

**CRI GROUP ANNUAL RESEARCH REPORT 2000/1
TABLE OF CONTENTS**

		Page
1.	INTRODUCTION	1
2.	PROGRAMME: MARKET ACCESS	2
2.1	Programme summary	2
	2.2.1 Project: Market Access Diseases	2
	2.2.2 <i>Phaeoramularia angolensis</i>	2
	2.2.3 Citrus Blackspot	2
2.2	Project: False Codling Moth	2
	2.2.1 Project summary	2
	2.2.2 Development of Rimon (novaluron) for the control of false codling moth	3
	2.2.3 Evaluation of a new pheromone dispenser for monitoring False Codling moth	5
	2.2.4 Development of Baythroid 050 EC (cyfluthrin) for the control of false codling moth on citrus	9
	2.2.5 Evaluation of a new chemistry insecticide for false codling moth on oranges	11
	2.2.6 Evaluation of the efficacy of a granulovirus (GV) for the control of false codling moth	14
	2.2.7 Assessment and development of the augmentation technique for FCM control with the parasitoid <i>Trichogrammatoidea cryptophlebiae</i>	23
	2.2.8 Improvement of the false codling moth mass rearing technique	29
	2.2.9 Evaluation of the potential for importation of natural enemies of false codling moth	40
	2.2.10 Fruit quality and disinfestations of Hass avocados and oranges using controlled atmosphere and modified CO ₂ levels	42
2.3	Project: Fruit Fly	49
	2.3.1 Project summary	49
	2.3.2 Fruit Fly rearing	50
	2.3.3 Cold sterilization of Mediterranean fruit fly-infested mandarins destined for Japan (Addendum to main report of November 1999)	51
	2.3.4 Sterile insect technique	52
	2.3.5 Cold sterilization of Natal fruit fly-infested oranges	53
	2.3.6 Cold sterilization of Natal fruit fly-infested apples	53
	2.3.1 Cold sterilization of Marula fruit fly-infested oranges	57
	2.3.8 The efficiency of fruit fly monitoring traps and attractants	58
	2.3.9 The distribution of fruit flies attracted to Ceratitis lure in citrus production regions of southern Africa	71
	2.3.10 Development of a resistance test for fruit flies	73
	2.3.11 Research to find a suitable insecticide that would increase the shelf life of the M3	78
	2.3.12 The use of M3s and Sensus traps to test an insecticide for use in the M3	82
	2.3.13 Determination of the mortality of fruit flies caused by Sulfluramid over time	82
	2.3.14 Suppressing fungal growth on the M3 bait capsule (Questlure)	84
	2.3.15 An investigation to determine whether Dithane or Folpan have any repellent effect on fruit fly when used in Questlure	86
	2.3.16 An investigation into other attractants for the M3 bait station	87
	2.3.17 Replacement of the Decis tablet in the Sensus trap with other insecticides	89

**CRI GROUP ANNUAL RESEARCH REPORT 2000/1
TABLE OF CONTENTS**

	Page
2.3.18 Could abnormal fruit drop in citrus orchards be caused by an alien fruit fly?	91
2.3.19 Basin-branch experiment with Sulfluramid liquid in a bait	92
2.3.20 Investigating the use of Sulfluramid powder in fruit fly bait sprays	93
2.3.21 Results obtained by the commercial use of M3s in deciduous fruit orchards	93
2.3.22 Using M3s to control fruit fly in table grapes in Paarl during the 1999/2000 season	95
2.3.23 Control of fruit flies with the M3 attract-and-kill product on deciduous fruits and grapes	96
2.3.24 An investigation into the commercial control of fruit fly with the M3 bait station	98
2.3.25 Investigating the use of Questlure instead of the protein hydrolysate fruit fly bait for fruit fly control	99
2.3.26 An investigation into the commercial use of Questlure as a fruit fly attractant	101
2.3.27 An examination of the effect of Sodium Chloride (NaCl) on the action of Malathion in fruit fly baits	103
2.4 Project: Other Market Access pests	104
2.4.1 Project summary	104
2.4.2 Development of a mealybug resistance test	105
2.4.3 Development of a DNA identification technique for life stages of a mealybug	108
2.5 Project: Residues	108
2.5.1 Project summary	108
2.5.2 Restrictions on the use of plant protection products on export citrus	109
3. PROGRAMME: INTEGRATED PEST MANAGEMENT	117
3.1 Programme summary	117
3.2 Project: Citrus Thrips IPM	117
3.2.1 Project summary	117
3.2.2 Identifying natural enemies of citrus thrips	118
3.2.3 Using a radioactive label to identify soil predators which prey on citrus thrips	119
3.2.4 Field evaluation of spinosad (480 SC) on citrus against citrus thrips	123
3.2.5 Identification of confusing <i>Scirtothrips</i> spp. on citrus	124
3.2.6 Microbial control of citrus thrips	125
3.2.7 Mass release of soil predators to control over-wintering citrus thrips	126
3.2.8 Evaluating systemic insecticides in drip lines for the control of citrus thrips	128
3.2.9 The abundance and distribution of spiders in the South African citrus ecosystem	132
3.3 Project: Red Scale IPM	137
3.3.1 Project summary	137
3.3.2 <i>Aphytis</i> rearing	138
3.3.3 Augmentation with <i>Aphytis</i>	139

**CRI GROUP ANNUAL RESEARCH REPORT 2000/1
TABLE OF CONTENTS**

	Page	
3.3.4	Effect of oil sprays on colour, yield and internal quality of citrus fruit	143
3.3.5	Phytotoxicity of the narrow distillation range oil, Wenfinex, on navel orange fruit	166
3.3.6	A parasitism related infestation threshold for intervention against red scale	168
3.3.7	The control of red scale, mealybug and thrips using Actara and other neonicotinoids, and their non-target effects	173
3.3.8	Efficacy and crop safety of two new oils applied in winter	174
3.3.9	Registration of Nemesis with Orchex and Win oil	177
3.3.10	Survey of southern African <i>Aphytis</i> species parasitising red scale on citrus	181
3.3.11	Kaolin	184
3.4	Project: Disruptive or sporadic pests	186
3.4.1	Project summary	186
3.4.2	Control of ants in orchards with baits and stem paints	187
3.4.3	The control of ants with the Donor band	188
3.4.4	Citrus grey mite: host susceptibility and natural enemy complex	190
3.4.5	Control of citrus bud mite, <i>Eriophyes sheldoni</i> , with propargite (Omite CR)	192
3.4.6	The use of Sulfluramid (SFA) for ant control	194
3.4.7	The control of mites with various products	195
3.4.8	Identification of <i>Brevipalpus</i> spp. (flat mites) on citrus in southern Africa	197
3.5	Project: Non-Target effects	198
3.5.1	Project summary	198
3.5.2	Development of a database on the non-target effects of pesticides on beneficial arthropods	198
3.5.3	Evaluation of the non-target effects of pesticides and fungicide treatments on biological control agents of importance to the southern African mango industry	202
3.5.4	Susceptibility of natural enemies associated with citrus grey mite to pesticides commonly used on citrus	204
3.5.5	Laboratory bioassay assessment of the potential impact of two Bayer products on indicator biocontrol agents of relevance to citrus in southern Africa	210
3.5.6	Laboratory bioassay assessment of the potential impact of a product from Dow Agrosience on indicator biocontrol agents of relevance to citrus in southern Africa	210
4.	PROGRAMME: DISEASE MANAGEMENT	211
4.1	Programme summary	211
4.2	Project: Graft Transmissible Diseases	213
4.2.1	Project summary	213
4.2.2	Biological and molecular characterization of field strains of CTV and selection of mild strains for cross protections of sweet orange and grapefruit	213
4.2.3	Cross protection of Star Ruby	214
4.2.4	Cross protection of Marsh and Star Ruby using ORE mild strain	215

