EFFECTS OF MOISTURE STRESS ON GERMINATION AND EARLY SEEDLING GROWTH OF THREE *ACACIA* SPECIES AND *BALANITES AEGYPTIACA* (L.) DEL.

BY

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DECLARATION

I declare that the work in the thesis entitled 'Effects of Moisture Stress on Germination and early seedling growth of three *Acacia* species and *Balanites aegytiaca* (L) Del.' has been performed by me in the Department of Biological Sciences under the Supervision of Drs. S.P. Bako and D. N. Iortsuun.

The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this thesis was previously presented for another degree or diploma at any University.

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CERTIFICATION

This thesis entitled "Effects of Moisture Stress on Germination and early seedling growth of three *Acacia* species and *Balanites aegytiaca* (L.) Del." by Gotan, Yillek Simon meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University, Zaria, and is approved for its contribution to knowledge and literary presentation.

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ABSTRACT

Experiments were conducted in the laboratory and screen house to determine the effects of moisture stress on germination and early seedlings growth of four savanna plants species namely; *Acacia albida, A. senegal, A.nilotica* and *Balanites aegyptiaca*. Raising seedlings for afforestation programmes in the savanna region of Nigeria has been a problem because the seedlings used do not survive the long dry periods experienced because they are exotic species. This research determines the effect of moisture stress on the germination of three *Acacia* species and *B. aegyptiaca* and to evaluate some growth parameters at the early seedlings stage exposed to four moisture stress levels. The experimental protocol used a complete randomize design with three replications. Laboratory experiment used ten seeds from each species and their dry weights determine, placed in 9cm diameter Petri dishes lined with Whatman No.1 filter paper that had been autoclave, kept near a beaker contain boiled water and covered by a bell jar for two house. The differences between the dry seeds weight and imbibed weight after two hours gave the imbibition rate. Seed coat diameter were measured with micro meter screw guage. Radicle elongation of ten seeds from each species were measured for; 24, 48,72, 96, 120, 144 and 168 hours. The screen house experiment used 200cm^3 plastic pots, four plant species, four moisture levels and three replications. Two seeds per pots were sown, the potted plants were arranged in four blocks of each containing 48 pots. Destructive harvesting was carried out fortnightly eight times to determine seedlings growth attributes. *Acacia senegal* had the highest imbibition rate, this indicates its thinnest seed coat diameter provided faster movement of water into these seeds. *Balanites. aegyptiaca* had the maximum radicle elongation after 144 hours; being the largest seeds were able to absorbed more water that permitted longer radicle elongation. Seedlings growth attributes

varied significantly ($P \leq 0.05$) in response to the four moisture levels. *Acacia albida* seedlings had the highest significant root length at the slight (M1) and moderate (M2) moisture stress treatments. This indicated that the slight and the moderate moisture stress treatment stimulated their roots length. *Acacia senegal* had the highest significant ($P \leq 0.05$) shoot and root length increase at the severe moisture stress treatment (M3). This suggest that exposure of these seedlings to severe moisture stress benefited the shoot and root growth. *Acacia nilotica* had the highest shoot length, root length and shoot dry weight at the control treatment M0. This probably indicates that these seedlings needed more water during the early seedlings growth. *Balanites aegyptiaca* had the least growth attributes at all the four moisture stress treatments, indicates that these seedlings grow slowly at any moisture stress treatment in the early seedlings growth. The main interaction (weeks after sowing X plant species, weeks after sowing X moisture levels, plant species X moisture levels, weeks after sowing X plant species X moisture levels) were all significant ($P \leq 0.05$) for the growth attributes studied. The correlation between the growth parameters in each species was significant ($P \leq 0.05$ and 0.01) except in shoot/root ratio that exhibited non significant association. These seedlings growth attributes could be used for screening nursery stock for afforestation programmes in the savanna region of Nigeria.

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CHAPTER ONE

INTRODUCTION

1.0 DESCRIPTION OF STUDIED PLANTS

The genus *Acacia* (Mill.) belongs to the family leguminosae, subfamily Mimosaceae. *Acacia* species are widely distributed through the drier tropical and sub tropical regions, they have been called the most successful survivors in arid and semi – arid regions and possess most of the features required to withstand severe climatic conditions(El – Amin, 1976). In Nigeria, the genus is represented by trees and shrubs, mostly heavily armed with spines or thorns (Keay, 1989). The genus Balanites (L.) Del. belongs to the family *Balanitaceae. Balanites aegyptiaca* are widely distributed in the Sudan and Sahel Savanna zone of Africa, Israel, Jordan and India.

This species is easily recognized by the presence of long straight green spines arranged spirally (Keay, 1989).

1.1.1 Uses of *Acacia* Species

- Has ability to improve soil fertility by fixing nitrogen to increase the nitrogen economy
- Use in pharmaceutical preparations
- Yield commercial gum Arabic, the gum is used in practically all categories of processed food (candy, snack food, alcoholic and non-alcoholic beverages).
- Use for treatment of colds, diarrhoea, haemorrhage and leprosy.
- Ashes of the wood is used in making soap and is depilatory and tanning agent for hides.
- Use in inks, pottery pigment, water colours, wax polishes and liquid gum.

- Extracts made from the leaves are used in the treatment of menstrual problems, eye infections, sores ulcer and indigestion (fagg and stewart, 1994).

1.1.2 Uses of *Balanites aegyptiaca* (L.) Del.

- Tress are tolerant to termites and are sources of timber therefore good for construction purposes.
- The thorny branches are good for fencing.
- In medicine, the roots are used as laxative, the bark is used for sore throat, sterility, mental diseases, epilepsy, yellow fever, syphilis and tooth aches. The fruit extracts and bark are used against guinea worm and snail harboring bilharzias.
- Fruits are edible (Wickens, 1969)

1.2 STATEMENT OF THE PROBLEM

Periods of moisture stress of varying length and severity are features of the savanna region in Nigeria to which *Acacia* species and *Balanites aegyptiaca* are frequently exposed to. Lack of adequate water had accounted for about 80% of planted seedlings mortality in the Nigeria/Niger boarder region (Famuyide and Ojo, 2004).

Germination and root development are often influenced by moisture stress. Most seedlings emerged but dies during moisture stress. Seeds differ in their were germination responses under moisture stress (Pirdashti *et al.*, 2003). Abscisic acid increased in germinating seeds exposed to moisture stress (Walton, 1977). The first process which occurs during germination is the uptake of water known as imbibition. The extent to which imbibition occurs is determine by three factors; the composition of the seed, the

permeability of the seed coat or fruit wall to water and the availability of water in liquid or gaseous form in the environment. Non imbibition of water by some seeds is a delayed mechanism that prevents water from getting into the seeds, thereby hindering germination, common in the family Fabaceae (Fernner, 1989). Vapour is the major source of water for imbibition under normal soil moisture condition (Wuest, 2002). Moisture stress in plants may cause a reduction in the diffusion of carbon dioxide and water Vapour through the stomata, loss of cell turgor pressure, and reduced leaf elongation (Alcocer *et al*., 1989). The time when moisture stress occurs and the duration and frequency of moisture stress period can be an important environmental factor that determines the growth and survival of plants. However, there is considerable variation among species in their physiological and morphological responses to moisture stress . Levitt (1980) explain that moisture stress in plants is the condition of the soil, atmosphere or both that prevents plants from obtaining sufficient water for growth. These can be defined in three ways:

i. Physiological: is a condition whereby enough water is available but plants can not use it due to excessive salt, low temperature or reduced oxygen as in boggy soil.

ii. Edaphic: occurs when the soil moisture in the root zone is at or below permanent wilting point.

iii. Atmosphere: characterized by low humidity, high temperature and strong desiccating wind.

1.3 JUSTIFICATION

- Most of the trees plants are used for afforestation programmes in the savannah region of Nigeria are exotic species. In agro forestry, Eucalyptus which is commonly used exhibit allelophatic behaviour (Igboanugo, 1988).
- This is an act by which the plants are release chemicals that inhibit the germination and growth of plants near them. However, this mechanism reduces the value of our arable land for agricultural practices in the savannah. Therefore there is a need to explore the usefulness of our indigenous plants for afforestation and agro-forestry programmes.
- Quite often afforestation programmed are unsuccessful in the savannah region of Nigeria because the seedlings used do not survive the long day period of six to nine months experienced in the Sudano-Sahelian belt of Nigerian (Famuyide *et al.*,2004).
- Knowledge on responses of tree seedlings to moistures stress levels will be important in choosing the right species for establishment and management practices for agro forestry in the savanna.
- Little has been reported on the effect of moisture stress on the germination and early seedlings growth on the Nigerian savanna tree species.

1.4 RESEARCH QUESTIONS

Are there any significant differences in the germination of *Acacia* species and *Balanites aegyptiaca* under moisture stress?

Are there any significant differences in seedlings growth of *Acacia* species *and B. aegyptiaca* under moisture stress levels?

1.5 NULL HYPOTHESIS

There are no significant differences in the germination of *Acacia* species and *B. aegyptiaca* under moisture stress.

There are no significant differences in the seedling growth of Acacia species and *B.aegyptiaca* when exposed to moisture stress levels?

1.6 OBJECTIVES:

This study will therefore:

i. Determine the effects of moisture stress on the germination of three *Acacia* species and *Balamites aegyptiaca*

ii. Evaluate growth parameters of the seedlings exposed to four moisture stress levels.

CHAPTER TWO

LITERATURE REVIEW

2.1. GENERAL RESPONSES OF PLANTS TO MOISTURE STRESS.

Plants response to moisture stress is on a whole- plant basis. Moisture stress had direct effects on photosynthesis and indirectly on the stomata (Wardlaw, 1967). Moisture stress is often characterized by reduction in transpiration, stomata size, carbon dioxide assimilation, respiration, Nitrogen metabolism, enzyme activities and photosynthate translocation (Hsiao, 1973). During moisture stress, cell extension is more sensitive processes while photosynthesis and respiration are less inhibited (Hsiao, 1973). The late growth stages appeared to be the most sensitive to moisture stress than the early growth stage in *Bouteloua Scorpioides* seedlings (Alcocer *et al*., 1989). There were rapid reduction in leaf area growth, stomata closure and increase in abcisic acid in the leaves of cassava under moisture stress (Alves and setter, 2000). The response of Mediterranean tall fescue (*Festuca arundinacea*) to moisture stress was primarily morphological; short plant size, higher root/shoot ratio, lower growth rate, while temperate cultivars contrast in response primarily physiological by having lower stomata conductance (Assuero *et. al*., 2002). Moisture stress reduced water and nutrient uptake without significantly affecting leaf nutrient status in *Acer saccharum* Marsh.

(Piloon *et al*., 1996). There were earlier flowing with lower number of leaves and higher water use efficiency in durum wheat grown under moisture stress (Giunta *et al* .,1995) moisture stress in *Pinus densiflora* and *Quercus serrata* increased the length of primary roots and the number of secondary roots (Beon and Bartch, 2003). Two edaphic races of

Lasthenia californica differed in their allocation patterns to roots and in days of flowering under moisture stress; race A allocates more biomass to roots while race C flower earlier (Rajakaruna *et al* .,2003).

2.2 EFFECT OF MOISTURE STRESS ON GERMINATION

The first stage of germination is the physical process of imbibition and if water supply is restricted germination may be delayed or prevented. Under water stress, it has been shown that the inhibition of radicle emergence is mainly because of a decrease in water potential gradient between the external environment and the seed and genotypes cultivated in the same geographic area, show distinct responses to drought stress (Pirdashti *et al*., 2003).

Big seeds have an advantage over the small ones under moisture stress, since their large reserves will enable the young seedling to survive for a longer time under stress (Sanchez and King, 1994). Cervantes *et al*. (1998) reported a direct relationship between seed weight and germination in *A. Cochliacantha* and *Pithecellobium dulce* under water stress. Humara *et al*. (2002) similarly, reported large seed size of *Eucalyptus globules* showed higher germination capacity than smaller seed size subjected to water stress. Janzen (1983); Sharma and Dakshini (1996) reported that seed coat contributed a great deal to the total seed weight and the total nutrient allocated to seed during germination under water stress. When compared to C4 species, C3 grasses had larger seeds and produced more vigorous seedlings which were better able to survive water stress (Qi and Redman, 1993). In red clover and *Lucerne* species initiation of cell elongation is the process most sensitive water stress than cell division (Hegarty, 1981). The most obvious limiting factor

in germination of *Parthenium hysterophorus* in Ethiopia was moisture stress at higher temperature (Tamado *et* al., 2002). Seed germination percentage and seedling growth decreases with increasing water stress in all the genotypes of paddy rice studies (Pirdashti *et al.,* 2003). Plumule growth is more sensitive than radicle growth to water stress in Rice genotypes (Pirdashti *et al.,* 2003). *Quercus variabilis* germinated faster under moisture stress, primarily root elongation was more favoured than the control (Beon and Bartsch, 2003). Abscisic acid synthesis increases in germinating seeds subjected to water stress (Walton, 1977).

2.3. EFFECT OF MOISTURE STRESS ON SHOOT LENGTH

Water stress reduced the shoot height in cotton plant more dramatically than other measurements (Ball *et al.*, 1994). The shoot growth of *Arabidopsis thaliana* seedlings was acutely sensitive to water deficit, growing slowly at moderate stress and not all at severe stress (Van der Weele *et al.*, 2000). Similarly, drought significantly decrease the mean height of 12 durum wheat cultivars subjected to water stress (Gebeyehou and Knott, 1983). Shoot height of *Atriplex lapa* was reduced by 50% under moisture stress (Trione and Passera, 1993). In *Azadirachta indica*, seedlings subjected to moisture stress showed great reduction in plant height (Puri and Swamy, 2001). Also moisture stress reduced shoot growth in *Fagus sylvatica* (Leuschner *et al.*, 2001). In root box experiments, water stress for up to 35 days reduced the shoot height in *Medicago minima* (Fresnillo *et al.*, 1995). Water stress often reduces shoot growth more than it reduces photosynthesis and thus proportionally more photosynthate is allocated to root growth resulting in an increase in root growth. (Kozlowski *et al.*, 1991). Water stress significantly reduced shoot growth in *Acacia nilotica* and *Leucaena leucocephala*

(Michelsen and Rosendahl, 1990). Repeated periods of water stress reduced growth of all plant organs but did not affect their absolute nitrogen content in terms of both free and bound nitrogen of *Atriplaex lapa* (Trione and Passera, 1993). However, *Pinus radiate* seedlings subjected to moderate water stress shows a higher growth than the control (Kaufmann, 1977). Martinez *et al.* (2002) reported a similar result when *Pinus lecophylla* was subjected to moderate water stress.

