# IDENTIFICATION OF DROUGHT TORELANT VARIETIES OF COMMON BEAN (*Phaseolus vulgaris* L.) IN TANZANIA

**BY**

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

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## ABSTRACT

The aim of this research was to assess for levels of drought tolerance among common bean (*Phaseolus vulgaris* L.) lines developed for drought tolerance; grown under non-stress (NS) and drought-stress (DS) water conditions. The research was conducted at Sokoine University of Agriculture (SUA) located at $6^{0}$5' latitude south, $37^{0}$3' longitude east and 525 m.a.s.l. It was done in a screen house. The experimental design was Completely Randomized Design (CRD), two water regimes and twelve bean lines were combined in split- plot arrangement. Water regimes were the main plots and bean lines were sub-plots. The soil in pots was irrigated to 95 ± 5% field capacity (fc) which was determined by a tensiometers reading. Three seeds were planted in each pot, after germination (7-10 days) thinning was done to leave two (2) uniform bean plants in each pot. Then the NS and DS treatments were initiated at two weeks after germination. For non-stress (NS) treatment, irrigation was done once/day depending on the requirements of the plant and environmental conditions receiving water to make 95 ± 5% field capacity, which kept the plant water-stress free. In drought stress, watering was cut down to mimick a drought condition. Stress was imposed starting at different stages i.e. before flowering, at podding and thereafter stress condition was maintained at 20 ± 5 % fc. Data were collected for plant height, pod length, leaf area, number of seeds per pod, number of pods per plant and seed weight per plant. The results showed that some lines had a high capacity for tolerating DS conditions namely RWR 109, UBR (92) 09, MMS 243, CNF 5547, HHL MD 30-75 and G 4523.

# DECLARATION

I, **JASPA SAMWEL** do hereby declare to the Senate of Sokoine University of Agriculture that this dissertation is my own original work, and has not been submitted for a degree award in any University.

____________________ ___________________

Jaspa Samwel Date

(MSc. Candidate)

The above declaration confirmed

_______________________ ___________________

Prof. S. Nchimbi-Msolla Date

(Supervisor)

# COPYRIGHT

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## DEDICATION

This dissertation is dedicated to my family especially after my Father’s death and my Uncle S. S. Kamala for sending me to school despite the poor resources they have.

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## LIST OF ABBREVIATION AND SYMBOLS

| | |
|---|---|
| % | percent |
| / | per |
| ± | plus or minus |
| ≤ | less or equal to |
| a.s.l | above sea level |
| ANOVA | Analysis of Variance |
| ARI | Agriculture Research Institute |
| C.V | Coefficient of Variation |
| cm | centimeter |
| $cm^2$ | centimetre squares |
| CRD | Completely Randomized Design |
| DNMRT | Duncan's New Multiple Range Test |
| DREB | Dehydration Response Element Binding Protein |
| DS | Drought Stress |
| g | gram |
| GM | Geometric mean |
| i.e. | That is |
| m | meter |
| MAS | Marker-assisted Selection |
| MSTAT-C | Statistical-computer program for data analysis |
| N | Nitrogen |
| NPK | Nitrogen, Phosphorus and Potassium |
| NS | Non Stress |
| ns | No significant difference |

| | |
|---|---|
| P | Probability |
| PEG | Polyethylene glycol |
| QTL | Quantitative Trait Loci |
| S | Susceptibility index |
| S.I-Unit | Standard International Unit |
| s/n | serial number |
| SE | Standard Error |
| SUA | Sokoine University of Agriculture |
| WHO | World Health Organisation |

# CHAPTER ONE

## 1.0 INTRODUCTION

Common bean *(Phaseolus vulgaris* L.) is believed to have originated from central and southern America; it is also believed to be the most ancient of the cultivated crops (Maghembe, 1999). Introduced to Eastern Africa coast by the Portuguese traders in the sixteenth century, common bean quickly became established as the food crop in many environments of the country. Presently, beans are the second most important source of human protein and the third most important source of calories for over 100 million people in rural and poor urban communities in Africa (Robin, 2005).

Common bean is grown in wetter and cool areas, In Tanzania, it is mainly grown in Kilimanjaro, Arusha, Tanga, Kigoma, Kagera, Mbeya, Rukwa and Morogoro regions. It is the most important grain legume in the country. The crop forms an integral part of the diet of the people in many African and Latin American countries (Maghembe, 1999), but mainly in developing countries (Perla *et al*., 2003 ). In Latin America it is part of the traditional diet (Broughton *et al*., 2003). The common bean is the worlds most important food legume. Grain legumes (including common bean) occupy an important place in human nutrition, especially in the dietary pattern of low income groups of people in developing countries. Legumes considered as poor man's meat, are generally a good source of nutrients (Tharanathan and Mahadevamma, 2003). The leaves can be consumed as a green vegetable and in some areas including Southern Tanzania, this is an important consideration in the varieties grown (Hillocks *et al*., 2006; Scuba, 2006). The immature pods are also widely eaten as green vegetables and they are a good source of vitamins A and C. Nutrition is a key element to any strategy to reduce the global burden of disease, hunger, malnutrition, obesity and unsafe food all cause disease and better nutrition will translate into large improvement in health among all of us, irrespective of our wealth and home country (WHO, 2002).

Common bean are sold for cash especially in urban areas where animal protein is less affordable. The nutritional benefits and contribution of beans to healthy human diets is recognized by non-profit organizations targeting human-ailments like cancer, diabetes, and heart disease ( Hangen and Bennink, 2003).

Latin America produces nearly half (5.1 x $10^6$ Tons) of the world's supply (11.6 x $10^6$ Tons) of dry beans harvested from 14.3 x $10^6$ hectares. The market value of annual dry bean production is around 10 x $10^{12}$ of US dollars. Nearly 80% of dry bean production occurs on small-scale farms in developing countries (Anonymous, 2005). The majority of the bean production occurs under low input agriculture on small scale farms in developing countries. Beans produced by these resource-poor farmers are more vulnerable to attack by disease, insect pests and abiotic stresses including drought and low soil fertility (Miklas *et al*., 2006). Bean yield has remained relatively low in Tanzania despite the good weather conditions prevailing in the major producing areas of the country. Breeders have, therefore concentrated on improving bean yield potential by breeding for such factors (Mduruma and Nchimbi, 1991). This is to stabilize bean production in these regions, there has been a need to stratify the been growth environments.

Poor yields are mainly due to lack of suitable cultivars for the different production areas, inappropriate agronomic practices, pests, diseases and the drought. Of all the environmental factors limiting bean production, drought plays a big role in yield reduction in most of the bean producing areas (Teri *et al.*, 1990). Drought stress is a worldwide production constraint of common bean (Teran and Singh, 2002). Sixty percent of common bean production Worldwide is grown under water stress, making drought the second largest contributor to yield reduction after disease (Singh, 1995). Pandey *et al.,* (1984) reported that common beans are extremely sensitive to drought, and significant yield reductions due to drought are common in the tropics.

Although the main objective is to asses for levels of drought tolerance varieties, common bean has a lot of constraints which affect its production such as low yield, susceptibility to major diseases and pests of beans; some characteristics eg seed coat, colour, seed size, cooking time, low protein content, which are not appealing to consumers; and limitations like low nitrogen fixing ability and inability to resist drought (Nchimbi, 1989; Tharanathan and Mahadevamma, 2003). Development of cultivars with improved resistance to biotic and abiotic stresses is a primary goal of bean breeding programs throughout the World (Miklas *et al*., 2006)

Drought can cause loss of almost all the crops in the field and cause famine (Nchimbi, Personal communication, 2005). Drought tolerance in agronomic terms means the ability of the crop to produce a satisfactory yield when subjected to water deficit (Madata, 1991). Drought tolerance in common bean encompasses all mechanisms that allow greater yield under soil moisture deficit (Maghembe, 1999) like thick cuticle with hairs, narrow leaves, and deep roots. Drought is considered as one of the most limiting factors to agricultural production (Kramer and Boyer, 1995; Castellanos *et al*., 1996).

Intermittent and terminal droughts are the two distinct kinds of drought associated with limited rainfall. Intermittent drought is due to climatic patterns of sporadic rainfall that cause intervals of drought and can occur at anytime during the growing season (Schneider *et al.,* 1997) or when farmers have the option of irrigation but the supply is occasionally limited. In contrast, terminal drought occurs when plants suffer lack of water during later stages of reproductive growth or when crops are planted at the beginning of a dry season (Frahm *et al*., 2004). In general, the lack of water interferes with the normal metabolism.