**CRI GROUP ANNUAL RESEARCH REPORT 2000/1
TABLE OF CONTENTS**

		Page
4.2.5	Molecular characterization of CTV isolates for cross protection of grapefruit and sweet orange	216
4.3	Project: Greening	217
4.3.1	Project summary	217
4.4	Project: Citrus Blight (CB)	218
4.4.1	Project summary	218
4.4.2	Suppression of citrus blight using injection of rolitetracycling (PMT) and chelated nutrients	219
4.4.3	Screening of rootstocks for blight susceptibility	220
4.4.4	Factor exclusion	221
4.4.5	Studies on the etiology of citrus blight using trees in containers	222
4.4.6	Studies on a stem pitting factor associated with citrus blight affected trees	223
4.4.7	Effect of different sources of potassium (K) on the incidence of citrus blight	224
4.4.8	Suppression of citrus blight using amended fertilizer regimes	224
4.4.9	Studies on the etiology of CB : Injection of CB protein into healthy trees	225
4.5	Project: Fruit and Foliar Diseases	227
4.5.1	Project summary	227
4.5.2	Evaluation of registered fungicides against Botrytis blight on lemons in the Western Cape	227
4.5.3	Evaluation of four new fungicides (Ortiva, Flint, Cabrio and Fenamidone) for the control of <i>Alternaria</i> brown spot on Mandarins	230
4.5.4	Purchase, installation and maintenance of a weather station network in the Gamtoos Valley	235
4.5.5	Effect of Azoxystrobin for the control of a Benzimidazole 30 resistant Citrus Black Spot strain on Valencia oranges in South Africa	345
4.5.6	A study to determine the epidemiology and control of the 30 fungus, <i>Phaeoramularia angolensis</i> on citrus in Zimbabwe	356
4.6	Project: Soil borne Diseases	263
4.6.1	Project summary	263
4.6.2	Stimulation of egg hatching of <i>T. semipenetrans</i> eggs	264
4.6.3	Evaluation of biological control agents against <i>Tylenchulus semipenetrans</i>	269
4.6.4	Assessment of citrus rootstocks for citrus nematode resistance	270
4.6.5	Phytex aerial applications against <i>Phytophthora</i> brown rot	271
4.6.6	Phytex commercialisation and phytotoxicity	272
4.6.7	Phytex drip application against <i>Phytophthora</i>	273
4.6.8	Control of <i>Phytophthora</i> root / collar rot in apples	274
4.6.9	<i>Phytophthora</i> control in Avocados using Phosphonates	275
4.7	Project: Post-Harvest Pathology	276
4.7.1	Project summary: Miscellaneous Lab-scale trials	276

**CRI GROUP ANNUAL RESEARCH REPORT 2000/1
TABLE OF CONTENTS**

		Page
	4.7.2 Miscellaneous Lab-scale trials	277
	4.7.3 The screening of new chemicals, <i>in vitro</i> and <i>in vivo</i> against post-harvest citrus pathogens	278
	4.7.4 Induced resistance of citrus fruit by pre-harvest application of phosphonate (Phytex) for post-harvest disease control	291
	4.7.5 Biological control	292
	4.7.6 Prevention of post-harvest decay on litchis using vinegar vapour	294
	4.7.7 Prevention of <i>Botrytis</i> decay on table grapes using vinegar vapour	299
5.	PROGRAMME: CROP AND FRUIT QUALITY MANAGEMENT	309
5.1	Programme summary	309
5.2	Project: Flower manipulation	310
	5.2.1 Project summary	310
	5.2.2 Pruning affects fruit size and quality of lemons	310
	5.2.3 Pruning affects fruit size and quality of lemons and grapefruit	317
5.3	Project: Fruit set and retention	320
	5.3.1 Project summary	320
	5.3.2 The effect of various treatments on increasing navel fruit set	320
	5.3.3 The effect of girdling on Midnight Valencia fruit set (Northern areas only)	320
5.4	Project: Fruit size	324
	5.4.1 Project summary	324
5.5	Project: Internal Fruit Quality	324
	5.5.1 Project summary	324
	5.5.2 Tree mapping to assess variability of fruit quality parameters from different canopy zones	324
	5.5.3 The effect of girdling on the improvement of internal fruit quality and re-allocation of carbohydrate reserves in grapefruit trees	327
5.6	Project: External appearance	334
	5.6.1 Project summary	334
	5.6.2 Degreening of lemons for in-transit cold sterilization	334
5.7	Project: Rind condition	338
	5.7.1 Project summary	338
	5.7.2 The effect of pre- and post-harvest treatments on the occurrence of chilling injury in lemons	338
	5.7.3 A physiological study to determine the causes of, and solutions to Rind Breakdown on citrus fruit	341
6.	PROGRAMME: CULTIVAR AND ROOTSTOCK DEVELOPMENT	344
6.1	Programme summary	344
6.2	Project: Evaluation of cultivars in the Cape region	345

**CRI GROUP ANNUAL RESEARCH REPORT 2000/1
TABLE OF CONTENTS**

	Page
6.2.1 Project summary	345
6.2.2 Evaluation of Satsuma mandarins in the Cape areas	345
6.2.3 Evaluation of Clementine mandarins in the Cape areas	354
6.2.4 Evaluation of Mandarin hybrids in the Cape areas	361
6.2.5 Evaluation of Navels in the Cape areas	368
6.2.6 Evaluation of Midseason oranges in the Cape areas	379
6.2.7 Evaluation of Valencia oranges in the Cape areas	388
6.2.8 Evaluation of Lemons in the Cape areas	392
6.3 Project: Evaluation of cultivars in the northern region	396
6.3.1 Evaluation of Clementine mandarins in Mpumalanga	396
6.3.2 Evaluation of late maturing Mandarins in the inland areas	398
6.3.3 Evaluation of navels in the intermediate and cool inland areas	400
6.3.4 Evaluation of Valencia selections in the inland areas	403
6.3.5 Evaluation of grapefruit types in Mpumalanga, KwaZulu Natal, Northern province, Swaziland and Mozambique	408
6.3.6 Evaluation of midseason oranges in the inland areas	410
6.3.7 Evaluation of lemons in the inland areas	411
6.3.8 Cultivar evaluation in Zimbabwe	412
6.3.9 Overseas evaluation of experimental consignments	415
6.4 Project: Evaluation of citrus rootstocks	416
6.4.1 The evaluation of Star Ruby grapefruit, Midnight, Du Roi and Delta Valencia on different rootstocks in the Northern Province	417
6.4.2 Evaluation of five grapefruit varieties on three rootstocks in Nkwalini Natal	420
6.4.3 The evaluation of Midseason oranges and Valencia type oranges at Riversbend Estates	425
6.4.4 Evaluation of grapefruit varieties and Delta Valencia oranges on imported rootstocks in Swaziland and Malelane respectively	426
6.4.5 Evaluation of Eureka and Lisbon Lemon on different rootstocks in an intermediate production area	428
6.4.6 The evaluation of five grapefruit varieties on different rootstocks in Northern Natal	430
6.4.7 Evaluation of Delta Valencia on 42 rootstocks on sandy soils in Marble Hall	432
6.4.8 Vaalharts Rootstock Trial	433
7. INTERNATIONAL VISITS	433
8. TECHNOLOGY TRANSFER	442
8.1 Presentations, talks and workshops	442
8.2 Pruning instruction video	447
9. PUBLICATIONS	447

