REFERENCES

Alpert, P. and Oliver, M.J. 2002. Desiccation and survival in plants : Drying without dying. In : Black, M. & Pritchard, H.M. (Eds.), *Desiccation and Plant Survival.* King's College University of London.

Ayres, N.M., and Park, W.D. 1994. Genetic transformation of rice. *Critical Rev. Plant Sci.* 13:219-239.

Block, M.De., Botterman, J., Vandewiele, M., Dockx, J., Thoen, C., Gossele', V., Movva, N.R., Thompson, C., Montagu, M.V. and Leemans, J. 1987. Engineering herbicide resistance in plants by expression of a detoxifying enzyme, 6:2513-2518

Budar, F., Thia-Toong, S., van Montagu, M. and Hernalsteens, J.P. 1986. *Agrobacterium*-mediated gene transfer results mainly in transgenic plants transmitting T-DNA as a single mendelian factor. *Genetics.* 114:303-313

Burns, W.C., Maitra, N. and Cushman, J.C. 1997. Isolation and characterization of a cDNA encoding a GroupI LEA protein (Accession No. U66317) from Soybean1 113:663.

Cao, J., Duan, X., McElroy, D. and Wu, R. 1992. Regeneration of herbicide resistant transgenic rice plants following microprojectile- mediated transformation of suspension culture cells. *Plant Cell Rep.* 11:586-591

Chalfie, M., E, Y.T.G., Ward, W.W. and Prasher, D.C. 1994. Green fluorescent protein as a marker for gene expression. *Science.* 263:802-805.

Chen, P.W. and Chen, L.J. 1996. A rice embryo-specific cDNA (Accession No.U57641) encoding a late embryogenesis abundant group3 protein. *Plant Physiol.* 111:1353.

Cheng, M., Fry, J.E., Pang, S., Zhou, H. Hironaka, C.M., Duncan, D.R., Conner, T.W. and Wan, Y. 1997. Genetic transformation of wheat mediated by *Agrobacterium tumefaciens*. *Plant Physiol.* 115:971-980.

Chilton, M.D., Currier, T.C., Farrand, S.K., Bendich, A.J., Gordon, M.P. and Nester, E.W. 1974. *Agrobacterium tumefaciens* DNA and PS8 bacteriophage DNA not detected in crown gall tumors. *Proc. Natl. Acad. Sci. USA*. 71: 3672-3676

Close, T. 1997. A commonality in the response of plants to dehydration and low temperature. *Physiologia Platarum* 100:291-296.

Cristou, P., Ford, T.L. and Kofron, M. 1991. Production of transgenic rice (*Oryza sativa* L.) plants from agronomically important *indica* and *japonica* varieties via electric discharge particle acceleration of exogenous DNA into immature zygotic embryos. *Bio/Technology* 9:957-962.

Conett, R.J.A. and Barfoot, P.D. 1992. The development of genetically modified varieties of agricultural crops by the seeds industry. In: Gatehouse, A.M.R., Hilder, V.A. and Boulter, D., (Eds.), *Plant genetic manipulation for crop protection.* Wallingford: CAB International. pp.45-73.

Crazzolara, C.S., Klemm, M. and Reiss, B. 1995. Reporter genes. In : Galbraith, D.W., Bourque, D.P., and Bohnert, H.J. (Eds.), *Method in cell biology.* California : Academic press. pp. 425-428.

Cubitt, A., Heim, R., Adams, S., Boyd, A., Gross, L. and Tsien, R. 1995. Understanding, improving and using green fluorescent protein. *TIBS.* 20:448-455.

Datta, S.K., Peterhans, A., Datta, K., and Potrykus, I. 1990. Genetically engineered fertile *indica*-rice recovered from protoplasts. *Bio/Technology* 8:736-740.

Dure, L.III, Crouch, M., Harada, J., Ho, T-H.D., Mundy, J., Quantrano, R., Thomas, T. and Sung, Z.R. 1989. Common amino acid sequence domain among the LEA proteins of higher plants. *Plants Molecular Biology* 12:475-486.

Elliott, A.R., Campbelll, J.A., Dugdale, B., Brettel, R.L.S. and Grof, C.P.L. 1999. Green-fluorescent protein facilitates rapid *in vivo* detection of genetically transformed plant cell. *Plant Cell Rep.* 18:707-714.

Filichkin, S.A. and Gelvin, S.B. 1993. Formation of a putative relaxation intermediate during T-DNA precessing directed by the *Agrobacterium tumefaciens* Vir D1 , D2 endonuclease. *Mol Microbiol.* 8:915-926.

Galau, G.W., Hughes, D.W., and Dure, L.III 1986. Abscisic acid induction of bloned cotton late embryogenesis abundant (LEA) messenger RNAs. *Plant Molecular Biology* 7:155-170.

Galllie, D.R., Lucas, W.J. and Walbot, V. 1989. Visualizing mRNA expression in plant protoplasts: factors influencing efficient mRNA uptake and translation. *Plant Cell.* 1:301-311.

Galun, E. and Breiman, A. 1997. *Transgenic plants.* London: Imperial College Press. pp.44-75.

Gelvin, S.B. and Schilperoort, R.A. 1994. *Plant Molecular Biology Manual.* 2nd Edn. London: Kluwer Acedamic Publishers.

Gordon-Kamm, W.J., Spencer, T.M., Mangano, M.L., Adams, T.R., Daines, R.J., Start, W.G., O'Brien, J.V., Chambers, S.A., Adams, W.R., Willetts, N.G., Rice, T.B., Mackey, C.J., Krueger, R.W., Kaush, A.P. and Lemaux, P.G. 1990. Transformation of mize cells and regeneration of fertile transgenic plants. *Plant cell.* 2 : 603-618.

Guerineau, F., 1995. Plant gene transfer and expression protocols: Tools for expressing foreign genes in plants, *Methods in Molecular Biology* 49. Totowa, New Jersey : Humana Press. pp. 1-32.

Halluin, K.D., Block, M.D., Denecke, J., Janssens, J., Leeman, J., Reynaerts, A. and Botterman, J. 1992. The *bar* gene as selectable and screenable marker in plant engineering. *Methods in Enzymology.* Ner York: Academic Press. pp.415-426.

Helmer, G., Casadaban, M., Bevan, M., Kayes, L. and Chilton, M.D. 1984. A new chimeric gene as a marker for plant transformation : the expression of *Escherichia coli* β-galactosidase in sunflower and tobacco cells. *Bio/ Technology*. 2:520-527.

Hiei, Y., Komari, T. and Kubo, T. 1997. Transformation of rice mediated by *Agrobacterium tumefaciens. Plant Mol. Biol.* 35:205-218.

Hiei, Y., Ohta, S., Komari, T. and Kumashiro, T. 1994. Efficient transformation of rice (*Oryza sativa* L.) mediated by *Agrobacterium* and sequence analysis of the boundaries of the T-DNA. *Plant J.* 6:271-282.

Hooykaas, P.J.J. 2000. *Agrobacterium*, a natural metabolic engineer of plants, *Molecular engineering of plant secondary metabolism.* Netherlands: Kluwer Academ Plublisher. pp.51-67.

Hughes, A.M. 1996. *Agrobacterium tumefaciens, Plant Molecular Genetics*. Harlow England : Longman. pp.77-87

Ingram, J. and Bartel, D. 1996. The molecular basis of dehydration tolerance in plants. *Annual Review of Plant Physiology and Plant Molecular Biology.* 47:377-403.

Irvine, J.E. 1984. The frequency of marker change in sugarcane plants regenerated from callus culture. *Plant Cell Tiss Org Cult*. 3 : 201-209

Jefferson, R.A. 1987. Assaying chimeric genes in plants: The GUS gene fusion system. *Plant Mol. Biol. Rep.* 5:387-405.

Jefferson, R.A., Kavanagh, T.A. and Bevan, M.W. 1987. GUS fusions: glucuronidase as a sensitive and versatile gene fusion marker in higher plants. *EMBO J.* 6:3901-3907.

Klee, H.J., Horsh, R. and Rogers, S. 1987. *Agrobacterium*-mediated plant transformation and its further applications to plant biology. *Ann Rev Plant Physiol.* 38:467-486.

Klee, H.J., White, F.F., Iyer, V.N., Gordon, M.P and Nester, E.W. 1983. Mutational analysis of the virulence region of an *Agrobacterium tumefaciens* Ti plasmid. *J Bacteriol.* 153:878-883.

Li, L., Qu, R., de Kochko, A., Fauquet, C. and Beachy, R.N. 1993. An improved rice transformation system using the biolistic method. *Plant Cell Rep.* 12:250-255

McElroy, D. and Brettel, R.I.S. 1994. Foreign gene expression in transgenic cereals. *Trends Biotechnol.* 12:62-68.

McElroy, D., Zhang, W., Cao. J. and Wu, R. 1990. Isolation of an efficient actin promoter for use in rice transformation. *The Plant cel*l. 2:163-171.

Millar, A.J., Short, S.R., Hiratsuka, K., Chua, N.H. and Kay, S.A. 1992. Firefly luciferase as a reporter of regulated gene expression in higher plants. *Plant Mol. Biol. Rep.* 10:324-337.