Drought in common bean causes abscission of many blossoms, thus resulting in poor fruit set (Stocker, 1974). Drought may also cause reduction in several yield components of common bean, that is number of pods per plant, seeds per pod and an individual seed mass (Stocker, 1974). Under water stress, common bean is seriously affected from flowering to early pod set. Drought occurring during the flowering and grain filling periods that generally are enhanced by heat and low air relative moisture are the most damaging for bean. This type of drought causes an increase frequency of barren plants and incomplete seed setting. Water stress during flowering and grain filling periods reduces seed yield and seed weight (Singh, 1995). Moderate to high drought stress can reduce biomass, number of seeds and pods, days of maturity, harvest index, seed yield and seed weight in common bean (Acosta-Gallegos and Adams, 1991; Ramirez-Vallejo and Kelly, 1998). A moderate drought stress reduces yield by 41% without altering nitrogen (N) portioning (Foster *et al*., 1995). However, severe drought stress reduces yield by 92%, N harvesting index and water use efficiency in common bean; severe drought in reproduction reduces nodulation by an average of 43% and nitrogen fixation to one sixth of a well-irrigated control (Castellanos *et al*., 1996).

Water requirement in common bean depends on soils and climatic factors. Overall, common bean is considered to be poorly tolerant to water stress (Fageria *et al*., 1997). Therefore, drought resistant varieties or cultivars of bean are important in bean producing areas with erratic rainfall as in many parts of tropical Africa (Tesha, 1987). Few farmers apply irrigation, but irrigation facilities are not within economic reach of most farmers; in such areas drought is one of the major limiting factor in bean production.

To maximize and sustain bean production, high yielding, high quality cultivars that are dependent on water, fertilizer, pesticides and manual labour should be developed. This need warrant sustained comprehensive, and integrated genetic improvement, in which favourable alleles from cultivated and wild relatives are accumulated in superior cultivars. Drought is among the most widely distributed and endemic abiotic problems affecting bean production in many regions of the world.

Among physiological and agronomic traits used as selection criteria in breeding for drought resistance in common bean, seed yield was the most reliable (Ramirez-Vallejo and Kelly, 1998).

Developing the new drought tolerant varieties in bean is the only long-term sustainable solution to the problem. Genotypic differences for drought tolerant have been reported for common bean (Abebe *et al*., 1998; Singh, 1992). The most effective selection criterion between various morphological, phenological, yield and yield related traits for identifying drought tolerant genotypes is important for drought stress and non-stress environments.

## 1.2 Objectives

### 1.2.1 Main objective

To assess for levels of drought tolerance among common bean (*Phaseolus vulgaris* L.) lines developed for drought tolerance.

### 1.3.2 Specific objectives

i) To screen bean lines for tolerance to water- stress.

ii) To evaluate bean lines for other agronomic traits under water-stress and non-stress conditions.

# CHAPTER TWO

## 2.0 LITERATURE REVIEW

### 2.1 Breeding for drought tolerance

Drought tolerance is related to moisture stress environment. It involves the ability of one genotype to be more productive in a given amount of soil moisture than the other genotype. Earliness in crop maturity can contribute to crop productivity in moisture stress environments. Earliness, though not necessarily a true mechanism of drought tolerance, although it is an important attribute of escaping drought (Madata, 1991). Many studies have attempted to partition the performance of common bean under moisture stress into discrete components. These include morphological, physiological, and phenological characteristics for which genetic variation have been demonstrated (Acosta-Gallegos, 1988).

Since drought conditions vary widely from season to season worldwide, a genotype that performs well under both non-stress and drought-stress conditions is preferred. Breeding for improved performance under drought-stress conditions while maintaining yield potential under non-stress conditions is difficult since selection based on drought tolerance often reduces yield performance under non-stress conditions (Rosielle and Hamblin, 1981). Breeding method to improve drought tolerance in common bean by basing the primary selection on Geometric Mean (GM) followed by secondary selection based on susceptibility index (S) (Ramirez-Vallejo, 1992); will assure sustained progress in breeding for drought tolerance in common bean. Selection for drought tolerance should be carried out from already proven high yielding genotypes to avoid selection for low yielder (Tarimo *et al*., 1994). Backcross conversion program may be required to introgress drought tolerance from the tolerance races into locally adapted lines or a two or three stage selection strategy (Singh, 2001).

Although management practices can contribute to increase in moisture stressed environments, major progress will be realized through genetic improvement (Singh, 1995). While the ultimate effect of drought is limitation of growth and yield, specific physiological effects of water stress vary depending on previous history of the crop (such as possible acclimation) and timing intensity of the stress (Jeffrey and Juan, 1991). Interactions of these factors probably explain a larger number of conflicting results from studies of drought effects (Kramer, 1983). This review considers different drought effect from near instantaneous effects to long-term growth effects, specific conclusion are not always given (Jeffrey and Juan, 1991). Roselle and Hamblin (1981) provided theoretical arguments suggesting that selection for tolerance to stress condition alone will increase stability of performance. Drought effects vary greatly depending on specific drought conditions and plant genetic variability (White and Izquierdo, 1994). Breeding crops for drought tolerance is considered to be a slow and difficult process (Singh, 2001). The effect of drought is complex in its mode of action, highly variable in response accentuated by interacting factors and localized within environmental regions. The development of bean genotypes that are more tolerant to drought is a practical and economical approach to lessen the negative effects of drought on the productivity of the crops (Ramirez-Vallejo and Kelly, 1998).

## 2.2 Tolerance mechanisms and selection criteria

Many drought resistance mechanisms have been proposed and been demonstrated to function in very specific contexts. The warning from previous section that drought effects vary greatly depending on specific drought conditions however is equally valid for consideration of tolerant mechanism (Jeffrey and Juan, 1991).

An outline of possible drought tolerance mechanisms is provided below according to Kramer (1983): Drought escapes i.e. earliness, recuperation. Drought tolerant with high plant water potential i.e. Maintenance of water uptake by greater root growth which extracts soil moisture and greater water uptake; increased hydraulic conductance; and reduction of water loss by reduced area of water loss, greater resistance along pathway of water loss, reduced gradient leaf to atmosphere. Drought tolerannce with low water potential i.e. Maintenance of turgor by osmotic adjustment, increased cell elasticity; desiccation tolerance by membrane stability, protein function; integrated mechanism by assimilate partitioning, remobilization. Drought tolerant through adaptation to factors related to drought heat resistance, low soil fertility, salt resistance and soil diseases and pests.

Assuming tolerance along pathway of water loss is equal; cultivars may differ in water use through effects on the water vapour pressure gradient from leaf tissue to the atmosphere. The external pressure will be equal, but internal vapour pressure will vary with leaf temperature. This factor affecting leaf will reduce water loss, variation in leaf colour both among the varieties and between dorsal and ventral sides of the same leaf area is considerable in beans, but has not been examined in relation to leaf temperature effects (Jeffrey and Juan, 1991). Reduced leaf size can also reduce temperature since for a given total leaf area, convective cooling is greater for a surface divided into smaller sections (Gates, 1968). This effect has led breeders in other crops to breed for smaller leaf sizes.

Although the preceding mechanism will reduce water loss, most stress conditions are sufficiently severe that water potentials drop to levels, which affect plant function. This leads to the possibility of adaptations permitting the plant to function at low water potentials (Jeffrey and Juan, 1991).

Drought does result in large reductions in water potential as happens in bean mechanisms, which permit the plant to continue growth. Turgor may be maintained by osmotic adjustment (increased cellular content of solute) or by low bulk tissue elastic modulus (Turner and Jones, 1980). This in turn, permits greater extraction of soil moisture. Coefficients of elasticity are obtained from the cumbersome technique of pressure volume curves used to determine osmotic adjustment (Wilson *et al.,* 1979). It has been suggested that tissue elasticity is probably more important than osmotic adjustment in crops such as beans, which seldom reach water potentials below 1.5 MPa (Jeffrey and Juan, 1991).

Due to complexities of measuring and interpreting effects of osmotic adjustment and changes in tissue elasticity, researchers have attempted to detect effects of turgor maintenance on rates of tissue elongation (Boyer and McPherson, 1975). Cell elongation in seedlings as one criterion of tolerant. Seedlings growth, but not seed germination, under osmotic stress provided by polyethylene glycol (PEG) was thought to show promise as a screening technique in wheat although no attempt was made to relate results with field conditions (Blum *et al.*, 1980).

The factors which are related to agronomic practices are important under water deficits. Cultivar improvements have been found as the most promising approach to increase yield (Singh *et al.,* 1990). This shows that selection of seed yield in common bean can be effective for both well watered and drought stress (White *et al*., 1994).

