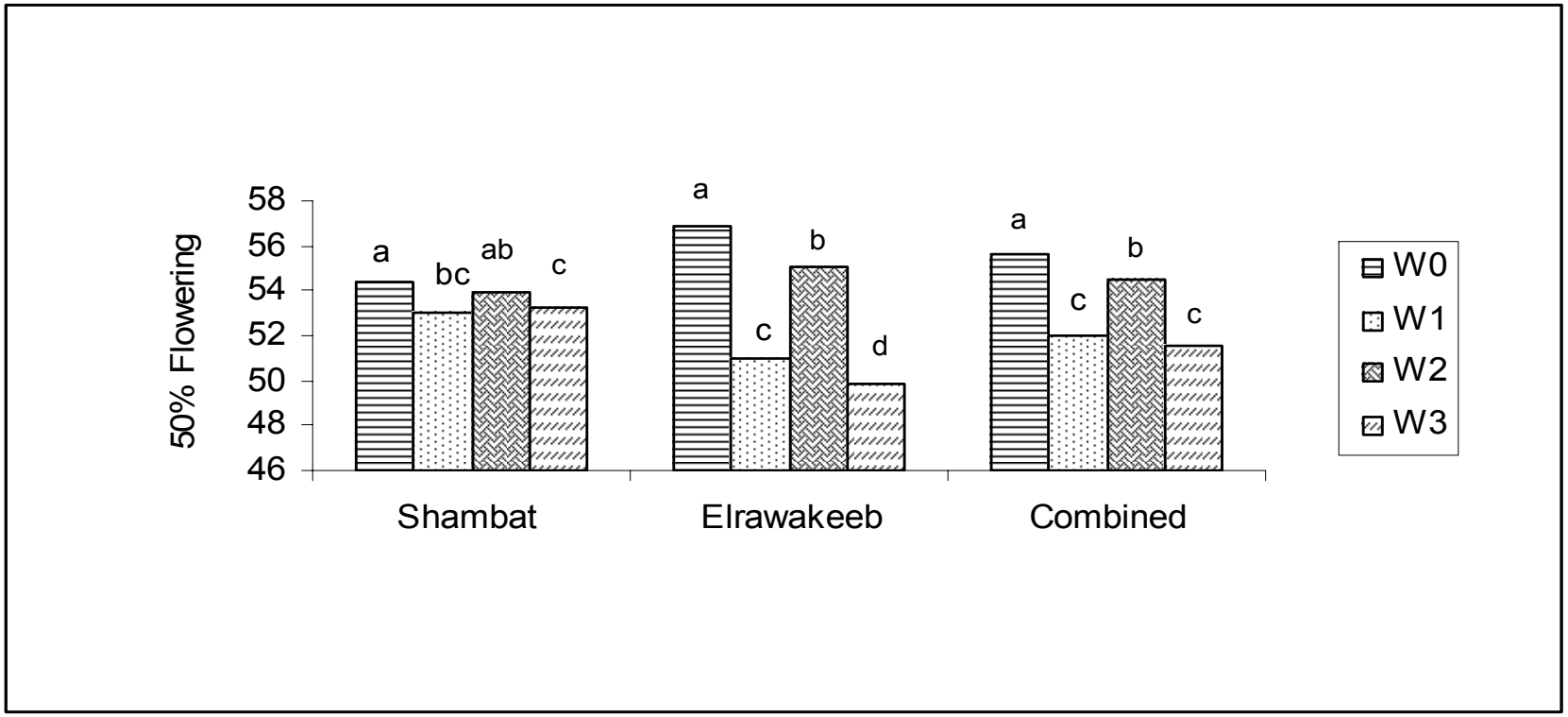

Fig .9. Effect of water treatments on the 50 % flowering (days) of 15 genotypes of pearl millet evaluated at two different Locations (ELrawakeeb 2003/04 and Shambat 2004/05)

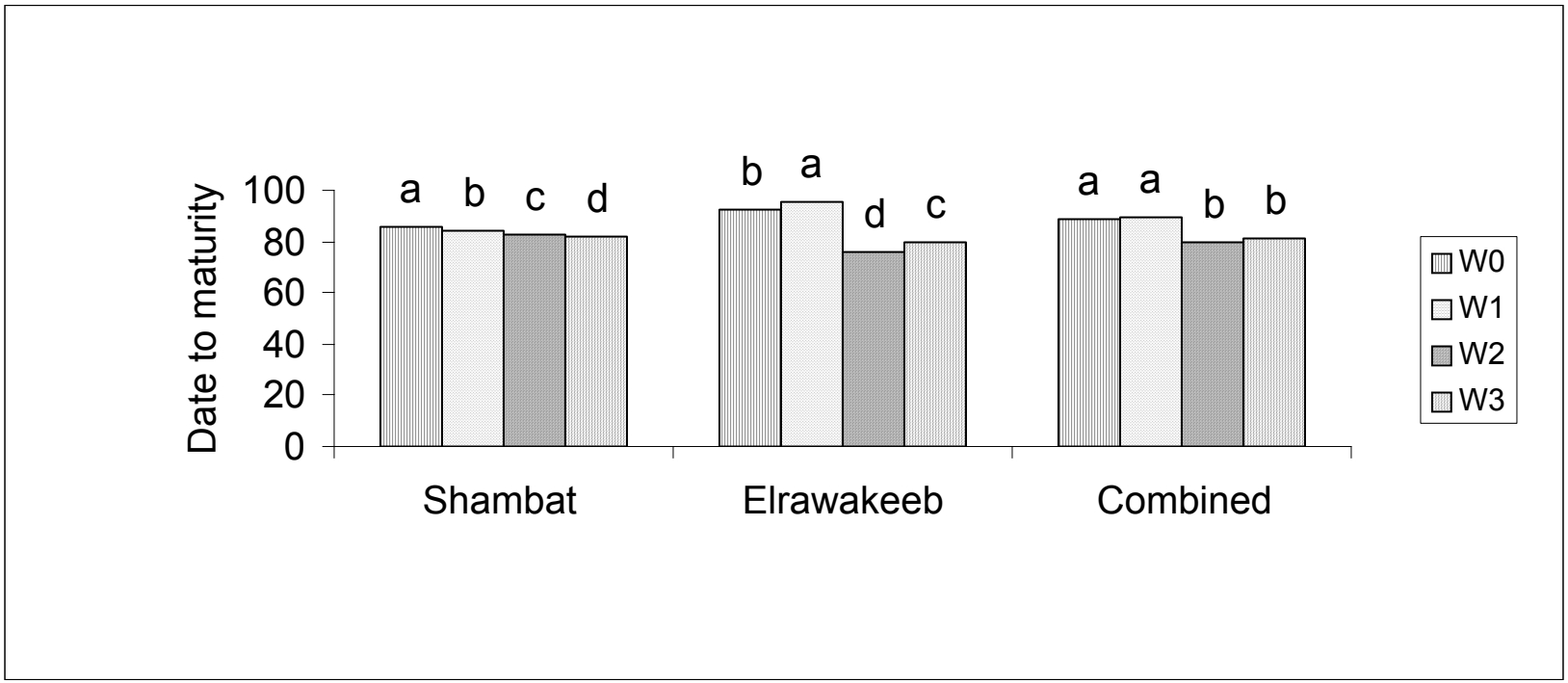

Fig .10. Effect of water treatments on the maturity (Days) of 15 genotypes of pearl millet evaluated at two different Locations (ELrawakeeb 2003/04 and Shambat 2004/05)

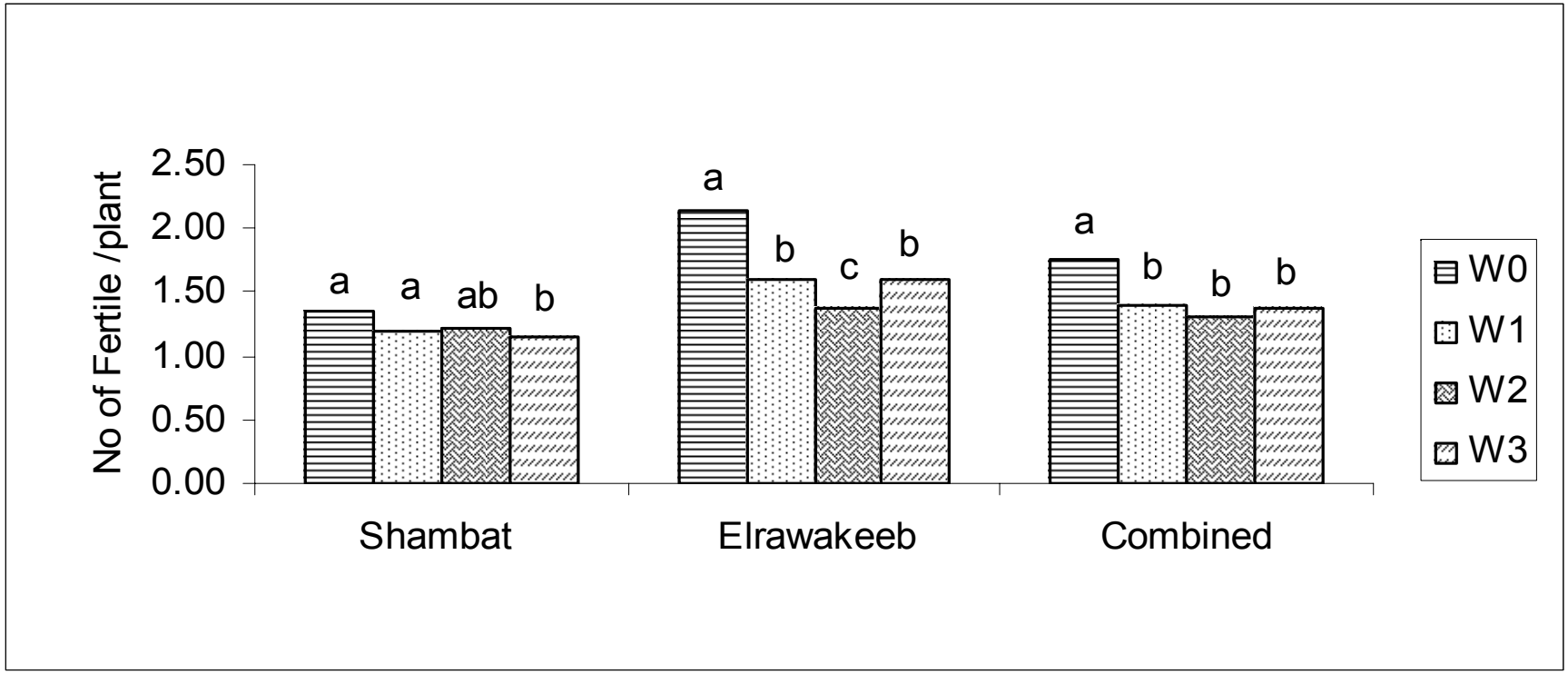

Fig .11. Effect of water treatments on the fertile tillers per plant of 15 genotypes of pearl millet evaluated at two different Locations (ELrawakeeb 2003/04 and Shambat 2004/05)

4.2.3 Effect of drought during both vegetative and reproductive stage:

Drought treatment W3 greatly and significantly reduced the value of most of the investigated traits. (Table 4.4 – 4.6). Generally, the reduction in values of traits due to W_3 was smaller at Shambat than at ELrawakeeb (Fig 1 – 14 and Table 4.4 – 4.6).

Treatment W3 reduced significantly the grain yield (ton /ha) by 63.53%, 8.0 % and 37.2 % at ELrawakeeb, Shambat and the average of both locations (Fig 1). Reductions in grain yield /plant due to W_3 was 8.0%, 38.1 % and 31.2 % at ELrawakeeb, Shambat and average of both locations (Fig 2). For each location, and their average, W_3 significantly reduced the number of seeds /plant, panicle length and 1000 – seed weight (Fig 3, 4 and 5). At ELrawakeeb and for the average of both locations, W_3 was significantly reduced days to 50 % flowering, date to maturity, dead part length and fertile tillers / plant (Table 4.4 and 4.6). At Shambat, W3 significantly reduced days to maturity, days to 50 % flowering, fertile tillers /plant and dead part length (Table 4.5). Where as, it has non significant effect on the harvest index, plant height, number of tillers /plant and leaf area index (30 DAS) (Table 4.5).

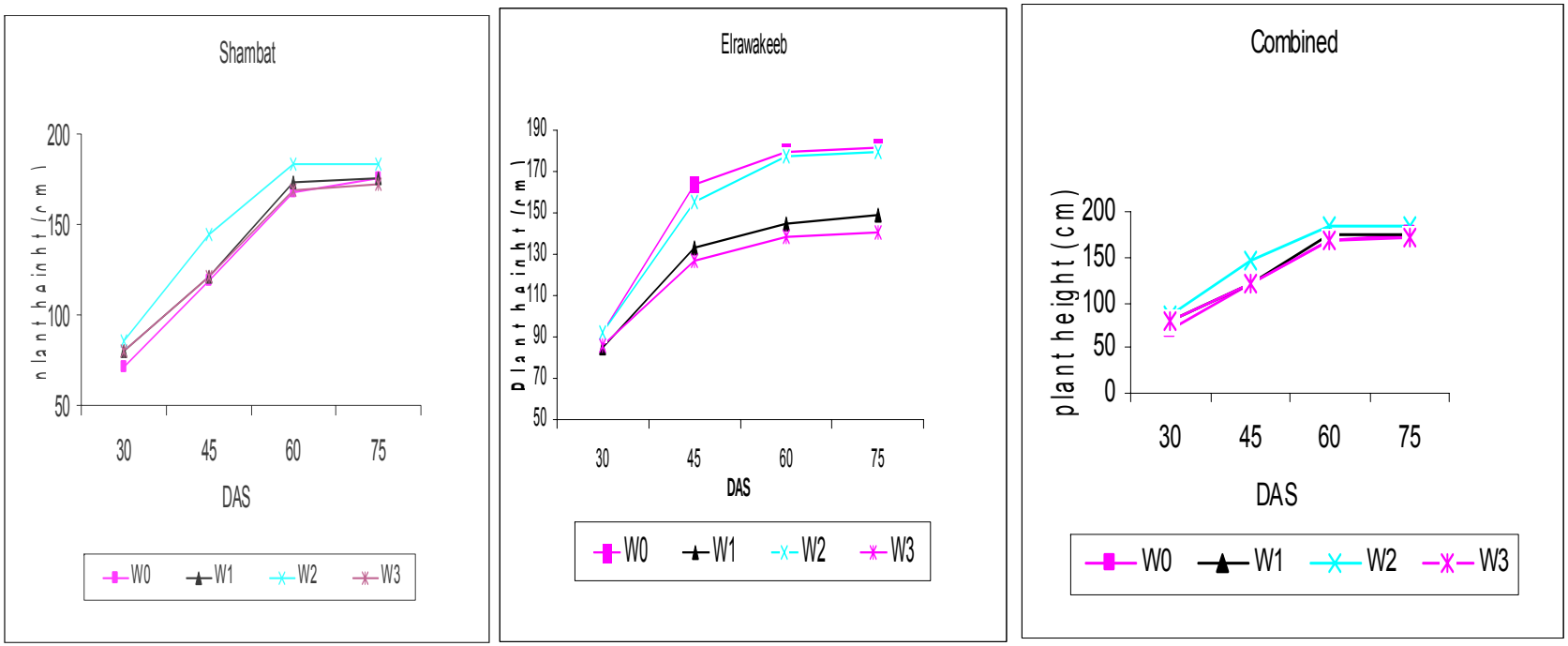

Fig .12 . Effect of water treatments on Plant height (cm) of 15 genotypes of pearl millet , during different periods of growth (30 – 75 days) , evaluated at two different Locations (Elrawakeeb 2003/04 and Shambat 2004/05).