2.4 EFFECT OF MOISTURE STRESS ON ROOT LENGTH

Root growth, has been shown to be less sensitive to water deficit than shoot growth. Root development continues, although at a reduced rate compared with the unstressed plant (Saab and Sharp, 1989; Creelman *et al.*, 1990). Water stress in cotton reduces root elongation and root volume (Ball *et al.*, 1994). Number of studies showed a shift of carbon allocation from shoot to root, with an increase of root in absolute terms during mild water stress (Teskey and Hinckley, 1981; Kramer and Boyer, 1995). Leuschner *et al.* (2001) reported that moderate water deficit stimulated primary root elongation, lateral root elongation and initiation were unaffected, and at higher stress levels both were inhibited. Moderate water deficit also simulated the rate of cell production in *Arabidopsis thaliana* seedlings under water deficit (Van der Weele, 2000). In water stressed cotton seedlings small roots were more sensitive to drought stress than medium size roots, tips of small roots stopped growing several days before those of medium sized roots (Ball *et al.*, 1994). Root and stem growth were more susceptible to soil water stress than leaf expansion and photosynthesis in *Quercus petrae* (Leuschner *et al.*, 2001).

2.5 EFFECT OF MOISTURE STRESS ON DRY WEIGHT (BIOMASS PRODUCTION)

Growth is a balance between the source-sink integrated complex systems. Dry matter partitioning involves the production of assimilate in photosynthesis organs (source) and their translocation to the growing point (sink) (Wardlaw, 1967). Biomass production is directly proportional to the supply and use of water. Photosynthesis of well-watered and lighted plants can almost be increased by raising the level of carbon dioxide in the atmosphere (Tinus and John, 1972). Growth may be expressed as increase in fresh or dry weight. It has been assumed than plants with high rate of photosynthesis per unit of leaf area will produced more dry matter and grow more rapidly than plants with low rate, this is not always true (Carter, 1972). Higher productivity of some plants is associated to larger total plant biomass and higher dry matter partitioning to above ground organs (Greco and Cavagnaro, 2002). Dry matter production decreased, and water use efficiency (WUE) and chlorophyll content increased in water deficit *Acacia saligna* seedlings (Native *et al.*, 1999). Similarly, under drought stress, shoot dry matter, root dry matter and relative growth rate (RGR) were affected, water use efficiency (WUE) was high under stress condition, water use efficiency had a positive association with relative growth rate, but water use efficiency had weak association with root length of spring durum wheat (El-Hafid *et al.*, 1998). From dry matter harvest, *Eucalyptus maculate* seedlings showed increased dry weight under moderate moisture stress than the control (Neave and Florence, 1998). Shoot biomass diminished by about 30% under water stress, with a similar reduction in root dry matter in three varieties of *Trichloris Crinita* P. (Greco and Cavagnaro., 2002). Caloin *et al. (*1990) proposed that partitioning of assimilates between the shoot and root depends on two factors: one factor is genetically

controlled and the other is dependent on the environment. Chirara and Dijkman (1999) reported an increase in dry matter to root than the shoot in *Acacia karroo* under water stress. Moisture stress reduced dry matter assimilation more than Nitrogen uptake in Durum wheat grown in the Mediterranean environment (Giunta *et al.,* 1995). Moderate water stress in *Arabidopsis thaliana* increased shoot and root dry weight however, severe water deficit decreased these growth attributes (Van der Weele *et al.,* 2000).

2.6 EFFECT OF MOISTURE STRESS ON SHOOT: ROOT RATIO.

Water stress often reduced shoot growth more than it reduces photosynthesis and thus proportionally more photosynthate is allocated to root growth resulting in an increased in root to shoot ratio (Kozlowski *et al., 1991).* Ratio of shoot to root was drastically decreased by moisture stress in *Azadirachta indica* seedlings subjected to moisture stress (Puri and Swamy, 2001). Water deficit increased the root-to-shoot ratio of cotton plants (Malik *et al.,* 1979; Ball *et al.,* 1994). Soil water deficit increase root/shoot ratio of several trees species through increased carbon allocation to the roots (Kramer and Boyer, 1995). Similarly *Acacia karroo* seedlings grown in dry condition had higher root/shoot ratio than the control (Chirara and Dijkman, 1999).

In the same vein, Assuero *et al*. (2002) reported that the water stress increased root: shoot ratio in *Festuca arundinacea.* However, there was no change in either shoot/root ratio in *Trichloris crinita* seedlings subjected to drought stress (Greco and Cavagnaro, 2002). Similarly, drought treatment significantly reduced shoot and root dry weight in *Acacia nilotica* and *Leucaena leucocephala*, however, the root to shoot ratio was not affected (Michelsen and Rosedahl, 1990).

2.7. EFFECT OF MOISTURE STRESS ON LEAF AREA

Plants with large leaf area usually transpire more than those with small leaf area. Water deficit inhibits leaf expansion and in general cell elongation (Kramer and Boyer, 1995). Plants with higher rate of photosynthesis per unit area of leaf produced more dry matter (Carter, 1972). Decrease in photosynthesis has been ascribed to the effects of water stress because many photosynthetic processes such as; enzymatic, respiration, dark reaction and formation of chlorophyll (Aberte *et al.,* 1976). Similarly, an unfavourable water status in the soil or atmosphere can reduce net photosynthesis by stomata or non-stomata pathways (Dreyer, 1997). Drought reduced the leaf area of trees because cell extension is highly sensitive to water stress (Boyer, 1988). The leaf area of trees reduced because the carbon source strength decreased during moisture stress (Gower *et al.*, 1992). Leaf expansion of moisture stressed cotton seedlings grown in the growth chamber drastically declined (Ball *et al.,* 1994). Soybean and cotton leaves responded to moisture stress some how differently, the more severe reduction was in soybean than in cotton (Bunce, 1978). Drought affected the maximum leaf area of durum wheat grown in the Mediterranean environment (Giunta *et al.,* 1995). However, both leaf area index and light saturation net photosynthesis of *Fagus sylvatica* (L) and *Quercus petraea* (Matt.) showed only weak influence of drought stress (Leuschner *et al.,* 2001).

2.8 BENEFICIAL IMPACT OF MOISTURE STRESS ON PLANTS

Water stress is not always entirely injurious to plants. Moderate water deficit improved the quality of apples and avocado plants (Richard and Wadleight, 1952). The desirable aromatic properties of Turkish tobacco were greatly increased under moderate water stress (Wolf, 1962). Water stress strengthens the vigour of *Eucalyptus maculata* seedlings

and improved their capacity for survival under some field condition (Neave and Florence, 1998). The water use efficiency (WUE), nutrient use efficiency (NUE) and increased chlorophyll content of water stressed, *Acacia saligma* was recorded (Puri and Swamy, 2001). Similarly, there was increase in water use efficiency (WUE) of spring durum wheat under water stress condition (El-Hafid et al., 1998). There were earlier flowering associated with lower number of leaves and higher water use efficiency (WUE) in durum wheat grown in the Mediterranean environment under water deficit (Giunta *et al.*, 1995). During the recovery period after water stress, there was compensatory increase in plant height of *Pinus leiophylla* (Martinez *et al.*, 2002). Moisture stress stimulates the subsequent growth of *Eucalyptus maculata* seedlings (Neave and Florence, 1998). Periodical water stress decreases the size of cells, and the intercellular spaces, however, the number of stomata per unit of leaf surface area increase (May and Mithorpe, 1962). The cell division factor, cytokinin, a natural growth promoting hormone synthesis in the root tip is not reduce under water stress, some of the metabolites saved in the roots are channeled to the roots and eventually, caused acceleration in growth of roots (Gupta, 1992). Roots of *Arabidopis thaliana* under moderate stress, elongated more and cell length increased more than the well-watered (Van der Weele *et al.*, 2000).

2.9. IMPACT OF *ACACIA* SPECIES AND *BALANITES AEGYPTIACA* IN AGROFORESTRY

Agroforestry is an intensive land use management practice that optimizes the benefits (whether physical, biological, ecological, economic or social) from biophysical interactions created when trees and/or shrubs are deliberately combined with crops and/or live stocks (Gold *et al.*, 2000).

The use of N_2 – fixing trees in agroforestry systems in Africa has shown considerable promise in terms of benefits to crop and livestock production (Masutha *et al.,* 1997).

The fast growth and subsequent high biomass production of the *Acacia* species indicated their potentials for use in other agroforestry systems to improve soil fertility (Ngulube *et al*, 1993). Crops planted under the tree cover of (*Balanites aegyptiaca, Acacia tortilis* and *Bascia senegalensis* shows greater yield than the open sun light (Grouzis and Akpo, 1997). *Acacia* species with a higher root-to-shoot ratio are probably better adapted to deep nutrients and water capture, this may be an important adaptive trait for agroforestry tree growing in drier areas (Masutha *et al.,* 1997). Research has shown that organic matter and total mineral nitrogen flux are higher beneath trees such as *Acacia senegal* and *Balanites aegyptical* (Young, 1989).

CHAPTER THREE

MATERIALS AND METHODS

3.1 EXPERIMENTAL SITES

Laboratory experiments were conducted at the Department of biological Sciences, Ahmadu Bello University Zaria. The screen house experiment were carried out at the faculty of Agriculture, Department of Plant, Ahmadu Bello University, Zaria (7^0 38'N and 11^0 11' E, 686M above sea level). The study area is located in the Northern Guinea savanna of Nigeria. The studies were carried out during the rainy season of the year 2005. Both experiments were of complete randomized design with three replications.

3.2 METEOROLOGICAL DATA

Data on climatic variable (temperature, rainfall, relative humidity and evaporation) were collected from the meteorological unit, institute of agriculture Research, Ahmadu Bello University Zaria, Nigeria (Appendix 1).

3.3 SOURCE OF SEEDS

The seeds were obtained from Kano State Afforestation programme office (Ministry of Environment, Kano state).

The plant species were:

A = *Acacia albida* (L.) Del.

B = *Acacia senegal* (L.) Willd.

C = *Acacia nilotica* (L.) Willd. ex Del.

D = *Balantes aegyptiaca* (L.) Del.

3.4 PRE- TREATMENT OF SEEDS

The seeds were soaked in boiled water overnight before sowing (Bonkik, 1996).

3.5 SOIL PREPARATION AND FILLING OF POTS

The pots used for the experiment were 200mm^3 plastic pots. The soil use was a mixture of topsoil, cow dung and river sand in the ratio of 3: 2: 1 respectively according to Jackson *et al.*, 1974). Dry leaves were placed at the bottom of the pots to prevent the holes at the base of the pots from being blocked by the soil mixture. Then the pots were filled with the soil mixture.

3.6 LABORATORY SOIL ANALYSIS

Routine soil analysis was carried out according to the procedure of (Black, 1965) to determine particle size, soil pH, organic carbon, total nitrogen, available phosphorus and cation exchange capacity of the soil mixture (Appendix 2)

3.7.1 Determination of Imbibition Rate: The dry weight of ten seeds per replicate of each species was measured using a weighing balance model meter P.163 (max. 160g). The seeds were then placed in 9cm diameter Petri dishes lined with Whatman No.1 filter paper. These seeds were kept near a beaker containing boiled water and covered by a bell jar for two hours. The dishes were kept on a bench top in the laboratory. There was no contact between the seeds and the boiled water. These seeds imbibed water from the vapour. The differences between the dry weight and imbibed weight gave the imbibition rate. This method was proposed by (Bouaziz and Bruckler (1989); Wuest (2002).

3.7.2 Determination of seed coat diameter

Ten seeds from each species were peel using a scapel. The seed coat diameters were determined using a micrometer screw gauge.

3.7.3. Determination of radicle elongation

Ten seeds from each species were surface sterilized for 15-20 minutes in 10% Sodium hypochlorite solution, soaked in boiled water over night according to the procedure suggested by (Bonkik, 1996). These seeds were then placed in 9 cm diameter Petri dishes lined with wet Whatman No.1 filter paper that had been autoclaved. Germination was determined as length of radicle from 2mm as starting point of measurement for, 24,48,72,96,120,144 and 168 hours.

3.8 SCREEN HOUSE EXPERIMENT.

Two seeds of each plant species were sown in plastic pot of 200mm^3 diameter.

A total of 192 pots were employed for the experiment. The pots were watered as follows:

M0 = watered three times a week (control)

M1= watered once a week (slight moisture stress)

M2 = watered once in two weeks (moderate moisture stress)

M3 = watered once in four weeks (severe moisture stress).

One litre of water was applied to the pots for each watering regime.

Destructive harvesting was carried out fortnightly on forty eight randomly selected plants to the determine the following growth parameters:

1. Shoot length (cm): This was obtained by placing a metre rule at the collar base to the tip of the apical bud.

2. Root length (cm): Obtained by digging out the root and washing in water and measured with metre rule.
3. Leaf Area (cm^2): Obtained by placing graph sheets on each leaf and tracing the outline then counting the numbers of squares covered by the leaf surface. The total numbers counted gives the leaf area.
4. Shoot dry weight (g): The shoots were oven dried at 70^oC for 72 hours and weight obtained by using weighing balance model mettle P163 (max. 160g).
5. Root dry weight (g): The roots were washed with water and oven dry at 70^0C for 72 hours and weight obtained
6. Shoot to root ratio: This measures the ratio of shoot dry weight and root dry weight.
7. The total dry matter accumulation (g): This represent the absolute weight of the seedlings, which is the leaf dry weight, stem dry weight and root dry weight.

3.9 STATISTICAL ANALYSIS

The data from the laboratory experiment were analyzed using percentages. The data from the screen house experiment were analysed using analysis of variance (ANOVA). Means were compared using least significant difference (LSD) ($P \leq 0.05$). Pearson's correlation coefficient was used to determine relationship between growth parameters in each of the four plant species.

CHAPTER FOUR

RESULTS

4.1 WATER IMBIBITION OF SEEDS

Acacia senegal had the highest imbibition rate after two hours (36.30%) followed by *Acacia nilotica* (27.27%) and *Acacia albida* (12.50%), imbibition rate was lowest in *Balanites aegyptiaca* (5.86%). (Table 4.1).

