Sudan University of Science and Technology

College of Graduate Studies

Effect of Drying Cycles and Fertilization on the Vegetative Growth of Aloe (*Aloe vera*L.) Plants.

أثر دورات التجفيف والتسميد على النمو الخضري لنبات الألوفيرا

(*Aloe vera* L.)

By

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Dedication

To my beloved father who gave me hope and care,,,

To my great mother who gave me love,,,

To my Husband and small family,,,

To my dear brothers and sisters who were there when I'm in need,,,

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Thanks and gratefulness firstly and lastly to *"Allah"* who gave me mind, determination and patience to carry out this study successfully.

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Abstract

An experiment was carried out in the nursery of the college of Agricultural Studies, Sudan University of Science and Technology during the period from 23th October 2016 to 5th May 2017 to investigate the effect of drying cycles and fertilization on the vegetative growth of aloe (*Aloe vera* L.) plants. The drying cycle treatments consisted of irrigating the plants every 3,5,10 and 15 days, whereas the fertilization treatments consisted of spraying the plants with 1.25, 2.5 and 5ml of a per-prepared liquid fertilizer per a liter of an aqueous solution. The fertilizer consisted of Nitrogen (N), Phosphorus (P), Potassium (K), Magnesium (M) and trace elements (T.E). The analysis of NPK was 11-8-6 and the concentration of Mg was 100ppm. The trace elements were 50,50,25 and 25 ppm of Iron (Fe), Zinc (Zn), Manganese (Mn) and copper (Cu), respectively. Split plot was used with the drying cycle treatments assigned to the main plots and the fertilization treatments to the subplots. A completely randomized design (CRD) with three replicates was used .The parameters determined were plant height, root length, number of leaves per plant, number of roots per plant, number of offshoots per plant and the weight of offshoots, fresh plants, fresh roots, dry roots, dry plant and dry offshoots. The height of the plants was almost the same for all treatments, whereas there were significant variations for the roots. However, the overall means were not statistically different. The number of leaves, roots and offshoots per plant were significantly affected with the 15 days drying cycle which resulted in the least numbers. The fresh weight parameters followed the same trend .Like-wise, were the dry weight parameters. In contrast, none of the fertilization treatments enhanced any of the parameters. It seems that it is better not to subject aloe plant to drought stress lest to affect their vegetative growth negatively

الملخص

أجريت التجربة في مشتل كلية الدراسات الزراعية , جامعة السودان للعلوم والتكنولوجيا في الفترة من 25/أكتوبر/2015 الى 5/مايو/2017 لدراسة أثر دورات الجفاف والتسميد في النمو الخضري لنبات الألوى (*Aloe vera* L.) . تكونت معاملات فترات الري من إضافة الماء كل 3 أو 5 أو 10 أو 15 يوم, بينما معاملات التسميد تكونت من رش النباتات بمعدل. 1.25أو 2.50أو 5 مل من المحلول مسبق التكوين في لتر محلول مائي من السماد الورقي المكون من نيتروجين(N), فسفور(P) بوتاسيوم (K) وماغنيزيوم (Mg) وعناصرأثرية (T.E). تحليل NPK هو 11-8-6 بينما تركيز Mg 100جزء في المليون. أما العناصر الأثرية: 25,25,50,50 جزء في المليون حديد (Fe), خارصين (Zn), مانغنيز (Mn), و نحاس (Cu), بالتتالي . استخدمت القطع المنشقة والتصميم العشوائي الكامل وثلاثة مكررات. شغلت معاملات دورات الجفاف القطع الرئيسية ومعاملات التسميد القطع الثانوية. تم قياس طول النبات والجذور وتسجيل عدد الأوراق والخلف والجذور والوزن الرطب والجاف للنبات والخلف والجذور. كانت أطوال النبات متقاربة في كل المعاملات بينما وجدت اختلافات معنوية في طول الجذور . اختلفت المتوسطات الرئيسة ولم توجد اختلافات معنوية إحصائيا. تأثر عدد الأوراق والجذور و الخلفات معنويا بمعاملة الري كل 15 يوم التي ادت الى أقل عدد . كذلك الأوزان كان للمعاملات نفس التأثير عليها . علي النقيض لم يؤدي التسميد الى زيادة ملحوظة في أي من هذه القياسات . عليه ربما يجب عدم تعرض نباتات الألوي الى إجهاد جفاف كي لا يؤدي الى التأثير على المجموع الخضري سلبا .

CHAPTER ONE

INTRODUCTION

Aloe *(Aloe vera* L.) ,synonym *Aloe barbadensis* Miller, belongs to Asphodelaceae, Liliaceae, or Aloeceae family, The name aloe was derved from the Arabic word Alloeh means "shining bitter substance" while vera is Latin name "true". It grows mainly in Africa , Asia, Europe, and America (Dagne *et al*.,2000).

The plant has triangular, ample leaves with saw – like edges, blonde tubular flowers, and fruits contain several seeds. The leaf of aloe has medicinal and other uses. Leaves are cut when one year old. Usually the juice and pulp of leaves are used.

Aloe vera contains the bulk of the required amino acids and vitamins that the human skin needs to heal. The glue – like substance keeps out any bacteria or that could cause healing to slow or cease completely (Josisas, 2008).

Aloe is used for therapeutic, cosmetics and several other purposes and to care for several diseases specially disease of digestive system. It is used to treat the wounds, burns and skin problems .The fresh juice extracted from the leaves is said to be cathartic, cooling and useful in fever, spleen and liver diseases .The leaf extract inhibits the growth of the microorganisms .Aloe gel mixed with water is very helpful in curing jaundice . *Aloe vera* is an excellent source of nutrients that can help our body in a multitude of ways. The herbal products today symbolize safety in contrast to the synthetics that are regarded as unsafe to human and environment. Although herbs had been priced for their medicinal, flavoring and aromatic qualities for centuries, the synthetic products of the modern age surpassed their importance, for a while. However, the

blind dependence on synthetics is over and people are returning to the naturals with hope of safety and security. Over three-quarters of the world population relies mainly on plants and plant extracts for health care. More than 30% of the entire plant species, at one time or an -other were used for medicinal purposes (Grindlay and Renolds, 1986). It has been estimated that in developed countries such as the United States, plant drugs constitute as much as 25% of the total drugs, while in fast developing countries such as China and India, the contribution is as much as 80% (FAO, 2012). These countries provide two thirds of the plants used in modern systems of medicine and the health care system of rural population depends on indigenous systems of medicine (FAO, 2012).

Having all these medicinal and cosmetic uses, it would be warranted to try growing this plant in Sudan. The Sudan environment seems to be conducive to its production and it could make an important exported commodity. However, as yet, there are little information regarding the cultural practices in Sudan. Thus, this study was carried out to investigate the vegetative growth response of this plant to drying cycles and fertilization and their interactive effects.

CHAPTER TWO

LITERATURE REVIEW

2.1. Distribution:

Aloe vera (syn. A.barbadensis) plants were grown as pot plants at least as long ago as the days of the Roman Empire. The chief species cultivated in ancient times was the true aloe, cultivated then as now for the soothing ointment that can be made from the juice of its leaves. All of the aloes described here produce rosettes of succulent leaves that resemble those of agaves. The plant often bears clusters of small tubular, red, orange or yellow flowers in winter.

The geographic origin of *Aloe vera* L. is believed to be in Sudan, with the plant subsequently being introduced in the Mediterranean region and most other warm areas of the world (Grindlay and Reynolds, 1986). Aloe (*Aloe vera*) is an important traditional medicinal plant of the family Liliaceae and it is indigenous to Africa and Mediterranean countries. The species do not have any naturally occurring populations, although closely related aloes do occur in North Africa (Boudreau and Blend, 2006). However, it was reported to grow wild in islands of Cyprus, Malta, Sicily, Canary Islands, Cape Verde and arid tracts of India. It is hardly perennial tropical plant that can be cultivated in drought areas but its potential is yet to be exploited (Lans, 2006). Aloe, despite being identified as a new plant resource with the most promising prospects in the world, remains a disregarded plant. It is scattered in the world, along the coast of Southern India, China, U. S. A., Mexico and Australia. Some of the Latin Amercan countries are the major producers and exporters of aloe products. These countries are exploiting the plant potential with growing cosmetic and neutraceutical market (Danhof, 1987). (Abdul Rahman, 2016).