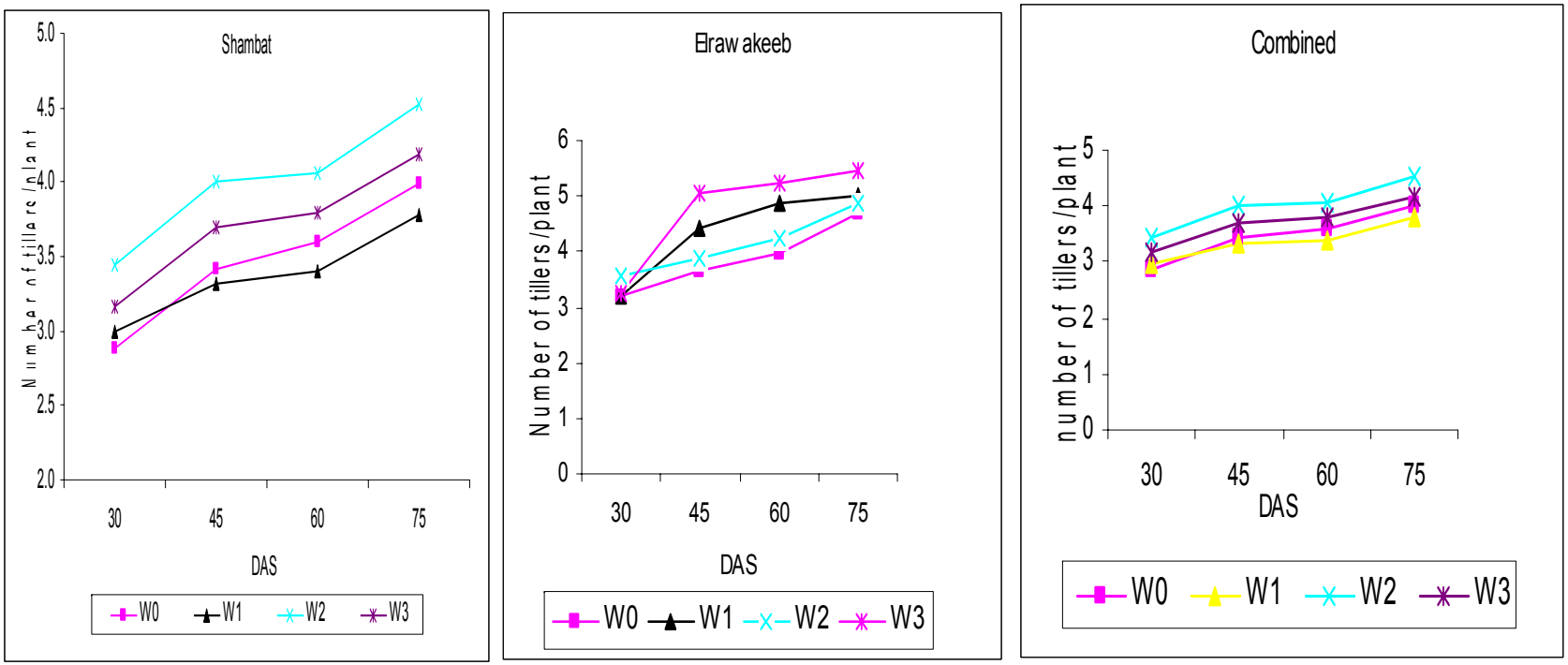

Fig .13. Effect of water treatments on the number of tillers per plant 15 genotypes of pearl millet at different periods of growth (30 – 75 days) , evaluated at two different Locations (ELrawakeeb 2003/04 and Shambat 2004/05)

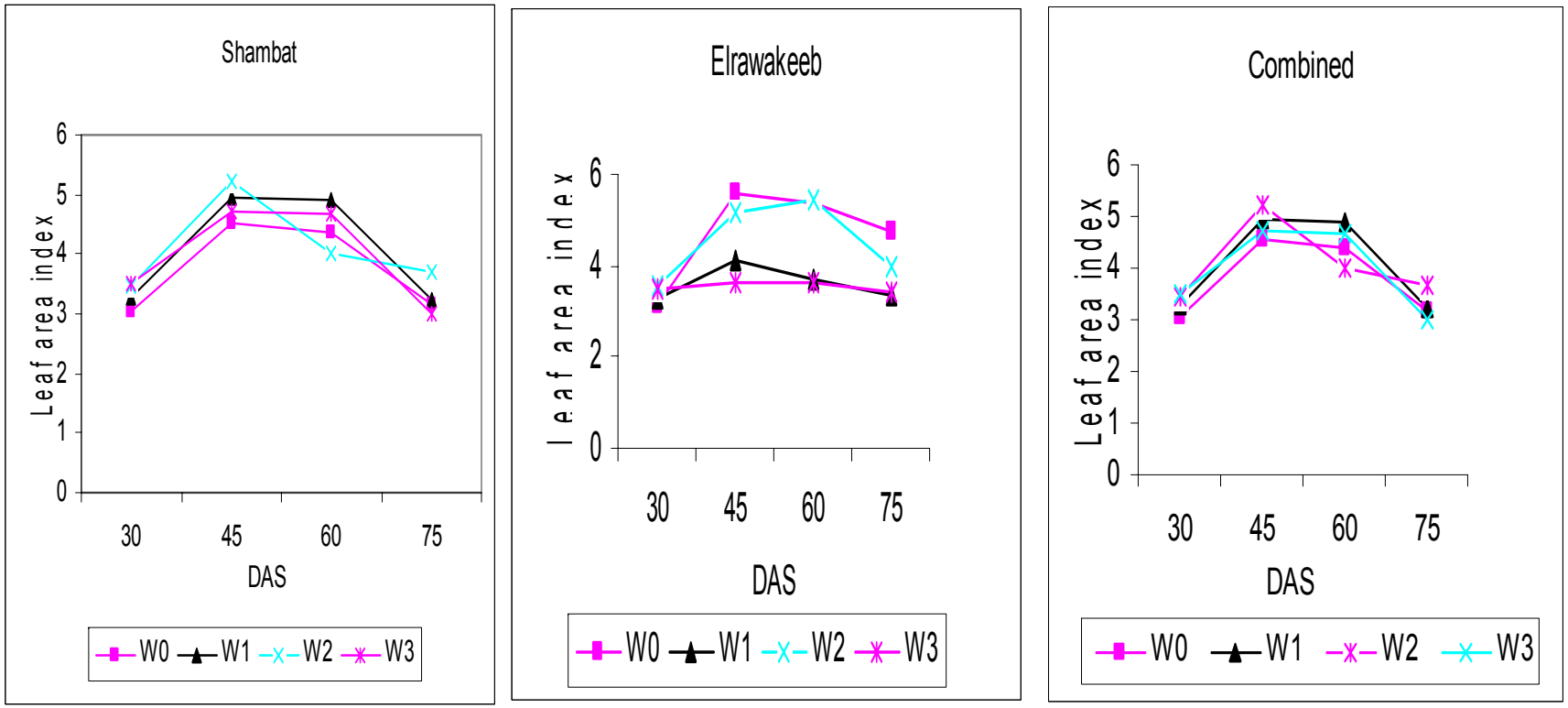

Fig .14. Effect of water treatments on the leaf area index of 15 genotypes of pearl millet at different periods of growth (30-75 days) , evaluated at two different Locations (ELrawakeeb 2003/04 and Shambat 2004/05).

Table 4.4. Means of some vegetative traits for 15 genotypes evaluated under four water treatments W_0, W_1, W_2 and W_3 at ELRawakeeb during the 2003/04 Season.

Water Treatment	Vegetative Traits

a , b , c , d : refer to TMRT of comparison between means . See material and methods .

	HI%	Plant height (cm)				Biomass/plant (g)	FTL	50%Flr (Days)	Matur (Days)
		Ph 30 DAS	Ph 45 DAS	Ph 60 DAS	Ph 75 DAS				
W0	22.8 a	89.2 ab	163.8 a	179.90a	182.0 a	211.7 ab	2.2 a	56.8 a	**92.1 b**
W1	15.9 c	84.3 b	133.5 c	145.1 b	149.4 b	177.0 bc	1.6 b	51.0 c	95.2 a
W2	20.3 a	92.2 a	155.0 b	177.8 a	179.8 a	213.3 a	1.4 c	55.1 b	76.3 d
W3	19.6 b	86.4 ab	126.5 d	137.9 c	140.8 c	151.4 c	1.6 b	49.9 d	80.0 c
Mean	19.6	88.2	144.7	160.2	163.0	188.3	1.7	53.2	85.9
CV %	26.6	15.2	3.9	3.2	3.1	28.2	10.1	3.4	4.3
LSD 5 %	1.9	6.9	2.9	2.7	2.6	27.4	0.09	0.9	1.92

Table 4.5. Means of some vegetative traits for 15 genotypes evaluated under four water treatments W_0, W_1, W_2 and W_3 at Shambat during the 2004/05 Season.

Water Treatment	Vegetative Traits								
	HI%	Plant height (cm)				Biomass/plant (g)	FTL	50%Flr (Days)	Matur (Days)
		Ph 30 DAS	Ph 45 DAS	Ph DAS 60	Ph 75 DAS				
W0	17.9 a	71.4 a	119.3 a	164.5 a	175.25a	171.8 ab	1.4 a	59.02a	**85.9 a**
W1	13.8 b	79.8 a	121.3 a	168.9 a	175.35 a	161.2 bc	1.2 ab	55.6 bc	84.2 b
W2	14.7 b	85.8 a	144.8 a	171.2 a	183.54 a	173.5 a	1.2 a	55.8 ab	82.9 c
W3	15.5 ab	80.3 a	121.4 a	162.0 a	171.90 a	155.1 c	1.14 b	54.0 c	81.8 d
Mean	15.5	79.3	126.7	166.66	176.5	165.2	1.23	56.6	83.6
CV %	36.7	33.1	35.4	15.85	19.66	12.9	25.89	2.5	1.5
LSD 5 %	2.9	13.5	23.2	13.63	17.90	11.0	0.16	0.7	0.6

a , b , c , d : refer to TMRT of comparison between means . see material and methods .

Table 4.6. Mean of some vegetative traits for 15 genotypes evaluated under four water treatment W_0, W_1, W_2 and W_3 averaged over two locations (ELRawakeeb 2003/04 and Shambat 2004/05) respectively

Water Treatment	Vegetative Traits								
	HI%	Plant height				Biomass/ Plant (g)	FTL	50%Flr (Days)	Matur (Day)
		Ph 30 DAS	Ph 45 DAS	Ph DAS 60	Ph 75 DAS				
W_0	20.4 a	80.6 a	141.5 b	173.2 a	178.6 a	191.8a	1.2 a	57.9 a	89.0 a
W_1	14.8 c	82.1 a	127.4 c	156.0 b	162.4 b	169.1b	1.0 b	53.3 c	89.7 a
W_2	17.5 b	89.0 a	149.9 a	174.5 a	181.7 a	193.4 a	1.0 b	56.4 b	79.4 b
W_3	17.5 b	83.4 a	123.9 c	150.0 c	156.3 c	153.2 b	1.0 b	51.9 c	80.9 b
Mean	17.6	83.8	135.7	163.4	169.8	176.9	1.0	54.9	84.8
CV %	16.4	15.9	17.4	5.8	11.2	15.9	15.4	1.8	2.5
LSD 5 %	1.5	6.9	12.2	4.8	9.8	15.9	0.1	0.5	1.1

a , b , c , d : refer to TMRT of comparison between means . See material and methods.

4.3. Genetic analysis of drought tolerance

4.3.1 Genetic variability for drought tolerance

Combined analysis showed highly significant ($P \leq 0.01$) differences among genotypes for most of drought tolerance parameters,except for Yd 3 and GMP3 (Table 4.7). Significant differences due to the interaction of genotypes with location (G× e) were observed for the parameters Yw, Yd and SSI (Table 4.7). However, non significant (G × e) interaction was determined for Yd/Yw.

4.3.1.1 Means of drought tolerance of genotypes:

A wide range for values of drought tolerance parameters was exhibited by genotypes (Table 4.8). Most of the genotypes were less affected by drought stress W_2 was compared to W_1 and W_3 (Table 4. 8).

Performance of genotypes. The highest value of grain yield /plant (Yw = 60.67) was obtained by genotype Madelakawyia and the lowest value (Yw = 34.55) was produced by genotype JM 3. Under W_1, the highest grain yield /plant (Yd1 = 36.30) was reached by Madelakawyia while the lowest value of grain yield (Yd 1 = 20.71) was obtained by genotypes JM 21. When drought was induced during reproductive stage (W_2) , the range of Yd2 was from 31.9 g for genotypes JM 3 to 50.29 g for genotype JM 24. Under drought stress W_3 the highest value was obtained by genotype JM 38 and the lowest was produced by genotype JM 49.

High value of drought tolerance as measured by (Yd/Yw) were exhibited under W_2, and low values when genotypes were evaluated under W_3 (Table 4.8) . The highest value of Yd/Yw under W_1 (78 %) was produced by the genotypes Bs / Sh / 94. When drought was induced under W_2, the highest Yd/Yw (94 %) was obtained by genotypes Madelkawiya .Highest value (87 %) of drought tolerance Yd/Yw under W_3 was exhibited by genotypes JM 38 (Table 4.8) .

Estimates of stress susceptibility index under different level of drought are given in Table 4.8. The highest value (1.45) of SSI under W_1 was obtained by genotype JM 24. (Table 4.8). The highest value (2.11) of SSI under W_2 was exhibited by genotype JM 30. Under W_3 the highest SSI (2.19) was obtained by genotype JM 24 (Table 4.8).

The highest value of geometric mean of productivity (GMP1 = 46.90) under W_1 was exhibited by genotype 23, while the highest value of (GMP2 = 54.73) under W_2 was exhibited by Madelkawiya. Under W_3 the highest value of geometric (GMP3 = 50.10) was obtained by obtained by genotype Madelkawiya. Whereas, the lowest value of GMP under W_1 was exhibited by genotype JM21 and by genotypes JM3 under W_2 and W_3 (Table 4.8).

Table 4.7. Variance components due to genotypes (G) and their interaction with location (G×L) among 15 pearl millet genotypes for drought tolerance traits (Yd, Yd/Yw, GMP, and SSI).

Drought tolerance parameters		G	G × L
DF		**14**	**14**
Yw	W_0	2.29 *	3.32 **
Yd	W_1	3.70 **	3.88 **
	W_2	2.86 **	2.38 **
	W_3	1.98 *	1.55 ns
Yd/Yw (%)	W_1	2.26 *	2.07 *
	W_2	0.91 ns	0.81 ns
	W_3	1.29 ns	1.24 ns
GMP	W_1	3.66 **	3.87 **
	W_2	2.85 **	3.89 **
	W_3	2.46 *	2.28 *
SSI	W_1	1.35 ns	1.52 ns
	W_2	0.98 ns	0.84 ns
	W_3	1.30 ns	1.35 ns

*, ** = significant of probability 0.05 and 0.01 , respectively

ns = non significant

Yw, Yd, Yd/Yw, SSI, GMP = Drought tolerance parameters W_0, W_1, W_2, W_3 water treatment s as in the materials and methods.

Table 4.8. Mean of drought tolerance parameters of 15 pearl millet genotypes evaluated at four water treatments across two locations (Shambat and ELRawakeeb) in 2003/2004.

