Title	Content	Page No.
	Declaration by the Candidate	Ι
	Certificate by Supervisor	II
	Acknowledgement	III
	Contents	IV
	List of Figures	VII
	List of Tables	Х
	Abstract	XIII
Chapter: 1	Introduction	1
	1.1 Introduction of micropropagation.	1
	1.1.1 Limitation of micropropagation	6
	1.1.2 Factors affecting micropropagation	10
	1.2 Problem statement based on literature review	16
	1.3 Objectives	17
Chapter: 2	General laboratory supplies and practices	29
	2.1 Selection and preparation of plant material	29
	2.2 Methods of micropropagation	30
	2.2.1 Media composition	30
	2.2.2 Culture growth condition	32
Chapter: 3	Micropropagation in altered growth condition - morphological study	35
	3.1 Effect of different growth condition on plant growth	35
	3.1.1 Materials and methods	39
	3.1.1.1 Liquid culture experiment	39
	3.1.1.2 Temporary immersion in <i>in vitro</i> shoot growth	39
	3.1.1.3 CO ₂ Enrichment experiment	40
	3.1.1.4 Culture vessels environment experiment	41
	3.1.1.5 Altered gelling agents experiment	42
	3.1.1.6 Liquid seaweed extract experiment	42
	3.1.1.7 Materials and methods of <i>in vitro</i> rooting)	42
	3.1.2. Results	43

C	on	te	nt	S
-				~~

Title	Content	Page No.
	3.1.2.1 Role of liquid Medium	43
	3.1.2.2 Effect of TI in in vitro shoot growth	44
	3.1.2.3 Effect of CO ₂ Enrichment on <i>in vitro</i> plant growth	44
	3.1.2.4 Effect of culture vessels environment	44
	3.1.2.5 Effect of different gelling agents	46
	3.1.2.6 Effect of liquid Seaweed extract	46
	3.1.2.7 Effect on <i>in vitro</i> rooting	47
	3.2 Studies on leaf surface structure	48
	3.2.1 Materials and methods	49
	3.2.1.1 Light microscopy	49
	3.2.1.2 Scanning Electron Microscopy	50
	3.2.2 Result	51
	3.3 Histological studies	52
	3.3.1 Materials and methods	53
	3.3.2 Result	53
Chapter: 4	Micropropagation in altered growth condition- physiological studies	74
	4.1 Studies on chlorophyll fluorescence	75
	4.1.1 Materials and methods	76
	4.1.2 Results	78
	4.2 Studies on water relations.	81
	4.2.1 Materials and methods	82
	4.2.2 Results	83
	4.3 Carbonic anhydrase enzyme activity	86
	4.3.1 Materials and methods	86
	4.3.2 Results	87
Chapter: 5	Micropropagation in altered growth condition- Biochemical studies	105
	5.1 Study different biochemical parameters	105
	5.1.1 Materials and methods	109
	5.1.2 Results	112

Title	Content	Page No.
Chapter: 6	Micropropagation in altered growth condition- Molecular Evaluation.	131
	6.1 Molecular evaluation	131
	6.1.1 Materials and methods	134
	6.1.2 Result	136
Chapter: 7	Discussion	142
	7.1 Studies on growth of plant in different growth condition	143
	7.2 Studies on leaf surface structure	151
	7.3 Studies on chlorophyll fluorescence	155
	7.4 Studies on water relation	160
	7.5 Studies on carbonic anhydrase activity	164
	7.6 Studies on biochemical investigation	165
	7.7 Studies on molecular evaluation	167
Chapter: 8	Summary	171
	Bibliography	181
Appendix A	Plagiarism Report	
Appendix B	Publication	231