**CRI GROUP ANNUAL RESEARCH REPORT 2001/2
TABLE OF CONTENTS**

		Page
1.	INTRODUCTION	1
2.	PROGRAMME: MARKET ACCESS TECHNICAL COORDINATION	7
3.	PROGRAMME: INTEGRATED PEST MANAGEMENT	10
3.1	Programme summary	10
3.2	Project: Biocontrol Disruption	11
3.2.1	Project summary	11
3.2.2	The beneficial effect of ants as predators in citrus orchards	12
3.2.3	Die beheer van miere in sitrus boorde	20
3.2.4	Development of a database of non-target effects of pesticides on beneficial arthropods	24
3.3	Project: Cosmetic Pests	31
3.3.1	Project summary	31
3.3.2	Identifying natural enemies of citrus thrips <i>Scirtothrips aurantii</i>	32
3.3.3	Identification of confusing <i>Scirtothrips</i> spp, on citrus in southern Africa	38
3.3.4	Mass releases of soil predators to control winter populations of citrus thrips, <i>Scirtothrips aurantii</i>	38
3.3.5	Chemical attractants for mass rapping of citrus thrips	42
3.3.6	The evaluation of Socusil for the control of snails in citrus orchards	44
3.3.7	Controlling rust mite (and bud mite) with various chemicals	48
3.4	Project: False Codling Moth	51
3.4.1	Project summary	51
3.4.2	Evaluation of the efficacy of a granulovirus (GV) for the control of false codling moth	53
3.4.3	Assessment and development of the augmentation technique for FCM control with the parasitoid <i>Trichogrammatoidea cryptophlebiae</i>	68
3.4.4	Improvement of the false codling moth mass rearing technique	77
3.4.5	Evaluasie van 'n kouedisinfestasiëbehandeling teen 0,50°C vir 22 dae om valskodlingmotarwes in voedingsmedium te dood	81
3.4.6	Evaluation of a genetically modified pathogen for control of false codling moth	87
3.4.7	Evaluation of the egg parasitoid, <i>Trichogrammatoidea cryptophlembiae</i> , against false codling moth on navel oranges	88
3.4.8	Evaluasie van die lok-en-vrekprodukt, Last Call, teen valskodlingmot op nawellemoene	91
3.4.9	Evaluasie van Quant vir die bestriding van valskodlingmot <i>Cryptophlebia leucotreta</i> , op sitrus deur paringsontwrigting	98
3.4.10	Evaluasie van Isomate vir die bestriding van valskodlingmot <i>Cryptophlebia laucoreta</i> , op sitrus deur paringsontwrigting	102
3.4.11	Identifikasie van lok- en afdryfmiddels vir valskodlingmot	106
3.4.12	Controlled Atmosphere: The effect of treatments with increased CO ₂ and O ₂ levels on fruit quality and their efficacy against False Codling Moth (FCM) in oranges	107
3.4.13	'n Ondersoek na lokmiddels wat veroorsaak dat VKM-wyfies na lemoene gelok word	109
3.4.14	<i>In vitro</i> rearing of <i>Trichogrammatoidea cryptophlebiae</i> egg parasitoids	110

**CRI GROUP ANNUAL RESEARCH REPORT 2001/2
TABLE OF CONTENTS**

	Page	
3.5	Project: Fruit Fly	112
3.5.1	Project summary	112
3.5.2	Fruit Fly rearing	112
3.5.3	Cold treatment of Natal fruit fly-infested apples	113
3.5.4	Cold treatment of Natal fruit fly-infested oranges	121
3.5.5	The effect of trap colour on the attractiveness of Questlure-baited Sensus traps to female fruit flies	128
3.5.6	Does the placement of the Questlure attractant in the Sensus trap affect its efficacy?	134
3.5.7	Methyl bromide disinfestations of fruit fly and false codling moth-infested avocados	135
3.6	Project: Production Pests	138
3.6.1	Project summary	138
3.6.2	A parasitism related infestation threshold for intervention against red scale in the Eastern Cape	139
3.6.3	The control of red scale using Actara	147
3.6.4	Die invloed van toedieningstyd op die doeltreffendheid van Confidor 350 SC teen rooidopluis (<i>Aonidiella aurantii</i>) op siffts	154
3.6.5	The efficacy of Citrocare against red scale	159
3.6.6	Chemical attractants for mass trapping of citrus psylla	161
3.6.7	IPM-compatible treatment options for citrus psylla	163
4.	PROGRAMME: DISEASE MANAGEMENT	166
4.1	Programme summary	166
4.2	Project: Graft Transmissible Diseases	166
4.2.1	Project summary	166
4.2.2	Glasshouse evaluation of CTV strains for cross protection of grapefruit and sweet oranges	168
4.2.3	Cross protection of Marsh and Star Ruby using ORE mild strain	169
4.2.4	Cross protection of Star Ruby grapefruit	170
4.2.5	The response of Star Ruby to different CTV isolates	171
4.2.6	Field evaluation of promising mild Isolates for Star Ruby in two climatic areas	174
4.2.7	The response of different red grapefruit cultivars to CTV	175
4.2.8	Identification of mild CTV strains and assessment of their cross-protection abilities by molecular techniques	176
4.2.9	Evaluation of CTV isolates in Clementine	180
4.2.10	Evaluation of CTV isolates in Valencia	183
4.2.11	Identification of single strain mild CTV for cross-protection of sweet orange and mandarin	184
4.2.12	Evaluation of CTV isolates in Navels	186
4.2.13	Evaluation of cross protecting traits of citrus tristeza virus (CTV) sub- isolates and the use of sub-isolates with specific characteristics to construct a superior isolate for the protection of grapefruit	187
4.2.14	Establish the effect of CTV isolates and citrus rootstocks on Huanglongbing (greening) infection of navel and Valencia trees	190
4.2.15	Separation of CTV stains, characterization and evaluation of for cross-protection against citrus tristeza virus	193