Genotypes	yw	yd			Yd/Yw			SSI			GMP		
	W_0	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
JM 49	46.49	28.70	34.01	20.64	0.62	0.73	0.44	0.78	2.09	1.97	35.94	39.70	30.65
JM 25	53.48	29.16	40.50	40.77	0.55	0.76	0.76	0.85	1.92	1.03	38.60	46.46	45.93
JM 21	39.98	20.71	32.58	23.79	0.52	0.81	0.60	1.30	1.44	1.59	28.67	35.19	30.35
JM 45	49.54	28.50	35.75	28.00	0.58	0.72	0.57	1.00	1.39	1.53	36.98	41.09	36.36
JM 44	55.63	23.76	48.33	34.37	0.43	0.87	0.62	1.29	1.29	0.41	36.03	51.73	42.61
JM 48	45.52	33.89	38.95	30.04	0.74	0.86	0.66	0.61	1.10	1.47	39.16	41.63	36.58
JM 36	47.27	32.52	44.42	29.70	0.69	0.94	0.63	0.79	0.27	1.19	38.83	45.63	36.96
Madelkawiya	60.67	36.30	50.29	42.70	0.60	0.83	0.70	0.89	1.20	1.15	46.17	54.73	50.10
JM 3	34.55	25.12	31.88	26.86	0.73	0.92	0.78	0.57	-0.10	0.53	28.93	32.76	29.89
JM 30	55.09	22.88	41.30	37.29	0.42	0.75	0.68	1.32	2.11	1.36	34.45	47.64	44.44
JM 23	59.67	37.43	46.12	44.53	0.63	0.77	0.75	0.64	1.89	0.54	46.90	52.30	51.24
JM 38	55.29	25.90	47.96	48.01	0.47	0.87	0.87	1.11	0.63	0.02	36.98	51.10	50.09
BS / Sh /94	43.96	34.31	37.68	36.55	0.78	0.86	0.83	0.54	0.50	0.20	38.69	40.11	39.19
JM 24	50.51	23.20	49.80	26.87	0.46	0.99	0.53	1.45	0.07	2.19	33.96	49.58	36.34
Ugandi	45.88	27.65	44.02	31.31	0.60	0.96	0.68	0.63	0.12	0.34	34.95	44.79	36.69
Mean	49.57	28.67	41.57	33.43	0.58	0.84	0.67	0.92	1.06	1.03	37.02	44.96	39.83
LSD (0.05)	9.18	6.05	8.10	11.12	0.16	0.21	0.22	6.26	7.36	8.78	0.48	1.60	1.05

Yw, Yd, Yd/Yw, SSI, GMP = Drought tolerance parameters W_0, W_1, W_2, W_3 water treatment s as in the materials and methods.

4.3.1.2 Yield components variability:

The combined analysis of variance (Table 4.9) revealed highly significant differences among genotypes under different levels of drought for most of yield components. Variation due to genotypes × locations interaction was non- significant for most of yield components, except for 1000 – seed weight under (W_2), number of seeds / main panicle under (W_0) and panicle length under W_0 , W_1, W_2 , (Table 4.9).

Grain yield (ton / ha):

Highly significant differences were obtained between different levels of water stress among genotypes for this trait (Table 4.9). The highest value under W_0 was produced by JM 23. Under W_1, W_2 and W_3 treatments, the highest value of grain yield (ton / ha) was obtained by Ugandi, JM 44 and Ugandi respectively. (Appendix .6) Where as , the lowest value of grain yield (ton/ha) under W_1 , W_2 , W_3 exhibited by JM 3 , JM 36 and JM 21 respectively (Appendix . 6)

Number of seeds /main panicle:

The analysis of variance (Table 4.9) showed significant difference ($P \leq 0.01$) among genotypes for these traits under W_0, W_1, W_2 and W_3 treatments. How ever , the highest number of seeds per main panicle was obtained by genotype Bs / sh / 94 under W_0 , by genotype JM 23 under W_1 , by genotype JM 36 under W_2 and by genotype ugandi under W_3 (Appendix 8) . Under W_1 , W_2 and W_3 the lowest value of number of seeds per main panicle was JM 38 , JM JM 3 and JM 25 repectively (Appendix .8)

Main panicle length / head (Cm):

The combined analysis exhibited significant difference ($P \leq 0.05$) among the evaluated millet genotypes between the four water treatments (Table 4.9). The water × genotypes interaction was significantly for this trait. The

genotypes JM 45, JM 38 and Madelakwayia produced highest value of panicle under W_0, W_1, W_2 respectively .The genotype JM 36 reached the highest value of panicle under W_3. (Appendix 11) , the lowest value of panicle length per main head was exhibited by JM45 , JM 21 , JM 45 under W_1 , W_2 , W_3 respectively .

1000 – Seed weight (g):

Analysis of variance revealed significant different ($P \leq 0.05$) among the evaluated millet genotypes between the four water treatments (Table 4.9). The water × genotypes interaction was significant for this trait, except for W_2. The highest value of the 1000 – seed weight was produced by the genotype JM 45 under W_0, JM 38 under W_1, Madelakawyia under W_2 and genotype JM 36 under W_3 (Appendix. 9). Where as, the lowest value of the 1000- seed weight was obtained by genotype JM 23 under W_1 , JM 48 under W_2 and JM 21 under W_3 (Appendix . 9)

Table 4. 9: Mean squares from combined analysis of variance due to genotypes and genotypes × location interaction for different yield components to study the variability of genotypes under different water treatments.

		d.f	W_0	W_1	W_2	W_3
Grain yield (Ton /ha)	G	14	0.66 **	1.17 **	0.85 *	0.39 *
	G × L	14	0.28 ns	0.40 ns	0.32 ns	0.40
Number of fertile tillers /plant	G	14	4.00 ns	0.64 **	0.15 ns	0.57 **
	G × L	14	0.16 ns	0.39 ns	0.42 **	0.43 **
Main panicle length	G	14	18.74 **	36.45 **	18.37 **	36.78 *
	G × L	14	19.01 **	17.18 **	4.30 **	20.74 **
Number of seed /main panicle	G	14	0.86 ns	0.15 **	0.63 **	0.30 ns
	G × L	14	0.17 ns	0.15 **	0.31 **	0.15 ns
1000 – Seed Weight (g)	G	14	9.86 **	9.66 **	5.07 **	2.31 *
	G × L	14	6.18 *	5.53 *	1.60 ns	2.40 *

*, ** = significant of probability 0.05 and 0.01, respectively

ns = non significant

4.3.2 Heritability (h^2), genotypic coefficient of variation (GCV) and genetic advance (GA) under different water treatments.

4.3.2.1 Drought tolerance parameters

The highest estimates values of h^2 were recorded for Yd1, Yd2 and GMP2. The lowest value of h^2 was observed for Yd3/yw and SSI3. Moreover, the highest value of GCV was recorded for SSI3 and Yd3 (Table 4.10). The highest of genetic advance (GA) was found for Yd1, Yd3/Yw, SSI and GMP2 (Table 4.10).

4.3.2.1 Yield and yield components

For yield components, the highest value of GCV was obtained by grain yield (ton /ha) under most water treatments. Under W_0 the characters which obtained high heritability ($h^2 > 60$) were number of seed / main panicle and panicle length / main head although. Under W_1 the high values of heritability were obtained by panicle length / main panicle but under W_3 the high value of heritability were given by panicle length / main head. Nevertheless, under W3 the high values of heritability were attained by 1000 – seed weight. The grain yield / plant attained high value of GA under all water treatments.

Grain yield (Ton / ha)

The highest value (45.71) of genotypic cofficient of variation was recorded for grain yield (ton / ha) under W_1. Relatively high estimate of heritability (h^2 = 0.49) was recorded for gain yield (ton / ha) under W_2. Also the highest value of genetic advance (GA = 0.55) was obtained under W_1.

Number of seeds / main panicle

The highest value of genotypic coefficient of variation (GCV = 24.81), heritability (h^2 = 0.82) and genetic advance (GA = 0.74) were obtained under W_2 (Table 4.10).

Panicle length/head (Cm).

The highest value of genotypic coefficient of variation (GCV = 16.35) was recorded under W_0. More over, the highest value of heritability (h^2 = 0.73) and genetic advance (GA = 5.97) were observed for panicle length under W_0 (Table 4.10).

1000 – Seed weight (g).

The highest value of GCV was recorded under W_0. Whereas, the highest value of heritability (h^2 = 0.47) was found under W_0 .The highest value of GA was 1.50.

Table 4.10. Estimates of heritability, genotypic coefficient of variation and genetic advance under different water treatments for drought tolerance and other yield components at (Shambat and ELrawakeeb) Locations.

Traits	Water treatments	h^2	GCV (%)	GA (%)
Grain yield /plant	W_0	0.30	15.53	4.77
	W_1	0.48	22.07	6.26
	W_2	0.40	17.48	6.00
	W_3	0.25	23.92	4.06
Yd/Yw	W_1	0.12	14.37	0.02
	W_2	#	#	#
	W_3	0.09	12.90	0.02
SSI	W_1	0.10	23.58	0.05
	W_2	#	#	#
	W_3	0.09	43.52	0.09
GMP	W_1	0.38	15.17	2.20
	W_2	0.47	17.41	3.78
	W_3	0.33	19.65	2.64
Grain yield ton / ha	W_0	0.37	21.73	0.28
	W_1	0.49	45.71	0.55
	W_2	0.28	25.07	0.23
	W_3	0.24	23.08	0.12
No of seed /main panicle	W_0	0.71	25.57	0.73
	W_1	0.47	16.09	0.19
	W_2	0.82	24.81	0.74
	W_3	0.10	11.71	0.03
Panicle length / main head	W_0	0.73	16.35	5.97
	W_1	0.59	14.97	3.78
	W_2	0.26	6.60	0.82
	W_3	0.23	13.35	1.12
1000- Seed weight	W_0	0.47	19.65	1.50
	W_1	0.46	21.21	1.43
	W_2	0.34	21.12	0.71
	W_3	0.30	13.91	0.55

the value were not calculated because their variance was negative

4.3.3 Correlation between drought tolerance parameters:

Highly significant correlation coefficient between performances of 15 pearl millet genotypes under the different water treatment were exhibited (Table 4.11)

The relationship between Yd and Yw was strong and positive it ranges from (0.291 — 0.576). The correlation between Yd/Yw and Yw was negative and significant under W_1 and W_2. Whereas, it was non significant negative (-0.092) under W_3. On the other hand, the relationship between W_0 and other drought parameter SSI, GMP was strong and positive. (Table 4.11).

The correlation for Yd1 was significant and positive with Yd3/Yw, SSI3, GMP2 and GMP3, but it was non significant and negative with Yd2/Yw and SSI 3 (Table 4.11).

The correlation for Yd/Yw under the different water stress treatments with Yw was negative and significant. The negative correlations for Yd/Yw was found with Yd1, Yd2, SSI and GMP determined under different treatments (Table 4.11)

Significant negative correlation was recorded for Yd2/Yw with SSI1 and GMP1.

Non significant positive correlation was obtained for SSI , with other SSI determined under other water treatments GMP2 and GMP3 , also SSI2 had non significant positive correlation with SSI3 and GMP1 . The correlation was found for SSI3 with GMP1 and GMP2 (Table 4.11).

Significant positive correlations were recorded for GMP with Yw and for drought tolerance determined by GMP under different water treatments (Table 4.11)

Table 4.11: Phenotypic correlation coefficient between the different drought tolerance parameters for pearl millet genotypes average over locations and under four water treatments.

Parameters		Yd			Yd / Yw			SSI			GMP		
		W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3	W_1	W_2	W_3
YW		0.291	0.576*	0.547*	-0.527*	-0.478	-0.092	0.460	0.511	0.114	0.753**	0.885**	0.810**
Yd	W_1		0.126	0.230		-0.176	0.115		0.188	-0.100		0.238	0.295
	W_2			0.363	-0.298		0.076	0.236		-0.327	0.401		0.495
	W_3				-0.186	-0.159		-0.556*	0.188		0.442	0.511	
Yd/Yw	W_1					0.309	0.259		-0.326	-0.286		-0.457	-0.350
	W_2						0.243	-0.945**		-0.286	-0.392		-0.318
	W_3							-0.300	-0.247		-0.300	-0.939**	
SSI	W_1								0.330	0..381		0.412	0.009
	W_2									0.382	0.110		-0.019
	W_3										0.290	0.340	
GMP	W_1											0.651**	0.639**
	W_2												0.731**

Yw , Yd , Yd/Yw , SSI , GMP = Drought tolerance parameters
W_0, W_1, W_2, W_3 = Water treatment as in material and methods
**,* = Significant of probability 0.01 and 0.05 respectively

4.4 Phenotypic variability:

The analysis of variance (Table 4.2) revealed highly significant differences ($P \leq 0.01$) among the 15 pearl millet genotypes for most of the characters studied. Variation due to genotypes × treatments interaction was non significant for most of the investigated traits at Shambat .Whereas, it was significant different for all the characters at Elrawakeeb, except the number of tillers / plant at 30 DAS, grain yield (ton /ha), harvest index, biomass/ plant and panicle length/ main head (Table 4.2).

The combined analysis (Table 4.3) showed that the 15 pearl millet genotypes were significantly different in all characters, more over, the interaction between locations × genotypes was significant for most of character, except number of tillers / plant at 30 DAS and leaf area index at 30 DAS. The phenotypic variability for the yield, yield components and vegetative traits is described as follows:

4.4.1 Plant height (CM):

Highly significant differences ($P \leq 0.01$) in plant height (75 DAS) were shown by 15 pearl millet genotypes (Table 4.2) at both locations. The combined analysis revealed highly significant variation due to genotypes and genotypes × locations interactions (Table 4.3). The over all mean was 176.5, 162.9 and 169.8 at Shambat, Elrawakeeb and the average of both locations respectively. The range was from 160.7 to 195.2 cm recorded for the genotypes BS/ Sh /94 and JM 30 respectively at Shambat (Appendix .4). At Elrawakeeb plant height ranges from 151.1 cm for genotypes JM 38 to 186.1 cm for genotypes JM 23. For the average of both locations range from 159.8 for JM 36 to 181.30 for JM 23. (Appendix .3). The coefficient of variations for this character was 9.5, 2.4 and 5.0 at Shambat, Elrawakeeb and the average of both locations.

4.4.2 Days to 50 % flowering:

The differences among the evaluated genotypes for this character were found to be highly significant ($P \leq 0.01$) in both locations (Table 4.2). The combined analysis revealed highly significant variation due to genotypes and genotypes × locations interactions. The over all mean was 56.6, 53.1 and 54.9 days at Shambat, Elrawakeeb and for the average of both locations respectively. The genotypes Ugandi was the earliest one at Shambat (Appendix .4). Genotype BS/ Sh /94 was the earliest at Elrawakeeb (Appendix .3). The earliest genotype for the average of both locations was Ugandi. The latest flowering genotype was JM 24 at Shambat, JM 3 at Elrawakeeb and for the average of both locations (Appendix 3, 4 and 15).

4.4.3 Days to maturity:

Highly significant differences ($P \leq 0.01$) among the genotypes were recorded at both locations (Table 4.2). The combined analysis showed significant difference among genotypes and genotypes × locations interaction for this traits (Table 4.3). The over all mean for this trait was 83.6 at Shambat, 85.9 at Elrawakeeb and 84.8 days for the average of both locations. The genotypes BS /Sh / 94 was the earliest one at Elrawakeeb, Shambat and the average of both locations (Appendix 3 ,4 , 16) .The latest maturing genotypes was JM 3 at Shambat, Elrawakeeb and the average of both locations.

4.4.4 Grain yield / plant

Highly significant differences ($P \leq 0.01$) among genotypes were recorded at both locations (Table 4.2). The combined analysis showed significant difference among genotypes and non-significant difference variation due to genotypes × locations interaction for this traits. (Table 4.3). The over all mean were 30.5, 46.1 and 38.3 g at Shambat, Elrawakeeb and the

average of both locations respectively .The high grain yields were obtained by Madelakawyia at Shambat and the average of both locations and by JM 23 at ELrawakeeb locations (Appendix 3, 4 and 7).

4.4.5 Grain yield ton / ha:

At both locations, there were highly significant differences ($P \leq 0.01$) among the genotypes for this character (Tables 4.2). The combined analysis releaved highly significant variation due to genotypes and genotypes × locations interaction (Table 4.3). The over all mean was 1.5, 1.2 and 1.4 ton / ha at Shambat, Elrawakeeb and the average of both locations. The genotype Madelakayia was produced the highest grain yield (ton / ha) at Shambat and the genotype BS / Sh / 94 at Elrawakeeb and the average of both locations.

4.4.6 Others vegetative traits:

Highly significant differences ($P \leq 0.01$) among the genotypes were recorded at both locations (Table 4.2). The combined analysis (Table 4.3) showed highly significant difference among genotypes for all vegetative traits. The interactions between location × genotypes were highly significant for most of investigated traits except for number of tillers (30 DAS) and leaf area index at 45 DAS (Table 4.3). The over all mean, range and coefficient of variation of genotypes for different characters at Shambat, Elrawakeeb and the average of both locations were presentation (Appendix 3 – 18).

