REFINEMENT OF MACRO-PROPAGATION TECHNIQUE FOR MASS-MULTIPLICATION OF ALOE (*Aloe vera* Burm.f.)

By

SARANYA.K.S

(2014-12-117)

THESIS

Submitted in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF PLANTATION CROPS AND SPICES

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695 522

KERALA, INDIA

2017

DECLARATION

I hereby declare that this thesis entitled **"REFINEMENT OF MACRO_PROPAGATION TECHNIQUE FOR MASS MULTIPLICATION OF ALOE (*Aloe vera* Burm.f.)"** is bonafide record of research work done by me during the course of research and that the thesis has not previously formed the basis for the award of any degree,diploma,fellowship or other similar title,of any other University or Society.

Vellayani

Date: 16-09-2017

Saranya .K.S

(2014-12-117)

CERTIFICATE

Certified that this thesis entitled **"REFINEMENT OF MACRO_PROPAGATION TECHNIQUE FOR MASS MULTIPLICATION OF ALOE (*Aloe vera* Burm.f.)"** is a record of research work done independently by Ms. Saranya.K.S. (2014-12-117) under my guidance and supervision and that it has not previously formed the basis for the award of any degree,diploma,fellowship or associateship to her.

Vellayani

16.09.2017

Dr.P.C.Jessykutty

Chairman,Advisory Committee

Professor & Head

Dept.of Plantation Crops & Spices

College of Agriculture,Vellayani

CERTIFICATE

We, the undersigned members of the advisory committee of Ms.Saranya.K.S a candidate for the degree of **Master of Science in Horticulture** with major in Plantation Crops and Spices agree that the thesis entitled **"REFINEMENT OF MACRO_PROPAGATION TECHNIQUE FOR MASS MULTIPLICATION OF ALOE (*Aloe vera* Burm.f.)"** may be submitted by Ms. Saranya.K..S, in partial fulfilment of the requirement for the degree.

Dr. P.C.Jessykutty
(Chairman, Advisory Committee)
Professor & Head
Department of Plantation Crops and Spices
College of Agriculture, Vellayani

Dr.G.S.Sreekala
(Member, AdvisoryCommittee)
Assistant Professor
Department of Plantation Crops and Spices
College of Agriculture, Vellayani

Dr.V.A.Celine
(Member, AdvisoryCommittee)
Professor & Head(Retired)
Department of Olericulture

Smt.Brigit Joseph
(Member, AdvisoryCommittee)
Associate Professor
Department of Agricultural Statistics
College of Agriculture, Vellayani

EXTERNAL EXAMINER

ACKNOWLEGMENT

I extol the genuine and constant encouragement, worthy guidance , critical comments, constant supervision , support , unceasing patience and timely advice offered by major advisor Dr. P.C.Jessykutty, Professsor and Head, Department of Plantation crops and spices during the course of my work.

I express my deep-felt gratitude to Dr. G. S. Sreekala, Assistant professor, Department of Plantation Crops and Spices for her constant support and treasured suggestions and cooperation during the course of my investigation.

I consider it my honor in expressing my loyalty to the member of my advisory committee Dr.V.A.Celine,Professor and Head, Department of Olericulture, College of Agriculture, Vellayani for her unambiguous advices, agile help and valuable suggestions throughout my research.

I sincerely express my deep gratitude to Smt.Brigit Joseph, Associate Professor Department of Agricultural Statistics ,member of advisory committee for her incessant support, encouragement and profound help rendered throughout my study.

I wish to express my bottomless sense of thanks to Dr. G.R. Sulekha (Rtd) and Dr. Deepa S Nair faculty members of Department of Plantation Crops and Spices for the assistance and support rendered in all phases of my thesis work.

My heartful thanks to my respected teachers Dr.Mini.C,Professor & Head ,Dr.Geethalekshmi.P.R,Assistant Professor of Department of Post Harvest Technology,and Dr.Arya.K,Professor & head, Department of Plant breeding & Genetics ,for their bondless advice,support and encouragement throughout my study.

My special thanks for Dr. Babu Mathew, Professor and Head, Instructional farm, Vellayani for his help, motivation and support in the course of study.

I express my immense gratitude to farm mangers and all labourers for their timely help and support.

I express my gratitude to my juniors Aparna, Sandra,Aparna.G.S and seniors Soniya chechi, Maheswari chechi, Vidya chechi,,Aswathy chechi and Thanuja chechi . I thankfully own up and I express my gratitude to Unni chettan,Jincy,Remya, Suja chechi, Sugandi chechi, Anila chechi ,Arya Suresh chettan for their unswerving co-operation and help during the entire period of my research work.

I express my heartful gratitude to my dear and dearest Jeffi,my roomie,and Binzu.

I am indebted to my friends Aiswarya,Lekshmi,Shymi,Shwethasree,Irshana and Ambareesh for their company, relentless help, support and motivation. I do not have words to express my love, affection and gratitude to my classmates Athulya and Deepthi Monica who were my pillar of support in the course of my work.

I do not have words to express my obligations to my juniors for their assistance and support during the work.

Words fail to express my immense thankfulness to my dearest friend Jaffin who was beside me during the inevitable ups and down of my life

I am grateful to the KAU for awarding the KAU fellowship during my study.

Words are not enough to express my whole-hearted and affectionate gratitude to my Dady and Mummy for their love, affection and copious encouragement throughout my career , I express my love to my dear sister Priya and my little princess Parukutty who were there for me always.

I also wish to express my warm gratitude to my achan, amma,Prasanthannan,Saranyachechi,Sureshannan and other family members.

I am grateful to my friend Vishnu.V.Nair,Vinu chettan,Achu,Rukku,My uncle who were beside me during the inevitable ups and down of my life

I am grateful to Almighty for the good health and wellbeing that were required to complete this thesis.

I felt elated to express my bountiful thanks to those all those people who have made this thesis possible

Saranya K.S

LIST OF FIGURES

LIST OF PLATES

LIST OF TABLES

10

TABLE OF CONTENTS

LIST OF ABBREVIATIONS

%	: Per cent
@	: At the rate of
AGR	:Absolute Growth Rate
BA	:Benzyl Adenine
B.C.R	:Benefit-Cost ratio
^0C	: Degree Celsius
CAGR	: Compound Annual Growth Rate
CD	: Critical Difference
cm	: centimeter
CRD	: Completely Randomized Design
day^{-1}	:per day
et al	: et alia
Fig.	: Figure
ft	: feet
FW	:Fresh Weight
g	: gram
GA3	:Gibberellic Acid
ha^{-1}	:Per hectare
Hl	: Harvest Index
hrs	:hours
IAA	:Indole Acetic Acid
i.e.	:that is
KAU	:Kerala Agricultural University

kg : kilogram

l :Litre

LAI :Leaf Area Index

LAR :Leaf Area Ratio

m :meter

m^2 :meter square

MAP :Month After Planting

mg : milligram

ml : milli litre

mm :milli metre

MSL : Mean Sea Level

NAR :Net Assimilation Ratio

NS :Non Significant

ppm : parts per million

RGR :Relative Growth Rate

Rs. :Rupees

SE :Standard Error

t : tonnes

viz. :namely

$year^{-1}$:per year

INTRODUCTION

1. INTRODUCTION

Aloe vera Burm.f. is the oldest medicinal plant ever known and is the most utilized medicinal plant worldwide. It is a perennial, drought-resisting, succulent plant belonging to the Liliaceae family. The plant has been known and used for centuries for its health, beauty, medicinal and skin care properties; had its origin in Africa and Mediterranean countries. It grows mainly in the dry regions of Africa, Asia, Europe and America. Aloe has been used for pharmaceutical, food, and cosmetic industries (Gui *et al.*,1990; Meyer and Staden, 1991). In the food industry, *A. vera* has been utilized as a resource of functional food, especially for the preparation of health food drinks and other beverages, including tea. The amount of *A.vera* gel that finds its application in the pharmaceutical industry is not negligible as far as the manufacturing of topical ointments, gel preparations, and tablets and capsules are concerned. *A. vera* gel also finds its application in the cosmetic and toiletry industries, where it is used as a base material for the preparation of creams, lotions, soaps, shampoos, and facial cleansers. The major producers and exporters of the aloe products are China, U.S.A., Mexico, Australia and some the Latin American countries. Presently, these countries are exploiting its potential especially with the growing demand amongst cosmetic and nutraceuticals demands. In terms of value, the future market of *Aloe vera* extracts is expected to expand at a CAGR of 7.7% during the year 2016-2026 (PR Newswire, London, June 2016). According to NUTRA (2014) the current global market for aloe products is estimated to reach $ 13 billion. In cosmetic industry, aloe can be a good substitute to the synthetic ingredients. According to market demand, many processing units have already established in the country & according to estimation, more than 300 industries are processing *Aloe vera* leaf.

In India, it is found as a wild herb along the coast of south India. It is under cultivation in fairly large areas in many parts of India viz; Tamil Nadu, Gujarat, Maharashtra etc. Aloe is often thought to only grow in hot and dry climates but they actually grow in a variety of climates including desert, grassland, and coastal or even alpine locations. It is a hardy perennial tropical plant that can be cultivated in drought prone areas and is one of the crops whose potential is yet to be exploited, despite being identified as 'a new plant resource with the most promising prospects in the world'. Farmers in India regularly faces problem like lack of rain, low ground

water level, soil degradation etc. Therefore cultivation of *Aloe vera* would be beneficial as it requires minimum usage of water and the returns from it would be more than 50,000 yearly per acre. Cultivation of *Aloe vera* is expanding day by day as it provides quick and regular income to the farmers. In Kerala, it has traditionally been a household plant used extensively in home remedies and its commercial exploitation is rather limited.

In nature, *A. vera* is propagated through lateral buds, which is slow, very expensive and low income practice (Meyer and Staden, 1991). About 28000 – 34000 suckers are needed for one hectare planting and the traditional offset propagation is used almost exclusively even now. Although the offset production rate in *Aloe vera* plants is high, it is not enough for commercial production, and slow rate of offset production is a serious obstacle in developing its cultivation (Hazrati *et al.*, 2011). I*n vitro* propagation protocols have been developed for aloe, but is not easily affordable for an ordinary farmer/gardener. For commercial production and increasing leaves yield, we need to have a method that plantlet can be produced in a short period of time. Although mention about propagation using stem cuttings is there (Hartmann and Kester, 1978), beyond the basic observations, the method has not been optimised. Fine tuning of this propagation technique for aloe permitting rapid multiplication of limited quantities of planting materials will be a boon to the farming community. Hence, the present study entitled "Refinement of macro-propagation technique for the mass multiplication of aloe (*Aloe vera* Burm.f.)"has been undertaken at the department of Plantation Crops and Spices with the following objectives:

- To refine the stem disc method of macro propagation of aloe by evaluating the capacity of stem sections of varying size to sprout with or without the application of root and/or shoot-inducing growth regulators
- To evaluate various pre treatments for inducing axillary bud break in aloe
- To select the best treatment by analysing the seedling growth at different stages
- To compare the economics of different treatments

REVIEW OF LITERATURE

2. REVIEW OF LITERATURE

Aloe vera is one of the oldest medicinal plant ever known and the most demanded medicinal plant world-wide. The present study aims at the refinement of macro-propagation techniques for the mass-multiplication of aloe (*Aloe vera* Burm.f.)"and the following pages provides a brief review of the research carried out in this area as well as on related aspects. Wherever information is lacking pertinent literature on other crop has been included.

2.1 Genus Aloe

The genus *Aloe* L. is a member of family Liliaceae (Tribe Aloineae). Its representatives are perennial succulent plants, often arboreal, bearing rosettes of leaves at the end of juicy green branches (Hepper, 1968).Leaves are fleshy, stiff, molted, lance shaped with glabrous surfaces, sharp apices and spiny edges. The leaves send out sticky exudates when they are broken or injured. The name *Aloe* is derived from the Arabic word Alloeh, meaning shining bitter substances (Ajabnoor, 1990). According to Anselm (2004), over 325 species of genus Aloe have been identified by the year 2004. Basically, all the various species of Aloe have similar constituents but *A. vera* is more popular all over the world because it propagates itself faster than any other species of Aloe (Anselm, 2004). Hence, *Aloe vera* is more readily available for use than any other species of Aloe. *A. vera* is native to Africa but was taken out to other tropical climates for cultivation. It was later introduced to the Caribbean Island, India, Venezuela and Mexico. It was only during the 1970s that people in the USA started cultivating *A. vera* for its gel. *A. vera* belongs to a large class of plants known as xeroids because it possesses the ability to close its stomata completely to avoid loss of water. This makes the plant to have the natural ability to survive long periods of drought (Hect, 1981). *A. vera* is monocotyledonous plant which grows to about three feet in height (Davis et al., 2000). It takes four to five years to mature and can live up to 25 years (Aloe vera company, 2002). *A. vera* grows best in full sunshine and does not perform well at temperature below 32^0 F. It requires little water for its reproduction (Shelton, 1991). The plant has been in existence for over 2000 years.

2.2 Uses of *Aloe vera*

Apart from its use as ornament in homes, gardens and yards, *A. vera* is one of the medicinal

plants widely used throughout the world (Sofowora, 1984). Biblical report, as recorded in John 19 verses 39 and 40, reveals that it was used to embalm the body of Jesus Christ. There is also a report that Alexander the Great used *A. vera* to treat the wounds of his soldiers that got injured during the war and that Cleopatra used it for the care of skin (Ajabnoor, 1990). Works carried out on *A. vera* show that the plant is effective in the treatment of cancer (Grimando et al. ,1997) and intestinal ulcer and has a modulating effect on Human Immunodeficiency Virus- HIV (Anselm, 2004).The sap of the plant is used to sooth the pain of burns, rashes, insect bites and other skin irritations (Womble and Helderman, 1998). *A. vera* is also used to cure such illness and impotence, liver and kidney problems, piles, eczema, glaucoma, jaundice and ameneorrhea. It has been established that the inner gel of the leaf contains most of its beneficial part (Swaminathan and Kochhar, 1992). McCauley (1992) reported that the eight essential amino acids that human body needs, which cannot be manufactures but can only be obtained from food, are present in *A. vera*. These amino acids are isoleucine, leucine, lysine, methioine, phenylalanine, threonine, valine and tryotophan. Enzymes that are beneficial to human metabolism such as amylase, bradykinase, catalase, cellulose, lipase, oxidase, phosphokinase, proteolytiase and carboxypeptidase can also be obtained from the plant (Blumenthal and Mark, 2000). Tyler (1994) found out that the gel of the leaf of *A. vera* is made up of 96% of water and that the other 4% consists of at least 75 different elements such as vitamin B (including B_1, B_2, B_3, B_6, B_{12}) , vitamin C, vitamin E, folic acid and minerals. The minerals such as magnesium, calcium, potassium, phosphorous, sodium, manganese, zinc, copper, nitrogen, iron and chromium found in the gel all contribute to the healing property of A. vera. Hect (1981) found out that the plant contains cineole, cariofilene and pinene which are essential oils needed by human body. The plant also contains glutamic acids, aspartic acid, aloetic acid, formic acid, palmitic acid, estearic acid and ascorbic acid all of which are essential components of food (Davis et al., 2000). *A. vera* is commonly referred to as miracle plant for its numerous uses, particularly in the area of man's health.

Aloe has been used for pharmaceutical, food, and cosmetic industries (Gui *et al.*,1990; Meyer and Staden, 1991). In the food industry, *A. vera* has been utilized as a resource of functional food, especially for the preparation of health food drinks and other beverages, including tea. The amount of *A.vera* gel that finds its application in the pharmaceutical industry is not negligible as far as the manufacturing of topical ointments, gel preparations, and tablets

and capsules are concerned (Cristiano *et al*, 2016). *A. vera* gel also finds its application in the cosmetic and toiletry industries, where it is used as a base material for the preparation of creams, lotions, soaps, shampoos, and facial cleansers. Currently, production of aloe leaves is insufficient to meet the industrial demand.(Sampath Kumar *et al*,2010)

A.vera is found as a wild herb along the west coast of South India (Robert and Henry,2004). It is under cultivation in fairly large areas in many parts of India such as TamilNadu, Gujarat, Maharashtra etc. Genus Aloe is found in the tropics and was introduced to India for ornamental and medicinal purpose.

2.3 Propagation techniques in *Aloe vera*

Propagation in aloe is either by seed or by sucker (Duke, 1987). Aloe plants are propagated by two methods: sexual and vegetative. In *Aloe barbadensis*, the most common species in gel production, there is high rate of male sterility which results in cross-pollination; therefore propagation *via* seed leads to genetic segregation in daughter plants (Natali et al., 1990; Keijzer and Cresti, 1987). Aloe can be propagated from seeds, suckers, cuttings and tissue culture (Mukonyi and Oduor, 2008).

Main vegetative propagation method of Aloe plants is by using offsets. Offsets are produced from the end of short stolon and can be used as a propagule in perennial plants propagation (Carey, 2008). Although the offset production rate in *Aloe vera* plants is high, it is not enough for commercial production of plantlets, and this is a serious obstacle in developing its cultivation (Hazrati *et al*., 2011).. Therefore, offset production should somehow be increased. Due to these reasons, using agronomy practices seems to be necessary in order to produce maximum plants number in minimum time. The application of nitrogen had a significant effect on number of offsets and an increase in levels significantly increased the number of plant offsets in aloe (Hazrati *et al*., 2012).

Aloe vera is usually propagated through lateral shoots which the donor-plant produces mostly over the growth season. The number of lateral shoots/donor plant is low and also variable over time, becoming difficult to plan in a rational basis a production system in commercial scale for obtainment of plant propagation material. In general, 3 to 4 lateral shoots/donor plant/year are

found in conventional production systems, what is a time-consuming and tedious task, as well as an obviously meaningful drawback for purpose of large scale production of plant propagation material. This picture points to a significant constraint concerning the availability of propagation material from *A. vera* with superior genetic and sanity qualities, so that the enlargement of the cultured area is a difficult task (Campestrini *et al.*, 2006).

Van Shaik *et al.*, (1997) reported that in aloe vegetative reproduction by suckers was reduced by drought.

Aloe vera (and many other *Aloe* species) reproduces only by vegetative propagation as the seeds are not viable due to the sterility of the male flowers (Keijzer and Cresti, 1987). Adventitious shoots and/or buds are formed on the underground stem. The frequency of formation of vegetative shoots is very low and seasonal. Due to slow natural rate of reproduction, the ever-increasing demand of this wonder "potted physician" in various industries cannot be met with (Singh and Sood, 2009).

2.3.1 Micro propagation in *Aloe vera*

One of the major applications of plant tissue culture is micropropagation or rapid multiplication. Compared to conventional propagations, microprogation has the advantage of allowing rapid propagation in limited time and space. The microprogation of elite or selected plants have shown good results, which benefits the forestry, agriculture and horticultural industries (Drew, 1979). *A. vera* L. has been cultured *in vitro* by various researchers (Natali et al., 1990; Roy and Sarkar, 1991; Abrie and Staden, 2001; Corneanu et al., 1994; Chaudhuri and Mukandan, 2001). Based on previous researches, it is believed that the best explants for micropropagation of aloe are shoot tips and axillary buds (Meyer and Staden, 1991). Besides shoot tip, underground stems bearing adventitious buds in Chinese variety of Aloe vera (Liao et al., 2004), axillary shoot segments (Roy and Sarkar, 1991) and leaf (Hosseini and Parsa, 2007) of Aloe vera have also been utilized as explants for its *in vitro* multiplication.

Plant growth regulators and explants are very important factors for successful plant regeneration. Natali *et al.* (1990) reported a rapid highly effective plant micropropagation from meristems. Rich- wine *et al.* (1995) reported and Velcheva *et al.* (2005) developed a system for *in vitro* regeneration of aloe, using young inflorescences as explants.

2.3.2. Apical Dominance

Apical dominance may be defined as the control exerted by the shoot apex over the outgrowth of the lateral buds (Cline, 1994). As an apical shoot meristem of a herbaceous plant develops, axillary buds ''arise exogenously from superficial cell layers in the axils of leaf primordia'' (Fahn, 1990).These embryonic lateral buds may have inhibition imposed upon them shortly after their formation or after a brief period of growth. Lateral bud formation is inhibited by the shoot apical meristem (SAM). The lateral bud primordium (from which the lateral bud develops) is located below SAM. The shoot tip rising from the SAM inhibits the growth of the lateral bud by repressing auxin.

Typically, the end of a shoot contains an apical bud, which is the location where shoot growth occurs. The apical bud produces an auxin (IAA) that inhibits growth of the lateral buds further down on the stem towards the axillary bud. It was first discovered that the plant hormone auxin likely regulates apical dominance (Thimann &Skoog;1934) Auxin is predominantly produced in the growing shoot apex and is transported throughout the plant via the phloem and diffuses into lateral buds which prevents elongation (Booker *et.al*,2003).When the apical bud is removed, the lowered IAA concentration allows the lateral buds to grow and produce new shoots, which compete to become the lead growth.

2.3.3. Breaking of apical dominance

If the shoot apex is decapitated apical dominance is released and one or more lower axillary buds begins to grow out. Within a few hours after apex removal, measurable increases in the length of the emerging lateral bud can be detected in some species. In other species the lag period may be longer depending upon the degree of inhibition and the stage of the cell cycle at the time of inhibition (Tamas, 1987). In the days and weeks following decapitation, subsequent elongation and development of the lateral bud into a branch shoot occur.

The release of apical dominance may be promoted by direct application of cytokinin to the lateral bud (Pillay and Railton, 1983) and is often repressed by auxin treatment of the decapitated stump just above the lateral bud (Thimann and Skoog, 1934). In contrast, soon after apical dominance has been released and lateral bud elongation is underway (Stage IV), this developing lateral shoot or branch may begin to produce its own auxin, which may enhance

elongation (Thimann and Skoog, 1934) as may gibberellic acid at this time (Prochazka and Jacobs, 1984), although Isbell and Morgan (1982) have reported gibberellin repression of tiller growth in sorghum. Any treatment given to a plant 24 hour after apex removal will have a much different effect on lateral bud outgrowth than if it is given immediately following decapitation (Cline,1977).

Cytokinins are present in all parts and are equally distributed between the apical, lateral, and internodal tissue when dormant. However, the breaking of dormancy coincided with a rapid increase in the free base cytokinin levels in the apical buds and the tissue adjacent to it. These high levels of cytokinin in the apical tissue were maintained while apical dominance was displayed. Once apical dominance was overcome the cytokinin levels in the lateral buds and the tissue adjacent to them were similar to the levels in the apical regions. The present evidence suggests that cytokinin glucosides are transported to the meristematic regions of the tubers where they are hydrolysed to their free bases. Amounts of free bases in excess of those required for growth are apparently again converted to storage forms (particularly zeatin glucoside) in the meristematic regions of the tubers and in the sprouts.(van Staden and Dimall, 1978.)

2.3.3.1.Role of Cytokinin

Cytokinin is widely used in ornamental plants production. It is one of the most important plant hormones which regulates plant growth and development and has an important role in promoting cell division with similar functions to kinetin such as differentiation, leaf development and increased nutrients mobility in plants (Duan *et al.*, 2006; Shudo, 1994). Previous study results show that plant growth regulators such as cytokinins could improve shoot growth (Carey, 2008). Spraying cytokinins on *Hemerocallis citrine* shows that this group of plant growth regulators can increase offset production via affecting cell division, offsets size and growth by stimulating lateral buds growth (Amling *et al.*, 2007).

2.3.3.2.Role of auxin

Applying naphthaleneacetic acid (NAA) to the shoot of decapitated plants almost eliminated the effect of shoot tip removal on cytokinin concentration, suggesting that cytokinins in the xylem exudate of intact plants are under the control of the polar auxin transport system. Other xylem constituents, such as potassium or free amino acids did not show this strong increase after decapitation and did not respond to NAA application. It is concluded that the observed

auxin/cytokinin interaction has an important regulatory role to play, not only in apical dominance but in many other correlative events as well (Bangerth,1994).

2.3.3.3.Role of Benzyl adenine

Sucrose and BA were recognized the most important factors affecting the bud initiation and promoted efficient multiplication (Abrie and Staden ,2001).

2.4.Honey as a rooting hormone

Honey is a natural antiseptic and contains antifungal properties; both of which are believed to be one of the reasons honey as a root hormone seems to work so well.In addition to containing possible rooting agents, it is thought that honey for cuttings helps guard against bacterial or fungal problems, allowing the little cuttings to remain healthy and strong(Nikki Philips,2005).

Honey when added to water aid in rooting,but the ratio is adjusted as 1:3 of honey to water . Dip each cutting into the honey mixture and plant the cuttings in selected potting medium. Honey for cuttings has been found effective using a number of potting mediums, including soil, water and even rockwool.

2.5.Minisett Technique

In the late 1970s,the "minisett technique" was developed for the production of seed tubers separated from the production of yam.The technique utilizes a small (20-25g) part of a whole non-dormant tuber containing periderm and some cortex parenchyma (Okoli,1982).

In the study conducted by George (1990),four different minisett sizes (15g 30,45 and 60)were tried in *Dioscorea alata* and *D.rotundata*. Minisetts weighing 60g was found to be superior.However the performance of mini-setts weighing 30g was found to be par with 45g minisett.

Okwuowulu (1992) studied the influence of varying minisett weights,intra row spacing,sites and weather condition on yield of ginger cv.Taffin-giwa. He observed that small seed rhizome

weighing 3g can give potential setts.Using minisetts stimulated complete harnessing food reserve in mother rhizome.

MATERIALS AND METHODS

3.MATERIALS AND METHODS

The experiment entitled "Refinement of macro-propagation technique for mass multiplication of aloe(*Aloe vera* Burm.f.) was carried out at the Department of Plantation Crops and Spices,College Of Agriculture,Vellayani,Thiruvananthapuram during 2014-2016.The objective of the study was to refine the stem disc method of macropropagation of aloe for rapid mass multiplication,which has been used in pharmaceutical,food and cosmetic industries.

The details of the materials used and methods adopted for the study are discussed in this chapter.

3.1.PLANTING MATERIAL

The planting material used for the study was collected from the mature plants with elongated stem (after the final harvest of the fertilizer trial going on in the department).

3.2.SEASON

The experiment was conducted during March 2016-January 2017

3.3.EXPERIMENT

The experiment was conducted with the following technical programme.

Outline of the technical programme

Design:CRD

Material:Mature aloe plants after final harvest

Treatment combinations:48

Replication:3

The experiment was laid out in CRD with three replications during December 2015-January 2016.

Fig.1.Mature mother aloe

Plate.1.Matured mother plant stem

I.Pre-curing of stem for triggering adventitious/axillary bud break.

Treatments

P1-*In-situ* decapitation

P2-Partial crushing of internode

P3-foliar spraying of BA

P4-control(no pre curing)

For the study,mature plants with elongated stem were selected.These plants were subjected to certain *in -situ* pre-curing treatments for inducing adventitious/axillary bud break.

In-situ decapitation(P1)

The entire leaves were removed and only the stem portion kept in the field.

Partial Crushing of Internode(P2)

The intermodal region has crushed using cutting plair in order to restrict the apical auxin flow.

Foliar Spraying of BA (P3)

The selected plants were given a foliar spray of BA(500ppm).

Control(P4)

Without pre-curing.

II.Optimization of segment size

One month after pre-curing cylindrical stems(both pre-cured and control) having uniform length and girth will be taken.Each pre-cured plants were divided into one,two and three nodes.The stems were treated with bavistin(0.1%) for 15 minutes before cutting into different nodal segments.The different nodal segments are exposed to air for 2 hrs (suberization).

Plate.2.Mother plant subjected *to in-situ* decapitation

Plate.3.Mother plant subjected to partial crushing of inter-node

Treatments

S1- disc with one node

S2- disc with two nodes

S3- disc with three nodes

Exogenous hormone application done to the stem segments.The treated segments were weighed.