Mohanty, A., Sarma, N.P. and Tyagi, A.K. 1999. *Agrobacterium*–mediated high frequency transformation of an elite indica rice variety Pusa Basmati 1 and transmission of the transgenes to R2 progeny. *Plant science*. 147:127-137.

OW, D.W., Wood, K.V., Deluca, M., de Wet, J.R., Heilinski, D.R. and Howell, S.H. 1986. Transient and stable expression of the firefly luciferase gene in plant cells and transgenic plants. *Science* 234:856-859.

Palm, J.G. and Wlodawer, A. 1999. Spectral variants of green fluorescent protein, *Method in Enzymology.* USA: Academic press. pp.378-394.

Park, S.H., Pinson, S.R.M. and Smith, R.H. 1996. T-DNA integration into genomic DNA of rice following *Agrobacterium* inoculation of isolated shoot apices. *Plant Mol Biol.* 32:1135-1148.

Peterson, G. and Smith , R. 1991. Effect of abscisic acid and callus size on regeneration of American and international rice varieties. *Plant Cell Rep.* 10:35-38.

Philips, J.R., Oliver, M.J. and Bartels, D. 2002. Molecular genetics of desiccation and tolerant systems. In : Black, M. & Pritchard, H.M. (Eds.), *Desiccation and Plant Survival*. Oxford University press. pp. 319-342

Prasher, D.C., Eckenrode, V.K., Ward, W.W., Prendergast, F.G. and cormier, M.J. 1992. Primary structure of the *Aequorea victoria* green-fluorescent protein. *Gene* 111:229-233.

Rathore, K.S., chowdhury, V.K. and Hodges, T.K. 1993. Use of as a selectable marker gene and for the production of herbicide resistant rice plants from protoplasts. *Plant Molecular Biology* 21:871-884.

Rashid, H., Yokoi, S., Toriyama, K. and Hinata, K. 1996. Transgenic plant production mediated by *Agrobacterium* in *indica* rice. *Plant Cell Rep.* 15:727-730.

Riva, G.A., Cabrera, J.G., Padron, R.V. and Pardo, C.A. 1998. *Agrobacterium tumefaciens*: a natural tool for plant transformation . *EJB Journal of Biotechnology* 15.

Sambrook, J., Fritsch, E.F. and Manitis, T. 1989. *Molecular cloning*: A Laboratory Manual, 2nd Edn. Cold Spring Habor, NY: Cold Spring Harbor Laboratory Press.

Sanford, J.C. 1990. Biolistic plant transformation. *Physiol. Plant.* 79:206-209.

Schrott, M. 1995. Selectable marker and reporter genes. In: Potrykus, T. and Spangenbert, (Eds.), *Gene transfer of Plants*. Berlin: Springer Verlag. pp.325-336.

Seed, B. and Sheen, J.Y. 1988. A simple phase-extraction assay for chloramphenicol acetyltransferase activity. *Gene*. 67:271-277

Sheen, J., Hwang, S.B., Niwa, Y., Kobayashi, H. and Galbraith, D.W. 1995. Green fluorescent protein as a new vital marker in plant cells. *Plant J.* 8:777-784.

Shimamoto, K., Terada, R., Izawa, T. and Fujimoto, H. 1989. Fertile transgenic rice plants regenerated from transformed protoplasts. *Nature* 338:274-276.

Sivamani, E., Bahieldin, A., Wraith, J.M., Al-Niemi, T., Dyer, W.E., Ho, T.H.D. and Qu, R.D. 2000. Improved biomass productivity and water use efficiency under water deficit conditions in transgenic wheat constitutively expressing the barley *hva*1 gene. *Plant Science* 155:1-9.

Somer, D.A., Rines, H.W., Gu, W., Kaepple, H.F. and Bushnell, W.R. 1992. Fertile, transgenic oat plants. *Bio/Technol.* 10 : 1589-1594.

Stachel, S.E., Timmerman, B. and Zambryski, P. 1986. Generation of single-stranded T-DNA molecules during the initial stages of T-DNA transfer from *Agrobacterium tumefaciens* to plant cells. *Nature* 322:706-712.

Terri, T.H., Lehvashaiho, H., Franck, M., Heino, U.P., Palva, E.T., Van Montagu, M. and Herrera-Estrella, L. 1989. Gene fusions to *lac* Z reveal new expression patterns of chimeric genes in transgenic plants. *EMBO J.* 8: 343-350.

Tingay, S., McElroy, D., Kalla, R., Fieg, S., Wang, M-B, Thornton, S. and Brettel, R. 1997. *Agrobacterium tumefaciens*-mediated barley transformation. *Plant J.* 11:1369-1376.

Toki, S., Takamatsu, S., Nojiri, C., Ooba, S., Anzai, H., Iwata, M., Christensen, A.H. Quail, P.H. and Uchimiya, H. 1992. Expression of a maize ubiquitin gene promoter-*bar* chimeric gene in transgenic rice plants. *Plant Physiol.* 100 : 1503-1507.

Toriyama, K., and Hinata, K. 1985. Cell suspension and protoplast culture in rice. *Plant Sci.* 41:179-183

Urwin, P.E., Moller, S.G., Blumsom, J.K. and Atkinson, H.J. 1999. Continual green fluorescent protein monitoring of promoter activity in plants. *Method in Enzymology.* USA.: Academic press. pp.316-329.

Vasil, V., Castillo, A.M., Fromm, M.E. and Vasil, J.K. 1992. Herbicide resistant fertile transgenic wheat plants obtained by microprojectile bombardment of regenerable embryogenic callus. *Bio/Technol.* 10 : 667-674.

Wan, Y. and Lemaux, P.G. 1994. Generation of large numbers of independently transformed fertile barley plants. *Plant Physiol.* 104: 37-48.

Weeks, J.T., Anderson, O.D. and Blechl, A.E. 1993. Rapid production of multiple independent lines of fertile transgenic wheat (*Triticum aestivum*). *Plant Physiol.* 102 : 1077-1084.

Yang, F., Moss, L. and Phillips, G.N.Jr. 1996. The molecular structure of green fluorescent protein. *Nature Biotech.* 14:1246-1251.

Xu, D., Duan, X., Wang, B., Hong, B., Davis Ho, T-H. and Wu, T. 1996a. Expression of a late embryogenesis abundant protein gene, *hva*1, from barley confers tolerance to water deficit and salt stress in transgenic rice. *Plant Physiol.* 110:249-257.

Zheng, Z., Hayashimoto, A., Li, Z. and Murai, N. 1991. Hygromycin resistance gene cassettes for vector construction and selection of transformed rice protoplasts. *Plant Physiol.* 97:823-835.

Zupan, J.R. and Zambryski, P. 1995. Transfer of T-DNA from *Agrobacterium* to the plant cell. *Plant Physiol.* 107:1041-1047.

Appendices

Appendix A

The composition of rice tissue culture and *Agrobacterium tumefaciens* medium

Table 1. The composition of NB medium (Li et al., 1993)

Solution	Chemical	Concentration (mg/l)
N6 Macronutrients	KNO_3	2,830
	$(NH_4)_2SO_4$	463
	$CaCl_2.2H_2O$	166
	$MgSO_4.7H_2O$	185
	KH_2PO_4	460
B5 micronutrients	KI	0.75
	H_3BO_3	3
	$CoCl_2.6H_2O$	0.025
	$MnSO_4.7H_2O$	10
	$ZnSO_4.7H_2O$	2
	$Na_2MoO_4.7H_2O$	0.25
	$CuSO_4.5H_2O$	0.025
FeEDTA	$FeSO_4.7H_2O$	27.8
	$Na_2EDTA.2H_2O$	37.8
B5 vitamin	Myo-inositol	100
	Nicotinic acid	1
	Pyridoxine HCl	1
	Thiamine HCl	10
	Casein hydrolysate	300
	L-Proline	500
	L-glutamine	500
	Sucrose	30,000
	Phyta gel	4,000

pH 5.8

Table 2. The composition of NB-0-0-0 medium

Solution	Chemical	Concentration (mg/l)
N6 Macronutrients	KNO_3	2,830
	$(NH_4)_2SO_4$	463
	$CaCl_2.2H_2O$	166
	$MgSO_4.7H_2O$	185
	KH_2PO_4	460
B5 micronutrients	KI	0.75
	H_3BO_3	3
	$CoCl_2.6H_2O$	0.025
	$MnSO_4.7H_2O$	10
	$ZnSO_4.7H_2O$	2
	$Na_2MoO_4.7H_2O$	0.25
	$CuSO_4.5H_2O$	0.025
FeEDTA	$FeSO_4.7H_2O$	27.8
	$Na_2EDTA.2H_2O$	37.8
B5 vitamin	Myo-inositol	100
	Nicotinic acid	1
	Pyridoxine HCl	1
	Thiamine HCl	10
	Sucrose	30,000
	Phyta gel	4,000

pH 5.8

Table 3. The composition of NB-0-0 medium

Solution	Chemical	Concentration (mg/l)
N6 Macronutrients	KNO_3	2,830
	$(NH_4)_2SO_4$	463
	$CaCl_2.2H_2O$	166
	$MgSO_4.7H_2O$	185
	KH_2PO_4	460
B5 micronutrients	KI	0.75
	H_3BO_3	3
	$CoCl_2.6H_2O$	0.025
	$MnSO_4.7H_2O$	10
	$ZnSO_4.7H_2O$	2
	$Na_2MoO_4.7H_2O$	0.25
	$CuSO_4.5H_2O$	0.025
FeEDTA	$FeSO_4.7H_2O$	27.8
	$Na_2EDTA.2H_2O$	37.8
B5 vitamin	Myo-inositol	100
	Nicotinic acid	1
	Pyridoxine HCl	1
	Thiamine HCl	10
	L-Proline	500
	Sucrose	30,000
	Phyta gel	4,000

pH 5.8

Table 4. The composition of NB-RE medium (Li et al., 1993)