When water deficit is severe, plant cells accumulate solutes, which lower osmotic potential of the cells, thus at least partially maintaining turgor pressure. Osmotic potential may be regulated through shifts in concentrations of potassium, sugars, amino acids, and organic acids (Morgan, 1984). At very low water potential, physiological processes may be disrupted. Many physiological processes are disrupted by low tissue contents, thus relative intensities to desiccation or desiccation tolerant should also contribute to drought tolerance. Membrane such as in chloroplasts and mitochondria appear particularly sensitive to desiccation, loss of water apparently causing lesions in membrane (Leopord *et al.,* 1981). Cell membrane characteristics are sensitive to temperature effects and chloroplasts membrane stability is probably a primary determinant of temperature response of photosynthesis (Raison *et al.,* 1980). Mulched plots have usually shown a higher water use efficiency that is weight of dry matter produced/mass of water used than bare plots (Kramer and Boyer, 1995).

Crop plants, unless they are specially adapted to water deficits, are normally subjected to a certain degree of drought stress at least during part of their life cycle. Considerable evidence exist in literature showing that almost all metabolic processes and plant constituents leading to normal growth, development and yield performance are adversely affected by drought stress (Mwandemele and Doto, 1987). A lot of evidence exists in literature showing that the production and hence final economic yield in common bean is extremely sensitive to drought stress.

**2.3 Sources of drought tolerant**

Barnes (1983) advocated that many sources representing a broad range of germplasm be evaluated and the priority be placed on adapted cultivars and advanced breeding population since these will contain needed pest resistance, quality traits, and adaptation characteristics. Lines for common beans tolerant to drought stress are like A54, A170, A195, BAT336, BAT477, BAT1289, V8025, Rio Tibagi, San Cristobal 83 and other species of *Phaseolus* like *P.acutifolius* (Jaffey and Juan, 1991; Wright and Redden, 1997).

Drought susceptibility of a genotype is often measured as a function of the reduction of yield under drought stress (Blum, 1988), but values are confounded with differential yield potential of genotypes. Other yield-based estimates of drought tolerant are geometric mean (GM) of seed yield, pod number/plant, seed number/pod, and days to maturity; followed by secondary selection based on susceptibility index (S) (Ramirez-Vallejo, 1992)
or the drought susceptibility index (S) (Fischer and Maurer, 1978; Kelly, 2000). Breeders interested in performance usually use the geometric mean since drought stress can vary in severity in field environments over years. Genotypic differences in both GM and S have been demonstrated in common bean (Schneider *et al.,* 1997). Yield-based S did not differentiate between potentially drought tolerant genotypes and those that possessed low yield potential (Clarke *et al*., 1992).

Selection based solely on yield under extreme stress is a poor estimate of drought tolerant since tolerance to severe stress may be associated with reduced yield in non-stress environments (Rosielle and Hamblin, 1981). Selection should be equally effective under different levels of stress (Schneider *et al.,* 1997). Root characteristics are of primary importance in determining drought response of common bean whereas shoot characteristics are of less importance (White and Castillo, 1989). All putative traits are assessed for their contribution to grain yield and crop survival under stress.

Both quality and yield of beans are negatively affected by brief periods of water shortage (Halterlein, 1983). The development of bean genotypes that are more tolerant to drought is a practical and economical approach to lessen the negative effects of drought in the production of crop. Because seed yield is the most important part of common bean, the most practical method to improve performance is through the direct measurement of yield related characteristics (Acosta-Gallegos and Adams, 1991). Positive correlation between seed yield in drought stress (DS) and non stress (NS) environments support similar findings by Ramirez-Vallejo and Kelly (1998). Thus, genotypes that were high yielding in DS were also high in NS environment. The positive correlation between seed yield in DS and NS environments may have occurred because the mean yield in DS and NS environments due to drought stress, were taken into consideration for selecting drought tolerance lines (Fernandez, 1993).

The most important question is not whether we can breed for drought tolerant, but what level of drought tolerance can be achieved and how we can reach it efficiently. Identifying appropriate parental materials is one step, using selection criteria besides yield will help if such criteria truly reflect drought resistance, and finally yield testing should be done in such a way that truly tolerant materials are selected (Jeffrey and Juan, 1991).

# CHAPTER THREE

## 3.0 MATERIAL AND METHODS

### 3.1 Materials

Bean lines were obtained from Seliani ARI and Sokoine University of Agriculture (SUA) in Tanzania. These lines originated from the African drought nurseries in Tanzania, Malawi, and Zambia. Ten lines were evaluated [UBR (92) 17, MUS 97, MMS 243, UBR (92) 09; RWR 109, CNF 5547, DN 40, G 4523, HHL MD 30- 75, HHL 9435- 129] including two checks (SUA 90 and Canadian Wonder).

### 3.2 Methodology and experimental design

The experimental design was Complete Randomized Design (CRD), two water regimes and twelve bean lines were combined in split- plot arrangement. Water regimes were the main treatment and bean lines were sub –plots. The experiment was in three replications. For both the non-stress and water- stress conditions the loam type of soil was used. Loam soil was collected from horticultural unit SUA – Morogoro and sterilized for screen house usage. But before sterilizing 500g of the loamy soil was taken to the soil laboratory for analysis. The soil was irrigated up to 95% field capacity, which was determined by tensiometers readings; three (3) bean seeds were planted in each pot; after germination (7 – 10 days) thinning was done to leave two (2) uniform bean plants in each pot. Then the non-stress and drought-stress treatment were initiated two weeks after germination.

For non-stress treatment (NS), irrigation was done once/day depending on the requirements of the plant and environmental conditions receiving water to make 95 ± 5% field capacity, which kept the plant out of water stress. In drought stress (DS), stress was imposed at different stages i.e. before flowering, at podding and maturity stage was stressed and maintained at 20 ± 5 % of field capacity. The field capacity was measured by using tensiometer, the porous portion of the tensiometer was installed 15cm below the soil surface and the pressure obtained was changed into percentage (%) to obtain the required readings of NS and DS. Near flowering 2g of NPK fertilizer was applied per pot to increase the production capacity of the bean.

### 3.3 Data collection

Data collection included; leaf area; plant height at maturity; pod length; grain yield i.e. Seeds/pod; pods/plant and seed weight per plant.

#### 3.3.1 Pod length

Pod length was determined by measuring length of each pod and taking the average length of pods per plant.

#### 3.3.2 Number of seeds per pod

Number of seeds per pod was obtained by counting and taking the average number of seeds in pods of a plant.

#### 3.3.3 Leaf area

Leaf area was determined in the Department of Wood Utilization laboratory, by using a light box in which the drawings of the leaf was taken, and then digital planimeter was used to determine the area of the leaf. Three leaves were taken from each plant and the average of the area recorded as leaf area of the plant.

#### 3.3.4 Plant height

Plant height was determined by using a tape to measure the plant from the ground level to the tip of the main branch. The measurement was done during harvesting.

### 3.3.5 Number of pods per plant

Numbers of pods per plant were obtained by counting the total number of pods of each sampled plant; two plants were sampled per pot. In each pot the average of plant number was determined.

### 3.3.6 Seed weight per plant

Seed weight per plant was measured in the Crop Science laboratory by using the digital electronic balance and the weight recorded as grams. The mean seed weight of the two plants was recorded as the seed weight/plant.

## 3.4 Data analysis

Analysis of variance (ANOVA) was done using MSTAT-C computer program and Mean Separation Test was done by using Duncan's New Multiple Range Test (DNMRT).

# CHAPTER FOUR

## 4.0 RESULTS AND DISCUSSION

### 4.1 Plant height

Plant height was significantly different between treatments (Water regimes). Non stress had taller plants with average of 218.7 cm than the drought stress plants with average of 117 cm. Bean lines showed significant differences ($P<0.05$) in plant height. Under non stress conditions UBR (92) 17 was the tallest (312.2 cm) while SUA 90 was the shortest (79.5 cm). Under drought stress condition, the plant height ranged from 78.5 cm to 170.8 cm for Canadian Wonder and CNF 5547 respectively. The mean plant height for non stress and drought stress ranged from 79 cm to 232.8 cm for SUA 90 and UBR (92) 17 respectively. SUA 90 is shorter compared to other lines due to its bushy stature; and is the only one which showed that habit (Table 1).