4.2 SEED COAT DIAMETER

Balanites aegyptiaca had the thickest seed coat of 2. 01± 0.01mm this was followed by *A. nolitica* with 1.00 ±0.03mm, *A. albida* 0.30 ± 0.01mm and *A. senegal* had the thinnest seed coat diameter of 0.21 ± 0.02 mm(Table 4.1).

4.3 EFFECT OF MOISTURE STRESS ON RADICLE ELONGATION

Balanites. aegyptiaca generally recorded longest radicle 7.47 ± 0.04mm at 144 hours and it was followed by *A. nilotica* with 4.05 ± 0.05mm at 96 hours. The shortest elongation of radicle was obtained in *A. senegal* 3.65 $\pm$ 0.04mm at 72 hours (Table 4.2).

TABLE 4.1: SEED DRY WEIGHT, SEED COAT DIAMETER AND IMBIBITION RATE (%) OF THREE *ACACIA* SPECIES AND *BALANITES AEGYPTIACA* AFTER TWO HOURS.

Plant species	Dry Weight (g)	Seed coat diameter (mm)	Imbibed weight (g)	Imbibition Rate %
A. abida	0.16 ± 0.02	0.300 ± 0.001	0.18 ± 0.02	12.50%
A. senegal	0.11 ± 0.01	0.210 ± 0.02	0.15 ± 0.01	36.30%
A. nilotica	0.22 ± 0.02	1.00 ± 0.03	0.28 ± 0.02	27.27%
B. aegyptiaca	3.07 ± 0.02	2.013 ± 0.01	3.25 ± 0.03	5.86%

Means ± SE

TABLE 4.2: EFFECT OF WATER STRESS ON RADICAL ELONGATION OF THREE ACACIA SPECIES AND *BALANITES AEGYPTICAL* AFTER 168 HOURS

Plants Species	Time (hours)	Radicle length (mm)
A. abida	24	3.01 ± 0.04
	48	3.49 ± 0.03
	72	3.65 ± 0.04
A . senegal	24	3.04 ± 0.05
	48	3.54 ± 0.04
	72	3.64 ± 0.05
A. nilotica	24	3.01 ± 0.04
	48	3.53 ± 0.05
	72	3.87 ± 0.04
	96	4.05 ± 0.05
B. aegyptiaca	24	3.88 ± 0.02
	48	4.77 ± 0.03
	72	5.67 ± 0.04
	96	6.63 ± 0.03
	120	7.28 ± 0.02
	144	7.47 ± 0.04

Means ± SE

4.4 EFFECT OF MOISTURE STRESS LEVELS ON GROWTH PARAMETERS BETWEEN 3 – 17 WEEKS AFTER SOWING (WAS)

4.4.1 Effect of Moisture Stress on Shoot Length.

Shoot length increased significantly ($P \leq 0.05$) with age under all moisture stress treatments in all the four plant species (Figure 1). The differences between the shoot lengths of the four plant species studied were also significant. In the control treatment (M0), *Acacia nilotica* had the highest increased in shoot length at 17 WAS followed by *A. senegal*. Generally, shoot length was lowest in *B. aegyptiaca* at 17 WAS. However, there were no significant differences between shoot length of *A. albida* and *A. senegal* at this sampling date. Weeks after sowing, plant species and moisture levels were significant ($P \leq 0.05$) for shoot length. The main interaction (weeks after sowing X plants species, weeks after sowing X moisture levels, plant species X moisture levels, weeks after sowing X plant species X moisture levels) were also significant ($P \leq 0.05$) for shoot length.

In the slight moisture stress treatment (M1), *A. nilotca* had the highest increase in shoot length at all the sampling dates. At 17WAS, *A. nilotica* had the highest significant ($LSD_{0.05} = 0.3$) increase in shoot length followed by *A. senegal*. However, *B. aegyptiaca* had the shortest shoot length.

For the moderate moisture stress treatment (M2), *A. nilotica* had the highest significant ($P \leq 0.05$) increase in shoot length at all the sampling dates. However, by 7 – 9 WAS there were no significant ($P \leq 0.05$) differences between the shoot length of *A. nilotica* and *A. senegal*. By 11-17 WAS there were significant differences ($P \leq 0.05$) among the four plant

species with *A. nilotica* having the highest shoot length compared with the other plants species.

In the severe moisture stress treatment (M3), *A. senegal* had the highest significant ($P \leq 0.05$) increase in shoot length at all the sampling dates followed by *A. nilotica* and while, *A. albida* had the shortest shoot length.

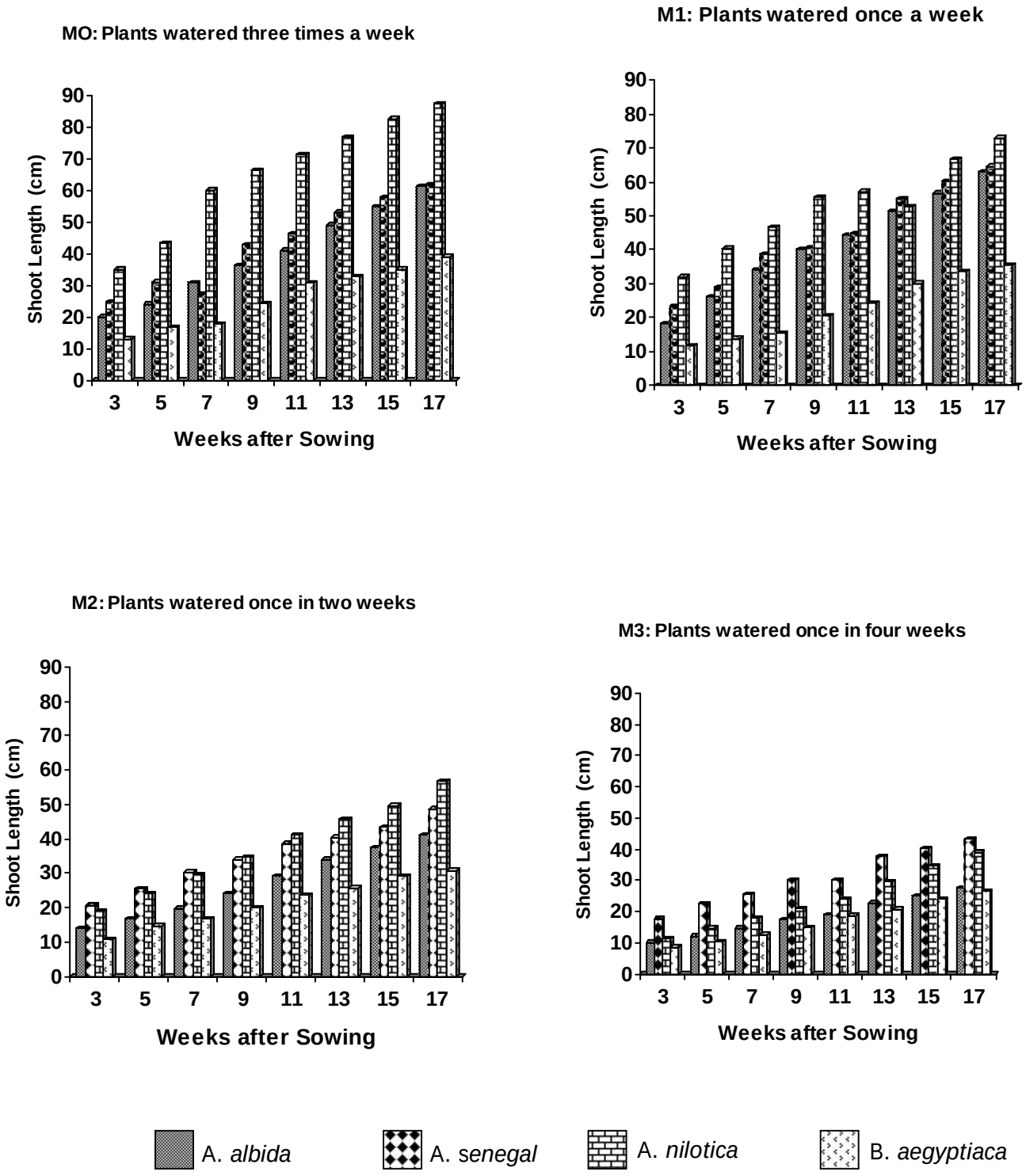


Figure 1: Variation in shoot length (cm) of three *Acacia* species and *Balanites aegyptiaca* under four moisture stress levels, over a period of 17 weeks.

4.4.2 Effect Of Moisture Stress On Root Length

Root length increased significantly ($P \leq 0.05$) with age among the four plant species at all the moisture stress treatment (M0). In the control treatment M0, there were significant $LSD_{0.05} = 2.24$ increased in *A. senegal* root length however, there were no significant differences between the root length of *A. nilotica* and *B. aegyptiaca* by 3 WAS. From 7-17 WAS there were significant differences in shoot length among the plant species with *A. nolitica* having highest root length followed by *A. albida* and lowest in *B. aegyptiaca*. The weeks after sowing, plant species and moisture levels treatment significantly ($P \leq 0.05$) affected root length. The main interaction (weeks after sowing X plant species, weeks after sowing X moisture levels, plant species X moisture levels, week after sowing X plant species X moisture levels) were also significant ($P \leq 0.05$) for root length (Appendix 5).

In the slight moisture stress treatment (M1), *A. albida* and *A. senegal* showed no significant ($LSD_{0.05} = 2.24$) differences in root length at 3 WAS however, *A. nilotica* showed significant decrease in root length than other plant species. By 17 WAS, *A. albida*, had the highest significant ($LSD_{0.05}=2.68$) increase in root length compared with the other plant species.

Root length in the moderate moisture stress treatment (M2), had significant ($LSD_{0.05}=1.12$) increased by 3 WAS in *A. senega*l than the other plant species and was lowest in *B. aegyptiaca*. By 17 WAS, *A. albida* had the highest significant ($LSD_{0.05}=1.34$) increased than other plant species.

In the severe moisture stress treatment (M3), root length was significantly ($P \leq 0.05$) higher in *A. senegal* in all the sampling dates except at 17WAS went *A. Albidal* had the highest significant increase followed by *A. senegal* and was lowest in *B. aegyptiaca*

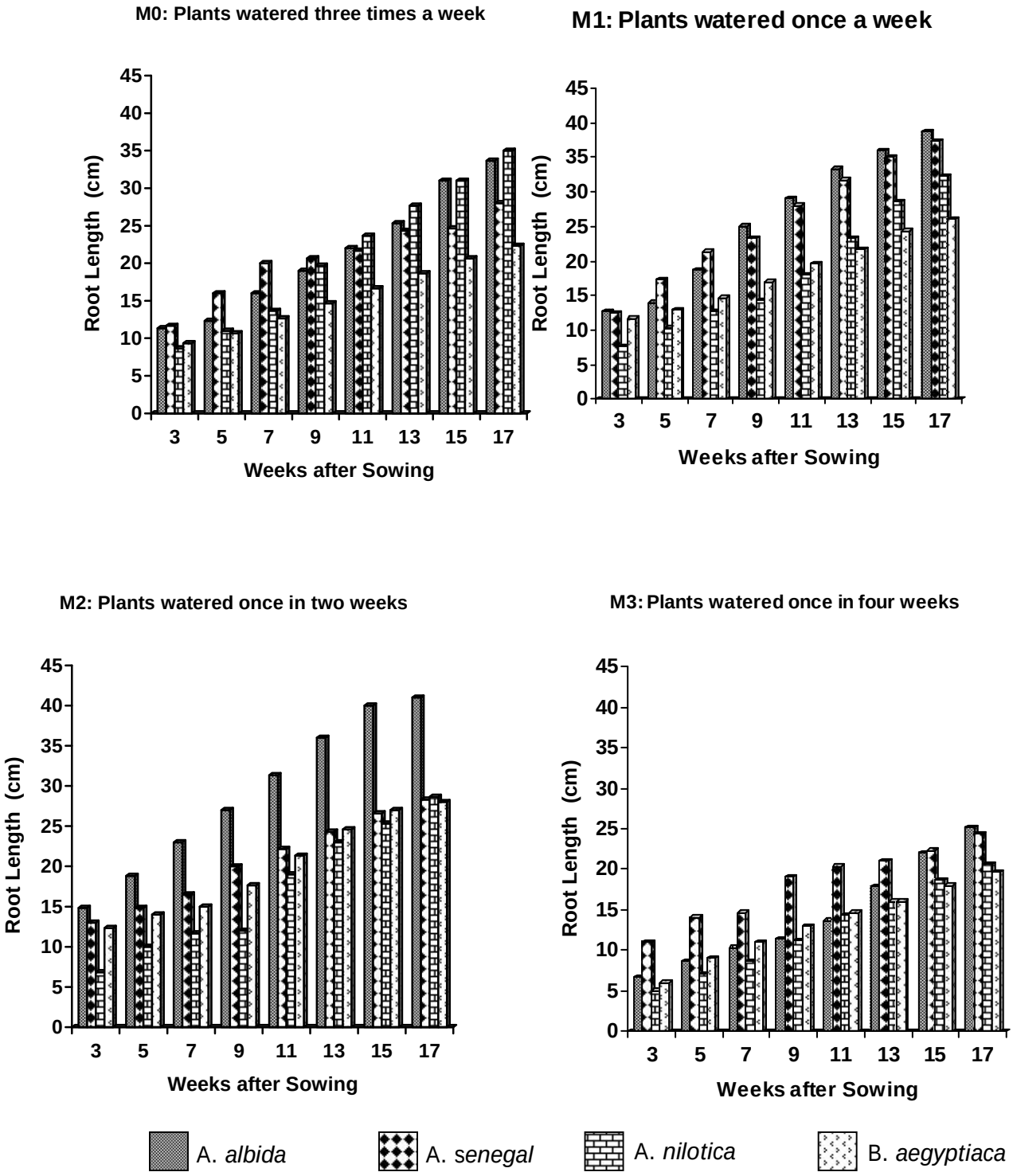


Figure 2: Variation in root length (cm) of three *Acacia* species and *Balanites aegyptiaca* under four moisture stress levels, over a period of 17 weeks.