III.Standardization of Sprouting Treatment

G1- 1000ppm BA + 25ppm GA3

G2-2ppm IAA +2ppm BA

G3-Honey treatment

G4-Control

TREATMENT COMBINATIONS :48

T_1-$P_1S_1G_1$:*in-situ* decapitation +one node disc+BA(1000ppm)& GA3(25ppm)

T_2-$P_1S_1G_2$:*in-situ* decapitation+ one node disc+BA(2ppm)&IAA(2ppm)

T_3-$P_1S_1G_3$:*in-situ* decapitation+ one node disc+honey

T_4-$P_1S_1G_4$:*in-situ* decapitation+ one node disc+control

T_5- $P_1S_2G_1$:*in-situ* decapitation +two node disc+BA(1000ppm)& GA3(25ppm)

T_6- $P_1S_2G_2$:*in-situ* decapitation +two node disc+BA(2ppm)&IAA(2ppm)

T_7- $P_1S_2G_3$:*in-situ* decapitation+ two node disc+honey

T_8- $P_1S_2G_4$:*in-situ* decapitation+ two node disc+control

T_9- $P_1S_3G_1$*: in-situ* decapitation+three node+ BA(1000ppm)& GA3(25ppm)

T_{10}-$P_1S_3G_2$*: in-situ* decapitation+three node+ BA(2ppm)&IAA(2ppm)

T_{11}-$P_1S_3G_3$: *in-situ* decapitation+three node+honey

T_{12}-$P_1S_3G_4$*: in-situ* decapitation+three node+control

T_{13}-$P_2S_1G_1$: Partial crushing of internode+one node+ BA(1000ppm)& GA3(25ppm)

T_{14}-$P_2S_1G_2$: Partial crushing of internode+one node+ BA(2ppm)&IAA(2ppm)

T_{15}-$P_2S_1G_3$: Partial crushing of internode+one node+honey

T_{16}-$P_2S_1G_4$: Partial crushing of internode+one node+control

T_{17}-$P_2S_2G_1$: Partial crushing of internode+two node+ BA(1000ppm)& GA3(25ppm)

T_{18}-$P_2S_2G_2$: Partial crushing of internode+ two node+ BA(2ppm)&IAA(2ppm)

T_{19}-$P_2S_2G_3$: Partial crushing of internode+two node+honey

T_{20}-$P_2S_2G_4$: Partial crushing of internode+two node+control

T_{21}-$P_2S_3G_1$: Partial crushing of internode+three node+ BA(1000ppm)& GA3(25ppm)

T_{22}-$P_2S_3G_2$: Partial crushing of internode+three node+ BA(2ppm)&IAA(2ppm)

T_{23}-$P_2S_3G_3$: Partial crushing of internode+three node+honey

T_{24}-$P_2S_3G_4$: Partial crushing of internode+three node+control

T_{25}-$P_3S_1G_1$:foliar spraying of BA+one node+BA(1000ppm)& GA3(25ppm)

T_{26}-$P_3S_1G_2$: foliar spraying of BA+one node+ BA(2ppm)&IAA(2ppm)

T_{27}-$P_3S_1G_3$: foliar spraying of BA+one node+honey

T_{28}-$P_3S_1G_4$: foliar spraying of BA+one node+control

T_{29}-$P_3S_2G_1$: foliar spraying of BA+ two node disc+BA(1000ppm)& GA3(25ppm)

T_{30}-$P_3S_2G_2$: foliar spraying of BA+ two node disc+ BA(2ppm)&IAA(2ppm)

T_{31}-$P_3S_2G_3$: foliar spraying of BA+ two node disc+honey

T_{32}-$P_3S_2G_4$: foliar spraying of BA+ two node disc+control

T_{33}-P_3S_3G1: foliar spraying of BA +three node+ BA(1000ppm)& GA3(25ppm)

T_{34}-$P_3S_3G_2$: foliar spraying of BA+ three node+ BA(2ppm)&IAA(2ppm)

T_{35}-$P_3S_3G_3$: foliar spraying of BA+three node+honey

T_{36}-$P_3S_3G_4$: foliar spraying of BA+three node+control

Plate.4.Stem disc cuttings with different sizes prepared from mother plant stem

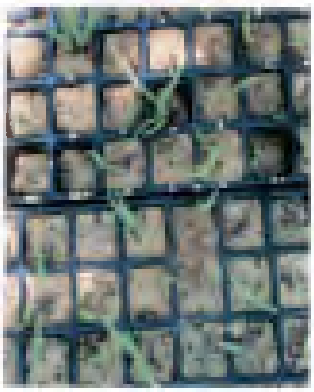

Plate.5.a.Sprouted stem disc cuttings of *Aloe vera*

T_{37}-$P_4S_1G_1$: no pre-curing+one node+ BA(1000ppm)& GA3(25ppm)

T_{38}-$P_4S_1G_2$: no pre-curing+one node+ BA(2ppm)&IAA(2ppm)

T_{39}-$P_4S_1G_3$: no pre-curing+one node+honey

T_{40}-$P_4S_1G_4$: no pre-curing+one node+control

T_{41}-$P_4S_2G_1$: no pre-curing+two node+ BA(1000ppm)& GA3(25ppm)

T_{42}-$P_4S_2G_2$: no pre-curing+two node+ BA(2ppm)&IAA(2ppm)

T_{43}-$P_4S_2G_3$: no pre-curing+two node+honey

T_{44}-$P_4S_2G_4$: no pre-curing+two node+control

T_{45}-$P_4S_3G_1$: no pre-curing+three node+ BA(1000ppm)& GA3(25ppm)

T_{46}-$P_4S_3G_2$: no pre-curing+three node+BA(2ppm)&IAA(2ppm)

T_{47}-$P_4S_3G_3$: no pre-curing+three node+honey

T_{48}-$P_4S_3G_4$: no pre-curing+three node+control

3.4.OBSERVATIONS

3.4.1.In the Nursery

3.4.1.1.Sprouting percent

The number of disc cuttings sprouted were counted for a period of first two weeks and expressed as percentage.

3.4.1.2.Survival percent

The number of sprouted disc cuttings survived in the nursery stage were counted for first two months and expressed as percentage.

3.4.1.3.Seedling height

The height of the seedlings was measured from the ground level to the top most leaf of all observational plants,mean worked out and expressed in centimeter.

3.4.1.4.Number of leaves

Number of leaves were determined by counting the number of leaves at weekly interval.

3.4.1.5.Number of roots

The plants were uprooted 2 MAP and maximum number of roots was counted and mean worked out.

3.4.1.6.Root length

The plants were uprooted with disc and maximum length of roots were measured and the mean length expressed in centimeter.

3.4.1.7.Root girth

Root girth is the circumference or perimeter of the roots.Circumference of the roots were measured and expressed in centimeter.

3.4.2.Morphological Characters

Three plants from each treatment were selected and tagged for recording the morphological parameters from planting till harvesting at monthly intervals.

3.4.2.1.Plant Height

Plant height is the shortest distance between the upper boundary of the main photosynthetic tissues (excluding inflorescences) on a plant and the ground level.The height of the plant was measured from ground level to the top most leaf of all observational plants,mean worked out and expressed in centimeter.

3.4.2.2.Number of leaves

The number of fully opened leaves was counted at weekly interval and the mean was recorded.

3.4.2.3.Leaf length

The length of the leaf was measured from the base of the leaf to the tip and expressed in centimetres.As the *Aloe vera* plant show similarity with pineapple in the leaf orientation the

"D"leaf(Ray,1999) which is the longest flly grown leaf was selected for recording the morphological characters.

3.4.2.4.Leaf breadth

The maximum breadth of the reference leaf was measured from the basal portion of the leaf and expressed in centimeter.

3.4.2.5.Leaf thickness

The maximum thickness from the middle portion of the reference leaf was measured using vernier calipers and expressed in centimeter.

3.4.2.6.Leaf weight

Fresh weight of the reference leaf was measured and expressed in gram.

3.4.2.7.Number of offsets

The number of offsets produced by the sample plants for the growth period as counted and recorded as number of offsets per plant.

3.4.3.GROWTH CHARACTERS

Absolute Growth Rate(AGR),Relative Growth Rate(RGR) and Net Assimilation Rate(NAR)were computed at bimonthly intervals from 2 MAP till final harvest.

3.4.3.1.Absolute Growth Rate(AGR)

Absolute Growth Rate (AGR) is the total gain in height or weight by a plant within a specific time interval.It is generally expressed as mm per day in case of plant height.AGR was computed by the following formula.

$$AGR(\text{height day}^{-1}) = \frac{H_2-H_1}{t_2-t_1}$$

where,H_1 and H_2 stand for plant height per plant at t_1 and t_2 times,respectively.

3.4.3.2.Relative Growth Rate(RGR)

From two consecutive harvests at time t1 and t2,yielding plant masses M1 and M2,the average Relative Growth Rate was expressed as g day^{-1}.

$$RGR = \frac{(\log_e M_2 - \log_e M_1)}{(t_2 - t_1)}$$

Logarithmic transformation was done before the statistical analysis.

3.4.3.3.Net Assimilation Rate (NAR)

Net Assimilation Rate (NAR) was calculated and expressed in g m^2day^{-1}.NAR was calculated as per the procedure given by Watson (1958) and modified by Buttery (1970).

$$NAR = \frac{W_2 - W_1}{(t_2 - t_1)(A_1 + A_2)/2}$$

Where,

W_2-total dry weight of the plant in g at time t_2

W_1-total dry weight of the plant in g at time t_1

(t2-t1) = time interval in days

A_2 = Leaf area (cm^2)at time t_2

A_1= Leaf area (cm^2)at time t_1

3.4.3.4.Leaf Area Index

Leaf area index (LAI) was calculated by bimonthly intervals from 2MAP.Leaf Area Index refers to the leaf area per unit area of land.Length (l) and breadth(b) of one hundred leaves were recorded.The corresponding leaf area of these leaves was recorded graphically.Based on the

relationship between the above parameters,the following regression equation was computed statistically to estimate the leaf area of the sample plants.

Leaf Area = 0.521(lxb)

Where,l and b is the length and breadth of the sample leaves respectively.

The LAI was computed using the equation

$$LAI = \frac{\text{Sum of leaf area of N sample } (cm^2)}{\text{Area of land covered by N plants } (cm^2)}$$

3.4.4.Yield

3.4.4.1.Fresh Leaf Yield

Three cuttings were taken from each plant.First cutting was taken 2 months after planting and subsequent two cuttings were taken at two months intervals at 4 and 6MAP.The fully grown mature leaves from the tagged plants were judged by visual observation .These leaves were removed from the plants at their point of attachment with a sharp knife and counted.The leaves were then wiped with a clean cloth to remove the soil particles adhered to it and weighted and the pooled data presented as yield per plant and expressed in kg $plant^{-1}$.

3.4.4.2.Fresh Latex Yield

The leaves after cleaning were given a transverse cut 2 cm above the basal portion and immediately placed in a slanting position in a pre-weighed petri dish and allowed to remain undisturbed for half an hour for complete draining of the latex.After the cessation of latex exudation,the petri dish along with the latex was weighed again and difference in weight was recorded.The latex weights per leaf during each harvest were summed upto get the total weight and were expressed in grams $plant^{-1}$ $year^{-1}$.

3.4.4.3.Gel Yield

Immediately after harvesting, the Aloe leaves are tipped, tailed, and its spiny ridges are removed after harvesting. For the extraction, juice is allowed to drain from the cut leaves into suitable vessels or it can simply be squeezed or grinded to get the gel. There are other sophisticated ways

to separate the gel without loss of the product quality (Nilanjana Das and R N Chattopadhay,2004).The gel yield per leaf were expressed in grams plant^{-1}year-^{1}.

3.5.Incidence of pests and diseases

The plants were closely observed at regular intervals for the presence of any pest and disease.

3.6.Economics

The total income,total cost,net return and benefit:cost ratio (BCR) of various treatments as worked out considering the cost of cultivation and the income derived from each treatment.The norms and rates prevalent at Instructional Farm,College of Agriculture,Vellayani during 2014-2016 were followed for estimation.The cost of planting material was taken as Rs.15 per sucker.

Net Return(Rs ha^{-1})=Gross income-cost of cultivation

$$BCR = \frac{\text{Gross income}}{\text{Total expenditure}}$$

Statistical analysis was worked out using Analysis of Variance.

RESULTS

4. RESULTS

The study entitled "Refinement of macro-propagation technique for mass-multiplication of aloe (*Aloe vera* L.Burm.f.) was conducted at the Department of Plantation Crops and Spices,College of Agriculture,Vellayani during 2014-2016.The data collected from the field experiment were statistically analysed and the results are presented in this chapter.

4.1. Sprouting percentage

The data recorded 21DAP of disc cuttings in protray suggest that both the segment size as well as the pre-treatments given significantly influenced sprouting (Table.1).

Three node disc cuttings collected from *in situ* decapitated parent material which were treated with Benzyl Adenine (1000 ppm) and Gibberillic Acid (25 ppm) (T_9-$P_1S_3G_1$) recorded the highest sprouting percentage(80.60%) followed by T_{10} (78.20%)[($P_1S_3G_2$-three node disc cuttings from *in situ* decapitated mother plants soaked in Benzyl Adenine (2ppm) and Indole Acetic Acid (2ppm)].Treatments T_{21}[($P_2S_3G_1$: Partial crushing of internode+three node+ BA(1000ppm)& GA3(25ppm)],T_{33}[$P_3S_3G_1$: foliar spraying of BA +three node+ BA(1000ppm)& GA3(25ppm)] and T_{34} [$P_3S_3G_2$: foliar spraying of BA+ three node+ BA(2ppm)&IAA(2ppm)] showed more than 70% sprouting percentage. The lowest sprouting percentage (27.85) was given by one node disc cuttings treated with honey taken from mother plants without pre-curing (T39-P4S1G3) which was on par with control T_{48}(28%)[$P_4S_3G_4$: no pre-curing+three node+control]

Overall perusal of the data indicates that, treatment combinations with three node disc cuttings showed better sprouting than 2 node and 1 node disc cuttings. Among the pre curing treatments, partial crushing of the internodes of mother plants was found to be more effective (48.20) than *in situ* decapitation (43.20) in inducing axillary bud break. Axillary bud break in control plants was very low. Among the pre sprouting treatments, soaking the cuttings in growth regulators BA(1000ppm), GA3(25ppm), BA(2ppm)&IAA(2ppm) were found to enhance sprouting while honey treatment had practically no effect. Sprouting percentage was low in untreated cuttings also.

Table 1. Effect of treatments on the sprouting percentage(%) of *Aloe vera* cuttings

Treatment	21DAS
T_1 $P_1S_1G_1$	33.50
T_2 $P_1S_1G_2$	33.50
T_3 $P_1S_1G_3$	00.00
T_4 $P_1S_1G_4$	30.00
T_5 $P_1S_2G_1$	48.20
T_6 $P_1S_2G_2$	52.30
T_7 $P_1S_2G_3$	32.30
T_8 $P_1S_2G_4$	44.60
T_9 $P_1S_3G_1$	80.60
T_{10} $P_1S_3G_2$	78.20
T_{11} $P_1S_3G_3$	46.00
T_{12} $P_1S_3G_4$	42.30
T_{13} $P_2S_1G_1$	30.00
T_{14} $P_2S_1G_2$	33.20
T_{15} $P_2S_1G_3$	34.50
T_{16} $P_2S_1G_4$	34.00
T_{17} $P_2S_2G_1$	52.60
T_{18} $P_2S_2G_2$	64.00
T_{19} $P_2S_2G_3$	48.50
T_{20} $P_2S_2G_4$	46.60
T_{21} $P_2S_3G_1$	75.30
T_{22} $P_2S_3G_2$	66.45
T_{23} $P_2S_3G_3$	45.50
T_{24} $P_2S_3G_4$	48.00
T_{25} $P_3S_1G_1$	32.30
T_{26} $P_3S_1G_2$	35.60
T_{27} $P_3S_1G_3$	30.30

T_{28} $P_3S_1G_4$	32.50
T_{29} $P_3S_2G_1$	46.60
T_{30} $P_3S_2G_2$	54.20
T_{31} $P_3S_2G_3$	34.50
T_{32} $P_3S_2G_4$	31.00
T_{33} $P_3S_3G_1$	72.40
T_{34} $P_3S_3G_2$	70.50
T_{35} $P_3S_3G_3$	44.50
T_{36} $P_3S_3G_4$	48.00
T_{37} $P_4S_1G_1$	30.00
T_{38} $P_4S_1G_2$	30.50
T_{39} $P_4S_1G_3$	27.85
T_{40} $P_4S_1G_4$	32.30
T_{41} $P_4S_2G_1$	44.40
T_{42} $P_4S_2G_2$	42.70
T_{43} $P_4S_2G_3$	38.00
T_{44} $P_4S_2G_4$	42.00
T_{45} $P_4S_3G_1$	48.80
T_{46} $P_4S_3G_2$	44.50
T_{47} $P_4S_3G_3$	42.30
T_{48} $P_4S_3G_4$	28.00
SEm	0.015
CD(0.05)	0.042

DAS :Days after sowing

4.2.Survival percentage

The survival percentage calculated at 4WAP revealed that pre-treatments, segment size and growth regulator treatments significantly influenced the survival of sprouted seedlings (Table.2).

Three node disc cuttings collected from *in situ* decapitated parent material which were treated with BA(1000ppm) and GA3(25ppm) (T_9 - $P_1S_3G_1$) recorded the highest survival percentage(100) followed by T_{10}- $P_1S_3G_2$ (92.50). A survival percentage of more than 70 was noticed in treatment combinations T_{11}, T_{17}, T_{18}, T_{21}, T_{22}, T_{30}, T_{34} and T_{35} ($P_1S_3G_3$, $P_2S_2G_1$, $P_2S_2G_2$, $P_2S_3G_1$, $P_2S_3G_2$, $P_3S_2G_2$, $P_3S_3G_2$and $P_3S_3G_3$ respectively). Treatment T_{40} ($P_4S_1G_4$) showed the lowest survival percentage (33.80) after 4 weeks of planting.

4.3. Morphological Characters of the Seedlings in the Nursery

4.3.1. Seedling height

The size of the stem disc as well as the pre-curing and pre –sprouting treatments combination significantly influenced seedling growth as observed by the steady increase in seedling height throughout the observational period (Table.3).

At 1 WAP, T_{21}($P_2S_3G_1$) recorded the highest (4.30 cm) seedling height which was on par with T_9 (P1S3G1-3.70cm), T_{10}- $P_1S_3G_2$ -3.20cm) and T_{10}- $P_1S_3G_2$ 3.30cm). At 2 and 5 WAP no significant difference in seedling height was noticed among the treatments. At 3 WAP, T_9 recorded the highest seedling height (6.70cm) followed by T_{10}-$P_1S_3G_2$-4.90cm), T_{21}($P_3S_3G_1$) and T_{41}($P_4S_2G_1$)-4.80cm. T_9 ($P_1S_3G_1$ -7.90cm) showed superior seedling height at 4WAP which was on par with T_{21}($P_2S_3G_1$-7.1cm) followed by T_{10}-$P_1S_3G_2$ -6.70cm and T_{25}($P_3S_1G_1$-5.60cm).

During the 6th week of observation the highest seedling height (10.20cm) was recorded by treatment T_9 ($P_1S_3G_1$) which was on par with T_{10}-$P_1S_3G_2$-9.90cm), T_{21}($P_2S_3G_1$-9.80cm) and T_{25} ($P_3S_1G_1$-9.80cm).The lowest value was given by T_{48} ($P_4S_3G_4$-3.80cm) during the observational period.

4.3.2. Number of leaves

Table 2. Effect of treatments on the survival percentage (%) *Aloe vera* seedlings

Treatment	Survival percentage(%)
	4 WAP
T_1 $P_1S_1G_1$	74.50
T_2 $P_1S_1G_2$	68.00
T_3 $P_1S_1G_3$	00.00
T_4 $P_1S_1G_4$	65.50
T_5 $P_1S_2G_1$	58.60
T_6 $P_1S_2G_2$	54.00
T_7 $P_1S_2G_3$	60.00
T_8 $P_1S_2G_4$	52.00
T_9 $P_1S_3G_1$	100.0
T_{10} $P_1S_3G_2$	92.50
T_{11} $P_1S_3G_3$	74.00
T_{12} $P_1S_3G_4$	54.00
T_{13} $P_2S_1G_1$	48.40
T_{14} $P_2S_1G_2$	64.60
T_{15} $P_2S_1G_3$	44.50
T_{16} $P_2S_1G_4$	68.90
T_{17} $P_2S_2G_1$	76.00
T_{18} $P_2S_2G_2$	85.90
T_{19} $P_2S_2G_3$	40.00
T_{20} $P_2S_2G_4$	43.20
T_{21} $P_2S_3G_1$	72.60
T_{22} $P_2S_3G_2$	78.60
T_{23} $P_2S_3G_3$	34.00
T_{24} $P_2S_3G_4$	64.00
T_{25} $P_3S_1G_1$	48.50
T_{26} $P_3S_1G_2$	46.60
T_{27} $P_3S_1G_3$	45.90
T_{28} $P_3S_1G_4$	46.00
T_{29} $P_3S_2G_1$	42.30
T_{30} $P_3S_2G_2$	74.00
T_{31} $P_3S_2G_3$	52.20
T_{32} $P_3S_2G_4$	44.50
T_{33} $P_3S_3G_1$	68.30
T_{34} $P_3S_3G_2$	74.50
T_{35} $P_3S_3G_3$	82.80
T_{36} $P_3S_3G_4$	54.10
T_{37} $P_4S_1G_1$	45.60
T_{38} $P_4S_1G_2$	44.40
T_{39} $P_4S_1G_3$	48.50

T_{40} $P_4S_1G_4$	33.80
T_{41} $P_4S_2G_1$	48.30
T_{42} $P_4S_2G_2$	45.00
T_{43} $P_4S_2G_3$	48.50
T_{44} $P_4S_2G_4$	36.40
T_{45} $P_4S_3G_1$	42.60
T_{46} $P_4S_3G_2$	58.20
T_{47} $P_4S_3G_3$	38.60
T_{48} $P_4S_3G_4$	47.50
SEm	0.356
CD(0.05)	1.024

WAP :Weeks after planting

Fig:2.Effect of different pre-treatments and disc size on sprouting percentage of *Aloe vera*

Fig:3. Effect of different pre-treatments and disc size on survival percentage of *Aloe vera*

Fig:4.Effect of honey treated disc on sprouting percentage of *Aloe vera*

T_9 T_{48} T_{25} T_{21} T_{10}

Fig:5.Effect of treatment on seedling height of *Aloe vera* at the time of transplanting

Table 3. Effect of treatments on seedling height(cm) of *Aloe vera* at nursery

Treatments	Seedling height(cm)					
	1WAP	2WAP	3WAP	4WAP	5WAP	6WAP
T_1 $P_1S_1G_1$	1.00	1.80	2.90	3.80	5.00	5.80
T_2 $P_1S_1G_2$	1.30	2.10	3.00	4.10	5.00	6.30
T_3 $P_1S_1G_3$	0.00	0.00	0.00	0.00	0.00	0.00
T_4 $P_1S_1G_4$	0.80	1.20	1.90	2.40	3.60	4.00
T_5 $P_1S_2G_1$	1.70	1.90	2.60	4.40	6.20	8.00
T_6 $P_1S_2G_2$	1.60	1.90	4.20	4.60	6.10	8.20
T_7 $P_1S_2G_3$	0.70	0.90	2.85	3.15	3.90	4.20
T_8 $P_1S_2G_4$	1.00	1.40	1.40	3.60	4.20	5.70
T_9 $P_1S_3G_1$	3.70	5.20	6.70	7.90	9.80	10.20
T_{10} $P_1S_3G_2$	3.20	4.60	4.90	6.70	9.10	9.90
T_{11} $P_1S_3G_3$	0.60	1.80	2.35	3.10	3.40	4.10
T_{12} $P_1S_3G_4$	1.10	2.40	2.90	4.00	4.30	5.00
T_{13} $P_2S_1G_1$	1.00	1.20	2.30	3.00	3.20	4.20
T_{14} $P_2S_1G_2$	1.10	1.70	2.60	3.90	4.00	5.60
T_{15} $P_2S_1G_3$	1.00	1.40	1.90	2.50	3.40	4.20
T_{16} $P_2S_1G_4$	1.00	1.50	2.00	2.70	3.20	4.00
T_{17} $P_2S_2G_1$	1.40	1.80	2.30	4.00	4.60	5.80
T_{18} $P_2S_2G_2$	1.70	2.90	3.80	5.10	6.00	6.70
T_{19} $P_2S_2G_3$	1.40	2.80	3.50	5.00	5.90	6.20
T_{20} $P_2S_2G_4$	0.90	1.20	1.80	2.30	3.00	5.80
T_{21} $P_2S_3G_1$	4.30	4.80	4.80	7.10	9.20	9.80
T_{22} $P_2S_3G_2$	1.30	1.70	3.40	4.10	6.00	6.60
T_{23} $P_2S_3G_3$	1.00	1.60	1.90	3.60	5.00	5.70
T_{24} $P_2S_3G_4$	0.90	1.20	3.10	4.00	4.30	5.00
T_{25} $P_3S_1G_1$	2.40	2.90	3.80	5.60	9.00	9.80

T_{26} $P_3S_1G_2$	1.60	2.60	3.20	3.25	5.40	6.20
T_{27} $P_3S_1G_3$	1.10	2.60	3.20	3.35	5.00	4.20
T_{28} $P_3S_1G_4$	0.90	1.80	2.30	2.80	3.10	4.00
T_{29} $P_3S_2G_1$	1.20	1.90	2.40	2.40	5.00	5.80
T_{30} $P_3S_2G_2$	1.50	2.10	2.90	3.25	5.30	6.10
T_{31} $P_3S_2G_3$	1.60	2.10	2.70	3.70	5.50	6.20
T_{32} $P_3S_2G_4$	1.00	2.60	2.60	3.10	4.00	4.70
T_{33} $P_3S_3G_1$	1.40	2.30	3.60	4.40	5.00	6.20
T_{34} $P_3S_3G_2$	1.60	2.60	3.20	3.25	5.00	6.20
T_{35} $P_3S_3G_3$	0.90	2.20	3.00	3.10	3.00	4.20
T_{36} $P_3S_3G_4$	1.10	2.50	3.10	3.35	4.00	4.60
T_{37} $P_4S_1G_1$	1.70	2.40	2.90	3.80	5.70	6.10
T_{38} $P_4S_1G_2$	1.60	2.30	2.80	3.85	5.50	6.00
T_{39} $P_4S_1G_3$	0.90	1.60	2.10	3.00	3.60	4.20
T_{40} $P_4S_1G_4$	3.00	3.70	3.80	4.30	4.70	4.90
T_{41} $P_4S_2G_1$	3.30	4.80	4.80	4.10	4.20	4.80
T_{42} $P_4S_2G_2$	3.70	4.20	4.50	4.50	4.80	5.20
T_{43} $P_4S_2G_3$	1.10	2.40	2.90	3.20	4.20	4.60
T_{44} $P_4S_2G_4$	1.00	2.30	2.80	3.00	3.70	3.90
T_{45} $P_4S_3G_1$	1.10	1.70	3.00	3.80	4.00	4.90
T_{46} $P_4S_3G_2$	1.10	1.60	1.90	2.50	3.20	4.30
T_{47} $P_4S_3G_3$	0.90	1.50	2.50	3.20	4.00	4.00
T_{48} $P_4S_3G_4$	0.80	1.20	1.30	2.30	3.20	3.80
SEm	0.354	-	0.010	0.217	-	0.060
CD(0.05)	1.194	NS	0.257	0.945	NS	0.495

WAP – Weeks After Planting

Table 4. Effect of treatments on number of leaves of *Aloe vera* at nursery

Treatments	Number of leaves				
	2WAP	3WAP	4WAP	5WAP	6WAP
T_1 $P_1S_1G_1$	2.00	2.00	3.00	3.00	3.00
T_2 $P_1S_1G_2$	2.00	2.00	3.00	3.00	3.00
T_3 $P_1S_1G_3$	0.00	0.00	0.00	0.00	0.00
T_4 $P_1S_1G_4$	2.50	2.50	3.00	3.00	3.00
T_5 $P_1S_2G_1$	2.00	2.00	3.00	4.00	4.00
T_6 $P_1S_2G_2$	2.00	2.00	2.00	3.00	3.00
T_7 $P_1S_2G_3$	2.00	2.00	2.00	2.00	2.00
T_8 $P_1S_2G_4$	2.00	2.00	2.00	2.00	2.00
T_9 $P_1S_3G_1$	2.00	3.00	3.00	4.00	4.00
T_{10} $P_1S_3G_2$	2.00	3.00	3.00	3.00	4.00
T_{11} $P_1S_3G_3$	2.00	2.00	2.00	2.00	3.00
T_{12} $P_1S_3G_4$	2.00	2.00	2.00	2.00	3.00
T_{13} $P_2S_1G_1$	2.00	2.00	2.50	2.50	4.00
T_{14} $P_2S_1G_2$	2.00	2.00	2.00	2.00	3.00
T_{15} $P_2S_1G_3$	2.00	2.00	2.00	2.00	2.00
T_{16} $P_2S_1G_4$	2.00	2.00	2.00	2.00	2.00
T_{17} $P_2S_2G_1$	2.00	2.00	2.00	3.00	3.00
T_{18} $P_2S_2G_2$	2.00	2.00	2.00	3.00	3.00
T_{19} $P_2S_2G_3$	2.00	2.00	2.00	3.00	3.00
T_{20} $P_2S_2G_4$	2.00	2.00	2.00	3.00	3.00
T_{21} $P_2S_3G_1$	2.00	3.00	3.00	4.00	4.00
T_{22} $P_2S_3G_2$	2.00	3.00	3.00	3.00	3.00

T_{23} $P_2S_3G_3$	2.00	2.00	2.00	3.00	3.00
T_{24} $P_2S_3G_4$	2.00	2.00	2.00	3.00	3.00
T_{25} $P_3S_1G_1$	2.00	3.00	4.00	4.00	5.00
T_{26} $P_3S_1G_2$	2.00	2.00	2.00	2.00	3.00
T_{27} $P_3S_1G_3$	2.00	2.00	2.00	2.00	3.00
T_{28} $P_3S_1G_4$	2.00	2.00	3.00	3.00	3.00
T_{29} $P_3S_2G_1$	2.00	2.00	3.00	3.00	3.00
T_{30} $P_3S_2G_2$	2.00	2.00	3.00	4.00	4.00
T_{31} $P_3S_2G_3$	2.00	2.00	3.00	3.00	3.00
T_{32} $P_3S_2G_4$	2.00	3.00	3.00	4.00	4.00
T_{33} $P_3S_3G_1$	2.00	3.00	4.00	4.00	5.00
T_{34} $P_3S_3G_2$	2.00	3.00	4.00	4.00	5.00
T_{35} $P_3S_3G_3$	2.00	2.00	2.00	3.00	3.00
T_{36} $P_3S_3G_4$	2.00	2.00	3.00	4.00	4.00
T_{37} $P_4S_1G_1$	2.00	2.00	3.00	3.00	4.00
T_{38} $P_4S_1G_2$	2.00	3.00	4.00	4.00	4.00
T_{39} $P_4S_1G_3$	2.00	2.00	2.00	4.00	4.00
T_{40} $P_4S_1G_4$	2.00	3.00	3.00	4.00	4.00
T_{41} $P_4S_2G_1$	2.00	2.00	2.00	3.00	3.00
T_{42} $P_4S_2G_2$	2.00	2.00	2.00	2.00	2.50
T_{43} $P_4S_2G_3$	2.00	2.00	2.00	3.00	3.00
T_{44} $P_4S_2G_4$	2.00	2.00	2.00	3.00	3.00
T_{45} $P_4S_3G_1$	2.00	2.00	2.00	3.00	3.00
T_{46} $P_4S_3G_2$	2.00	3.00	3.00	4.00	4.00

T_{47} $P_4S_3G_3$	2.00	2.00	2.00	3.00	3.00
T_{48} $P_4S_3G_4$	2.00	2.00	2.00	2.00	2.00
SEm	-	-	0.014	0.014	0.014
CD(0.05)	NS	NS	0.202	0.202	0.202

WAP:Weeks After Planting

No significant difference in the number of leaves among the treatment combinations was observed during first 3 weeks of observation (Table. 4)

The trend in the number of leaves followed more or less similar pattern for various treatment combinations during 4^{th} and 5^{th} weeks of observation. At 6^{th} week of observation, treatments $T_{25}(P_3S_1G_1)$, $T_{33}(P_3S_3G_1)$ and $T_{34}(P_3S_3G_2)$ recorded the highest number of leaves(5.00).