**Table 1: Plant height (cm) of 12 bean lines grown in screen house 2006**

| Variety/line | Non stress | Drought stress | Mean |
|---|---|---|---|
| CNF 5547 | 238.67abc | 170.83a | 204.75abc |
| HHL MD 30-75 | 201.33 bc | 87.50 b | 144.42 bcde |
| MMS 243 | 233.17abc | 130.33ab | 181.75abcd |
| DN 40 | 197.17 bc | 82.50 b | 139.83 cde |
| MUS 97 | 279.67ab | 127.33ab | 203.50abc |
| Canadian Wonder | 165.33cd | 78.50 b | 121.92 de |
| UBR (92) 17 | 312.17a | 153.50a | 232.83a |
| UBR (92) 09 | 266.50ab | 164.17a | 215.33ab |
| SUA 90 | 79.50 d | 78.67 b | 79.08 e |
| RWR 109 | 275.17 ab | 156.83a | 216.00ab |
| G 4523 | 159.67 cd | 83.67 b | 121.67 de |
| HHL 9435-129 | 216.00 abc | 90.00 b | 153.00 bcd |
| Mean | 218.69 | 116.97 | 167.84 |
| CV (%) | 22.35 | 22.13 | 23.31 |
| SE | 28.23 | 14.95 | 22.58 |

Means in the same column followed by the same letter(s) are not significantly different (P≥0.05) following separation by Duncan's Multiple Range Test.

When bean crop is grown under adequate soil moisture, it is always not affected as compared to when is grown under drought condition (Mayaki *et. al*., 1976). The decline in plant height may have been due to increase in evapotranspiration and cell senescence during the growth season.

There was a difference in plant height among the lines within a treatment and a bigger difference still, between non-stress and drought-stress treatments. For non-stress, UBR (92) 17 was the tallest and SUA 90 the shortest at 312.2 cm and 79.5 cm respectively,while for drought-stress treatment CNF 5547, was the tallest and Canadian Wonder was the shortest at 170.8 cm and 78.5 cm respectively. Line SUA 90 the least variation 0.83 cm, in plant height bween the treatments. This implies that even under adverse conditions of drought-stress, SUA 90 was able to almost maintain the same plant height.

This shows that when these lines under drought stress with good characters are crossed with other lines under that water regime with good characteristics apart from plant height, like leaf area, pod length, number of pods per plant, number of seeds per pod and seed weight per plant, will give the required line susceptiblility to drought stress.

**4.2 Leaf area**

There was a significant difference ($P<0.05$) in leaf area across the main treatment (water regime). Non-stress environments resulted in plants with higher leaf area of 1041.6 $cm^2$ compared to drought stress with the leaf area of 669.2 $cm^2$. There were significant ($p \leq 0.05$) differences among bean lines within each condition (NS and DS) for leaf area. Under non-stress condition lines G 4523 had the highest leaf area (1342.7 $cm^2$) while line HHL 9435- 129 had the lowest leaf area (788.9 $cm^2$). Under drought stress G 4523 had the highest leaf area (762.1 $cm^2$) while the lowest was SUA 90 (581.9 $cm^2$). The combined mean leaf area range from 743.0 $cm^2$ of CNF 5547 to 1052.9 $cm^2$ for G 4523 (Table 2).

**Table 2: Leaf area ($cm^2$) of 12 bean lines grown in screen house 2006**

| Variety/line | Non stress | Drought stress | Mean |
|---|---|---|---|
| CNF 5547 | 859.28 b | 626.75 ab | 743.02 d |
| HHL MD 30-75 | 1242.12 b | 679.17 ab | 960.64 ab |
| MMS 243 | 880.72 d | 607.08 ab | 743.90 d |
| DN 40 | 1078.68 c | 740.25 ab | 909.47 b |
| MUS 97 | 875.42 d | 693.17 ab | 784.29 cd |
| Canadian Wonder | 1066.25 c | 636.92 ab | 851.58 bcd |
| UBR (92) 17 | 1095.08 c | 650.17 ab | 872.63 bc |
| UBR (92) 09 | 882.95 d | 630.58 ab | 756.77 cd |
| SUA 90 | 1132.65 c | 581.92 b | 857.28 bcd |
| RWR 109 | 1253.85 ab | 672.67 ab | 963.26 ab |
| G 4523 | 1342.65 a | 762.33 a | 1052.99 a |
| HHL 9435-129 | 788.88 d | 750.08 a | 769.48 cd |
| Mean | 1041.63 a | 669.26 b | 855.44 |
| CV (%) | 4.9 | 12.09 | 7.93 |
| SE | 29.79 | 46.7 | 39.15 |

Means in the same column followed by the same letter(s) are not significantly different (P≥0.05) following separation by Duncan's Multiple Range Test.

Under moisture stress treatment the yield was affected mostly because there was severe leaf curling, shedding and wilting which indicates a reduction in cell turgour, closure of stomata, and reduction in cell enlargement. As a result both the leaf surface area and the rate of photosynthesis are severely reduced. The major disadvantage with the decrease in leaf expansion and an increase in leaf senescence is that there is often incomplete light interception. Thus a net gain is reduced because the assimilating surface is greatly reduced (White and Izquierdo, 1994). The closed stomata affected gaseous exchange for both photosynthesis and respiration.

According to the purpose of the research; it will be better to have improvement of common bean with small leaves in order to have lines tolerant to drought stress so as to have low evapotranspiration which will maintain water to plants. Therefore, CNF 5547 should be crossed with other lines of good quality under drought stress to have bean line sustainable with stable drought tolerance. Reduced leaf size can also reduce temperature since for a given total leaf area, convective cooling is greater for a surface divided into smaller sections (Gates, 1968). This effect has led breeders in other crops to breed for smaller leaf sizes under drought tolerance.

**4.3 Pod length (cm)**

There was a significant difference between two watering regimes at ($P<0.05$) for pod length; the pods under non-stress condition were longer with mean of 11.3 cm compared to those under drought-stress conditions which were shorter with a mean of 8.9 cm. Within the treatment, under non-stress Canadian Wonder had the longest pods at 14.7 cm while DN 40 had the shortest (9.3 cm). In drought-stress SUA 90 had the longest pod (11.2 cm) followed by MUS 97 (10.2 cm) while UBR (92) 17 had the shortest pod length (6.7 cm). The mean pod length for the two treatments ranged from 8.2 cm for DN 40 to 12.2 cm for SUA 90 and Canadian Wonder (Table 3).

**Table 3: Pod length (cm) of 12 bean lines grown in screen house 2006**

| Variety/line | Non stress | Drought stress | Mean |
|---|---|---|---|
| CNF 5547 | 10.33 def | 8.83 abcd | 9.58 cde |
| HHL MD 30-75 | 10.00 efd | 8.00 bcd | 9.00 de |
| MMS 243 | 11.50 cd | 8.83 abcd | 10.17 bcd |
| DN 40 | 9.33 g | 7.00 d | 8.17 e |
| MUS 97 | 13.00 b | 10.18 ab | 11.58 ab |
| Canadian Wonder | 14.67 a | 9.67 abc | 12.17 a |
| UBR (92) 17 | 10.00 efg | 6.67 d | 8.33 e |
| UBR (92) 09 | 9.67 fg | 8.83 abcd | 9.25 de |
| SUA 90 | 13.18 b | 11.18 a | 12.17 a |
| RWR 109 | 10.50 def | 7.50 cd | 9.00 de |
| G 4523 | 10.83 cde | 9.83 abc | 10.33 bcd |
| HHL 9435-129 | 12.17 c | 9.67 abc | 10.92 abc |
| Mean | 11.26 | 8.85 | 10.06 |
| CV (%) | 3.19 | 13.98 | 8.97 |
| SE | 0.31 | 0.71 | 0.52 |

Means in the same column followed by the same letter(s) are not significantly different (P ≥0.05) following separation by Duncan's Multiple Range Test.

The results showed that for pod length, lines performed better in non-stress than in drought stress treatment. So water is very important in growth and development of common bean. However; for pod length, some lines seem to do better in water stress conditions compared to others in non stress; like pod length for SUA 90 , MUS 97 , G 4523 gave 11.2 cm, 10.2 cm, 9.8 cm, respectively compared to DN 40 of non stress which 9.33 cm.

In pod length differences between NS and DS conditions, the UBR (92) 09 showed low value (0.84 cm) which indicates that the line can tolerate the drought stress and perform better as in non stress condition compared to Canadian Wonder with high difference value of pod length (5 cm). For the trait pod length, lines SUA 90 and MUS 97 have exhibited greater stability in both NS and DS compared to other lines. These lines should be considered in bean improvement programmes in developing new bean varieties tolerant to drought.