Solution	Chemical	Concentration (mg/l)
N6 Macronutrients	KNO_3	2,830
	$(NH_4)_2SO_4$	463
	$CaCl_2.2H_2O$	166
	$MgSO_4.7H_2O$	185
	KH_2PO_4	460
B5 micronutrients	KI	0.75
	H_3BO_3	3
	$CoCl_2.6H_2O$	0.025
	$MnSO_4.7H_2O$	10
	$ZnSO_4.7H_2O$	2
	$Na_2MoO_4.7H_2O$	0.25
	$CuSO_4.5H_2O$	0.025
FeEDTA	$FeSO_4.7H_2O$	27.8
	$Na_2EDTA.2H_2O$	37.8
B5 vitamin	Myo-inositol	100
	Nicotinic acid	1
	Pyridoxine HCl	1
	Thiamine HCl	10
	BAP	4
	Casein hydrolysate	300
	L-Proline	500
	L-glutamine	500
	Sucrose	30,000
	Yeast extract	1,000
	Agar	8,000

Coconut water 15% (v/v)

pH 5.8

Table 5. The composition of NB-RE-0-0 medium

Solution	**Chemical**	**Concentration (mg/l)**
N6 Macronutrients	KNO_3	2,830
	$(NH_4)_2SO_4$	463
	$CaCl_2.2H_2O$	166
	$MgSO_4.7H_2O$	185
	KH_2PO_4	460
B5 micronutrients	KI	0.75
	H_3BO_3	3
	$CoCl_2.6H_2O$	0.025
	$MnSO_4.7H_2O$	10
	$ZnSO_4.7H_2O$	2
	$Na_2MoO_4.7H_2O$	0.25
	$CuSO_4.5H_2O$	0.025
FeEDTA	$FeSO_4.7H_2O$	27.8
	$Na_2EDTA.2H_2O$	37.8
B5 vitamin	Myo-inositol	100
	Nicotinic acid	1
	Pyridoxine HCl	1
	Thiamine HCl	10
	BAP	4
	L-Proline	500
	Sucrose	30,000
	Yeast extract	1,000
	Agar	8,000

Coconut water 15% (v/v)

pH 5.8

Table 6. The composition of AB medium (Chilton et al., 1974)

Solution	Chemical	Concentration (mg/l)
AB buffer	K_2HPO_4	1,500
	NaH_2PO_4	200
AB salt	NH_4Cl	1000
	$MgSO_47H_2O$	300
	KCl	150
	$CaCl_2.2H_2O$	150
	$FeSO_4.7H_2O$	2.5
	Glucose	5,000
	Agar	15,000

Table 7. The composition of AAM medium (Toriyama and Hinata, 1985)

Solution	**Chemical**	**Concentration (mg/l)**
AA Macronutrients	$Na_2HPO_4.2H_2O$	169.6
	KCl	150
	$CaCl_2.2H_2O$	150
	$MgSO_4.7H_2O$	500
AA micronutrients	KI	0.75
	H_3BO_3	3.0
	$CoCl_2.6H_2O$	0.025
	$MnSO_4.4H_2O$	10
	$ZnSO_4.7H_2O$	2.0
	$Na_2MoO_4.2H_2O$	0.25
	$CuSO_4.5H_2O$	0.0387
AA iron	$FeSO_4.7H_2O$	28
MS vitamin	Inositol	100
	Nicotinic acid	0.5
	Pyridoxine HCl	0.5
	Thiamine HCl	0.5
AA amino acid	Glycine	7.5
	Arginine	174
	Glutamine	876
	Casamino acid	500
	Sucrose	68,500
	Glucose	35,000

Acetosyringone 100 μl (add after autoclave)

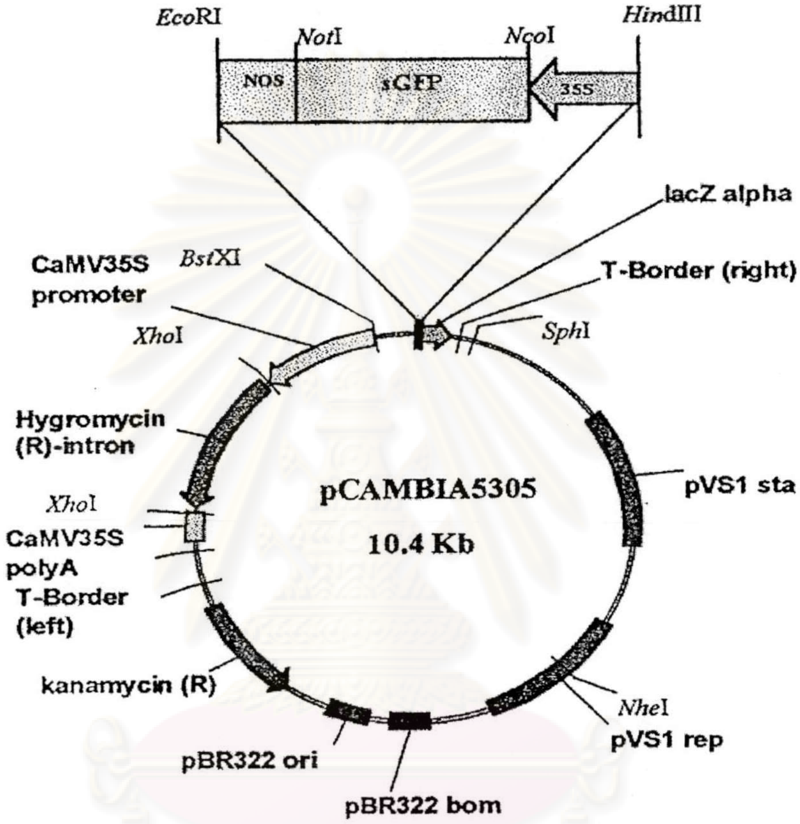
pH 5.2

Table 8. The preparation of chemicals used in tissue culture

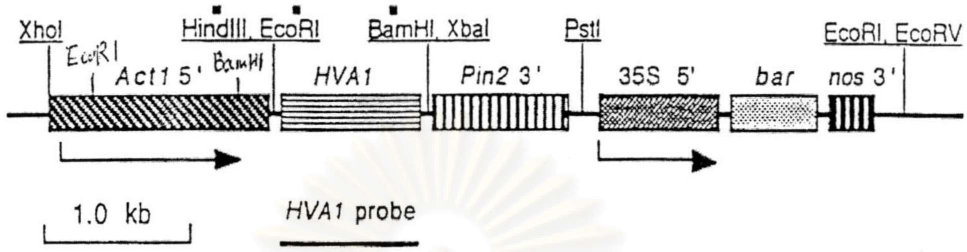
Chemical	Preparation
2,4-Dichlorophenoxyacetic acid) (2,4-D) (1 mg/ml)	Dissolve 100 mg of 2,4-D in 1 ml absolute ethanol, add 3 ml of 1 N KOH, adjust to pH 6.0 with 1 N HCl(very sensitive adjust carefully) and make up to 100 ml with sterilize deionized water.
6-Benzylaminopurine (BAP) (2 mg/ml)	Weigh 100 mg BAP, add 1 N KOH dropwise until powder is dissolved, make upto 50 ml with sterilize deionized water.
AS-Acetosyringone (100 μM)	Add 19.62 mg of acetosyringone to 1 ml of Dimethyl sulphoxide (DMSO) or methanol. Protect from light and add to media after autoclave