4.3.3.Number of roots

Significant difference in the number of roots was observed due to the pre-curing and pre-sprouting treatments on the planted discs during the period of observation (Table. 5).

Among the treatment combinations, $T_9(P_1S_3G_1)$ recorded maximum number of roots (6.00) during 1month after planting which was on par with $T_{10}(P_1S_3G_2)$(5.50) and T_{33}($P_3S_3G_1$)(5.50). During 2 months after planting also T_9 $P_1S_3G_1$ recorded maximum number of roots (6.00) treatments which was on par with T_1 $(P_1S_1G_1)$ (5.0), T_{10} $(P_1S_3G_2)$ (5.5), T_{13} $(P_2S_1G_1)$(5.00), T_{17} $(P_2S_2G_1)$(5.00), T_{18} $(P_2S_2G_2)$ (5.00), T_{20} $(P_2S_2G_{40})$(5.00), T_{21} $(P_2S_3G_1)$ (5.00), T_{22} $(P_2S_3G_2)$ (5.00), and T_{33} ($P_3S_3G_1$)(5.50).

Seedlings of single noded disc without pre-curing treated with honey, T_{39} $(P_4S_1G_3)$recorded the lowest number of roots(2.0) during the nursery period.

4.3.4. Root length (cm)

As observed in Table. 6, the size of the disc cutting, the pre-curing and the pre-sprouting treatment combination significantly influenced the length of roots throughout the nursery period.

Among the treatment combinations,T_{10} $(P_1S_3G_1)$ recorded the maximum root length(4.65cm) at 1^{st} month of observation at nursery followed by $T_{41}(P_4S_2G_1$-3.50cm) and $T_6(P_1S_2G_2$-3.35cm).Treatment,T_9 $(P_1S_3G_1$-8.85cm) showed the highest value which was on par with $T_{10}(P_1S_3G_2$-8.60cm) during the 2^{nd} month of observation at nursery. Treatments $T_1,T_5,T_{12},T_{15},T_{21},T_{22},T_{23},T_{26},T_{27},T_{29},T_{33},T_{43},T_{45}$ and T_{47} attained root length more than 5cm.

Plate.6.a,b. Experimental view of *Aloe vera* stem disc cuttings in pro-trays

Seedlings of single node disc without pre-curing and growth regulator treatment,T_{40} ($P_4S_1G_4$) recorded the lowest value(3.6cm) at 2 MAP.

4.3.5.Root Girth(cm)

As observed in Table.7, the size of the disc cuttings, pre-curing as well as the pre-sprouting treatment combination significantly influenced the girth of roots throughout the nursery period. Among the treatment combinations, T_{10} ($P_1S_3G_2$) recorded the maximum root girth(0.65cm) which was on par with T_9(0.63cm),followed by T_{34}($P_3S_3G_2$-0.41cm) and T_{45} $P_4S_3G_1$-0.40cm) at 1st month of observation at nursery. At 2 MAP, T_9 (0.74cm) recorded the highest root girth which was on par with T_{10}(0.73cm).Seedlings of single node disc(0.20cm) recorded the lowest value during the observational period.

4.4.Morphological characters after transplanting

4.4.1.Plant height(cm)

Average height of the plant recorded at 1,2,3,4,5 and 6 MAP is presented in the Table.9.

The perusal of the data revealed that the various pre-curing as well as the growth regulator treatments significantly influenced the plant height at all growth stages. Among the type of seedlings, seedlings of 3 node stem disc from *in situ* decapitated parent material treated with BA(1000ppm) and GA3(25ppm)($P_1S_3G_1$) produced significantly superior plant height. Lowest plant height was noticed in T_{48} ($P_4S_3G_4$) in all the stages.

With regard to seedling height, treatment T_9 (10.85cm) was found superior followed by T_{10}(10.00cm) and T_{33}(9.60cm) at 1st month of observation. At 2 MAP, the treatment T_{33} (16.03cm) recorded highest plant height which was followed by T_9(14.20cm) and T_{10} (13.36cm).At 3MAP also,T_{33}($P_3S_3G_1$-21.60cm)recorded the highest plant height followed by T_{25} (18.63cm) and T_9(18.40cm). T_{33}(27.36cm) recorded highest plant height at 4MAP followed by T_{21}(24.20cm) and T_{10}(24.16cm).At 5MAP,the highest plant height was noticed in T_{33}(33.33cm) followed by T_9(30.06cm) and T_{10}. At 6 MAP, maximum plant height (37.70 cm) was associated with T_9($P_1S_3G_1$) which was on par with T_{10}(36.80cm) and T_{21}(36.80cm).Treatment combinations involving honey also gave positive response with regard to seedling height.

Table 5. Effect of treatments on number of roots at different growth stages in nursery

Treatments	Number of roots	
	1MAP	2MAP
T_1 $P_1S_1G_1$	3.50	5.00
T_2 $P_1S_1G_2$	4.00	4.50
T_3 $P_1S_1G_3$	0.00	0.00
T_4 $P_1S_1G_4$	2.00	4.00
T_5 $P_1S_2G_1$	3.00	4.00
T_6 $P_1S_2G_2$	2.00	4.00
T_7 $P_1S_2G_3$	2.00	4.00
T_8 $P_1S_2G_4$	2.00	4.00
T_9 $P_1S_3G_1$	6.00	6.00
T_{10} $P_1S_3G_2$	5.50	5.50
T_{11} $P_1S_3G_3$	2.00	3.50
T_{12} $P_1S_3G_4$	2.00	2.50
T_{13} $P_2S_1G_1$	2.50	5.00
T_{14} $P_2S_1G_2$	3.00	4.00
T_{15} $P_2S_1G_3$	2.00	3.50
T_{16} $P_2S_1G_4$	2.00	3.50
T_{17} $P_2S_2G_1$	5.00	5.00
T_{18} $P_2S_2G_2$	2.50	5.00
T_{19} $P_2S_2G_3$	2.50	3.50
T_{20} $P_2S_2G_4$	2.00	5.00
T_{21} $P_2S_3G_1$	4.00	5.00
T_{22} $P_2S_3G_2$	3.50	5.00
T_{23} $P_2S_3G_3$	2.00	3.00
T_{24} $P_2S_3G_4$	2.00	3.00
T_{25} $P_3S_1G_1$	4.50	4.50
T_{26} $P_3S_1G_2$	2.50	2.50
T_{27} $P_3S_1G_3$	2.00	3.50
T_{28} $P_3S_1G_4$	2.50	3.00
T_{29} $P_3S_2G_1$	2.00	4.00
T_{30} $P_3S_2G_2$	2.50	3.50
T_{31} $P_3S_2G_3$	2.00	4.00
T_{32} $P_3S_2G_4$	2.00	4.00
T_{33} $P_3S_3G_1$	5.50	5.50
T_{34} $P_3S_3G_2$	2.50	3.50
T_{35} $P_3S_3G_3$	2.00	2.50
T_{36} $P_3S_3G_4$	2.00	3.50

T_{37} $P_4S_1G_1$	3.50	3.50
T_{38} $P_4S_1G_2$	3.00	3.00
T_{39} $P_4S_1G_3$	2.00	2.00
T_{40} $P_4S_1G_4$	2.00	3.00
T_{41} $P_4S_2G_1$	2.00	3.00
T_{42} $P_4S_2G_2$	2.50	3.50
T_{43} $P_4S_2G_3$	2.50	2.50
T_{44} $P_4S_2G_4$	3.00	3.00
T_{45} $P_4S_3G_1$	2.00	3.50
T_{46} $P_4S_3G_2$	2.00	3.50
T_{47} $P_4S_3G_3$	2.00	3.00
T_{48} $P_4S_3G_4$	2.00	2.50
SEm	0.217	0.375
CD(0.05)	0.945	1.234

MAP – Month After Planting

Table 6. Effect of treatments on the root length(cm) of *Aloe vera* in nursery

Treatments	Root length(cm)	
	1MAP	2MAP
T_1 $P_1S_1G_1$	2.70	5.00
T_2 $P_1S_1G_2$	3.05	6.30
T_3 $P_1S_1G_3$	0.00	0.00
T_4 $P_1S_1G_4$	1.35	4.45
T_5 $P_1S_2G_1$	2.85	5.35
T_6 $P_1S_2G_2$	3.35	4.50
T_7 $P_1S_2G_3$	1.35	4.30
T_8 $P_1S_2G_4$	1.50	4.60
T_9 $P_1S_3G_1$	2.35	8.85
T_{10} $P_1S_3G_2$	4.65	8.60
T_{11} $P_1S_3G_3$	1.25	4.85
T_{12} $P_1S_3G_4$	2.75	6.00
T_{13} $P_2S_1G_1$	1.70	4.30
T_{14} $P_2S_1G_2$	1.35	4.45
T_{15} $P_2S_1G_3$	1.30	5.20
T_{16} $P_2S_1G_4$	1.35	4.50
T_{17} $P_2S_2G_1$	1.25	4.65
T_{18} $P_2S_2G_2$	2.15	4.30
T_{19} $P_2S_2G_3$	1.60	4.20
T_{20} $P_2S_2G_4$	1.25	4.65
T_{21} $P_2S_3G_1$	2.20	5.15
T_{22} $P_2S_3G_2$	2.35	5.50
T_{23} $P_2S_3G_3$	2.60	5.85
T_{24} $P_2S_3G_4$	2.40	4.10
T_{25} $P_3S_1G_1$	1.65	4.40
T_{26} $P_3S_1G_2$	3.10	5.45
T_{27} $P_3S_1G_3$	2.15	5.15
T_{28} $P_3S_1G_4$	1.25	4.00
T_{29} $P_3S_2G_1$	2.80	5.00
T_{30} $P_3S_2G_2$	2.75	4.10
T_{31} $P_3S_2G_3$	2.30	4.95
T_{32} $P_3S_2G_4$	2.65	4.95
T_{33} $P_3S_3G_1$	2.25	5.95
T_{34} $P_3S_3G_2$	2.25	4.55
T_{35} $P_3S_3G_3$	1.70	4.40
T_{36} $P_3S_3G_4$	1.50	4.40
T_{37} $P_4S_1G_1$	2.10	4.30

T_{38} $P_4S_1G_2$	2.05	4.55
T_{39} $P_4S_1G_3$	1.65	4.35
T_{40} $P_4S_1G_4$	3.15	3.60
T_{41} $P_4S_2G_1$	3.50	4.00
T_{42} $P_4S_2G_2$	3.15	3.95
T_{43} $P_4S_2G_3$	1.70	5.10
T_{44} $P_4S_2G_4$	1.40	4.25
T_{45} $P_4S_3G_1$	2.85	5.40
T_{46} $P_4S_3G_2$	2.60	4.50
T_{47} $P_4S_3G_3$	2.40	5.60
T_{48} $P_4S_3G_4$	1.05	4.05
SEm	0.028	0.103
CD(0.05)	0.345	0.638

MAP:Months After Planting

Table.7. Effect of treatments on root girth(cm) in *Aloe vera* at nursery

Treatments	Root girth(cm)	
	1MAP	2MAP
T_1 $P_1S_1G_1$	0.33	0.45
T_2 $P_1S_1G_2$	0.24	0.36
T_3 $P_1S_1G_3$	0.00	0.00
T_4 $P_1S_1G_4$	0.36	0.46
T_5 $P_1S_2G_1$	0.21	0.31
T_6 $P_1S_2G_2$	0.31	0.56
T_7 $P_1S_2G_3$	0.19	0.31
T_8 $P_1S_2G_4$	0.23	0.34
T_9 $P_1S_3G_1$	0.63	0.74
T_{10} $P_1S_3G_2$	0.65	0.73
T_{11} $P_1S_3G_3$	0.30	0.36
T_{12} $P_1S_3G_4$	0.22	0.31
T_{13} $P_2S_1G_1$	0.20	0.30
T_{14} $P_2S_1G_2$	0.25	0.33
T_{15} $P_2S_1G_3$	0.24	0.31
T_{16} $P_2S_1G_4$	0.28	0.37
T_{17} $P_2S_2G_1$	0.31	0.42
T_{18} $P_2S_2G_2$	0.22	0.27
T_{19} $P_2S_2G_3$	0.18	0.26
T_{20} $P_2S_2G_4$	0.23	0.27
T_{21} $P_2S_3G_1$	0.21	0.33
T_{22} $P_2S_3G_2$	0.21	0.29
T_{23} $P_2S_3G_3$	0.23	0.30
T_{24} $P_2S_3G_4$	0.27	0.35
T_{25} $P_3S_1G_1$	0.24	0.35
T_{26} $P_3S_1G_2$	0.32	0.44
T_{27} $P_3S_1G_3$	0.34	0.43
T_{28} $P_3S_1G_4$	0.39	0.49
T_{29} $P_3S_2G_1$	0.27	0.37
T_{30} $P_3S_2G_2$	0.23	0.30
T_{31} $P_3S_2G_3$	0.24	0.35
T_{32} $P_3S_2G_4$	0.26	0.28
T_{33} $P_3S_3G_1$	0.38	0.47
T_{34} $P_3S_3G_2$	0.41	0.46
T_{35} $P_3S_3G_3$	0.38	0.47
T_{36} $P_3S_3G_4$	0.41	0.46

T_{37} $P_4S_1G_1$	0.21	0.26
T_{38} $P_4S_1G_2$	0.28	0.38
T_{39} $P_4S_1G_3$	0.30	0.40
T_{40} $P_4S_1G_4$	0.23	0.35
T_{41} $P_4S_2G_1$	0.27	0.37
T_{42} $P_4S_2G_2$	0.34	0.44
T_{43} $P_4S_2G_3$	0.35	0.46
T_{44} $P_4S_2G_4$	0.37	0.42
T_{45} $P_4S_3G_1$	0.40	0.50
T_{46} $P_4S_3G_2$	0.21	0.30
T_{47} $P_4S_3G_3$	0.19	0.27
T_{48} $P_4S_3G_4$	0.23	0.29
SEm	0.006	0.006
CD(0.05)	0.044	0.044

MAP:Month After Planting

Plate.7.a.General field view after transplanting

Plate.7.b.General field view after transplanting

Table. 8. Effect of treatments on the plant height(cm) of *Aloe vera* at different growth stages

Treatments	Plant Height (cm)					
	1MAP	2MAP	3MAP	4MAP	5MAP	6MAP
T_1 $P_1S_1G_1$	4.50	7.40	12.83	17.00	21.13	25.45
T_2 $P_1S_1G_2$	8.55	11.63	18.30	23.13	28.40	34.10
T_3 $P_1S_1G_3$	0.00	0.00	0.00	0.00	0.00	0.00
T_4 $P_1S_1G_4$	4.25	5.03	5.46	7.10	12.83	17.10
T_5 $P_1S_2G_1$	9.10	10.56	16.26	20.33	27.26	29.45
T_6 $P_1S_2G_2$	6.20	7.76	13.80	18.40	26.70	28.80
T_7 $P_1S_2G_3$	4.10	6.23	10.60	14.03	18.50	21.55
T_8 $P_1S_2G_4$	10.50	13.16	17.76	20.83	26.20	31.70
T_9 $P_1S_3G_1$	10.85	14.20	18.40	23.83	30.06	37.70
T_{10} $P_1S_3G_2$	10.00	13.36	16.30	24.16	28.53	36.80
T_{11} $P_1S_3G_3$	4.30	6.00	8.86	13.10	17.86	20.70
T_{12} $P_1S_3G_4$	9.10	13.20	16.00	19.50	22.03	27.65
T_{13} $P_2S_1G_1$	4.55	7.40	12.83	17.00	21.13	25.45
T_{14} $P_2S_1G_2$	5.60	6.70	12.00	17.00	24.26	29.45
T_{15} $P_2S_1G_3$	4.70	4.86	5.36	11.56	15.23	18.20
T_{16} $P_2S_1G_4$	4.25	7.50	10.43	12.23	14.00	17.00
T_{17} $P_2S_2G_1$	5.65	6.10	7.20	9.23	14.23	20.25
T_{18} $P_2S_2G_2$	5.05	6.80	8.66	13.53	19.46	22.90
T_{19} $P_2S_2G_3$	4.40	6.56	9.06	9.70	12.80	17.70
T_{20} $P_2S_2G_4$	4.25	6.56	8.43	10.76	12.90	17.85
T_{21} $P_2S_3G_1$	7.40	12.36	18.00	24.20	28.93	36.80
T_{22} $P_2S_3G_2$	6.70	8.30	10.00	13.80	21.13	27.15

T_{23} $P_2S_3G_3$	5.65	8.60	12.20	13.96	19.00	24.25
T_{24} $P_2S_3G_4$	5.30	8.70	10.46	13.03	17.03	21.85
T_{25} $P_3S_1G_1$	9.50	10.66	18.63	22.16	28.26	32.75
T_{26} $P_3S_1G_2$	5.35	8.20	12.25	14.13	18.36	22.60
T_{27} $P_3S_1G_3$	5.40	8.26	11.10	11.10	17.63	23.10
T_{28} $P_3S_1G_4$	4.40	7.26	9.26	13.26	18.90	20.95
T_{29} $P_3S_2G_1$	6.30	8.33	10.16	13.96	21.60	25.35
T_{30} $P_3S_2G_2$	6.20	8.36	10.83	14.36	21.90	27.75
T_{31} $P_3S_2G_3$	5.25	8.56	10.90	14.13	16.36	22.55
T_{32} $P_3S_2G_4$	5.45	6.26	6.86	9.60	15.93	19.85
T_{33} $P_3S_3G_1$	9.60	16.03	21.60	27.36	33.33	35.65
T_{34} $P_3S_3G_2$	5.95	7.73	9.66	15.66	25.33	31.20
T_{35} $P_3S_3G_3$	4.50	6.20	7.36	11.00	15.50	19.60
T_{36} $P_3S_3G_4$	4.70	5.60	7.00	10.20	14.20	20.00
T_{37} $P_4S_1G_1$	6.10	6.83	9.06	14.00	20.63	26.70
T_{38} $P_4S_1G_2$	5.90	7.43	13.60	16.53	21.36	26.80
T_{39} $P_4S_1G_3$	4.60	8.00	9.50	14.00	18.80	22.15
T_{40} $P_4S_1G_4$	6.90	9.80	12.63	14.86	17.83	23.40
T_{41} $P_4S_2G_1$	6.50	10.00	13.56	15.00	21.66	27.50
T_{42} $P_4S_2G_2$	6.45	7.36	10.00	16.93	18.90	23.00
T_{43} $P_4S_2G_3$	4.75	6.03	8.23	12.86	16.80	22.60
T_{44} $P_4S_2G_4$	4.20	4.76	6.16	10.26	14.10	19.25
T_{45} $P_4S_3G_1$	7.25	9.46	11.46	14.13	21.06	26.80
T_{46} $P_4S_3G_2$	7.50	9.20	11.60	15.23	21.86	25.65

T_{47} $P_4S_3G_3$	4.15	5.23	6.16	13.50	15.40	18.60
T_{48} $P_4S_3G_4$	3.90	4.10	4.66	5.46	7.83	16.90
SEm	0.157	0.397	0.795	0.921	0.957	0.960
CD(0.05)	0.798	1.020	1.555	1.555	1.580	1.803

MAP:Month After Planting

4.4.2.Number of leaves

The number of leaves were significantly different under different treatments throughout the growth period from 1 MAP to 6 MAP (Table.9).During 1st month of observation,T_{25}(5.00)recorded the highest value which was on par with T_{37},T_{34},T_{22},T_{18}(4.50).Treatment T_{22} produced maximum number of leaves(6.50 and 8.00 during 2 MAP and 3 MAP respectively) followed by treatment T_{33} and T_{25} and they were on par. At 4MAP,treatment T_{33}(10.0) produced the highest number of leaves which was on par with T_{27}(8.50),T_{18}(8.50) and T_9(8.50).

Treatment T_9 produced maximum number of leaves (10.5 and 10.7 during 5 MAP and 6MAP respectively) followed by T_5,T_6,T_{10},T_{25},T_{26} and T_{33} and they were on par. During 1MAP,T_{15} had the least number(2.00) of leaves and during 6 MAP,T_{48} produced the least number(5.00) of leaves.

4.4.3.Leaf length

As observed in the Table.10, the length of *A.vera* leaves varied significantly by the different treatment combinations. The treatment T_9 recorded the highest leaf length of 37.40 cm followed by T_{10} (36.20cm),T_6(35.40cm) and T_{18} (35.80cm) and they were on par during 6th month of observation. At 5MAP, T_{18} (35.00cm) showed the maximum leaf length followed by T_6(32.40cm), T_9(29.25cm) and T_{10}(27.90cm).

The treatments T_9(23.35 cm),T_{10}(23.9cm) and T_{18} (23.75cm) were on par with T_6 (26.85 cm) at 4 MAP. During 3rd month of observation, treatment T_6 (21.50 cm) was on par with T_9 (21.55 cm).Treatment T40 showed the lowest leaf length during 4 MAP, 5MAP and 6MAP(6.70cm,8.50cm and 11.50cm respectively).Treatment T_6 recorded the maximum leaf length during 1st and 2nd month of observation(10.60cm and 15.46cm respectively) followed by T_9 and T_{10} and they were on par.

The lowest value was observed in T_{15}(3.60cm) and T_8(4.20cm) during 1MAP and 2 MAP respectively.

4.4.4.Leaf breadth

Table.9. Effect of treatments on number of leaves of *Aloe vera* at different growth stages

Treatments	Number of leaves					
	1MAP	2MAP	3MAP	4MAP	5MAP	6MAP
T_1 $P_1S_1G_1$	3.00	4.00	6.50	6.50	8.00	8.00
T_2 $P_1S_1G_2$	4.00	4.00	4.50	7.00	7.00	7.00
T_3 $P_1S_1G_3$	0.00	0.00	0.00	0.00	0.00	0.00
T_4 $P_1S_1G_4$	3.00	3.00	4.00	5.00	6.00	6.00
T_5 $P_1S_2G_1$	4.00	4.00	6.00	7.00	8.00	10.5
T_6 $P_1S_2G_2$	3.50	4.00	6.00	8.00	10.0	10.5
T_7 $P_1S_2G_3$	2.50	3.00	5.00	5.00	7.00	7.00
T_8 $P_1S_2G_4$	3.00	3.50	4.50	5.50	7.00	7.00
T_9 $P_1S_3G_1$	4.00	4.50	6.50	8.50	10.5	10.7
T_{10} $P_1S_3G_2$	3.00	4.00	6.00	8.00	10.0	10.5
T_{11} $P_1S_3G_3$	3.00	4.00	5.00	5.00	6.00	6.50
T_{12} $P_1S_3G_4$	3.00	4.00	5.00	6.00	6.50	6.50
T_{13} $P_2S_1G_1$	4.00	5.00	5.00	7.000	7.00	7.50
T_{14} $P_2S_1G_2$	3.50	4.50	5.00	6.00	7.50	7.50
T_{15} $P_2S_1G_3$	2.00	3.00	4.50	4.50	6.00	6.00
T_{16} $P_2S_1G_4$	2.00	3.00	4.00	5.00	6.00	6.00
T_{17} $P_2S_2G_1$	3.00	5.00	6.00	8.00	9.50	9.50
T_{18} $P_2S_2G_2$	4.50	5.50	6.50	8.50	9.00	9.00
T_{19} $P_2S_2G_3$	3.50	4.00	4.00	4.00	5.00	5.50
T_{20} $P_2S_2G_4$	3.00	3.00	4.00	4.00	5.00	5.50
T_{21} $P_2S_3G_1$	4.00	5.00	6.00	7.00	8.00	9.00
T_{22} $P_2S_3G_2$	4.50	6.50	8.00	8.00	9.00	9.00

T_{23} $P_2S_3G_3$	3.00	5.00	5.50	6.00	7.00	7.00
T_{24} $P_2S_3G_4$	3.00	4.00	5.00	6.00	7.00	8.00
T_{25} $P_3S_1G_1$	5.00	6.00	7.00	8.00	10.0	10.0
T_{26} $P_3S_1G_2$	3.00	5.00	6.00	8.00	9.50	9.50
T_{27} $P_3S_1G_3$	3.00	5.50	6.50	8.50	9.00	9.00
T_{28} $P_3S_1G_4$	3.00	4.00	5.00	6.00	7.00	8.00
T_{29} $P_3S_2G_1$	3.00	4.00	5.00	6.00	6.00	6.00
T_{30} $P_3S_2G_2$	4.00	5.00	5.00	7.00	9.00	9.00
T_{31} $P_3S_2G_3$	3.00	3.00	5.00	6.00	6.00	7.00
T_{32} $P_3S_2G_4$	3.50	4.00	5.00	5.00	6.00	7.00
T_{33} $P_3S_3G_1$	4.00	6.00	7.00	9.00	10.0	10.0
T_{34} $P_3S_3G_2$	4.50	4.50	5.50	5.50	6.50	7.00
T_{35} $P_3S_3G_3$	4.00	4.00	5.00	6.00	7.00	7.00
T_{36} $P_3S_3G_4$	3.50	3.00	4.50	4.50	5.00	6.00
T_{37} $P_4S_1G_1$	4.50	5.50	6.00	7.00	8.00	9.00
T_{38} $P_4S_1G_2$	4.00	4.00	5.00	6.00	7.00	9.00
T_{39} $P_4S_1G_3$	3.50	3.50	4.50	4.50	6.00	7.00
T_{40} $P_4S_1G_4$	4.00	4.00	5.00	5.00	6.00	6.50
T_{41} $P_4S_2G_1$	4.00	4.00	6.00	6.50	6.50	7.00
T_{42} $P_4S_2G_2$	4.00	4.50	5.50	6.00	6.50	6.50
T_{43} $P_4S_2G_3$	3.50	4.00	6.00	6.50	7.00	7.50
T_{44} $P_4S_2G_4$	3.50	4.00	6.00	6.00	7.00	7.50
T_{45} $P_4S_3G_1$	3.50	4.500	5.00	5.00	5.50	6.00
T_{46} $P_4S_3G_2$	3.50	4.00	6.00	6.00	7.00	7.00

T_{47} $P_4S_3G_3$	4.00	4.50	6.50	8.00	8.50	8.50
T_{48} $P_4S_3G_4$	3.00	4.00	4.00	4.50	4.50	5.00
SEm	0.174	0.174	0.174	0.200	0.248	0.224
CD(0.05)	0.831	0.831	0.831	0.900	0.996	0.953

Table.10. Effect of treatments on leaf length (cm) of *Aloe vera* at different growth stages

Treatments	Leaf length(cm)					
	1MAP	2MAP	3MAP	4MAP	5MAP	6MAP
T_1 $P_1S_1G_1$	4.00	6.90	12.30	16.30	21.10	24.60
T_2 $P_1S_1G_2$	4.60	6.60	8.10	13.00	13.90	22.30
T_3 $P_1S_1G_3$	0.00	0.00	0.00	0.00	0.00	0.00
T_4 $P_1S_1G_4$	3.66	5.83	7.80	10.10	12.25	15.20
T_5 $P_1S_2G_1$	5.60	9.30	12.65	17.50	21.10	26.30
T_6 $P_1S_2G_2$	10.60	15.46	21.50	26.85	32.40	35.40
T_7 $P_1S_2G_3$	4.13	5.40	6.50	10.05	14.05	18.60
T_8 $P_1S_2G_4$	3.93	4.20	5.90	9.80	13.55	18.50
T_9 $P_1S_3G_1$	10.16	13.83	17.45	23.35	29.25	37.40
T_{10} $P_1S_3G_2$	9.43	12.63	15.90	23.90	27.90	36.20
T_{11} $P_1S_3G_3$	3.93	4.83	5.75	13.10	14.25	18.25
T_{12} $P_1S_3G_4$	4.00	5.80	7.20	9.72	13.20	16.40
T_{13} $P_2S_1G_1$	6.80	9.03	10.75	13.85	20.70	26.20
T_{14} $P_2S_1G_2$	4.10	7.50	9.30	13.50	18.50	21.50
T_{15} $P_2S_1G_3$	3.60	5.30	10.35	13.50	17.50	20.70
T_{16} $P_2S_1G_4$	5.60	6.33	9.50	15.10	17.95	22.85
T_{17} $P_2S_2G_1$	7.83	12.20	15.80	17.70	21.05	24.60
T_{18} $P_2S_2G_2$	6.73	11.83	17.05	23.75	35.00	35.80
T_{19} $P_2S_2G_3$	3.93	4.83	5.75	13.10	14.25	18.25
T_{20} $P_2S_2G_4$	4.10	4.26	5.10	10.90	14.30	17.80
T_{21} $P_2S_3G_1$	4.36	6.26	12.40	16.45	23.50	27.30
T_{22} $P_2S_3G_2$	9.50	12.33	15.00	21.50	27.20	34.80

T_{23} $P_2S_3G_3$	4.53	8.13	9.90	13.20	16.35	21.05
T_{24} $P_2S_3G_4$	5.10	8.10	11.45	13.35	18.35	24.05
T_{25} $P_3S_1G_1$	3.90	5.06	7.90	12.30	17.20	19.70
T_{26} $P_3S_1G_2$	5.53	7.20	13.25	17.40	24.80	27.20
T_{27} $P_3S_1G_3$	4.03	4.73	5.65	9.25	13.70	19.30
T_{28} $P_3S_1G_4$	3.86	6.53	8.90	12.80	18.65	20.70
T_{29} $P_3S_2G_1$	5.80	6.96	12.25	14.80	25.15	30.75
T_{30} $P_3S_2G_2$	6.60	13.46	19.00	25.10	30.50	33.00
T_{31} $P_3S_2G_3$	4.86	7.83	10.65	12.80	18.65	20.70
T_{32} $P_3S_2G_4$	4.93	6.06	6.25	9.35	15.50	19.35
T_{33} $P_3S_3G_1$	9.13	10.16	17.70	21.80	27.50	31.90
T_{34} $P_3S_3G_2$	8.10	9.96	16.75	20.15	27.20	31.60
T_{35} $P_3S_3G_3$	5.93	8.10	10.55	14.00	21.80	27.35
T_{36} $P_3S_3G_4$	4.03	4.73	5.65	9.25	13.70	19.30
T_{37} $P_4S_1G_1$	5.36	6.10	8.35	13.20	20.05	26.15
T_{38} $P_4S_1G_2$	5.16	6.90	13.20	16.25	20.95	26.05
T_{39} $P_4S_1G_3$	4.10	7.50	9.30	13.50	18.50	21.50
T_{40} $P_4S_1G_4$	3.86	4.53	5.00	6.70	8.50	11.55
T_{41} $P_4S_2G_1$	6.00	7.50	9.80	13.30	20.90	25.25
T_{42} $P_4S_2G_2$	4.90	8.60	10.35	13.50	15.85	21.80
T_{43} $P_4S_2G_3$	4.10	5.20	7.60	12.30	16.25	21.90
T_{44} $P_4S_2G_4$	3.93	4.20	5.90	9.80	13.55	18.50
T_{45} $P_4S_3G_1$	6.30	7.90	9.65	13.30	21.10	26.50
T_{46} $P_4S_3G_2$	6.56	8.50	10.95	14.85	21.65	24.85

T_{47} $P_4S_3G_3$	3.86	5.90	8.80	9.15	12.15	16.25
T_{48} $P_4S_3G_4$	4.00	5.46	7.00	10.30	13.10	15.70
SEm	0.159	0.397	1.167	0.891	1.157	1.033
CD(0.05)	0.647	1.011	2.179	1.895	2.159	2.042

MAP: Month After Planting

Fig:9. Effect of treatment on number of leaves of seedling of *Aloe vera* at the time of transplanting

Plate.9.1node disc,2 node disc and 3 node disc of *Aloe vera*

T_{39}

Fig:10.Sprouted *Aloe vera* disc treated with honey

T_{10}

Fig:11.Effect of treatment on number of roots of *Aloe vera* at transplanting

Significant differences were observed among various treatment combinations with respect to mean leaf breadth during different crop periods in the Table.11.In the 1st and 2nd month of observation,treatment T6 showed the superior leaf breadth of 1.75 cm and 2.0cm respectively which was on par with treatments T_{28},T_{29} and T_{37}(1.50cm) at 1MAP and T_2(1.50cm),T_5(1.75cm),T_9(1.90cm),T_{12}(1.80cm),T_{16}(1.90cm),T_{21}(1.85cm) and T_{28}(1.70cm) at 2MAP.