4. 4.3 Effect of Moisture Stress on Shoot Dry Weight

Shoot dry weight increased ($P \leq 0.05$) with age in all the plants species under the four moisture stress treatments (Figure 3). In the control moisture stress treatment (M0), *A. nilotica* and *B. aegyptiaca* between 3-5 WAS had no significant differences ($P \geq 0.05$) in shoot dry weight. However by 7- 17 WAS, the were significant ($P \leq 0.05$) differences among the four plant species with *A. nilotica* having the highest shoot dry weight at 17 WAS and lowest in *A. albida*. Weeks after sowing, plant species and moisture levels were significant ($P \leq 0.05$) for shoot dry weight. The main interaction (weeks after sowing X plant species, weeks after sowing X Moisture levels, plant species X moisture levels, weeks after sowing X plant species X moisture levels) were significant ($P \leq 0.05$) for shoot dry weight (Appendix 7).

Under the slight moisture stress treatment (M1) *A. albida* and *A. senegal* at 3 WAS had no significant differences ($P \leq 0.05$) in shoot dry weight. *Acacia senegal* at 17 WAS had the significantly higher $LSD_{0.05}$ =0.22 followed by *A. nolitica* and lowest in *B. aegyptiaca*.

In the moderate moisture stress treatment (M2), *B. aegyptiaca* had the significantly ($LSD_{0.05}$ = 0.04) increase in shoot dry weight followed by *A. nilotica* and was lowest in *A. albida* at 3 WAS. By 11-17 WAS, there were significant differences ($P \leq 0.05$) among the four plants species with *A. senegal* having the highest shoot dry weight followed by *A. nilotica* and lowest in *A. albida*.

In the severe moisture stress treatment (M3), shoot dry weight decrease significantly ($P \leq 0.05$). However, at 17 was *A. senegal* had the highest $LSD_{0.05}=0.44$ increase in shoot dry weight followed by *A. nilotica* and lowest in *A. albida*.

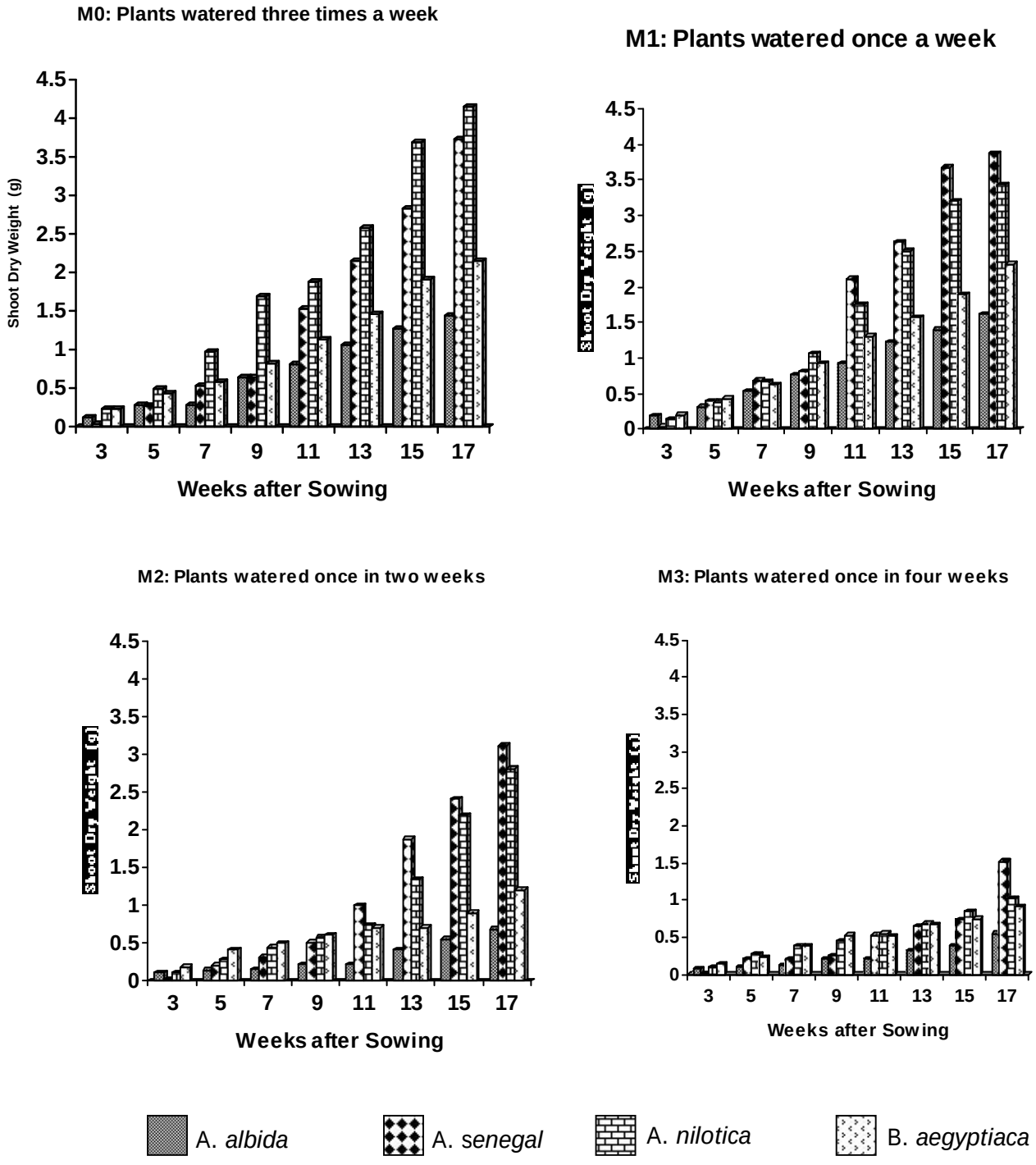


Figure 3: Variation in Shoot Dry weight (g) of three *Acacia* species and *Balanites aegyptiaca* under four moisture stress levels, over a period of 17 weeks.

4.4.4 Effect of Moisture Stress on Root Dry Weight

Root dry weight increased significantly (P≥0.05) with age under the different moisture stress treatments in the four plant species. (Figure 4). In the control treatment (M0), *B. aegyptiaca* had the highest significant ($LSD_{0.05}$ = 0.03) increase in root dry weight than other plant species. By 5 WAS, *A. senegal* had the significant ($LSD_{0.05}$ = 0.05) increased in root dry weight followed by *B. aegyptiaca* and was least in *A. albida.* As from 7 – 17 WAS, there were significant differences (P ≤ 0.05) among the plant species and *A. senegal* had the highest root dry weight followed by *B. aegyptiaca* in root dry weight. Weeks after sowing, plant species and moisture stress levels were significant (P ≤ 0.05) for root dry weight. The main interaction (weeks after sowing X plant species, weeks after sowing X moisture levels, plant species X moisture levels, weeks after sowing X plant species and moisture levels) were also significant (P ≤ 0.05) for root dry weight (Appendix 7).

In the slight moisture stress treatment (M1), *B. aegyptiaca* at 3 WAS had the significantly ($LSD_{0.05}$ = 0.03) higher root dry weight compared to other plants species. By 5 – 17 WAS, there were significant differences (P ≤ 0.05) among the plant species and *A. senegal* had the highest root dry weight followed by *B. aegyptiaca* and was least in *A. nilotica* .

For the moderate moisture stress (M2), *B. aegyptiaca* had the significantly ($LSD_{0.05}$ = 0.03) higher root dry weight at 3 WAS and was lowest in *A. nilotica.* By 13 – 17 WAS, there were significant (P ≤ 0.05) differences in dry root weight, *Acacia senegal* had the highest followed by *B. aegyptiaca* and was least in *A. nilotica.*

Under the severe moisture stress treatment (M3), plants species varied significantly ($P \leq 0.05$) in root dry weight by 3-17 WAS and the greater variability was in *A. senegal* followed by *B. aegyptiaca* and was lowest in *A. nilotica.*

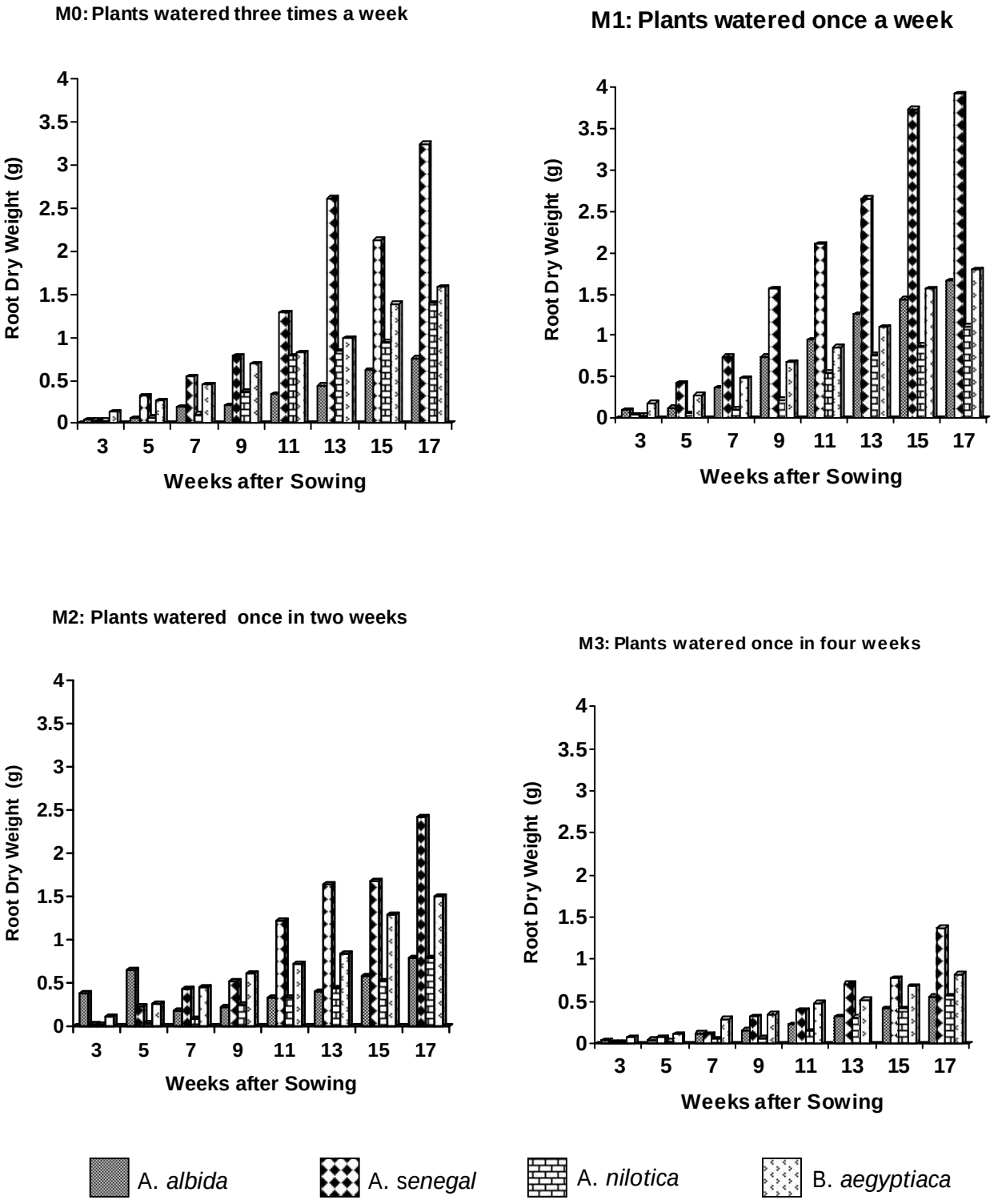


Figure 4: Variation in Root Dry weight (g) of three *Acacia* species and *Balanites aegyptiaca* under four moisture stress levels, over a period of 17 weeks.

4.4.5 Effect of Moisture Stress on Shoot / Root Ratio

Shoot / root ratio among the four plant species decreased with age significantly ($P \leq 0.05$) in all the four moisture stress treatments (Figure 5). In the control treatment (M0), shoot / root ratio in *A. nilotica* had significantly higher ($LSD_{0.05} = 0.92$) at 3 WAS followed by *A. albida* and lowest in *A. senegal.* By 7 WAS, there were significantly ($LSD_{0.05} = 0.72$) higher shoot / root ratio in *A. albida* as compared to other plant species. At 9 WAS there were significant ($LSD_{0.05} = 0.30$) decline in the shoot / root ratio in *A. nilotica* followed by *A. albida* and least in *A. senegal.*

By 17 WAS, there were significantly ($LSD_{0.05} = 0.31$) decrease in shoot/root ratio in *A. nilotica* followed by *A. albida* and lowest in *A. senegal.* Weeks after sowing, plant species and moisture levels in shoot/root ratio were significant ($P \leq 0.05$) for shoot/root ratio. The main interaction (weeks after sowing X plant species, weeks after sowing X moisture levels, weeks after sowing X plant species X moisture levels interaction in shoot / root ratio were similarly, significant ($P \leq 0.05$) for shoot/root ratio (Appendix 11).