2.2. Botany:

Aloe is a perennial plant, which has a short stem. The plant is about 60 cm high. It bears a rosette of large, thick and succulent leaves. Leaves are about 30 cm long, 10 cm broad, pale green in color and taper to a blunt point with thorny margins. Bright yellow flowers are borne on a simple or branched scope originating from the rosette. The plant has well developed fibrous root system. Aloe is generally multiplied by separation of suckers arising from the basal portion of the mother plant (Das 2006). *Abrevifolia* grows up to 7.5 to 10 cm (3 to 4 in.) across and has pale green leaves that are edged with small teeth. *A. stans*, 15 to 25 cm (6 to 10 in.) high, has pale green leaves with prickly teeth along their edges. *A variegate* is the most attractive species for use as a house plant. The leaves which eventually form a mound nearly 30cm (12 in.) tall and 15cm (6 in.) across, are accented with bronze if they grow in bright light. .*A barbadensis* has pale green leaves 45 to 50cm (18 to 20 in.) long. Old plants of this species become too large for most indoor situations and should be discarded, but new plants are easy to propagate (Crockett, 1977). Each leaf has a three layers which are:

(i) Aloe rind- the protective, green, outer leaf skin. This layer does not contain any significant nutritional value. (ii) Aloe latex- the pungent, yellowish, deplete fluid which has strong odor and flows in between the leaf ring and the inner fleshy part of leaf. Aloe latex is not recommended for consumption (iii) Inner leaf juice- the lucid, inner fleshy portion of leaf has a tremendous nutritional value for the health and can be consumed both internally and externally (Abdul Rahman,2016).

2.3. Varieties:

Arabian aloes or aden aloes known as yamini or moka, yielded by *Aloes* Indica. It is of a blackish color, shining on the surface, porous and translucent; when held before the sunlight the color change to red. It is also known as Bandhano Eliyo and Petino Eliyo. The former is mixed with stone, caly..etc, and is wrapped up in mats; the latter is clean and is packed in boxes. Cape aloes is yielded by *Aloes* spicata. *Aloe* socotrina , Zanzibar aloes, Bombay aloes are other varieties (Singh,2005)

2.4. Cultural practices:

2.4.1. Growth:

Aloes are fairly easy plants which do best where they get plenty of direct sunlight, or where artificial and natural light average more than 12 hours a day, but they will grow fairly well in bright indirect light, such as that reflected from light walls. Night temperatures should not fall below 4℃ and should be higher if possible. To sparingly watered during winter, more freely in summer. The soil should be moderately dry between thorough watering. Newly potted plants should not be fertilized for the first year; established plants should be fed occasionally with standard house- plant fertilizer diluted to half the minimum strength recommended on the label. For best results use a mixture of 1 part loam, 1 part leaf-mould, 1 part sand and ½ part crushed charcoal, or else to use a mixture of equal parts of any proprietary potting soil and sharp sand; to each bucket of whichever of these mixtures one tablespoon of ground lime stone and 1 table spoon of bone meal to be added. Propagation is at any season from the young shoots, or suckers, that spring up from the base of larger plants, or from seeds sown in spring in a temperatures of around 21℃. (Corockett, 1977).

2.4.2. Soils:

According to Lans (2006) tile plant can be grown in avariety of soils ranging from sandy coastal soils to loamy soils of plains. It is sensitive to water logged conditions. The crop also comes up well in light soils. It can tolerate higher pH and high sodium (Na) and potassium (K) salts. Growth is faster under medium fertile, heavy soils such as black cotton soils.

A well drained loam to coarse sandy loam range up to 8.5 makes it grows well with higher foliage.

2.4.3. Climate:

As reported by (Rynold, 2004), aloe has wide adaptability and can be grown in various climatic conditions. It can be seen growing equally good in warm humid dry climate. However, it is tolerant to extreme cool conditions. The plant flourishes well on dry sandy soils at localities with lower annual rainfall of 50 to 300 mm. It needs protection against frost and low winter temperature. The species is popular with modern gardeners as a putatively medicinal plant and due to its interesting flowers, form and succulence. This succulence enables the species to survive in areas of low natural rainfall, making it ideal for rockeries and other low- water use gardens. The species is hardly in warm zones of the world and intolerant to very heavy frost or snow (Eshun and Qian, 2004).

2.4.4.Propagation:

It is generally propagated by root suckers or rhizome cuttings. For this purpose, medium size root suckers are chosen and carefully dug out without damaging the parent plant at the base and directly planted in the main field (Lans, 2006). It can also be propagated through rhizome

cuttings. In this case, after the harvest of the crop, the underground rhizome is also dug out and made in 5-6cm length cuttings which should have a minimum of 2-3 nodes on them. It is rooted in specially prepared sand beds or containers and after starting sprouting, it is ready for transplanting. On an average, about 36500 suckers are required for a nursery of 1 ha size (14550 for 1 acre nursery) (IJAS, 2012).

2.4.5. Land preparation and planting:

The land is ploughed and cross ploughed thoroughly. Farm yard manure is added at 15t/ha during the last ploughing. Ridges and furrows are formed at 45 or 60 cm apart. The plot may be irrigated if necessary. The suckers are planted at 40 or 30 cm apart, maintaining the spacing suggested (IJAS, 2012).

2.4.6. Irrigation:

According to IJAS (2012), aloe can be successfully cultivated both under irrigated and rain fed conditions. Provision of irrigation immediately after planting and during summer season will ensure good yields. However, the plants are sensitive to water logged conditions (Abdul Rahman,2015).

2.4.7. Ornamental and home care:

A beautiful small species for the window still is the partridge breasted aloe, *A. varietgata*. *A. arborescens*, a taller growing species which is fairly common (Herwig, 1982).

2.5. Effect of cultivation and processing:

The composition of *Aloe vera* extracts differs according to the plant variety, climatic and seasonal variations and the age of the plant (Eshun and He, 2004). However, the processing method has the largest effect on the number and amount of active ingredients in the product (Wang and Strong, 1995). The commercial production process of *Aloe vera* products typically involves crushing, grinding, or pressing of the whole *Aloe vera* leaf to produce juice, followed by various steps of filtration and stabilization to achieve the desired extract (Eshun and He, 2004). This method provides ease of processing and higher efficiency in the recovery of the solids (Agarwala, 1997), but it can result in a product that contains little or no active ingredients (Eshun and He, 2004).

2.5.1. Plant part used:

The leaf of aloe has the medicinal and other uses. Therefore, the leaf of the plant is used for various purposes. Leaves are cut when one year old. Usually the juice and pulp of leaves are used

2.5.2. Chemical constituent:

The leaf juice of aloe contains an array of chemical compounds. This leaf juice forms an important constituent of a large number of Ayurvedic medicines. Leaves contain 1.6- 68.7 mg/100ml of “aloin”, an active ingredient which has laxative property. The mucilage of the leaves contains glucose, galactose, galacturonic acid and several amino acids. The leaves also contain “barbaloin” (Das, 2006).

2.5.3. Constituents:

Mixture of polysaccharides containing pectic acid, a D- galactan, a glucomannan and an arabinan; D- galactan composed of galactose

(29.9%) and galacturonic acid (3.8%); A glucomannan fraction isolated from leaf pulp containing glucose and mannose (1:2) and structure of its repeating unit assigned; a galactomannan from plant, on hydrolysis gave glucose, mannose and galactose in molar ratios 2:2:1, together with very small amounts of arabinose and rhamnose Chemical studies showed it to be linear polymer having glucose, mannose and galactose units linked by 1,4- bonds; an acidic oligosaccharide containing galacturonic acid and galactose in molar ratio of 5:1, obtained by controlled hydrolysis of pectic acid. Chemical studies showed that galacturonic acid residues were (1-4) linked and galactose was glycosidically linked to 0-3 of galacturonic acid residues(Singh, 2005).

2.5.4. Description of plant:

- There are more than 360 species of the *Aloe* genus.
- Perennial succulents native to Africa, now grown throughout the world.
- Short plant has 15 to 30 tapering leaves about 20 inch long and 5 inch wide.
- Leaf has three layers; outer (tough), middle (corrugate lining) and inner (a colorless mucilaginous pulp, the aloe gel). The plant contains 99% water.
- Yields both aloe gel and aloe latex. Although they share certain chemical components, the gel and latex are distinct with different properties and uses.
- The gel is naturally occurring. Undiluted gel is obtained by stripping away the outer layer of the leaf. It is for topical use and is famous for its wound- healing properties. It provides moisture and soothes the skin thus is widely used in cosmetics, moisturizing creams and lotions.

- *Aloe vera* concentrates is gel from which the water has been removed. For topical use.
- *Aloe vera* juice contains a minimum of 50% *aloe vera* gel usually mixed with fruit juice. For internal use.
- *Aloe vera* latex is the bitter yellow liquid derived from per cyclic tubules of the rind of *aloe vera*. The primary constituent is aloin. It is rarely used internally because of its powerful cathartic activity.

2.6. Uses

Ancient Egypt (1500 BC) and Middle East; used to heal the skin and treat wounds, hemorrhoids and hair loss. In US, the latex has been used as a purgative since colonists brought it from Europe in their medicine chests (Marrily, 2000).