Appendix B

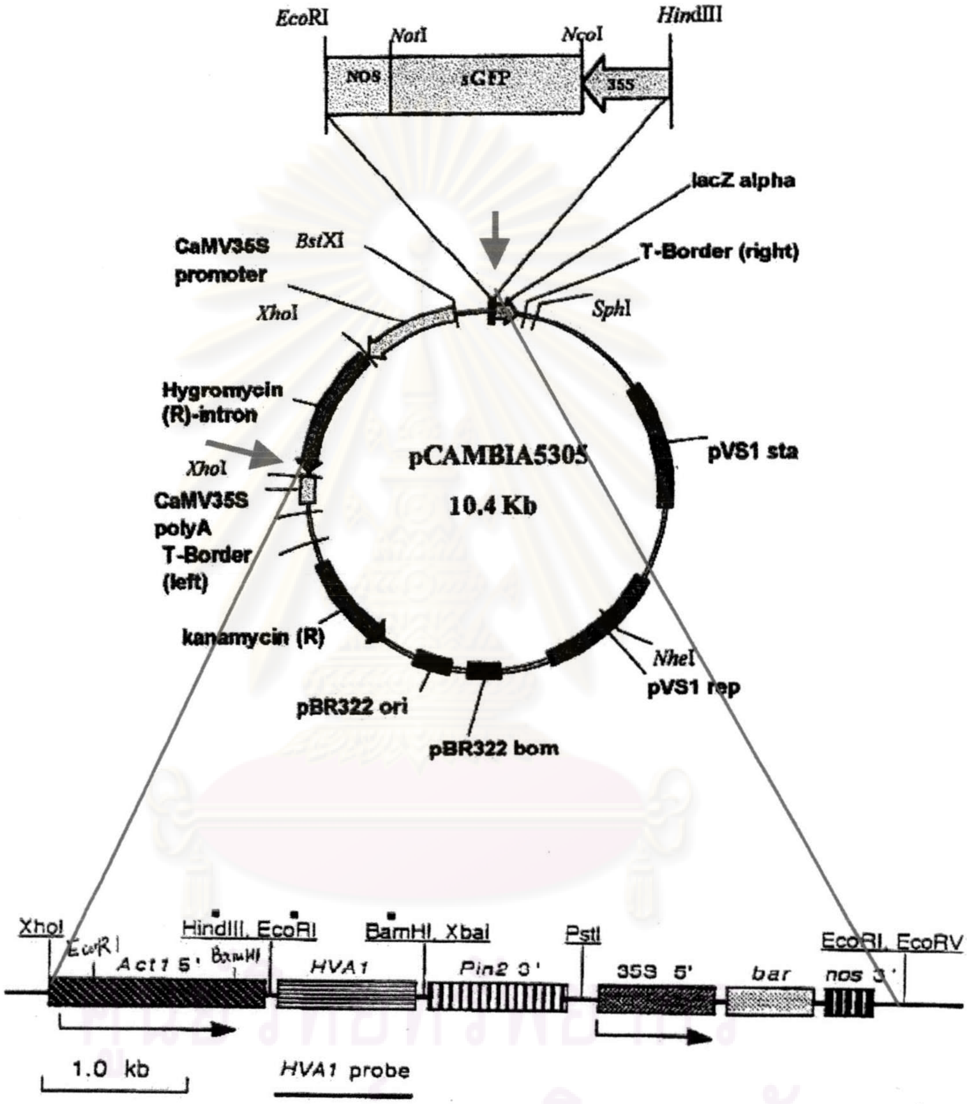
pCAMBIA5305



pBY520 (LEA3)


XhoI
HindIII, EcoRI
BamHI, XbaI
PstI
EcoRI, EcoRV
EcoRI
BamHI
Act1 5'
HVA1
Pin2 3'
35S 5'
bar
nos 3'
1.0 kb
HVA1 probe

Position site of pCAMBIA5305 was inserted with the 6 kb of *hva*1 cassette



Appendix C

Completely randomized design

A complete randomized design (CRD) is one where the treatments are assigned completely at random so that each experimental unit has the same chance of receiving any one treatment. For the CRD, any difference among experimental units receiving the same treatment is considered as experimental error. Hence, the CRD is only appropriate for experiments with homogeneous experimental units, such as laboratory experiments, where environmental effects are relatively easy to control. For field experiments, where there is generally large variation among experimental plots, in such environmental factors as soil, the CRD is rarely used.

Analysis of Variance

There are two sources of variation among the *n* observations obtained from a CRD trial. One is the treatment variation, the order is experimental error. The relative size of the two is used to indicate whether the observed difference among treatments is real or is due to chance. The treatment difference is said to be real if treatment variation is suffciently larger than experimental error.

Equal Replication. The steps involved in the analysis of variance for data from a CRD experiment with an equal number of replications are given below.

Step1 Group the data by treatments and calculate the treatment totals (T) and grand (G).

Step2 Construct an outline of the analysis of variance as follows;

Source of Variation	Degree of Freedom	Sum of Squares	Mean Square	Calculated F	Tabular F 5%	Tabular F 1%
Treatment						
Experimental error						
Total						

Step 3. Using t to represent the number of treatments and r, the number of replications, determine the degree of freedom ($d.f.$) for each source of variation as follows:

$$\text{Total } d.f. = (r)(t) - 1$$

$$\text{Treatment } d.f. = t - 1$$

$$\text{Error } d.f. = t(r-1)$$

The error $d.f.$ can also be obtained through subtraction as:

$$\text{Error } d.f. = \text{Total } d.f. - \text{treatment } d.f.$$

Step 4. Using X_i to represent the measurement of the ith plot, T_I as the total of the ith treatment, and n as the total number of experimental plots [i.e., $n = (r)(t)$], calculate the correction factor and the various sums of squares (SS) as:

$$\text{Correction factor } (C.F.) = \frac{G^2}{n}$$

$$\text{Total SS} = \sum_{i=1}^{n} X_i^2 - C.F.$$

$$\text{Treatment SS} = \frac{\sum_{i=1}^{t} T_I^2}{r} - C.F.$$

$$\text{Error } SS = \text{Total } SS - \text{Treatment } SS$$

Throughout this book, we use the symbol Σ to represent " the sum of." For example, the expression $G = X_1 + X_2 + \ldots\ldots + X_n$ can be written as $G = \Sigma_{i=1}^{n} X_I$ or simply $G = \Sigma X$.

Step 5 Calculate the mean square (*MS*) for each source of variation by dividing each *SS* by its corresponding *d.f.*:

$$\text{Treatment } MS = \frac{\text{Treatment SS}}{t-1}$$

$$\text{Error } MS = \frac{\text{Error } SS}{t\,(r-1)}$$

Step 6 Calculate the *F* value for testing significance of the treatment difference as:

$$F = \frac{\text{Treatment } MS}{\text{Error } MS}$$

Note here that the *F* value should be computed only when the error *d.f.* is large enough for a reliable estimate of the error variance. As a general guideline, the *F* value should be computed only when the error *d.f.* is six or more

Step 7 Obtain the tabular *F* values from Appendix D, with f_1 = treatment *d.f.* = $(t-1)$ and f_2 = error *d.f.* $= t\,(r-1)$

Step 8 Enter all the values computed in steps 3 to 7 in the outline of the analysis of variance constructed in step 2.

Step 9 Compare the computed *F* value of step 6 with the tubular *F* values of step 7, and decide on the significance of the difference among treatments using the following rules:

1. If the computed *F* value is larger than the tubular *F* value at the 1% level of significance, the treatment difference is said to be *highly significant*. Such a result is generally indicated by placing two asterisks on the computed *F* value in the analysis of variance.
2. If the computed *F* value is larger than the tubular *F* value at the 5% level of significance but smaller than or equal to the tabular *F* value at the 1% level of significance, the treatment difference is said to be *significant* . Such a result is indicated by placing one asterisk on the computed *F* value in the analysis of variance.

3. If the computed *F* value smaller than or equal to the tabular *F* value at the 5% level of significance, the treatment difference is said to be *nonsignificant*. Such a result is indicated by placing *ns* on the computed *F* value in the analysis of variance.

Note that the nonsignificant *F* test in the analysis of variance indicates the failure of the experiment to detect any difference among treatments. It does not, in any way, prove that all treatments are the same, because the failure to detect treatment difference, based on the nonsignificant *F* test, could be the result of either a very small or nil treatment difference or a very large experimental error, or both. Thus, whenever the *F* test is nonsignificant, the researcher should examine the size of experimental error and the numerical difference among treatment means. If both values are large, the trail may be repeated and efforts made to reduce the experimental error so that the difference among treatments, if any, can be detected. On the other hand, if both values are small, the difference among treatments is probably too small to be of any economic value and, thus, no additional trails are needed.

Step 10 Compute the grand mean and the coefficient of variation *cv* as follows:

$$\text{Grand mean} = \frac{G}{n}$$

$$\text{cv} = \frac{\sqrt{Error\ MS}}{\text{Grand mean}} \times 100$$

The *cv* indicates the degree of precision with which the treatments are compared and is a good index of the reliability of the experiment. It expresses the experimental error as percentage of the mean; thus, the higher the *cv* value, the lower is the reliability of the experiment. The *cv* value is generally placed below the analysis of variance table.

PAIR COMPARISON

Equal Replication

Step1 Compute the mean difference between the control treatment and each of the treatments.

Step2 Compute the LSD value at α level of significance as:

$$LSD_{\alpha} = t_{\alpha}\sqrt{2s^2/r}$$

S^2 = The error mean square

r = The number of replications

Obtain the tabular t values (t_{α}) from Appendix E, with n = the error degree of freedom

Step3 Compare each of the mean differences computed in step1 to the LSD values computed in step2 and indicate its significance with the appropriate asterisk notation. The mean difference between the treatment and the control exceeds both computed LSD values, thus, receives two asterisks to indicate that the treatments are significantly difference at 1% level of significance.