For the slight moisture stress treatment (M1), *A. nilotica* had the significantly ($LSD_{0.05} = 0.93$) higher shoot / root ratio at 3WAS, followed by *A. senegal* and was lowest in *A. albida.* By 5 WAS *A. nilotica* had the significant highest ($LSD_{0.05} = 1.96$) increase in shoot / root ratio and *A. senegal* had the least shoot / root ratio in this sampling date. As the seedlings get mature *A. nilotica* had significant ($P \leq 0.05$) decreased in shoot / root ratio among the four plants species followed by *B. aegyptiaca* and least in *A. senegal.*

Under the moderate moisture stress treatment M2, *A. nilotica* had the significantly higher ($LSD_{0.05} = 0.92$) at 3 WAS followed by *A. albida* and was lowest in *A. senegal. Acacia*

nilotica had the highest shoot/root ratio between 3-5 WAS followed by *A. albida* and lowest in *A. senegal.*

There were significant differences ($P \leq 0.05$) among the four plant species from 11-7 WAS, *A. nilotica* had the highest shoot/root ratio followed by *B. aegyptiaca* and lowest in *A. albida.*

For the severe moisture stress treatment M3, *A. nilotica* had the highest significant ($LSD_{0.05} = 1.96$) increase in shoot / root ratio at 5 WAS followed by *A. senegal* and lowest in *B. aegyptiaca.* Generally, From 7 – 17 WAS there were gradual decrease in shoot / root ratio among the plant species. *Acacia nilotica* had the higher significant ($P \leq 0.05$) differences in shoot / root ratio followed by *B. aegyptiaca* and least in *A.albida.*

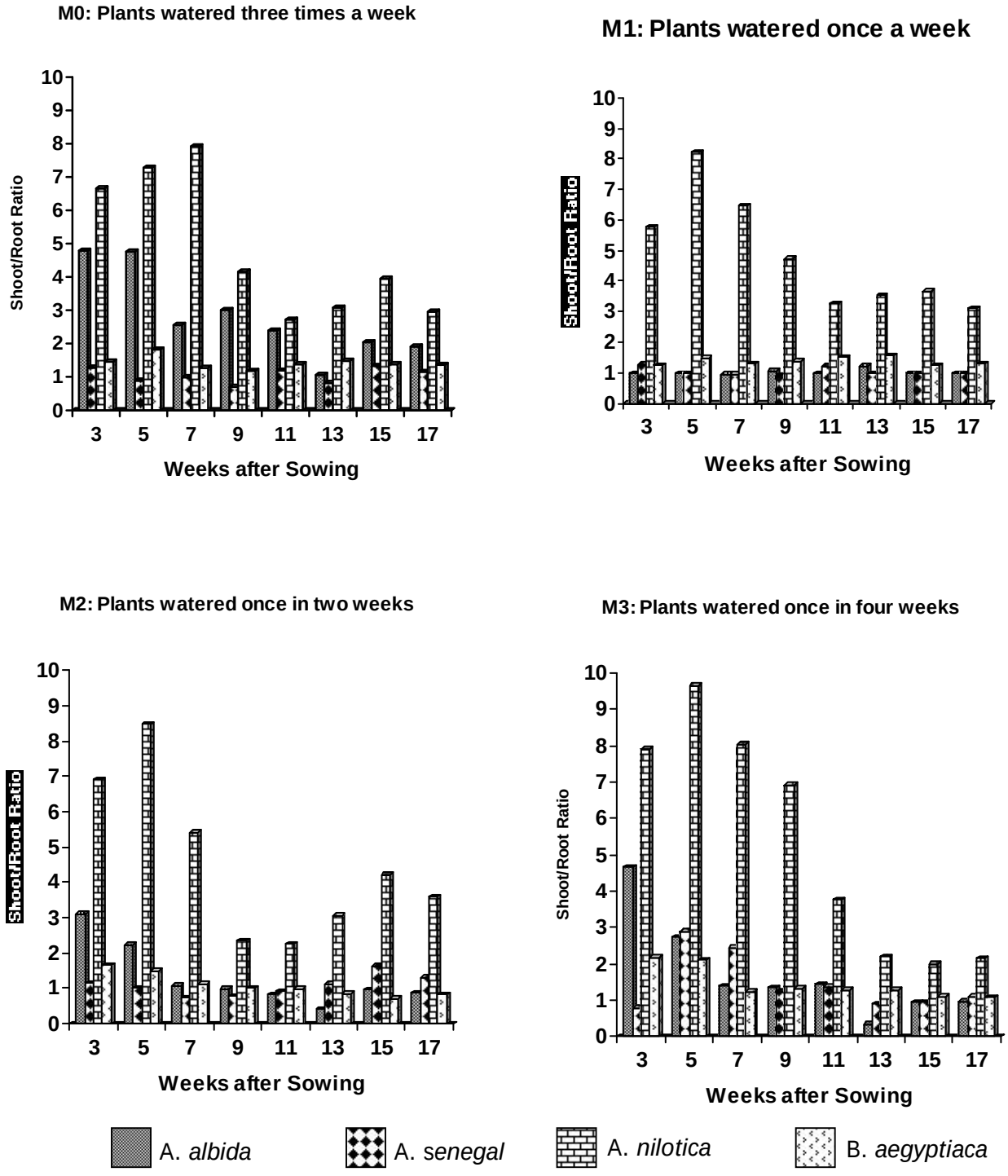


Figure 5: Variation in Shoot/Root Ratio of three *Acacia* species and *Balanites aegyptiaca* under four moisture stress levels, over a period of 17 weeks.

4.4.6 Effect of Moisture Stress on Total Dry Matter

Total dry matter in all the four plants species increase with age significantly ($P \leq 0.05$) among the four moisture stress treatments (Figure 6). In the control treatment (M0), *A. nilotica* at 3 WAS had significant ($P \leq 0.05$) higher total dry matter followed by *B. aegyptiaca* and lowest in *A. albida*. *Acacia senegal* had significant ($P \leq 0.05$) higher total dry matter from 11-17 WAS followed by *A. nilotica* and lowest in *A. albida*.

Weeks after sowing, plants species and moisture levels were significant ($P \leq 0.05$) for total dry matter. The main interaction (weeks after sowing X plant species, plants species X moisture levels, weeks after sowing X plants species X moisture levels) were also significant ($P \leq 0.05$) for total dry matter (Appendix 13).

Under the slight moisture stress treatment (M1), *A. senegal* had the significant ($P \leq 0.05$) increase in total dry matter in all the sampling dates followed by *A. nilotica* and *B. aegyptiaca* and was lowest in *A. albida.*

In the moderate moisture stress treatment (M2), *B. aegyptiaca* had the significant ($LSD_{0.05} = 0.1$) increase in total dry matter at 5 WAS followed by *A. senegal* and lowest in *A. albida*. *Balantes aegyptiaca* and *A. senegal* had no significant ($P \leq 0.05$) differences in total dry matter at 9 WAS. From 11 – 17 WAS, *A. senegal* had the highest significant ($P \leq 0.05$) differences in total dry matter followed by *A. nilotica* and lowest in *A. albida*

Total dry matter in the severe moisture stress treatment (M3), showed that *B. aegyptiaca* at 3 WAS had the significant ($LSD_{0.05} = 0.1$) increase in total dry matter and was lowest

in *A. albida.* At 7 WAS, *B. aegyptiaca* had the significant ($LSD_{0.05}$ = 0.1) increase in total dry matter followed by *A. nilotica* and was lowest in *A. albida.* At 17 WAS, *A. senegal* had significant ($LSD_{0.05}$ = 0.1) increase in total dry matter followed by *B. aegyptiaca* and was lowest in *A. albida.*

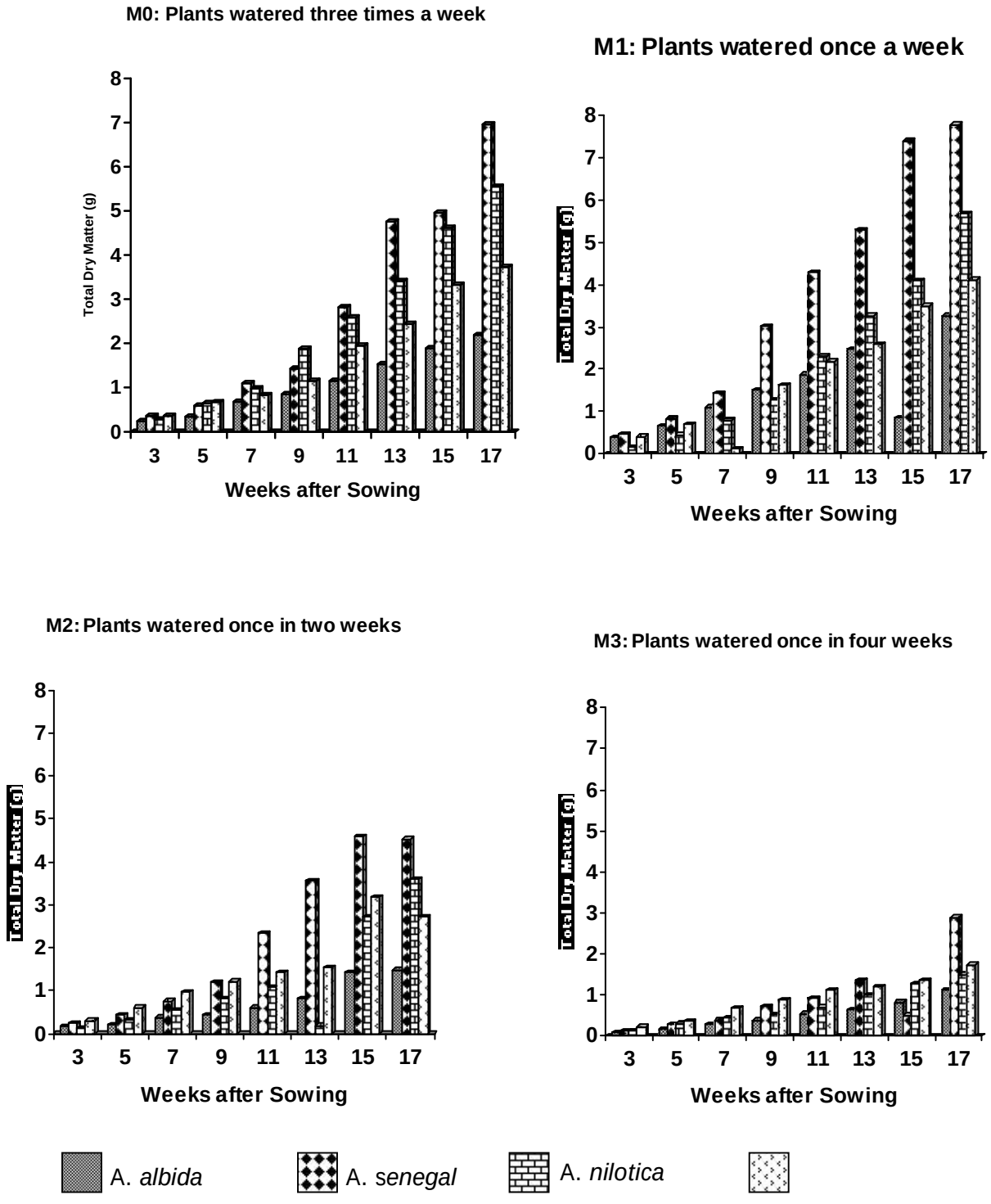


Figure 6: Variation in Total Dry Matter (g) of three *Acacia* species and *Balanites aegyptiaca* under four moisture stress levels, over a period of 17 weeks.

4.4.7 Effect of Moisture Stress Levels on Leaf Area

Leaf are increased significantly ($P \leq 0.05$) with age under the four moisture stress treatment in the four plant species (Figure 7). In the control treatment (M0), *A. senegal* had significant ($LSD_{0.05} = 0.39$) increase in leaf area at 3 WAS followed by *A. nilotica* and was lowest in *A. albida*. Generally, in all the sampling dates *A. senegal* produced the highest significant ($P \leq 0.05$) increase in leaf area followed by *A. nilotica* and lowest in *A. albida*. Weeks after sowing, plants species and moisture stress levels were significant ($P \leq 0.05$) for leaf area. The main interaction (weeks after sowing X plant species, plant species X moisture levels, weeks after sowing X plant species X moisture levels) were also significant ($P \leq 0.05$) for leaf area (Appendix 15).

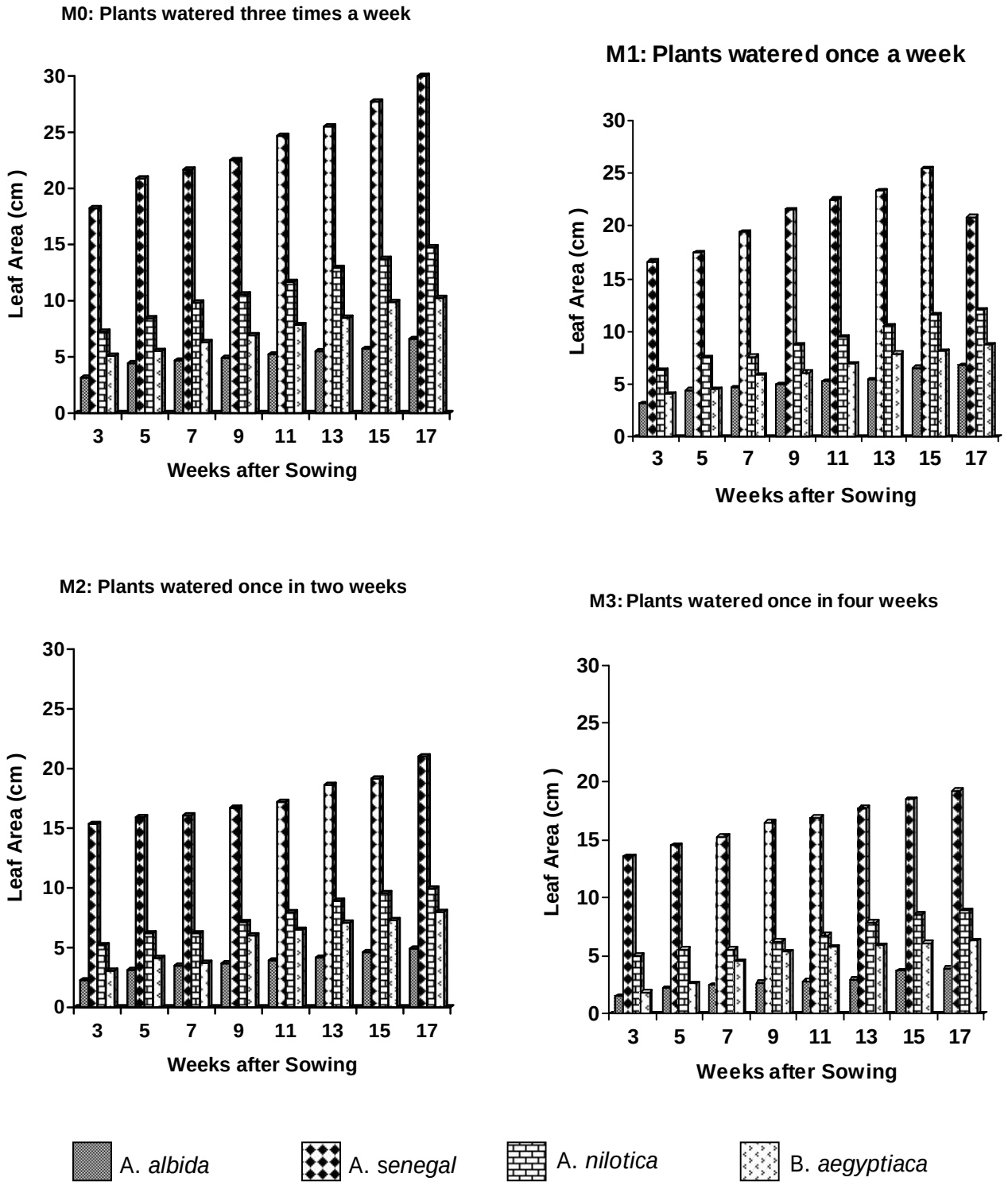


Figure 7: Variation in Leaf Area (cm^2) of three *Acacia* species and *Balanites aegyptiaca* under four moisture stress levels, over a period of 17 weeks.