4.4.7 Genetic coefficient of variation, heritability and genetic advance:

Estimates of genetic coefficient of variation (GCV) for all of the characters were greater at Shambat than at ELRawakeeb, except 50 % flowering and leaf area index at 45, 60 and 75 DAS (Table 4.15). High estimates of GCV in both locations were recorded for grain yield/ha (23.02), number of seeds / head (24.46) and grain yield / plant (23.02). Where as low GCV estimates were obtained for plant height, 50 % flowering, days to maturity and biomass/ plant (Table 4.13).

Regarding heritability estimates, the values of h^2 were greater at ELrawakeeb than Shambat (Table 4.15). Moreover, the grain yield / plant, grain yield (ton / ha), 1000- seed weight, harvest index and leaf area index were more or less similar at the two locations. High value of heritability ($h^2 > 0.60$) were recorded for grain yield / plant (0.71) , grain yield (ton / ha) (0.75), number of seeds / head (0.61), 50 % flowering (0.64), date to mayurity (0.69) and panicle length / main head (0.68) at Elrawakeeb, and number of fertile tillers / plant (0.89) at Shambat . However , high estimates of heritability ($h^2 > 0.60$) were recorded for 50 %flowering (0.98), date to maturity (0.97), number of fertile tillers / plant (0.64), panicle length (0.67) and number of seeds/ head (0.75) at both locations (Table 4.15).

Similar to the trend of the heritability estimates, the values of excepted genetic advance under selection were different in the two locations.The value of genetic advance were greater at Elrawakeeb than Shambat (Table 4.13). The highest genetic gain was estimated for plant height at 75 DAS (39.65 %) at Elrawakeeb and for plant height at 75 DAS (16.48 %) at Shambat .However, the highest value of genetic advance was estimated for plant height at 75 DAS at both locations (Table 4.15).

Table 4.12. Phenotypic (σ^2 Ph), Genotypic (σ^2g) and environmental (σ^2e) variance for the different characters in 15 pearl millet (*Pennisteum glaucum L.*) genotypes evaluated over two Locations (Shambat, ELRawakeeb).

		σ^2g		σ^2Ph		σ^2e	
No	**Traits**	**ELRawakeeb**	**Shambat**	**ELRawakeeb**	**Shambat**	**ELRawakeeb**	**Shambat**
1	Ph 30 (cm)	54.69	39.08	105.78	198.09	51.08	159.02
2	Ph 45 (cm)	319.58	50.38	342.19	464.46	22.60	414.07
3	Ph 60 (cm)	289.30	207.79	303.36	698.28	14.06	490.49
4	Ph 75 (cm)	398.69	268.57	413.58	550.26	14.89	281.69
5	TL 30	0.03	0.17	0.39	0.56	0.36	0.39
6	TL 45	0.33	0.20	0.52	0.63	0.19	0.43
7	TL 60	0.28	0.18	0.38	0.65	0.10	0.47
8	TL 75	0.20	0.21	0.29	0.72	0.09	0.50
9	50% Flr (Day)	44.85	43.45	46.41	45.28	1.56	13.03
10	Matur (Day)	123.56	15.14	128.10	17.08	4.54	7.10
11	LAI 30	0.35	0.58	0.55	2.13	0.20	2.15
12	LAI 45	0.64	0.59	0.93	2.65	0.29	2.06
13	LAI 60	1.14	0.58	1.26	2.73	0.12	2.15
14	LAI 75	0.87	0.24	0.97	0.98	0.10	0.74
15	FTL	0.14	0.34	0.18	0.61	0.04	0.27
16	Deleng (Cm)	1.04	0.14	1.21	0.48	6.24	0.17
17	Y(g)/p (g)	281.02	105.76	395.73	218.95	114.71	113.19
18	yd (t)/h (Ton/ha)	0.19	0.33	0.05	0.31	0.01	0.12
19	HI%	8.18	20.85	24.96	43.78	16.78	22.92
20	Biomass (g)	875.51	232.01	2787.47	864.40	1911.16	632.38
21	Pnlng (Cm)	15.75	18.09	22.48	30.49	6.73	12.40
22	Sd/pn	186708.92	185461.97	248719.31	327910.19	62010.40	142448.21
23	1000-sd (g)	2.15	2.81	3.84	5.70	1.69	2.89

Table 4.13. Estimates of Phenotypic (PCV), Genotypic (GCV), broad sense heritability (h^2), expected genetic advance (GA) for different characters measured on 15 pearl millet genotypes evaluated under four water treatments at average over two locations (Shambat and ELRawakeeb).

		GCV		h^2		PCV		GA	
No	Traits	SH	RW	SH	RW	SH	RW	SH	RW
1	Ph 30 (cm)	8.38	7.88	0.20	0.52	17.75	11.66	2.54	7.88
2	Ph 45 (cm)	12.36	5.60	0.11	0.93	17.01	12.79	1.59	34.39
3	Ph 60 (cm)	10.62	8.65	0.30	0.95	15.86	10.87	8.84	33.41
4	Ph 75 (cm)	12.25	9.28	0.49	0.96	13.29	12.48	16.48	39.65
5	TL 30	5.67	13.02	0.30	0.09	23.69	19.04	0.26	0.03
6	TL 45	13.61	12.39	0.32	0.64	21.83	17.00	0.30	0.76
7	TL 60	11.57	11.12	0.27	0.75	21.37	13.52	0.23	0.80
8	TL 75	8.91	11.09	0.30	0.69	20.33	10.72	0.28	0.64
9	50% Flr (Day)	11.65	22.92	0.96	0.64	11.89	21.82	13.03	13.33
10	Matur (Day)	17.26	15.83	0.22	0.69	33.56	20.84	7.10	22.09
11	LAI 30	23.55	17.02	0.21	0.91	36.83	24.75	0.43	0.77
12	LAI 45	24.13	14.88	0.24	0.90	30.29	25.75	0.35	1.13
13	LAI 60	19.36	7.74	0.20	0.48	17.52	27.98	0.34	1.99
14	LAI 75	12.59	26.04	0.98	0.92	11.65	27.12	0.24	2.00
15	FTL	12.94	4.65	0.89	0.96	4.94	13.18	0.67	0.57
16	Deleng (Cm)	17.53	18.97	0.59	0.69	24.63	21.05	0.23	1.81
17	Y(g)/p (g)	33.74	36.33	0.48	0.71	48.55	43.12	10.23	24.52
18	Yd(t/h) (Ton / ha)	21.92	47.79	0.56	0.75	63.98	25.25	0.50	0.55
19	HI%	29.52	14.56	0.45	0.33	42.78	25.43	4.48	1.93
20	Biomass (g)	4.79	15.71	0.18	0.31	31.22	28.04	8.42	19.14
21	Pnlng (Cm)	33.45	36.13	0.40	0.68	57.17	40.61	5.20	5.73
22	Sd/pn	30.59	37.17	0.57	0.61	40.68	45.14	0.50	0.67
23	1000-sd (g)	24.84	19.93	0.49	0.56	35.39	26.66	1.70	1.69

Table 4.14 Phenotypic (σ^2 Ph), Genotypic (σ^2g) and environmental (σ^2e) variance for the different characters in 15 pearl millet (*Pennisteum glaucum L.*) genotypes evaluated over two Locations (ELRawakeeb 2003/04 and Shambt 2004/05).

No	Traits	Genotypic σ^2g	Phenotypic σ^2Ph	Environmental σ^2e
1	Ph 30 DAS (Cm)	27.17	84.57	57.40
2	Ph 45 DAS (Cm)	92.14	187.75	95.61
3	Ph 60 DAS (Cm)	122.98	257.67	134.68
4	Ph 75 DAS (Cm)	158.36	228.80	70.44
5	TL 30 DAS	0.06	0.23	0.17
6	TL 45 DAS	0.18	0.34	0.16
7	TL 60 DAS	0.57	0.71	0.14
8	TL 75 DAS	0.13	0.27	0.15
9	50 %flr (Days)	35.89	36.77	0.88
10	Matur (Days)	50.85	52.61	1.76
11	LAI 30 DAS	0.13	0.54	0.40
12	LAI 45 DAS	0.48	1.12	0.63
13	LAI 60 DAS	0.53	1.12	0.59
14	LAI 75 DAS	0.33	0.56	0.24
15	FTL	0.10	0.17	0.07
16	Deleng (Cm)	0.31	0.43	0.12
17	Y(g)/p (g)	98.77	154.23	55.46
18	Yd(t)/h (ton / ha)	0.19	0.33	0.14
19	HI %	7.15	17.31	10.15
20	Biomass (g)	369.90	1755.90	682.74
21	Pnlng (Cm)	8.69	12.97	4.28
22	Sd/pn	146232.46	194486.22	48253.76
23	1000-sd (g)	1.73	3.02	1.30

No	Traits	PCV	GCV	h^2	GA

Table 4 .15 Estimates of Phenotypic (PCV), Genotypic (GCV), broad sense heritability (h^2), expected genetic advance (GA) for different characters measured on 15 pearl millet genotypes evaluated under four water treatments averaged over two locations (Shambat and ELRawakeeb).

1	Ph 30 DAS (Cm)	10.98	6.22	0.32	3.45
2	Ph 45 DAS (Cm)	10.10	7.07	0.49	9.70
3	Ph 60 DAS (Cm)	9.82	6.79	0.48	10.90
4	Ph 75 DAS (Cm)	8.91	7.41	0.69	17.94
5	TL 30 DAS	15.02	7.83	0.27	0.14
6	TL 45 DAS	14.68	10.62	0.52	0.45
7	TL 60 DAS	21.46	19.21	0.80	1.25
8	TL 75 DAS	11.37	7.77	0.47	0.34
9	50 %flr (Day)	11.05	10.91	0.98	12.05
10	Matur (Day)	8.56	8.41	0.97	14.20
11	LAI 30 DAS	21.90	10.58	0.23	0.17
12	LAI 45 DAS	22.33	14.68	0.43	0.62
13	LAI 60 DAS	23.42	16.12	0.47	0.71
14	LAI 75 DAS	21.05	15.98	0.58	0.68
15	FTL	24.87	30.84	0.60	0.40
16	Deleng (Cm)	30.45	21.25	0.73	0.84
17	Y(g)/p (g)	32.42	25.94	0.64	13.11
18	Yd(t)/h (Ton / ha)	24.81	31.51	0.58	0.52
19	HI %	23.70	15.24	0.41	2.28
20	Biomass (g)	18.48	10.88	0.35	13.73
21	Pnlng (Cm)	28.21	13.58	0.67	4.07
22	Sd/pn	28.21	24.46	0.75	5.92
23	1000-sd (g)	24.67	18.64	0.57	1.55

Grain yield / plant had significant positive phenotypic and genotypic correlations with number of seeds / head at Elrawakeeb. It had negetative genotypic and phenotypic correlations with this trait at Shambat. It also had highly significant positive genotypic correlations with grain yield (ton /ha) at Shambat (Table 4.16 and 4.17).

4.5.1.2 Correlation between yield components:

4.5.1.2.1 The number of fertile tillers /plant had highly significant ($P \leq 0.01$) positive genotypic and phenotypic correlations with grain (ton / ha) and number of seeds / head at ELRawakeeb (Table 4.16).It had highly negetative genotypic correlation with all yield components at Shambat except panicle length and 1000 – seed weight (Table 4.17). .

4.5.1.2.2. The number of seeds / head was highly and positively correlated, at the genotypic and phenotypic level, with all yield components at ELRawakeeb, except with panicle length / head and dead part length, where it exhibited positive and non-significant association (Table 4.16). On the other hand, number of seeds / head had negetative association with other yield components except with panicle length, which exhibited positive association at Shambat (Table 4.17).

4.5 Interrelationship between the different characters:

4.5.1 Phenotypic and genotypic correlations

Phenotypic and genotypic coefficients between pair wise combinations of the different characters in each environment are presented in table 4.16 and 4.17. The results can be summarized as follows:

4.5.1.1Correlation between grain yield / plant and its components: There were highly significant ($P \leq 0.01$) positive genotypic and phenotypic correlation between grain yield and all grain yield components at both locations except 1000- seed weight and panicle length at Elrawakeeb (Table 4.16) as well as the number of seed /head, 1000- seed weight and biomass dry weight / plant at Shambat (Table 4.17) .

4.5.1.2.3 1000 – Seed weight was significantly and negatively associated at phenotypic and genotypic levels with grain yield / plant and number of seeds / head at Elrawakeeb, while it has non significantly correlated with other components at both locations (Table 4.16 and Table 4.17) .

4.5.1.2.3 Panicle length / head exhibited highly significant ($P \leq 0.01$) positive correlation with grain yield ton / ha, although it had positive non-significant correlation with fertile tillers / plant and harvest index. Panicle length had negative association at phenotypic and genotypic levels with dead part length. On the other hand at Elrawakeeb, it had strong positive genotypic correlation grain yield ton / ha (Table 4.16).

4.5.1.2.6 Grain yield (ton / ha) had significant positive phenotypic correlations with the number of seeds / head, and panicle length / head at Elrawakeeb. While it had positive genotypic correlation with 1000 – seed weight (Table 4.17). Further more, at Shambat there were non significant positive correlations between grain yield (ton / ha) and the other yield components, except number of seeds / head (Table 4.16).

4.5.1.3. Correlation of grain yield / plant with other characters:

Grain yield / plant had ($P \leq 0.01$) positive genotypic and phenotypic correlation with plant height at 75 DAS, number of tiller / plant at 75 DAS and leaf area index at 75 DAS at Elrawakeeb locations (Table 4.16). Although, it had negetative phenotypic and genotypic correlation with 50 % flowering and date to maturity (Table 4.16)**.** On the other hand, at Shambat grain yield / plant had significant negative genotypic and phenotypic correlation with plant height at 75 DAS, although it positively associated with number of tillers at 75 DAS, leaf area index and 50%flowering (Table 4.17).

Table 4.16: Phenotypic (Ph) and Genotypic (G) correlation coefficients between characters in pearl millet genotypes at Elrawakeeb averaged over four water treatments during (2003/04 season)

	1	2	3	4	5	6	7
Characters	PH 75	**TL 75**	50% Flr	Matur	LAI 75	FTL	Dpleng
PH 75 (Cm)		0.637*	0.075	0.016	0.649**	0.990**	0.146
TL 75	0.707 **		-0.286	-0.382	0.667**	0.341	-0.134
50% Flr (Days)	0.074	-0.369		0.878**	-0.228	-0.420	0.346
Matur (Days)	0.016	-0.472	0.905 **		-0.205	-0.457	0.425
LAI 75	0.689 **	0.821**	-0.243	-0.224		0.129	-0.034
FTL	0.111	0.485	0.491	0.534*	0.148		-0.179
Dpleng (Cm)	0.157	-0.198	0.364	0.458**	-0.039	-0.147	
Y(g)/p (g)	0.433	0.608 *	-0.088	-0.083	0.444	0.509	0.125
Yd(t)/h (Ton / ha)	0.0.49	0.663**	0.965**	-0.979 **	0.392	0.730**	-0.531*
HI%	0.482	0.426	0.163	0.126	0.346	0.560	0.117
Biomass (g)	0.275	0.811**	-0.470	0.467	0.520*	0.550*	0.084
Pnlng (Cm)	0.237	0.545*	-0.628 *	-0.777**	0.356	0.430	-0.184
Sd/pn	0.340	0.577*	0.330	-0.291	0.428	0.696**	0.105
1000-sd (g)	-0.779**	-0.348	-0.175	0.200	-0.466	-0.204	-0.497

Continuous Table 4.16 :

	8	9	10	11	12	13	14
Characters	Y(g)/p	Yd(t)/h	HI%	Biomass	Pnlng	Sd/pn	1000 - sd
PH 75 (Cm)	0.365	0.039	0.292	0.149	0.199	0.282	-0.592*
TL 75 (Cm)	0.411	0.446	0.229	0.337	0.404	0.383	-0.233
50% Flr (Days)	-0.071	-0.756**	0.088	-0.247	-0.515*	-0.294	-0.126

Matur (Days)	-0.180	-0.095	0.077	-0.261	-0.649**	-0.244	0.163
LAI 75	0.363	0.312	0.143	0.333	0.278	0.344	-0.327
FTL	0.371	0.517*	0.247	0.320	0.331	0.536*	-0.113
Dpleng (Cm)	0.109	0.446	0.076	0.053	-0.143	0.064	-0.374
Y(g)/p (g)	[redacted]	0.205	0.754**	0.639*	-0.289	0.608*	-0.377
Yd(t)/h (Ton / ha)	0.272	[redacted]	0.056	0.280	0.484	0.443	0.064
HI%	1.027**	0.105	[redacted]	0.015	-0.353	0.460	-0.409
Biomass (g)	1.064**	0.568*	1.166**	[redacted]	0.104	0.392	-0.073
Pnlng (Cm)	-0.392	0.704**	-0.666**	0.229	[redacted]	0.032	0.217
Sd/pn	[redacted]	0.592*	0.869**	0.793**	0.138	[redacted]	-0.509
1000-sd (g)	-0.582*	0.046	-0.880**	-0.180	0.441	-0.681**	[redacted]

Characters PH 75 TL 75 50% Flr Matur LAI 75 FTL Dpleng

1 2 3 4 5 6 7

PH 75 (Cm) 0.291 0.248 0.291 0.305 0.068

- * and ** are levels of significance at 5% and % respectively .