**CRI GROUP ANNUAL RESEARCH REPORT 2001/2
TABLE OF CONTENTS**

	Page
4.2.16 Identification of suitable citrus tristeza virus (CTV) isolates for pre-immunizing Midseason sweet oranges and Turkey Valencia	195
4.2.17 Indexing for citrus leaf blotch virus which is associated with budunion crease	197
4.2.18 Screening of rootstocks of Citrus Blight tolerance	198
4.3 Project: Fruit and Foliar diseases	200
4.3.1 Project summary	200
4.3.2 Investigation and identification of a new leaf spot disease occurring in the Onderberg and Swaziland regions	200
4.3.3 A study to determine the epidemiology and control of the fungus, <i>Phaeoramularia angolensis</i> , on citrus in Zimbabwe	201
4.3.4 Evaluation new fungicides and spray programmes for the control of a benzimidazole resistant citrus blackspot strain on Valencia oranges	204
4.3.5 The effect of plant defence activators (pda) DL-methionine GABA (4-aminobutyric acid), Ethepon and a phosphonate fungicide on the production of phytoalexin in citrus fruit	207
4.3.6 Evaluation of post-infection control of Citrus Blackspot with mancozeb, Ortiva, Octave and Benlate	210
4.3.7 Evaluation of warm water dip treatments for the elimination of endophyte <i>Guignardia citricarpa</i> in budwood and fruit infections	212
4.4 Project: Soil borne diseases	213
4.4.1 Project summary	213
4.4.2 Stimulation of egg hatching of <i>T. semipenetans</i> eggs	214
4.4.3 The effect of Captafol against <i>Phytophthora</i> root rot on citrus and Avocado nurseries	216
4.4.4 Evaluation of biological control agents against <i>Tylenchulus semipenetrans</i>	218
4.4.5 Assessment of citrus rootstocks for citrus nematode resistance	223
4.4.4 Potassium phosphonate	227
4.5 Project: Post-harvest pathology	234
4.5.1 Project summary	234
4.5.2 The screening of sanitizing agents, new chemicals (GRAS chemicals) and potential new fungicides, <i>in vitro</i> and <i>in vivo</i> against the post-harvest citrus pathogens	236
4.5.3 Screening of Penicillium spore samples for resistance to the post-harvest fungicide Imazalil	244
4.5.4 The evaluation of Argentinian citrus waxes	245
4.5.5 Biological control	251
4.5.6 Evaluation of potential yeast antagonist against <i>P. digitatum</i> (green mould) and <i>G. candidum</i> (sour rot)	252
5. PROGRAMME: CROP AND FRUIT QUALITY MANAGEMENT	254
5.1 Programme summary	254
5.2 Project: Fruit Set and Retention	255
5.2.1 Project summary	255

**CRI GROUP ANNUAL RESEARCH REPORT 2001/2
TABLE OF CONTENTS**

	Page
5.2.2 The effect of different treatments on the fruit set of Navels: The effect of leaf-applied nitrogen, Bioboost and gibberellic acid and girdling on the set of Palmer navel fruit	257
5.2.3 Physiological measurements of open hydroponic citrus trees	262
5.2.3.1 Comparison of stomatal conductance, sap flow, water potential and chlorophyll a fluorescence between daily daylight fertigated and conventionally irrigated citrus trees	262
5.2.3.2 Sap flow, stomatal conductance. xylem water and chlorophyll a fluorescence of daily daylight fertigation citrus trees during an artificial soil drying event	264
5.2.4 Physical and chemical aspects of the roof system and soil under daily drip fertigation	266
5.2.4.1 Drip fertigation: System effect on soil characteristics and root distribution	266
5.2.4.2 Drip fertigation: System effects on water movement and root: Distribution in sandy soils	268
5.3 Project: Fruit size	269
5.3.1 Project summary	269
5.3.2 The effect of Corasil E on the fruit size of grapefruit	271
5.3.3 Fruit size enhancement in Clementine and Valencia	276
5.3.3.1 The effect of hand thinning on fruit size and yield of 'Nules Clementine' mandarin (<i>Citrus reticulata</i> Blanco)	276
5.3.3.2 The effect of multiple dichlorprop sprays with different surfactants on fruit size and yield of 'Nules Clementine' mandarin (<i>Citrus reticulata</i> Blanco) and 'Valencia' orange [<i>Citrus sinensis</i> (L.) Osbeck]	277
5.3.4 Crop and fruit size prediction	278
5.3.5 Factors influencing fruit shape of lemons	286
5.3.5.1 Fruit shape of Eureka' lemon (<i>Citrus limon</i> L.): fruit growth, seed count, number of segments, rind thickness and positional differences in the tree canopy	286
5.3.5.2 The effect of scion and rootstock on the fruit shape of lemons	287
5.3.5.3 'Eureka' (<i>Citrus limon</i> L.) lemon fruit shape relative to different climatic regions in South Africa	289
5.3.5.4 Manipulation of 'Eureka' lemon fruit shape by means of chemical manipulation	290
5.4 Project: External Fruit Condition	292
5.4.1 Project summary	292
5.4.2 Effect of foliar application of N, K and P on fruit aspects	292
5.4.2.1 Effect of foliar nitrogen applications on fruit colour development, yield and fruit size of 'Miho wase' Satsuma (<i>Citrus Unshiu</i> Marc.)	292

**CRI GROUP ANNUAL RESEARCH REPORT 2001/2
TABLE OF CONTENTS**

	Page
5.4.2.2 Effect of mono-potassium phosphate (MKP), urea ammonium phosphate (UAP) and mono-ammonium phosphate (MAP) on yield, rind characteristics and internal quality of <i>Citrus</i> spp)	293
5.5 Project: Rind condition	294
5.5.1 Project summary	294
5.5.2 A physiological study to determine the causes of and solutions to Rind Breakdown on citrus fruit	294
5.5.3 Decay prevention, shelf life extension and avoidance of chilling injury through development of time-temperature protocols to address new export requirements	297
5.5.4 Storage potential of promising selections from the citrus breeding programme	302
6. PROGRAMME: CULTIVAR AND ROOTSTOCK DEVELOPMENT	306
6.1 Programme summary	306
6.2 Project: Evaluations	306
6.2.1 Project summary	306
6.2.2 Sub-Project: Evaluation of cultivars in the Cape region	309
6.2.2.1 Sub-project summary	309
6.2.2.2 Evaluation of Satsuma mandarins in the Cape areas	309
6.2.2.3 Evaluation of Clementine mandarins in the Cape areas	317
6.2.2.4 Evaluation of Mandarin hybrids in the Cape areas	319
6.2.2.5 Evaluation of Navels in the Cape areas	321
6.2.2.6 Evaluation of citrus rootstocks for the Eastern Cape	323
6.2.2.7 Evaluation of citrus scion cultivars and selections of navels, midseasons, Valencias, lemons, grapefruit, Mandarins and Clementines in the Eastern Cape	333
6.2.3 Sub-Project: Evaluation of cultivars in the Northern regions	342
6.2.3.1 Sub-Project summary	342
6.2.3.2 Evaluation of citrus rootstocks in the Northern production area	343
6.2.3.3 Evaluation of Clementine mandarins in Mpumalanga	346
6.2.3.4 Bostam kultivar evaluasie van Valencias, pomelos, mandaryns en suurlemoene vir die warmer noordelike binnelandse areas (Malelane, Mpumalanga)	348
6.2.3.5 Evaluation of late maturing mandarins in the inland areas	354
6.2.3.6 Evaluation of navels in the Intermediate and cool inland areas	355
6.2.3.7 Evaluation of Valencia selections in the inland areas	356
6.2.3.8 Evaluation of mid-season oranges in the inland areas	358
6.2.3.9 Evaluation of lemons in the inland areas	361
6.2.3.10 Cultivar evaluation in Zimbabwe	362
6.2.3.11 Overseas evaluation of experimental consignments	366
6.2.4 Sub-Project: Evaluation of citrus rootstocks	367
6.2.4.1 Sub-Project summary	367
6.2.4.2 The evaluation of Star Ruby grapefruit, Midnight and Delta Valencia on different rootstocks at Letaba Estates, Northern Province	368