### 4.4 Number of pods per plant

Number of pods was significantly different between the treatment (water regimes). Non stress had more pods (10.2 pods per plant) than drought stress plants (3 pods per plant). Within the treatment under non stress conditions, MMS 243 and DN 40 had the highest number of pods per plant (15) followed by RWR 109 which had 14 pods per plant and the least line was SUA 90 with 5 pods per plant. On the other hand, in drought stress HHL 9435- 129 and HHL MD 30- 75 had highest number of pods per plant (5) and the lowest was Canadian Wonder (1). The mean range for combined data (NS and DS of number of pods per plant) were 4.0 (SUA 90) to 9.2 (RWR 109) (Table 4).

**Table 4: Number of pods per plant of 12 bean lines grown in screen house 2006**

| Variety/line | Non stress | Drought stress | % difference | Mean |
|---|---|---|---|---|
| CNF 5547 | 10.33 abc | 3.00 bcd | 67.7 | 6.67 abc |
| HHL MD 30-75 | 10.33 abc | 4.67 ab | 57.7 | 7.50 abc |
| MMS 243 | 15.00 a | 3.00 bcd | 80.0 | 9.00 ab |
| DN 40 | 15.00 a | 2.67 bcd | 82.2 | 8.83 ab |
| MUS 97 | 7.00 c | 1.67 d | 76.1 | 4.33 c |
| Canadian Wonder | 10.33 abc | 1.33 d | 87.1 | 5.83 abc |
| UBR (92) 17 | 9.33 bc | 2.00 cd | 78.6 | 5.67 abc |
| UBR (92) 09 | 10.67 abc | 3.00 bcd | 71.8 | 6.83 abc |
| SUA 90 | 5.33 c | 2.67 bcd | 49.9 | 4.00 c |
| RWR 109 | 14.33 ab | 4.00 abc | 72.1 | 9.17 a |
| G 4523 | 7.67 c | 2.33 cd | 69.6 | 5.00 bc |
| HHL 9435-129 | 7.33 c | 5.33 a | 27.2 | 6.33 abc |
| Mean | 10.22 | 2.97 | 68.3 | 6.60 |
| CV (%) | 27.39 | 36.3 | | 32.16 |
| SE | 1.62 | 0.62 | | 1.23 |

Means in the same column followed by the same letter(s) are not significantly different (P≥0.05) following separation by Duncan's Multiple Range Test.

Moreover the number of pods per plant will depend on plant type (i.e. determinate and indeterminate plants). For plants having determinate plant type (which include Canadian Wonder, SUA 90, G 4523 and DN 40) produced few pods compared to lines from indeterminate plants under drought stress condition. But according to the drought tolerant condition, SUA 90 seems the best by having small difference values (3 pods per plant) in NS and DS condition. Indeterminate lines produced more pods than determinate lines because their production does not stop, they keep on flowering and giving more pods.

Poor formation of the pods is due to competition among larger pods, small pods and flowers for assimilation. The number of lines obtained after screening and evaluation should be crossed/ hybridized as they can withstand drought especially during pod filling stage. The lines showing high number of pods per plant in drought stress are important; moreover, HHL 9435-129, SUA 90 and HHL 30-75 seem to withstand the drought stress as their percentage (%) difference is low compared to other lines i.e. 27.2%, 49.9% and 57.7% respectively. They indicate high yielding varieties under drought tolerance.

### 4.5 Number of seeds per pod

There was a significant difference in number of seeds per pod across the main treatment (Water regimes). Generally plants in non stress condition produced more seeds per pod (6.1) than the drought stress condition (3.8), and each treatment performed better under NS than DS. Within the treatment, under non stress conditions MMS 243, CNF 5547 and MUS 97 had the highest number of seeds per pod (7) and the least lines were Canadian wonder, SUA 90 and G 4523 with 5 seeds per pod. Under drought stress condition the lines which gave high number of seeds per pod were CNF 5547, UBR (92) 09 and MUS 97 both with 5 seeds per pod and the least line was Canadian Wonder (2 seeds per pod). The mean for the two conditions showed that seeds per pods ranged from 3.7 (Canadian Wonder) to 6.0 (CNF 5547) (Table 5).

**Table 5: Number of seeds per pod of 12 bean lines grown in screen house 2006**

| Variety/line | Non stress | Drought stress | Mean |
|---|---|---|---|
| CNF 5547 | 7.00 ab | 5.00 a | 6.00 a |
| HHL MD 30-75 | 5.67 cd | 3.33 ab | 4.50 abc |
| MMS 243 | 7.33 a | 4.00 ab | 5.67 ab |
| DN 40 | 6.33 abc | 3.33 ab | 4.83 abc |
| MUS 97 | 7.00 ab | 4.67 a | 5.83 a |
| Canadian Wonder | 5.00 de | 2.33 b | 3.67 c |
| UBR (92) 17 | 6.67 abc | 3.67 ab | 5.17 abc |
| UBR (92) 09 | 6.33 abc | 5.00 a | 5.67 ab |
| SUA 90 | 4.67 e | 3.00 ab | 3.83 c |
| RWR 109 | 6.00 bcd | 4.00 ab | 5.00 abc |
| G 4523 | 4.67 e | 3.67 ab | 4.17 bc |
| HHL 9435-129 | 6.33 abc | 4.00 ab | 5.17 abc |
| Mean | 6.08 | 3.83 | 4.96 |
| CV (%) | 10.02 | 26.38 | 16.84 |
| SE | 0.35 | 0.58 | 0.48 |

Means in the same column followed by the same letter(s) are not significantly different (P≥0.05) following separation by Duncan's Multiple Range Test.

Results show that water stress imposed at flower initiation did affect both the flowering process and pod setting. Also, water stress caused flower and young pod abortion which resulted into low yield. It is observed that, under water-stress conditions the pods were small, most of them were empty. Seeds produced by such pods were very small and sometimes wrinkled and they were few with low weight and quality. Moisture stress imposed to common bean during flowering and pod filling reduced yield components significantly**.** The reproductive cells are also sensitive to water, especially during interphase stage of cell division, which without enough moisture may cause mutation to occur or to produce sterile pollen and ovules. For this particular trait, some lines seemed to show tolerance to drought stress, this was true for CNF 5547, UBR (92)09, MUS 97. Two lines G4523 and UBR (92) 09, showed stability for trait, number of seeds/pod by showing a very slight fluctuations of about 1, in seeds/pod between NS and DS. These two lines can be crossed to other lines with good attributes to introgress the stability in number of seeds/pod, thus develop an improved variety better than its parents. The results show that the lines which yielded highest had the highest number of pods per plant and therefore increased pods per plant can be selected.

### 4.6 Seed weight per plant

The difference in seed weight per plant was significant (P≤0.05) between watering regimes. The non stress had a greater seed weight per plant of 14.3g while the drought stress had less seed weight per plant of 2.4g. Within the treatments under non stress condition there was significant differences (P<0.05) among lines in seed weight. Seed weight ranged from 5.8 (SUA 90) to 21.3 (MMS 243). Under drought stress conditions the line with the low seed weight per plant was Canadian Wonder (1.1) and the lines with high seeds weight per plant was HHL 9435- 129 (3.6). The mean ranged from 3.6g of SUA 90 to 11.7g (MMS 243) (Table 6).

**Table 6: Seed weight per plant (g) of 12 bean lines grown in screen house 2006**

| Variety/line | Non stress | Drought stress | % difference | Mean |
|---|---|---|---|---|
| CNF 5547 | 15.33 ab | 2.87 abc | 80.3 | 9.10 ab |
| HHL MD 30-75 | 12.43 bc | 2.97 abc | 76.1 | 7.70 ab |
| MMS 243 | 21.33 a | 2.03 abc | 90.1 | 11.68 a |
| DN 40 | 18.43 ab | 1.87 abc | 89.5 | 10.15 a |
| MUS 97 | 12.20 bc | 2.43 abc | 80.0 | 7.32 ab |
| Canadian Wonder | 14.07 ab | 1.13 c | 91.9 | 7.60 ab |
| UBR (92) 17 | 13.97 ab | 1.60 bc | 88.5 | 7.78 ab |
| UBR (92) 09 | 15.97 ab | 2.77 abc | 82.6 | 9.37 a |
| SUA 90 | 5.80 c | 1.47 bc | 74.6 | 3.63 b |
| RWR 109 | 18.60 ab | 3.13 ab | 83.1 | 10.87 a |
| G 4523 | 11.50 bc | 2.43 abc | 78.8 | 6.97 ab |
| HHL 9435-129 | 12.33 bc | 3.60 a | 70.8 | 7.97 ab |
| Mean | 14.33 | 2.36 | 82.2 | 8.35 |
| CV (%) | 27.84 | 40.48 | | 34.64 |
| SE | 2.31 | 0.55 | | 6.67 |

Means in the same column followed by the same letter(s) are not significantly different (P≥0.05) following separation by Duncan's Multiple Range Test.