2.6.1. Current use:

2.6.1.1. Topical (Gel):

Helps to heal burns and reduce burn pain. Useful for first and second- degree burns (sunburn, radiation burns, scalds). First report of clinical use for radiation burns was in 1935. There are several negative studies using bottled aloe gel for healing burns. Many of these products contain stabilizers and preservatives, and they may not have the same effect as fresh aloe gel from the leaf.

May help to heal venous ulcers.

Anti- inflammatory activity by inhibiting arachidonic acid.

Soothes skin and may enhance skin healing.

2.6.1.2. Confection, Tincture, Lotion and juice:

It is a favorite remedy for intestinal worms in children. Dissolved in attar of roses, or in water with borax and a little opium added, strained, The water or lotion is applied to eyes in various infection of the eye, as in catarrhal and purulent ophthalmic. Dissolved in spirit it is used as a hair-dye to stimulate hair- growth. A sweet confection prepared from the pulp of the leaves is given in pies. Pulp with honey or saltpeter and turmeric is given in coughs and colds. To correct its griping effect confection of roses and mastic is added. In colic and pneumonia of infants its inspiassated juice with a little gum asafetida is given internally in doses of 1 grain; it may also be given in mother's milk with the addition of a little borax. Juice of the leaves is applied to painful inflammations of the body and to chronic ulcers. The pulp washed in cold water and then mixed with a little burnt alum is a good remedy to persons predisposed to apoplexy. The following ayurvedic preparation known as Kumari Asava is useful in several ailments and it is prepared it: Take of Aloe- juice 100, Jaggery 20, Cannabis Indica 5 and water 50 parts. Make a decoction to this when ready add honey1, flowers of Wood for diafibribunda 6, nutmeg, cloves, Cubebs, nasdostachys, Jatamansi, dried unripe spikes of black- pepper, root of plumbago Zeylanica mace or the arillus of *myristica officinalis*, the gall of Rhus succedanea, bellericmyrobalan, root of *Aplotaxisa uriculata* each1 part. Tamra Bhasma and LohaBhasma (prepared power of Copper and Iron) each ½ part. Mix, keep for about a month old allow it to ferment. Used in general debility cough, dysponoea, asthma, consumption, piles, epilepsy, colic and tympaitis (Singh, 2005).

2.6.1.3. Medicinal uses:

Aloe is used for therapeutic, cosmetics and several other purposes. Aloe has long been in use to cure several diseases specially the disease of digestive system. It is used to treat the wounds, burns and skin problems. The fresh juice extracted from the leaves is said to be cathartic, cooling and useful in fever, spleen and liver diseases. The leaf extract inhibits the growth of the microorganisms. Aloe gel mixed with water is very helpful in curing jaundice.

2.6.1.4. Cosmetic uses:

The second most important use of aloe is in the cosmetic industry. The mucilaginous pulp obtained from the leaf parenchyma is used in various types of skin disorders. Aloe gel is a commercial product of the leaf mucilage. It prevents loss of moisture from the skin. Aloe gel also has the action on the dead epithelia cells on the skin surface, which causes ageing of the skin due to cellular buildup on the outer layer. Aloe gel also softens the dead cells and makes their removal easier from the skin surface and the skin becomes smooth. Aloe gel has softening, healing and moisturizing actions. It also protects the skin from sun-damage (Das, 2006).

2.7. Available forms, dosage and administration guidelines

Preparations:

Gel: Sunscreens, skin creams, lotions, cosmetics.

Juice: Available in various concentrations and as powdered juice. Highly concentrated products degrade quickly; check for inclusion of gums, sugars, starches and other additives.

2.7.1. Typical dosage:

Fresh gel (Topical): Cut a leaf lengthwise, scrape out the gel and apply extremely as needed. Discontinue if burning or irritation occurs.

Juice (Internal): 1 tee spoon after meals, or follow manufacturer or practitioner recommendations.

Pharmacokinetics- if available (form or route when known): None known.

Toxicity: Internal use of latex can cause severe GI cramping.

2.7.2. Contraindications:

Topical: Deep, vertical wounds; hypersensitivity to aloe products.

Internal: Bowel obstruction, kidney and liver disease.

2.7.3. Side effects:

Topical: Contact dermatitis is possible but uncommon.

Internal (latex): May cause fluid and electrolyte imbalances and intestinal cramping.

Long- term safety:

Gel: Safe.

Latex: Not safe for daily long- term dosing because it is irritating to the bowel. When used for more than 1 or 2 weeks, it may cause intestinal sluggishness and laxative dependence.

2.7.4. Use in pregnancy/ lactation/ children:

Oral: Latex contraindicated in all because of severe GI symptoms.

Topical: Safe in all.

Drug/ herb interactions and rationale (if known):

Gel, taken internally, may reduce absorption of some medications. Separate by at least 2 hours from most drugs.

In recent study, aloe gel taken concurrently with vitamins C and E significantly increased absorption of both nutrients (Vinson *et al*., 2005).

Latex, because of its cathartic effect, causes loss of K^+ and therefore, may increase the likelihood of toxicity with cardiac glycosides, antiarrhythmics, steroids, loop diuretics and other K^+ washing drugs. Avoid concurrent use of internal latex and these drugs.(Merrily,2000).

2.8. The effect of soil application of nitrogen phosphorus and potassium (NPK) fertilizer on growth and yield parameters of *Aloe vera* plants:

reported that, the soil application of NPK to *Aloe vera* plants increased the yield by 25% under $N_{120}P_{60}K_{120}$ treatment compared to control. Growth rate over a period of four months showed a maximum increase of 43% in $N_{120}P_{60}K_{120}$ and minimum of 23% in control and the maximum average number of leaves per plant was obtained at highest concentration of chemical fertilizer .

Chlorophyll content in leaves was significantly higher under fertilizer treatments as compared to control and also stated that, the maximum chlorophyll content of 39.13mg/g was recorded under treatments supplied with the highest dose of chemical fertilizers at $N_{120}P_{60}K_{120}$ level. The above showed that, *Aloe vera* responded to fertilizer dose in increasing the growth parameters.

The biological yield and gel yield of *Aloe vera* (fresh and dry weights) were significantly increased under different fertilizer treatments as compared to control, as reported by Saradhi *et* al .,(2007). Maximum biological yield of 130g/ plant and gel yield of 61.4g/ plant were obtained under chemical fertilizer treatment at$N_{120}P_{60}K_{120}$ level (Saradhi *et al*., 2007).

Mersetal .,(1996) reported that, the growth and weight of *Aloe vera* root (fresh weight) attained maximum weight of 9.8g/ plant when the crop received chemical fertilizer at$N_{120}P_{60}K_{120}$ compared to the control. High dose of chemical fertilizer is expected to release greater quantity of nutrients particularly N, P and K at faster rate and higher level and there by greater uptake by the plants which resulted in higher growth and yield parameters of *Aloe vera* plants (Saradhi*et al*., 2007).

2.8.1. The role of macro- nutrient elements on plant growth:

The role of macronutrients, some plants extracts and growth regulators in various physiological and biochemical processes in plant is well known, which enables a rapid change in the physiology of plant within one season to achieve desirable results. The essential mineral elements which are required in higher concentrations by the plant have a major role in determining the growth and development of aloes, often produces more vegetative growth, than needed for maximum latex production especially when climatic conditions favor vegetative growth by directing the nutrients and photo assimilates towards vegetative growth at the expense of latex production (Harzrati, 2012).

Minerals have a diversified role in medicinal plants metabolism. Severity or scarcity of these causes multifarious effects in plant metabolism. Each and every aspect of plant biochemistry, physiology,

anatomy…etc is affected due to mineral nutrient composition of soil. Medicinal plants inherit resistance due to biosynthesis of bioactive substance (secondary metabolisms) against various types of diseases caused by fungus, bacteria, viruses, mycoplasmas, insects and pests. The concentration of these minerals of both group i. e. activators or inhibitors present in the soil play a vital role in secondary plant metabolism. Minerals also play a major role in the reproduction of these medicinally important plants. Bioactive molecules of medical relevancy such as alkaloids, flavonoids, lignin, lipids, carbohydrates, resins, glycosides, phenolic compounds, volatile oils, vitamins, tannins..etc produced through various biosynthetic pathways of plants are a boon to urban, hilly and remote population of each nation. However, soils with different compositions of mineral elements adversely influence the metabolic activities of such valuable medicinal plants (Saradhi *et al*., 2007). Various physiological activities are governed through important mineral elements present in soils from where these are transferred to area where their need arises. So, accumulation and biosynthesis of these bioactive molecules in plants system are widely dependent on the availability of mineral elements in the soil. Different development stages of the medicinal plants need supplementation of different macro- elements during its various growth and biosynthesis steps (Babatunde and Yongabi 2008; Abdul Rahman, 2015).