**CRI GROUP ANNUAL RESEARCH REPORT 2001/2
TABLE OF CONTENTS**

	Page
6.2.4.3 Evaluation of Valencia and Grapefruit varieties on new imported rootstocks in the Malelane and Swaziland areas	370
6.2.4.4 Delta Valencia rootstock trial at Moosriver Estates, Groblersdal. Mpumalanga	371
6.3 Project: Breeding	372
6.3.1 Project summary	372
6.3.2 Development of improved cultivars using conventional breeding methods	373
6.3.3 Development of improved citrus scion cultivars via conventional breeding for the North	377
6.3.4 Development of seedless citrus cultivars using irradiation	381
6.3.5 Breed well adapted disease resistant rootstocks for the Cape	383
6.3.6 Development of seedless citrus cultivars using irradiation — Malelane	390
6.3.7 <i>In vitro</i> embryo rescue for the development of new seedless mandarin cultivars	394
6.3.8 Development of improved citrus cultivars using <i>in vitro</i> ovule rescue	396
6.3.9 Using biotechnology techniques in the development of new and/or improved citrus cultivars tolerant to citrus greening disease — identification and recovery of potentially greening-resistant citrus plants using fruit sector chimeras	397
7. INTERNATIONAL VISITS	398
7.1 S.P. van Vuuren - Participation in the XVth conference of the International Organization of Citrus Virologists in Paphos, Cyprus, 11-16 November 2001	398
8. TECHNOLOGY TRANSFER	402
8.1 Summary	402
8.2 Grower talks and presentations	402
8.3 Publications	404
8.4 The Cutting Edge	404
8.5 Electronic media	404

**CRI GROUP ANNUAL RESEARCH REPORT 2002/3
TABLE OF CONTENTS**

		Page
1	INTRODUCTION	1
2	PROGRAMME: MARKET ACCESS TECHNICAL CO-ORDINATION	3
	2.1 Programme summary	3
	2.2 Market Access Extension	8
	2.2.1 <i>Phaeoramularia angolensis</i> (PA) Mozambique	8
	2.2.2 CBS surveys in the Limpopo, Northern and Eastern Cape Provinces	9
3	PROGRAMME: INTEGRATED PEST MANAGEMENT	10
	3.1 Programme summary	10
	3.2 Project: Biocontrol Disruption	11
	3.2.1 Project summary	11
	3.2.2 Develop a database of non-target effects of pesticides on beneficial arthropods	11
	3.2.3 Reducing the non-target of citrus thrips sprays on orange trees by applying at low pressure and without wind	17
	3.3 Cosmetic pests	18
	3.3.1 Project summary	18
	3.3.2 Identifying natural enemies of citrus thrips <i>Scirtothrips aurantii</i>	20
	3.3.3 Mass releases of soil predators to control winter populations citrus thrips, <i>Scirtothrips aurantii</i>	21
	3.3.4 Evaluating systemic insecticides in drip lines for the control of citrus thrips (Eastern Cape)	24
	3.3.5 Evaluating systemic insecticides in drip lines for the control of citrus thrips (Swaziland)	27
	3.3.6 Identification of tydeid predatory mites on citrus	29
	3.3.7 Determining the developmental threshold for citrus thrips in order to develop a prediction model	31
	3.4 Project: false Codling Moth	31
	3.4.1 Project summary	31
	3.4.2 Evaluation of the efficacy of a granulovirus (GV) for the control of false codling moth	33
	3.4.3 Assessment and development of the augmentation technique for FCM control with the parasitoid <i>Trichogrammatoida cryptophlebiae</i>	51
	3.4.4 Efficacy of a cold treatment at +0.5°C for 22 days to kill false codling moth larvae post harvest	57
	3.4.5 Comparing the relative cold tolerance of false codling moth larvae in artificial diet and oranges	61
	3.4.6 Evaluation of a genetically modified pathogen for control of false codling moth	63
	3.4.7 Evaluation of the attract&kill product Last Call for the commercial control of false codling moth	64
	3.4.8 Evaluation of the mating disruptor Isomate for the commercial control of false codling moth on navel orange trees	68
	3.4.9 Evaluation of Klartan EW (240 g/l) (tau-fluvalinate) against false codling moth on navel oranges	74
	3.4.10 Development of semiochemical odorants for the attraction and repellence of false codling moth in citrus	76

**CRI GROUP ANNUAL RESEARCH REPORT 2002/3
TABLE OF CONTENTS**

	Page
3.4.11 Radiation Biology and Inherited Sterility in false codling moth	100
3.4.12 Acceptability and suitability of eggs of false codling moth from irradiated parents to parasitism by <i>Trichogrammatoidea cryptophlebiae</i>	111
3.4.13 Development of a technique for mass rearing of sterile false codling moth for SIT purposes	119
3.4.14 Understanding and improving biological control of false codling moth larvae	126
3.4.15 Evaluation of Triflumuron 480 SC (triflumuron) against false codling moth on navel oranges	134
3.4.16 Evaluation of the entomopathogenic fungus <i>Beauveria bassiana</i> against false codling moth	135
3.5 Fruit Fly	138
3.5.1 Project summary	138
3.6 Project: Mealybug and other phytosanitary pests	138
3.6.1 Project summary	138
3.6.2 Description of adults and immature stages of some mealybugs occurring in the Western Cape	139
3.6.3 Evaluation of the host range of <i>Coccidoxenoides peregrinus</i> and the species composition of parasitoids associated with some mealybug species occurring in the Western Cape	139
3.6.4 Investigating biocontrol agents of mealybug species other than citrus mealybug	149
3.7 Project: Production Pests	149
3.7.1 Project summary	149
3.7.2 A parasitism related infestation threshold for intervention against red scale in the Eastern Cape	150
3.7.3 The evaluation of a new medium/heavy grade mineral oil (SWE1) as a scalcicide on citrus	162
3.7.4 Investigating control options for soft green scale	167
3.7.5 IPM-compatible treatment options for citrus psylla, <i>Trioza erytrae</i>	168
4 PROGRAMME: DISEASE MANAGEMENT	169
4.1 Programme summary	169
4.2 Project: Graft Transmissible Diseases	169
4.2.1 Project summary	169
4.2.2 <i>Citrus tristeza</i> virus differentiation based on 5'-terminal genomic region	172
4.2.3 Rapid screening of <i>Citrus tristeza</i> virus infection at low cost	176
4.2.4 Glasshouse evaluation of <i>Citrus tristeza</i> virus isolates for cross-protection of grapefruit and sweet oranges	178
4.2.5 Cross protection of Marsh and Star Ruby using the ORE mild isolate	183
4.2.6 Cross protection of Star Ruby grapefruit	184
4.2.7 Cross protection of Marsh and Star Ruby grapefruit using Beltsville sub-isolates of Nartia mild strain	186