Appendix D

Table 9. Points for the Distribution of *F* [5% (light type) and 1 % (bold face type)]

f_2	f_1 Degrees of freedom (for greater mean square)																								f_2
	1	2	3	4	5	6	7	8	9	10	11	12	14	16	20	24	30	40	50	75	100	200	500	∞	
1	161	200	216	225	230	234	237	239	241	242	243	244	245	246	248	249	250	251	252	253	253	254	254	254	1
	4,052	**4,999**	**5,403**	**5,625**	**5,764**	**5,859**	**5,928**	**5,981**	**6,022**	**6,056**	**6,082**	**6,106**	**6,142**	**6,169**	**6,208**	**6,234**	**6,261**	**6,286**	**6,302**	**6,323**	**6,334**	**6,352**	**6,361**	**6,366**	
2	18.51	19.00	19.16	19.25	19.30	19.33	19.36	19.37	19.38	19.39	19.40	19.41	19.42	19.43	19.44	19.45	19.46	19.47	19.47	19.48	19.49	19.49	19.50	19.50	2
	98.49	**99.00**	**99.17**	**99.25**	**99.30**	**99.33**	**99.36**	**99.37**	**99.39**	**99.40**	**99.41**	**99.42**	**99.43**	**99.44**	**99.45**	**99.46**	**99.47**	**99.48**	**99.48**	**99.49**	**99.49**	**99.49**	**99.50**	**99.50**	
3	10.13	9.55	9.28	9.12	9.01	8.94	8.88	8.84	8.81	8.78	8.76	8.74	8.71	8.69	8.66	8.64	8.62	8.60	8.58	8.57	8.56	8.54	8.54	8.53	3
	34.12	**30.82**	**29.46**	**28.71**	**28.24**	**27.91**	**27.67**	**27.49**	**27.34**	**27.23**	**27.13**	**27.05**	**26.92**	**26.83**	**26.69**	**26.60**	**26.50**	**26.41**	**26.35**	**26.27**	**26.23**	**26.18**	**26.14**	**26.12**	
4	7.71	6.94	6.59	6.39	6.26	6.16	6.09	6.04	6.00	5.96	5.93	5.91	5.87	5.84	5.80	5.77	5.74	5.71	5.70	5.68	5.66	5.65	5.64	5.63	4
	21.20	**18.00**	**16.69**	**15.98**	**15.52**	**15.21**	**14.98**	**14.80**	**14.66**	**14.54**	**14.45**	**14.37**	**14.24**	**14.15**	**14.02**	**13.93**	**13.83**	**13.74**	**13.69**	**13.61**	**13.57**	**13.52**	**13.48**	**13.46**	
5	6.61	5.79	5.41	5.19	5.05	4.95	4.88	4.82	4.78	4.74	4.70	4.68	4.64	4.60	4.56	4.53	4.50	4.46	4.44	4.42	4.40	4.38	4.37	4.36	5
	16.26	**13.27**	**12.06**	**11.39**	**10.97**	**10.67**	**10.45**	**10.29**	**10.15**	**10.05**	**9.96**	**9.89**	**9.77**	**9.68**	**9.55**	**9.47**	**9.38**	**9.29**	**9.24**	**9.17**	**9.13**	**9.07**	**9.04**	**9.02**	
6	5.99	5.14	4.76	4.53	4.39	4.28	4.21	4.15	4.10	4.06	4.03	4.00	3.96	3.92	3.87	3.84	3.81	3.77	3.75	3.72	3.71	3.69	3.68	3.67	6
	13.74	**10.92**	**9.78**	**9.15**	**8.75**	**8.47**	**8.26**	**8.10**	**7.98**	**7.87**	**7.79**	**7.72**	**7.60**	**7.52**	**7.39**	**7.31**	**7.23**	**7.14**	**7.09**	**7.02**	**6.99**	**6.94**	**6.90**	**6.88**	
7	5.59	4.74	4.35	4.12	3.97	3.87	3.79	3.73	3.68	3.63	3.60	3.57	3.52	3.49	3.44	3.41	3.38	3.34	3.32	3.29	3.28	3.25	3.24	3.23	7
	12.25	**9.55**	**8.45**	**7.85**	**7.46**	**7.19**	**7.00**	**6.84**	**6.71**	**6.62**	**6.54**	**6.47**	**6.35**	**6.27**	**6.15**	**6.07**	**5.98**	**5.90**	**5.85**	**5.78**	**5.75**	**5.70**	**5.67**	**5.65**	
8	5.32	4.46	4.07	3.84	3.69	3.58	3.50	3.44	3.39	3.34	3.31	3.28	3.23	3.20	3.15	3.12	3.08	3.05	3.03	3.00	2.98	2.96	2.94	2.93	8
	11.26	**8.65**	**7.59**	**7.01**	**6.63**	**6.37**	**6.19**	**6.03**	**5.91**	**5.82**	**5.74**	**5.67**	**5.56**	**5.48**	**5.36**	**5.28**	**5.20**	**5.11**	**5.06**	**5.00**	**4.96**	**4.91**	**4.88**	**4.86**	
9	5.12	4.26	3.86	3.63	3.48	3.37	3.29	3.23	3.18	3.13	3.10	3.07	3.02	2.98	2.93	2.90	2.86	2.82	2.80	2.77	2.76	2.73	2.72	2.71	9
	10.56	**8.02**	**6.99**	**6.42**	**6.06**	**5.80**	**5.62**	**5.47**	**5.35**	**5.26**	**5.18**	**5.11**	**5.00**	**4.92**	**4.80**	**4.73**	**4.64**	**4.56**	**4.51**	**4.45**	**4.41**	**4.36**	**4.33**	**4.31**	
10	4.96	4.10	3.71	3.48	3.33	3.22	3.14	3.07	3.02	2.97	2.94	2.91	2.86	2.82	2.77	2.74	2.70	2.67	2.64	2.61	2.59	2.56	2.55	2.54	10
	10.04	**7.56**	**6.55**	**5.99**	**5.64**	**5.39**	**5.21**	**5.06**	**4.95**	**4.85**	**4.78**	**4.71**	**4.60**	**4.52**	**4.41**	**4.33**	**4.25**	**4.17**	**4.12**	**4.05**	**4.01**	**3.96**	**3.93**	**3.91**	
11	4.84	3.98	3.59	3.36	3.20	3.09	3.01	2.95	2.90	2.86	2.82	2.79	2.74	2.70	2.65	2.61	2.57	2.53	2.50	2.47	2.45	2.42	2.41	2.40	11
	9.65	**7.20**	**6.22**	**5.67**	**5.32**	**5.07**	**4.88**	**4.74**	**4.63**	**4.54**	**4.46**	**4.40**	**4.29**	**4.21**	**4.10**	**4.02**	**3.94**	**3.86**	**3.80**	**3.74**	**3.70**	**3.66**	**3.62**	**3.60**	
12	4.75	3.88	3.49	3.26	3.11	3.00	2.92	2.85	2.80	2.76	2.72	2.69	2.64	2.60	2.54	2.50	2.46	2.42	2.40	2.36	2.35	2.32	2.31	2.30	12
	9.33	**6.93**	**5.95**	**5.41**	**5.06**	**4.82**	**4.65**	**4.50**	**4.39**	**4.30**	**4.22**	**4.16**	**4.05**	**3.98**	**3.86**	**3.78**	**3.70**	**3.61**	**3.56**	**3.49**	**3.46**	**3.41**	**3.38**	**3.36**	
13	4.67	3.80	3.41	3.18	3.02	2.92	2.84	2.77	2.72	2.67	2.63	2.60	2.55	2.51	2.46	2.42	2.38	2.34	2.32	2.28	2.26	2.24	2.22	2.21	13
	9.07	**6.70**	**5.74**	**5.20**	**4.86**	**4.62**	**4.44**	**4.30**	**4.19**	**4.10**	**4.02**	**3.96**	**3.85**	**3.78**	**3.67**	**3.59**	**3.51**	**3.42**	**3.37**	**3.30**	**3.27**	**3.21**	**3.18**	**3.16**	

Table 10. Points for the Distribution of F [5% (light type) and 1 % (bold face type)] ; Continued