2.9. Effect of water intervals on growth of *Aloe vera*:

Drought stress has become the major factor in plant growth and yield(Yardenov et al., 2000). When the full crop requirements are not met water deficit in the plant can develop to appoint where crop growth and yield are affected. Water deficit during the reproductive growth is considered to have the most adverse effect on crop productivity, Over all

plant growth is a process biomass accumulation (Karamanon&Gimenez,1991) and consequence of the interaction of photosynthesis , water relation and mineral nutrition processes. Growth is the most important process to understand in predicting plant responses to environment. Plant dry matter production and accumulation can be analyzed through crop growth rate that are the most important growth indices (Kareemi and Siddige,1991). Lack of water is the major factor limiting tolerance plan productivity on a global scale. Wide loss of crop yield from all other causes combined (Kramer,1980)

Plant water balance

2.9.1. Water deficit

Although water in earths is most abundant compound, lack of water is the major factor limiting tolerance plant productivity on a global scale wide loss in crop yield from all other causes combined.

2.9.2. Water stress in plant:

Drought or water stress is one of the major a biotic stress factors that affect all living organisms including human interest of the health and food. Water absence from the soil solutions affects the natural evaporative cycle between the earth and the atmosphere that contribute amount of irrigation. Drought occurs when the soil moisture level and relative humidity in the air are low while temperature is also high (UN, 2006), Water stress resulting from withholding of water, also changes and the physical environment of plant growth as well as crop physiology (Bernacia *et* al., 2004).). Drought, as an a biotic stress, is a multitude signal in nature, and it affects plants at various levels of their organization. In fact, under prolonged drought, many plants will dehydrate and die (Yudanor et al., 2000)

2.9.3. Water stress why and how:

Plant experience water stress either when water supply to their roots becomes limited or when the transpiration rate becomes intenece. Water stress is primarily caused by water deficit (drought or high soil salinity). In the case of high soil salinity and also in other condition like flood and low soil temperature, water exist in soil solution, but the plant cannot uptake it, a situation commonly known as physiological drought. Drought occurs in many parts of the world every year and frequently experienced in the field grown plants under arid and semi-arid climate. Regions with adequatc but non uniform precipitation also experience water limited environment (Reddy et al. 2004).Since the dawn of agriculture mild to severe drought has been one of the major production limiting factors. The general plant growth are fairly well known; however, the primary effect of water deficit at biochemical and molecular levels are not considered under stood yet is crucial (Taiz, 2002). All plants have tolerance to water stress, but the extent varies from species to the other. Knowledge of biochemical and molecular responses to drought is essential for aholistic perception (Warg *et* al., 2003)

2.9.4. Morphological and anatomical changes:

In the majority of plant species stress is linked to changes in leaf anatomy and ultra structure, shrinkage of eyes in the size of the leaves, decrease in the number of stomata, thickening of leave cell walls, colonization of the leave and under development of the conductive system increase in number of large vessels, submersion of stomata in succulent plants and in xerophytes, formation of tube leaves in cereal and induction of early senescence .The other reported morphological changes (Nayyar *et* al., 2006) the root to shoot ratio increases under water stress

condition to facilitate water absorption and to increase osmotic pressure , although the root dry weight and length decrease as reported in some plants.

2.9.5. Plant resistance to water stress:

Plants adapt themselves to drought conditions by physiological, biochemical, anatomical and morphological expressions. The whole plant level is highly complex and involves deleterious for adaptive changes. This complexity is due to some factors such as plant species and variety, the dynamic duration and intensity of soil water depletion, changes in water demand from the atmosphere environmental condition, as well as plant growth and phonological state in which water deficit is developed.

Plant optimize the morphology, physiology and metabolism of the drought organs and cell in order to maximize productivity under conditions. The reaction of plant to water stress differ significantly at various organizational levels depending upon intensity and duration of stress as well as plant species and its stage of development (chao, 2008). Water stress resistance in plant is divided in two categories; stress tolerance and stress avoidance. Drought avoidance is the ability of plant to maintain high tissue water potential under drought condition, while drought tolerance is the ability to maintain its normal even at its low tissue Water Potential (wrg *et* al., 2003).

2.10. The effect of water stress on plant growth and development:

Growth of plant is controlled by the role of cell division and by supply of organic and in-organic compounds required for the synthesis of new protoplasm and cell walls .Plants that suffer from water deficit often

show reduction or cessation of growth, photosynthesis and respiration. However, water deficit can directly affect the size of plant or its components through the action of turgor pressure in cell expansion. Cell division appears to be less severely affected than cell expansion, but growth may be further inhibited by change in carbohydrate metabolism, nitrogen metabolism and possibly by the production of growth substance and translocation of material (Banniste, 1976). Effect of water stress on plant development is likely dependent on growth stage of the plant and is controlled by the rate of cell division and by supply of organic and inorganic compounds required for synthesis of new protoplasm and cell wall ((Helan *et* al., 1989; Elnadi, 1979, and Ageeb, 1976)). It was found that productive growth phase was more sensitive to water stress than the vegetative phase. It was reported that irrigation during the reproductive phase increased intercalary meristem of inter- nodes meditation by the interaction of plant hormones such as ethylene and gibberellic acid, thus, the plant develops more nodes and longer inter- nodes under water stress. Salyter(1969) found that the reduction in relative increase height of the plant during late flowering and early grain filing stages coincided with start of pods growth and the reduction in crop vegetative growth .

2.10.1. Vegetative phase:

Plant height (cm): Generally the number of nodes and internodes length determined the plant height of the crop and they were both affected by water stress. The reduction of plant height due to water stress was reported by Conover *et* al. (1989).

2.10.2. Flower:

Water stress causes substantial reduction in crop productivity and the extent of damage depends upon the developmental stage of the crop.It

is therefore, important to determine the stage of plant deficit and irrigation scheduling recommended to play particular attention to moisture sensitive period, namely flowering. Water stress during this phase greatly reduces yield and water stress during the formation produced fewer flowers. Found that water stress reduced the number of reproductive organs intensity, where-as percentage of flower shedding was increased .

CHAPTER THREE

MATERIALS AND METHODS

3.1. Experimental site

An experiment was conducted at the Nursery of the College of Agricultural Studies Sudan University of Science, shambat and Technology, (Latitud 15º 40' N, longitude 32º 32' E , 375 meters above sea level during the period from 23.10.2016 to 5.5.2017).

Source of plants samples were retrieved from a nursery and selected so that plant lengths were between 10 and 15 cm.

plastic bags of size 30 × 40cm were filled with site / sand mixed soil 3: 1

The plants were planted on Sunday 23.10.2016. where each bag contained one plant . The leaves were cut and the number was reduced on 8.11.2016 to the 2 leaves in each plant. As all the excess leaves were disposed of, the plants were irrigated in this period every 5 days. Each plant was fertilized with a 2 g urea fertilizer to encourage vegetative growth. Plants were moved outside the nursery on 18-12-2016 and placed in a sunny place. A plant irrigation treatment was started on 17.1.2017.

3.2. Treatments

The treatments include 4 irrigation intervals and 3 fertilization levels. In addition to the control.

The irrigation interval (the drying cycle) were every 3 days for one group of plants. The second group was irrigated every 5 days. The third group was irrigated every 10 days. The fourth group was irrigated every 15 days. The fertilizer is prepared in three quantities: 1.25 , 2.50 , and 5.0ml of fertilizer per 1 liter of water, of Nitrogen, Phosphorus and Potassuim (NPK) and Magnesiume (Mg) + trace elements. The trace elements were 25 ppm copper(cu), 25ppm manganese(mn), 50ppm zinc(zn) and 50ppm iron(fe). The treatments were arranged in split plot

using irrigation intervals (drying cycles) as main plots and the fertilizers as subplots in a completely randomized design (CRD) with three replicates. Each treatments per replicate was represented by three plants.

The initial dose of fertilizer was applied on 17.1.2017. The second dose was on 5.2. The third dose was on 9.3. The fourth dose was on 11.4.2017.

3.4. Parameters

Plants were taken off on 5.5.2017 to take the readings. The plant was completely removed from the soil carefully.

3.4.1. The mother plant weight

Using a sensitive balance, the shoot was weighed and the readings were recorded. Roots were weighed and readings were recorded.

3.4. 2. Plant height

The height of the plant was measured by using the longest leaf found in the plant by a ruler. Measure the length of the longest root by using the longest root present, by a ruler. All readings were recorded.

3.4.3 Number of leaves

The number of leaf was recorded from the largest leaf to the smallest leaf.

3.4.4. The number of roots

Was recorded

3.4.5. The number of offshoots

3.4.6. Dry weight

Each plant was weighed and put each part of it separately (leaves of the plant, roots and offshoots) and then placed in aluminum foil and numbering to prevent mixing and dried in an oven for three days at 70^{o}C and then weighed using a sensitive balance .

3.4.7. Fresh weight of shoot.

3.4.8. Root length (cm).

3.5. Experimental design and statistical analysis

Data were subjected to analysis of variance using computer. Mean separation was performed according to Dancan's Multiple range test at 5%level.