The value in upper triangular are the phenotypic and in the lower one are the genotypic correlation coefficient

Table 4.17: Phenotypic (Ph) and Genotypic (G) correlation coefficients between characters in pearl millet genotypes at Shambat averaged over four water treatments during (2004 /05 season)

TL 75	0.439	[redacted]	-0.456	-0.413	0.143	0.259	-0.173	
50% Flr (Days)	0.351	-0.880**	[redacted]	0.667**	-0.143	-0.218	0.138	
Matur (Days)	0.439	-0.803**	0.736**	[redacted]	-0.342	-0.055	0.226	
LAI 75	0.687**	0.781**	-0.350	-0.342	[redacted]	0.224	-0.063	
FTI	0.066	0.550*	-0.279	-0.055	0.994**	[redacted]	0.006	
Dpleng (Cm)	-0.095	-0.508	0.289	0.326	-0.450	-0.032	[redacted]	
PH 75 (Cm)	-0.293	-0.341	-0.321	0.248	-0.363	[redacted]	0.052	
Y(g)/p (g)	-0.668**	0.230	0.295	-0.103	-0.325	-0.241	-0.489	
TL 75 (Cm)	0.053	0.115	-0.002	0.165	0.305	0.233	0.150	
yd (t)/h (Ton / ha)	-0.795**	0.315	-0.138	-0.466	-0.479	-0.187	-0.489	
50% Flr (Days)	0.199	-0.088	0.260	0.181	-0.466	-0.570*	0.065	
HI%	-0.709**	0.158	0.391	-0.021	-0.318	-0.288	-0.245	
Matur (Days)	-0.058	-0.296	-0.004	-0.032	-0.213	-0.519*	0.073	
Biomass (g)	0.431	0.264	0.364	-0.079	0.365	0.481	0.681**	
Pnlng (Cm)	-0.690**	0.819**	-0.608*	-0.285	-0.373	0.490	-0.040	
Sd/pn	-0.404	0.514*	-0.770**	-0.789**	0.163	-0.385	-0.433	
1000-sd (g)	-0.172	0.278	0.086	0.054	0.037	0.230	-0.186	

	8	9	10	11	12	13	14
Characters	Y(g)/p	Yd(t)/h	HI%	Biomass	Pnlng	Sd/pn	1000 - sd

Continuous Table 4.17 :

LAI 75	-0.195	-0.262	-0.251	0.226	-0.104	0.036	0.087
FTL	-0.105	-0.060	-0.137	0.212	0.279	-0.204	0.085
Dpleng (Cm)	-0.042	-0.245	-0.076	0.121	-0.085	-0.153	-0.033
Y(g)/p (g)		0.796**	0.942**	-0.036	0.080	-0.105	0.292
yd (t)/h (Ton / ha)	0.891**		0.694**	0.112	0.222	-0.041	0.235
HI%	0.965**	0.807**		-0.347	0.027	-0.255	0.304
Biomass (g)	-0.212	-0.109	-0.459		0.144	0.009	-0.046
Pnlng (Cm)	0.260	0.402	0.177	0.304		0.126	-0.043
Sd/pn	-0.241	-0.043	-0.488	-0.015	0.295		-0.250
1000-sd (g)	0.485	0416	0.522*	-0.171	-0.015	-0.550	

- * and ** are levels of significance at 5% and % respectively .
- The value in upper triangular are the phenotypic and in the lower one are the genotypic correlation coefficient

4.5.2 Path coefficient analysis:

The results of the path coefficient analysis are depicted in Table 4.18 . The path analysis showed that fertile tillers / plant had the highest positive direct effect (0.513) on grain yield / plant, followed by number of seeds / head (0.120) (Table 4.18) . On the other hand, grain yield / plant was directly and negatively affected with dead part length (-0.385) and panicle length (- 0.294). The relatively high positive indirect effect on grain yield / plant were caused by number of seeds / head (0.173) and panicle length / head (0.131). The highest negetative indirect effect on grain yield / plant were caused by panicle length (-0.117) and fertile tillers / plant (-0.108).

The number of fertile tillers / plant had positive direct and indirect effected with other characters. The highest negetative indirect effect of number of fertile tillers was expressed through panicle length (-0.117).

The number of seeds / head expressed the least positive direct effects on grain yield / plant (0.120). This character exhibited its indirect positive effect on grain yield / plant through the panicle length / head (0.173) and its negative indirect one through the other traits (Table 4.18).

1000 – Seed weight showed the least positive direct effect (0.072) on grain yield / plant. The negetative indirect effect of 1000 – seed weight was expressed through fertile tillers / plant (-0.004) and number of seeds / head (-0.071).

The panicle length / head showed the negetative direct effect (-0.294). On the other hand, the positive indirect effect was expressed through fertile tiller / plant (0.204), dead part length / head (0.062) number of seed / head (0.053)

Dead part length / head showed the highest negetative direct effect (-0.385). This character exhibited its indirect negetative effect through fertile tillers / plant (-0.108) and 1000- seed weight (-0.061). Whereas, it expressed positive

indirect effect on grain yield / plant through panicle length and number of seeds / head (Table 4.18).

Table 4.18. Path Coefficient analysis of the direct and indirect effects of the different yield components and their genotypic correlation coefficient with grain yield / plant Characters Effect on grain yield /plant Indirect effect

	Effect on grain yield / plant						
		Indirect effect via :					Direct effect
Traits		**FTL**	**Sd/p**	**1000-sd**	**Pnlng**	**Lgmde**	**Genotypic correlation**
FTL	0.512	-	0.040	0.001	-0.117	0.081	0.517
Sd/P	**0.120**	**0.173**	**-**	**-0.042**	**- 0.131**	**- 0.002**	**0.119**
1000-SD	0.072	-0.004	-0.071	-	0.021	0.325	0.352
Pnlng	-0.294	0.204	0.053	-0.005	-	0.062	0.020
Lgmde	**-0.385**	**-0.108**	**0.001**	**-0.061**	**0.047**	**-**	**-0.507**

Residual effects = 0.892

4.6 Phenotypic Stability:

Stability of the performace of fifteen genotypes evaluated over the eight different environments for grain yield / plant (an important grain yield components) was determined using analysis of variance as well as regression coefficient. The mean squares of genotypes, environments (Linear) and pooled deviation from regression linearity over all means are presented in (Table 4 .20).

The analysis of variance for grain yield / plant across the eight macro-enviroments (ME) revealed alarge and highly significant environmental effect (Table 4.19).

For grain yield / plant, the means of genotypes over all environments (μ) ranged between 29.26 and 47.49 g . Seven genotypes yielded greater than the grand mean (38.31g). Of these JM 36 and JM 38 had regression coefficient (bi) smaller than unity , and did not significantly deviate from regression linearity on the over all mean . The genotypes JM 25 , JM44 , JM30 were greater than the grand mean but they had (bi) greater than unity and asignificant (Sd^2). Moreover , the genotypes JM 3 had the smallest value (0.35) of (bi) and JM 23 the highest (1.69) value , indicating that JM 3 was adapted to dry (unfavorable) conditions and JM 23 was adapted to well – watered (farvorable) conditions .

The average of deviations (Sd^2) from linear response was greater for most of genotypes (Table 4.20). The range for Sd^2 among genotypes was (9.3 – 97.2). This stability parameters unlike (bi) distinguished the genotypes JM 21 and JM 23 with the highest and lowest yield stability, respectively (Table 4.20). Moreover , the lowest value of deviations (Sd^2) was exhibited by genotypes JM49, JM21,JM44, JM48 , JM 3 and BS/Sh/94 and the highest value of (Sd^2) was exhibited by JM38 and JM 23 (Table 4.20) .

Table 4.19 : Analysis of variance for regression of 15 pearl millet genotypes under eight macro - environment: Sum of squares (SS) , mean squares (MQ) and variance components (var .comp .) for grain yield/plant, averaged over three replicates .

Analysis of variance for mean data

SS due to	
En.+(gXe)	23747.12
SS en.(linear)	1.00
SSgxen.(linear)	19501.57

S.V		d.f	SS	MS	Fcal.	Ftab 1%	Ftab 5%	Sig.
Total		119	27030.34					
Genotype		14	3283.23	234.52	4.97	2.29	1.80	**
Environment+(gXe)		105	23747.12	226.16	-			
Envirnment(linear)		1	16887.70	16887.70	-			
gXe (linear)		14	2614.86	186.78	3.96	2.29	1.80	**
pooled deviation		90	4244.5	47.16				
	JM 49	6	223.38	37.23	0.98	2.90	2.14	ns
	JM 25	6	406.92	67.82	1.79	2.90	2.14	ns
	JM 21	6	56.10	9.35	0.25	2.90	2.14	ns
	JM 45	6	311.51	51.92	1.37	2.90	2.14	ns
	JM 44	6	138.83	23.14	0.61	2.90	2.14	ns
	JM 48	6	151.68	25.28	0.67	2.90	2.14	ns
	JM 36	6	162.23	27.04	0.71	2.90	2.14	ns
	Madelkawiya	6	460.62	76.77	2.02	2.90	2.14	ns
	JM 3	6	223.53	37.26	0.98	2.90	2.14	ns
	JM 30	6	274.66	45.78	1.21	2.90	2.14	ns
	JM 23	6	583.29	97.21	2.56	2.90	2.14	*
	JM 38	6	449.92	74.99	1.97	2.90	2.14	ns
	BS / Sh /94	6	232.69	38.78	1.02	2.90	2.14	ns
	JM 24	6	412.66	68.78	1.81	2.90	2.14	ns
	Ugandi	6	156.52	26.09	0.69	2.90	2.14	ns
Pooled error		224		37.98	-			

Table 4.20 : Estimates of several stability parameters , Coefficient of regression (bi) , mean square deviation ($\sigma^2 d$), and (μ) the mean of pearl millet genotypes, across eight macro environments.

Serial No.	Genotypes	Stability parameters		
		μ	bi	$S^2đ$
1	JM 49	32.46	0.96	24.6
2	JM 25	40.98	1.31	67.8
3	JM 21	29.26	0.85	9.3
4	JM45	35.45	0.67	51.9
5	JM 44	40.52	1.56	23.1
6	JM 48	37.10	0.41	25.3
7	JM 36	38.48	0.91	27.0
8	Madelkawiya	47.49	0.78	76.8
9	JM 3	29.60	0.35	37.3
10	JM 30	39.14	1.63	45.8
11	JM 23	46.94	1.69	97.2
12	JM 38	44.29	0.90	75.0
13	BS / Sh / 94	38.12	0.80	38.8
14	JM 24	37.59	1.13	68.8
15	Ugandi	37.22	1.04	26.1

CHAPTER FIVE

DISSCUSSION

5.1 Effect of environments:

In the present study, the general means of yield and yield components at Elrawakeeb were greater than at Shambat. These results, would be attributed to the fact that, the environment of Elrawakeeb was more productive than Shambat.In addition, the change in mean of these characters was due to the interactions of genotypes with the environment interms of water × genotypes (W × G) interaction and locations × genotype (L × G) interaction as well . It is interest to mention that, the difference between the millet genotypes for these traits can be due to genetic cause as well as the interaction with environment. These finding were in agreement with that obtained by Abraham et al (1989) in finger millet, Elings (1991) and Fadlalla (1994) in wheat and khalafalla (1993) in maize, Prasad et al. (1995), Rao et al (1998) and Yadav et al.(1999) in pearl millet .

5.2 Effect of drought:

Drought stress is one of the most common environmental stresses that affects growth and development of plant through alterations in metabolism and gene expression. It continues to be challenge to agricultural scientists in general and to plant breeder in particular, despite many decades of research.

In this study, drought stress reduced greatly and significantly the value of all investigated traits. Similar findings were obtained by Malakashmi and Rao, (1990). Further more, the stress during vegetative growth was the more sensitive to drought stress than other growth stage. This results indicated that the time of transition from the vegetative to the reproductive phase in cereals is

the most sensitive to water deficit. Similar results were obtained by Bunting and Kassam (1988) in pearl millet. On the other hand, the yield reductions due to stress initiated at vegetative stage resulted from both reduced seed size and seed number. Where as, only seed size was reduced when stress was imposed at filling stage. It is of interest mention that , the relative response of the different genotypes to water stress was highly affected by timing of stress .

Effect of the stress imposed at filling stage was not severe on yield and its components. These results were in accordance with those reported by Seetharama et al (1984) who attributed the small reductions in yield to the fact that this stage of plant development was less sensitive to moisture deficit .

5.2.1 Effect of drought on the vegetative traits:

In the present study, most of the investigated traits were sensitive to water deficit particularly, plant height, leaf area index, number of tillers / plant, days to 50 % flowering and date to maturity. Similar results were reported by ElDikhery (1992) and Osmanzai (1992). These results indicated that plant height decreased with water deficit imposed at different stages of plant growth, except after anthesis. The increase in plant height recorded at Shambat could be attributed relatively to moderate amounts of rainfall that occurred after 60 days after sowing date (DAS) of crop growth. Which had resulted in rapid growth of plants.

Number of tillers per plant were progressively increased with plant age. The stress during the vegetative stage (W_1) and the stress during both the vegetative and filling stage (W_3) increased the number of tillers per plant by 0.91% and 10.50% respectively at both locations. A similar increase was shown by Unger (1991) and VanderLip (1991), who reported substantial tillers production as results of water stress. The biomass dry weight was increased

with plant growth in both locations. These results were in accordance with those reported by Done et al. (1984), Mahalakhshmi *et al*. (1991).

The leaf area index (LAI) increased with plant age. The stress during the vegetative stage (W_1) and the stress during both stages vegetative and filling stage (W_3) reduced the leaf area index by 17.17% and 18.94% respectively. A similar decline in LAI due to water stress was recorded by ELDikhery. (1992).

The effect of drought stress on the phenology of pearl millet depends up on the severity of the stress. i. e, the degree and duration of water deficit and on the stage of development of the crop at time of stress. However, the stress during vegetative growth (W_1) and the stress during both stages vegetative and filling stage (W_3) reduced the days to 50 % flowering at both locations. These results were in accordance with those reported by Mahalakshmi, (1987). These results indicated that time to flowering clearly was affected by drought stress.

5.2.2 Effect of drought on yield

At Shambat and for the average of both locations, with exception of drought during filling stage (W_2) , all other drought treatments reduced seed yield / plant and seed yield (ton / ha). Higher reduction in yield was found when the stress was occured at the vegetative stage. This reduction was due to mainly reduction in the number of seeds / head. A similar result was obtained by Anon (1987).

The large yield produced under drought during filling stage (W_2) may be due to the fact that the growth and yield components have been already defined by the end of flowering. This also was found by Tawadros (1986) and Grashoff (1990). On the other hand, there were small reductions in yield when stress was applied during filling stage (W_2), which was recorded by Younise, (2002) and Desouza et al. (1997).

5.2.3 Effect of drought on yield components

At Shambat and for the average of both locations, the reduction in the number of seeds / head, when stress was during the vegetative stage may be due to the fact that the formation of the flowers was happened at this stage. Similar results were obtained by Anon (1987). On the other hand, drought stress during filling stage (W_2) had no effect on the number of seeds / head, but it reduced seed weight. These findings were in agreement with that obtained by Seetharama et al. (1984), Mahalakshmi and Bidinger (1986) and Mahalakshmi et al. (1991).