The treatment,T_9(2.50cm) recorded the highest leaf breadth which was on par with T_6(2.35cm),T_{12}(2.30cm),T_{16}(2.25cm),T_{21}(2.45cm),T_{26}(2.35cm),T_{28}(2.15cm) and T_{33}(2.45cm) during 3rd month of observation.At 4 MAP,T_9(5.00cm) recorded the maximum leaf breadth followed by T_{33}(3.50cm) and T_6(3.40cm).The treatment T_9(5.00cm) recorded the maximum leaf breadth followed by T_{33}(4.30cm),T_6(4.10cm) and T_{23}(4.10cm) at 5 MAP.During 6th month of observation,T_9(5.60cm) showed the highest leaf breadth which was on par with T_{33}(5.20cm) and T_{10}(5.45cm). The lowest leaf breadth was recorded in treatment T_{40}(2.70cm) in 6 MAP.

4.4.5.Leaf thickness

As observed in the Table.10,the thickness of *A.vera* leaves varied significantly by the different treatment combinations.The treatment T_{25} recorded the highest leaf thickness of (0.55cm) which was on par with T_6(0.50cm),T_{21}(0.53 cm),T_{26}(0.51cm),T_{27}(0.46cm),T_{41}(0.47 cm)T_{45}(0.51cm) and T_{46}(0.50cm) at 1MAP..

At 2MAP,the treatment T_6(0.750 cm) showed highest value which was on par with T_{26}(0.67cm),T_{27}(0.68cm) and T_{21}(0.70cm).Treatment T_9(0.86cm) showed highest leaf thickness which as on par with treatmentsT_6(0.80cm),T_{25}(0.79cm),T_{26}(0.83cm) during 3rd month of observation.At 4MAP,T9(1.00cm) was on par with T_{26}(0.87cm),T_{22}(0.84cm),T_{21}(0.88cm),T_6(0.85cm),T_8(0.85cm)and T_{12}(0.85cm).Treatment T_9(1.22cm) recorded the superior leaf thickness at 5 MAP followed by T_6 and T_8(1.05cm).At 6MAP T_9 showed the highest leaf thickness(1.35cm) which was on par with T_{21}(1.26cm) and T_{10}(1.30cm).Lowest leaf thickness was recorded in treatment T_{44}($P_4S_2G_4$-0.52cm) during the observation period.

4.4.6.Leaf Weight

Table11:Effect of treatments on leaf breadth(cm) of *Aloe vera* at different growth stages.

Treatments	Leaf breadth(cm)					
	1MAP	2MAP	3MAP	4MAP	5MAP	6MAP
T_1 $P_1S_1G_1$	0.50	0.65	0.95	1.80	2.50	3.20
T_2 $P_1S_1G_2$	0.55	1.50	1.50	1.90	2.40	3.40
T_3 $P_1S_1G_3$	0.00	0.00	0.00	0.00	0.00	0.00
T_4 $P_1S_1G_4$	0.35	0.70	0.95	1.40	2.75	3.00
T_5 $P_1S_2G_1$	1.30	1.75	1.95	3.20	3.90	4.65
T_6 $P_1S_2G_2$	1.75	2.00	2.35	3.40	4.10	4.75
T_7 $P_1S_2G_3$	0.30	0.50	0.90	1.60	3.10	3.20
T_8 $P_1S_2G_4$	0.50	1.10	1.40	2.10	2.40	2.85
T_9 $P_1S_3G_1$	1.35	1.90	2.50	4.10	5.00	5.60
T_{10} $P_1S_3G_2$	0.90	1.15	1.55	2.95	3.95	5.45
T_{11} $P_1S_3G_3$	1.00	1.40	1.75	2.10	2.75	3.00
T_{12} $P_1S_3G_4$	1.45	1.80	2.50	3.15	3.25	4.50
T_{13} $P_2S_1G_1$	0.75	1.20	1.65	2.90	3.00	3.00
T_{14} $P_2S_1G_2$	0.35	0.45	0.80	2.20	3.00	3.00
T_{15} $P_2S_1G_3$	0.55	0.75	1.35	2.10	2.50	3.10
T_{16} $P_2S_1G_4$	1.75	2.00	2.25	3.20	3.90	4.35
T_{17} $P_2S_2G_1$	1.20	1.50	1.85	2.60	3.50	3.65
T_{18} $P_2S_2G_2$	0.80	1.00	1.20	2.60	3.10	4.45
T_{19} $P_2S_2G_3$	0.45	0.85	1.15	1.45	1.85	2.80
T_{20} $P_2S_2G_4$	0.60	0.95	1.30	1.95	2.50	3.40
T_{21} $P_2S_3G_1$	1.35	1.85	2.45	2.85	3.35	3.90

T_{22} $P_2S_3G_2$	0.90	1.35	1.85	2.60	3.00	3.50
T_{23} $P_2S_3G_3$	1.10	1.35	1.90	3.20	4.10	4.85
T_{24} $P_2S_3G_4$	1.00	1.35	1.80	2.35	3.25	4.30
T_{25} $P_3S_1G_1$	0.45	0.85	1.10	1.70	3.40	3.40
T_{26} $P_3S_1G_2$	1.20	1.40	2.35	2.90	3.75	4.75
T_{27} $P_3S_1G_3$	0.75	0.95	1.10	1.80	3.00	3.35
T_{28} $P_3S_1G_4$	1.50	1.70	2.15	2.80	3.00	3.40
T_{29} $P_3S_2G_1$	1.50	1.30	1.75	2.35	3.20	3.80
T_{30} $P_3S_2G_2$	0.50	0.75	1.75	2.15	2.70	3.35
T_{31} $P_3S_2G_3$	0.85	1.10	1.50	2.25	3.35	3.35
T_{32} $P_3S_2G_4$	0.95	1.10	1.70	2.55	3.25	3.60
T_{33} $P_3S_3G_1$	1.20	1.75	2.45	3.50	4.30	5.50
T_{34} $P_3S_3G_2$	0.65	0.80	1.15	2.00	3.00	3.20
T_{35} $P_3S_3G_3$	0.30	0.50	0.90	1.60	3.10	3.20
T_{36} $P_3S_3G_4$	0.60	0.85	1.50	2.95	3.35	3.90
T_{37} $P_4S_1G_1$	1.50	1.35	1.70	2.35	2.80	3.00
T_{38} $P_4S_1G_2$	0.60	0.85	1.50	2.95	3.00	3.50
T_{39} $P_4S_1G_3$	0.35	0.45	0.80	2.20	3.00	3.00
T_{40} $P_4S_1G_4$	0.90	1.35	1.85	2.40	2.60	2.70
T_{41} $P_4S_2G_1$	0.90	1.15	1.55	2.95	3.10	3.70
T_{42} $P_4S_2G_2$	0.45	0.65	0.90	1.80	2.90	3.00
T_{43} $P_4S_2G_3$	1.20	1.55	2.00	2.10	2.90	3.40
T_{44} $P_4S_2G_4$	0.50	1.10	1.40	2.10	2.40	2.85
T_{45} $P_4S_3G_1$	0.75	1.20	1.65	2.90	3.25	3.50

T_{46} $P_4S_3G_2$	0.55	1.00	1.25	2.00	2.20	2.90
T_{47} $P_4S_3G_3$	0.45	0.85	1.15	1.45	1.85	2.80
T_{48} $P_4S_3G_4$	0.30	0.50	0.90	1.60	3.10	3.20
SEm	0.017	0.025	0.038	0.023	0.017	0.029
CD(0.05)	0.268	0.320	0.358	0.295	0.244	0.297

Table12. Effect of treatments on the leaf thickness(cm) of *Aloe vera* at different growth stages

Treatments	1MAP	2MAP	3MAP	4MAP	5MAP	6MAP
T_1 $P_1S_1G_1$	0.15	0.30	0.30	0.40	0.50	0.65
T_2 $P_1S_1G_2$	0.15	0.30	0.35	0.50	0.60	0.75
T_3 $P_1S_1G_3$	0.00	0.00	0.00	0.00	0.00	0.00
T_4 $P_1S_1G_4$	0.15	0.20	0.30	0.40	0.50	0.55
T_5 $P_1S_2G_1$	0.35	0.60	0.60	0.75	0.75	0.85
T_6 $P_1S_2G_2$	0.50	0.75	0.80	0.85	1.05	1.15
T_7 $P_1S_2G_3$	0.30	0.45	0.50	0.60	0.72	0.80
T_8 $P_1S_2G_4$	0.50	0.60	0.75	0.85	1.05	1.15
T_9 $P_1S_3G_1$	0.47	0.71	0.86	1.00	1.22	1.35
T_{10} $P_1S_3G_2$	0.20	0.40	0.55	0.80	0.95	1.30
T_{11} $P_1S_3G_3$	0.30	0.45	0.50	0.55	0.62	0.75
T_{12} $P_1S_3G_4$	0.45	0.55	0.65	0.85	0.95	1.05
T_{13} $P_2S_1G_1$	0.35	0.45	0.55	0.65	0.85	1.05
T_{14} $P_2S_1G_2$	0.30	0.40	0.55	0.70	0.90	0.95
T_{15} $P_2S_1G_3$	0.40	0.40	0.50	0.50	0.55	0.55
T_{16} $P_2S_1G_4$	0.25	0.30	0.30	0.40	0.45	0.55
T_{17} $P_2S_2G_1$	0.28	0.37	0.40	0.50	0.56	0.65
T_{18} $P_2S_2G_2$	0.40	0.45	0.60	0.65	0.75	0.85
T_{19} $P_2S_2G_3$	0.42	0.51	0.51	0.61	0.65	0.73
T_{20} $P_2S_2G_4$	0.30	0.41	0.44	0.50	0.62	0.62
T_{21} $P_2S_3G_1$	0.53	0.70	0.77	0.88	0.96	1.26
T_{22} $P_2S_3G_2$	0.33	0.50	0.75	0.84	0.84	0.89
T_{23} $P_2S_3G_3$	0.51	0.62	0.70	0.83	0.97	1.02
T_{24} $P_2S_3G_4$	0.40	0.41	0.44	0.53	0.59	0.72
T_{25} $P_3S_1G_1$	0.55	0.70	0.79	0.82	1.05	1.10
T_{26} $P_3S_1G_2$	0.51	0.67	0.83	0.87	1.00	1.10
T_{27} $P_3S_1G_3$	0.46	0.68	0.73	0.76	0.83	0.88
T_{28} $P_3S_1G_4$	0.29	0.47	0.64	0.66	0.69	0.75
T_{29} $P_3S_2G_1$	0.44	0.57	0.61	0.72	0.84	0.95
T_{30} $P_3S_2G_2$	0.35	0.49	0.57	0.65	0.76	0.85
T_{31} $P_3S_2G_3$	0.30	0.39	0.48	0.55	0.63	0.68
T_{32} $P_3S_2G_4$	0.23	0.43	0.49	0.56	0.61	0.62
T_{33} $P_3S_3G_1$	0.30	0.48	0.50	0.60	0.66	0.73
T_{34} $P_3S_3G_2$	0.37	0.51	0.63	0.68	0.90	1.05
T_{35} $P_3S_3G_3$	0.30	0.32	0.38	0.49	0.59	0.64
T_{36} $P_3S_3G_4$	0.31	0.37	0.41	0.53	0.58	0.61

T_{37} $P_4S_1G_1$	0.30	0.48	0.52	0.67	0.76	0.81
T_{38} $P_4S_1G_2$	0.40	0.51	0.68	0.69	0.75	0.82
T_{39} $P_4S_1G_3$	0.31	0.42	0.52	0.57	0.64	0.70
T_{40} $P_4S_1G_4$	0.36	0.53	0.72	0.76	0.80	0.82
T_{41} $P_4S_2G_1$	0.47	0.53	0.66	0.75	0.75	0.82
T_{42} $P_4S_2G_2$	0.45	0.50	0.60	0.72	0.78	0.81
T_{43} $P_4S_2G_3$	0.28	0.52	0.61	0.63	0.68	0.72
T_{44} $P_4S_2G_4$	0.30	0.37	0.40	0.46	0.51	0.52
T_{45} $P_4S_3G_1$	0.51	0.60	0.68	0.77	0.88	0.95
T_{46} $P_4S_3G_2$	0.50	0.58	0.67	0.80	0.92	1.05
T_{47} $P_4S_3G_3$	0.37	0.37	0.43	0.47	0.57	0.62
T_{48} $P_4S_3G_4$	0.37	0.51	0.63	0.68	0.90	1.05
SEm	0.000	0.007	0.006	0.007	0.000	0.009
CD(0.05)	0.092	0.086	0.085	0.163	0.120	0.128

Table.13. Effect of treatment on leaf weight(g) of *Aloe vera* at different growth stages

Treatments	Leaf weight(g)					
	1MAP	2MAP	3MAP	4MAP	5MAP	6MAP
T_1 $P_1S_1G_1$	32.75	47.00	52.40	63.40	72.60	92.30
T_2 $P_1S_1G_2$	35.80	51.05	64.30	75.30	86.20	98.80
T_3 $P_1S_1G_3$	0.00	0.00	0.000	0.000	0.000	0.000
T_4 $P_1S_1G_4$	16.00	28.40	40.10	51.50	62.66	75.98
T_5 $P_1S_2G_1$	29.40	40.10	51.50	61.00	78.64	86.30
T_6 $P_1S_2G_2$	18.10	28.60	38.95	46.60	54.50	68.60
T_7 $P_1S_2G_3$	10.90	25.30	35.80	47.30	52.60	72.40
T_8 $P_1S_2G_4$	38.75	58.05	66.90	77.65	88.60	104.4
T_9 $P_1S_3G_1$	46.15	71.05	80.82	92.55	116.4	134.6
T_{10} $P_1S_3G_2$	41.10	64.75	76.50	92.40	103.80	128.3
T_{11} $P_1S_3G_3$	11.95	22.90	33.00	40.10	52.30	66.80
T_{12} $P_1S_3G_4$	31.60	42.80	54.90	65.20	77.80	84.20
T_{13} $P_2S_1G_1$	13.60	23.30	32.97	45.20	62.30	74.80
T_{14} $P_2S_1G_2$	13.15	22.65	34.80	46.20	52.20	72.60
T_{15} $P_2S_1G_3$	13.25	27.80	36.40	47.60	54.50	68.40
T_{16} $P_2S_1G_4$	15.40	27.25	38.50	49.20	60.60	68.20
T_{17} $P_2S_2G_1$	17.20	29.00	39.50	51.80	72.50	94.60
T_{18} $P_2S_2G_2$	19.20	29.15	40.00	50.20	74.30	96.40
T_{19} $P_2S_2G_3$	16.40	28.60	37.10	47.10	58.40	64.30
T_{20} $P_2S_2G_4$	15.70	26.35	36.00	46.50	60.60	78.20
T_{21} $P_2S_3G_1$	31.05	43.65	52.10	58.90	77.50	104.5
T_{22} $P_2S_3G_2$	31.65	43.75	53.70	63.60	84.20	106.6
T_{23} $P_2S_3G_3$	26.80	35.00	44.85	54.95	63.20	74.60
T_{24} $P_2S_3G_4$	23.15	34.30	43.80	55.30	62.50	76.30
T_{25} $P_3S_1G_1$	37.80	49.10	59.80	69.60	78.90	84.60
T_{26} $P_3S_1G_2$	30.90	44.30	56.30	64.10	76.70	82.50
T_{27} $P_3S_1G_3$	16.10	26.35	37.60	49.50	54.90	68.30
T_{28} $P_3S_1G_4$	13.90	27.85	36.25	47.10	57.30	72.60
T_{29} $P_3S_2G_1$	33.95	47.95	58.77	66.25	84.50	95.40
T_{30} $P_3S_2G_2$	43.90	59.35	70.10	79.60	94.60	110.2
T_{31} $P_3S_2G_3$	20.50	32.00	45.55	57.20	64.30	76.40
T_{32} $P_3S_2G_4$	20.75	33.40	44.80	56.80	68.20	80.60
T_{33} $P_3S_3G_1$	29.50	42.25	51.40	60.40	72.60	98.20
T_{34} $P_3S_3G_2$	32.10	45.45	56.00	65.20	89.60	110.2
T_{35} $P_3S_3G_3$	25.30	39.30	51.15	61.85	68.70	72.40
T_{36} $P_3S_3G_4$	24.10	37.30	45.90	59.90	65.30	74.60

T_{37} $P_4S_1G_1$	34.25	44.25	59.50	69.65	72.40	76.30
T_{38} $P_4S_1G_2$	31.50	41.90	53.00	64.00	70.30	73.20
T_{39} $P_4S_1G_3$	34.50	45.25	57.35	67.50	72.50	78.60
T_{40} $P_4S_1G_4$	15.60	25.45	36.15	42.00	49.30	62.62
T_{41} $P_4S_2G_1$	34.15	44.30	52.10	58.10	62.40	68.60
T_{42} $P_4S_2G_2$	14.65	30.25	43.10	52.80	64.50	70.30
T_{43} $P_4S_2G_3$	16.40	31.25	41.40	51.40	65.20	72.65
T_{44} $P_4S_2G_4$	15.30	25.10	38.10	49.55	52.30	64.50
T_{45} $P_4S_3G_1$	29.20	43.15	53.45	62.45	75.45	79.80
T_{46} $P_4S_3G_2$	25.30	30.00	40.00	50.50	62.70	70.40
T_{47} $P_4S_3G_3$	20.45	31.90	42.10	55.10	60.40	68.50
T_{48} $P_4S_3G_4$	15.95	27.65	36.40	41.40	52.30	64.20
SEm	1.513	5.562	1.041	3.137	1.625	2.781
CD(0.05)	2.478	4.749	2.058	3.556	4.663	8.032

MAP: Month After Planting

T_{30} T_{29} T_{22} T_{18} T_{10} T_{9}

Fig: 12.Effect of treatments on leaf length(cm) of *Aloe vera*

Treatment,T9 recorded the maximum leaf weight with 46.5 gm,71.05 gm,80.82 gm,92.55 gm,116.40 gm and 134.60 gm respectively during 1,2,3,4,5 and 6 MAP.T_{30} (43.90gm) was on par with T_9 at 1 MAP.At 4 MAP,T_{10} (92.40gm) found on par with the highest value (92.55gm).T_{10} (128.30gm) found on par with T_9 (134.68gm) at 6 MAP.T_{40} (62.62gm)recorded the least value at 6 MAP.

4.4.7.Number of offsets

There was no significant difference among treatment combinations with respect to the number of suckers produced during the first 2 MAP.

At 3 MAP,the number of offsets produced by different treatment combinations were more or less in a similar trend with value 1.00.During 4 MAP,the maximum number of offsets was recorded by treatment T_{26}(2.50)and which was on par with T_{14},T_{21},T_{22},T_{25},T_{32} and T_{41}(2.00).

At 5 MAP,treatment T_{26} and T_{32} (3.00) recorded the highest number of offsets which was on par with treatment T_9 (2.50).During 6 MAP, treatment T_9 (3.50) recorded the highest number of offsets which was on par with treatments T_{10},T_{25},T_{26} T_{32} (3.00).

4.5.Growth Characters

4.5.1.Absolute Growth Rate(AGR)

In the case of Absolute Growth Rate(AGR) there was no significant difference was noticed during the initial crop growth periods and significant difference was noticed at 6 MAP(Table15.)

T_9 recorded the highest AGR (1.15) at 6MAP

4.5.2. Relative Growth Rate(RGR)

In the case of Relative Growth Rate(RGR) there was no significant difference was noticed during the initial crop growth periods and significant difference was noticed at 6 MAP.

4.5.3. Net Assimilation Rate(NAR)

In the case of Net Assimilation Rate(NAR) there was no significant difference was noticed during the initial crop growth periods and significant difference was noticed at 6 MAP.

4.5.4.Leaf Area Index

Table. 14. Effect of treatments on the number of offsets at different growth stages

Treatments	Number of offsets					
	1MAP	2MAP	3MAP	4MAP	5MAP	6MAP
T1	0.000	0.000	0.000	0.000	0.000	0.000
T2	0.000	0.000	0.000	0.500	0.500	1.500
T3	0.000	0.000	0.000	0.000	0.000	0.000
T4	0.000	0.000	0.000	0.500	0.500	0.500
T5	0.000	0.000	0.000	0.000	0.000	0.000
T6	0.000	0.000	0.000	0.500	0.500	0.500
T7	0.000	0.000	0.000	1.000	1.000	1.000
T8	0.000	0.000	0.000	0.000	0.000	0.000
T9	0.000	0.000	0.000	1.500	2.500	3.500
T10	0.000	0.000	0.000	0.000	0.000	3.000
T11	0.000	0.000	0.000	0.000	0.000	0.000
T12	0.000	0.000	0.000	0.000	0.000	0.000
T13	0.000	0.000	0.000	0.000	0.000	0.000
T14	0.000	0.000	1.000	2.000	2.000	2.000
T15	0.000	0.000	0.000	0.000	0.000	0.000
T16	0.000	0.000	0.000	0.000	0.000	0.000
T17	0.000	0.000	1.000	1.000	1.000	1.000
T18	0.000	0.000	0.500	1.500	1.500	1.500
T19	0.000	0.000	0.000	0.000	0.000	0.000
T20	0.000	0.000	0.000	0.000	0.000	0.000
T21	0.000	0.000	1.000	2.000	2.000	2.000
T22	0.000	0.000	1.000	2.000	2.000	2.000
T23	0.000	0.000	0.000	0.000	0.000	0.000
T24	0.000	0.000	0.000	0.000	0.000	0.000
T25	0.000	0.000	1.000	2.000	2.000	3.000
T26	1.000	1.000	1.000	2.500	3.000	3.000
T27	0.000	0.000	0.000	0.000	0.000	0.000
T28	0.000	0.000	0.000	0.000	0.000	0.000
T29	0.000	0.000	0.000	0.000	0.000	0.000
T30	0.000	0.000	0.000	0.000	0.000	0.000
T31	0.000	0.000	0.000	0.000	0.000	0.000
T32	0.000	0.000	1.000	2.000	3.000	3.000
T33	0.000	0.000	0.000	0.000	1.000	1.000
T34	0.000	0.000	0.000	0.000	1.000	1.000
T35	0.000	0.000	0.000	0.000	0.000	0.000
T36	0.000	0.000	0.000	0.000	0.000	0.000

T37	0.00	0.00	0.00	0.00	0.00	0.00
T38	0.00	0.00	1.00	1.00	2.00	2.00
T39	0.00	0.00	0.00	0.00	0.00	0.00
T40	0.00	0.00	1.00	1.00	1.00	1.00
T41	0.00	0.00	1.00	2.00	2.00	2.00
T42	0.00	0.00	1.00	1.00	2.00	2.00
T43	0.00	0.00	1.00	1.00	1.00	1.00
T44	0.00	0.00	0.00	0.50	0.50	1.00
T45	0.00	0.00	1.00	1.50	1.50	1.50
T46	0.00	0.00	1.00	1.50	2.00	2.00
T47	0.00	0.00	0.00	0.00	0.00	0.00
T48	0.00	0.00	0.00	0.00	0.00	0.00
SEm	-	-	0.014	0.097	0.083	0.083
CD(0.05)	NS	NS	0.202	0.617	0.585	0.585

Fig:13. Offset production of *Aloe vera* dise

Table 15.Effect of treatments on Absolute Growth Rate(mm day^{-1}) of *Aloe vera* at different growth stages

Treatments	Absolute Growth Rate(mm day^{-1})		
	2MAP	4MAP	6MAP
T_1 $P_1S_1G_1$	0.744	0.900	0.85
T_2 $P_1S_1G_2$	0.967	0.828	0.70
T_3 $P_1S_1G_3$	0.000	0.000	0.00
T_4 $P_1S_1G_4$	0.761	0.744	0.18
T_5 $P_1S_2G_1$	0.772	0.778	0.61
T_6 $P_1S_2G_2$	0.856	0.850	0.66
T_7 $P_1S_2G_3$	0.798	0.806	0.88
T_8 $P_1S_2G_4$	0.672	0.961	0.66
T_9 $P_1S_3G_1$	0.839	0.772	1.15
T_{10} $P_1S_3G_2$	0.756	0.678	1.05
T_{11} $P_1S_3G_3$	1.050	0.760	1.00
T_{12} $P_1S_3G_4$	0.922	1.022	0.76
T_{13} $P_2S_1G_1$	0.756	0.678	0.48
T_{14} $P_2S_1G_2$	0.772	0.778	0.61
T_{15} $P_2S_1G_3$	0.833	0.744	0.47
T_{16} $P_2S_1G_4$	0.722	0.833	1.01
T_{17} $P_2S_2G_1$	0.861	0.967	0.82
T_{18} $P_2S_2G_2$	0.833	0.639	0.41
T_{19} $P_2S_2G_3$	1.033	0.756	0.67
T_{20} $P_2S_2G_4$	0.772	0.778	0.61
T_{21} $P_2S_3G_1$	0.756	0.678	0.48
T_{22} $P_2S_3G_2$	0.850	0.944	0.70
T_{23} $P_2S_3G_3$	0.706	0.794	0.52
T_{24} $P_2S_3G_4$	0.794	0.661	0.21
T_{25} $P_3S_1G_1$	0.889	0.806	0.79
T_{26} $P_3S_1G_2$	0.944	0.711	0.86
T_{27} $P_3S_1G_3$	0.744	0.900	0.85
T_{28} $P_3S_1G_4$	0.850	0.667	0.38
T_{29} $P_3S_2G_1$	0.839	0.944	0.83
T_{30} $P_3S_2G_2$	0.772	0.778	0.61
T_{31} $P_3S_2G_3$	0.794	0.661	0.21
T_{32} $P_3S_2G_4$	0.756	0.678	0.48
T_{33} $P_3S_3G_1$	1.072	0.772	0.77
T_{34} $P_3S_3G_2$	0.806	0.794	0.66
T_{35} $P_3S_3G_3$	1.011	0.667	0.23