CHAPTER FOUR

RESULTS AND DISCUSSION

4. Growth parameters of aloe plant as affected by different rates of fertilizers and drying cycles

4.1. Plant height (cm)

Table (1) showed the effects of different rates of fertilizer and drying cycles on plant length (cm) of aloe. The results revealed that plant length (cm) was not significantly affected by the different rates of fertilizer and drying cycles. The control in five days gave the highest plant length (25.67).while; 1.25ml on fifteen days gave the lowest plant length (18.00). This result is contradictory to that reported by Abdul Rahman (2016).and similar to that reported by Nematian *et* al. (2011) and Eisa (2016) With NPK fertilization.

4.2. Length of roots (cm)

Table (2) Statistical analysis revealed that aloe length of roots exhibited significant effect. The control produced longest of roots of aloe in(10)days (15.00cm), followed by (1.25ml)in(3)days(14.67cm) while, (1.25 ml) on (10) days gave the lowest length of roots (8.667cm).this result is contradictory to that reported by Abdul Rahman (2016), but similar to that reported by Nematian *et* al.(2011) and Eisa (2016) with NPK application.

Table 1: Effect of fertilizer and drying cycles on plant length of aloe (cm).

Fertilizer (ml/L)	Drying cycles (days)				
	3	**5**	**10**	**15**	**Mean**
(control) 0.00	21.33[a*]	25.67[a]	20.33[a]	19.33[a]	**21.67[A]**
1.25	20.00[a]	24.00[a]	25.33[a]	18.00[a]	**21.83[A]**
2.50	20.67[a]	22.00[a]	24.00[a]	18.67[a]	**21.33[A]**
5.00	24.33[a]	24.00[a]	19.33[a]	18.33[a]	**21.50[A]**
Mean	**21.58[A]**	**23.92[A]**	**22.24[A]**	**18.58[A]**	

*Means followed by the same letter are not significantly different using Duncan's Multiple Range Test at 5% level .

Table 2: Effect of fertilizer and drying cycles on length of roots of aloe (cm).

Fertilizer (ml/L)	Drying cycles (days)				
	3	**5**	**10**	**15**	**Mean**
0.00(control)	9.667^{bc*}	11.00^{bc}	15.00^{a}	9.667^{bc}	**11.33^{A}**
1.25	14.67^{a}	10.67^{bc}	8.667^{c}	9.333^{bc}	**10.83^{A}**
2.50	11.00^{bc}	12.33^{ab}	11.33^{bc}	10.67^{bc}	**11.33^{A}**
5.00	12.00^{abc}	11.33^{bc}	10.00^{bc}	10.67^{bc}	**11.00^{A}**
Mean	**11.83^{A}**	**11.33^{A}**	**11.25^{A}**	**10.08^{A}**	

*Means followed by the same letter(s) are not significantly different using Duncan's Multiple Range Test at 5% level.

4.3. Number of leaves/plant

Table (3) showed the effects of different rates of fertilizer and drying cycles on number of leaves of aloe. The results revealed that the number of leaves of Aloe was significantly affected by the different rat of fertilizer and drying cycles. The control in ten days gave highest number of leaves (8.667), while, 1.25 (ml) on 15 days gave the lowest number of leaves (5.667).). This result is contradictory to that reported by Abdul Rahman (2016) and similar to that reported by Nematian *et* al. (2011) and Eisa (2016) with NPK treatments.

4.4. Number of roots/plant

Table (4) showed the effects of different rates of fertilizer and drying cycles on number of roots of aloe. The results revealed that the number of roots of aloe was significantly affected by the different rates of fertilizer and drying cycles. The control in 10 days gave highest number of roots (10.67) while, 2.50 (ml) in fifteen days gave the lowest number of roots (2.667).). This result is similar to that reported by Abdul Rahman (2016) and similar to that reported by Nematian *et* al. (2011).

Table 3: Effect of fertilizer and drying cycles on number of leaves /plant of aloe.

Fertilizer (ml/L)	Drying cycles (days) 3	5	10	15	Mean
0.00(control)	6.000^{bc*}	8.333^{ab}	8.667^{a}	7.000^{abc}	**7.000^{A}**
1.25	6.667^{abc}	8.000^{abc}	6.667^{abc}	5.667^{c}	**6.750^{A}**
2.50	6.333^{abc}	8.000^{abc}	8.000^{abc}	6.333^{abc}	**7.167^{A}**
5.00	8.333^{ab}	8.333^{ab}	7.333^{abc}	6.330^{abc}	**7.785^{A}**
Mean	**6.833^{A}**	**8.167^{A}**	**7.607^{A}**	**6.333^{A}**	

*Means followed by the same letter(s) are not significantly different using Duncan's Multiple Range Test at 5% level.

Table 4: Effect of fertilizer and drying cycles on number of roots /plant of aloe.

Fertilizer (ml/L)	Drying cycle (days)				
	3	**5**	**10**	**15**	**Mean**
0.00(control)	7.6677^{bcde*}	5.667^{def}	10.67^{a}	5.333^{ef}	**7.333^{A}**
1.25	7.000^{bcde}	6.333^{bcdef}	8.667^{abc}	4.000^{fg}	**6.5000^{A}**
2.50	6.667^{bcdef}	7.667^{bcdef}	6.000^{cdef}	2.667^{g}	**5.750 ^{A}**
5.00	9.000^{ab}	8.333^{abcd}	8.333^{abcd}	5.00^{efg}	**7.667 ^{A}**
Mean	**7.583^{AB}**	**7.000^{AB}**	**8.417^{A}**	**4.250^{B}**	

*Means followed by the same letter(s) are not significantly different using Duncan's Multiple Range Test at 5% level.

4.5. Number offshoots/plant

Table (5) statistical analysis revealed that aloe number offshoots were significantly affected. (2.50-5.00ml) produced the highest number of shoot of aloe in (3-5) days (7.667ml). While, (1.25-5 ml) on (15) days gave the lowest number of shoot (1.667) then followed by (1.25-control) in (3,5)days (2.000,2.667), respectively. This result is similar to that reported by Abdul Rahman (2016) and similar to that reported by Nematian *et al*. (2011).

4.6. Weight of fresh offshoots (g)

Statistical analysis revealed that the weight of fresh shoot of aloe was significantly affected Table (6). Control produced the highest shoot weight of aloe in (10) days(32.63) followed by (2.50-5ml) in (5-3)days (32.24-29.63gm) while,(5 ml) on (15) days gave the lowest weight of fresh shoot (3.367gm).This result is similar to that reported by Abdul Rahman (2016) and contradictory to that reported by Nematian *et al*.(2011).

Table 5: Effect of fertilizer and drying cycles on number offshoot /plant of aloe.

Fertilizer (ml/L)	Drying cycles (days)				
	3	**5**	**10**	**15**	**Mean**
0.00(control)	6.000^{ab*}	2.667^{e}	6.333^{ab}	3.000^{de}	**4.500^{A}**
1.25	2.000^{e}	3.667^{cde}	3.667^{cde}	1.667^{e}	**2.750^{B}**
2.50	5.333^{bc}	7.667^{a}	5.000^{bcd}	3.333^{cde}	**5.333^{A}**
5.00	7.667^{a}	6.667^{ab}	6.333^{ab}	1.667^{e}	**5.583^{A}**
Mean	**5.250^{A}**	**5.167^{A}**	**5.333^{A}**	**2.417^{A}**	

*Means followed by the same letter (s) are not significantly different using Duncan's Multiple Range Test at 5% level.

Table 6: Effect of fertilizer and drying cycles on weight of fresh shoot of aloe (g).

Fertilizer (ml/L)	Drying cycles (days)				
	3	**5**	**10**	**15**	**Mean**
0.00(control)	16.20^{b*}	14.23^{b}	32.63^{a}	7.900^{c}	**17.74^{A}**
1.25	8.200^{c}	14.90^{b}	14.13^{b}	3.600^{d}	**10.21^{B}**
2.50	9.333^{cd}	32.24^{a}	13.53^{b}	6.433^{cd}	**15.39^{A}**
5.00	29.63^{a}	16.20^{b}	8.267^{c}	3.367^{d}	**14.3^{AB}**
Mean	**15.84^{A}**	**19.40^{A}**	**17.14^{A}**	**5.325^{B}**	

*Means followed by the same letter(s) are not significantly different using Duncan's Multiple Range Test at 5% level.

4.7. Fresh plant weight (g)

Statistical analysis revealed that aloe fresh plant weight was significantly affected Table (7). (5ml) produced highest fresh plant weight of aloe in(3)days(125.0gm) followed by the control in (10) days(108.9gm), while, (2.50 ml) on (15) days gave the lowest fresh plant weight (31.70gm). This result is similar to that reported by Abdul Rahman (2016) and similar to that reported by Nematian *et al*. (2011).