**CRI GROUP ANNUAL RESEARCH REPORT 2002/3
TABLE OF CONTENTS**

	Page
4.2.8 The response of Star Ruby to different <i>Citrus tristeza</i> virus isolates	187
4.2.9 Field evaluation of promising mild isolates for Star Ruby in two climatic areas	191
4.2.10 The response of different red grapefruit cultivars to <i>Citrus tristeza</i> virus	192
4.2.11 Evaluation of cross protecting traits of <i>Citrus tristeza</i> virus sub-isolates and the use of sub-isolates with specific characteristics to construct a superior isolate for the protection of grapefruit	194
4.2.12 Evaluation of <i>Citrus tristeza virus</i> isolates in Clementine	203
4.2.13 Evaluation of <i>Citrus tristeza virus</i> isolates in Valencia	209
4.2.14 Evaluation of <i>Citrus tristeza</i> virus isolates in navel	208
4.2.15 Identification of suitable <i>Citrus tristeza</i> virus isolates for pre-immunising Midseason sweet oranges and Turkey Valencia	209
4.2.16 Indexing for citrus leaf blotch virus which is associated with bud-union crease	211
4.2.17 Greening survey in Swellendam	213
4.2.18 Establish the effect of CTV isolates and citrus rootstocks on Huanglongbing (greening) infection of navel and Valencia trees	215
4.2.19 Presence of <i>Liberibacter</i> , the causal agent of Huanglongbing, in field psylla	218
4.2.20 Separation of GXI strains, characterisation and evaluation for cross-protection against Huanglongbing and <i>Citrus tristeza</i> virus	222
4.2.21 Screening of rootstocks for Citrus Blight tolerance	227
 4.3 Project: Fruit and Foliar Diseases	 231
4.3.1 Project summary	231
4.3.2 Evaluation of various fungicidal spray programmes for the control of <i>Alternaria</i> brown spot on Novas	231
4.3.3 Prolonged effect of strobilurin fungicides sprayed for CBS control on the control of <i>Phytophthora</i> brown rot of citrus	234
4.3.4 <i>Pseudocercospora angolensis</i> in Zimbabwe	235
 4.4 Project: Soil Borne Diseases	 236
4.4.1 Project summary	236
4.4.2 Assessment of citrus rootstocks for citrus nematode resistance	238
4.4.3 Evaluation of fifteen different rootstocks in an interplant situation against the citrus nematode, <i>Tylenchulus semipenetrans</i> and <i>Phytophthora</i>	243
4.4.4 Evaluation of biological control agents against <i>Tylenchulus semipenetrans</i>	246
4.4.5 The effect of fulvic acid, humic acid and cuprous oxide on the efficacy of the potassium phosphonate compound, Phytex® against <i>Phytophthora</i> brown rot in citrus	248
4.4.6 To determine the effect of a phosphonate soil drench to control <i>Phytophthora nicotianae</i> in citrus nurseries	252
4.4.7 Rootstock evaluation against <i>Hemicycliophora</i> in the Gamtoos River Valley	254
4.4.8 Stimulation of egg hatching of <i>Tylenchulus semipenetrans</i> eggs	256
4.4.9 Evaluation of Cadusafos on citrus trees in nematode infested replant soils	262

**CRI GROUP ANNUAL RESEARCH REPORT 2002/3
TABLE OF CONTENTS**

	Page
4.4.10 Evaluation of Crop Guard against the citrus nematode, <i>Tylenchulus semipenetrans</i>	262
4.5 Project: Citrus Black spot (CBS)	262
4.5.1 Project summary	262
4.5.2 A rapid identification technique to distinguish between <i>Guignardia citricarpa</i> and <i>Guignardia mangiferae</i> on citrus	265
4.5.3 Inoculation of leaves with <i>Guignardia</i> spp.	270
4.5.4 Colonisation of dead leaves by infected fruit in three climatic zones. Set up growth chamber experiments	271
4.5.5 Germination of pycnidiospores and toxicity of chemicals and phenylpropanoids	272
4.5.6 Viability of <i>Phyllosticta citricarpa</i> pycnidiospores in cold storage	277
4.5.7 Development of selective medium in isolation of <i>Guignardia</i> spp.	278
4.5.8 Epiphytic and endophytic occurrence of <i>Guignardia citricarpa</i> (Exp. PPL 11)	280
4.5.9 Epiphytic and endophytic occurrence of <i>Guignardia citricarpa</i> (Exp. 11B)	283
4.5.10 Seasonal availability of ascospore inoculum of <i>Guignardia citricarpa</i>	284
4.5.11 Correlation between ascospore inoculum and infection potential in an orchard	285
4.5.12 Breaking the life cycle of <i>Guignardia citricarpa</i> : Removal and confinement of leaf litter	287
4.5.13 Breaking the life cycle of <i>Guignardia citricarpa</i> : Accelerated decomposition of leaf litter	289
4.5.14 Long term effect of different chemical spray programs on inoculum potential in a citrus black spot infected orchard	290
4.5.15 Evaluation of warm water dip treatments for the elimination of endophytic <i>Guignardia citricarpa</i> in budwood	291
4.5.16 Field evaluation of fungicides for the control of a benzimidazole resistant citrus black spot strain	293
4.6 Project: Post-Harvest Pathology	298
4.6.1 Project summary	298
4.6.2 The screening of sanitizing agents, new chemicals and potential new fungicides <i>in vitro</i> and <i>in vivo</i> against the post-harvest citrus pathogens	299
4.6.2.1 The evaluation of Sporekitl in a hot water fungicide bath in combination with the post-harvest fungicides to combat decay as well as a sanitizing agent to keep such a system clean	301
4.6.2.2 Determination of the ability of Sporekill to prevent fungal infections during the washing process in a citrus packhouse dumptank and to evaluate the effect of Sporekill on the Imazalil resistant <i>Penicillium</i> spore populations in such a system	302
4.6.2.3 The <i>in vivo</i> screening of three generic formulations of the post-harvest fungicide Imazalil	304
4.6.2.4 The <i>in vivo</i> screening of three generic formulations of the post-harvest fungicide, Guazatine	305
4.6.2.5 The <i>in vitro</i> screening of the two sanitizing agents, Bacsan and Supergel, against the post-harvest fungal spores of citrus green mould, <i>Penicillium digitatum</i> , to determine the efficacy of the compounds in killing the spores	308

**CRI GROUP ANNUAL RESEARCH REPORT 2002/3
TABLE OF CONTENTS**

	Page
4.6.2.6 The <i>in vitro</i> and <i>in vivo</i> screening of the sanitizing agent, Neutral Anolyte from Radical Waters, against the post-harvest diseases of citrus green mould, <i>Penicillium digitatum</i> , and sour rot, <i>Geotrichum candidum</i> , to determine the efficacy of the product as a sanitizing agent and to determine if the product has any fungicidal properties	310
4.6.2.7 The <i>in vitro</i> and <i>in vivo</i> screening of the quaternary ammonium compound "Quattro Kill" from Hyper Agrochem against the post-harvest diseases of citrus green mould, <i>Penicillium digitatum</i> , and sour rot, <i>Geotrichum candidum</i>	314
4.6.2.8 The <i>in vivo</i> evaluation of the QAC formulation "Quattro Kill" from Hyper Agrochem against the post-harvest citrus pathogens, <i>Penicillium digitatum</i> (green mould) and <i>Geotrichum candidum</i> (sour rot), to determine whether the product has any fungicidal properties	315
4.6.3 Evaluation of citrus waxes	317
4.6.3.1 Pilot trial on Spanish waxes from Technidex	318
4.6.3.2 Repeat of cold sterilization protocol on Argentinian natural wax, Qualifresh	319
4.6.4 Evaluation of GRAS (Generally Regarded as Safe) chemicals against Citrus Black Spot (CBS)	320
4.6.5 Evaluation of an Israeli product, Canon PH (a phosphonate) for post-harvest control of <i>Phytophthora</i> brown rot on citrus	321
4.6.6 Screening of <i>Penicillium</i> spore samples for resistance to the post-harvest fungicide Imazalil	322
4.6.7 Buccaneer Chlorine Generators	323
4.6.8 Evaluation of a fumigation chamber system for the application of alternative post-harvest disease control gas such as chlorine dioxide	323
5 PROGRAMME: CROP LOAD AND FRUIT QUALITY MANAGEMENT	327
5.1 Programme summary	327
5.2 Project: Crop Load Management	327
5.2.1 Project summary	327
5.2.2 Effects fertigation frequency and irrigation system on performance of Midnight Valencia oranges in a cool subtropical area of SA	328
5.2.3 Evaluation of the Open Hydroponic System (OHS) approach in SA	346
5.2.4 Physiological and horticultural aspects related to OHS	354
5.3 Project: Fruit Quality Enhancement	359
5.3.1 Project summary	359
5.3.2 Manipulation of soluble solids concentration with EcoLyst™	362
5.3.3 Reduction of acidity of high acid citrus cultivars using alternatives to calcium arsenate	366
5.3.4 Effect of Thiovit® and other mineral nutrients on rind colour of Miho Wase Satsuma and Nules Clementine mandarins and Navelina and Palmer navel oranges	369
5.3.5 Initial trials on the effect of prohexadione calcium on rind colour development of <i>Citrus</i>	374