T_{36} $P_3S_3G_4$	0.922	1.022	0.76
T_{37} $P_4S_1G_1$	0.806	0.794	0.52
T_{38} $P_4S_1G_2$	0.756	0.678	0.48
T_{39} $P_4S_1G_3$	0.770	0.778	0.61
T_{40} $P_4S_1G_4$	0.917	0.689	0.73
T_{41} $P_4S_2G_1$	0.716	0.917	0.84
T_{42} $P_4S_2G_2$	0.839	0.944	0.83
T_{43} $P_4S_2G_3$	1.050	0.500	0.45
T_{44} $P_4S_2G_4$	0.639	0.411	0.39
T_{45} $P_4S_3G_1$	0.700	0.278	0.31
T_{46} $P_4S_3G_2$	0.667	0.233	0.32
T_{47} $P_4S_3G_3$	0.578	0.278	0.21
T_{48} $P_4S_3G_4$	0.861	0.964	0.82
SEm	-	-	0.078
CD(0.05)	NS	NS	0.227

Table 16.Effect of treatments on Relative Growth Rate(gg day^{-1}) at different growth stages

Treatments	Relative Growth Rate(g g day^{-1})	
	2-4 MAP	4-6 MAP
T_1 $P_1S_1G_1$	0.00180	0.00163
T_2 $P_1S_1G_2$	0.00342	0.00092
T_3 $P_1S_1G_3$	0.00427	0.00154
T_4 $P_1S_1G_4$	0.00254	0.00774
T_5 $P_1S_2G_1$	0.00600	0.00101
T_6 $P_1S_2G_2$	0.00605	0.00120
T_7 $P_1S_2G_3$	0.00200	0.00784
T_8 $P_1S_2G_4$	0.01055	0.00214
T_9 $P_1S_3G_1$	0.00575	0.00147
T_{10} $P_1S_3G_2$	0.01246	0.01352
T_{11} $P_1S_3G_3$	0.01242	0.00246
T_{12} $P_1S_3G_4$	0.01254	0.00104
T_{13} $P_2S_1G_1$	0.01161	0.00621
T_{14} $P_2S_1G_2$	0.01327	0.00084
T_{15} $P_2S_1G_3$	0.02141	0.00152
T_{16} $P_2S_1G_4$	0.00124	0.00056
T_{17} $P_2S_2G_1$	0.00642	0.00054
T_{18} $P_2S_2G_2$	0.00102	0.00016
T_{19} $P_2S_2G_3$	0.00054	0.00024
T_{20} $P_2S_2G_4$	0.00046	0.00018
T_{21} $P_2S_3G_1$	0.00242	0.00021
T_{22} $P_2S_3G_2$	0.00180	0.00042
T_{23} $P_2S_3G_3$	0.00012	0.00016
T_{24} $P_2S_3G_4$	0.00078	0.00022
T_{25} $P_3S_1G_1$	0.00054	0.00014
T_{26} $P_3S_1G_2$	0.00122	0.00056
T_{27} $P_3S_1G_3$	0.00058	0.00014
T_{28} $P_3S_1G_4$	0.00048	0.00016
T_{29} $P_3S_2G_1$	0.00124	0.00020
T_{30} $P_3S_2G_2$	0.00076	0.00018
T_{31} $P_3S_2G_3$	0.00068	0.00012
T_{32} $P_3S_2G_4$	0.00084	0.00014
T_{33} $P_3S_3G_1$	0.00078	0.00023
T_{34} $P_3S_3G_2$	0.00174	0.00012
T_{35} $P_3S_3G_3$	0.00120	0.00124
T_{36} $P_3S_3G_4$	0.00242	0.00054
T_{37} $P_4S_1G_1$	0.00272	0.00046
T_{38} $P_4S_1G_2$	0.00054	0.00242
T_{39} $P_4S_1G_3$	0.00060	0.00180

T_{40} $P_4S_1G_4$	0.00012	0.00012
T_{41} $P_4S_2G_1$	0.00018	0.00078
T_{42} $P_4S_2G_2$	0.00020	0.00054
T_{43} $P_4S_2G_3$	0.00050	0.00122
T_{44} $P_4S_2G_4$	0.00012	0.00058
T_{45} $P_4S_3G_1$	0.00042	0.00048
T_{46} $P_4S_3G_2$	0.00054	0.00124
T_{47} $P_4S_3G_3$	0.00016	0.00076
T_{48} $P_4S_3G_4$	0.00018	0.00068
SEm	0.012	0.018
CD(0.05)	0.028	0.042

Table 17..Effect of treatments on Net Assimilation Rate(mg m^{-2} day-^{1}) of *Aloe vera* at different growth stages

Treatments	Net Assimilation Rate (mg $m^{-2}day^{-1}$)	
	4MAP	6MAP
T_1 $P_1S_1G_1$	1.03	0.44
T_2 $P_1S_1G_2$	1.26	0.42
T_3 $P_1S_1G_3$	0.00	0.00
T_4 $P_1S_1G_4$	1.63	0.23
T_5 $P_1S_2G_1$	1.76	0.26
T_6 $P_1S_2G_2$	0.61	0.62
T_7 $P_1S_2G_3$	0.55	0.62
T_8 $P_1S_2G_4$	0.61	0.42
T_9 $P_1S_3G_1$	2.98	1.82
T_{10} $P_1S_3G_2$	2.96	1.43
T_{11} $P_1S_3G_3$	2.72	1.16
T_{12} $P_1S_3G_4$	0.55	0.63
T_{13} $P_2S_1G_1$	1.04	0.96
T_{14} $P_2S_1G_2$	0.96	0.26
T_{15} $P_2S_1G_3$	1.02	0.68
T_{16} $P_2S_1G_4$	0.88	0.96
T_{17} $P_2S_2G_1$	1.28	1.40
T_{18} $P_2S_2G_2$	1.82	0.80
T_{19} $P_2S_2G_3$	1.96	0.84
T_{20} $P_2S_2G_4$	1.12	0.96
T_{21} $P_2S_3G_1$	2.96	1.43

T_{22} $P_2S_3G_2$	2.44	1.48
T_{23} $P_2S_3G_3$	1.04	0.98
T_{24} $P_2S_3G_4$	1.02	0.76
T_{25} $P_3S_1G_1$	1.76	0.26
T_{26} $P_3S_1G_2$	1.87	0.46
T_{27} $P_3S_1G_3$	2.96	1.48
T_{28} $P_3S_1G_4$	2.44	1.40
T_{29} $P_3S_2G_1$	2.58	0.56
T_{30} $P_3S_2G_2$	3.14	1.40
T_{31} $P_3S_2G_3$	1.20	0.78
T_{32} $P_3S_2G_4$	0.84	1.74
T_{33} $P_3S_3G_1$	1.64	0.23
T_{34} $P_3S_3G_2$	1.36	0.46
T_{35} $P_3S_3G_3$	1.87	1.18
T_{36} $P_3S_3G_4$	1.32	0.95
T_{37} $P_4S_1G_1$	1.67	1.04
T_{38} $P_4S_1G_2$	1.72	0.96
T_{39} $P_4S_1G_3$	0.98	0.78
T_{40} $P_4S_1G_4$	1.24	1.06
T_{41} $P_4S_2G_1$	1.44	0.24
T_{42} $P_4S_2G_2$	1.63	0.27
T_{43} $P_4S_2G_3$	0.94	0.68
T_{44} $P_4S_2G_4$	0.88	1.02
T_{45} $P_4S_3G_1$	0.61	0.46

T_{46} $P_4S_3G_2$	2.14	1.24
T_{47} $P_4S_3G_3$	2.92	1.04
T_{48} $P_4S_3G_4$	1.03	0.44
SEm	0.303	0.178
CD(0.05)	0.876	0.514

Leaf area index was influenced by the size of disc as well as the pre-curing and growth regulator treatments and significant differences were noticed among the treatments (Table.18).

At 2 MAP,treatment T_{10} recorded the highest value of 0.224 which was on par with T_9 (0.202).The next best result was given by T_{21}(0.172).T_{39} recorded the least value(0.050).

During 4 MAP,treatment T_{10} recorded significantly superior leaf area index of 0.742 which was on par with T_9 (0.726).Next best treatment was T_{22} (0.650) and the lowest LAI value was recorded for T_{43} (0.128).

At 6 MAP,treatment T_9 recorded the maximum LAI of 0.928 and treatment T_{10} (0.910)and T_{26}(0.914) were on par with it.T_{22} also recorded superior value (0.846) and the lowest value was observed for T_{39} (0.188).

4.6.Yield

4.6.1.Fresh Leaf Yield

There was significant difference in the fresh leaf yield of *A.vera* under different treatments (Table 19).Treatment T_9 had the highest fresh leaf weight (4.20kg/plant) which was significantly superior to all treatments followed by T_{10}(3.94kg/plant).The treatments $T_5(P_1S_2G_1\_3.20kgplant^{-1})$,$T_6(P_1S_2G_2\_3.40kgplant^{-1})$,$T_{10}(P_1S_3G_2\text{-}3.94kgplant^{-1})$,$T_{18}(P_2S_2G_2\text{-}3.90kgplant^{-1})$,$T_{21}(P_2S_3G_1\text{-}3.20kgplant^{-1})$,$T_{22}(P_2S_3G_2\text{-}3.72kgplant^{-1})$,$T_{33}(P_3S_3G_1\text{-}3.62kgplant^{-1})$ and $T_{34}(3.32kgplant^{-1})$ found on par with the highest value.The control T_{48} recorded the lowest value (0.520kg/plant). Plants raised from 3 node disc recorded comparatively higher leaf yield than other plants of single or double node disc.

4.6.2.Latex Yield

There was significant difference in the latex yield of *A.vera* under different treatments (Table 20).Treatment T_9 had the highest latex yield (16.60g/plant) which was significantly superior to all treatments which was on par with T_{10} (16.40 g/plant),T_8(15.90gplant-1),T_{18}(15.95g/plant) and T_{21}(15.70g/plant) during the observation period.The control T_{48} recorded the lowest value (6.250g/plant).

4.6.3.Gel Yield

Table 18: Effect of treatment on Leaf Area Index of *Aloe vera* at different growth stages

Treatments	LAI		
	2MAP	4MAP	6MAP
T_1 $P_1S_1G_1$	0.088	0.256	0.464
T_2 $P_1S_1G_2$	0.062	0.167	0.442
T_3 $P_1S_1G_3$	0.000	0.000	0.000
T_4 $P_1S_1G_4$	0.116	0.330	0.484
T_5 $P_1S_2G_1$	0.072	0.174	0.386
T_6 $P_1S_2G_2$	0.128	0.362	0.665
T_7 $P_1S_2G_3$	0.136	0.254	0.321
T_8 $P_1S_2G_4$	0.126	0.228	0.280
T_9 $P_1S_3G_1$	0.202	0.726	0.928
T_{10} $P_1S_3G_2$	0.224	0.742	0.914
T_{11} $P_1S_3G_3$	0.081	0.193	0.223
T_{12} $P_1S_3G_4$	0.080	0.172	0.190
T_{13} $P_2S_1G_1$	0.086	0.190	0.199
T_{14} $P_2S_1G_2$	0.082	0.103	0.188
T_{15} $P_2S_1G_3$	0.077	0.216	0.224
T_{16} $P_2S_1G_4$	0.070	0.202	0.216
T_{17} $P_2S_2G_1$	0.086	0.190	0.382
T_{18} $P_2S_2G_2$	0.082	0.182	0.361
T_{19} $P_2S_2G_3$	0.076	0.210	0.326
T_{20} $P_2S_2G_4$	0.078	0.216	0.315
T_{21} $P_2S_3G_1$	0.172	0.606	0.846
T_{22} $P_2S_3G_2$	0.130	0.650	0.768
T_{23} $P_2S_3G_3$	0.099	0.320	0.476
T_{24} $P_2S_3G_4$	0.116	0.372	0.720
T_{25} $P_3S_1G_1$	0.149	0.426	0.910
T_{26} $P_3S_1G_2$	0.118	0.638	0.918
T_{27} $P_3S_1G_3$	0.104	0.381	0.600
T_{28} $P_3S_1G_4$	0.109	0.336	0.533
T_{29} $P_3S_2G_1$	0.068	0.188	0.224
T_{30} $P_3S_2G_2$	0.072	0.128	0.276
T_{31} $P_3S_2G_3$	0.060	0.242	0.316
T_{32} $P_3S_2G_4$	0.067	0.198	0.328

T_{33} $P_3S_3G_1$	0.099	0.168	0.340
T_{34} $P_3S_3G_2$	0.081	0.198	0.254
T_{35} $P_3S_3G_3$	0.062	0.328	0.344
T_{36} $P_3S_3G_4$	0.224	0.224	0.274
T_{37} $P_4S_1G_1$	0.202	0.498	0.740
T_{38} $P_4S_1G_2$	0.130	0.542	0.726
T_{39} $P_4S_1G_3$	0.050	0.180	0.188
T_{40} $P_4S_1G_4$	0.066	0.188	0.234
T_{41} $P_4S_2G_1$	0.153	0.192	0.224
T_{42} $P_4S_2G_2$	0.162	0.188	0.206
T_{43} $P_4S_2G_3$	0.120	0.128	0.260
T_{44} $P_4S_2G_4$	0.054	0.216	0.268
T_{45} $P_4S_3G_1$	0.141	0.498	0.582
T_{46} $P_4S_3G_2$	0.098	0.354	0.572
T_{47} $P_4S_3G_3$	0.086	0.182	0.398
T_{48} $P_4S_3G_4$	0.070	0.220	0.284
SEm	0.0011	1.242	2.8280
CD(0.05)	0.0253	0.0200	0.0166

Table19.Effect of treatment on fresh leaf yield(kg/plant) of *Aloe vera*

Treatment	Fresh leaf yield (kg/plant)
T_1 $P_1S_1G_1$	0.72
T_2 $P_1S_1G_2$	0.76
T_3 $P_1S_1G_3$	0
T_4 $P_1S_1G_4$	0.60
T_5 $P_1S_2G_1$	3.20
T_6 $P_1S_2G_2$	3.40
T_7 $P_1S_2G_3$	0.81
T_8 $P_1S_2G_4$	0.68
T_9 $P_1S_3G_1$	4.20
T_{10} $P_1S_3G_2$	3.94
T_{11} $P_1S_3G_3$	0.72
T_{12} $P_1S_3G_4$	0.78
T_{13} $P_2S_1G_1$	0.96
T_{14} $P_2S_1G_2$	1.05
T_{15} $P_2S_1G_3$	0.72
T_{16} $P_2S_1G_4$	0.68
T_{17} $P_2S_2G_1$	1.64
T_{18} $P_2S_2G_2$	3.90
T_{19} $P_2S_2G_3$	0.71
T_{20} $P_2S_2G_4$	0.70
T_{21} $P_2S_3G_1$	3.20
T_{22} $P_2S_3G_2$	3.72
T_{23} $P_2S_3G_3$	1.33
T_{24} $P_2S_3G_4$	0.82
T_{25} $P_3S_1G_1$	1.45
T_{26} $P_3S_1G_2$	1.90
T_{27} $P_3S_1G_3$	0.95
T_{28} $P_3S_1G_4$	0.88
T_{29} $P_3S_2G_1$	1.42
T_{30} $P_3S_2G_2$	2.45
T_{31} $P_3S_2G_3$	1.23
T_{32} $P_3S_2G_4$	0.85
T_{33} $P_3S_3G_1$	3.62
T_{34} $P_3S_3G_2$	3.32
T_{35} $P_3S_3G_3$	1.12
T_{36} $P_3S_3G_4$	0.75
T_{37} $P_4S_1G_1$	1.55

T_{38} $P_4S_1G_2$	1.20
T_{39} $P_4S_1G_3$	0.72
T_{40} $P_4S_1G_4$	0.77
T_{41} $P_4S_2G_1$	0.94
T_{42} $P_4S_2G_2$	1.16
T_{43} $P_4S_2G_3$	0.98
T_{44} $P_4S_2G_4$	0.62
T_{45} $P_4S_3G_1$	0.65
T_{46} $P_4S_3G_2$	0.98
T_{47} $P_4S_3G_3$	0.68
T_{48} $P_4S_3G_4$	0.52
SEm	0.252
CD(0.05)	1.248

Table 20:- Effect of treatment on latex yield(g/plant) of *Aloe vera*

Treatment	Latex Yield (g/plant)
T_1 $P_1S_1G_1$	5.40
T_2 $P_1S_1G_2$	4.40
T_3 $P_1S_1G_3$	0.00
T_4 $P_1S_1G_4$	0.50
T_5 $P_1S_2G_1$	11.50
T_6 $P_1S_2G_2$	13.95
T_7 $P_1S_2G_3$	11.30
T_8 $P_1S_2G_4$	15.90
T_9 $P_1S_3G_1$	16.60
T_{10} $P_1S_3G_2$	16.40
T_{11} $P_1S_3G_3$	8.55
T_{12} $P_1S_3G_4$	12.20
T_{13} $P_2S_1G_1$	7.30
T_{14} $P_2S_1G_2$	7.55
T_{15} $P_2S_1G_3$	5.65
T_{16} $P_2S_1G_4$	6.65
T_{17} $P_2S_2G_1$	6.25
T_{18} $P_2S_2G_2$	15.95
T_{19} $P_2S_2G_3$	6.10
T_{20} $P_2S_2G_4$	6.30
T_{21} $P_2S_3G_1$	15.70
T_{22} $P_2S_3G_2$	13.20
T_{23} $P_2S_3G_3$	9.15
T_{24} $P_2S_3G_4$	8.20
T_{25} $P_3S_1G_1$	8.95
T_{26} $P_3S_1G_2$	8.20
T_{27} $P_3S_1G_3$	9.20
T_{28} $P_3S_1G_4$	8.45
T_{29} $P_3S_2G_1$	11.75
T_{30} $P_3S_2G_2$	11.20
T_{31} $P_3S_2G_3$	7.65
T_{32} $P_3S_2G_4$	6.70
T_{33} $P_3S_3G_1$	14.70
T_{34} $P_3S_3G_2$	14.65
T_{35} $P_3S_3G_3$	8.15
T_{36} $P_3S_3G_4$	6.75
T_{37} $P_4S_1G_1$	7.10

T_{38} $P_4S_1G_2$	8.25
T_{39} $P_4S_1G_3$	7.45
T_{40} $P_4S_1G_4$	7.55
T_{41} $P_4S_2G_1$	6.60
T_{42} $P_4S_2G_2$	6.40
T_{43} $P_4S_2G_3$	7.30
T_{44} $P_4S_2G_4$	8.80
T_{45} $P_4S_3G_1$	8.20
T_{46} $P_4S_3G_2$	7.00
T_{47} $P_4S_3G_3$	9.15
T_{48} $P_4S_3G_4$	6.25
SEm	0.380
CD(0.05)	1.257

Table 21:-Effect of treatment on gel yield(g/plant) of *Aloe vera*

Treatment	Gel Yield
T_1 $P_1S_1G_1$	0.93
T_2 $P_1S_1G_2$	0.90
T_3 $P_1S_1G_3$	0.00
T_4 $P_1S_1G_4$	0.15
T_5 $P_1S_2G_1$	0.80
T_6 $P_1S_2G_2$	0.85
T_7 $P_1S_2G_3$	0.20
T_8 $P_1S_2G_4$	0.88
T_9 $P_1S_3G_1$	1.05
T_{10} $P_1S_3G_2$	0.98
T_{11} $P_1S_3G_3$	0.18
T_{12} $P_1S_3G_4$	0.32
T_{13} $P_2S_1G_1$	0.28
T_{14} $P_2S_1G_2$	0.38
T_{15} $P_2S_1G_3$	0.18
T_{16} $P_2S_1G_4$	0.17
T_{17} $P_2S_2G_1$	0.16
T_{18} $P_2S_2G_2$	0.97
T_{19} $P_2S_2G_3$	0.18
T_{20} $P_2S_2G_4$	0.17
T_{21} $P_2S_3G_1$	0.80
T_{22} $P_2S_3G_2$	0.93
T_{23} $P_2S_3G_3$	0.33
T_{24} $P_2S_3G_4$	0.20
T_{25} $P_3S_1G_1$	0.36
T_{26} $P_3S_1G_2$	0.48
T_{27} $P_3S_1G_3$	0.24
T_{28} $P_3S_1G_4$	0.22
T_{29} $P_3S_2G_1$	0.36
T_{30} $P_3S_2G_2$	0.61
T_{31} $P_3S_2G_3$	0.31
T_{32} $P_3S_2G_4$	0.21
T_{33} $P_3S_3G_1$	0.91
T_{34} $P_3S_3G_2$	0.83
T_{35} $P_3S_3G_3$	0.28
T_{36} $P_3S_3G_4$	0.19
T_{37} $P_4S_1G_1$	0.39

T_{38} $P_4S_1G_2$	0.30
T_{39} $P_4S_1G_3$	0.18
T_{40} $P_4S_1G_4$	0.19
T_{41} $P_4S_2G_1$	0.24
T_{42} $P_4S_2G_2$	0.29
T_{43} $P_4S_2G_3$	0.26
T_{44} $P_4S_2G_4$	0.16
T_{45} $P_4S_3G_1$	0.16
T_{46} $P_4S_3G_2$	0.25
T_{47} $P_4S_3G_3$	0.17
T_{48} $P_4S_3G_4$	0.13
SEm	0.055
CD(0.05)	0.159

Table 22:_Economics of production of seedlings

Treatments	Benefit (Gross income) Rs.	Cost (Rs.)	Profit (Net income) Rs.	BC Ratio
T_1 $P_1S_1G_1$	556093	534774	21318	1.03
T_2 $P_1S_1G_2$	543060	490326	52734	1.11
T_3 $P_1S_1G_3$	605951	540593	65358	1.12
T_4 $P_1S_1G_4$	642776	537269	105506	1.20
T_5 $P_1S_2G_1$	556093	534780	21313	1.04
T_6 $P_1S_2G_2$	615248	591584	23664	1.04
T_7 $P_1S_2G_3$	487846	387179	100667	1.26
T_8 $P_1S_2G_4$	512234	538411	-26176	0.95
T_9 $P_1S_3G_1$	966508	600452	366056	1.60
T_{10} $P_1S_3G_2$	966508	635827	330681	1.52
T_{11} $P_1S_3G_3$	487652	497604	-9952	0.98
T_{12} $P_1S_3G_4$	496894	432081	64813	1.15
T_{13} $P_2S_1G_1$	584329	449483	134846	1.30
T_{14} $P_2S_1G_2$	564874	455543	109331	1.24
T_{15} $P_2S_1G_3$	646284	489609	156675	1.32
T_{16} $P_2S_1G_4$	389842	397798	-7956	0.98
T_{17} $P_2S_2G_1$	681049	526548	154500	1.29
T_{18} $P_2S_2G_2$	711253	537269	171802	1.32
T_{19} $P_2S_2G_3$	452698	435286	17412	1.04
T_{20} $P_2S_2G_4$	384974	356457	28517	1.08
T_{21} $P_2S_3G_1$	868795	665724	203071	1.30
T_{22} $P_2S_3G_2$	859872	626548	233324	1.37
T_{23} $P_2S_3G_3$	581476	531476	53148	1.10
T_{24} $P_2S_3G_4$	524684	494985	29699	1.06
T_{25} $P_3S_1G_1$	386486	402589	-16103	0.96
T_{26} $P_3S_1G_2$	504324	382063	122261	1.32
T_{27} $P_3S_1G_3$	465421	375340	90081	1.24
T_{28} $P_3S_1G_4$	642776	537269	105506	1.20
T_{29} $P_3S_2G_1$	636776	527690	109086	1.21
T_{30} $P_3S_2G_2$	681049	526548	154500	1.29
T_{31} $P_3S_2G_3$	435698	427154	8544	1.02
T_{32} $P_3S_2G_4$	489652	425784	63868	1.15
T_{33} $P_3S_3G_1$	681049	526548	154500	1.29
T_{34} $P_3S_3G_2$	711253	539451	171802	1.32
T_{35} $P_3S_3G_3$	556096	545192	10904	1.02
T_{36} $P_3S_3G_4$	565486	418878	146608	1.35
T_{37} $P_4S_1G_1$	365847	556457	-190610	0.65
T_{38} $P_4S_1G_2$	358488	549564	-191076	0.64
T_{39} $P_4S_1G_3$	259844	322798	-62954	0.80
T_{40} $P_4S_1G_4$	575486	728462	-152976	0.79

T_{41} $P_4S_2G_1$	352483	456894	-104411	0.77
T_{42} $P_4S_2G_2$	558576	664971	-106395	0.84
T_{43} $P_4S_2G_3$	512230	538400	-26170	0.95
T_{44} $P_4S_2G_4$	447864	481574	-33710	0.93
T_{45} $P_4S_3G_1$	437324	476587	-39263	0.91
T_{46} $P_4S_3G_2$	459874	586742	-126868	0.77
T_{47} $P_4S_3G_3$	359404	460774	-101370	0.78
T_{48} $P_4S_3G_4$	487498	499756	-12258	0.97

There was significant difference in the gel yield of *A.vera* under different treatments (Table 21).Treatment T_9($P_1S_3G_1$-1.05kgplant^{-1}) recorded the highest gel yield which was on par with T_{10}(0.98kgplant^{-1}),T_1(0.93kgplant^{-1}),T_2(0.90kgplant^{-1})

4.7.INCIDENCE OF PESTS AND DISEASES

No serious pest and disease incidence was noticed during the study period.

4.8.ECONOMICS

Comparison of economics of production of seedlings using different treatments (Table 23) revealed that majority of treatments had a B:C ratio >1 and the treatments T_9 and T_{10} recorded the highest B:C ratios of 1.6 and 1.5 respectively.

Plate.8.General field view of *Aloe vera* at 6 MAP

Plate 10.3 node & 2 node disc of *Aloe vera*

Plate.11.Morphological view of treatment T_9[$P_1S_3G_1$]

(A)

(B)

Plate .12.Latex collection from fresh *Aloe vera* leaves

(A)

(B)

Plate.13.The best treatment T_9(A) at seedling stage.(B) at 6 MAP

DISCUSSION

5.DISCUSSION

The present study entitled "Refinement of macro-propagation technique for the mass-multiplication of aloe (*Aloe vera* Burm.f.)" was undertaken to refine the stem disc method of macro propagation of aloe for rapid mass multiplication. It was also aimed to analyze the effect of various pre-curing treatments on inducing axillary bud break, to optimize the segment size and to find out best sprouting treatments. The results of these experiments are discussed below.

5.1. MORPHOLOGICAL CHARACTERS AT NURSERY

5.1.1. Sprouting and Survival percentage

The data recorded three weeks after planting of different sized disc cuttings subjected to various pre curing and sprouting treatments, in pro trays, suggested that both the segment size as well as the pre-treatments significantly influenced the sprouting of cuttings.

As observed in Table 1, treatment combinations involving three node disc cuttings showed better sprouting than two node and single node disc cuttings. Higher content of reserve food material coupled with the presence of more viable buds in larger seed bits might have induced early sprouting and higher sprouting percentage. The increasing trend of sprouting with increasing size of planting material was reported in banana (Hernandez *et al.*, 1988) and in turmeric (Hussain and Said, 1967).

Among the pre curing treatments, partial crushing of the internodes of mother plants was found to be more effective in inducing axillary bud break, than foliar spraying of BA or *in situ* decapitation. Axillary bud break in control plants was very low. Orsi (2012) has reported that localized axillary bud break on the growing flower stem of *Rosa hybrida* „Kardinal" can be induced through mechanical manipulation of the stem by partially compressing the internode above a specific axillary bud.