In the present study, drought stress had significantly reduced yield components.This results indicated that the water stress was severe enough to make marked reduction in yield components.

5.2.4 Drought tolerance:

In this work, the water stress was severe enough to make a marked reduction in yield by 42.2%, 16.1% and 32.56% for stresses occured during vegetative stage (W_1), and during filling stage (W_2) , and during both stages the vegetative and filling stage (W_3), respectively. However, stress during vegetative stage had more reduction in yield than other stresses. In addition, the stress was adequate to reveal a significant genotypes × treatments interaction variation for grain yield / plant, this indicated the response of genotypes to the degree of drought intensity based on the difference in their genetic structure and adapted ness. These results are in accord with those reported by Haussmann et al ., (1998) in sorghum and Schneider et al ., (1997) in common bean .

The lowest the grain yield was produced when the stress was induced during both the vegetative and filling stage (W3). Generally, some genotypes showed higher yield when stress was during vegetative stage (W_1) than during vegetative and filling stage (W_3). For example JM 45, JM 48 and JM 36

exhibited seed yield under W_1 lower than that obtained under W_3. Its intersting to mention that, different response in yields of the genotypes depend upon the different drought period. Similar results were obtained by Sullivan and Eastin (1974).

5.2.5 Mean of drought tolerance parameters of genotypes:

In the present study, wide ranges for drought tolerance parameters were exhibited by genotypes.Most of the genotypes were less affected by stress during the filling stage (W_2) compared with the other water treatments. On the other hand, the highest value of grain yield / plant was attained by genotypes Madelakawiya under (W_0), by JM21 under (W_2) and by JM38 under (W_3). These results indicates that, the different response in yields of genotypes to the different drought periods according to their genetic structure and adaptedness. These results are accord with those reported in sorghum (Haussmann et al., 1998).

Regrading, stress susceptibility index (SSI) estimates, awide range in the values was dectected for grain yield / plant. The highest value of SSI under (W_1) was obtained by genotype JM 24, by JM30 under (W_2) and by JM24 under JM3. Whereas, the lowest value of geometric mean of productivity under (W_1, W_2 and W_3) was exhibited by JM3. These significant levels of drought tolerance suggest that the breeding programme should encourage the development of genotypes each has tolerance to drought conditions.

5.2.6 Relationship between drought tolerance and yield:

In the present study, a positive correlation between yield under stress (Yd) and yield under non – stress (Yw) was observed. The strong positive correlation between Yd and Yw indicates that, the genes controlling grain yield under both stress conditions (Yd and Yw) are probably common (Alza and Fernandez - Martinez, 1997). The correlation between Yd and Yw has strong implications on the relationship between other drought tolerance parameters. All investigated drought tolerance parameters can be classified in two groups. One group, including Yd / Yw, SSI, Showed negative and significant relationship with yield (Yw and Yd). Selection for improving these parameters decreases yield potential. Similar results were found by other workers (Fisher and Maurer, 1978 ; Abdelmula and link, 1998) .The other group of parameters exhibited positive relationship with Yd and Yw e.g GMP. These drought parameters however, describe more the productivity than drought tolerance.

5.3 Phenotypic and genotypic variability:

Estimation of the phenotypic and genotypic variances is of paramount importance in plant breeding programme. This is because their relative values would indicate weather selection would be effective or not. Further more, the relative value of these variances will help the breeder in using the efficient methods of selection to improve and to study the genotypic properties of population. The phenotypic variance is attributed to the genotypic as well as environmental factors. Thus the estimation of the role of heredity versus the environment is important in determining how well the genotype is represented by the phenotype.

At both locations (Shambat and Elrawakeeb), significant differences between 15 pearl millet genotypes were observed for all the characters studied. The observed variation for these characters could be attributed to genotypic and

environmental factors as well as their interactions. Similar results have been reported in pearl millet for the different characters by many workers (Abraham et al., 1989 and Yadav et al., 1999).

For all characters studied in both locations, the phenotypic variances were greater than the corresponding genotypic ones, and this result would be attributed to the fact that, the phenotypic variance include the environmental variance, in addition to the genotypic one. These findings were in agreement with that obtained by Mohamood and Mahdy. (2003) in sunflower. It is of interest to mention that, the differences between two variances were large for most characters studied. This indicates that, most of the variation for these characters was attributed to the environmental conditions.

Estimates of genetic coefficient of variation (GCV) usually determines the degree of the 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. In this study, a wide range of genetic variability among the evaluated pearl millet genotypes was detected for the studied characters. At both locations, the highest estimate of GCV was shown for the grain yield (ton /ha) and its components, where as, the lowest one was shown for plant height, 50%flowering, date to maturity and biomass dry weight. Similar results under different environments were reported by Yadav et al. (1995) and Harver and Karad, (1998) in pearl millet.

Regarding heritability, the most characters were fluctuating in their heritability estimates and genetic advance estimates at locations. The differences in the magnitude of heritability would be attributed to the effect of of the environment. Robinson et al. (1949) attributed the change in heritability estimates in maize (Zea mays) to differential response of genotypes to the environment. The variation in heritability estimates for these characters was

more obvious for separate location. These results would draw effort on the breeder to evaluate these characters in different environments.

Therefore, heritability estimates would be more meaningful when accompanied by GCV in predicting the expected genetic advance under selection. Similar results were reported by Ahamed (2001) in millet and Abdelmulla (1992) in faba bean.

At both locations, the highest estimate of heritability was shown by the number of fertile tillers/plant, days to 50 % flowering and date to maturity. Where as, the lowest one was shown by leaf area index , number of tillers and biomass / plant . Similar result was observed by Faddalla, (1994) in wheat.

5.4 Interrelationship between yield and yield components:

Yield is a complex character in inheritance, and depends on several components (Kambal, 1969 ; Ishag, 1973 ; Magyarosi and Sjodin, 1976 ; El – Hosary, 1983). Accordingly, crop improvement can not be achieved by intensifying selection for one or few of these components while disregarding others. Therefore, for an effective selection for improvement, determination of the degree of association between these related characters is very essential. Moreover, the partitioning of the total correlation between the associated traits into genotypic and phenotypic correlations exposes the hidden association between such characters.

In the present study, the estimated genotypic correlations for most of the characters were greater than their corresponding phenotypic ones. Similar results were reported by Salih and Khidir (1975) in Castor and Mohammed et al. (1988) in faba bean.This was attributed to the fact that the strong inherent association between the different characters studied were reduced and modified under the influence of the environment.

With few exceptions, the different associations of grain yield / plant with its components arrived at in this study were in accordance with the findings obtained by Barkhiet and Mahdy, (1988). Further more, the grain yield / plant had significant positive phenotypic and genotypic correlation with number of seeds / head, grain yield / ha and number of fertile tillers / plant. Similar results were reported by Tolok et al. (1998) in pearl millet.

The present study, results showed a significant positive phenotypic correlation between grain yield / plant and 1000- seed weight. These results are in accordance with that obtained by Balakrishnan and Das (1995) and Singh et al. (1995).However, negative genotypic correlation between these two traits was reported. This difference in sign of the phenotypic and genotypic association between the two characters may be due to, as stated by Falconer (1980), the fact that the genetic and environmental sources of variation affect these traits through different physiological mechanisms. Furthermore, the difference between the two locations in estimates of the genotypic correlations of grain yield with its components could be attributed to the fact that estimates of genetic correlation are affected by environmental factors and sampling errors, so they are seldom very precise (Falconer, 1980).

Significant genotypic and phenotypic correlations were indicated between the yield components, namely number of seeds / plant, grain yield / ha, 1000 – seed weight and number of fertile tillers / plant .Such associations have been attributed to pleiotropy or genetic linkage (Yassin, 1973). Or may be due to developmentally induced relationship between those components that are only indirectly the consequence of gene action (Adam, 1967).

In the present study, the negative association of number of seeds / head with 1000 – seed weight, on the other hand, is attributed to the competition

between these characters for assimilates during their development (Abraham et al.1989 and Kulkarni et al. 2000) in finger millet.

5.5 Path analysis:

When a great number of variables are included in a correlation study , the association among them will be very complex. Thus path analysis is necessary to elucidate the true direct and indirect relationship among such characters. In this study, path analysis was carried out to examine the relationship between grain yield / plant and its components.

With regards to the grain yield / plant and its components, the analysis showed that the number of fertile tillers / plant had the highest direct effect on grain yield / palnt, followed by number of seeds / head and the 1000- seed weight. This great direct influence of these components is indicative of their important role in determing yield. Similar results were found by Muhammed et al (2003) in pearl millet.

Each of these four yield components had a positive genotypic correlation with grain yield / plant, except the panicle length and the dead part length. This unexpected negative correlation of the panicle length and dead part length had resulted from its high negative indirect effect (-0.108) through the number of fertile tillers / plant.

Although the number of fertile tillers / plant had the highest positive direct contribution, it exhibited the lowest genotypic correlation with grain yield / plant. This can be attributed to the negative indirect effects of this character through the panicle length (-0.117) .

Grain yield/plant was negatively and directly affected by panicle length (-0.294) and dead part length (-0.380) . However, these traits had the highest positive indirect effects on grain yield / plant (0.204) through number of fertile

tillers / plant and (0.047) for dead part length through panicle length. Their high positive indirect effects were reduced by their negative indirect effects.

The negative direct effects and the reduction in positive indirect effects of these character resulted in their low genotypic correlation with grain yield / plant.

The number of seeds / head and 1000- seed weight had the highest negative indirect effects on grain yield / plant. These negative indirect effects resulted from the inverse relationship with the panicle length. The results are in agreement with findings of Abraham et al. (1989), Harver and Karad (1998), Kulkarni et al (2000) and Yadav et al. (2001).

5.6 Phenotypic yield stability:

In this study there were highly significant differences among the genotypes for the grain yield / plant, G × E interactions and pooled deviation from regression on the over all mean .The significance in variance due to G × E interaction for the grain yield / plant indicates that, this character was sensitive to the environmental changes. The significant pooled deviation from regression for the character suggests that, the genotypes differed considerably with respect to their stability. This would probably be due to the difference in the soil properties of Elrawakeeb and Shambat. Similar differences were reported by Khalid (2003).

According to grain yield, stability parameters, genotypes can be categorized in three groups first one; Which had mean value (u) higher than the average mean (38.81), regression coefficient (bi) above unity and deviation ($S^2đ$) from the regression line not significantly different from zero . This group was considered to be below average in stability. So it was sensitive to environmental change and hence it could be recommended for favorable environment.This group includes the following genotypes JM 23, JM 30, JM 44

and JM 25. The second group comprises JM 38 , JM 36 and Medalakawyia are said to be specifically adapted for unfavorable environment ,because it was above average in stability , in that it had grain yield / plant above the average, (bi) below unity and deviation not significantly different from zero . The third group which includes JM 49, JM 21, JM45, JM 48, JM 3 and JM 24. We conclude that genetic diversity, either in heterozygote or in mixtures of different genotypes often leads to stability under varying environmental.

In the present study, the basic differences between the genotypes in their yield stability, is due to the occurrence of genotype × environment interaction, that is the ranking of the genotypes depends on the particular environmental condition, where it is grown. However, this results contradicts that obtained by Karale et al. (1997), Gupta and Ndoge (1991) who worked in sorghum and millet and found significant variety × location level for all characters studied. These significant levels of interactions suggest that the breeding programme should encourage the development of genotype each adapted to specific kind of environment.

CHAPTER SIX

SUMMARY AND CONCLUSION

The experiment was carried out, at two sites, to evaluate 15 pearl millet genotypes, under four level of water stress, split – plots design with three replications was used.

The individual analysis of variance as well as the combined analysis was carried out for the collected data. Significant variation due to genotypes and genotypes x locations interaction for most of the characters was recorded.

Yield and yield components were significantly affected by water treatments.Whereas; the water stress during filling stage had small effect on yield and its components

Grain yield exhibited strong correlation with its components and other characters. In addition, the path analysis reflected that the fertile tiller per plant had positive direct effect.

A wide ranges for values of drought tolerance parameters were exhibited by genotypes .on the other hand, the significance of G x E interaction and pooled deviation from regression linearly on the over all mean, which exhibited by grain yield / plant, suggest that the evaluated genotypes were considerably different with respect to stability. The high yield and high stability was obtained by Madelkawyia, JM38, JM36 therefore,these genotypes could be recommended for improvement of the pearl millet under drought conditions.

Based on the resulted obtained in this study , it can be concluded that:

1. A wide range of genetic variability was detected among the genotypes for drought tolerance. This variability can be exploited in the improvement for drought tolerance in this crop.

2. The genotypes were significantly different in phenology, growth, and yield components.

3. The genotypes expressed different degrees of relative response to water stress with respect to time to 50 % flowering, days to maturity, plant height, yield and yield components

4. The relative response of the different genotypes to water stress was highly affected by timing of stress relative to the development of the genotypes for tolerance to water stress.

5. Water stress before the flowering stage greatly affected plant growth, development, yield and yield components.

6. Water stress after the flowering stage resulted in early maturity and reduced 1000 - seed weight.

7. Grain yield per plant and its components were more sensitive to water stress than morphological characters.

8. The reduction in yield per plant was mainly due to the reduction in number of seeds / plant and 1000- seed weight.

9. Grain yield per plant had strong positive phenotypic and genotypic correlation with some of its components and some of morphological characters.

10. The genotypes Madelkawiya, JM 36 and JM 3 could be identified for genetic improvement of drought tolerance and production under drought stress.

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CHAPTER SEVEN

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Appendix .1. Physical – chemical analysis of experimental top soil (30) cm at Shambat and Elrawakeeb Locations .

Determination	Shambat	Elrawakeeb
Mechanical analysis		
Sand (%)	23	36
Silt (%)	32	21
Clay (%)	45	29
Chemical analysis		
PH (Paste)	8.0	7.85
Ece (ds/m)	0.52	0.135
O.C (%)	1.40	0.094
Total N (%)	0.05	0.011
Available P (mg / Kg)	1.29	1.15
Available K (mg / Kg)	0.12	0.405

Source : Laboratory data from Shambat and Elrawakeeb

Appendix .2 . Meteorological data for the crop growing at Elrawakeeb 2003/04 and Shambat 2004/05

Month	Elrawakeeb (2003/04)			Shambat 2004/05		
	Temp (C˚)		Rainfall (mm)	Temp (C˚)		Rainfall (mm)
	Max	Mini		Max	Mini	
June	43.2	37.8	2.3	41.3	26.7	0.5
July	38.3	32.1	27.1	40.3	26.3	4.6
August	40.3	34.8	36.8	38.8	24.7	4.4
September	43.5	30.7	21.7	40.0	26.6	0.10
October	42.6	34.6	2.6	39.5	23.9	50.2
November	39.4	31.0	0.0	23.3	31.4	0.00

Sources : Shambat and Elrawakeeb meteorological Station

Appendix 3 : Means of different characters of 15 pearl millet (*Pennsetium glaucum*) genotypes evaluated in Elrawakeeb location