f_2	f_1 Degrees of freedom (for greater mean square): 1	2	3	4	5	6	7	8	9	10	11	12	14	16	20	24	30	40	50	75	100	200	500	∞	f_2
14	4.60	3.74	3.34	3.11	2.96	2.85	2.77	2.70	2.65	2.60	2.56	2.53	2.48	2.44	2.39	2.35	2.31	2.27	2.24	2.21	2.19	2.16	2.14	2.13	14
	8.86	**6.51**	**5.56**	**5.03**	**4.69**	**4.46**	**4.28**	**4.14**	**4.03**	**3.94**	**3.86**	**3.80**	**3.70**	**3.62**	**3.51**	**3.43**	**3.34**	**3.26**	**3.21**	**3.14**	**3.11**	**3.06**	**3.02**	**3.00**	
15	4.54	3.68	3.29	3.06	2.90	2.79	2.70	2.64	2.59	2.55	2.51	2.48	2.43	2.39	2.33	2.29	2.25	2.21	2.18	2.15	2.12	2.10	2.08	2.07	15
	8.68	**6.36**	**5.42**	**4.89**	**4.56**	**4.32**	**4.14**	**4.00**	**3.89**	**3.80**	**3.73**	**3.67**	**3.56**	**3.48**	**3.36**	**3.29**	**3.20**	**3.12**	**3.07**	**3.00**	**2.97**	**2.92**	**2.89**	**2.87**	
16	4.49	3.63	3.24	3.01	2.85	2.74	2.66	2.59	2.54	2.49	2.45	2.42	2.37	2.33	2.28	2.24	2.20	2.16	2.13	2.09	2.07	2.04	2.02	2.01	16
	8.53	**6.23**	**5.29**	**4.77**	**4.44**	**4.20**	**4.03**	**3.89**	**3.78**	**3.69**	**3.61**	**3.55**	**3.45**	**3.37**	**3.25**	**3.18**	**3.10**	**3.01**	**2.96**	**2.98**	**2.86**	**2.80**	**2.77**	**2.75**	
17	4.45	3.59	3.20	2.96	2.81	2.70	2.62	2.55	2.50	2.45	2.41	2.38	2.33	2.29	2.23	2.19	2.15	2.11	2.08	2.04	2.02	1.99	1.97	1.96	17
	8.40	**6.11**	**5.18**	**4.67**	**4.34**	**4.10**	**3.93**	**3.79**	**3.68**	**3.59**	**3.52**	**3.45**	**3.35**	**3.27**	**3.16**	**3.08**	**3.00**	**2.92**	**2.86**	**2.79**	**2.76**	**2.70**	**2.67**	**2.65**	
18	4.41	3.55	3.16	2.93	2.77	3.66	2.58	2.51	2.46	2.41	2.37	2.34	2.29	2.25	2.19	2.15	2.11	2.07	2.04	2.00	1.98	1.95	1.93	1.92	18
	8.28	**6.01**	**5.09**	**4.58**	**4.25**	**4.01**	**3.85**	**3.71**	**3.60**	**3.51**	**3.44**	**3.37**	**3.27**	**3.19**	**3.07**	**3.00**	**2.91**	**2.83**	**2.78**	**2.71**	**2.68**	**2.62**	**2.59**	**2.57**	
19	4.38	3.52	3.13	2.90	2.74	2.63	2.55	2.48	2.43	2.38	2.34	2.31	2.26	2.21	2.15	2.11	2.07	2.02	2.00	1.96	1.94	1.91	1.90	1.88	19
	8.18	**5.93**	**5.01**	**4.50**	**4.17**	**3.94**	**3.77**	**3.63**	**3.52**	**3.43**	**3.36**	**3.30**	**3.19**	**3.12**	**3.00**	**2.92**	**2.84**	**2.76**	**2.70**	**2.63**	**2.60**	**2.54**	**2.51**	**2.49**	
20	4.35	3.49	3.10	2.87	2.71	2.60	2.52	2.45	2.40	2.35	2.31	2.28	2.23	2.18	2.12	2.08	2.04	1.99	1.96	1.92	1.90	1.87	1.85	1.84	20
	8.10	**5.85**	**4.94**	**4.43**	**4.10**	**3.87**	**3.71**	**3.56**	**3.45**	**3.37**	**3.30**	**3.23**	**3.13**	**3.05**	**2.94**	**2.86**	**2.77**	**2.69**	**2.63**	**2.56**	**2.53**	**2.47**	**2.44**	**2.42**	
21	4.32	3.47	3.07	2.84	2.68	2.57	2.49	2.42	2.37	2.32	2.28	2.25	2.20	2.15	2.09	2.05	2.00	1.96	1.93	1.89	1.87	1.84	1.82	1.81	21
	8.02	**5.78**	**4.87**	**4.37**	**4.04**	**3.81**	**3.65**	**3.51**	**3.40**	**3.31**	**3.24**	**3.17**	**3.07**	**2.99**	**2.88**	**2.80**	**2.72**	**2.63**	**2.58**	**2.51**	**2.47**	**2.42**	**2.38**	**2.36**	
22	4.30	3.44	3.05	2.82	2.66	2.55	2.47	2.40	2.35	2.30	2.26	2.23	2.18	2.13	2.07	2.03	1.98	1.93	1.91	1.87	1.84	1.81	1.80	1.78	22
	7.94	**5.72**	**4.82**	**4.31**	**3.99**	**3.76**	**3.59**	**3.45**	**3.35**	**3.26**	**3.18**	**3.12**	**3.02**	**2.94**	**2.83**	**2.75**	**2.67**	**2.58**	**2.53**	**2.46**	**2.42**	**2.37**	**2.33**	**2.31**	
23	4.28	3.42	3.03	2.80	2.64	2.53	2.45	2.38	2.32	2.28	2.24	2.20	2.14	2.10	2.04	2.00	1.96	1.91	1.88	1.84	1.82	1.79	1.77	1.76	23
	7.88	**5.66**	**4.76**	**4.26**	**3.94**	**3.71**	**3.54**	**3.41**	**3.30**	**3.21**	**3.14**	**3.07**	**2.97**	**2.89**	**2.78**	**2.70**	**2.62**	**2.53**	**2.48**	**2.41**	**2.37**	**2.32**	**2.28**	**2.26**	
24	4.26	3.40	3.01	2.78	2.62	2.51	2.43	2.36	2.30	2.26	2.22	2.18	2.13	2.09	2.02	1.98	1.94	1.89	1.86	1.82	1.80	1.76	1.74	1.73	24
	7.82	**5.61**	**4.72**	**4.22**	**3.90**	**3.67**	**3.50**	**3.36**	**3.25**	**3.17**	**3.09**	**3.03**	**2.93**	**2.85**	**2.74**	**2.66**	**2.58**	**2.49**	**2.44**	**2.36**	**2.33**	**2.27**	**2.23**	**2.21**	
25	4.24	3.38	2.99	2.76	2.60	2.49	2.41	2.34	2.28	2.24	2.20	2.16	2.11	2.06	2.00	1.96	1.92	1.87	1.84	1.80	1.77	1.74	1.72	1.71	25
	7.77	**5.57**	**4.68**	**4.18**	**3.86**	**3.63**	**3.46**	**3.32**	**3.21**	**3.13**	**3.05**	**2.99**	**2.89**	**2.81**	**2.70**	**2.62**	**2.54**	**2.45**	**2.40**	**2.32**	**2.29**	**2.23**	**2.19**	**2.17**	
26	4.22	3.37	2.98	2.74	2.59	2.47	2.39	2.32	2.27	2.22	2.18	2.15	2.10	2.05	1.99	1.95	1.90	1.85	1.82	1.78	1.76	1.72	1.70	1.69	26
	7.72	**5.53**	**4.64**	**4.14**	**3.82**	**3.59**	**3.42**	**3.29**	**3.17**	**3.09**	**3.02**	**2.96**	**2.86**	**2.77**	**2.66**	**2.58**	**2.50**	**2.41**	**2.36**	**2.28**	**2.25**	**2.19**	**2.15**	**2.13**	

Table 11. Points for the Distribution of F [5% (light type) and 1 % (bold face type)] ; Continued