Among the pre sprouting treatments, soaking the cuttings in growth regulators BA(1000ppm), GA3(25ppm), BA(2ppm)&IAA(2ppm) were found to enhance sprouting while

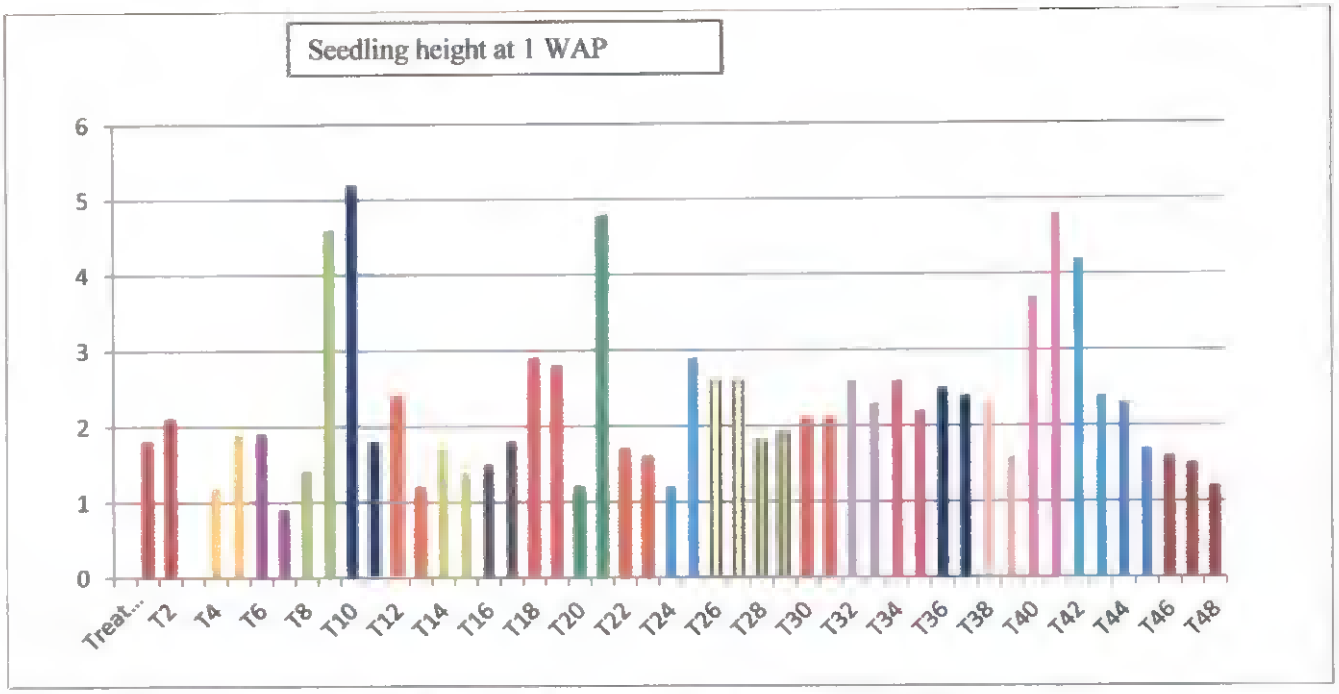

Fig:6a.Effect of treatments on seedling height of *Aloe vera* at 1 WAP in nursery

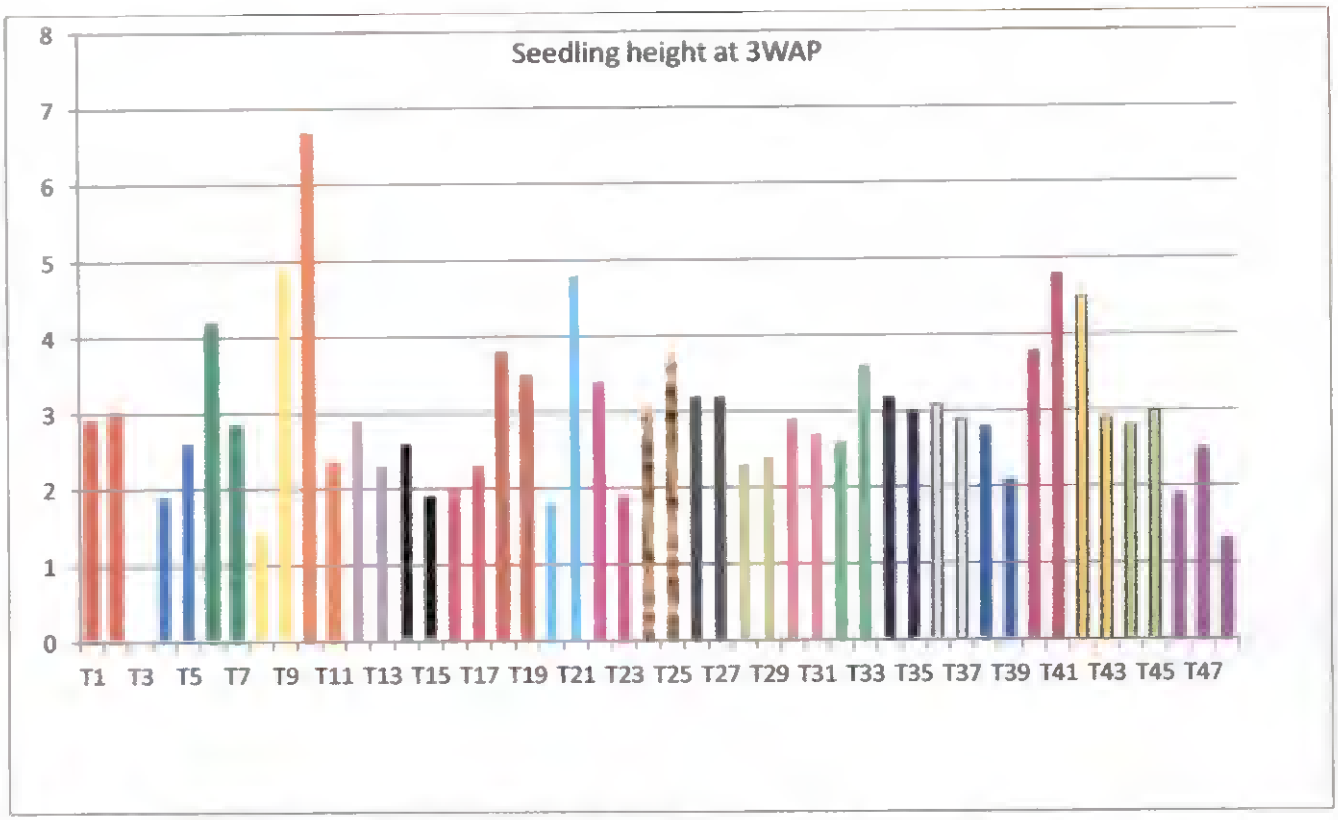

Fig:6b. Effect of treatments on seedling height of *Aloe vera* at 3 WAP in nursery

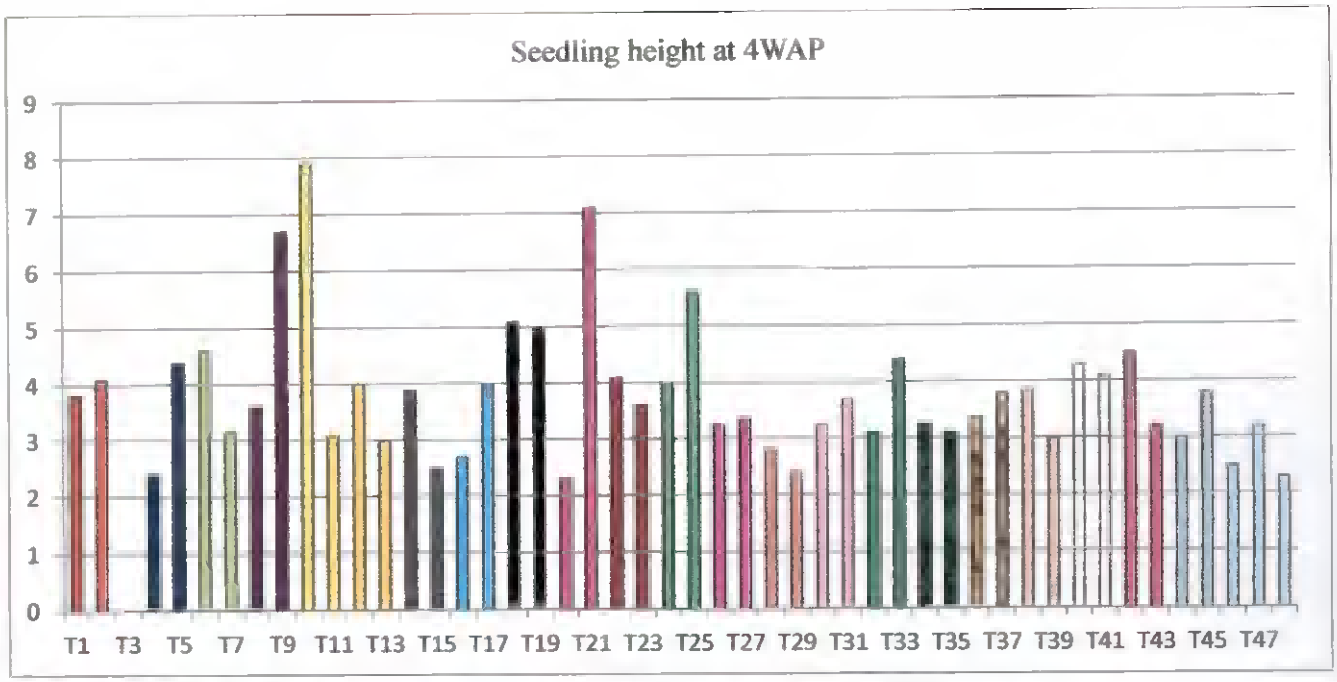

Fig:6c. Effect of treatments on seedling height of *Aloe vera* at 4 WAP in nursery

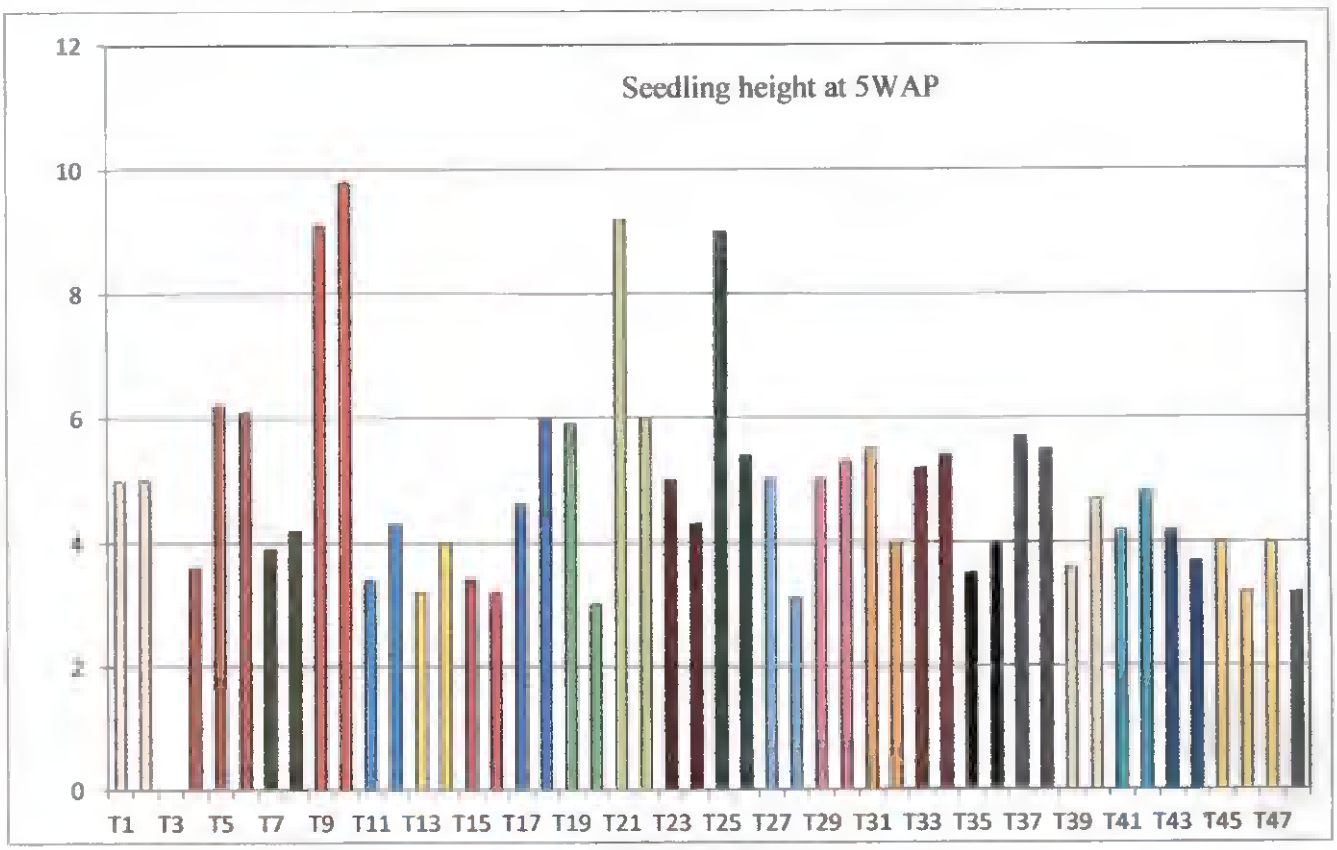

Fig.6.d. Effect of treatments on seedling height of *Aloe vera* at 5 WAP in nursery

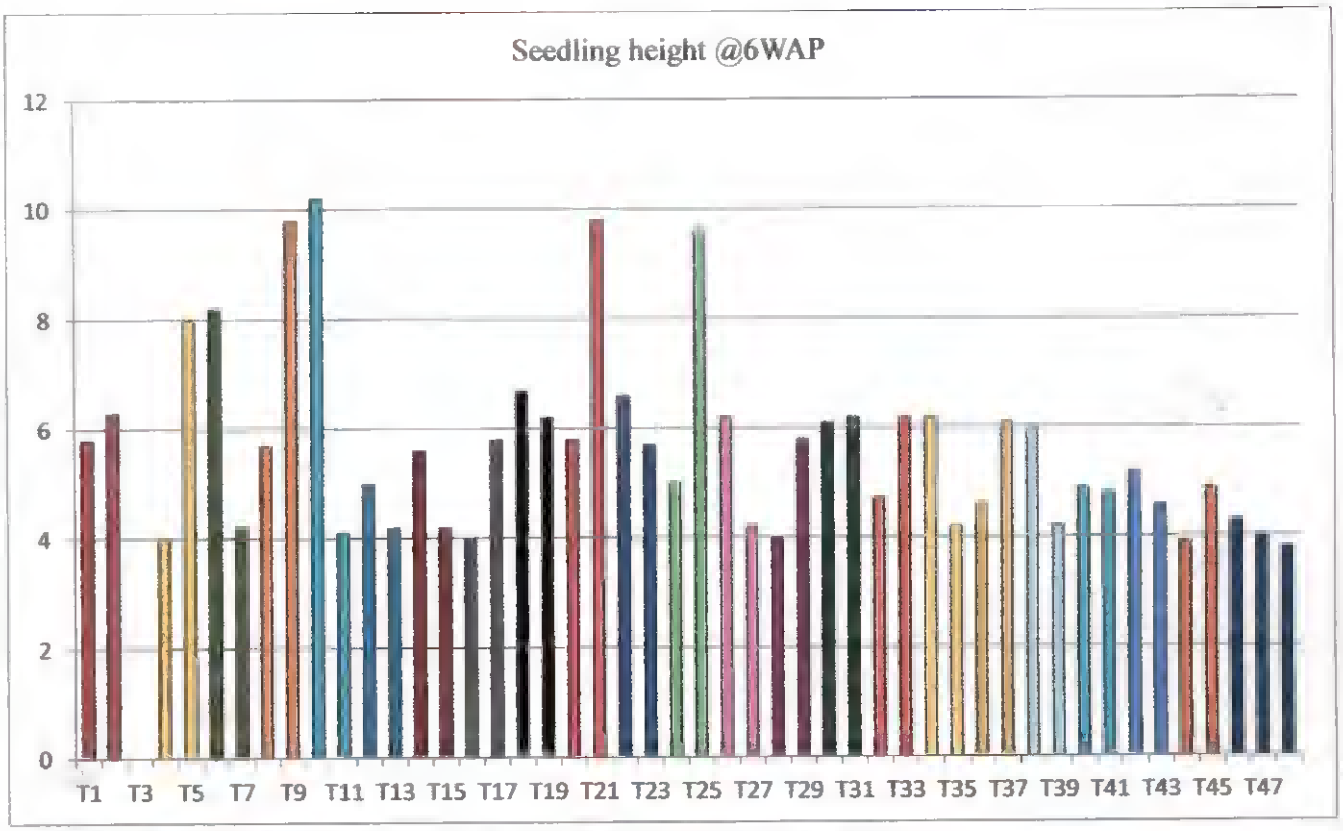

Fig:6.e.Effect of treatments on seedling height of *Aloe vera* at 6 WAP

honey treatment had practically no effect. Sprouting percentage was low in untreated cuttings also. Many people have found success with using honey to root cuttings. It is a natural antiseptic and contains antifungal properties – both of which are believed to be one of the reasons for using honey as a root hormone. But in the present study honey is found to have no beneficial effect on sprouting of aloe stem cuttings.

Three node disc cuttings collected from *in situ* decapitated parent material, treated with BA(1000 ppm) and GA_3(25 ppm) (T_9-$P_1S_3G_1$) recorded the highest sprouting percentage (80.60%) followed by T_{10} [($P_1S_3G_2$-three node disc cuttings from *in situ* decapitated mother plants treated with BA(2ppm) and IAA(2ppm)]. The lowest sprouting percentage (27.85) was given by single node disc cuttings treated with honey taken from mother plants without pre-curing (T_{39}-$P_4S_1G_3$) which was on par with control T48(28%)[$P_4S_3G_4$: no pre-curing+three node+control]

Significant influence of pre sprouting treatments with growth regulators were also noticed in the sprouting of stem cuttings. Among the pre-treatments, cuttings treated with BA(1000ppm) and GA3(25ppm) recorded higher sprouting percentage(80.60%) followed by T_{10} [($P_1S_3G_2$-three node disc cuttings from *in situ* decapitated mother plants treated with BA(2ppm) and IAA(2ppm)]. Breaking of dormancy and enhanced sprouting with higher concentrations of benzyl adenine has been reported in rhizome halves of achimenes as well as several bulbous and tuberous plants by Vlahos (1985). Cytokinins are known to induce bud break in many kinds of plants on both aerial and below-ground parts (Criley, 2001).Comparing all the other treatments the increase in sprouting percentage as a result of BA treatment might be due to optimum absorption of chemicals by stem cuttings, which might have been further utilized for physiological processes to influence the sprouting parameters and also the increase in the quantum of alternate respiration in stem cuttings due to these treatments.

Among the pre curing treatments, seedlings produced from *in situ* decapitated mother plants recorded better survival percentage followed by seedlings produced from mother plants with partially crushed of internodes. Repression of apical dominance to stimulate lateral bud development and increased suckering rate is achieved through decapitation of a sucker in the field (in-situ) or by detached corm technique (Dayarani *et al.*, 2013).

Spraying of mother plants with BA had better effect than control plants where no pre curing treatment was given to the mother plants. Regarding stem disc size, three noded discs gave better survival followed by two noded and single noded seedlings had the least survival percentage. Among the pre sprouting treatments, soaking the cuttings in growth regulators BA(1000ppm), GA3(25ppm), BA(2ppm)&IAA(2ppm) were found to have much influence on the survival of seedlings also. The effect of honey treatment was negligible as in the case of axillary bud break. It has been shown (Wang and Wareing, 1979) that while shoots are able to synthesize cytokinin, repressed axillary buds are not. Consequently it would seem that a redirection of cytokinin supply or a decline in auxin supply, may be necessary to either initiate axillary bud growth or to enable axillary buds to synthesize cytokinin, respectively.

5.1.2. Morphological parameters of seedlings in the nursery

From the study it was observed that the size of the stem disc as well as the pre-curing and growth regulator treatment combination have significant influence on the morphological characters like height, number of leaves, number of root, root length and root girth of the pro-tray seedlings throughout the observational period. The influence of pre curing of mother plants was visible in the growth of seedlings in the nursery and the seedlings from pre cured mother plants had better morphological parameters compared to seedlings produced from mother plants without any pre curing treatments. Segment size also had positive influence on seedling growth in the nursery with three noded seedlings having better performance. Pre sprouting treatments, soaking the cuttings in growth regulators BA (1000ppm), GA3 (25ppm), BA (2ppm)&IAA(2ppm) were found to enhance the growth of seedlings in the nursery compared to control. There is strong evidence that cytokinins are key factors in promoting bud growth (Tamas, 1987). Application of cytokinins to quiescent axillary buds from a range of species has been shown to stimulate their growth, for example in soybean (Ali and Fletcher, 1971) and in bulbous and cormous, monocotyledonous plants (Hussey, 1976). There are few reports on the relationship between axillary bud development and endogenous gibberellin levels and the data that exists is often contradictory. Studies with applied gibberellins indicate a possible role in the regulation of bud development. Kinetin strongly promotes the release of axillary buds from apical dominance when applied together with GA3 (Catalano and Hill, 1969; Sachs and

Thimann, 1964). It has, however, been suggested that this may be the action of GA3 on the buds after their release from inhibition by kinetin. Application of kinetin or benzyladenine, two synthetic cytokinins, to buds induces axillary shoot development by releasing axillary buds from the inhibition caused by apical dominance (Greene and Autio, 1989; Lyons and Hale, 1987). The cytokinin benzyl adenine, when applied basally, favored lateral bud development in *Arabidopsis* cuttings, but when applied apically, they remained dormant (Chatfield *et al.*, 2000).

The treatment combination T_9 ($P_1S_3G_1$) was found to be the best in enhancing the growth parameters of seedlings compared to other treatment combinations. In the above treatment combination growth parameters such as sprouting percentage, survival percentage and seedling height were significantly superior compared to other treatment. Regarding root characters of the seedlings, treatment combination, T_9 [($P_1S_3G_1$-three node disc from *in situ* decapitated parent material treated with BA(1000ppm) and GA3(25ppm)] recorded maximum number of roots at the nursery period which was on par with T_{10} ($P_1S_3G_2$), T_{17} ($P_2S_2G_1$), T_{18}($P_2S_2G_2$), T_{21}($P_2S_3G_1$),T_{22}($P_2S_3G_2$),T_{23}($P_2S_3G_3$),T_{25}($P_3S_1G_1$) and T_{33}($P_1S_3G_1$)during the nursery period. Seedlings of single noded disc without pre-curing treated with honey, T_{39}($P_4S_1G_3$)recorded the lowest number of roots in the nursery period. Regarding root length and girth also T_9 recorded the highest values which was on par with T_{10}.

Plants with better root system obviously will give better growth of the plant. The ramified root system might have promoted better nutrient uptake and consequent improved growth attributes. It was observed that more number of leaves and roots was produced by seedlings of three node disc treated with BA and GA_3. The result is in conformity with findings of Aswathy (2015) who reported that in kasturi turmeric, three node rhizome bits treated in benzyl adenine registering high percent sprouting and survival rate of raised plants. The presence of plant growth promoting hormones might have contributed to the better growth characters observed in the seedlings. Lowest number of roots in seedlings of disc cuttings without pre-curing and growth regulator treatment {T_{40} ($P_4S_1G_4$)} also agrees to this.

Another factor noticed in this experiment was that the vegetative characters of the seedlings increased with increasing seed size. On the other hand, seedling sprouting was almost uniform irrespective of the size of seed rhizomes. Studies carried out in amorphophallus using different

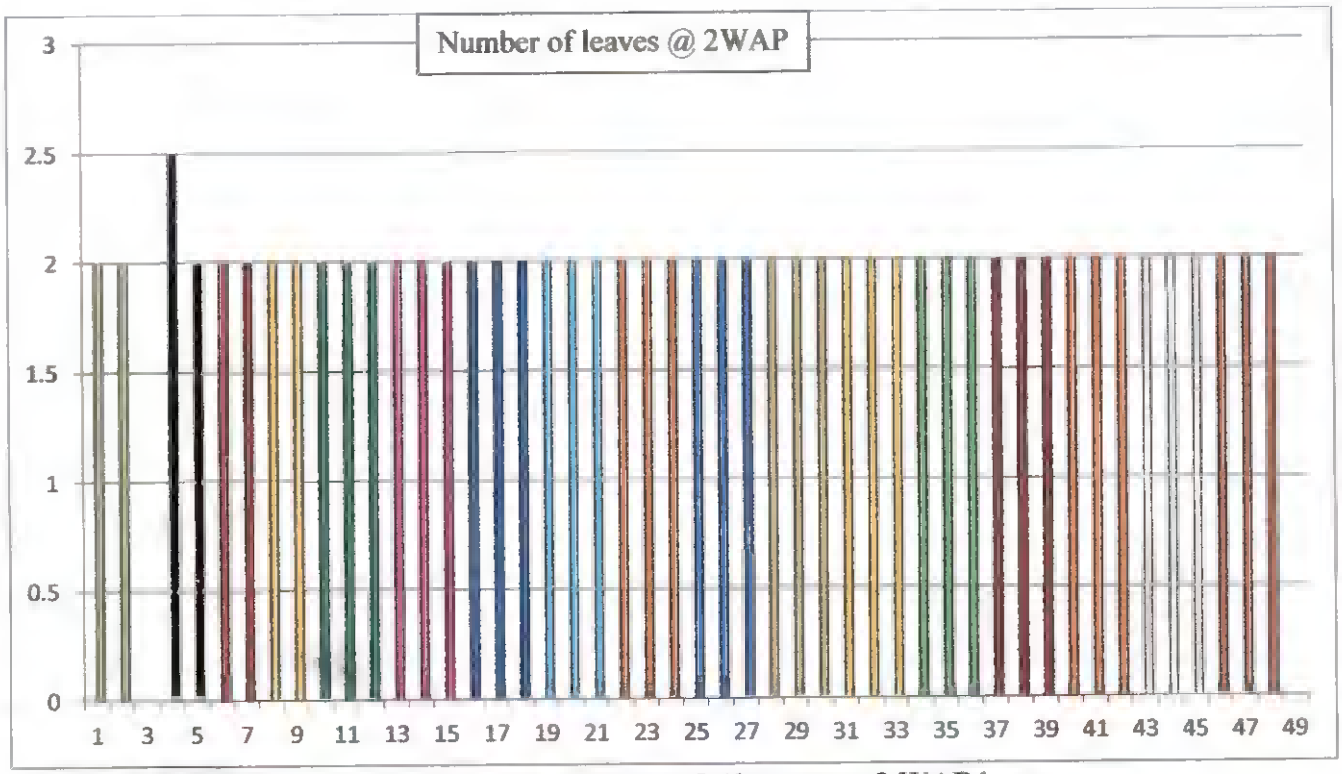

Fig:7.a. Effect of treatments on number of leaves of *Aloe vera* at 2 WAP in nursery

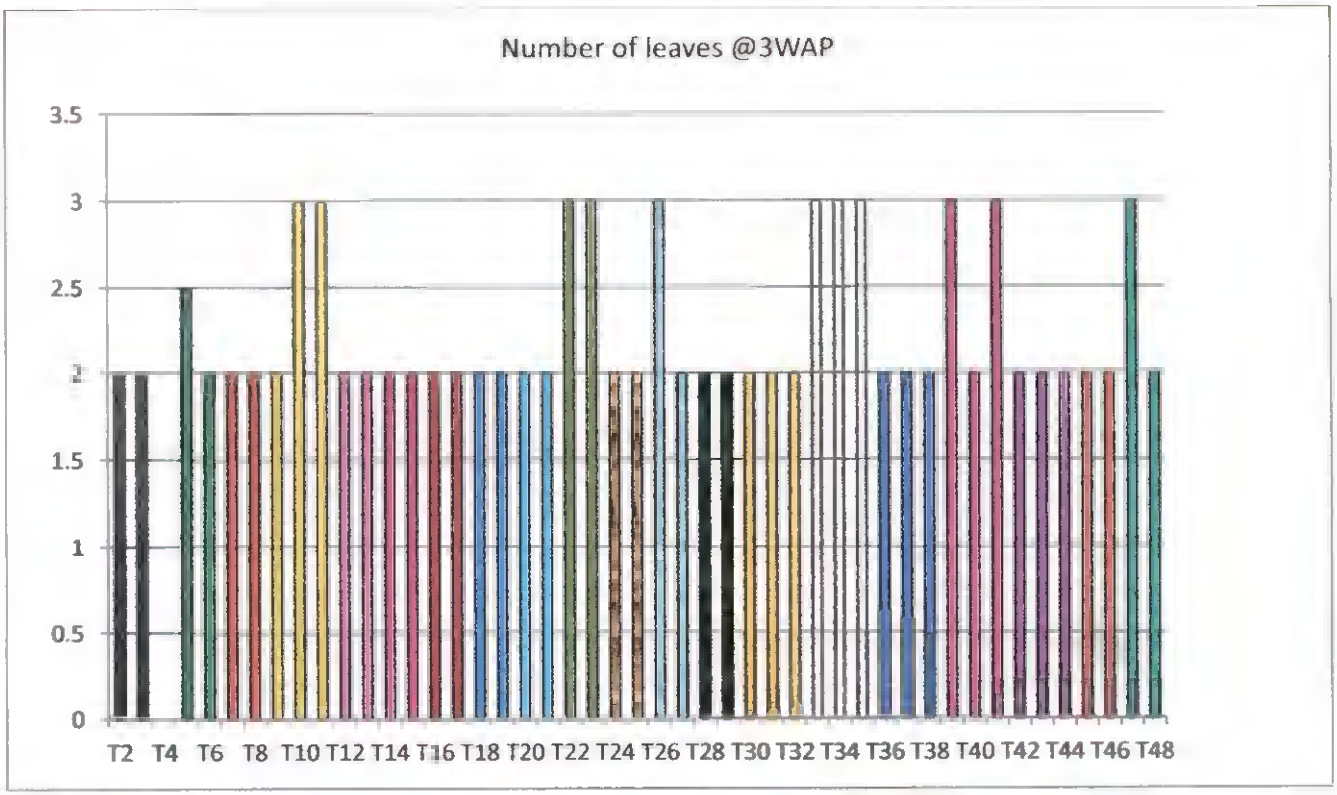

Fig:7.b. Effect of treatments on number of leaves of *Aloe vera* at 3 WAP in nursery