Genotypes	PH 30	PH 45	PH 60	PH 75	TL 30	TL 45	TL 60	TL 75	Flr 50	Matur	LAI 30	LAI 45
JM 49	87.36	135.65	157.98	159.43	2.93	4.50	4.69	4.95	55.83	87.50	3.55	5.17
JM 25	85.22	140.77	157.54	159.23	3.25	3.76	4.16	4.69	55.00	89.67	3.22	3.93
JM 21	88.98	135.85	157.68	158.71	3.15	4.00	4.45	4.87	54.33	89.08	3.12	4.42
JM 45	86.46	137.00	160.54	161.43	3.16	4.39	4.70	5.04	53.42	85.67	3.23	4.36
JM 44	91.78	146.02	163.62	164.34	3.21	3.87	4.45	5.05	53.58	86.83	3.44	5.04
JM 48	85.02	135.29	153.26	154.03	3.18	3.74	4.12	4.61	54.42	85.08	2.66	3.86
JM 36	87.10	144.66	151.29	151.42	3.35	4.19	4.34	4.83	54.00	87.75	3.68	4.78
Madelkawiya	96.88	154.19	171.35	182.14	3.41	4.47	4.87	5.33	52.50	84.75	3.18	4.60
JM 3	88.83	148.04	161.62	165.08	3.33	4.03	4.33	4.75	56.67	93.67	3.44	4.46
JM 30	85.57	142.13	151.80	158.26	3.19	4.22	4.69	5.08	53.83	90.33	3.44	4.40
JM 23	95.06	169.87	181.53	186.13	3.56	4.59	4.75	5.40	55.33	87.75	3.59	5.33
JM 38	85.83	138.04	149.77	151.13	3.15	4.15	4.29	4.93	53.33	87.17	3.13	4.55
BS / Sh /94	80.13	145.32	155.05	159.68	3.71	4.56	4.99	5.32	47.08	71.25	4.04	4.44
JM 24	91.73	147.72	169.37	171.26	3.44	4.58	4.83	5.22	54.75	86.33	3.71	5.08
Ugandi	87.36	149.67	160.50	162.49	3.48	4.66	4.88	5.06	43.83	75.67	3.40	4.92
mean	88.22	144.68	160.19	162.93	3.30	4.25	4.57	5.01	53.19	85.90	3.39	4.62
LSD (0.05)	5.81	3.86	3.05	3.14	0.49	0.35	0.26	0.24	1.02	1.73	0.36	0.44
CV %	8.10	3.29	2.34	2.37	18.18	10.19	7.00	5.95	2.35	2.48	13.14	11.67

Continues Appendix 3 :

Genotypes	LAI 60	LAI 75	FTL	Dpleng	Ydg/p	Yd t/h	HI%	Biomass	PnLng	Sd/pn	1000-sd
JM 49	4.89	4.04	1.66	3.26	39.34	1.13	18.71	176.57	23.82	1550.00	7.83
JM 25	4.13	3.57	1.78	3.41	53.71	1.04	20.62	203.62	19.00	1800.00	7.17
JM 21	4.16	3.62	1.60	3.62	35.61	1.16	17.36	171.71	21.09	1909.17	7.00
JM 45	4.53	3.49	1.74	1.59	38.69	1.39	19.79	156.93	21.03	1562.50	8.25
JM 44	4.74	3.86	1.55	2.99	52.11	1.20	21.18	193.44	18.07	1805.00	7.33
JM 48	3.25	3.02	1.65	3.04	38.29	1.03	19.53	163.78	21.66	1514.17	7.42
JM 36	4.18	3.51	1.73	3.41	46.84	1.31	21.09	178.93	20.06	1770.00	7.33
Madelkawiya	4.50	3.50	1.77	3.39	49.21	1.25	19.89	195.83	23.80	1660.00	7.17
JM 3	4.73	3.76	1.09	3.59	29.83	0.79	15.96	161.09	19.96	1201.67	7.50
JM 30	4.51	3.66	1.76	3.32	54.74	1.21	20.21	213.42	20.51	1912.50	7.58
JM 23	5.79	4.72	1.72	3.18	65.78	1.26	24.12	206.44	21.51	2125.00	5.08
JM 38	4.35	3.89	1.62	2.94	48.95	1.11	19.45	202.60	20.18	1484.17	8.58
BS / Sh /94	4.72	4.36	1.76	2.54	48.30	1.73	18.08	219.55	25.27	1802.50	8.33
JM 24	4.57	4.44	1.94	3.68	45.88	1.19	19.34	189.90	21.63	1769.17	6.75
Ugandi	4.99	4.58	1.92	2.96	44.77	1.71	19.29	19.97	24.01	1919.17	6.92
mean	4.54	3.87	1.68	3.13	46.14	1.23	19.64	188.32	21.44	1719.00	7.35
LSD (0.05)	0.28	0.25	0.17	0.33	8.70	0.28	2.88	35.52	2.11	174.86	17.71
CV %	7.6	8.1	12.54	13.07	23.21	28.13	20.85	23.22	12.36	14.49	1.06

Appendix 4: Means of different characters of 15 pearl millet (*Pennsetium glaucum*) genotypes evaluated in Shambat location

Genotypes	PH 30	PH 45	PH 60	PH 75	TL 30	TL 45	TL 60	TL 75	Flr 50	Matur	LAI 30	LAI 45
JM 49	76.66	118.33	173.75	180.40	3.08	3.52	3.70	3.90	56.67	85.92	2.66	5.02
JM 25	81.12	119.43	171.67	177.20	3.08	3.37	3.53	4.35	53.42	82.83	3.31	4.47
JM 21	73.94	122.01	168.37	183.16	2.98	3.30	3.38	3.86	55.75	81.58	3.41	4.59
JM 45	78.85	125.25	176.13	183.30	3.25	3.53	3.68	4.03	59.33	83.67	3.44	5.33
JM 44	77.58	131.38	161.96	170.73	2.98	3.67	3.73	4.02	57.83	83.58	4.28	4.42
JM 48	89.21	126.33	156.63	165.75	3.22	3.83	3.91	4.22	58.17	84.83	3.20	3.93
JM 36	82.01	120.92	159.38	168.17	2.80	3.38	3.58	3.85	58.25	84.00	3.04	5.19
Madelkawiya	84.46	118.92	158.71	163.42	2.78	3.42	3.54	4.18	58.58	82.75	4.60	3.93
JM 3	78.68	123.10	169.75	179.60	3.25	3.58	3.74	4.23	61.33	87.00	3.02	5.14
JM 30	78.73	128.62	186.03	195.23	3.37	3.82	3.88	4.07	59.42	85.67	3.43	5.10
JM 23	74.32	123.15	167.83	176.47	2.98	3.80	3.83	4.28	52.17	84.08	3.26	4.81
JM 38	82.45	140.08	169.00	178.23	3.30	3.99	4.15	4.04	58.67	83.33	3.14	4.50
BS / Sh /94	69.21	134.97	149.27	160.70	3.25	3.67	3.72	4.52	50.25	81.00	2.58	5.17
JM 24	79.78	131.20	175.67	189.13	2.97	3.40	3.60	3.92	67.67	84.92	3.39	6.11
Ugandi	82.52	136.67	155.83	176.13	3.89	4.42	4.57	5.04	51.17	79.33	3.12	5.08
mean	79.30	126.69	166.66	176.51	3.15	3.65	3.77	4.17	56.64	83.63	3.33	4.85
LSD (0.05)	10.24	16.53	17.99	13.64	0.51	0.53	0.56	0.58	1.10	1.13	1.01	1.17
CV %	15.9	16.06	13.29	9.51	19.78	17.97	18.25	17.04	2.39	1.67	37.37	29.59

Continues Appendix 4 :

Genotypes	LAI 60	LAI 75	FTL	Dpleng	Ydg/p	Yd t/h	HI%	Biomass	PnLng	Sd/pn	1000-sd
JM 49	4.75	3.60	1.49	2.22	25.58	1.28	13.09	170.88	20.95	1185.83	7.51
JM 25	4.42	3.45	1.06	2.29	28.24	1.41	14.54	169.12	23.21	1600.00	7.39
JM 21	4.28	3.30	0.82	2.49	22.92	1.15	11.77	166.67	19.71	1765.00	4.13
JM 45	5.66	3.25	0.90	2.32	32.21	1.61	15.43	167.39	18.21	1269.17	8.49
JM 44	4.70	3.32	1.76	2.12	28.93	1.46	15.99	159.05	22.18	1159.17	6.81
JM 48	4.28	3.01	1.13	2.26	35.91	1.55	17.73	166.91	21.77	1430.83	6.25
JM 36	3.45	2.99	0.91	1.97	30.11	1.42	16.45	151.72	23.19	1691.67	6.79
Madelkawiya	3.75	2.78	1.10	2.14	45.77	2.46	20.66	175.09	24.87	1255.83	6.94
JM 3	4.44	3.10	1.02	2.21	29.37	1.14	16.42	150.94	22.41	1171.67	6.68
JM 30	5.42	3.91	1.72	2.14	23.54	1.18	11.37	184.52	21.93	1210.00	6.03
JM 23	4.34	2.82	1.53	2.57	28.09	1.49	13.71	179.88	27.50	1384.17	6.59
JM 38	4.58	3.16	1.21	2.15	39.62	1.90	20.39	153.15	21.69	1128.33	7.66
BS / Sh /94	3.94	3.29	1.17	1.61	27.94	1.90	14.84	159.81	24.94	1821.67	6.44
JM 24	4.47	3.08	0.87	1.78	29.31	1.64	14.82	163.09	19.70	1370.83	6.20
Ugandi	4.87	3.96	1.70	1.89	29.66	1.57	14.79	170.90	24.00	1672.50	7.28
mean	4.49	3.27	1.23	2.14	30.48	1.54	15.47	165.94	22.42	1407.78	6.75
LSD (0.05)	1.19	0.70	0.42	0.47	8.64	0.54	3.89	20.43	2.86	265.02	1.38

CV %	32.66	26.38	42.54	26.99	35.91	43.23	30.96	15.21	15.7	26.81	25.20

Appendix 5 : Mean of different characters of pearl millet genotypes averaged across four water treatment over two locations (Shambat and Elrawakeeb)

Genotypes	PH 30	PH 45	PH 60	PH 75	TL30	TL 45	TL 60	TL 75	Flr 50	Matur	LAI 30	LAI 45	LAI 60
JM 49	82.01	126.99	165.86	169.91	3.00	4.01	4.19	4.43	56.25	86.71	3.11	5.09	4.82
JM 25	83.17	130.10	164.60	168.21	3.17	3.57	3.84	4.52	54.21	86.25	3.27	4.20	4.28
JM 21	81.46	128.93	163.02	170.93	3.07	3.65	3.92	4.36	55.04	85.33	3.26	4.50	4.22
JM 45	82.66	131.13	168.33	172.36	3.20	3.96	4.19	4.53	56.38	84.67	3.33	4.84	5.09
JM 44	84.68	138.70	162.79	167.54	3.09	3.77	4.09	4.54	55.71	85.21	3.86	4.73	4.72
JM 48	87.11	130.81	154.94	159.89	3.20	3.79	4.02	4.42	56.29	84.96	2.93	3.90	3.76
JM 36	84.55	132.79	155.33	159.79	3.07	3.78	3.96	4.34	56.13	85.88	3.36	4.98	3.81
Madelkawiya	90.67	136.55	165.03	172.78	3.10	3.94	4.15	4.75	55.54	83.75	3.89	4.26	4.12
JM 3	83.76	135.57	165.68	172.34	3.29	3.80	4.03	4.49	59.00	90.33	3.23	4.80	4.58
JM 30	82.15	135.38	168.92	176.75	3.28	4.02	4.24	4.58	56.63	88.00	3.44	4.75	4.96
JM 23	84.69	146.51	174.68	181.30	3.27	4.19	4.31	4.84	53.75	85.92	3.42	5.07	5.06
JM 38	84.14	139.06	159.39	164.68	3.23	4.07	4.26	4.49	56.00	85.25	3.14	4.52	4.46
BS / Sh /94	74.67	140.14	152.16	160.19	3.48	4.12	3.19	4.92	48.67	76.13	3.31	4.80	4.33
JM 24	85.75	139.46	172.52	180.20	3.20	3.99	3.02	4.57	56.21	85.63	3.55	5.59	4.52
Ugandi	84.94	143.17	158.17	169.31	3.69	4.54	3.49	5.05	47.50	77.50	3.26	5.00	4.93
Mean	83.76	135.69	163.43	169.75	3.22	3.95	3.93	4.59	54.89	84.77	3.36	4.74	4.51
LSD (0.05)	6.15	7.94	9.43	6.82	0.34	0.33	0.31	0.31	0.76	1.08	0.52	0.65	0.62
CV %	9.05	7.21	7.1	4.94	12.82	10.14	9.57	8.31	1.71	1.57	19.18	16.82	16.99

Continues Appendix 5 :

Genotypes	LAI 75	Ftl/p	Dpleng	Ydg/p	Yd t/h	HI%	Biomass	PnLng	Sd/pn	1000-sd
JM 49	3.82	1.16	2.74	32.46	1.20	15.90	173.72	22.39	1.37	7.67
JM 25	3.51	0.98	2.85	40.98	1.23	17.58	186.37	21.10	1.70	7.28
JM 21	3.46	0.81	3.06	29.26	1.15	14.57	169.19	20.40	1.84	5.57
JM 45	3.37	0.89	1.96	35.45	1.50	17.61	162.16	19.20	1.42	8.37
JM 44	3.59	1.27	2.56	40.52	1.33	18.59	172.08	20.12	1.48	7.07
JM 48	3.01	0.98	2.65	37.10	1.29	18.63	165.35	21.71	1.47	6.83
JM 36	3.25	0.89	2.69	38.48	1.36	18.77	165.32	21.62	1.73	7.06
Madelkawiya	3.14	0.99	2.77	47.49	1.85	20.27	185.46	23.50	1.46	7.05
JM 3	3.43	0.78	2.90	29.60	0.96	16.19	156.01	21.19	1.19	7.09
JM 30	3.78	1.30	2.73	39.14	1.19	15.79	198.97	20.81	1.56	6.81
JM 23	3.77	1.20	2.87	46.94	1.37	18.92	193.16	22.84	1.75	5.84
JM 38	3.53	1.01	2.54	44.29	1.50	19.92	177.87	20.93	1.31	8.12
BS / Sh /94	3.83	1.02	2.07	38.12	1.81	16.46	189.68	25.10	1.81	7.39
JM 24	3.76	0.92	2.73	37.59	1.42	17.08	176.50	20.67	1.57	6.47
Ugandi	4.27	1.33	2.42	37.22	1.64	17.04	180.94	24.01	1.80	7.10
Mean	3.57	1.03	2.64	38.31	1.39	17.55	176.85	21.71	1.56	7.05

LSD (0.05)	0.40	0.21	0.25	6.05	0.26	2.59	18.55	1.68	0.18	0.92
CV %	13.69	25.01	12.92	19.44	26.83	18.15	14.94	9.53	14.05	16.15

Appendix 6 : Mean of genotypes under the different water treatments W_0 , W_1 , W_2 , W_3 for grain yield (ton /ha) average over two locations (Shambat and Elrawakeeb)

Serial No	Genotypes	W_0	W_1	W_2	W_3	
1	JM 49	1.28	1.29	1.07	1.02	1.16
2	JM 25	1.27	0.81	0.83	0.99	0.98
3	JM 21	0.94	0.71	0.90	0.69	0.81
4	JM 45	1.07	0.81	0.86	0.80	0.89
5	JM 44	1.26	1.10	1.26	1.45	1.27
6	JM 48	1.20	0.81	0.94	0.96	0.98
7	JM 36	1.40	0.73	0.63	0.78	0.89
8	Madelkawiya	1.25	0.73	1.07	0.91	0.99
9	JM 3	0.95	0.63	0.83	0.72	0.78
10	JM 30	1.28	1.45	0.97	1.48	1.30
11	JM 23	1.60	1.32	0.91	0.95	1.20
12	JM 38	1.09	1.03	1.09	0.83	1.01
13	BS / Sh /94	1.42	0.98	0.90	0.78	1.02
14	JM 24	1.05	0.97	0.95	0.70	0.92
15	Ugandi	1.22	1.58	1.02	1.50	1.33
	Mean	1.22	1.00	0.95	0.97	1.03

LSD (G) 0.08

LSD (W) 0.21

LSD (W X G) 0.42

Appendix 7 : Mean of genotypes under the different water treatments W_0 , W_1 , W_2 , W_3 for grain yield per plant (g) average over two locations (Shambat and Elrawakeeb)

Serial No	Genotypes	W_0	W_1	W_2	W_3	Mean
1	JM 49	46.49	28.70	34.01	20.64	32.46
2	JM 25	53.48	29.16	40.50	40.77	40.98
3	JM 21	39.98	20.71	32.58	23.79	29.26
4	JM 45	49.54	28.50	35.75	28.00	35.45
5	JM 44	55.63	23.76	48.33	34.37	40.52
6	JM 48	45.52	33.89	38.95	30.04	37.10
7	JM 36	47.27	32.52	44.42	29.70	38.48
8	Madelkawiya	60.67	36.30	50.29	42.70	47.49
9	JM 3	34.55	25.12	31.88	26.86	29.60
10	JM 30	55.09	22.88	41.30	37.29	39.14
11	JM 23	59.67	37.43	46.12	44.53	46.94
12	JM 38	55.29	25.90	47.96	48.01	44.29
13	BS / Sh /94	43.96	34.31	37.68	36.55	38.12
14	JM 24	50.51	23.20	49.80	26.87	37.59
15	Ugandi	45.88	27.65	44.02	31.31	37.22
	Mean	49.57	28.67	41.57	33.43	38.31