**CRI GROUP ANNUAL RESEARCH REPORT 2002/3
TABLE OF CONTENTS**

		Page
5.3.6	The effect of cold shock on rind colour development of <i>Citrus</i>	382
5.3.7	Fruit size enhancement of Valencia Late orange with dichlorprop (2,4-DP) and alternative adjuvants	386
5.3.8	The use of 2,4-D dichlorphenoxy propionic acid to improve fruit size of Marsh grapefruit	389
5.4	Project: Rind Condition	395
5.4.1	Project summary	395
5.4.2	Methods to prevent chilling injury on grapefruit	399
5.4.3	Methods to prevent chilling injury on lemons	402
5.4.4	The effect of Ozone on the shelf life of citrus fruit	408
5.4.5	Establishing the causes of rind pitting in Onderberg citrus and the development of a control strategy for the prevention of the disorder	409
6	PROGRAMME: CULTIVAR AND ROOTSTOCK DEVELOPMENT	412
6.1	Programme summary	412
6.2	Project: Evaluations	412
6.2.1	Project summary	412
6.2.2	Sub-Project Evaluation of cultivars in the Cape region	413
6.2.2.1	Sub-Project introduction	413
6.2.2.2	Evaluation of Clementine mandarins in the Cape areas	414
6.2.2.3	Evaluation of Genoa Lemon on various rootstocks in Citrusdal	422
6.2.2.4	Evaluation of Mandarin hybrids in the Cape areas	424
6.2.2.5	Evaluation of Satsuma mandarins in the Cape areas	434
6.2.2.6	Evaluation of Midseason oranges in the Cape areas	437
6.2.2.7	Evaluation of Valencia oranges in the Cape areas	442
6.2.2.8	Evaluation of navels in the Cape areas	445
6.2.2.9	Evaluation of citrus rootstocks for the Eastern Cape	452
6.2.2.10	Evaluation of citrus scion cultivars and selections/navels, midseasons, Valencias, lemons, pomelos and mandarins in the Eastern Cape	464
6.2.3	Project: Evaluation of cultivars in the Northern region	508
6.2.3.1	Sub-Project introduction	508
6.2.3.2	Evaluation of Clementine mandarins in Mpumalanga	508
6.2.3.3	Evaluation of late maturing mandarins in the inland areas	510
6.2.3.4	Evaluation of navels in the intermediate and cool inland areas	510
6.2.3.5	Evaluation of Valencia selections in the inland areas	512
6.2.3.6	Evaluation of midseason oranges in the inland areas	515
6.2.3.7	Evaluation of lemons in the inland areas	518
6.2.3.8	Overseas evaluation of experimental consignments	519
6.2.3.9	Evaluation of citrus cultivars and selections: Valencias, lemons, grapefruit and mandarins in the hot northern inland areas (Malelane, Mpumalanga)	520
6.2.4	Sub-Project: Evaluation of citrus rootstocks	527

**CRI GROUP ANNUAL RESEARCH REPORT 2002/3
TABLE OF CONTENTS**

		Page
	6.2.4.1 Sub-Project introduction	527
	6.2.4.2 The evaluation of Star Ruby grapefruit, Midnight and Delta Valencia on different rootstocks at Letaba Estates. Limpopo Province	528
	6.2.4.3 Evaluation of Valencia and Grapefruit varieties on new imported rootstocks in the Malelane and Swaziland areas	533
	6.2.4.4 Delta Valencia rootstock trial at Moosrivier Estates, Groblersdal, Mpumalanga	534
6.3	Project: Breeding	537
	6.3.1 Project summary	537
	6.3.2 Breed well adapted disease resistant rootstocks for the Cape	538
	6.3.3 Development of seedless citrus cultivars using irradiation	552
	6.3.4 Development of improved citrus cultivars using conventional breeding methods	557
	6.3.5 <i>In vitro</i> embryo rescue for the development of new seedless mandarin cultivars	566
	6.3.6 Development of improved citrus cultivars using <i>in vitro</i> ovule rescue	570
	6.3.7 Using biotechnology techniques in the development of new and/or improved citrus cultivars tolerant to citrus greening disease — identification and recovery of potentially greening-resistant citrus plants using fruit sector chimeras	572
6.4	The Citrus Improvement Programme	573
	6.4.1 The Citrus Foundation Block (CFB)	573
	6.4.2 Nursery accreditation and tree certification	577
7	INTERNATIONAL VISITS	578
8	TECHNOLOGY TRANSFER	578
	8.1 Summary	578
	8.2 Extension	579
	8.2.1 Summary	579
	8.3 Publications in 2002	583
	8.4 Grower talks and presentations	583

**CRI GROUP ANNUAL RESEARCH REPORT 2003/4
TABLE OF CONTENTS**

		Page
1	INTRODUCTION	1
2	PROGRAMME: MARKET ACCESS TECHNICAL CO-ORDINATION	2
2.1	Programme summary	2
2.2	Mapping the potential distribution of Citrus Black Spot caused by <i>Guignardia citricarpa</i> Kiely	11
2.3	Proposed rejection level for FCM infestations intercepted during pre-shipping inspection of citrus for export from SA to USA	12
2.4	Molecular identification technique for mealybugs on citrus exported from South Africa to South Korea	16
2.5	Survey of potential phytosanitary pests and diseases in Mozambique and Zimbabwe	40
3	PROGRAMME: INTEGRATED PEST MANAGEMENT	48
3.1	Programme summary	48
3.2	Project: Biocontrol disruption	48
	3.2.1 Project summary	48
	3.2.2 Develop a database of non-target effects of pesticides on beneficial arthropods	49
	3.2.3 Efficacy and safety of new ant-band deterrents	55
3.3	Project: Cosmetic Pests	56
	3.3.1 Project summary	56
	3.3.2 Mass releases of soil predators to control winter populations of citrus thrips, <i>Scirtothrips aurantii</i>	57
	3.3.3 Determining the developmental thresholds for citrus thrips	61
	3.3.4 OP alternatives for citrus thrips compatible with biointensive IPM or organic production	62
	3.3.5 Natural enemies of citrus thrips in the Orange River area	66
	3.3.6 Identification of tydeid predatory mites on citrus	69
	3.3.7 The status and control of new moth pests on lemons	73
3.4	Project: False Codling Moth	76
	3.4.1 Project summary	76
	3.4.2 Evaluation of the efficacy of a granulovirus (GV) for the control of false codling moth (Exp. 169A)	77
	3.4.3 Evaluation of the efficacy of a granulovirus (GV) for the control of false codling moth (Exp. 169B)	92
	3.4.4 Development of the Lorelei II pheromone dispenser for commercial usage in false codling moth traps	94
	3.4.5 Evaluation of the mating disruption Isomate for the commercial control of false codling moth in navel trees	96
	3.4.6 Development of semiochemical odorants for the attraction and repellence of false codling moth in citrus	100
	3.4.7 Evaluation of Electrostatic Powder Technology for the control of false codling moth	101
	3.4.8 Control of false codling moth with Sterile Insect Releases	101
	3.4.9 Development of a technique for mass rearing of sterile FCM for SIT purposes	116
	3.4.10 Understanding and improving biological control of false codling moth larvae	123
	3.4.11 Ovipositional preferences and relative susceptibility amongst navel orange varieties by FCM	125