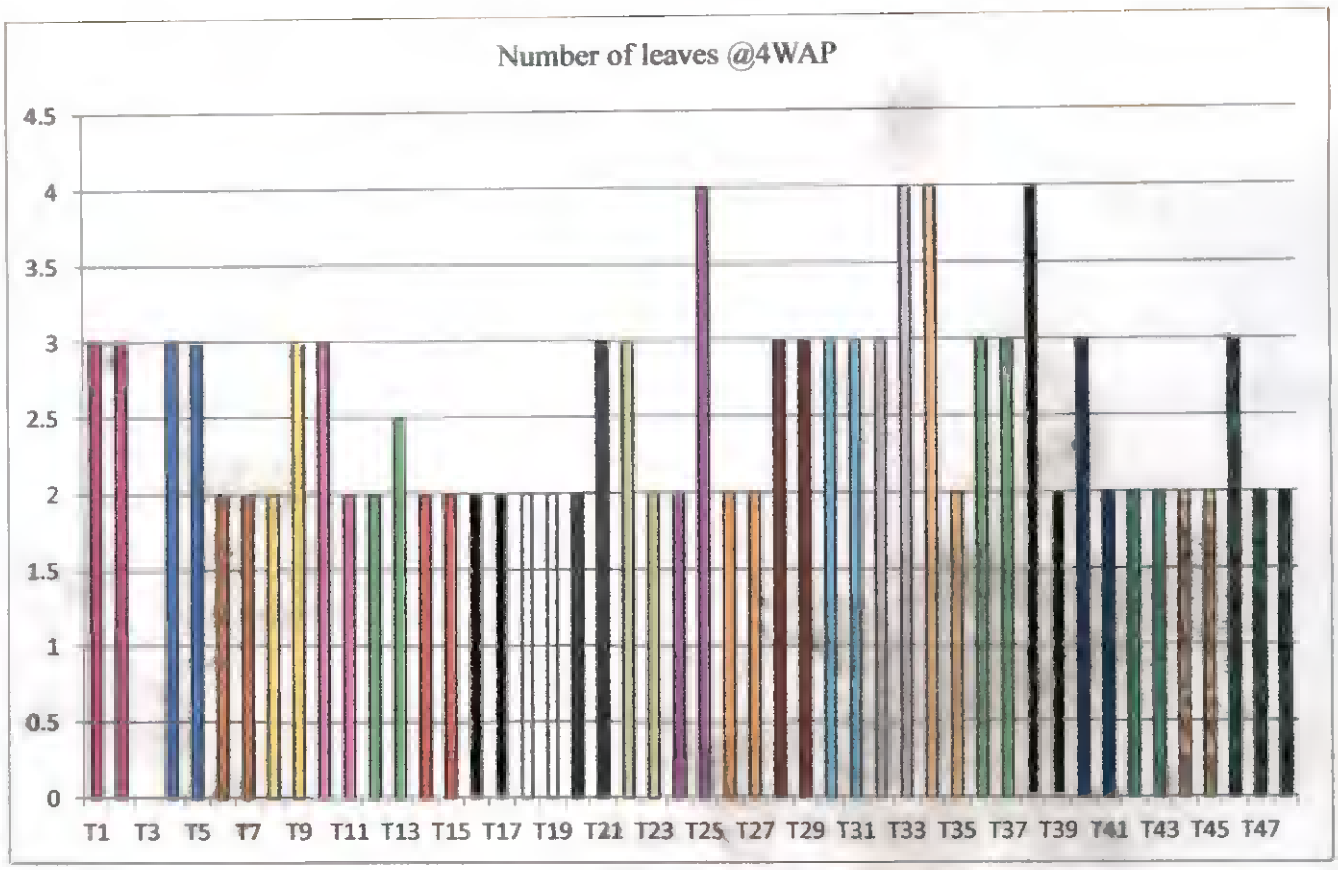

Fig:7.c. Effect of treatments on number of leaves of *Aloe vera* at 4 WAP in nursery

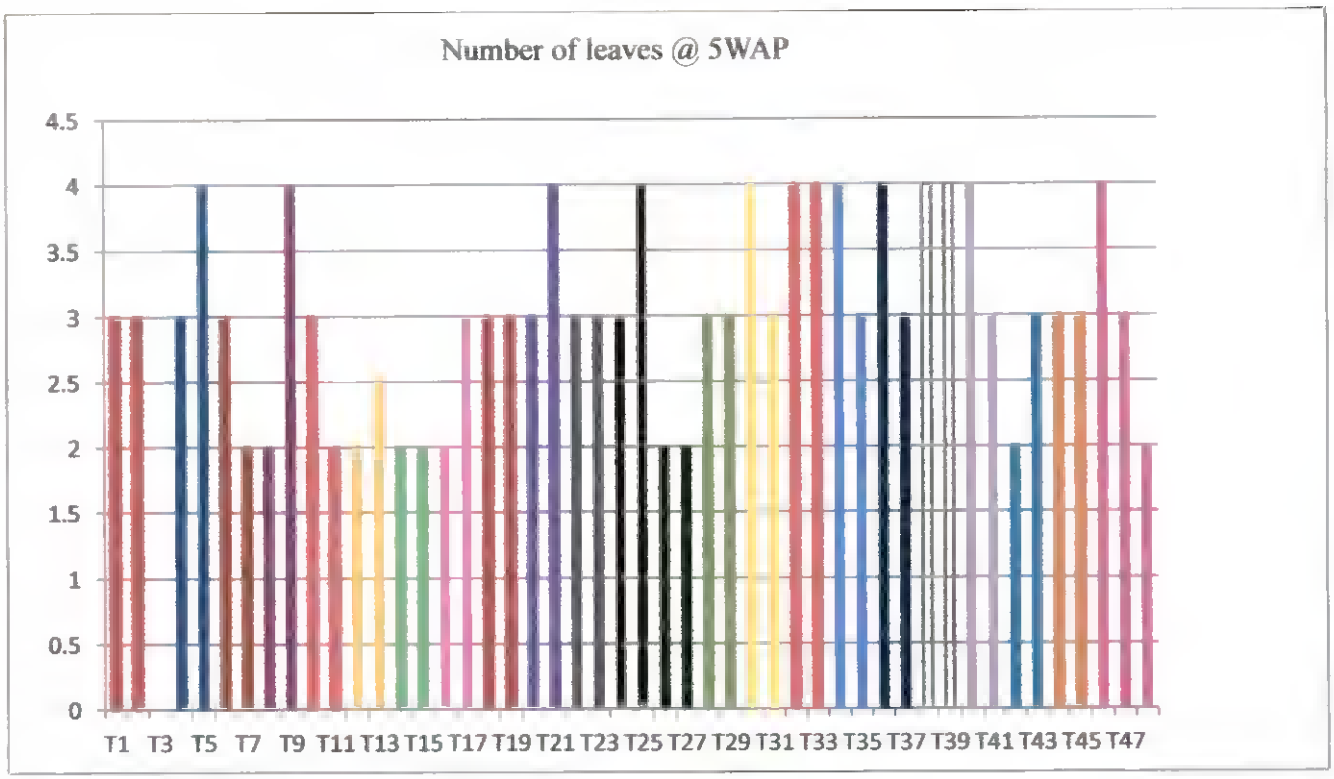

Fig:7.d.Effect of treatments on number of leaves of *Aloe vera* at 5WAP in nursery

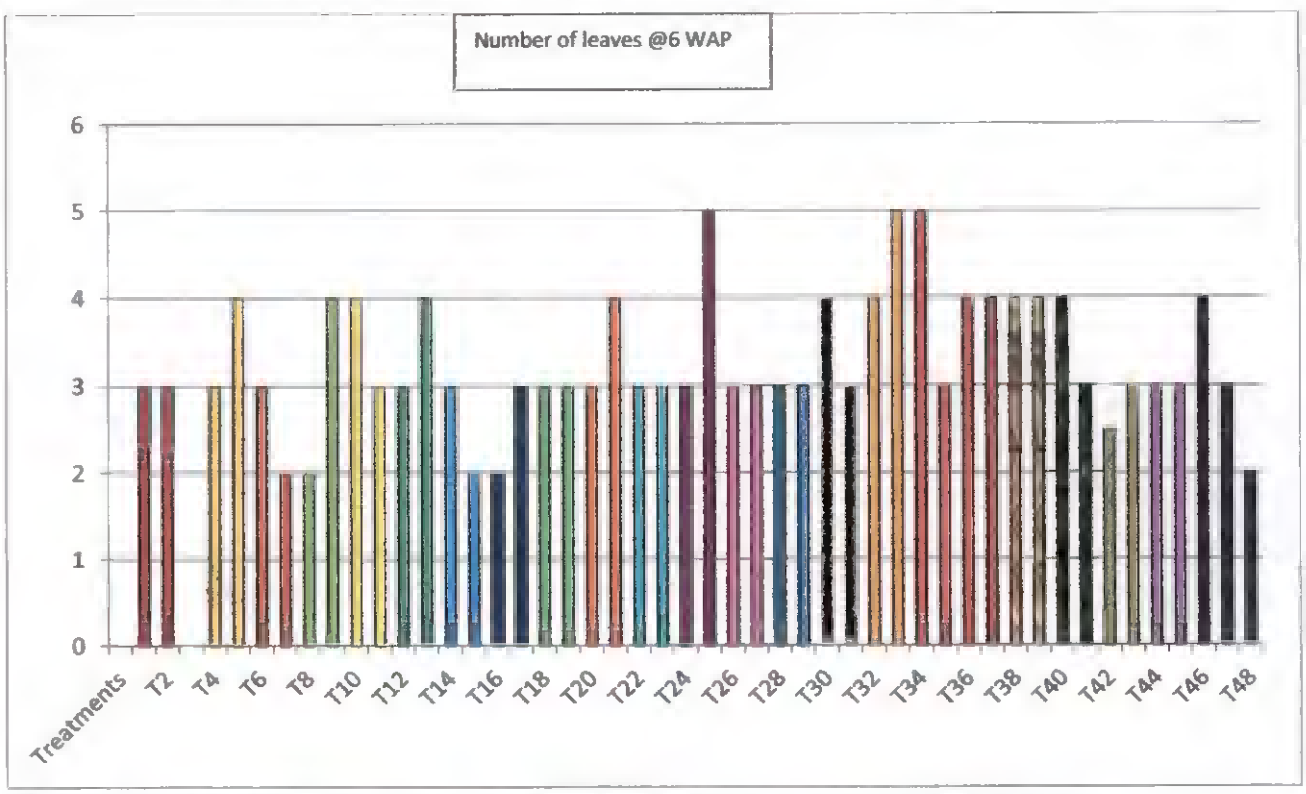

Fig:7.e.Effect of treatments on number of leaves of *Aloe vera* at 6 WAP in nursery

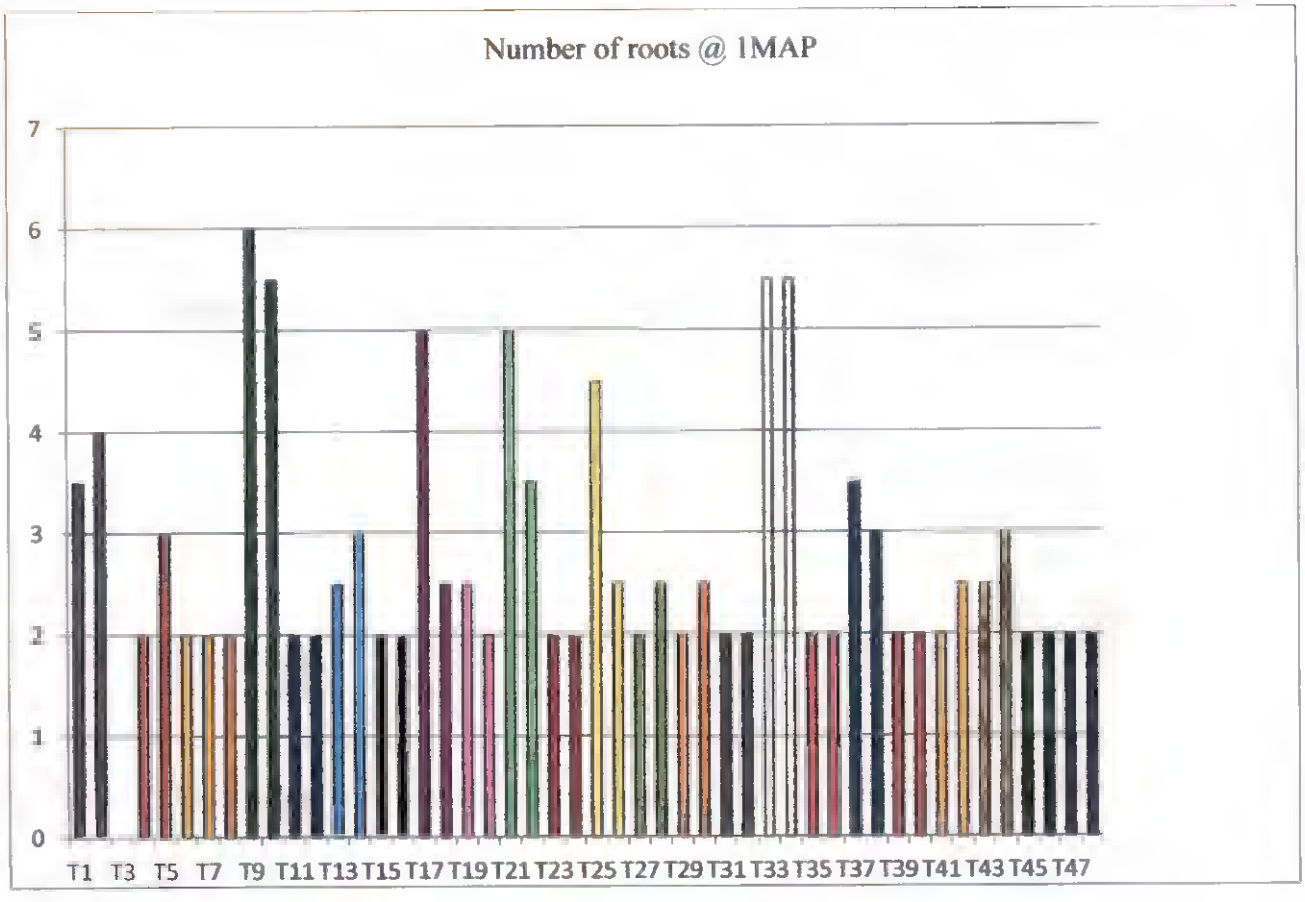

Fig:8.a.Effect of treatment on number of roots of *Aloe vera* at 1 MAP in nursery

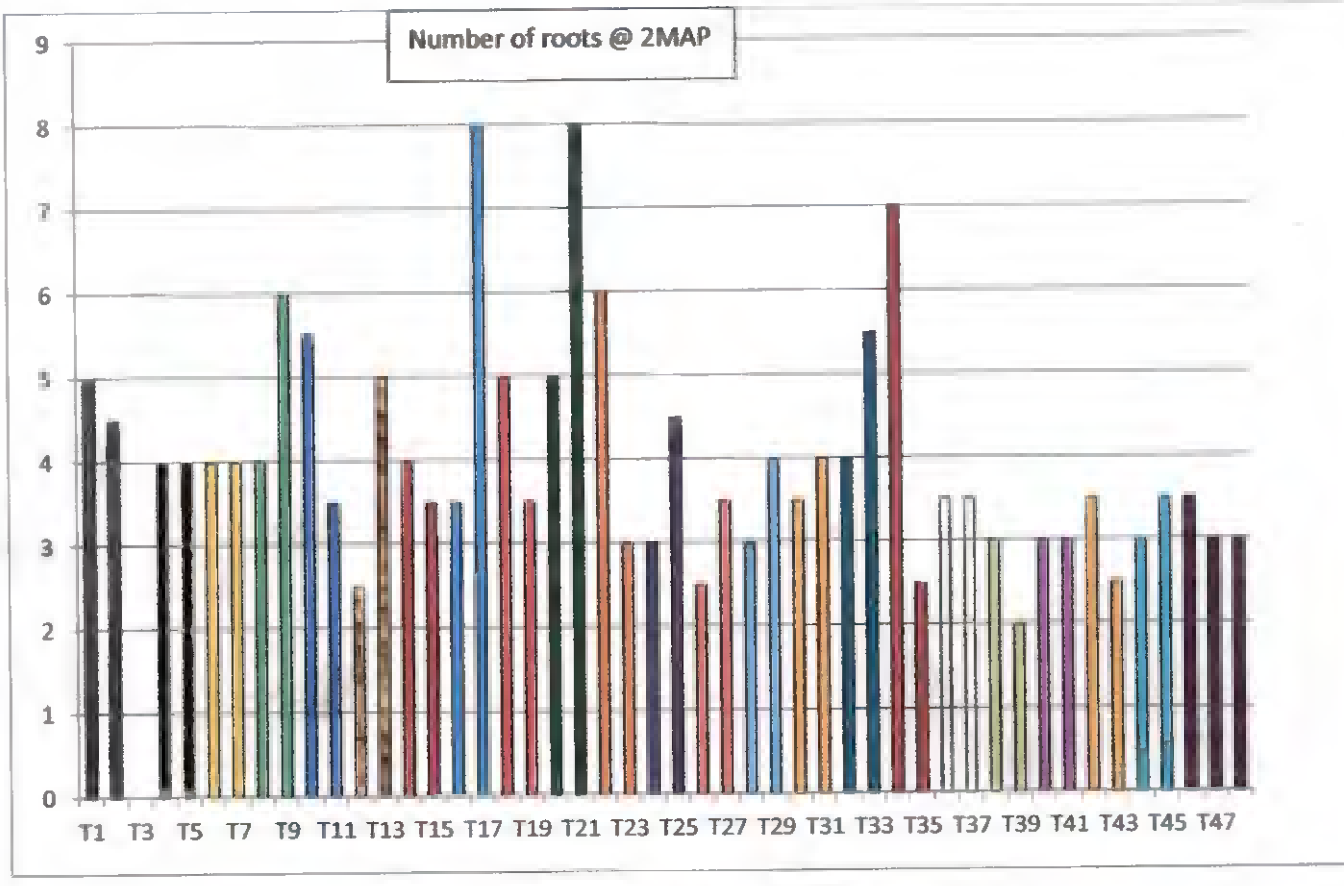

Fig:8.b.Effect of treatment on number of roots of *Aloe vera* at 2 MAP in nursery

sized rhizome bits also revealed the same trend. Here also, plant height and canopy size were less when planting bits were smaller (KAU,1983). Increase in plant height with increasing seed size has also been reported in ginger by Korla *et al.*, (1989). Better seedling growth and morphological characters in the treatment T_9 may be due to stored food materials in the stem cutting as well as the influence of the growth regulators.

5.2. Morphological (Growth)Characters after transplanting.

Morphological(growth) characters such as plant height, number of leaves, leaf length, leaf breadth, leaf thickness, and leaf weight after transplanting also showed significant difference among different treatment combinations. The influence of pre curing treatments were found to decrease after transplanting of the seedlings and not much difference in plant growth was observed among these treatments. However the influence of segment size and pre sprouting treatments were evident in plant growth after transplanting also. Three noded cuttings treated with growth regulators performed better than control plants.

Treatment T_9[$P_1S_3G_1$-3 node disc collected from *in situ* decapitated mother aloe which was treated with BA(1000ppm) and GA3(25ppm)] recorded the superior morphological characters among all remaining treatment combinations. Similar result was obtained in *Vitex negundo*(L.) from triple noded cuttings by Bhagya(2014) on the morphological characters. According to Bhagya,(2014) shoot parameters such as days taken to sprout (9 days), number of sprouts(3.23), length of the longest sprout (20.38 cm), fresh weight (3.6 g) and dry weight (0.88 g) of sprouts and the root parameters like time taken to root (30 days), number of roots (19.05), length of the longest root (21.75 cm), fresh weight (2.37 g) and dry weight (0.67 g) of roots were significantly higher in triple node stem cuttings treated with Indole Butyric Acid 3000 ppm. Application of Benzyladenine in *Codiaeum variegatum* plants significantly increased plant height, number of leaves and fresh weight of leaves in comparison to the control plants (Nahed and Aziz, 2007). The application of BA and their interaction had significant effect on number of offsets. Means comparison showed that an increase in nodal length and BA levels significantly increased the number of plant offsets. The highest number of offset was observed in the plants treated with 1500 mg BA alone, while the control treatment had no offsets.

5.4 Number of offsets

In the study pre curing of mother plants did not have any influence on offset production of the seedlings with more number of offsets in control plants compared to plants from pre cured mother plants. However, pre soaking treatments using growth regulators were found to influence offset production and such seedlings produced comparatively higher number of offsets than control plants. At 5 MAP, treatments T_{26} and T_{32} (3.00) recorded the highest number of offsets which was on par with treatment T_9 (2.50). During 6 MAP, treatment T_9 (3.50) recorded the highest number of offsets which was on par with treatments T_{10},T_{25},T_{26} T_{32} (3.00). Natural propagation of *Aloe vera* is primarily by means of axillary shoots and it is rather a slow way of multiplication to meet the growing demand . Sardoei(2014) has reported increased offset production in aloe by foliar application of BA and GA3 with concentration of 400 mg L^{-1} . Foliar application of BA with concentration of 1500 ml L^{-1} increased offsets number in aloe while higher levels of BA prevented root growth. Increased offsets number can be attributed to decreased apical dominance by main stem (Hazrati *et al.*, 2011)

Gibberellic acid is a very potent hormone whose natural occurrence in plants controls their development. Since GA regulates growth, applications of very low concentrations can have a profound effect while too much will have the opposite effect. It is usually used in concentrations between 0.01 and 10 mg/L.(RelyJohn,2014). Cytokinins are important plant hormones that regulate various processes of plant growth and development with cell division and differentiation, enhancement of leaf extension and nutrient mobilization (Shudo, 1994). Spraying cytokinins on *Hemerocallis citrine* shows that this group of plant growth regulators can increase offset production via affecting cell division, offsets size and growth by stimulating lateral buds growth (Amling *et al.*, 2007).

5.3.YIELD PARAMETERS

5.3.1. Leaf yield

Pre curing treatments were found to have great influence on the final yield and seedlings produced from mother plants with partially crushed internodes were found to give the highest yield followed by mother plants subjected to *in situ* decapitation. Similarly, plants raised from three node disc recorded comparatively higher leaf yield than plants of single or double

noded disc. Pre sprouting growth regulator treatments also were found to have influence on yield with the treatment G_2 giving the highest yield followed by G_1.

Treatment T_9 had the highest fresh leaf weight (4.20kg/plant) which was significantly superior to all treatments followed by T_{10}(3.94kg/plant).The treatments T_5($P_1S_2G_1$-3.20kg/plant),T_6($P_1S_2G_2$-3.40kgplant^{-1}),T_{10}($P_1S_3G_2$-3.94kgplant-^{1}),T_1($P_2S_2G_2$-3.90kg/plant),T_{21}($P_2S_3G_1$-3.20kgplant^{-1}),T_{22}($P_2S_3G_2$-3.72kgplant^{-1}),T_{33}($P_3S_3G_1$-3.62kgplant^{-1}) and T_{34}(3.32kgplant^{-1}) found on par with the highest value. The control T_{48} recorded the lowest value (0.520kg/plant). Regarding gel and latex yield also treatment T9 ($P_1S_3G_1$-1.05kgplant^{-1}) showed its superiority which was on par with T_{10}.

In nature, *A. vera* is propagated through lateral buds, which is slow, very expensive and low income practice (Meyer and Staden, 1991). About 28000 – 34000 suckers are needed for one hectare planting. Crop is ready to harvest after 18 months of sowing. Economic yields are obtained in 5 years after that it needs replanting. In India, the average yield for organically grown Aloe is about 12 tonnes/ha (on fresh weight basis) (Rajeswari *et al.*, 2012).In commercial cultivation of aloe using suckers, average per plant yield during the first year of cultivation comes to around 2-3kg.In the present study the best treatment combination (T_9) was able to give a fresh leaf yield of (4.20kg/plant).

5.3.2.Gel yield

Results of analysis of variance showed that application of growth regulator had significant effect on gel weight ($P<0.05$). Treatment T_9($P_1S_3G_1$-1.05kgplant^{-1}) recorded the highest gel yield which was on par with T_{10}(0.98kgplant^{-1}),T_1(0.93kgplant^{-1}),T2(0.90kgplant^{-1})

The highest gel weight was obtained in BA(1000ppm)& GA3(25ppm). Also, gel and peel weight were significantly affected by BA application ($P<0.01$). The maximum gel weight was observed in 1000 ppm BA treatment. The concurrent application of N and BA had significant effects on gel and peel weight. Similar results were obtained by Nahed and Aziz in 2007.According to them, the best growth parameters were obtained in the plants treated with 1000 ppm BA foliar spray.

In this regard, on the previous documents, growth parameter values were increased by enhancement of BA levels. There is scarcity of information about the application of hormones

sprayed on plants to this family. However, a number of studies showed that an increase in N and BA led to increase in photosynthesis, chlorophyll content and cell division in apex meristem and cambium that caused an increase in the leaf yield and growth parameters in A. vera plants (Sakakibara *et al.*, 2006; Halmann, 1990). Also, by increase in the levels of N and BA growth parameters were increased, while in the plants treated with N or BA increase in the growth parameters was less observable and these results were similar with other studies. In our study, volume of leaf increased as a result of increase in length and thickness of leaves. Thus, leaf volume can be an important factor for the determination of leaf yield and leaf fresh weight (Hernández-Cruz et al., 2002). Leaf of *Aloe vera* is an important factor in yield determining in *Aloe vera* plant (Eshun and He, 2005). The application of 1000 ppm BA had significantly increased the yield; similar results were obtained by Khandelwal *et al.* (2009). Increased N uptake from the soil by the root system of A. vera plant could be the reason for its higher gel content (Ray, 1999). Ji-Dong *et al.* (2006) reported that the N application increased leaf fresh weight and total biomass. On the other hand, Cytokinin can increase division, cell enlargement and distribution of assimilates in the succulent plants and thus cause to better development of the leaves and increase in gel weight (Carey, 2008). Hernández-Cruz *et al.* (2002) showed that the yield of aloe gel was better with a low frequency of watering and a high amount of fertilizer. It was observed that the BA increased the number of offsets in Aloe vera plants that might be due to the suppression of apical dominance and stimulation of branches in this experiment (Duck *et al.*, 2004). Similar results were obtained by Carey *et al.* (2008) on Echeveria and Sempervivum plants that belong to the Liliaceae family. Thus, BA may be used for increasing the number of offsets and the number of propagules or for reducing the apical dominance of the A. vera plants (Sakakibara *et al.*, 2006). Phenolic compounds are considered to be secondary metabolites synthesized in plants and make a defense mechanism that reacts to different biotic and abiotic stress conditions (Dixon and Paiva, 1995). In another study, application of N increased the phenolic compounds (aloin and Barbaloin) in latex leaves (Saradhi *et al.*, 2007). The treatment that had the highest level of yields had also the highest aloin concentration. Exogenous cytokinin increased the chlorophyll content in the chloroplast (Davies, 2004).

Therefore, the results of this study showed that the nodal length and BA increased growth, yield and aloin concentration in A. vera plants. From the results of this investigation, it can be concluded that the nodal length,pre-treatment and BA increased yield at

A. vera plant so that the highest yield and latex concentration were observed in the simultaneous application of BA and GA3.

In nature aloe mother plants produces suckers usually one year after planting and the rate of sucker production is very low ie., two to three per year. In the present study it has shown that from a single mother plant having 20 cm long stem 4 three node (5cm length) cuttings can be taken. From these cuttings on an average three seedlings can be produced within a period of three weeks with the mean sprouting and survival percentage of 80. These seedlings produced from the cuttings were seen producing offsets at the rate of three numbers after a period of eight to nine months of transplanting. Thus within one year 9 suckers can be produced from a single mother plant which nearly three times higher than using conventional planting material. Hence this method of raising plantlets from aloe stem cuttings can be considered as a rapid method for mass multiplication. The plant regenerated from nodal segment is considered to be one of the most promising ways for multiplying a selected variety true to its type (Alam *et al.*, 2015).

5.4. ECONOMICS OF PRODUCTION

Comparison of economics of production of seedlings using different treatments (Table 23) revealed that majority of treatments had a B:C ratio >1 and the treatments T_9 and T_{10} recorded the highest B:C ratios of 1.6 and 1.5 respectively. Hence production of seedlings using three node disc cuttings collected from *in situ* decapitated parent material, treated with BA(1000 ppm) and GA_3(25 ppm) and three node disc cuttings from *in situ* decapitated mother plants treated with BA(2ppm) and IAA(2ppm) can be recommended as a rapid, cost effective technique for mass multiplication of *Aloe vera*.

SUMMARY

SUMMARY

A study on "Refinement of Macro-propagation technique for the mass multiplication of aloe(Aloe vera.Burm.f.) was carried out at the College of Agriculture, Vellayani during 2014-2016.The objective of the study was to refine the stem disc method of macro propagation of aloe for rapid mass multiplication.It was also aimed to to analyze the effect of various pre-curing treatments on inducing axillary bud break, to optimize the segment size and to find out best sprouting treatments.

The major findings of the experiment are summarized in this chapter.

A significant influence in sprouting percentage,survival percentage and morphological parameters at nursery like seedling height, number of leaves, number of roots,length of roots and girth of roots was noticed among various treatments during the observation period.Treatment T_9[$P_1S_3G_1$-3 node disc collected from insitu decapitated mother aloe which was treated with BA(1000ppm) and GA3(25ppm)] recorded the maximum sprouting percentage,survival percentage,seedling height and root characters. The lowest sprouting percentage was given by one node disc cuttings without pre-curing treated with honey (T39-P4S1G3) which was on par with T40. Treatment T40(P4S1G4: no pre-curing-single node disc-no growth regulator) showed the lowest survival percentage(33.8%). The lowest seedling height was given by T48(P4S3G4) during the observational period.Treatment T40 showed the minimum values in root characters.

Morphological characters such as plant height,number of leaves,leaf length,leaf breadth,leaf thickness,leaf weight and number of offsets after transplanting also showed significant difference among different treatment combinations. Treatment T_9[$P_1S_3G_1$-3 node disc collected from insitu decapitated mother aloe which was treated with BA(1000ppm) and GA3(25ppm)] recorded the superior morphological characters among all remaining treatment combinations. Treatment T48(P4S3G4-16.90cm) showed the lowest plant height and produced minimum number of leaves. The lowest leaf breadth (2.70cm) and leaf weight (62.62gm) was recorded in treatment T_{40} at 6 MAP. Lowest leaf thickness was recorded in treatment T_{44}(P4S2G4-0.52cm) during the observation period.

The statistical analysis of physiological growth parameters revealed that there was significant variation in Absolute Growth Rate (AGR) among treatments during 6MAP,Relative

Growth Rate (RGR),Net Assimilation Rate (NAR) and Leaf Area Index (LAI) during the entire observation period.

LAI was influenced by the size of disc as well as the pre-curing and growth regulator treatments and significant differences were noticed among the treatments.At 2 MAP,treatment T_{10} recorded the highest value of 0.224 which was on par with T_9 (0.202).The next best result was given by T_{21}(0.172).T_{39} recorded the least value(0.050).During 4 MAP,treatment T_{10} recorded significantly superior leaf area index of 0.742 which was on par with T_9 (0.726).Next best treatment was T_{22} (0.650) and the lowest LAI value was recorded for T_{43} (0.128). At 6 MAP,treatment T_9 recorded the maximum LAI of 0.928 and treatment T_{10} (0.910)and T26(0.914) were on par with it.T_{22} also recorded superior value (0.846) and the lowest value was observed for T_{39} (0.188).