4.4.8 Correlation Between Seedlings Growth Parameters in *A. albida, A. senegal, A. nilotica and B. aegyptiaca.*

Shoot length of *A. albida* exhibited a significant positive ($p \leq 0.01$) correlation with, root length, shoot dry weight, root dry weight, total dry matter and leaf area (r = 0.70, 0.76, 0.76, 0.75 and 0.75 respectively) (Table 4.3). However, shoot / root ratio indicated negative non significant correlation with shoot length, shoot dry weight total dry matter and leaf area. Root length, root dry weight exhibited a negative significant correlation with shoot / root ratio (r= -0.526 and - 0.487) in *A. albida. A. senegal* showed similar trends of correlation as obtained in *A. albida* (Table 4.4). However, shoot / root ratio exhibited negative non significant correlation with shoot length, root length, shoot dry weight, root dry weight, total dry matter and leaf area.

A. nilotica exhibited similar correlation trends as observed in *A. albida* and *A. senegal* seedlings growth parameters. However, the shoot/root ratio showed negative significant correlation with shoot length, root dry weight and leaf area (r = - 0453, - 0.485 and – 0.529 respectively). However, root length, shoot dry weight and total dry matter had negative non significant correlation with shoot/root ratio in *A. nilotica* (Table 4.5). *Balantes aegyptiaca* showed similar correlation trends as obtained in the seedlings of *A. nilotica* (Table 4.6).

TABLE 4.3: PEARSON'S CORRELATION MATRIX BETWEEN GROWTH PARAMETERS FOR *ACACIA ALBIDA* SEEDLINGS FOR 16 WEEKS UNDER MOISTURE STRESS LEVELS.

	Shoot length (cm)	Root length (cm)	Shoot dry weight (g)	Root dry weight (g)	Shoot/root ratio	Total dry matter (g)	Leaf area $(cm)^2$
Shoot length (cm)	1						
Root length (cm)	0.786**	1					
Shoot dry weight (g)	0.974**	0.698**	1				
Root dry weight (g)	0.849**	0.762**	0.873**	1			
Shoot/root ratio	-.0.277	-0.526*	-.0.241	-0.487*	1		
Total dry matter (g)	0.945**	0.755**	0.970**	0.965**	-0.375	1	
Leaf area $(cm)^2$	.0.965 **	.0.748**	0.916**	0.810**	-0.302	0.895**	1

* Significant at $P \leq 0.05$.

** Significant at $P \leq 0.01$

TABLE 4.4: PEARSON'S CORRELATION MATRIX BETWEEN GROWTH PARAMETERS FOR *ACACIA SENEGAL S*EEDLINGS FOR 16 WEEKS UNDER MOISTURE STRESS LEVELS.

	Shoot length (cm)	Root length (cm)	Shoot dry weight (g)	Root dry weight (g)	Shoot /root ratio	Total dry matter (g)	Leaf area $(cm)^2$
Shoot length (cm)	1						
Root length (cm)	0.927**	1					
Shoot dry weight (g)	0.934**	0.924**	1				
Root dry weight (g)	0.947**	0.938**	0.974**	1			
Shoot/root ratio	-.0.222	-0.157	-0.075	-0.182	1		
Total dry matter (g)	0.944**	0.936**	0.995**	0.995**	-0.123	1	
Leaf area $(cm)^2$	0.857**	0.675*	0.734**	0.761**	-0.244	0.751**	1

* Significant at $P \leq 0.05$.

** Significant at $P \leq 0.01$

TABLE 4.5: PEARSON'S CORRELATION MATRIX BETWEEN GROWTH PARAMETERS FOR *ACACIA NILOTICA S*EEDLINGS FOR 16 WEEKS UNDER MOISTURE STRESS LEVELS.

	Shoot length (cm)	Root length (cm)	Shoot dry weight (g)	Root dry weight (g)	Shoot /root ratio	Total dry matter (g)	Leaf Area $(cm)^2$
Shoot length (cm)	1						
Root length (cm)	0.804**	1					
Shoot dry weight (g)	0.850**	0.896**	1				
Root dry weight (g)	0.849**	0.853**	0.973**	1			
Shoot/root ratio	-0.453*	-0.368	-0.388	-0.485*	1		
Total dry matter (g)	0.850**	0.898**	0.983**	0.978**	-0.348	1	
Leaf area $(cm)^2$	0.863**	0.800**	0.841**	0.864**	-0.529*	0.870**	1

* Significant at $P \leq 0.05$.

** Significant at $P \leq 0.01$

TABLE 4.6: PEARSON'S CORRELATION MATRIX BETWEEN GROWTH PARAMETERS FOR *BALANITES AEGYPTIACA* SEEDLINGS FOR 16 WEEKS UNDER MOISTURE STRESS LEVELS.

	Shoot length (cm)	Root length (cm)	Shoot dry weight (g)	Root dry weight (g)	Shoot/root ratio	Total dry matter (g)	Leaf area $(cm)^2$
Shoot length (cm)	1						
Root length (cm)	0.804**	1					
Shoot dry weight (g)	0.850**	0.896**	1				
Root dry weight (g)	0.849**	0.853**	0.973**	1			
Shoot/root ratio	-0.453*	-0.368	-0.388	-0.485*	1		
Total dry matter (g)	0.850**	0.898**	0.983**	0.978**	-0.348	1	
Leaf area $(cm)^2$	0.863**	0.800**	0.841**	0.864**	-0.529*	0.870**	1

* Significant at $P \leq 0.05$.

** Significant at $P \leq 0.01$

CHAPTER FIVE

DISCUSSION

5.1 WATER IMBIBITION OF SEEDS AND SEED COAT DIAMETER

Acacia senegal with the thinnest seed coat diameter had the highest imbibition rate after two hours 36.30% while *B. aegyptiaca* with the thickest seed coat diameter had the lowest 12.50% imbibition rate. The highest imbibition rate obtained in *A. senegal* could probably be due to the thinnest of the seed coat that provides the fastest movements of water into the seeds, while the thickest seed coat diameter in *B. aegyptiaca* hinders faster movement of water into the seeds. Faster imbibition rate is an adaptation to sub arid and arid tropical zones that enables seeds to germinate faster after sporadic rainfall. Sanchez and King (1994) reported that legumes with the thinnest seed coat may undergo faster imbibition rate than seeds from other seeds with thickest seed coat. Mullin and Xu (2001) found a similar trend in seven soybeans varieties, when it was observed that varieties with the thinner seed coat diameter had the highest imbibition rate than those with the thicker seed coat. Stabell (1998) also had similar report in Houndstongue *Cynoglossum officinale.*

5.2 EFFECT OF MOISTURE TRESS ON RADICLE ELONGATION

The higher radicle elongation observed in *B. aegyptiaca*, could probably be as a result of the seeds having the heaviest seeds weight and possibly took in more water that enables the radicle to elongate for up to 144 hours under moisture stress conditions. This agrees with the findings of Cervantes *et al.* (1998) that there is a direct relationship between seeds weight and initial growth rate in A. *Cochliacantha* and *Pithecellobium dulce*

exposed to water stress. Humara *et al.* (2002) reported a similar observation in lager seeds size of *Eucalyptus globules* that had longer germination capacity than the smaller seeds size subjected to moisture stress conditions.

5.3 EFFECT OF MOISTURE STRESS ON SEEDLINGS SHOOT LENGTH

In the control treatment (M0), *Acacia nilotica had the highest increase in* shoot length from 3-17 WAS than the other plant species. This probably indicates that *A. nilotica* seedlings were able to utilized more water for their physiological activities that resulted in higher shoot length growth or due to phonological differences in shoot growth that promoted faster growth than in other species. Wakamiya *et al.* (1999) reported differences in shoot growth of *Pinus traeda* and *P. virginiana* under the same moisture availability. By 17 WAS, *A. albida* and *A. senegal* showed no significant differences between their shoot length, indicating that both species were able to carry out their physiological functions at the same rate. Van der Weele *et al*. (2000) reported that the shoot growth of *Arabidopsis thaliana* seedlings was acutely sensitive to water deficit, growing slowly at moderate water stress and not at all at severe stress. Moisture availability increase shoot length in *Azadirachta indica* Puri and Swamy (2001); Leuschner *et al.* (2001) in *Fagus sylvatica.* A significant variation in the seedlings shoot length recorded among the four plant species at different moisture levels and the significant interaction between weeks after sowing and plant species, weeks after sowing and moisture levels, plant species and moisture levels, weeks after sowing and plant species and moisture levels indicates that the four plant species shoot length responded differently to the moisture stress levels at the different intervals of the moisture treatment. Rawat and Singh (2000) reported species shoot length differences in *Acacia nilotca,*

Albizzia, lebbeck, Dalbergia sisso and Eucaplytus camaldutensis seedlings watered once in two days for eight months.

In the slight stress treatment (M1), *A. nilotica* had the highest shoot length at 17 WAS. This means that the slight stress moisture level had no effect on the shoot length of *A. nilotica.* The plants species showed similar shoot length growth trends as obtained in the control treatment (M0).

Shoot length in the moderate stress moisture level showed that *A. nilotica* had the highest increase in all the sampling dates and was least in *B. aegyptiaca*. This probably means that *A. nilotica* seedlings were more efficient in carrying out photosynthetic activities that promotes shoot growth at moderate moisture stress than the other species. Mooney (1972) asserted that all things being equal, plants that allocates more to shoot will have a higher maximum growth than those that allocate less. From 5 – 11 WAS, there were no significant differences between the shoot length of *A. nilotica* and *A. senegal* probably due to the fact that at early seedlings growth stage had less effect of the slight moisture stress treatment with same magnitude however, when the seedlings get mature significant differences were observed. Alcocer *et al*. (1989) reported species shoot length differed only at the later phase and not at the early phases of growth in *Bouteoua scorpioidua.* Rawat and Singh (2000) reported that four plant species, *A. nilotica, A. lebbeck, D. Sissoo* and *E. camaldulensis* juvenile seedlings showed less significant differences than the mature seedlings.

In the severe moisture stress treatment (M3), all the four plant species had significant variation in shoot length. The maximum shoot length was recorded in *A. senegal*. This suggest that *A. senegal* seedlings benefits from exposure to moisture stress for maximum shoot growth. Martinez et al. (2002) reported compensatory effect in *Pinus lecophylla* seedlings a higher shoot growth than the control treatment.

5.4 EFFECTS OF MOISTURE STRESS ON ROOT LENGTH

In the control treatment, *A. nilotica* had the highest increase in root length followed by *A. albida, A. senegal* and *lowest in B. aegyptiaca.* This suggest that *A. nilotica* has the capacity to increase in root length more than the other species in the control moisture level. Abdul – Jabar *et al*. (1982) reported that the root length and root mass in Alfalfa were highest under high moisture level. Standhill (1975) reported excess moisture given at early seedling stage may stimulates shoot and root growth. At 3WAS, there were no significant differences between *A. albida* and *A. senegal* seedlings shoot length, however, by 17 WAS, a significant variation was observed. This probably indicates that at early seedlings growth stage, there may be less demand for water in these seedlings as these seedlings gets larger, their demands for soil resources increases and species difference were obtained. Wang *et al*. (1998) reported that at early seedlings stage, there were no significant differences in root growth of paper birch (*Betula papyrifera*) under different soil moisture regimes.

The plants species, weeks after sowing and moisture stressed levels showed significant root length differences, also the interaction between weeks after sowing and plant species, weeks after sowing and moisture levels, plant species and moisture levels, weeks

after sowing and plant species and moisture levels were significant. This indicates that the four plant species respond differently in root length at the moisture stress levels at the different sampling dates. Martinez *et al*. (2002) found significant interaction between moisture stress and plant species root length.

In the slight moisture stress treatment (M1), *A. albida* had the highest root length followed by *A. nilotica* and least in *B. aegyptiaca*. This results indicates that in *A. albida*, slight moisture stress (M1) stimulated the root growth. This agrees with the findings of Sharp and Davis (1979) that moderate stress stimulated root growth in maize seedlings. Van der Weele (2000) also reported that moderate moisture stress stimulated the root length in *Arabidopsis thaliana* seedlings. *B. aegyptiaca* had the lowest root length, suggesting that the slightly imposed moisture stress affected root growth. Wan *et al*. (1993) reported that moderate moisture stress caused a reduction in root length in Broom snakeweed seedlings while the root/shoot ratio remain constant. By 3WAS, there were no significant differences among the seedlings of *A. albida, A.senegal*, and *B. aegyptiaca* however, *A. nilotica* showed a significant decrease in root length.

In the moderate moisture stress treatment root length increase with age from 3 – 17 WAS. The plant species showed similar trends of root length growth as were obtained in (M1) moisture stress level.

In the severe moisture stress treatment (M3), root length increased with age. By 3 – 13 WAS, *A. senegal* produced the significantly higher root length followed by *A. albida*. This results indicated that *A. senegal* has the capacity to channel more photosynthate to the roots that caused the increased in root length than other species under the severe

stress. Kamaludin and Kabir (2002) reported increased in root length in *Chikrassia velutian* and *Acacia* hybrid (A. *mangium* Willd Versus *A. auricuformis*) under severe moisture stress. However, this findings contradicts Ball *et. al*. (1994) that water stress in cotton seedlings reduced roots elongation and roots volume. Leushner et. al. (2001) also reported that in *Quercus petraes* seedlings, roots were more susceptible to soil water stress than leaf expansion and photosynthesis. Fresnillo (1995) reported that in root box experiment, water stress reduced root growth in *Medicago minima*.