f_2	f_1 Degrees of freedom (for greater mean square)																								f_2
	1	2	3	4	5	6	7	8	9	10	11	12	14	16	20	24	30	40	50	75	100	200	500	∞	
27	4.21	3.35	2.96	2.73	2.57	2.46	2.37	2.30	2.25	2.20	2.16	2.13	2.08	2.03	1.97	1.93	1.88	1.84	1.80	1.76	1.74	1.71	1.68	1.67	27
	7.68	**5.49**	**4.60**	**4.11**	**3.79**	**3.56**	**3.39**	**3.26**	**3.14**	**3.06**	**2.98**	**2.93**	**2.83**	**2.74**	**2.63**	**2.55**	**2.47**	**2.38**	**2.33**	**2.25**	**2.21**	**2.16**	**2.12**	**2.10**	
28	4.20	3.34	2.95	2.71	2.56	2.44	2.36	2.29	2.24	2.19	2.15	2.12	2.06	2.02	1.96	1.91	1.87	1.81	1.78	1.75	1.72	1.69	1.67	1.65	28
	7.64	**5.45**	**4.57**	**4.07**	**3.76**	**3.53**	**3.36**	**3.23**	**3.11**	**3.03**	**2.95**	**2.90**	**2.80**	**2.71**	**2.60**	**2.52**	**2.44**	**2.35**	**2.30**	**2.22**	**2.18**	**2.13**	**2.09**	**2.06**	
29	4.18	3.33	2.93	2.70	2.54	2.43	2.35	2.28	2.22	2.18	2.14	2.10	2.05	2.00	1.94	1.90	1.85	1.80	1.77	1.73	1.71	1.68	1.65	1.64	29
	7.60	**5.42**	**4.54**	**4.04**	**3.73**	**3.50**	**3.33**	**3.20**	**3.08**	**3.00**	**2.92**	**2.87**	**2.77**	**2.68**	**2.57**	**2.49**	**2.41**	**2.32**	**2.27**	**2.19**	**2.15**	**2.10**	**2.06**	**2.03**	
30	4.17	3.32	2.92	2.69	2.53	2.42	2.34	2.27	2.21	2.16	2.12	2.09	2.04	1.99	1.93	1.89	1.84	1.79	1.76	1.72	1.69	1.66	1.64	1.62	30
	7.56	**5.39**	**4.51**	**4.02**	**3.70**	**3.47**	**3.30**	**3.17**	**3.06**	**2.98**	**2.90**	**2.84**	**2.74**	**2.66**	**2.55**	**2.47**	**2.38**	**2.29**	**2.24**	**2.16**	**2.13**	**2.07**	**2.03**	**2.01**	
32	4.15	3.30	2.90	2.67	2.51	2.40	2.32	2.25	2.19	2.14	2.10	2.07	2.02	1.97	1.91	1.86	1.82	1.76	1.74	1.69	1.67	1.64	1.61	1.59	32
	7.50	**5.34**	**4.46**	**3.97**	**3.66**	**3.42**	**3.25**	**3.12**	**3.01**	**2.94**	**2.86**	**2.80**	**2.70**	**2.62**	**2.51**	**2.42**	**2.34**	**2.25**	**2.20**	**2.12**	**2.08**	**2.02**	**1.98**	**1.96**	
34	4.13	3.28	2.88	2.65	2.49	2.38	2.30	2.23	2.17	2.12	2.08	2.05	2.00	1.95	1.89	1.84	1.80	1.74	1.71	1.67	1.64	1.61	1.59	1.57	34
	7.44	**5.29**	**4.42**	**3.93**	**3.61**	**3.38**	**3.21**	**3.08**	**2.97**	**2.89**	**2.82**	**2.76**	**2.66**	**2.58**	**2.47**	**2.38**	**2.30**	**2.21**	**2.15**	**2.08**	**2.04**	**1.98**	**1.94**	**1.91**	
36	4.11	3.26	2.86	2.63	2.48	2.36	2.28	2.21	2.15	2.10	2.06	2.03	1.98	1.93	1.87	1.82	1.78	1.72	1.69	1.65	1.62	1.59	1.56	1.55	36
	7.39	**5.25**	**4.38**	**3.89**	**3.58**	**3.35**	**3.18**	**3.04**	**2.94**	**2.86**	**2.78**	**2.72**	**2.62**	**2.54**	**2.43**	**2.35**	**2.26**	**2.17**	**2.12**	**2.04**	**2.00**	**1.94**	**1.90**	**1.87**	
38	4.10	3.25	2.85	2.62	2.46	2.35	2.26	2.19	2.14	2.09	2.05	2.02	1.96	1.92	1.85	1.80	1.76	1.71	1.67	1.63	1.60	1.57	1.54	1.53	38
	7.35	**5.21**	**4.34**	**3.86**	**3.54**	**3.32**	**3.15**	**3.02**	**2.91**	**2.82**	**2.75**	**2.69**	**2.59**	**2.51**	**2.40**	**2.32**	**2.22**	**2.14**	**2.08**	**2.00**	**1.97**	**1.90**	**1.86**	**1.84**	
40	4.08	3.23	2.84	2.61	2.45	2.34	2.25	2.18	2.12	2.07	2.04	2.00	1.95	1.90	1.84	1.79	1.74	1.69	1.66	1.61	1.59	1.55	1.53	1.51	40
	7.31	**5.18**	**4.31**	**3.83**	**3.51**	**3.29**	**3.12**	**2.99**	**2.88**	**2.80**	**2.73**	**2.66**	**2.56**	**2.49**	**2.37**	**2.29**	**2.20**	**2.11**	**2.05**	**1.97**	**1.94**	**1.88**	**1.84**	**1.81**	
42	4.07	3.22	2.83	2.59	2.44	2.32	2.24	2.17	2.11	2.06	2.02	1.99	1.94	1.89	1.82	1.78	1.73	1.68	1.64	1.60	1.57	1.54	1.51	1.49	42
	7.27	**5.15**	**4.29**	**3.80**	**3.49**	**3.26**	**3.10**	**2.96**	**2.86**	**2.77**	**2.70**	**2.64**	**2.54**	**2.46**	**2.35**	**2.26**	**2.17**	**2.08**	**2.02**	**1.94**	**1.91**	**1.85**	**1.80**	**1.78**	
44	4.06	3.21	2.82	2.58	2.43	2.31	2.23	2.16	2.10	2.05	2.01	1.98	1.92	1.88	1.81	1.76	1.72	1.66	1.63	1.58	1.56	1.52	1.50	1.48	44
	7.24	**5.12**	**4.26**	**3.78**	**3.46**	**3.24**	**3.07**	**2.94**	**2.84**	**2.75**	**2.68**	**2.62**	**2.52**	**2.44**	**2.32**	**2.24**	**2.15**	**2.06**	**2.00**	**1.92**	**1.88**	**1.82**	**1.78**	**1.75**	
46	4.05	3.20	2.81	2.57	2.42	2.30	2.22	2.14	2.09	2.04	2.00	1.97	1.91	1.87	1.80	1.75	1.71	1.65	1.62	1.57	1.54	1.51	1.48	1.46	46
	7.21	**5.10**	**4.24**	**3.76**	**3.44**	**3.22**	**3.05**	**2.92**	**2.82**	**2.73**	**2.66**	**2.60**	**2.50**	**2.42**	**2.30**	**2.22**	**2.13**	**2.04**	**1.98**	**1.90**	**1.86**	**1.80**	**1.76**	**1.72**	
48	4.04	3.19	2.80	2.56	2.41	2.30	2.21	2.14	2.08	2.03	1.99	1.96	1.90	1.86	1.79	1.74	1.70	1.64	1.61	1.56	1.53	1.50	1.47	1.45	48
	7.19	**5.08**	**4.22**	**3.74**	**3.42**	**3.20**	**3.04**	**2.90**	**2.80**	**2.71**	**2.64**	**2.58**	**2.48**	**2.40**	**2.28**	**2.20**	**2.11**	**2.02**	**1.96**	**1.88**	**1.84**	**1.78**	**1.73**	**1.70**	

Table 12. Points for the Distribution of F [5% (light type) and 1 % (bold face type)] ; Continued