The fresh leaf,gel,gel yield as well as the latex yield of aloe showed significant difference among different treatments. had The highest fresh leaf yield of 4.20kgplant-1 was obtained from treatment T9[P1S3G1 which was significantly superior to all treatments followed by T10 (3.94kg/plant).The treatments T5(P1S2G1_3.20kg plant-1),T6(P1S2G2_3.40kgplant-1),T10(P1S3G2-3.94kgplant-1),T18(P2S2G2-3.90kgplant-1),T21(P2S3G1-3.20kgplant-1),T22(P2S3G2-3.72kgplant-1),T33(P3S3G1-3.62kgplant-1) and T34(3.32kgplant-1) found on par with the highest value.

Similarly the highest latex yield (16.60g/plant) was also obtained from treatment T9 which was significantly superior to all treatments which was on par with T10 (16.40 g/plant),T8(15.90gplant-1),T18(15.95g/plant) and T21(15.70gplant-1) during the observation period.The control T48 recorded the lowest value for both fresh leaf yield. (0.520kg/plant). and latex yield (6.250g/plant). Treatment T9(P1S3G1-1.05kgplant-1) also recorded the highest gel yield which was on par with T10(0.98kgplant-1),T1(0.93kgplant-1),T2(0.90kgplant-1).No major pest and disease incidence were noticed throughtout the cropping period. BC ratio varied significantly for the treatments.The treatment T9 recorded the highest BC ratio.

Present study revealed that the treatment T9 (P1S3G1) was significantly superior in enhancing morphological,yield and quality attributes.The highest BC ratio was also the maximum in treatment T9.

REFERENCE

REFERENCE

Abrie, A. L and Staden ,J.V .2001. Micropropagation of the endangered *Aloe polyphylla*. *Plant Growth Regul*. 33: 19-23.

Aggarwal, D. and Barna , K. S. 2004.Tissue culture propagation of elite plant of *Aloe vera* L. *J. Plant Biochem Biotech*. 13: 77-79.

Ajabnoor, M. A. 1990. Effect of *Aloe* on blood glucose levels in normal and alloxen diabetic mice. *J. Ethnol. Pharmacol*. 28: 215-220.

Akinyele, B.O. 1998. Biosystematics studies in some Nigerian representatives of *Aloe* Linn. Ph.D. Thesis, University of Ilorin, Nigeria, 195p.

Alam, Osawa, and Namiki.2015.A novel type of antioxidant isolated from leaf wax of *Eucalyptus* leaves. *Agric. Biol. Chem*. 45:735-739.

Ali, A. and Fletcher, R. A. 1971. Hormonal interaction in controlling apical dominance in soybeans. *Canadian J. Bot*. 49,1727- 1731.

Aloe India .2007. The plant of immortality http://aloeupflorida.com/careofaloevera.html. p. 1-4.

Aloe vera company.2002.The miracle plant http://aloeindia.com/aloevera.html. P.6-9.

Amling J.W., Keever G.J., Kessler J.R.J., and Eakes D.J. 2007. Benzyl Adenine (BA) promotes ramet formation in *Hemerocallis itrina*. *J. Environ. Hortic*. 25(1):9-12.

Anselm, A. 2004a. Nature Power, Christian Approach to Herbal Medicine.(3rd Ed.).Publ. Generation Press Ltd., Lagos, Nigeria, 290p.

Anselm, A. 2004b. Nature power 3rd Edition Anselm Adodo Publications. OSB Ewu-Esan, Nigeria. Pp. 288.

Armitage, A.M. 1997. Herbaceous perennial plants, 2nd ed. Stipes Publishing, L.LC, Champaign, IL. p. 540.

Aswathy,T,S.2015. Rapid multiplication of Kasthuri turmeric (Curcuma aromatica Salisb.) through minisett technique and nursery management.M.Sc.(Hort.)thesis,Kerala Agricultural University,Thrissur,43p.

Atherton, P. 1998. *Aloe vera* revisited. *Br.J.Phytother.* 4: 76-83.

Balraj Singh and Neelu. S. 2009 .Significance of explant preparation and sizing in *Aloe vera* L.—A highly efficient method for *in vitro* multiple shoot induction. *Scientia Horticulturae* 122(1):146–151

Bangerth, F. 1994. Response of cytokinin concentration in the xylem exudate of bean (*Phaseolus vulgaris*.L.) plants to decapitation and auxin treatment, and relationship to apical dominance. *Plant* 194(3): 439-442.

Baskin, C.C. and Baskin, J.M.1998. *Seeds: Ecology, biogeography, and evolution of dormancy and germination (Academic Press, San Diego, CA).*

Basra, A.S. 2000. Plant growth regulators in agriculture and horticulture: Their role and commercial uses. *Food Products Press, Binghamton, NY.*

Bhagya, H. P., Lalithya, K. A., and Bharathi, K. 2014. Influence of growth hormones and nodal cuttings on rooting of *Vitex negundo* (L.). *Indian J.Agric. Res* .48(2): pp.81-88.

Blanchette, L.1998. Asexual propagation of Anemonella, Dodecatheon, and Trillium Combined Proceedings. *Int. Plant Propagators Soc.* 48: 327–328.

Blumenthal and Mark. 2002. Herbal gram. America Botanical Council, Austin,49: 52-53.

Booker, Jonathon, Steven Chatfield and Ottoline Leyser . 2003. Auxin acts in xylem-associated or medullary cells to mediate apical dominance. *Plant Cell* 15: 495–507.

Buttery, B. R.1970. Effect of variation in leaf area index on growth of maize and soyabeans. *Crop Sci*.10:9-13.

Campestrini, L.H., Kuhnen, S., Lemos, P.M.M., Bach, D.B., Dias, P. F., and Maraschin, M. 2006. Cloning protocol of Aloe vera as a study-case for "tailor-made" biotechnology to small farmers. *J.Technol. Manag. and Innovation* 1(5): 76-79.

Carey and Dennis John. The Effects of Benzyladenine on Ornamental Crops.2008. A thesis submitted to the Graduate Faculty of North Carolina State University in partial fulfillment of the requirements for the Degree of Master of Science.

Carey, D., Whipker, B., McCall, I.,and Buhler, W.2008a. Cytokinin based PGR affects growth of vegetative petunia. *Proc. Plant Growth Regulat. Soc. Amer.* 35:85–89.

Carey, D., Whipker, B., McCall, I., and Buhler ,W.2008b. Benzyladenine foliar sprays increase offsets in *Sempervivum* and *Echeveria*. *J.Hortic. Sci.* 53: 19-21.

Carey, J. C.2008. The effects of benzyladenine on ornamental crops. Thesis of Master of Science (M.Sc) in Horticultural Science, Graduate Faculty of North Carolina State University. 424p.

Catalano and Hill, T. A. 1969. Interaction between gibberellic acid and kinetin in overcoming apical dominance, natural and induced by IAA in tomato (Lycopersicon esculentum). Nature, 222,985-986.

Chatfield, S.P., Stirnberg, P., Forde, B.G., Leyser, O.*(2000) The hormonal regulation of auxiliary bud growth in Arabidopsis Plant J. 24:159–169.*

Chaudhari.S and Mukundan .2001. Aloe vera.L-Micropropagation and Characterization of its gel. Phytomorphology 51:155-157.

Cline, M.G.1991. Apical dominance. *Bot. Rev. 57:318–358.*

Cline, M. 1994. The role of hormones in apical dominance. New approaches to an old problem in plant development. *Physiologia Plant.* 90: 230–237.

Cline, M. 1997. Concepts and terminology of apical dominance. *American J. Bot.* 84(9): 1064–1069.

Coleby.Williams.J."Fact.Sheet:Aloe's Gardening Australia,Australian Broadcasting Corporation.July.2008.

Corneanu, M., Corneanu, G., Vekas, M.,and Minea, R. 1994. In vitro organogenesis of Aloe arborescencs (Liliaceae). Revue Roumaine de Biologie. 39: 45-52.

Criley, R. A. 1988. Propagation of tropical cut flowers: *Strelitzia*, *Alpinia*, and *Heliconia*. *ActaHorticulturae* 226: 509-517.

Criley, R. A.2001. Propagation of tropical cut flowers: *Strelitzia,Alpinia* and *Heliconia*. *Acta Hortic.*226:509-517.

Cristiano, G., Murillo-Amador, B., and Lucia, B. 2016. Propagation techniques and agronomic requirements for the cultivation of Barbados aloe (*Aloe vera* (L.) Burm. F.) - a review. *Frontiers in Plant Sci.*7.1410.

Davies, N.M., Norris, R.H., and Thoms, M.C. 2000. Prediction and assessment of local stream habitat features using large scale catchment characteristics. *Freshwater Biol.* 45:343-369.

Davis, R.H., Leither, M.G. Russo J.M., and Bryne, M.E. 2000. Advance methods in plant breeding and biotechnology. *J. Am. Ped.*79: 559-562.

Davies.2004 Antibacterial activity of anthraquinone fraction of *Vitex doniana*. Pakistan *J Biol Sci*. 1-3.

Dayarani, M., M. Dhanarajan and S. Uma .2013. *In-Vitro* response of ornamental banana (*Musa* spp.) *Advanced Biotechnol.12(12):16-18.*

Debiasi, C., Silvia, C., and Pescadore, R. 2007. Micropropagation of Aloe vera L. Rev. *Br. Plant. Med., Botucatu.* 9: 36-43.

Dixon and Paiva.1995.An evaluation of the biological and toxicological properties of Aloe Barbadensis (Miller), *Aloe vera J. Environ Sci Health*;.24:103-154.

Drew, R.K.L. 1979. Effect of activated charcoal on embryogenesis and regeneration of plantlets from suspension culture of carrot (*Daucus carota L.*). *Ann Bot.* 44: 387-389.

Duan, Y. H., Zhang, Y. L., Ye , L. T., Fan, X. R., Xu, G. H., .and Shen, Q. R. 2006. Responses of Rice Cultivars with Different Nitrogen Use Efficiency to Partial Nitrate Nutrition. *Ann. Bot.* 99(6): 1153–1160.

Duke, J. 1987. Handbook of Medicinal Herbs. CRC Press, Boca Raton, FL.,682p.

Eshun, K. and He, Q. 2004. *Aloe vera*: A Valuable Ingredient for the Food, Pharmaceutical and Cosmetic Industries. *Critical Reviews in Food Sci. and Nutri.* 44: 91–96.

Fahn, A. 1990. Plant anatomy (4th Ed.). Oxford, UK: Pergamon Press.

Farris, M.E., Keever, G.J., Kessler, J.R.and Olive, J.W.*2009. Benzyladenine and cyclanilide promote shoot development and flowering of Coreopsis verticillata 'Moonbeam' J. Environ. Hort. 27:176–182.*

Feil.C.1980.Aloe Cosmetics.Bestways(USA).1980,p.108.

George, B. E.1990. Effect of mini-sett sizes and nursery media sprouting of yams. *J. Root Crops*.16(2) :71-75.

Gjerstad G.1971.Chemical Studies of Aloe vera juice Advancing Frontiers of Plant Science,28.

Greene, D.W., Autio, W.R.1989. *Evaluation of benzyladenine as chemical thinner on 'McIntosh' apples. J. Amer. Soc. Hort. Sci. 114:68–73.*

Grimando, S., M. Tomomeo and Gancitano R.A. 1997. Effects of highly purified anthraquinoid compounds from *Aloe barbadensis* on sensitive and multi-drug resistant leukemia cells. Oncol. Rep., pp: 341-343.

Gui, Y.I, Xu,T.Y, Gu, S.R, Liu, S.Q, Zhang, Z, Sun, G.D. and Zhing .1990. Studies on stem tissue culture and organogenesis of *Aloe vera. Acta Bot Sinica*. 32: 606-610.

Halmann.1990. Tissue culture of *Aloe arborescence* Mill.*Acta Hort*. 27: 151-152.

Hartmann, H.T, Kester, D.E, Davies, F.T, and Genève, R.L. 1997. Plant propagation principles and practices. Prentice Hall, New Jersey, pp 276–391.

Hartmann, H.T., D.E. Kester, 1978. *Plant Propagation: Principles andPractices* (3rd edition). New York: Prentice-Hall.p.662.

Hazrati S., Sarvestani T.Z., Beyraghdar A., Mojab F. and Hosseini S.J. 2011. Effect of Benzyladenine Foliar Sprays on Offsets Production and Root Growth of *Aloe Barbadensis* Miller. *Nature and Science* 93 :100-104.

Hazrati, S.2012. *Aloe vera* gel: what is the evidence? *Pharm. J.* 244:360–362.

Hernandez, M. A.,Lima,M.,Cartaya.G., and Gonzalez,J.1988. Performance in nursery beds of planting materials of 'Zanzibar' and 'MZUZU Green' plantains weighing under two pounds. *Ciencia y technica en la Agricultura,Vindas Tropicales*.11(1):49-58.

Hernandez,C., Palmer, M.V., Wong, O.C. 2002. Identification of cytokinin from xylem exudate of *Phaseolus vulgaris*. *Plant Physiol*. 79, 296–298.

Hect, A. 1981. The Overselling of *Aloe vera*. FDA Consumer, 15: 26-29.

Heggers JP, Pelley RP, Robson MC. Phytotherapy research , 1993 , 7:S48–S52.

Hepper, F.N. 1968. *Floral of West Tropical Africa*. (2nd Ed.). University of Virginia Press, UK., pp.90-137.

Heslop-Harrison, J., 1955. *Conflicts of Categories in Species Study of British Flora.* Lousley, Oxford, pp.160-172.

Hess, C.E. and Snyder, W.E .1957. A physiological comparison of the use of mist with other propagation procedures used in rooting cuttings. In: Report on 14th International Horticulture Conference, Scheningen, vol 2, p 1133.

Hosseini, R., Parsa, M., 2007. Micropropagation of Aloe vera L. grown in South Iran. Pak. J. Biol. Sci. 10, 1134–1137.

Hank, S. 2014.Global Aloe market.NUTRA. 12Nov. 2014,p.11.

Hussain, C. and Said,M. 1967. Effect of size of seed on yield of turmeric(*Curcuma longa*). *W.Pakist.J.Agric.Res*.3(2/3):122-123.

Hussey, G. 1976. In inv- itro release of axillary shoots from apical dominance in monocotyledonous plantlets. *Annals of Bot.,* 40,1323-1325.

Isbell, V. and Morgan.P. 1982. Manipulation of apical dominance in sorghum with growth regulators. *Crop Science* .22: 30–34.

J. Mason Robertson, John S. Taylor, K. Neil Harker, Robert N. Pocock and Edward C. Yeung .1989.Apical Dominance in Rhizomes of Quackgrass (Elytrigia repens): Inhibitory Effect of Scale Leaves.*Weed Science* Vol. 37, No. 5 pp. 680-687

Jules J, Schery R,W., Woods, F,W,and Ruttan,V,W. 1981. Plant science, an introduction to world crops, 3rd edn. W. H. Freeman and Company, San Francisco

Liao, Z., Chen, M., Tan, F., Sun, X., Tang, K., 2004. Micropropagation of Chinese aloe. Plant Cell Tiss. Org. Cult. 76, 83–86

KAU [Kerala Agricultural University]. 1983. Studies on the economization of planting material in elephant foot yam.*KAU Research Report* 1980-81. Kerala Agricultural University.Thrissur,166-167pp.

Keijzer, C.J. and Cresti, M., 1987. A Comparison of Anther Tissue Development in Male sterile Aloe vera L. and Male Fertile Aloe ciliaris. Ann. Botany 59, 533–542

Khandelwal, Neelofar ,K., and Sharma, G. K.2009.Rapid *in vitro* propagation of *Aloe vera* L. with some growth regulators using lateral shoots as explants. World J.Pharmacy and Pharma. Sci.3(3) :2005-2018.

Korla, B.N.,Rattan,R.S., and Dohroo,N.P. 1989. Effect of seed rhizome size on growth and yield in ginger. *Indian Cocoa,Arecanut and Spices J.*13(2):47-48.

Liao Z, Chen M, Tan F, Sun X, Tang K 2004. Micropropagation of endangered Chinese aloe. Plant Cell Tissue Organ Cult. 76: 83–86.

Lyons, R.E.,Hale, C.L.1987. *Comparison of pinching methods on selected species of Columnea, Kalanchoe, and Crassula Hort Sci.* 22:72–74.

Martin, S., and Singletary, S.*(1999) N-6 Benzyladenine increases lateral offshoots in a number of perennial species. Proc. Intl. Plant Prop. Soc. 49:329–334.*

McCauley, M. 1992. The hitch-linking effect of a favourable gene. *J. Med. Assoc.*20: 1637-1640.

McCauley R. Postgraduate medicine , 1990 , 88:67–70.

Meyer, H .J. and Staden, J.V. 1991. Rapid *in vitro* culture of *Aloe barbadensis* Mill. Plant Cell. *Tiss. Org. Cult.* 26: 167-171.

Miracle of Aloe. http://www.miracleofaloe.com.

Mukonyi K.W and Oduor N.M. 2008. Guidelines for Growing Aloes. A Guide for Farmers and Extension Officers. KEFRI Guidelines Series: No.8. Unpublished manuscript.

Liao, Z., Chen, M., Tan, F., Sun, X., Tang, K., 2004. Micropropagation of Chinese aloe. Plant Cell Tiss. Org. Cult. 76, 83–86

Mustapha, O.T. 1991. Biosystematics studies in the *Urginea indica* (Roxb). Kunth Complex. Ph.D. Thesis, University of Ilorin, Ilorin, Nigeria, 258p.

Natali, L., Sanchez, I.C., and Cavallini, A. 1990. In virto culture of Aloe barbadensis Mill: micropropagation from vegetative meristems. Plant Cell Tiss. Org. Cult. 20: 71-74.

Nahed and Aziz.2007. The effects of different media on shoot proliferation from the shoot tip of *Aloe vera* L.*Int.J.Hort.*1:63-66.

Nilanjana,Das.and Chattopadhay, R.N.2004. Commercial cultivation of Aloe. Natural product radiance;3:85-87.

Nikki-Philips.2005.Honey root hormone[online].Available:http://www.honey.orglgetdoc.php[24 April 2016]

Okoli,O. O., Igbokwe, M.C., Ene,L. S. O., and Nwokoye,J.U.1982.Rapid Mltiplication of Yam by Minisett Technique.Research Bulletin,No.2 NRCRI,Umudike.

Okwuowulu,P.A. 1992. Influence of decreasing mini-sett weight and intra-row spacing on the coated ginger cv.Taffin-giwa.*J.Spices Aromat.Crops* 1(1):59-64.

Orsi, J.D. 2012 *Timed induction of axillary bud break of Rosa hybrida " Kardinal" due to mechanical manipulation of the stem* University of California, Davis, Pro Quest Dissertation Publishing p.48

Oyewole, S.O. 1971. Biosysystematic studies in the genus *Albuca* L. with particular reference to those species occurring in Nigeria. Ph.D. Thesis, University of Ibadan, Nigeria, 267p.

P.R.Newswire (a cision company) London June22.2016/ PR Newswire/Report Synopsis-Aloe vera extract market: Global Industry Analysis and Oppurtunity assessment 2016-2026.

Perkins,Yates.A.2002.Yates Garden guide.SF gate.com.Retrieved13.Feb.2016.

Pillay, I. and Railton, I. 1983. Complete release of axillary budsfrom apical dominance in intact, light-grown seedlings of Pisum sativum L. following a single application of cytokinin. *Plant Physiol.* 71: 972–974.

Pitman.J.C.Immune Enhancing Effects of Aloe.Health Consciousness 13:1-30.

Prochaska, S. and Jacobs, W. 1984. Transport of benzyladenine and gibberellic acid from roots in relation to the dominance between axillary buds of pea (Pisum sativum L.) cotyledons. *Plant Physiol.* 76: 224–227.

R. Rajeswari , M. Umadevi, C. Sharmila , R.Pushpa, S. Selvavenkadesh, Sampath Kumar and Debjit Bhowmik. 2012. *Aloe vera:* The Miracle Plant Its Medicinal and Traditional Uses in India *J.Pharmacog. and Phytochem.* 1(4): 118-124

Ray,P.K.1999. Orchard management In:Bos,T.K.(ed),Nayaprokash publishers,Calcutta,India,pp.43-45.

Richwine, A.M., Tipton, J.L., and Thompson, G.A. 1995. Establishment of Aloe, Gasteria and Hawothia shoot cultures from inflorescence explants. Hort. Sci. 30: 1443-1444.

Riley, John M. *.2014.*"Gibberellic Acid for Fruit Set and Seed Germination". *Pakistan Journal of Botany 45 (6): 2057–2064.*

Roy, S.C., Sarkar, A., 1991. In vitro regeneration and micropropagation of Aloe vera L. Sci.Hort. 47, 107–113.

Sanchez IC, Natali L, Cavallini A (1988) In vitro culture of Aloe barbadensis Mill. Morphogenetic ability and nuclear DNA content. Plant Sci. 55: 53-59.

Sachs, T. and Thimann K.V. 1967. The role of auxin and cytokinin in the release of buds from dominance. American Journal of Botany 54: 136-144.

Saeid Hazrati , Zeinolabedin Tahmasebi Sarvestani , Amin Salehi. 2012. The effect of differential nitrogen fertilization on morphological and physiological traits of Aloe vera plants. *Int. Res. J.Appl. and Basic Sci.* 3(4), 682-687.

Sakakibara, Robert, D,B, and Travis, E,L.2006. *Int.J. radiat.oncology, biol.and physiol.* 15:1047–1052.

Sampath Kumar K., Debjit, B., and Chiranjib, B.2010. Aloe vera : A Potential Herb and its Medicinal Importance. J. Chem. Pharm. Res., 2(1): 21-29.

Sampath Kumar, K. P., Rajeswari, R., Umadevi, M., Sharmila Rahale, C., Pushpa, R., Selvavenkadesh, S., and Debjit Bhowmik . 2012. *Aloe vera:* The Miracle Plant Its Medicinal and Traditional Uses in India. *J. Pharmacognosy and Phytochemistry* 1(4):118-124.

Santhoshkumar, T. 2004. Host parasite relationships and management of important nematodes associated with chethikkoduveli (*Plumbago rosea* L.). PhD., thesis,Kerala Agricultural University,Thrissur,242 p.

Saradhi, Joseph and Justin.2007. Pharmacognostic and phytochemical properties of *Aloe vera* Linn. - An overview. *Int. J. of Pharma. Sci. Review and Res.* 2:106-110.

Sardoei,A.S. 2014.Gibberilic acid and benzyl adenine foliar sprays increase offsets in *A.barbedensis.Eur. J.Exp.Biol.*4(1):646-650.

Shaik,V, Rabe and Staden.1997.Antibacterial activity of South African plants used for medicinal purposes. *J. Ethnopharmac.* 56:81-87.

Shelton, N. 1991. *Aloe vera*, its chemical and therapeutical properties. *Int. J. Dermatology*.30:679-683.

Shudo K .1994.. Chemistry of Phenylurea cytokinins. In Mokk DV, Mok Mc (Ed) Cytokinins: Chemistry, activity and function, CRC Press, Boca Raton, pp. 35-42.

Singh and Sood.2009. Impact of molecular environment on chemical reactions in heterogeneous food system. *J. Food Sci.* 65:1270-1282.

Sofowora, A., 1984. Medicinal Plants and Traditional Medicines in Africa. John Wiley and Sons Ltd., New York, pp: 256.

Srivastava, L.M. 2002. *Plant growth and development: Hormones and environment.* Academic Press, San Diego, CA.

Struve DK (1981) The relationship between carbohydrate and nitrogen in rooting of stem cutting. Plant Propag 27:6–7

Swaminathan, M.S. and. Kochhar S. L. 1992. Comparative Petiole Anatomy as an Aid to the Classification of *Africa genius*. CAB International, Wallingford, 409p.

Tamas, I. 1987. Hormonal regulation of apical dominance.In P. Davies [Ed.], Plant hormones and their role in plant growth and development, 393–410.

Thimann, K.V.; and F. Skoog. 1934. "On the inhibition of bud development and other functions of growth substance in Vicia faba.". *Proceedings of the Royal Society B* 114: 317–339.

*Thimann, Kenneth V. and Skoog,F.*1933. "Studies on the growth hormone of plants: III. The inhibiting action of the growth hormone on bud development" . *Proceeding National Academy Sciences (USA)* 19 (7): 714–716.

Thimann, K.V., T. Sachs, and K.N.M. Mathur. 1971. The mechanism of apical dominance. Physiol. Plant. 24:68-72.

Tyler, V.E., 1994. *Herbs of Choice: The Therapeutic Use of Phytomedicinals*. Haworth Press Inc., New York, ISBN-10: 1560248955.

Tyler V. 1993. The honest herbal: A sensible guide to the use of herbs and related remedies. 3rd ed. Binghamton, New York: Pharmaceutical Products Press;.

Van Staden, J. and Dimall. G. G. 1978. Endogenous cytokinins and the breaking of dormancy and apical dominance in potato tubers. *J. Experimental Botany*. 29(112): 1077-1084 .

Virendra Singh,2001. Propagating Medicinal Plants Using Modern Tools.*J. Chem.Pharm.Res*.,23(110):38-39.

Velcheva M, Faltin Z, Vardi A, Eshdat Y, Peral A .2005. Regeneration of Aloe arborescens via organogenesis from young inflorescences. Plant Cell, Tissue Organ Cult. 83: 293-301.

Vlahos.1985.High frequency in vitro propagation of *Aloe vera* . Through shoot tip culture.*Int. J.applied boil. and pharma. technol.*8:16.123-124.

Wang, T. L. and Wareing, P. F. 1979. Cytokinins and apical dominance in Solanum andigena: lateral shoot growth and endogenous cytokinin levels in the absence of roots. *New Phytologist*, 82,19-28.

Watson,D.J.1958. The dependence of net assimilation rate on leaf area index.*Ann.Bot.*02:37-45.

Wiegel K, Horn H, Hock B 1984. Endogenous auxin levels in terminal stem cuttings of *Chrysanthemum morifolium* during adventitious rooting. *Physiol Plant* 61:422–428

Womble, G. and Helderman, H. 1998. Population genetics of a sex-linked locus in *Drosophila melanogaster*. I. Linkage disequilibrium and associative over dominance. *Heredites*, 85: 169-179.

ABSTRACT

REFINEMENT OF MACRO-PROPAGATION TECHNIQUE FOR MASS-MULTIPLICATION OF ALOE (*Aloe vera* Burm.f.).

by

SARANYA.K.S

(2014-12-117)

ABSTRACT

Submitted in partial fulfilment of the requirements for the degree of

MASTER OF SCIENCE IN HORTICULTURE

Faculty of Agriculture

KERALA AGRICULTURAL UNIVERSITY

DEPARTMENT OF PLANTATION CROPS AND SPICES

COLLEGE OF AGRICULTURE

VELLAYANI, THIRUVANANTHAPURAM-695 522

KERALA, INDIA

2017

ABSTRACT

The study entitled "Refinement of macro-propagation technique for mass multiplication of aloe (*Aloe vera* Burm. f.)" was carried out during 2014-2016 in the department of Plantation Crops and Spices, College of Agriculture Vellayani, to standardize the stem disc method of macro propagation in aloe.The experiment was laid out in CRD with forty eight treatment combinations and three replications. The treatments included combinations of four pre-curing treatments, three segment size and four sprouting treatments.

Mature healthy aloe mother plants free from pests and diseases were subjected to various pre-curing treatments *viz., in situ* decapitation, partial crushing of internode, and foliar spraying of growth regulator (BA), one month before preparing stem segments. Stem segments having single, double and three nodes were prepared from both pre cured and non pre-cured mother plants. They were then subjected to three different sprouting treatments which include different combinations of growth regulators, BA, GA_3 and IAA and treatment with honey. Control without any pre curing and sprouting treatment was also maintained.

From the comparison of different treatment combinations it was observed that better sprouting percentage (80.60%) was noticed in T_9 {3 node disc cuttings treated with BA (1000 ppm) + GA_3 (25 ppm)} taken from mother plants subjected to *in situ* decapitation ($P_1S_3G_1$). The lowest sprouting percentage (27.72%) was seen in single node disc cuttings treated with honey and without pre-curing ($P_4S_1G_3$) which was on par with three node cutting without pre curing and sprouting treatments ($P_4S_3T_4$). Among the pre sprouting treatments, soaking the cuttings in growth regulators BA(1000ppm), GA3(25ppm), BA(2ppm)&IAA(2ppm) were found to enhance sprouting while honey treatment had practically no effect. Sprouting percentage was low in untreated cuttings also.

The treatment combination ($P_1S_3G_1$) also recorded significantly superior morphological parameters of seedlings like plant height, number of leaves, leaf length, breadth, thickness and weight. Significantly superior fresh leaf yield (4.20kgplant^{-1}) and latex yield (16.60gplant^{-1}) was also registered by T_9 ($P_1S_3G_1$).

Growth analysis of seedlings carried out at different growth stages also revealed the superiority of T_9. Significant improvement in gel yield was noticed for T_9 [($P_1S_3G_1$- *in situ* decapitation+three node+ BA(1000ppm)& GA3(25ppm)]and T_{10} ($P_1S_3G_2$).

Among the forty eight treatment combinations tried,T_9 ($P_1S_3G_1$- *in situ* decapitation+three node+ BA(1000ppm)& GA3(25ppm) was the best cost effective treatment with B:C ratio 1.6 for getting higher sprouting percentage, better seedling growth and higher yield characters.

By adopting the above pre curing and pre sprouting treatment ($P_1S_3G_1$) within one year nearly 9 suckers can be produced from a single mother plant which is nearly three times higher than the conventional planting material. Hence this method of raising plantlets from aloe stem cuttings can be considered as a rapid method for mass multiplication.