List of Figures

Figure No.	Name of the Figure	Page No.
Figure 1.1	Economics of banana plant is represented through its various products used in food and other industries.	27
Figure 1.2	Schematic diagram of different stages of micropropagation	27
Figure 2.1	Establishment of banana tissue culture in laboratory.	34
Figure 3.1	Effect of different supporting material on <i>in vitro</i> growth of the <i>Musa acuminata</i> on liquid medium	65
Figure 3.2	Effect of temporary immersion on <i>in vitro</i> growth of Musa acuminata.	66
Figure 3.3	Effect of CO ₂ enrichment on shoot multiplication of <i>Musa</i> acuminata plant grown on Sucrose Free Semi-solid Medium (SFSM) and Sucrose Containing Semi-solid Medium (SCSM)	66
Figure 3.4	Effect of CO ₂ enrichment on shoot multiplication of <i>Musa</i> acuminata plant grown on Sucrose Free Liquid Medium (SFLM) and Sucrose Containing Liquid Medium (SCLM)	67
Figure 3.5	Effect of different culture vessels on <i>in vitro</i> plant growth at multiplication stage of <i>Musa acuminata</i>	68
Figure 3.6	Effect of different gelling agents on <i>in vitro</i> plant growth at multiplication stage of <i>Musa acuminata</i>	69
Figure 3.7	Effect of different Liquid Sea weed Extract (LSE) on <i>in vitro</i> growth in multiplication stage of <i>Musa acuminata</i>	69
Figure 3.8 a	Effect of semi solid and liquid medium on <i>in vitro</i> rooting of <i>Musa acuminata</i>	70
Figure 3.8 b	Acclimatization of on in vitro grown plant of Musa acuminata	70
Figure 3.9	Scanning Electron Microscopy (SEM) analysis of leaf adaxial surface of <i>in vitro</i> gown plant of <i>Musa acuminata</i> .	71
Figure 3.10	SEM analysis of stomata on leaf adaxial surface of <i>in vitro</i> gown plant <i>Musa acuminata</i> in (A) semi solid, (B) Field grown plant leaves and (C) liquid medium, grown plant leaves	71
Figure 3.11	SEM analysis stomata on leaf adaxial surface of <i>in vitro</i> gown plant <i>Musa acuminata</i> in (A) semi solid, (B) CO ₂ enrichment	72

Figure No.	Name of the Figure	Page No.
	treated plant and (C, D) Field grown plant medium, grown plant leaves	
Figure 3.12	Transverse section through shoot, root and leaf of <i>Musa</i> acuminata during in vitro growth on semi solid and liquid medium.	73
Figure 4.1	Kaustsky plot showing the change in chlorophyll fluorescence parameters during different stage of micropropagation of <i>Musa acuminata</i> on semi solid and liquid medium	99
Figure 4.2	Kaustsky plot showing the change in chlorophyll fluorescence parameters during micropropagation under CO ₂ enrichment of <i>Musa acuminata</i> on semi solid sucrose contain medium	100
Figure 4.3	Kaustsky plot showing the change in chlorophyll fluorescence parameters during micropropagation under CO ₂ enrichment of <i>Musa acuminata</i> on sucrose contain liquid medium	101
Figure 4.4	Kaustsky plot showing the change in chlorophyll fluorescence parameters during micropropagation under CO ₂ enrichment of <i>Musa acuminata</i> on sucrose free semi solid medium	102
Figure 4.5	Kaustsky plot showing the change in chlorophyll fluorescence parameters during micropropagation under CO ₂ enrichment of <i>Musa acuminata</i> on sucrose free liquid medium	103
Figure 4.6	A-Ci curve of plant grown under CO2 enriched condition	104
Figure 5.1	Super oxide activity of micropropagated <i>Musa acuminata</i> during multiplication of plantlet in different growth condition	122
Figure 5.2	Super oxide activity of micropropagated <i>Musa acuminata</i> in CO ₂ enrichment condition during multiplication stage	125
Figure 5.3	Chlorophyll activity of micropropagated <i>Musa acuminata</i> during the multiplication of plantlets under CO ₂ enrichment on semi solid medium in multiplication stage	126
Figure 5.4	Chlorophyll activity of micropropagated <i>Musa acuminata</i> during the multiplication of plantlets under CO ₂ enrichment on liquid medium in multiplication stage.	127
Figure 5.5	Chlorophyll activity of micro propagated <i>Musa acuminata</i> during multiplication of plantlet in different growth condition	128
Figure 5.6	Effect of different LSE on accumulation of Chlorophyll a (A), Chlorophyll b (B) and total chlorophyll (C) in banana micro propagules grown under <i>in vitro</i> conditions.	129

Figure No.	Name of the Figure	Page No.
Figure 6.1	Molecular evaluation of <i>in vitro</i> grown <i>Musa acuminata</i> during different growth condition	140
Figure 6.2	Molecular evaluation of genetic fidelity in <i>Musa acuminata</i> grown under <i>in vitro</i> CO ₂ enrichment condition in liquid and solid medium	141
Figure 8.1	Summary of comparative analysis of different morphological and biochemical parameters: Effect of different growth condition on <i>Musa acuminata</i> during <i>in vitro</i> growth	179