f_2	1	2	3	4	5	6	7	8	9	10	11	12	14	16	20	24	30	40	50	75	100	200	500	∞	f_2
	f_1 Degrees of freedom (for greater mean square)																								
50	4.03	3.18	2.79	2.56	2.40	2.29	2.20	2.13	2.07	2.02	1.98	1.95	1.90	1.85	1.78	1.74	1.69	1.63	1.60	1.55	1.52	1.48	1.46	1.44	50
	7.17	**5.06**	**4.20**	**3.72**	**3.41**	**3.18**	**3.02**	**2.88**	**2.78**	**2.70**	**2.62**	**2.56**	**2.46**	**2.39**	**2.26**	**2.18**	**2.10**	**2.00**	**1.94**	**1.86**	**1.82**	**1.76**	**1.71**	**1.68**	
55	4.02	3.17	2.78	2.54	2.38	2.27	2.18	2.11	2.05	2.00	1.97	1.93	1.88	1.83	1.76	1.72	1.67	1.61	1.58	1.52	1.50	1.46	1.43	1.41	55
	7.12	**5.01**	**4.16**	**3.68**	**3.37**	**3.15**	**2.98**	**2.85**	**2.75**	**2.66**	**2.59**	**2.53**	**2.43**	**2.35**	**2.23**	**2.15**	**2.06**	**1.96**	**1.90**	**1.82**	**1.78**	**1.71**	**1.66**	**1.64**	
60	4.00	3.15	2.76	2.52	2.37	2.25	2.17	2.10	2.04	1.99	1.95	1.92	1.86	1.81	1.75	1.70	1.65	1.59	1.56	1.50	1.48	1.44	1.41	1.39	60
	7.08	**4.98**	**4.13**	**3.65**	**3.34**	**3.12**	**2.95**	**2.82**	**2.72**	**2.63**	**2.56**	**2.50**	**2.40**	**2.32**	**2.20**	**2.12**	**2.03**	**1.93**	**1.87**	**1.79**	**1.74**	**1.68**	**1.63**	**1.60**	
65	3.99	3.14	2.75	2.51	2.36	2.24	2.15	2.08	2.02	1.98	1.94	1.90	1.85	1.80	1.73	1.68	1.63	1.57	1.54	1.49	1.46	1.42	1.39	1.37	65
	7.04	**4.95**	**4.10**	**3.62**	**3.31**	**3.09**	**2.93**	**2.79**	**2.70**	**2.61**	**2.54**	**2.47**	**2.37**	**2.30**	**2.18**	**2.09**	**2.00**	**1.90**	**1.84**	**1.76**	**1.71**	**1.64**	**1.60**	**1.56**	
70	3.98	3.13	2.74	2.50	2.35	2.23	2.14	2.07	2.01	1.97	1.93	1.89	1.84	1.79	1.72	1.67	1.62	1.56	1.53	1.47	1.45	1.40	1.37	1.35	70
	7.01	**4.92**	**4.08**	**3.60**	**3.29**	**3.07**	**2.91**	**2.77**	**2.67**	**2.59**	**2.51**	**2.45**	**2.35**	**2.28**	**2.15**	**2.07**	**1.98**	**1.88**	**1.82**	**1.74**	**1.69**	**1.62**	**1.56**	**1.53**	
80	3.96	3.11	2.72	2.48	2.33	2.21	2.12	2.05	1.99	1.95	1.91	1.88	1.82	1.77	1.70	1.65	1.60	1.54	1.51	1.45	1.42	1.38	1.35	1.32	80
	6.96	**4.88**	**4.04**	**3.56**	**3.25**	**3.04**	**2.87**	**2.74**	**2.64**	**2.55**	**2.48**	**2.41**	**2.32**	**2.24**	**2.11**	**2.03**	**1.94**	**1.84**	**1.78**	**1.70**	**1.65**	**1.57**	**1.52**	**1.49**	
100	3.94	3.09	2.70	2.46	2.30	2.19	2.10	2.03	1.97	1.92	1.88	1.85	1.79	1.75	1.68	1.63	1.57	1.51	1.48	1.42	1.39	1.34	1.30	1.28	100
	6.90	**4.82**	**3.98**	**3.51**	**3.20**	**2.99**	**2.82**	**2.69**	**2.59**	**2.51**	**2.43**	**2.36**	**2.26**	**2.19**	**2.06**	**1.98**	**1.89**	**1.79**	**1.73**	**1.64**	**1.59**	**1.51**	**1.46**	**1.43**	
125	3.92	3.07	2.68	2.44	2.29	2.17	2.08	2.01	1.95	1.90	1.86	1.83	1.77	1.72	1.65	1.60	1.55	1.49	1.45	1.39	1.36	1.31	1.27	1.25	125
	6.84	**4.78**	**3.94**	**3.47**	**3.17**	**2.95**	**2.79**	**2.65**	**2.56**	**2.47**	**2.40**	**2.33**	**2.23**	**2.15**	**2.03**	**1.94**	**1.85**	**1.75**	**1.68**	**1.59**	**1.54**	**1.46**	**1.40**	**1.37**	
150	3.91	3.06	2.67	2.43	2.27	2.16	2.07	2.00	1.94	1.89	1.85	1.82	1.76	1.71	1.64	1.59	1.54	1.47	1.44	1.37	1.34	1.29	1.25	1.22	150
	6.81	**4.75**	**3.91**	**3.44**	**3.14**	**2.92**	**2.76**	**2.62**	**2.53**	**2.44**	**2.37**	**2.30**	**2.20**	**2.12**	**2.00**	**1.91**	**1.83**	**1.72**	**1.66**	**1.56**	**1.51**	**1.43**	**1.37**	**1.33**	
200	3.89	3.04	2.65	2.41	2.26	2.14	2.05	1.98	1.92	1.87	1.83	1.80	1.74	1.69	1.62	1.57	1.52	1.45	1.42	1.35	1.32	1.26	1.22	1.19	200
	6.76	**4.71**	**3.88**	**3.41**	**3.11**	**2.90**	**2.73**	**2.60**	**2.50**	**2.41**	**2.34**	**2.28**	**2.17**	**2.09**	**1.97**	**1.88**	**1.79**	**1.69**	**1.62**	**1.53**	**1.48**	**1.39**	**1.33**	**1.28**	
400	3.86	3.02	2.62	2.39	2.23	2.12	2.03	1.96	1.90	1.85	1.81	1.78	1.72	1.67	1.60	1.54	1.49	1.42	1.38	1.32	1.28	1.22	1.16	1.13	400
	6.70	**4.66**	**3.83**	**3.36**	**3.06**	**2.85**	**2.69**	**2.55**	**2.46**	**2.37**	**2.29**	**2.23**	**2.12**	**2.04**	**1.92**	**1.84**	**1.74**	**1.64**	**1.57**	**1.47**	**1.42**	**1.32**	**1.24**	**1.19**	
1000	3.85	3.00	2.61	2.38	2.22	2.10	2.02	1.95	1.89	1.84	1.80	1.76	1.70	1.65	1.58	1.53	1.47	1.41	1.36	1.30	1.26	1.19	1.13	1.08	1000
	6.66	**4.62**	**3.80**	**3.34**	**3.04**	**2.82**	**2.66**	**2.53**	**2.43**	**2.34**	**2.26**	**2.20**	**2.09**	**2.01**	**1.89**	**1.81**	**1.71**	**1.61**	**1.54**	**1.44**	**1.38**	**1.28**	**1.19**	**1.11**	
∞	3.84	2.99	2.60	2.37	2.21	2.09	2.01	1.94	1.88	1.83	1.79	1.75	1.69	1.64	1.57	1.52	1.46	1.40	1.35	1.28	1.24	1.17	1.11	1.00	∞
	6.64	**4.60**	**3.78**	**3.32**	**3.02**	**2.80**	**2.64**	**2.51**	**2.41**	**2.32**	**2.24**	**2.18**	**2.07**	**1.99**	**1.87**	**1.79**	**1.69**	**1.59**	**1.52**	**1.41**	**1.36**	**1.25**	**1.15**	**1.00**	

Appendix E

Distribution of probability

n	.9	.8	.7	.6	.5	.4	.3	.2	.1	.05	.02	.01	.001
1	.158	.325	.510	.727	1.000	1.376	1.963	3.078	6.314	12.706	31.821	63.657	636.619
2	.142	.289	.445	.617	.816	1.061	1.386	1.886	2.920	4.303	6.965	9.925	31.598
3	.137	.277	.424	.584	.765	.978	1.250	1.638	2.353	3.182	4.541	5.841	12.924
4	.134	.271	.414	.569	.741	.941	1.190	1.533	2.132	2.776	3.747	4.604	8.610
5	.132	.267	.408	.559	.727	.920	1.156	1.476	2.015	2.571	3.365	4.032	6.869
6	.131	.265	.404	.553	.718	.906	1.134	1.440	1.943	2.447	3.143	3.707	5.959
7	.130	.263	.402	.549	.711	.896	1.119	1.415	1.895	2.365	2.998	3.499	5.408
8	.130	.262	.399	.546	.706	.889	1.108	1.397	1.860	2.306	2.896	3.355	5.041
9	.129	.261	.398	.543	.703	.883	1.100	1.383	1.833	2.262	2.821	3.250	4.781
10	.129	.260	.397	.542	.700	.879	1.093	1.372	1.812	2.228	2.764	3.169	4.587
11	.129	.260	.396	.540	.697	.876	1.088	1.363	1.796	2.201	2.718	3.106	4.437
12	.128	.259	.395	.539	.695	.873	1.083	1.356	1.782	2.179	2.681	3.055	4.318
13	.128	.259	.394	.538	.694	.870	1.079	1.350	1.771	2.160	2.650	3.012	4.221
14	.128	.258	.393	.537	.692	.868	1.076	1.345	1.761	2.145	2.624	2.977	4.140
15	.128	.258	.393	.536	.691	.866	1.074	1.341	1.753	2.131	2.602	2.947	4.073
16	.128	.258	.392	.535	.690	.865	1.071	1.337	1.746	2.120	2.583	2.921	4.015
17	.128	.257	.392	.534	.689	.863	1.069	1.333	1.740	2.110	2.567	2.898	3.965
18	.127	.257	.392	.534	.688	.862	1.067	1.330	1.734	2.101	2.552	2.878	3.922
19	.127	.257	.391	.533	.688	.861	1.066	1.328	1.729	2.093	2.539	2.861	3.883
20	.127	.257	.391	.533	.687	.860	1.064	1.325	1.725	2.086	2.528	2.845	3.850
21	.127	.257	.391	.532	.686	.859	1.063	1.323	1.721	2.080	2.518	2.831	3.819
22	.127	.256	.390	.532	.686	.858	1.061	1.321	1.717	2.074	2.508	2.819	3.792
23	.127	.256	.390	.532	.685	.858	1.060	1.319	1.714	2.069	2.500	2.807	3.767
24	.127	.256	.390	.531	.685	.857	1.059	1.318	1.711	2.064	2.492	2.797	3.745
25	.127	.256	.390	.531	.684	.856	1.058	1.316	1.708	2.060	2.485	2.787	3.725
26	.127	.256	.390	.531	.684	.856	1.058	1.315	1.706	2.056	2.479	2.779	3.707
27	.127	.256	.389	.531	.684	.855	1.057	1.314	1.703	2.052	2.473	2.771	3.690
28	.127	.256	.389	.530	.683	.855	1.056	1.313	1.701	2.048	2.467	2.763	3.674
29	.127	.256	.389	.530	.683	.854	1.055	1.311	1.699	2.045	2.462	2.756	3.659
30	.127	.256	.389	.530	.683	.854	1.055	1.310	1.697	2.042	2.457	2.750	3.646
40	.126	.255	.388	.529	.681	.851	1.050	1.303	1.684	2.021	2.423	2.704	3.551
60	.126	.254	.387	.527	.679	.848	1.046	1.296	1.671	2.000	2.390	2.660	3.460
120	.126	.254	.386	.526	.677	.845	1.041	1.289	1.658	1.980	2.358	2.617	3.373
∞	.126	.253	.385	.524	.674	.842	1.036	1.282	1.645	1.960	2.326	2.576	3.291

Biography

Miss Kanyanee Samiphak was born on May 23, 1976 in Chanthaburi, Thailand. She graduated with the degree of Bachelor of Science in Biology from the department of Biology, Silpakorn University in 1998. In 1999, she enrolled in Master degree of Science at the department of Biochemistry, Chulalongkorn University.