Maintaining yield potential is achieved by increased seed weight accumulation. Breeding programmes have to identify superior parents with the desired architecture and a high seed weight accumulation that reflects in yield efficiency (Mduruma *et al.*, 1998).

For the trait seed weight/plant, line MMS 243 had the biggest difference between NS and DS at 19.3g while SUA 90 and HHL 9435-129 showed the least difference in performance of 4.3g and 8.7g respectively. This implies that, for this particular trait, these two lines should be considered as potential sources of genes for development of drought-tolerant varieties. Therefore, the mentioned lines should undergo cross breeding with other lines with good characteristics to drought. The research showed that, under drought stress the results have indicated pod filling to maturity period reflected high seed yield potential as well as great seed weight per plant like low percentage ( %) differences in HHL 9435-129, SUA 90 and HHL MD 30-75 with 70.8%, 74.6% and 76.1% respectively. This suggests that great seed weight per plant is associated with long pod filling period (Mduruma and Nchimbi, 1994).

Since drought conditions vary widely from season to season worldwide, genotypes that perform well under both non stress and drought stress conditions are preferred. Breeding for improved performance under drought stress conditions while maintaining yield potential under non stress conditions is difficult since selection based on drought tolerance often reduces yield performance under non stress conditions (Rosielle and Hamblin, 1981). Breeding method to improve drought tolerance in common bean basing on the primary selection on Geometric Mean (GM) followed by secondary selection basing on susceptibility index (S) (Ramirez-Vallejo, 1992); will assure sustained progress in breeding for drought tolerance in common bean. Selection for drought tolerance should be carried out from already proven high yielding genotypes to avoid selection for low yielder (Tarimo *et al*., 1994).

Local adaptation is an important component of drought tolerant, as evidenced by a common set of genotypes evaluated in several countries in the 1980’s (White, 1987). Conventional genetic studies by White and Castillo, (1994) suggest that drought tolerant genotypes available at that time did not adapt in the environment; and that the value of drought resistance sources was closely associated with the parent in the given environment, if the component of local adaptation is greater than that of drought tolerance *per se*, it suggests that even if genes or QTL are identified, these could be limited in expression if local adaptation dwarfs their effect ( Miklas *et al.*, 2006).

On the other hand as breeding increases level of drought tolerance in common bean and not specific genes are accumulated in elite lines, the drought tolerance components might become as local adaptations. This could lead to more stable expression of drought tolerance across sites and regions (Hillocks *et al*, 2006).

Phenotypic screening and evaluation has been practiced with considerable success to improve drought tolerance (White and Singh, 1991). There are several common bean varieties grown in Tanzania and others being kept in gene banks. It is quite possible that these different genotypes may differ in their responses to water stress as far as growth, development and yield performance are concerned (Frederick, 1994). This research was conducted to identify those lines with high yielding capacities under drought stress and correlating plant yield performance to plant traits that influence tolerance to drought stress for use as indicators in screening and evaluated programmes. Some lines seem to do well under drought stress. This was true for lines HHL 9435-129, CNF 5547, UBR (92) 09, RWR 109, MMS 243 and HHL MD 30-75 which were proved to be susceptible to water stress.

Generally, leaf shedding under drought stress causes the reduction of photosynthesis process which is important for food synthesis to support the survival of developed pods. The review from Galindo *et. al*., (2003) showed that when moisture is not enough for plant growth and development, many physiological and biochemical processes are adversely affected. Dehydration response element binding protein (DREB) genes have been identified in beans but their significance to drought tolerance remains to be demonstrated.

If these prove to have drought resistance functions in common bean, then gene based marker-assisted selection (MAS) might be feasible (Ishitani *et. al*., 2004) and will prove the most susceptible line to drought stress by using the mentioned lines screened for drought stress.

Bean yield has remained relatively low in Tanzania despite the good weather conditions prevailing in the major producing areas of the country. Breeders have, therefore concentrated on improving bean yield potential by breeding in for such factors (Mduruma and Nchimbi, 1991). This is to stabilize bean production in these regions, there has been a need to stratify the bean growth environments. As high drought stress significantly reduced grain yield i.e. number of pods per plant, reduced number of seeds per pod and seed weight per plant.

**4.7 Correlation among traits**

Correlation coefficient for non stress and drought stress conditions were all detected positively and highly significant (P<0.05) for characters (Table 7).

**Table 7: Correlation coefficients of parameters for 12 bean lines.**

| Parameters | 1 | 2 | 3 | 4 | 5 | 6 |
|---|---|---|---|---|---|---|
| 1. Pod length | | | | | | |
| 2. Number of seeds/pod | 0.441*** | | | | | |
| 3. Leaf area | 0.463*** | 0.442*** | | | | |
| 4. Plant height | $0.221^{ns}$ | 0.736*** | 0.415*** | | | |
| 5.Number of pods/plant | 0.326*** | 0.648*** | 0.642*** | 0.654*** | | |
| 6. Seed weight/plant | 0.420*** | 0.750*** | 0.644*** | 0.717*** | 0.952*** | |

*** Statistically significant at 0.05 level of probability.

ns no significant difference at 0.05 level of probability.

The correlation coefficient values range from 0.221 to 0.952. Positive correlation between pairs of parameters characters in DS and NS conditions supported similar findings by

Rosales-Serna *et al*., (2000). Number of seeds per pod is among the character which identifies the tolerance of the plant (common bean) to water-stress; when pod lengths were long, they produce more number of seeds per pod. Also when plant height increases produces more pods per plant which gave more number of seeds per pod. Moreover, this indicates that, a large number of seeds per pod in a tall plant with a lot of nodes which produces more pods, increases seed weight per plant. This has been indicated by a pair of parameters in table 7, which shows high yielding of the lines used.

Correlation between different traits is helpful in understanding the behaviour of the lines, value of the traits in selection and evaluation of the desired lines in a breeding programme. Therefore the parameters can be used as a selection and evaluation criteria, although there is a need to determine their heritability. So the goal of the breeder would to combine the two approaches i.e. after knowing the heritability of the parameters, using them as selection and evaluation criteria in the improvement of adaptable, high yielding bean varieties. A cross between a line with a high value in NS and the line with high value in DS would be the initial step, the selection, screening and evaluation will follow.

The results from this study showed that; high yield per plant is associated with high number of pods per plant. Mkandawire and Gundo (1990) found that moisture stress imposed to common bean during flowering and pod filling reduced yield and yield component significantly. Izquierdo and Hosfield (1983) reported that high yields of the beans were attributed to longer pod filling period. Seed filling (number of seed per pod) could thus be used as screening and evaluation criterion whenever the relationship with yield is sufficiently consistent and if it could easily be determined. Many pods per plants tend to compensate for few seeds per pod in case of longer pod fill period. This also suggests that when resources become limiting, seed is disrupted (Mduruma and Nchimbi, 1994).

# CHAPTER SIX

## 6.0 CONCLUSION AND RECOMMENDATIONS

### 6.1 Conclusion

The effects of drought stress on physiological and yield components have been demonstrated in this study. Drought stress which occurred during flowering and pod filling affected yield potential of many lines evaluated although some lines showed a slight change, in some parameters, in response to the treatments, thus exhibiting a certain degree of stability for these traits when put under stress. Bean lines RWR 109, MMS 243, HHL MD 30-75, UBR (92) 09 and CNF 5547 were found to perform relatively better under conditions of limited water supply than other lines. The differences among the lines were observed through screening and evaluation. Under drought stress conditions, these lines had relatively high values of relative water content and stomatal resistance which limited excessive water loss and thus enable photosynthesis and other biochemical process to take place better than was the case with the other lines. Plant height, leaf area, pod length, number of pods per plant, number of seeds per pod and seed weight per plant were significantly reduced in all lines by drought stress compared to non stress.

This research shows the potential of utilising important bean lines, directly associated with drought tolerance in identifying, screening and evaluating drought tolerance varieties. With careful screening and evaluating of parents used in hybridisation and with the application of an adequate selection method for maximum genetic gain it should be possible to obtain inbred lines of a moderate drought tolerance. Further use of new sources of drought tolerance in multiple parent interracial and intergene pool populations should be maximized. This should assure sustained progress in breeding for drought tolerance in common bean. Therefore, some of the problems of poor yield that result from lack of varieties adapted to drought stress condition could be minimised by putting varieties in areas with limited rainfall.