4.8. Weight of fresh roots (g):

Table (8) Statistical analysis revealed that aloe fresh weight of roots was significantly affected. The Control produced the highest fresh weight of root of aloe in (10) days (8.767gm). While, (1.25 ml) on (15) days gave the lowest wet weight root (3.433gm), followed by the control in (15) days (3.333gm). This result is contradictory to that reported by Abdul Rahman (2016) and reported by Nematian *et al*. (2011).

Table 7: Effect of fertilizer and drying cycles on fresh plant weight of aloe (g) plants.

Fertilizer (ml/L)	Drying cycles (days)				
	3	**5**	**10**	**15**	**Mean**
0.00(control)	47.37^{ef*}	83.83^{bc}	108.9^{a}	45.20^{ef}	$\mathbf{71.32^{AB}}$
1.25	47.20^{ef}	71.30^{bcd}	83.73^{bc}	31.70^{f}	$\mathbf{58.51^{AB}}$
2.50	46.00^{ef}	64.32^{cde}	57.10^{de}	43.57^{ef}	$\mathbf{52.83^{B}}$
5.00	$125.O^{a}$	85.57^{b}	51.90^{cdef}	48.53^{ef}	$\mathbf{77.97^{A}}$
Mean	$\mathbf{66.08^{A}}$	$\mathbf{76.28^{A}}$	$\mathbf{75.43^{A}}$	$\mathbf{42.25^{B}}$	

*Means followed by the same letter(s) are not significantly different using Duncan's Multiple Range Test at 5% level.

Table 8: Effect of fertilizer and drying cycles on the fresh weight of roots of aloe (g) plants.

Fertilizer (ml/L)	Drying cycles (days)				
	3	**5**	**10**	**15**	**Mean**
0.00(control)	6.300^{bcde*}	5.467^{cdef}	8.767^{a}	3.333^{f}	**5.967^{A}**
1.25	4.000^{ef}	5.600^{cdef}	4.767^{cdef}	3.433^{f}	**4.450^{A}**
2.50	4.433^{def}	6.600^{abcd}	5.000^{cdef}	4.633^{cdef}	**5.167^{A}**
5.00	8.533^{b}	6.433^{abcde}	7.033^{abc}	4.400^{def}	**6.600^{A}**
Mean	**5.817^{A}**	**6.025^{A}**	**6.392^{A}**	**3.950^{A}**	

*Means followed by the same letter(s) are not significantly different using Duncan's Multiple Range Test at 5% level.

4.9. Dry root weight (g):

Table (9) Statistical analysis revealed that aloe dry root weight was significantly affected. (5.00ml) produced the highest dry root weight of aloe in (3) days (1.477g). Followed by the control in (15) days (0.4533gm) gave the lowest dry root weight then followed by (control-1.25ml) in (15-3) days (0.4533-0.6233g). This result is in contradictory to that reported by Abdul Rahman (2016) and similar to that reported by Nematian *et al*. (2011).

4.10. Dry plant weight (g)

Table (10) Statistical analysis revealed that aloe of dry plant weight was significantly affected. (5.00ml) produced the highest dry plant weight of aloe in (3) days (5.370gm), while, (2.50ml) on (15) days gave the lowest dry plant weight (1.430gm), followed by (1.25-5ml) in (15-3) days (1.457-1.530gm).This result is similar to that reported by Abdul Rahman (2016) and contradictory to that reported by Nematian *et al*. (2011).

4.11. Dry shoots weight (g)

Table (11) Statistical analysis revealed that aloe dry shoot weight was significantly affected. (5.00ml) product highest dry shoot weight of aloe in (5) days (2.757gm) then followed by (1.25ml) in (10) days (2.333gm). While, (1.25ml) on (15) days gave the lowest dry shoot weight (0.2333gm). This result is contradictory to that reported by Abdul Rahman (2016) and similar to that reported by Nematian *et al.* (2011).

Table 9: Effect of fertilizer and drying cycles on dry root weight of aloe (g) plants.

Fertilizer (ml/L)	Drying cycles (days)				
	3	**5**	**10**	**15**	**Mean**
0.00(control)	0.8267^{ab*}	0.8233^{ab}	0.9000^{ab}	0.4533^{b}	**0.7508^{A}**
1.25	0.6233^{b}	0.9400^{ab}	0.7200^{ab}	0.4667^{b}	**0.6875^{A}**
2.50	0.8167^{ab}	0.9033^{ab}	0.7367^{ab}	0.6500^{ab}	**0.7767^{A}**
5.00	1.4770^{a}	1.2670^{ab}	1.1100^{ab}	0.7567^{ab}	**1.1530^{A}**
Mean	**0.9385^{A}**	**0.9833^{A}**	**0.8667^{A}**	**0.5817^{A}**	

*Means followed by the same letter(s) are not significantly different using Duncan's Multiple Range Test at 5% level.

Table 10: Effect of fertilizer and drying cycles on dry plant weight of aloe (g).

Fertilizer (ml/L)	Drying cycles (days)				
	3	**5**	**10**	**15**	**Mean**
0.00(control)	2.190^{cde*}	3.467^{b}	3.167^{bc}	1.787^{de}	**2.652^{A}**
1.25	1.830^{de}	3.073^{bc}	3.053^{bc}	1.457^{e}	**2.353^{A}**
2.50	1.797^{de}	2.900^{bcd}	2.707^{bcd}	1.430^{e}	**2.208^{A}**
5.00	5.370^{a}	1.530^{e}	2.330^{bcde}	2.707^{bcd}	**2.958^{A}**
Mean	**2.797^{A}**	**2.743^{A}**	**2.815^{A}**	**1.845^{A}**	

*Means followed by the same letter(s) are not significantly different using Duncan's Multiple Range Test at 5% level.

Table 11: Effect of fertilizer and drying cycles on dry shoot weight of aloe (mg)

Fertilizer (ml/L)	Drying cycles (days)				
	3	**5**	**10**	**15**	**Mean**
0.00(control)	0.7167^{bcd*}	0.5233^{cd}	0.9167^{bcd}	0.4400^{cd}	**0.6492^{A}**
1.25	0.9567^{bcd}	0.7233^{bcd}	2.3330^{a}	0.2333^{d}	**1.0490^{A}**
2.50	1.3500^{b}	0.6800^{bcd}	0.4733^{cd}	0.4500^{cd}	**0.7383^{A}**
5.00	1.1470^{b}	2.7570^{a}	0.4500^{cd}	0.5200^{cd}	**1.2180^{A}**
Mean	**1.030^{A}**	**1.171^{A}**	**1.043^{A}**	**0.410^{A}**	

*Means followed by the same letter(s) are not significantly different using Duncan's Multiple Range Test at 5% level .

Conclusion and Recommendation

1. Conclusion

1. The length of the plants was almost the same for all treatments, whereas there were significant variations for the roots .However the overall means were not statistically different.
2. The number of leaves, roots and offshoots per plant were significantly affected with the 15 days drying cycle resulted in the least numbers.
3. The fresh weight parameters followed the same trend .like-wise where the dry weight parameters.
4. In contrast none of the fertilization treatments enhanced any of the parameters.
5. It is better not to subject aloe plant to drought stress lest to affect their vegetative growth negatively.

2. Recommendation

Application of drying cycles and fertilizer had significant effect on the growth. Thus, more research in needed to be carried out to verity the obtained results.

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Appendices

Appendix 1: Image of a topical aloe plant

Appendix 2: Meteorological data at the experimental site

Month	Max. temperature (c^{o})	Min. temperature(c^{o})	Relative humidity (%)
October 2016	40.2	24.6	32
November 2016	37.0	21.4	31
December 2016	33.4	17.5	34
January 2017	34.2	16.7	30
February 2017	31.6	14.9	23

Source: Shambat metrological station

Appendix 3: Analysis of variance of the data

```
Data file:  &k0S&k2GESRAA&k0S
Title:      growth

Function: FACTOR

Experiment Model Number 2:
     Completely Randomized Design for Factor A, Factor B
     is a Split Plot
Data case no. 1 to 48.

Factorial ANOVA for the factors:
     Replication (Var 3: replication) with values from 1 to 3
     Factor A (Var 1: irr) with values from 1 to 4
     Factor B (Var 2: fert) with values from 1 to 4


Variable 4: 1

Grand Mean = 21.583   Grand Sum = 1036.000   Total Count = 48


              T A B L E   O F   M E A N S

  3   1   2              4             Total
-------------------------------------------------------
  *   1   *             21.583          259.000
  *   2   *             23.917          287.000
  *   3   *             22.250          267.000
  *   4   *             18.583          223.000
-------------------------------------------------------
  *   *   1             21.667          260.000
  *   *   2             21.833          262.000
  *   *   3             21.333          256.000
  *   *   4             21.500          258.000
-------------------------------------------------------
  *   1   1             21.333           64.000
  *   1   2             20.000           60.000
  *   1   3             20.667           62.000
  *   1   4             24.333           73.000
  *   2   1             25.667           77.000
  *   2   2             24.000           72.000
  *   2   3             22.000           66.000
  *   2   4             24.000           72.000
  *   3   1             20.333           61.000
  *   3   2             25.333           76.000
  *   3   3             24.000           72.000
  *   3   4             19.333           58.000
  *   4   1             19.333           58.000
  *   4   2             18.000           54.000
  *   4   3             18.667           56.000
```