LSD (G) 6.05

LSD (W) 4.05

LSD (W X G) 12.10

Appendix 8 : Mean of genotypes under the different water treatments W_0 , W_1 , W_2 , W_3 for number of seed per plant (×1000) average over two locations (Shambat and Elrawakeeb)

Serial No	Genotypes	W_0	W_1	W_2	W_3	Mean
1	JM 49	1576.67	1200.00	1546.67	1148.33	1367.92
2	JM 25	2355.00	1118.33	2250.00	1076.67	1700.00
3	JM 21	2220.00	1456.67	2250.00	1421.67	1837.08
4	JM 45	1670.00	1200.00	1658.33	1135.00	1415.83
5	JM 44	1825.00	1143.33	1748.33	1211.67	1482.08
6	JM 48	1785.00	1176.67	1773.33	1155.00	1472.50
7	JM 36	2348.33	968.33	2303.33	1303.33	1730.83
8	Madelkawiya	1745.00	1080.00	1723.33	1283.33	1457.92
9	JM 3	1363.33	1023.33	1078.33	1281.67	1186.67
10	JM 30	1753.33	1223.33	1713.33	1555.00	1561.25
11	JM 23	1853.33	1541.67	1763.33	1860.00	1754.58
12	JM 38	1578.33	971.67	1485.00	1190.00	1306.25
13	BS / Sh /94	2740.00	1235.00	1678.33	1595.00	1812.08
14	JM 24	2070.00	1156.67	1661.67	1391.67	1570.00
15	Ugandi	2261.67	1265.00	2038.33	1618.33	1795.83
	Mean	1943.00	1184.00	1778.11	1348.44	1563.39

LSD (G) 108.95

LSD (W) 178.46

LSD (W X G) 356.92

Appendix 9 : Mean of genotypes under the different water treatments W_0, W_1 , W_2 , W_3 for 1000 seed weight (g) average over two locations (Shambat and Elrawakeeb)

Serial No	Genotypes	W_0	W_1	W_2	W_3	Mean
1	JM 49	8.39	8.43	7.32	6.56	
2	JM 25	7.34	7.18	7.37	7.24	7.28
3	JM 21	6.20	5.95	5.35	4.77	5.57
4	JM 45	11.73	7.14	7.95	6.66	8.37
5	JM 44	6.67	7.17	7.76	6.70	7.07
6	JM 48	7.23	7.87	5.50	6.74	6.83
7	JM 36	6.97	7.17	6.39	7.72	7.06
8	Madelkawiya	7.62	6.99	8.09	5.51	7.05
9	JM 3	8.10	6.91	6.93	6.42	7.09
10	JM 30	8.68	6.31	5.93	6.32	6.81
11	JM 23	7.06	4.74	6.71	4.84	5.84
12	JM 38	8.52	10.26	7.48	6.23	8.12
13	BS / Sh /94	8.18	6.50	7.93	6.94	7.39
14	JM 24	7.41	6.38	6.49	5.62	6.47
15	Ugandi	7.92	8.44	5.89	6.14	7.10
	Mean	7.87	7.16	6.87	6.29	7.05

LSD (G) 0.44

LSD (W) 0.92

LSD (W X G) 1.85

Appendix 10 : Mean of genotypes under the different water treatments W_0, W_1 , W_2 , W_3 for dead part length per main panicle average over two locations (Shambat and Elrawakeeb)

Genotypes	W_0	W_1	W_2	W_3	Mean
JM 49	1.83	3.22	2.56	3.35	2.74
JM 25	2.06	2.78	2.89	3.67	2.85
JM 21	2.22	3.00	2.82	4.19	3.06
JM 45	1.56	2.28	1.80	2.19	1.96
JM 44	1.74	2.85	2.57	3.07	2.56
JM 48	1.97	3.37	1.99	3.26	2.65
JM 36	2.16	3.12	2.34	3.14	2.69
Madelkawiya	2.09	3.08	2.54	3.35	2.77
JM 3	2.21	2.56	2.97	3.87	2.90
JM 30	1.65	3.41	2.51	3.34	2.73
JM 23	2.50	2.75	2.40	3.84	2.87
JM 38	1.96	2.46	2.27	3.49	2.54
BS / Sh /94	1.10	2.92	1.42	2.85	2.07
JM 24	2.67	2.24	2.65	3.36	2.73
Ugandi	1.68	3.40	1.73	2.88	2.42
Mean	1.96	2.90	2.36	3.32	2.64

LSD (G)	0.15
LSD (W)	0.28
LSD (W X G)	0.55

Appendix 11 : Mean of genotypes under the different water treatments W_0, W_1 , W_2 , W_3 for Panicle length / main head average over two locations (Shambat and Elrawakeeb)

Serial No	Genotypes	W_0	W_1	W_2	W_3	Mean
1	JM 49	26.47	20.98	21.48	20.61	22.39
2	JM 25	24.49	19.87	23.56	16.50	21.10
3	JM 21	23.32	18.77	21.13	18.38	20.40
4	JM 45	24.31	18.01	22.11	12.39	19.20
5	JM 44	21.53	18.33	22.22	18.42	20.12
6	JM 48	23.52	19.18	24.98	19.17	21.71
7	JM 36	25.05	22.08	22.47	16.89	21.62
8	Madelkawiya	26.98	25.54	24.26	17.23	23.50
9	JM 3	25.65	21.19	22.63	15.28	21.19
10	JM 30	24.36	20.84	22.57	15.45	20.81
11	JM 23	25.37	23.10	23.51	19.38	22.84
12	JM 38	24.76	21.15	22.58	15.25	20.93
13	BS / Sh /94	28.32	26.00	25.81	20.29	25.10
14	JM 24	24.16	18.12	21.93	18.46	20.67
15	Ugandi	27.68	20.98	26.04	21.34	24.01
	Mean	25.06	20.94	23.15	17.67	21.71

LSD (G)	1.64
LSD (W)	1.68
LSD (W X G)	3.36

Appendix 12 : Mean of genotypes under the different water treatments W_0, W_1 , W_2 , W_3 for plant height at 75 days after sowing date average over two locations (Shambat and Elrawakeeb)

Serial No	Genotypes	W_0	W_1	W_2	W_3	Mean
1	JM 49	178.57	154.73	188.13	158.22	169.91
2	JM 25	183.15	158.10	181.37	150.23	168.21
3	JM 21	173.80	168.92	182.38	158.63	170.93
4	JM 45	181.00	167.18	177.42	163.85	172.36
5	JM 44	176.97	152.45	185.12	155.62	167.54
6	JM 48	162.67	156.43	171.55	148.92	159.89
7	JM 36	170.32	150.08	172.12	146.65	159.79
8	Madelkawiya	185.82	175.63	182.62	147.05	172.78
9	JM 3	187.58	150.80	187.60	163.37	172.34
10	JM 30	178.43	172.07	191.17	165.32	176.75
11	JM 23	193.53	178.05	189.28	164.32	181.30
12	JM 38	166.02	166.50	172.82	153.38	164.68
13	BS / Sh /94	170.90	156.12	168.17	145.57	160.19
14	JM 24	198.52	163.35	195.20	163.72	180.20
15	Ugandi	171.97	165.12	179.98	160.18	169.31
	Mean	178.62	162.37	181.66	156.33	169.75

LSD (G)	9.82
LSD (W)	6.82
LSD (W X G)	13.64

Appendix 13 : Mean of genotypes under the different water treatments W_0, W_1 , W_2 , W_3 for number of tillers per plant at 75 days after sowing date average over two locations (Shambat and Elrawakeeb)

Serial No	Genotypes	W_0	W_1	W_2	W_3	Mean
1	JM 49	4.42	4.35	4.29	4.64	4.43
2	JM 25	4.69	4.21	4.49	4.69	4.52
3	JM 21	3.85	4.90	4.11	4.59	4.36
4	JM 45	4.13	4.37	4.65	4.98	4.53
5	JM 44	3.96	4.61	4.78	4.79	4.54
6	JM 48	4.39	3.66	4.82	4.79	4.42
7	JM 36	4.13	4.16	4.64	4.43	4.34
8	Madelkawiya	4.42	4.10	5.39	5.11	4.75
9	JM 3	4.44	4.27	4.69	4.56	4.49
10	JM 30	4.28	4.38	4.67	4.98	4.58
11	JM 23	4.61	4.67	4.99	5.10	4.84
12	JM 38	4.27	4.32	4.72	4.65	4.49
13	BS / Sh /94	4.95	4.77	5.03	4.92	4.92
14	JM 24	4.19	4.34	4.49	5.25	4.57
15	Ugandi	4.91	5.21	4.87	5.21	5.05
	Mean	4.38	4.42	4.71	4.84	4.59

LSD (G)	0.30
LSD (W)	0.31
LSD (W X G)	0.62

Appendix 14 : Mean of genotypes under the different water treatments W_0, W_1 , W_2 , W_3 for leaf area index per plant at 75 days after sowing date average over two locations (Shambat and Elrawakeeb)

Serial No	Genotypes	W_0	W_1	W_2	W_3	Mean
1	JM 49	4.44	3.56	3.90	3.39	3.82
2	JM 25	3.40	3.37	4.01	3.26	3.51
3	JM 21	4.04	3.20	3.68	2.94	3.46
4	JM 45	4.04	3.36	3.14	2.93	3.37
5	JM 44	3.99	3.44	3.46	3.48	3.59
6	JM 48	2.58	2.53	3.85	3.09	3.01
7	JM 36	3.25	2.98	3.76	3.02	3.25
8	Madelkawiya	3.74	2.69	3.37	2.78	3.14
9	JM 3	4.15	2.86	4.00	2.71	3.43
10	JM 30	4.01	4.15	3.95	3.03	3.78
11	JM 23	4.51	3.77	3.09	3.71	3.77
12	JM 38	4.21	2.70	3.94	3.27	3.53
13	BS / Sh /94	3.85	3.51	4.36	3.58	3.83
14	JM 24	4.11	3.43	4.12	3.39	3.76
15	Ugandi	5.07	3.71	4.67	3.66	4.27
	Mean	3.96	3.28	3.82	3.21	3.57

LSD (G)	0.21
LSD (W)	0.40
LSD (W X G)	0.79

Appendix 15 : Mean of genotypes under the different water treatments W_0, W_1 , W_2 , W_3 for days to 50% flowering average over two locations (Shambat and Elrawakeeb)

Serial No	Genotypes	W_0	W_1	W_2	W_3	Mean
1	JM 49	58.67	55.33	56.83	54.17	56.25
2	JM 25	56.33	51.67	56.17	52.67	54.21
3	JM 21	58.83	52.00	57.83	51.50	55.04
4	JM 45	59.33	56.00	57.50	52.67	56.38
5	JM 44	57.83	55.17	57.17	52.67	55.71
6	JM 48	58.83	56.50	57.50	52.33	56.29
7	JM 36	58.67	53.50	59.33	53.00	56.13
8	Madelkawiya	58.33	55.33	57.33	51.17	55.54
9	JM 3	61.67	57.67	61.33	55.33	59.00
10	JM 30	61.17	56.00	56.33	53.00	56.63
11	JM 23	57.50	51.83	53.67	52.00	53.75
12	JM 38	60.00	55.83	56.00	52.17	56.00
13	BS / Sh /94	51.50	44.33	50.83	48.00	48.67
14	JM 24	59.50	54.00	58.00	53.33	56.21
15	Ugandi	50.67	44.33	50.33	44.67	47.50
	Mean	57.92	53.30	56.41	51.91	54.89

LSD (G)	0.50
LSD(W)	0.76
LSD W X G	1.52

Appendix 16: Mean of genotypes under the different water treatments W_0, W_1, W_2, W_3 for days to maturity average over two locations (Shambat and Elrawakeeb)

Serial No	Genotypes	W_0	W_1	W_2	W_3	Mean
1	JM 49	93.83	91.67	80.83	80.50	86.71
2	JM 25	92.83	92.00	79.17	81.00	86.25
3	JM 21	93.67	93.33	75.67	78.67	85.33
4	JM 45	91.67	89.83	75.17	82.00	84.67
5	JM 44	87.50	91.83	78.33	83.17	85.21
6	JM 48	90.50	91.00	80.33	78.00	84.96
7	JM 36	89.17	88.83	83.17	82.33	85.88
8	Madelkawiya	86.33	84.17	82.17	82.33	83.75
9	JM 3	94.33	96.50	82.33	88.17	90.33
10	JM 30	91.17	94.50	79.33	87.00	88.00
11	JM 23	88.83	90.33	82.33	82.17	85.92
12	JM 38	88.17	91.50	81.33	80.00	85.25
13	BS / Sh /94	77.17	77.67	74.67	75.00	76.13
14	JM 24	89.67	92.50	80.33	80.00	85.63
15	Ugandi	80.67	79.17	76.50	73.67	77.50
	Mean	89.03	89.66	79.44	80.93	84.77

LSD (G)	1.07
LSD (W)	1.08
LSD (W X G)	2.16

Appendix 17 : Mean of genotypes under the different water treatments W_0, W_1 , W_2 , W_3 for biomass dry weight (g) average over two locations (Shambat and Elrawakeeb)

Serial No	Genotypes	W_0	W_1	W_2	W_3	Mean
1	JM 49	191.48	188.70	158.47	156.24	173.72
2	JM 25	187.64	182.46	202.02	173.35	186.37
3	JM 21	213.85	148.78	188.30	125.84	169.19
4	JM 45	173.23	157.94	187.06	130.42	162.16
5	JM 44	201.07	164.82	198.38	124.05	172.08
6	JM 48	160.46	150.53	195.41	154.99	165.35
7	JM 36	183.91	167.80	176.68	132.92	165.32
8	Madelkawiya	214.36	170.82	199.56	157.10	185.46
9	JM 3	180.36	122.30	192.59	128.82	156.01
10	JM 30	202.15	200.06	223.52	170.16	198.97
11	JM 23	213.72	175.73	198.85	184.34	193.16
12	JM 38	172.62	174.10	183.06	181.71	177.87
13	BS / Sh /94	190.07	199.84	189.98	178.83	189.68
14	JM 24	197.19	172.58	179.58	156.63	176.50
15	Ugandi	194.09	159.66	227.12	142.87	180.94
	Mean	191.75	169.07	193.37	153.22	176.85

LSD (G) 14.52

LSD (W) 21.46

LSD(W X G) 42.92

Appendix 18 : Mean of genotypes under the different water treatments W_0, W_1 , W_2 , W_3 for harvest index (%) average over two locations(Shambat and Elrawakeeb)

Serial No	Genotypes	W_0	W_1	W_2	W_3	Mean
1	JM 49	13.93	12.29	6.10	9.74	9.74
2	JM 25	13.80	9.35	11.15	10.41	10.41
3	JM 21	8.73	8.71	9.68	8.63	8.63
4	JM 45	12.10	8.92	9.59	10.04	10.04
5	JM 44	12.55	10.64	10.83	10.59	10.59
6	JM 48	11.40	8.67	9.60	9.77	9.77
7	JM 36	9.50	10.75	11.17	10.15	10.15
8	Madelkawiya	10.25	11.56	10.96	9.90	9.90
9	JM 3	7.88	8.09	6.76	7.83	7.83
10	JM 30	12.13	9.97	11.81	10.11	10.11
11	JM 23	14.53	12.89	10.65	12.11	12.11
12	JM 38	13.36	11.10	9.03	9.83	9.83
13	BS / Sh /94	9.58	9.20	8.95	8.83	8.83
14	JM 24	10.14	10.85	10.33	9.57	9.57
15	Ugandi	11.65	7.98	10.25	9.56	9.56
	Mean	11.43	10.07	9.79	9.80	9.80

LSD (G) 1.02

LSD (W) 1.52

LSD (W X G) 3.00