List o	f Ta	bles
--------	------	------

Table No.	Name of Table	Page No.
Table 1.1	Statistics of banana production in India 2021-2022: Source National Horticulture Board (NHB).	18
Table 1.2	List of state wise DBT recognized tissue culture industries in India.	19
Table 1.3	Use of liquid culture system for the micropropagation of different plant species.	20
Table 1.4	Type of Temporary immersion system used during of micropropagation of different plant species.	22
Table 1.5	Use of CO ₂ Enrichment during of micropropagation of different plant species.	26
Table 2.1	Composition of Murashige and Skoog's (MS) and Schenk and Hildebrandt's (SH) Nutrient Medium.	33
Table 3.1	Effect of liquid culture medium on <i>in vitro</i> growth and shoot multiplication in banana shoot clusters.	55
Table 3.2	Effect of support systems in liquid culture medium on <i>in vitro</i> growth and shoot multiplication in banana shoot clusters.	56
Table 3.3	Effect of temporary immersion in liquid medium on <i>in vitro</i> shoot growth and multiplication in banana shoot clusters.	57
Table 3.4	Effect of CO_2 enrichment with and without sucrose on <i>in vitro</i> shoot growth and multiplication in banana, shoot clusters grown on semi–solid medium.	58
Table 3.5	Effect of CO_2 enrichment with and without sucrose on <i>in vitro</i> shoot growth and multiplication in banana, shoot clusters grown on liquid medium.	59
Table 3.6	Effect of vessel type on <i>in vitro</i> shoot growth and multiplication in banana, shoot clusters grown on liquid medium.	60
Table 3.7	Effect of Gelling agents on <i>in vitro</i> shoot growth and multiplication in banana, shoot clusters grown on liquid medium	61
Table 3.8	Effect of LSE on <i>in vitro</i> shoot growth and multiplication in banana, shoot clusters grown on semi solid medium.	62

Table 3.9 Table 3.10	Effect of liquid medium on <i>in vitro</i> rooting in banana.	
Table 3.10		63
	Stomatal characteristics of abaxial and adaxial leaf surfaces of banana during different stages of micropropagation.	64
Table 4.1	Various parameters of chlorophyll fluorescence in banana during different stages of micropropagation under semi-solid and liquid culture medium.	88
Table 4.2	Effect of CO ₂ Enrichment on chlorophyll fluorescence parameters of banana.	89
Table 4.3	Percent water loss in detached leaves of banana plantlets during different phases of its micropropagation in liquid and semi-solid medium.	90
Table 4.4	Percent water content and other growth parameters in banana grown under different types of liquid culture systems.	91
Table 4.5	Effect of different gelling agent on water content and other growth parameters in Banana during <i>in vitro</i> shoot multiplication	92
Table 4.6	Effect of vessel and closure types on water content and other growth parameters in Banana during <i>in vitro</i> shoot multiplication.	93
Table 4.7	Percent water content and other growth parameters in banana grown under LS.	94
Table 4.8	Percent water content and other growth parameters in banana grown under Solid growth medium CO ₂ enriched conditions.	95
Table 4.9	Percent water content and other growth parameters in banana grown under CO_2 enriched conditions in liquid growth medium.	96
Table 4.10	Carbonic anhydrase enzyme activity in the leaves of banana during <i>in vitro</i> growth on semi–solid and liquid medium, compared with leaves obtained from field grown plants.	97
Table 4.11	Carbonic anhydrase enzyme activity in the leaves of banana during <i>in vitro</i> growth CO ₂ Enrichment on semi–solid and liquid medium, compared with leaves obtained from field grown plants.	98
Table 5.1	Effect of semi-solid and liquid culture medium on some biochemical parameters of banana during multiplication stages of growth.	117

Table No.	Name of Table	Page No.
Table 5.2	Effect of CO ₂ enrichment on solid medium on some biochemical parameters of banana during Multiplication stages of growth.	118
Table 5.3	Effect of CO_2 enrichment on liquid medium on some biochemical parameters of banana during multiplication stages of growth.	119
Table 5.4	Effect of culture vessels on some biochemical parameters of banana during multiplication stages of growth.	120
Table 5.5	Effect of different gelling agents on some biochemical parameters of banana during multiplication stages of growth.	121
Table 5.6	Effect of different seaweed extract on some biochemical parameters of banana during multiplication stages of growth.	122
Table 5.7	Effect of semi-solid and liquid culture medium on some biochemical parameters of banana during different stages of growth.	123
Table 6.1	List of random decamer primers used for screening the PCR amplification of total genomic DNA in <i>Musa acuminata</i> .	138
Table 6.2	Concentration of PCR mixture for RAPD.	139
Table 6.3	RAPD analysis of genomic DNA extracted from micro-clones <i>Musa acuminata</i> using 09 random decamer primers.	139