*	4	4	18.333	55.000

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	178.667	59.556	4.0206	0.0513
-3	Error	8	118.500	14.813		
4	Factor B	3	1.667	0.556	0.0327	
6	AB	9	128.667	14.296	0.8406	
-7	Error	24	408.167	17.007		
	Total	47	835.667			

Coefficient of Variation: 19.11%

s_ for means group 2: 1.1110 Number of Observations: 12
y

s_ for means group 4: 1.1905 Number of Observations: 12
y

s_ for means group 6: 2.3810 Number of Observations: 3
y

==========

Variable 5: 2

Grand Mean = 7.250 Grand Sum = 348.000 Total Count = 48

T A B L E O F M E A N S

3	1	2	5	Total
*	1	*	6.833	82.000
*	2	*	8.167	98.000
*	3	*	7.667	92.000
*	4	*	6.333	76.000

*	*	1	7.500	90.000
*	*	2	6.750	81.000
*	*	3	7.167	86.000
*	*	4	7.583	91.000
*	1	1	6.000	18.000
*	1	2	6.667	20.000
*	1	3	6.333	19.000
*	1	4	8.333	25.000
*	2	1	8.333	25.000
*	2	2	8.000	24.000
*	2	3	8.000	24.000
*	2	4	8.333	25.000
*	3	1	8.667	26.000
*	3	2	6.667	20.000
*	3	3	8.000	24.000
*	3	4	7.333	22.000
*	4	1	7.000	21.000
*	4	2	5.667	17.000
*	4	3	6.333	19.000
*	4	4	6.333	19.000

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	24.333	8.111	3.8933	0.0551
-3	Error	8	16.667	2.083		
4	Factor B	3	5.167	1.722	1.1923	0.3337
6	AB	9	14.167	1.574	1.0897	0.4058
-7	Error	24	34.667	1.444		
	Total	47	95.000			

Coefficient of Variation: 16.58%

s_ for means group 2: 0.4167 Number of Observations: 12
y

s_ for means group 4: 0.3469 Number of Observations: 12
y

s_ for means group 6: 0.6939 Number of Observations: 3
y

Variable 6: 3

Grand Mean = 11.125 Grand Sum = 534.000 Total Count = 48

T A B L E O F M E A N S

3	1	2	6	Total
*	1	*	11.833	142.000
*	2	*	11.333	136.000
*	3	*	11.250	135.000
*	4	*	10.083	121.000
*	*	1	11.333	136.000
*	*	2	10.833	130.000
*	*	3	11.333	136.000
*	*	4	11.000	132.000
*	1	1	9.667	29.000
*	1	2	14.667	44.000
*	1	3	11.000	33.000
*	1	4	12.000	36.000
*	2	1	11.000	33.000
*	2	2	10.667	32.000
*	2	3	12.333	37.000
*	2	4	11.333	34.000
*	3	1	15.000	45.000
*	3	2	8.667	26.000
*	3	3	11.333	34.000
*	3	4	10.000	30.000
*	4	1	9.667	29.000
*	4	2	9.333	28.000
*	4	3	10.667	32.000
*	4	4	10.667	32.000

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	19.750	6.583	1.9506	0.2001
-3	Error	8	27.000	3.375		
4	Factor B	3	2.250	0.750	0.1725	
6	AB	9	113.917	12.657	2.9116	0.0176
-7	Error	24	104.333	4.347		
	Total	47	267.250			

Coefficient of Variation: 18.74%

s_ for means group 2: 0.5303 Number of Observations: 12
y

s_ for means group 4: 0.6019 Number of Observations: 12
y

s_ for means group 6: 1.2038 Number of Observations: 3
y

==========

Variable 7: 4

Grand Mean = 6.813 Grand Sum = 327.000 Total Count = 48

T A B L E O F M E A N S

3	1	2	7	Total
*	1	*	7.583	91.000
*	2	*	7.000	84.000
*	3	*	8.417	101.000
*	4	*	4.250	51.000
*	*	1	7.333	88.000
*	*	2	6.500	78.000
*	*	3	5.750	69.000
*	*	4	7.667	92.000
*	1	1	7.667	23.000
*	1	2	7.000	21.000
*	1	3	6.667	20.000
*	1	4	9.000	27.000
*	2	1	5.667	17.000
*	2	2	6.333	19.000
*	2	3	7.667	23.000
*	2	4	8.333	25.000
*	3	1	10.667	32.000
*	3	2	8.667	26.000
*	3	3	6.000	18.000
*	3	4	8.333	25.000
*	4	1	5.333	16.000
*	4	2	4.000	12.000
*	4	3	2.667	8.000
*	4	4	5.000	15.000

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob

```
  2     Factor A         3       117.229        39.076     13.1166
0.0019
 -3     Error            8        23.833         2.979
  4     Factor B         3        26.729         8.910      3.2646
0.0388
  6     AB               9        42.021         4.669      1.7108
0.1412
 -7     Error           24        65.500         2.729
-------------------------------------------------------------------
--------
        Total           47       275.313
-------------------------------------------------------------------
--------


     Coefficient of Variation: 24.25%

     s_ for means group 2:     0.4983       Number of Observations:
12
      y

     s_ for means group 4:     0.4769       Number of Observations:
12
      y

     s_ for means group 6:     0.9538       Number of Observations: 3
      y


===================================================================
========


     Variable 8: 5

     Grand Mean = 4.542   Grand Sum = 218.000   Total Count = 48


                  T A B L E   O F   M E A N S

       3   1   2              8             Total
     ---------------------------------------------------
       *   1   *              5.250           63.000
       *   2   *              5.167           62.000
       *   3   *              5.333           64.000
       *   4   *              2.417           29.000
     ---------------------------------------------------
       *   *   1              4.500           54.000
       *   *   2              2.750           33.000
       *   *   3              5.333           64.000
       *   *   4              5.583           67.000
     ---------------------------------------------------
       *   1   1              6.000           18.000
       *   1   2              2.000            6.000
       *   1   3              5.333           16.000
       *   1   4              7.667           23.000
       *   2   1              2.667            8.000
       *   2   2              3.667           11.000
       *   2   3              7.667           23.000
       *   2   4              6.667           20.000
       *   3   1              6.333           19.000
```

*	3	2	3.667	11.000
*	3	3	5.000	15.000
*	3	4	6.333	19.000
*	4	1	3.000	9.000
*	4	2	1.667	5.000
*	4	3	3.333	10.000
*	4	4	1.667	5.000

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	72.417	24.139	29.7094	0.0001
-3	Error	8	6.500	0.813		
4	Factor B	3	59.083	19.694	10.8659	0.0001
6	AB	9	64.417	7.157	3.9489	0.0034
-7	Error	24	43.500	1.813		
	Total	47	245.917			

Coefficient of Variation: 29.64%

s_ for means group 2: 0.2602 Number of Observations: 12
y

s_ for means group 4: 0.3886 Number of Observations: 12
y

s_ for means group 6: 0.7773 Number of Observations: 3
y

Variable 9: 6

Grand Mean = 14.427 Grand Sum = 692.500 Total Count = 48

T A B L E O F M E A N S

3	1	2	9	Total
*	1	*	15.842	190.100
*	2	*	19.400	232.800
*	3	*	17.142	205.700
*	4	*	5.325	63.900

*	*	1	17.742	212.900
*	*	2	10.208	122.500
*	*	3	15.392	184.700
*	*	4	14.367	172.400
*	1	1	16.200	48.600
*	1	2	8.200	24.600
*	1	3	9.333	28.000
*	1	4	29.633	88.900
*	2	1	14.233	42.700
*	2	2	14.900	44.700
*	2	3	32.267	96.800
*	2	4	16.200	48.600
*	3	1	32.633	97.900
*	3	2	14.133	42.400
*	3	3	13.533	40.600
*	3	4	8.267	24.800
*	4	1	7.900	23.700
*	4	2	3.600	10.800
*	4	3	6.433	19.300
*	4	4	3.367	10.100

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	1403.374	467.791	31.6909	0.0001
-3	Error	8	118.088	14.761		
4	Factor B	3	356.621	118.874	17.5095	0.0000
6	AB	9	2251.354	250.150	36.8459	0.0000
-7	Error	24	162.938	6.789		
	Total	47	4292.375			