5.5 EFFECT OF MOISTURE STRESS ON SHOOT DRY WEIGHT

In the control moisture treatment (M0), shoot dry weight increase with age in all the four plant species. By 3WAS, there were no significant difference between *A. nilotica* and *B.aegyptiaca* in shoot dry weight. This probably indicates that these seedlings were able to carry out their physiological processes at the same rate. Caloin *et al.* (1990) proposed that partioning of assimilates depends on genetic factor and environmental factor. From 7 – 17 WAS, *A. nilotica* produced the highest shoot dry weight with the maximum at 17 WAS. This suggests that *A. nilotica* was able to take in more water that promoted fast growth rate. Greco and Cavagnaro (2002) found that higher productivity of some plants species was associated to larger total plant biomass and higher dry matter partioning to above ground organs. The significant differences among plant species, weeks after sowing and moisture stress levels as well as in the interaction between weeks after sowing and plant species, weeks after sowing and moisture levels, plants species and moisture levels, weeks after sowing and plant species and moisture levels suggest that the plants species reacted differently to the moisture stress levels for shoot dry weight.

Li and Wang (2003) reported a significant interaction among three contrasting *Eucalyptus microtheca* between plant species and moisture stress levels, plant species and shoot height in response to moisture stress.

In the slight moisture treatment (M1), shoot dry weight in *A. nilotica* and *B. aegyptiaca* had no significant differences from 3 – 7 WAS which suggest that both plants carried out their physiological activities at the same rate. From 9 – 17 WAS, *A. senegal* produced the highest shoot dry weight with it maximum at 17 WAS. This probably indicates that being the seedling with the more leaf area as compared to other species was able to produced more shoot dry weight at the slight moisture stress treatment. Carter (1972) reported that plants with more leaf area produced more dry matter. Under the moderate moisture stress treatment (M2). The shoot dry weight showed similar trends as obtained in MI moisture stress treatment.

In the severe moisture stress treatment (M3), *A. albida* had the least shoot dry weight as compared to other species by 3 – 11 WAS. This indicates that the species had more effects of severe moisture stress treatment than other species. Assuero *et al*. (2002) reported significantly decreased in shoot dry weight in *Fescue arundinacea*. By 17 WAS, *A. senegal* produced the maximum shoot dry weight than other species, probably suggests that this species was able to produced more leaves which ultimately resulted in production or more shoot dry weight than in other species. Alcocer *et al*. (1989) reported that shoot biomass production in *Bouteoua scorpiodes* was directly related with rate of photosynthesis.

5.6 EFFECT OF MOISTURE STRESS ON ROOT DRY WEIGHT.

In the control treatment (M0), *B. aegyptiaca* had the highest root dry weight, at 3 WAS however, from 5 – 17 WAS, *A. senegal* had the highest root dry weights as compared with other plant species. This probably is associated with lager leaf area observed in *A. senegal* which contributes in the production of more photosynthate that were carried to the roots which promotes increased in root dry weight than obtained in other plant species. Wardlaw (1967) found that dry matter production involves the production of assimilate in photosynthetic organs (source) and their translocation to the growing point (sink). Root dry weight showed significant differences in plant species. Weeks after sowing and moisture levels. There were also significant differences in the interaction between weeks after sowing and plant species, weeks after sowing and moisture levels, weeks after sowing and moisture levels, and plant species. This suggest that the four plant species accumulated root dry weight at the four moisture stress levels at the different sampling periods. Gutierrez *et al*. (2002) reported a significantly interaction root dry weight and plant species, plant species and moisture stress levels in three species of Eucalyptus. In the slight, moderate and severe moisture treatment, root dry weight had similar trends as obtained in control moisture treatment (M0) and *A. senegal* having the highest root dry weights as compared with others species.

5.7 EFFECT OF MOISTURE STRESS ON SHOOT/ROOT RATION

In the control moisture treatment, shoot/root ratio in the four plant species decreased with age. By 7 WAS shoot / root ratio was highest in *A. nilotica* followed by *A. albida* and least in *A. senegal* and *B. aegyptiaca*. However, from 9 – 17 WAS, there were gradual significantly decreased in the shoot / root ratio among the four plant species. This

suggests that *A. nilotica* seedlings were able to allocates more dry matter to shoot relative to the roots growth. On the other hand, *A. senegal* with the lowest shoot / root ratio indicates that the seedlings were able to allocates more dry matter to the root relatives to the shoot. Puri and Swamy (2001) reported a higher shoot / root ratio in *Azadirachta indica* seedlings at control moisture level. Assurero *et al*. (2002) reported increased root / shoot ratio in Tall fescue *Fescue arundinacea* Schreb. The plants species, weeks after sowing and moisture stress levels had significantly differences in shoot / root ratio. The interaction between weeks after sowing and moisture stress levels, plant species and moisture levels, weeks after sowing and plant species and moisture levels was also significant. This suggests that each plant species reacted differently to the effects of the moisture stress levels at the different sampling periods.

In the slight (M1), moderate (M2), and severe (M3) moisture stress treatment, there were general decreased in shoot / root ratio among the four plant species. *Acacia nilotica had the ma*ximum and *B. aegyptiaca* had the minimum shoot/root ratio in all the sampling dates. This probably indicates that as these plants get mature the severe effects of the moisture stress caused a halt in the production of new leaves, undergone leaf senescence, rolling of leaves to mitigate the effects of the severe stress. Alcocer *et al*. (1989) reported that *Bouteoua scorpiodua* showed water stress tolerance mechanism by leaf rolling, reducing photosynthetic rate, chlorosis, and accelerated leaf senescence at the later stage of seedlings growth. Guenni *et al*. (2002) reported a decrease in shoot / root ratio in *Brachiaria mutica* and *B. humidicola* under moisture stress. Greco and cavagnaro (2002) however, reported no change in shoot / root ratio of *Trichloris crinita* seedlings subjected to drought stress.

5.8 EFFECT OF MOISTURE STRESS ON TOTAL DRY MATTER

Total dry matter increase with age in the control treatment. By 3 - 9 WAS, *A. nilotica* had the highest total dry matter and least in *A. albida*. However, from 11 – 17WAS, *A. senegal* had the maximum dry matter and minimum in *A. albida*. The results obtained probably indicates that at the early seedling stage, *A. nilotica* carried out maximum photosynthesis, but as the seedlings gets older, *A. senegal* seedlings were able to produced more leaves that eventually, increased higher dry matter as compared to other species. Turner and Begg (1978) found that dry matter production in plants involves the production of assimilates in leaves and their translocation to other growing parts. Weeks after sowing, plant species and moisture levels had significant differences in total dry matter respond, also the interaction between weeks after sowing and plant species, weeks after sowing and moisture levels, weeks after sowing and plant species and moisture levels were significant. This suggests that each plant species respond differently to the effects of the moisture stress at the different periods of sampling. Rawat and Singh (2000) reported that *A. nilotica, lebbeck, D. sissoo* and *E. camaldulensis* varied significantly in total dry matter production in the nursery at different moisture stress levels.

Under the slight moisture stress treatment M1, total dry matter showed that *A. senegal* had maximum values at 5 WAS, followed by *A.albida* and least in *A. nilotica.* Generally *A. senegal* had the highest total dry matter in all the sampling dates as obtained in M0 moisture level.

In the moderate moisture stress treatment M2, similar patterns were obtained as in M0 and MI moisture treatments. By 15 – 17 WAS, *A. senegal* maintain a constant total dry matter higher than other plant species . This probably indicates that no new leaves were produced or there were stomata closure. David *et al*.(1998) reported that at soil drying, stomata limitation to carbon dioxide influx cause photosynthetic depression in mature leaves than in new leaves.

In the severe moisture stress treatment M3, total dry matter was highest in *B. aegyptiaca* from 3 – 11 WAS and was least in *A. albida*. This probably suggest that B. *aegyptiaca* seedlings were able to controlled the effects of the severe moisture stress than the other plant species at those growing stages with respect to total dry matter production. Alcocer *et al*. (1989) found that moisture stress during early stages may be less detrimental than at later stage of growth in *B. scorpioides*. By 17 WAS, *A. senegal* produced the highest total dry matter than other species. This probably may be as a result of more leaves that were produced at this period than in other plant species that contributed in more dry matter. Carter (1972) found that plants with lager leaf area and photosynthetic rate produced more dry matter.

5.9 EFFECT OF MOISTURE STRESS OF LEAF AREA

In the control treatment (M0), *A. senegal* from 3 – 17 WAS produced the highest leaf area and was least in *A. albida*. This suggests that *A. senegal* was able to utilized the available soil water (control moisture stress) for faster leaf area growth than the other species. Greco and Cavagnaro (2002) reported that in three varieties of *Trichloris crinita*, the variety with lager leaf area was able to utilized the available soil moisture more than

variety with smaller leaf area. Plant species, weeks after sowing and moisture levels had significant differences in leaf area. The interaction was also significant between weeks after sowing and plant species, weeks after sowing and moisture levels, plant species and moisture levels, weeks after sowing and plant species and moisture levels. This suggests that the four plants species, differed in leaf area in response to the moisture stress levels at different sampling dates. Guenni *et al*. (2002) reported insignificant interaction between five *Brachiara* species and leaf area in response to drought stress.

Generally, under the slight (M1), moderate (M2) and severe (M3) moisture stress treatments, leaf area decrease in all four plant species with age. *Acacia senegal* produced the highest leaf area and was least in *A. albida*l. This indicates that from the slight to severe moisture stress treatments there was a negative effect in the leaf area among the four plant species. Greco and Cavagnaro (2002) reported that leaf area was the most affected growth parameters in three varieties of *Trichloris crinita* P. (Poaceae). Boyer (1998) found that water stress reduced leaf area of plants because cell extension is highly sensitive. Gower *et al*. (1992) found that leaf area is reduced by moisture stress because the carbon source strength decreased.

5.10 CORREALTION BETWEEN SEEDLINGS GROWTH PARAMETERS AMONG THREE ACACIA SPECIES AND BALANITES AEGYPTIACA

All the four plant species investigated exhibited a positive significant (P. $\leq$ 0.01) correlation between shoot length and root length, shoot dry weight, root dry weight, total dry matter, leaf area. This indicated that shoot length contributes to these growth attributes under the moisture stress levels. Li *et al*. (2000) reported a positive significant

correlation between plant height and total plant biomass in the seedlings *of E. murotheca* under drought stress. Rawat and Singh (2000) similarly reported a positive significant correlation between seedlings dry matter and seedlings height, root dry weight in *Albizzia lebbeck, Dalbergia sisso* and *Eucalyptus camaldulensis* under water stress. Shoot / root ratio in *A. albida* showed negative non significant correlation with shoot length, shoot dry weight, root dry weight, total dry matter and leaf area. This suggests that shoot/root ratio does not contributes to these growth attributes. However, shoot / root ratio with root length, root dry weight exhibited a negative significant correlation. This indicated that as shoot / root ratio increases, the root length and root dry weight decreases. Wan *et al*. (1993) reported that Broom snake weed plants showed a negative correlation between root length and root / shoot ratio under drought stress. Li and Wang (2003) similarly, reported a negative correlation between root / shoot ratio and leaf area in *E. microtheca* seedlings under moisture stress. *Acacia senegal* showed similar shoot / root ratio trends as obtained in *A. albida, Acacia nilotica* and *B. aegyptiaca* showed negative significant correlation between shoot/root ratio with shoot length, root dry weight and leaf area. This suggests that as shoot / root ratio increases, it has adverse effects on the shoot length, root dry weight and leaf area and vice versa.

CHAPTER SIX

SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 SUMMARY

Experiments were conducted in the laboratory and screen house to investigate the effects of moisture stress on germination and early seedlings growth of three *Acacia* species and *B. aegyptiaca*. The null hypothesis of the investigation postulates;

1. There are no significant differences in the germination of the three *Acacia* species and *B. aegyptiaca* under moisture stress
2. There are no significant differences in the early seedlings growth of the three *Acacia* species and *B. aegyptiaca* when exposed to four moisture stress levels. Laboratory experiment carried out routine soil analysis to determine, particle size, pH, organic carbon, total nitrogen, available phosphorus and cation exchange capacity of soil. Completely randomize design with three replication was used. The dry weight of ten seeds from each species were determine, placed in 9cm diameter Petri dishes lined with Whatman No.1 filter paper and kept near a beak contain boiled water then covered by a bell jar for two hours. The difference between the dry seeds weights and imbibed weights gives the imbibition rate. Seed coat diameters of ten seeds from each species were determine using micrometer screw gauge. Radicle elongation of ten seeds from each species were determine by the selection of seeds of about 2mm as the starting mark for measurement for, 24, 48, 72, 96, 120,144 and 168 hours. Screen house experiment used two seeds from each species sown in 200cm^3 plastic pots and 192 pots were used. The experiment involved four plant species four moisture levels and three

replications. The potted plants were arranged in four blocks, each containing 48 pots. Destructives harvesting was carried out fortnightly eight times to determine, shoot length, root length, leaf area, shoot dry weight, root dry weight, shoot root rate and total dry matter. Laboratory experiments were analyzed using %, while ANOVA at ($p \leq 0.5$) and Pearson's correlation coefficient were used to analyzed the screen house experiment. *Acacia senegal* had the highest imbibition rate, while *B. aegyptiaca* produced the least. *Balanites aegyptiaca* had the maximum radicle elongation at 144 hours, while *A. senegal* and *A. albida* had the minimum at 72 hours. *Acacia albida* produced its highest root length at the slight (M1) and moderate (M2) moisture stress treatment. *Acacia senegal* had its maximum root length, shoot length at the severe (M3), moisture stress treatment. The shoot dry weight was highest at the slight (M1), moderate (M2) and severe (M3) moisture stress treatment, while the total dry matter and leaf area were higher in all the moisture stress treatment. *Acacia nilotica* had the highest shoot length at the control and slight moisture treatment, root length and shoot dry weight were higher at the control treatment (M0), the shoot / root ratio was higher in all the moisture stress treatments. *Balanites aegyptiaca* had the least seedlings growth attributes at all the sampling dates.