The major traits to focus on in breeding for lines tolerant to drought stress include earliness, high yield, improved pods, improved seed quality, small leaves, and upright short lines just to mention few. Nonetheless, the genetic base of commercial cultivars within specific markets classes is narrow, and its production suffers from a wide range of abiotic and biotic constraints, some causing total yield losses. Improving resistance to abiotic stresses simultaneously with resistance to biotic stresses is the most formidable challenge. In order to maximize and sustain common bean production it is essential to develop high yielding, high quality cultivars that are adapted to low input sustainable farming systems. This need warrants sustained, comprehensive, and integrated genetic improvement programmes.

Recombination and selection methods will vary depending upon the genetic distance between parents, breeding objectives available resources, availability of an efficient and repeatable transformation system for *P. vulgaris* and marker assisted introgression and selection of useful alleles. The lines RWR 109, MMS 243, HHL MD 30-75, UBR (92) 09 and CNF 5547,which exhibit drought tolerance are recommended for use in development of new drought tolerant bean varieties. Breeding for drought tolerance in common bean varieties is of particular importance to this country because of the scarcity and fluctuation of rain in many areas. Furthermore, bean cultivation which rain-fed is mostly done by smallholders who are resourse-poor and cannot afford to irrigate their small plots. Such varieties can also be used in advanced breeding programmes in order to obtain varieties with other traits as well. As screening for good characters/yielding lines have been done, intercrossing of the selected lines should follow as to concentrate the desirable genes in the population. Indications in this study are that stability analysis is useful when screening bean lines for specific or wide adaptation (drought tolerant).

**6.2 Recommendations**

i. The drought-tolerant lines identified in this study should be field-tested in multiple locations before being approved as drought-tolerant.

ii. Green-house drought-stress experiments should be extended to water levels below 20% ± 5 field capacity in order to obtain more drought-tolerant lines.

iii. Breeding of small-leaved bean varieties should be considered, since small leaves will have low evapotranspiration rate compared to large leaves.

iv. In selection for drought tolerance, root characteristics that include root depth and density should be taken into consideration.

v. Promising bean lines should be tested in many locations in bean producing regions to determine their relative consistence in performance.

vi. Conditions in the screen house are not realistic as those in the field. Therefore, the research should be repeated in the field before specific recommendations are given to farmers.

## REFERENCES

Abebe, A., Brick, M. A. and Kirkby, R. (1998). Comparison of selection indices to identify productive dry bean lines under diverse environmental conditions. *Field Crops Research* 58:15 - 23.

Acosta-Gallegos, J. A. (1988). Selection of common bean (*Phaseolus vulgaris*) genotypes with enhanced drought tolerance and biological nitrogen fixation. Dissertation for Award of PhD Degree at Michigan State University, East Lansing. pp. 88 - 24816.

Acosta-Gallegos, J. A. and Adams, M. W. (1991). Plant traits and yield stability of dry bean (*Phaseolus vulgaris*) cultivars under drought stress. *Journal of Agriculture Science* 117: 213 - 219.

Anonymous (2005). South American genotypes of bean optimal use of light under abiotic stress; [http: //www.eubean.net/gen_info.htm]. Site visited on 03/12/2005.

Barners, D. N. (1983). Managing root system for efficient water: Breeding plants for efficient water use. In: *Limitations to efficient water use in crop production.* (Edited by Toylor, H. M., Jordan, W. R. and Sinclair, T. R.), American Society of Agronomy, Crop Science society of America and soil Science Society of America, Madison, WI, USA. pp.127 - 136.

Blum, A., Sinmena, B. and Ziv, O. (1980). An evaluation of seed and seedling drought tolerance screening tests in wheat. *Euphytica* 29(3): 727 - 736.

Blum, A. (1988). *Plant breeding for stress environment*. CRC Press, Florida. 156pp.

Boyer, J. S., and McPherson, J. (1975). Plant density against water-stress. *Crop Science*. Wiley, New York, NY, USA 18: 712 – 876.

Broughton, W. J., Hernandez, G., Blair, M. W., Beebe, S. E., Gepts, P. and Vanderleyden, J. (2003). Beans (*Phaseolus spp*) model food legumes. *Plant soil* 252:55 - 120.

Castellanos, J. Z., Pena-Cabriales, J. J. and Acosta-G, J. A. (1996). N-determination dinitrogen fixation capacity of common bean cultivars under water stress. *Journal of Agriculture Science* 126: 327 - 333.

Clarke, J. M., Depauw, R. M. and Townley-Smith, T. F. (1992). Evaluation of methods for qualification of drought tolerance in wheat. *Crop Science* 33: 1234 - 1238.

Fageria, N. K., Baligar, V. C. and Jones, C. A. (1997). *Growth and mineral nutrition of field crops*. Marcel Deuker. 624pp.

Fernandez, G.C.J. (1993). Effective selection criteria for assessing plant stress tolerance. In: *Adaptation of food crops to temperature and water stress*. (Edited by Kuo, C.G.), AVCRD, Shanhua, Taiwan. pp. 257 - 270.

Fischer, R. A. and Maurer, R. (1978). Drought resistance in spring wheat cultivars in Grain yields responses. *Australian Journal Agriculture Research* 29: 897 - 912.

Foster, E. F., Pajarito, A. and Acosta-Gallegos, J. (1995). Moisture stress impact on N portioning, N remobilization and N-use efficient in beans *(Phaseolus vulgaris*). *Journal of Agriculture Science* 124: 27 - 37.

Frahm, M. A., Rosas, J. C., Mayela-Perez, N., Lopez-Salinas, E., Acosta-Gallegos, J. A. and Kelly, J. D. (2004). Breeding beans for resistance to Terminal drought in the lowland tropics. *Euphytica* 136: 223 - 232.

Frederick, K. D. (1994). *Assessing the impacts of climate change on natural resources systems.* Westview Press Inc. USA. pp. 108 - 115.

Galindo, L., Blair, M. W., Beebe, S., Ishitani, M. and Tohme, J. (2003). Development of a molecular Marker: DREB for drought tolerance in Common Bean. In: *Annual Report, Biotechnology Research Project*, CIAT Cali Colombia. pp. 177 - 179.

Gates, D. M. (1968). Transpiration and leaf temperature. *Annual Review of Plant physiology* 19: 211 - 238.

Halterlein, A. J. (1983). Bean. In: *Crop water relations.* (Edited by Teare, I. D. and Peet, M. M.), Wiley publications, New York. pp. 157 - 185.

Hangen, L. A. and Bennink, M. R. (2003). Composition of black beans and navy beans (*Phaseolus vulgaris*) reduced azoxymethane–induced colon cancer in rats. *Nutrition Cancer* 44: 60 – 65.

Hillocks, R. J., Madata, C. S., Chirwa, R., Minja, E. M. and Msolla, S. (2006). Phaseolus bean improvement in Tanzania, 1956 – 2005. *Euphytica* 150: 215 - 231.

Ishitani, M., Rao, I., Wenzl, P., Beebe, S. and Tohme, J. (2004). Integration of genomics approach with traditional breeding towards improving abiotic stress adaptation: Drought and aluminium toxicity as case studies. *Field Crop Research* 90: 35 - 45.

Izquierdo, J. A. and Hosfield, G. L. (1983). The relationship of seed filling to yield among dry beans with differing architectural forms. *Journal of American Society of Horticultural Science* 108(1): 106 - 111.

Jeffrey, W. W. and Juan, I. (1991). Physiology of yield potential and stress tolerance In: *Common bean: Research for crop improvement*. (Edited by van Schoonhoven. A. and Voysest. O.), CBA International Walllingford. UK. pp. 287 - 364.

Kelly, J. D. (2000). International Agriculture and Rural Development: An investment with Mutual Benefits for the United States and Developing Countries. [http://www.css.edu/bean/International.cfm] site visited on 09/08/2005.

Kramer, P. J and Boyer, J. S. (1995). *Water relations of plants and soils*. Academic press. San Diego, New York. 377 - 393pp.

Kramer, P. J. (1983). *Water relations of plants*. Academic press, New York, USA. 489 - 490pp.

Leopold, A. C., Musgrave, M. E. and Williams, K. M. (1981). Solute leakage resulting from leaf dessication. *Plant Physiology* 68: 1222 - 1225.

Madata, C.S. (1991). Evaluation of early maturing bean varieties for possible use in dry areas and late planting in the Southern Highlands In: *Bean Research.* (Edited by Mabagala, R. B. and Mollel, N.), Interprets of Tanzania Ltd, Tanzania. 6: 125 - 130.

Maghembe, N. A. (1999). *The effects of soil water deficit and developing of selected common bean cultivars (Phaseolus vulgaris L.)* Morogoro, Tanzania. pp. 1- 6.

Mayaki, W. C., Stone, L.R., Teare, I. D. (1976). Soyabean root development soil water depletion. *Journal of Agronomy* 68(4): 677 - 688.