Coefficient of Variation: 18.06%

s_ for means group 2: 1.1091 Number of Observations: 12
y

s_ for means group 4: 0.7522 Number of Observations: 12
y

s_ for means group 6: 1.5043 Number of Observations: 3
y

Variable 10: 7

Grand Mean = 65.158 Grand Sum = 3127.600 Total Count = 48

T A B L E O F M E A N S

3	1	2	10	Total
*	1	*	66.683	800.200
*	2	*	76.275	915.300
*	3	*	75.425	905.100
*	4	*	42.250	507.000
*	*	1	71.325	855.900
*	*	2	58.508	702.100
*	*	3	52.833	634.000
*	*	4	77.967	935.600
*	1	1	47.367	142.100
*	1	2	47.267	141.800
*	1	3	46.300	138.900
*	1	4	125.800	377.400
*	2	1	83.833	251.500
*	2	2	71.333	214.000
*	2	3	64.367	193.100
*	2	4	85.567	256.700
*	3	1	108.900	326.700
*	3	2	83.733	251.200
*	3	3	57.100	171.300
*	3	4	51.967	155.900
*	4	1	45.200	135.600
*	4	2	31.700	95.100
*	4	3	43.567	130.700
*	4	4	48.533	145.600

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	9073.225	3024.408	19.7718	0.0005
-3	Error	8	1223.727	152.966		
4	Factor B	3	4778.512	1592.837	10.4366	0.0001
6	AB	9	16842.533	1871.393	12.2617	0.0000
-7	Error	24	3662.900	152.621		
	Total	47	35580.896			

Coefficient of Variation: 18.96%

s_ for means group 2: 3.5703 Number of Observations: 12
y

s_ for means group 4: 3.5663 Number of Observations: 12
y

s_ for means group 6: 7.1326 Number of Observations: 3
y

==========

Variable 11: 8

Grand Mean = 5.546 Grand Sum = 266.200 Total Count = 48

T A B L E O F M E A N S

3	1	2	11	Total
*	1	*	5.817	69.800
*	2	*	6.025	72.300
*	3	*	6.392	76.700
*	4	*	3.950	47.400
*	*	1	5.967	71.600
*	*	2	4.450	53.400
*	*	3	5.167	62.000
*	*	4	6.600	79.200
*	1	1	6.300	18.900
*	1	2	4.000	12.000
*	1	3	4.433	13.300
*	1	4	8.533	25.600
*	2	1	5.467	16.400
*	2	2	5.600	16.800
*	2	3	6.600	19.800
*	2	4	6.433	19.300
*	3	1	8.767	26.300
*	3	2	4.767	14.300
*	3	3	5.000	15.000
*	3	4	7.033	21.100
*	4	1	3.333	10.000
*	4	2	3.433	10.300
*	4	3	4.633	13.900
*	4	4	4.400	13.200

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob

```
  2     Factor A         3        42.781        14.260      3.4189
0.0730
 -3     Error            8        33.368         4.171
  4     Factor B         3        31.596        10.532      4.7425
0.0098
  6     AB               9        45.696         5.077      2.2863
0.0512
 -7     Error           24        53.298         2.221
-------------------------------------------------------------------
--------
        Total           47       206.739
-------------------------------------------------------------------
--------
     Coefficient of Variation: 26.87%

     s_ for means group 2:     0.5896       Number of Observations:
12
      y

     s_ for means group 4:     0.4302       Number of Observations:
12
      y

     s_ for means group 6:     0.8604       Number of Observations: 3
      y

===================================================================
========

     Variable 12: 9

     Grand Mean = 0.842   Grand Sum = 40.410   Total Count = 48

                  T A B L E   O F   M E A N S

       3   1   2              12              Total
     ---------------------------------------------------------
       *   1   *               0.936           11.230
       *   2   *               0.983           11.800
       *   3   *               0.867           10.400
       *   4   *               0.582            6.980
     ---------------------------------------------------------
       *   *   1               0.751            9.010
       *   *   2               0.687            8.250
       *   *   3               0.777            9.320
       *   *   4               1.153           13.830
     ---------------------------------------------------------
       *   1   1               0.827            2.480
       *   1   2               0.623            1.870
       *   1   3               0.817            2.450
       *   1   4               1.477            4.430
       *   2   1               0.823            2.470
       *   2   2               0.940            2.820
       *   2   3               0.903            2.710
       *   2   4               1.267            3.800
       *   3   1               0.900            2.700
       *   3   2               0.720            2.160
       *   3   3               0.737            2.210
       *   3   4               1.110            3.330
       *   4   1               0.453            1.360
```

*	4	2	0.467	1.400	
*	4	3	0.650	1.950	
*	4	4	0.757	2.270	

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	1.166	0.389	2.8828	0.1027
-3	Error	8	1.079	0.135		
4	Factor B	3	1.594	0.531	2.1922	0.1151
6	AB	9	0.488	0.054	0.2237	
-7	Error	24	5.818	0.242		
	Total	47	10.145			

Coefficient of Variation: 58.48%

s_ for means group 2: 0.1060 Number of Observations: 12
y

s_ for means group 4: 0.1421 Number of Observations: 12
y

s_ for means group 6: 0.2843 Number of Observations: 3
y

==========

Variable 13: 10

Grand Mean = 2.550 Grand Sum = 122.390 Total Count = 48

T A B L E O F M E A N S

3	1	2	13	Total
*	1	*	2.797	33.560
*	2	*	2.742	32.910
*	3	*	2.815	33.780
*	4	*	1.845	22.140
*	*	1	2.653	31.830
*	*	2	2.353	28.240
*	*	3	2.208	26.500
*	*	4	2.985	35.820
*	1	1	2.190	6.570

```
       *   1   2              1.830             5.490
       *   1   3              1.797             5.390
       *   1   4              5.370            16.110
       *   2   1              3.467            10.400
       *   2   2              3.073             9.220
       *   2   3              2.900             8.700
       *   2   4              1.530             4.590
       *   3   1              3.167             9.500
       *   3   2              3.053             9.160
       *   3   3              2.707             8.120
       *   3   4              2.333             7.000
       *   4   1              1.787             5.360
       *   4   2              1.457             4.370
       *   4   3              1.430             4.290
       *   4   4              2.707             8.120
     ---------------------------------------------------
         A N A L Y S I S   O F   V A R I A N C E   T A B L E

  K                Degrees of   Sum of         Mean          F
Value    Source       Freedom    Squares       Square       Value
Prob
-------------------------------------------------------------------------
--------
  2     Factor A         3         7.982         2.661      4.7411
0.0348
 -3     Error            8         4.489         0.561
  4     Factor B         3         4.262         1.421      2.8773
0.0570
  6     AB               9        33.378         3.709      7.5117
0.0000
 -7     Error           24        11.849         0.494
-------------------------------------------------------------------------
--------
        Total           47        61.960
-------------------------------------------------------------------------
--------
     Coefficient of Variation: 27.56%

     s_ for means group 2:     0.2163       Number of Observations:
12
      y

     s_ for means group 4:     0.2028       Number of Observations:
12
      y

     s_ for means group 6:     0.4057       Number of Observations: 3
      y

=========================================================================
========
```

Variable 14: 11

Grand Mean = 0.914 Grand Sum = 43.860 Total Count = 48

T A B L E O F M E A N S

3	1	2	14	Total
*	1	*	1.030	12.360
*	2	*	1.171	14.050
*	3	*	1.043	12.520
*	4	*	0.411	4.930
*	*	1	0.649	7.790
*	*	2	1.049	12.590
*	*	3	0.738	8.860
*	*	4	1.218	14.620
*	1	1	0.717	2.150
*	1	2	0.907	2.720
*	1	3	1.350	4.050
*	1	4	1.147	3.440
*	2	1	0.523	1.570
*	2	2	0.723	2.170
*	2	3	0.680	2.040
*	2	4	2.757	8.270
*	3	1	0.917	2.750
*	3	2	2.333	7.000
*	3	3	0.473	1.420
*	3	4	0.450	1.350
*	4	1	0.440	1.320
*	4	2	0.233	0.700
*	4	3	0.450	1.350
*	4	4	0.520	1.560

A N A L Y S I S O F V A R I A N C E T A B L E

K Value	Source	Degrees of Freedom	Sum of Squares	Mean Square	F Value	Prob
2	Factor A	3	4.192	1.397	3.2036	0.0835
-3	Error	8	3.489	0.436		
4	Factor B	3	2.543	0.848	4.7366	0.0098
6	AB	9	15.480	1.720	9.6127	0.0000
-7	Error	24	4.294	0.179		
	Total	47	29.998			

```
     Coefficient of Variation: 46.29%

     s_ for means group 2:     0.1906       Number of Observations:
12
      y

     s_ for means group 4:     0.1221       Number of Observations:
12
      y

     s_ for means group 6:     0.2442       Number of Observations: 3
      y
```

Appendix 4: Image of the container of the liquid fertilizers