6.2 CONCLUSION

Acacia. senegal with the highest imbibition rate after 2 hours probably indicates its thinnest seed coat diameter provides faster movement of water into the seeds. *Balanites aegyptiaca* with the maximum radicle elongation after 144 hour probably suggests that being the seeds with the heaviest seeds weight took in more water that allows longer

elongation of the radicle. *Acacia albida* had the highest root length at the slight (M1) and moderate (M2) moisture stress treatments. This suggests that at slight and moderate stress moisture levels stimulated root length growth better as compared to other species. *Acacia. senegal* produced maximum root length and shoot length at the severe (M3) moisture stress treatment . This indicates that severe moisture stress exposure benefits these seedlings growth with respect to shoot and root length. Shoot dry weight, root dry weight, total weight and leaf area were maximum in *A. senegal* at all the moisture stress treatments. This may be due to the presence of larger leaf area obtained from this species at all the four moisture stress treatment that provides maximum production of photosythate from the leaves for distribution to other parts of the plant. *Acacia. nilotica* had its highest shoot length, root length; shoot dry weight at the control moisture stress treatment (M0). This probably indicated that the species was able to utilize the available water at the control treatment M0 that provides maximum growth. However, at severe moisture stress treatment these growth attributes decreased. Shoot / root ratio showed highest value in *A. nilotica* at all the four moisture stress treatments. These suggest that the species allocates more dry matter to shoot growth than the roots in all the four moisture stress treatments. *Balanites aegyptiaca* had the least growth attributes in all the four moisture stress treatments. This indicates that, it is a slow growing plant given any amount of moisture stress treatment. Therefore, may be able to mitigate the effect of moisture stress by growing slowly. The four plant species response differently, at the four moisture levels, at the different sampling dates in their growth attributes. Shoot length exhibited positive significant correlation with root length, shoot dry weight, root dry weight, total dry matter and leaf area. This suggests that the shoot length contributes to

these growth attributes. Shoot / root ratio showed negative non significant correlation with shoot length, root dry weight, total dry matter and leaf area. This indicated that increased shoot / root ratio decreased these growth attributes and vice versa. These results indicated that seedlings characteristics such as; shoot length, root length, shoot dry weight, root dry weight, shoot / root ratio, total dry matter and leaf area could be used for screening nursery stocks for afforestation programmes in the savanna region of Nigeria.

6.3 RECOMMENDATION

1. Results showed that *Acacia* species grows faster than *B. aegyptiaca* when exposed to moisture stress levels. Therefore inter-planting these perennials, will lead to better use of light, water and nutrient due to the different spacing, height and root depth of these plants to optimize productivity in the savanna belt of Nigeria.
2. *Acacia albida* and *A. senegal* would be recommended to be exposed to slight (M1) to moderate (M2) moisture stress treatments at the nursery stage for better quality seedlings to be used for agroforestry projects or in the establishment of shelterbelt with *B. aegyptiaca* to ameliorate the problems associated with desertification in the Sudano – Sahelian belt of Nigeria.
3. More studies will be needed to give an understanding in the physiological and molecular attributes that gives *A. albida* and *A. senegal* better response at the slight (M1) and moderate (M2) moisture stress treatments with regards to shoot and root growth.

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Appendix 1: Weather condition within the experiment period (April to October, 2005).

Month	Temperature		Rainfall	Relatively humidity		Evaporation
	^{0}C		(mm)	(%)		(mm)
	Max	Min.		10 A.M	4 P.M	
April	40.00	24.00	63.10	41.00	23.00	11.8
May	35.00	23.00	102.70	68.00	44.00	7.70
June	31.60	21.00	160.20	78.40	60.30	6.60
July	30.20	20.90	152.60	83.00	67.50	5.20
August	29.20	20.10	235.50	86.70	72.20	5.00
September	31.70	20.30	122.40	74.90	62.60	5.60
October	33.20	18.50	16.80	57.10	43.30	7.00

Data collected from meteorological unit, institute for Agricultural Research, Ahmadu Bello University, Zaria, Nigeria.

Appendix 2: Physico – chemical properties of top soil used for the experiments.

Characteristics	Values
pH (H_2O)	5.5
pH ($CaCl_2$)	6.5
Organic carbon (g/kg)	1.35
Total Nitrogen (g/kg)	0.088
Available phosphorus (mg/kg)	15.80
Exchangeable Bases (Cmol/kg)	
Ca	6.32
Mg	2.30
Na	0.23
K	0.35
Cation exchange capacity (Cmol/kg)	12.6
Mechanical Analysis	
Sand	72.00%
Silt	16.00%
Clay	12.00%
Texture Class	Sandy loam

Appendix 3: **Analysis of Variance of shoot length in three *Acacia* Species and *Balanites aegyptiaca* seedlings at different moisture stress levels at 3 to 17 weeks after sowing WAS.**

Source of variation	SS	DF	MS	F	P
Model	568036.75	128	4437.79	316.59	0.001
Weeks after sowing	42819.29	7	6117.04	436.38	0.001
Plant species	26019.33	3	8673.11	618.73	0.001
Moisture levels	26967.10	3	8989.03	641.27	0.001
Weeks after sowing* Plant Species	1182.81	21	56.32	4.02	0.001
Weeks after sowing* Moisture levels	1981.12	21	94.34	6.73	0.001
Plant species* Moisture levels	10147.49	9	1127.50	80.44	0.001
Weeks after sowing* Plant species* Moisture levels	1967.10	63	31.22	2.23	0.001
Error	3588.50	256	14.02		
Total	571625.25	384			

$P \leq 0.05$

Appendix 4: **Mean shoot length of three *Acacia* species and *Balanites aegyptiaca* seedlings at different moisture stress treatments.**

Plant Species	Control (M0)	Slight Moisture Stress (M1)	Moderate Moisture Stress (M2)	Severe Moisture Stress (M3)
Acacia albida	39.63	41.50	26.96	18.63
Acacia senegal	44.35	44.25	35.29	30.88
Acacia nilotica	65.33	54.33	35.75	24.04
Balanites aegytiaca	27.21	23.04	21.38	19.38

$LSD_{(0.05)} = 4.57$

Appendix 5 Analysis of variance of root length in three *Acacia* species and *Balanties aegyptiaca* seedlings at different moisture stress levels at 3 to 17 weeks after sowing (WAS).

Source of Variation	SS	DF	MS	F	P
Model	173484.83	128	1355.35	974.18	0.001
Weeks after sowing	16171.88	7	2310.27	1660.5	0.001
Plant species	2340.55	3	780.18	560.77	0.001
Moisture levels	2568.62	3	780.18	560.77	0.001
Weeks after sowing* Plant species	879.52	21	41.88	30.10	0.001
Weeks after sowing* Moisture level	419.79	21	19.99	14.37	0.001
Plant species * Moisture level	2092.36	9	232.48	167.10	0.001
Week after sowing* Plant species* Moisture levels	725.36	63	11.51	8.28	0.001
Error	356.17	256	1.39		
Total	173841.00	384.00			

$P \leq 0.05$

Appendix 6: Mean root length of three *Acacia* species and *Balanites aegyptiace,* seedlings at four different moisture stress treatments.

Plant Species	Control (M0)	Slight Moisture Stress (M1)	Moderate Moisture Stress (M2)	Severe Moisture Stress (M3)
Acacia albida	21.33	25.92	29.00	14.46
Acacia senegal	20.88	25.69	20.73	18.63
Acacia nilotica	21.21	18.42	17.10	13.06
Balanites aegytiaca	17.67	19.67	15.17	15.50

$LSD_{(0.05)} = 1.92$

Appendix 7: Analysis of Variance of shoot dry weight in three *Acacia* species and *Balanties aegytiaca* seedlings at different moisture stress levels at 3 to 17 weeks after sowing (WAS).

Source of variation	SS	DF	MS	F	P
Model	754.68	128	5.89	73.79	0.001
Weeks after sowing	184.27	7	26.33	329.44	0.001
Plant species	38.89	3	12.96	162.24	0.001
Moisture levels	49.63	3	16.54	207.06	0.001
Weeks after sowing* Plant species	39.19	21	1.87	23.36	0.001
Weeks after sowing* Moistures levels	27.28	21	1.29	16.26	0.001
Plant species* Moisture level	11.48	9	1.28	15.96	0.001
Weeks after sowing* Plant species* Moisture level	12.66	63	0.20	2.51	0.001
Error	20.46	256	0.80		
Total	775.14	384			

$P \leq 0.05$

Appendix 8: Mean shoot dry weight of three *Acacia* species and *Balanites aeyyptiaca* seedlings at four different moisture stress treatments.

Plant Species	Control (M0)	Slight Moisture Stress (M1)	Moderate Moisture Stress (M2)	Severe Moisture Stress (M3)
Acacia albida	0.77	0.87	0.33	0.27
Acacia senegal	1.47	1.87	1.20	0.54
Acacia nilotica	1.96	1.65	1.24	0.53
Balanites aegytiaca	0.94	1.15	0.80	0.56

$LSD_{(0.05)} = 0.32$

Appendix 9: **Analysis of variance of root dry weight in three *Acacia* species and *Balanites aegyptica* seedlings at different moisture stress levels at 3 to 17 weeks after sowing (WAS)**

Source of variation	SS	DF	MS	F	P
Model	402.65	128	3.15	53.73	0.001
Weeks after sowing	101.78	7	14.58	248.32	0.001
Plant species	35.53	3	11.85	202.29	0.001
Moisture levels	24.85	3	8.28	141.44	0.001
Weeks after sowing* Plant Species	24.70	21	1.18	20.09	0.001
Weeks after sowing* Moisture level	12.74	21	0.61	10.36	0.001
Plant species* Moisture levels	10.32	9	1.15	19.59	0.001
Weeks after Sowing* Plant species* Moisture level	6. 60	63	0.11	1.79	0.001
Error	14.99		256	0.59	0.001
Total	417.66		384		

$P \leq 0.05$

Appendix 10: Mean root dry weight of three *Acacia* Species and *Balanites aegyptiaca* seedlings at four different moisture stress treatments.

Plant Species	Control (M0)	Slight Moisture Stress (M1)	Moderate Moisture Stress (M2)	Severe Moisture Stress (M3)
Acacia albida	0.33	0.89	0.33	0.23
Acacia senegal	1.36	1.86	1.04	0.52
Acacia nilotica	0.68	0.56	0.39	0.19
Balanites aegytiaca	0.79	0.85	0.73	0.42

$LSD_{(0.05)} = 0.23$

Appendix 11: Analysis of variance of shoot /root ratio in three *Acacia* species and *Balanites aegyptiaca* seedlings at different moisture stress levels at 3 to 17 weeks after sowing (WAS)

Source of Variation	SS	DF	MS	F`	P
Model	3534.40	128	27.61	103.56	0.001
Weeks after sowing	201.82	7	28.83	108.41	0.001
Plant Species	888.49	3	28.83	108.14	0.001
Moisture levels	24.06	3	296.17	1110.81	0.001
Weeks after Sowing* Plant species	258.03	21	12.29	46.08	0.001
Weeks after sowing* Moisture levels	43.30	21	2.06	7.73	0.001
Plant species * Moisture levels	44.06	9	4.89	18.36	0.001
Weeks after sowing * Plant species* Moisture levels	71.19	63	1.13	4.24	0.001
Error	68.26	256	0.27		
Total	3602.66	384			

$P \leq 0.05$

Appendix 12: Mean shoot/root ratio of three *Acacia* species and *Balanites aegyptiaca* seedlings at four different moisture stress treatments.

Plant Species	Control (M0)	Slight Moisture Stress (M1)	Moderate Moisture Stress (M2)	Severe Moisture Stress (M3)
Acacia albida	2.99	0.98	1.38	1.72
Acacia senegal	1.02	1.01	1.08	1.45
Acacia nilotica	4.84	4.84	4.54	5.33
Balanites aegytiaca	1.44	1.38	1.08	1.45

$LSD_{(0.05)} = 0.67$

Appendix 13: Analysis of variance of total dry matter in three *Acacia* species and *Balanites aegyptiaca* seedlings at different moisture stress levels at 3 to 17 weeks after sowing (WAS).

Source of variation	SS	DF	MS	F	P
Model	2073.81	128	16.20	1414.00	0.001
Weeks after sowing	520.56	7	74.37	6490.28	0.001
Plant species	104.52	3	34.84	3040.73	0.001
Moisture levels	149.15	3	49.72	4339.06	0.001
Weeks after sowing* Plant species	95.48	21	4.55	396.83	0.001
Weeks after sowing* Moisture levels	75.16	21	3.58	312.35	0.001
Plant species* Moisture levels	31.60	9	3.51	306.45	0.001
Weeks after sowing* Plant species* Moisture levels	23.36	63	0.37	32.37	0.001
Error	2.93	256	0.11		
Total	2076.75	384			

$P \leq 0.05$

Appendix 14: **Mean total dry matter of the three *Acacia* species and *Balanites aegyptiaca* seedlings at four different moisture stress treatments.**

Plant Species	Control (M0)	Slight Moisture Stress (M1)	Moderate Moisture Stress (M2)	Severe Moisture Stress (M3)
Acacia albida	1.10	1.76	0.65	0.50
Acacia senegal	2.83	3.77	2.25	1.01
Acacia nilotica	2.48	2.12	1.37	1.37
Balanites aegytiaca	1.88	2.01	1.38	0.94

$LSD_{(0.05)} = 0.18$

Appendix 15: Analysis of variance of leaf area in three *Acacia* species and *Balanites aegyptiaca* seedlings at different moisture stress levels at 3 to 17 weeks after sowing (WAS)

Source of variation	SS	DF	MS	F	P
Model	51096.91	128	399.19	383.14	0.001
Weeks after sowing	1001.88	7	143.13	137.37	0.001
Plant species	13561. 31	3	4520.44	4338.66	0.001
Moisture levels	998.41	3	332.81	319.42	0.001
Weeks after Sowing* Plant species	124.35	21	5.92	5.68	0.001
Weeks after sowing* Moisture levels	83.89	21	3.99	3.83	0.001
Plant species* Moisture levels	362.07	9	40.23	38.61	0.001
Weeks after sowing* Plant species* Moisture levels	139.29	63	2.21	2.12	0.001
Error	266.73	256	1.04		
Total	51363.64	384			

$P \leq 0.05$

Appendix 16: Mean leaf area of three *Acacia* species and *Balanites aegyptiaca* seedlings at four different moisture stress treatments.

Plant Species	Control (M0)	Slight Moisture Stress (M1)	Moderate Moisture Stress (M2)	Severe Moisture Stress (M3)
Acacia albida	4.82	5.12	3.69	2.67
Acacia senegal	23.61	21.27	16.56	16.33
Acacia nilotica	10.95	9.11	7.62	6.55
Balanites aegytiaca	7.62	6.19	5.89	4.72

$LSD_{(0.05)} = 1.06$