Mduruma, Z. O and Nchimbi, S. (1991). Variation in seed protein content and its relationship to other characteristics in common bean (*phaseolus vulgaris*). In *Bean Research*. (Edited by Mabagala, R. B. and Mollel, N.), Interprets of Tanzania Ltd, Tanzania 6: 138 - 143.

Mduruma, Z. O and Nchimbi, S. (1994). Estimation of pod filling period in common bean (*Phaseolus vulgaris* L.) and its relationship with seed yield, yield components and maturity characteristics. In: *Bean Research.* (Edited by Mabagala, R. B., Maeda, E. E. and Mduruma, Z. O.), Interprets of Tanzania Ltd, Tanzania 7: 78 - 88.

Mduruma, Z. O., Nchimbi- Msolla S., Reuben S. O. W. M. and Misangu R. N. (1998). Evaluation of maturity characteristics and of yield components of high protein bean (*Phaseolus vulgaris* L.) in Morogoro, Tanzania. *Tanzania Journal of Agicultural Sciences* 1(2): 131 - 140.

Miklas, N. P., James, D. K., Steve, E. B. and Mathew, W. B. (2006). Common bean breeding for resistance agaist biotic and abiotic stresses: from classical to MAS breeding. *Euphtica* 147: 105 - 131.

Mkandawire, A. B. C and Gundo, F. V. P. (1990). Progress with SADCC/ CIAT DROUGHT SUB- PROJECT, In: *Progress in improvement of common bean in Eastern and Southern Africa.* Proceeding of the ninth SUA/ CRSP and second SADCC/ CIAT bean research Workshop, held at Sokoine University of Agriculture, Morogoro, Tanzania 17-22 September, 1990. pp. 576 - 588.

Morgan, J. M. (1984). Osmoregulation and water stress in higher plants. *Annual Review of Plant physiology* 35: 299 - 319.

Mwandemele, O. P and Doto, A. L (1987). *Evaluation of soybean lines for drought tolerance and the influence of water availability on cookability*. Turrialba. 232pp.

Nchimbi, S. N. (1989). An overview of bean breeding program at SUA In: *Bean Research*. (Edited by Maeda, E. E. and Nchimbi, S. N.), Inter press of Tanzania Ltd. 4: 38 - 48.

Pandey, R. K., Herrera, W. A. T. and Pendleton, J. W. (1984). Drought tolerance of grain legumes under irrigation gradient: Yield and yield components. *Journal Agronomy* 76: 549 - 553.

Perla, O., Luis, A. B., Sonia, G. S., Maria, P. B., Juscelino, T. and Octario, P. L. (2003). Effect of Proceessing and storage times on in – vitro digestibility and resistant starch content of two bean (*Phaseolus vulgaris*, L.) varieties. *Journal of the Science and Agriculture* 83: 1283 - 1288.

Raison, J. K., Berry, J. A., Armond, P. A. and Pike, C. S. (1980). Membrane properties in relation to the adaptation of plants to temperature stress. In: *Adaptation of plants to* *water and high temperature stress*. (Edited by Turner, N. C. and Kramer, P. J.), Wiley, New York, NY, USA. pp. 261 - 73.

Ramirez-Vallejo, P. (1992). Identification and estimation of heritabilities of drought related resistance traits in common bean (*Phaseolus vulgaris*). Dissertation for Award of PhD Degree at Michigan State University, East Lansing. 92 - 26240pp.

Ramirez – Vallejo, P. and Kelly, J. D. (1998). Traits related to drought resistance in common bean. *Euphytica* 99: 127 - 135.

Robin, B. (2005). Bean Improvement. [http://www.african crops. Net/crop/beans/] site visited 2 January 2006.

Rosales-Serna, R., Ramirez-Vallejo, P., Acosta-Gallegos, J. A., Castillo-Gonzalez, F. and Kelly, J. D. (2000). Grain yield and drought tolerant of common bean under field conditions. *Agrociencia* 34: 153 - 165.

Rosielle, A. A. and Hamblin, J. (1981). Theoretical aspects of selection for yield in stress and non- stress environments. *Crop Science* 21(6): 943 - 946.

Schneider, K. A., Roseles-Serna, R., Ibarra-Perez, F., Cazares-Enriquez, B., Acosta-Gallegos, J. A., Ramirez-Vallejo, P., Wassimi, N. and Kelly, J. D. (1997). Improving common bean performance under drought stress. *Crop Science* 37: 43 - 50.

Scuba Equipment and Dive Gear leader. (2006). Archimedes Principle. [http://www.aquaholic.com/gases/archem.htm] site Visited 11 April 2006.

Singh, S. P., Lepiz, R., Gutierrez, J. A., Urrea, C., Molina, A. and Teran, H. (1990). Yield testing of early generation population of common bean. *Crop Science* 30: 874 - 878.

Singh, S. P. (2001). Broadening the genetic base of common bean cultivars: *a review*, *Crop Science* 41: 659 - 1675.

Singh, S. P. (1992*)*. Common bean improvement in the tropics. *Breeding review* 10: 199 -260.

Singh, S. P. (1995). Selection for water press tolerance in interracial populations of common bean. *Crop Science* 35: 118 - 124.

Stoker, R. (1974). Effects on dwarf bean of water stress at different phase of growth. *Journal of experimental Agriculture* 2: 13 - 25.

Tarimo, A. J. P., Noah, S. G. and Chilewa, P. R. (1994). Plant Characteristics associated with drought tolerance in common bean; edited by G. P. Msumali and Mabagala, R. B. In: *Bean Research*. The workshop held at the Sokoine University of Agriculture, Morogoro, Tanzania. 15 - 17 Sept., 1993: 193pp.

Teran, H. and Singh, S. P. (2002). Comparison of sources and lines selected for drought resistance in common bean. *Crop Science* 42: 64 - 70.

Teri, J. M., Silbernagerl, J. M. and Nchimbi, S. (1990). The SUA / WSU Bean / CRSP: A review of progress in disease resistance . In: *Bean Research*. (Edited by Smith, J. B.), CIAT Africa Workshop. Cali Colombia 12 (5): 166 - 189.

Tesha, A. J. (1987). Yield performance of tepary and common beans under drought conditions. *Bean research* 2: 122 - 128.

Tharanathan, R. N. and Mahadevamma, S. (2003). *A Review Grain Legumes a boon to Human Nutrition*. Trend in Food Science and technology 14: 507 - 515.

Turner, N. C. and Jones, M. M. (1980). Turgor maintenance by osmotic adjustment: a review and evaluation In: *Adaptation of plant to water and high temperature stress*. (Edited by Turner, N. C. and Kramer, P. J.), Wiley, New York, USA. pp. 87 - 103.

White, J. and Singh S. P. (1991). Breeding for adaptation to drought. In: *Common bean: Research for crop improvement*. (Edited by van Schoonhoven, A. and O.voysest, C. A. B.), International , CIAT, Cali, Colombia. pp. 501 - 560.

White, J. W. (1987). Preliminary results of the bean International Drought Yield Trial (BIDYT). In: *Proceedings of the International Bean Drought Workshop*, 19 - 21 October 1987, Cali, Colombia. 126 - 145pp.

White, J. W. and Izquierdo, J. (1994). Physiology of yield potential and stress tolerance In: *Common Bean research for crop improvement.* (Edited by Van Schoonhoven, A and O. Voysest, C.A.B.), International, CIAT, Cali, Colombia. pp. 278 - 382.

White, J. W., Ochoa, R., Ibarra, F. and Singh, S. P. (1994). Inheritance of seed yield, maturity and seed weight of common bean (*Phaseolus vulgaris*, L) under semi – arid rainfed conditions. *Journal of Agricultural Science.* pp. 256 - 273.

White, J. W. and Castillo, J. A. (1989). Relative effect of root and shoot genotypes and yield on common bean under drought stress. *Crop Science* 29: 360 - 362.

WHO. The World Health Report (2002). *Reducing Risks, Promoting Healthy Life* (World *Health Organization*, Geneva, Switzerland. 235pp.

Wilson, J. R., Fischer, M. J., Schulze, E. D., Dolby, G. R. and Ludlow, M. M. (1979). Comparison between pressure-volume and dewpoint hygrometry techniques for determining the water relations characteristics of grass and legume leaves. *Oecologia* 41(1): 77 - 88.

Wright, G. C. and Redden, R. J. (1997). Selection for improved tolerance *Phaseolus vulgaris* breeding programs/International food legume conference [http: www.regional.org.au/au/asit/compendium/m-06.htm] site visited on 09/11/2005.