**CRI GROUP ANNUAL RESEARCH REPORT 2003/4
TABLE OF CONTENTS**

	Page
3.4.12 Treatment of false codling moth larvae with gamma irradiation for the disinfestation of packed citrus fruit	131
3.4.13 Evaluation of Triflumuron 480 SC for the control of false codling moth	134
3.4.14 The spatial and temporal population dynamics of the false codling moth and its biocontrol agents' relative to an agricultural landscape mosaic	136
3.4.15 Genetic differentiation in some South African populations of the false codling moth, <i>Cryptophlebia leucotreta</i> (Meyrick) (Lepidoptera: Tortricidae), inferred from molecular markers	139
3.4.16 Evaluation of a genetically modified pathogen for control of False codling moth	146
3.5 Project: Fruit Fly	149
3.5.1 Project summary	149
3.5.2 Fruit Fly rearing	150
3.5.3 Area-Wide control of Fruit Fly	151
3.5.4 Cold disinfestation treatment for Medfly-infested Clementines	169
3.5.5 Cold disinfestations of Medfly-infested Barlinka grapes	176
3.5.6 Disinfestation treatments for citrus pests of phytosanitary significance	186
3.5.7 Marula fruit fly. Is it a threat to the citrus industry?	190
3.5.8 Spinosad GF 120 cage tests	192
3.5.9 Spinosad GF 120 field trial	196
3.5.10 Attractant combinations for Sensus trap fruit fly monitoring	203
3.5.11 Organic M3 bait station	209
3.5.12 M3 Product development	211
3.5.13 Maputo Corridor Survey of Fruit Flies	212
3.6 Project: Mealybug and other phytosanitary pests	213
3.6.1 Project summary	213
3.6.2 Descriptions of the adults and immature females of six South African mealybug species (Hemiptera: Pseudococcidae) found on citrus	213
3.6.3 Evaluation of the host range of <i>Coccidoxenoides peregrinus</i> and the species composition of parasitoids associated with some mealybug species occurring in the Western Cape	215
3.6.4 Investigating biocontrol agents of mealybug species other than citrus mealybug	217
3.6.5 Experiment 717: Research on the grain chinch bug, <i>Macchiademus diplopterus</i> , as a phytosanitary citrus pest	220
3.6.6 The development of gamma irradiation for the disinfestation of packed, mealybug-infested citrus fruit	220
3.7 Project: Production Pests	221
3.7.1 Project summary	221
3.7.2 Investigating control options for Soft Green Scale	222
4 PROGRAMME: DISEASE MANAGEMENT	232
4.1 Programme summary	232
4.2 Project: Graft Transmissible Diseases	232
4.2.1 Project summary	232
4.2.2 Glasshouse evaluation of <i>Citrus tristeza virus</i> isolates for crossprotection of grapefruit and sweet oranges	236
4.2.3 Cross protection of Star Ruby grapefruit	238

**CRI GROUP ANNUAL RESEARCH REPORT 2003/4
TABLE OF CONTENTS**

	Page	
4.2.4	Cross-protection of Marsh and Star Ruby grapefruit using Beltsville sub-isolates of Nartia mild strain	239
4.2.5	The response of Star Ruby to different <i>Citrus tristeza virus</i> isolates	240
4.2.6	Field evaluation of promising mild isolates for Star Ruby in two climatic areas	243
4.2.7	The response of different red grapefruit cultivars of <i>Citrus tristeza virus</i>	245
4.2.8	Evaluation of cross-protecting traits of <i>Citrus tristeza virus</i> sub-isolates and the use of sub-isolates with specific characteristics to construct a superior isolate for the protection of grapefruit	246
4.2.9	Evaluation of <i>Citrus tristeza virus</i> isolates in Clementines	249
4.2.10	Evaluation of <i>Citrus tristeza virus</i> isolates in Valencia	254
4.2.11	Evaluation of <i>Citrus tristeza virus</i> isolates in navel oranges	256
4.2.12	Identification of suitable <i>Citrus tristeza virus</i> isolates for pre-immunizing Midseason sweet oranges and Turkey Valencia	258
4.2.13	Indexing for citrus leaf blotch virus which is associated with bud-union crease	260
4.2.14	Screening of rootstocks for Citrus Blight tolerance	261
4.3	Project: Fruit and Foliar diseases	265
4.3.1	Project summary	265
4.3.2	Investigation and identification of unknown leaf and fruit symptoms on Palmer navels, Midnight Valencias and Delta Valencias at Naboomspruit	265
4.3.3	Mancozeb residue analysis of spray programmes used for citrus black spot control	271
4.3.4	Investigation into die-back of Clementines in the Eastern Cape	273
4.3.5	Etiology, epidemiology and prediction modelling of <i>Alternaria</i> brown spot of citrus in South Africa	275
4.4	Project: Soilborne diseases	275
4.4.1	Project summary	275
4.4.2	Assessment of citrus rootstocks for citrus nematode resistance	278
4.4.3	Stimulation of egg hatching of <i>Tylenchulus semipenetrans</i> eggs	284
4.4.4	Evaluation of biological control agents against <i>Tylenchulus semipenetrans</i>	291
4.4.5	Rootstock evaluation against <i>Hemicycliphora</i> in the Gamtoos River Valley	294
4.4.6	Determining the effect of a biological control product and a phosphonate in combination with a chemical which induces systemic acquired resistance in <i>Phytophthora</i> -infected nursery seedlings	296
4.4.7	Evaluation of cadusafos on citrus trees in nematode-infested soils	300
4.4.8	Evaluation of Crop Guard against the citrus nematode, <i>Tylenchulus semipenetrans</i>	300
4.4.9	Resistance of citrus rootstocks to root pathogens	301
4.5	Project: CitrusBlack Spot (CBS)	303
4.5.1	Project summary	303
4.5.2	Inoculation of citrus leaves with <i>Guignardia citricarpa</i>	303
4.5.3	Colonisation of dead decaying leaves with <i>Guignardia citricarpa</i>	312
4.5.4	<i>In vitro</i> germination and infection conditions of <i>Guignardia</i> spp.	319

**CRI GROUP ANNUAL RESEARCH REPORT 2003/4
TABLE OF CONTENTS**

	Page	
4.5.5	Development of semi-selective media for direct isolation of <i>Guignardia</i> spp. from plant material	323
4.5.6	Epiphytic and endophytic occurrence of <i>Guignardia citricarpa</i> on twigs	325
4.5.7	Seasonal availability of ascospore inoculum of <i>Guignardia citricarpa</i>	329
4.5.8	Breaking of life cycle of <i>Guignardia citricarpa</i> : Removal or confinement of inoculum	330
4.5.9	Field evaluation of chlorothalonil of Syngenta for the control of citrus black spot	332
4.5.10	Positioning of a single benomyl application in a strobilurin spray programme	334
4.5.11	Evaluation of copper fungicides as replacements for mancozeb in a strobilurin spray programme for the control of CBS	335
4.5.12	Evaluation of a gas-operated incinerator for the elimination of dead citrus leaves on the orchard floor	340
4.5.13	Correlation between ascospore inoculum and infection potential in an orchard	341
4.5.14	Epiphytic and endophytic occurrence of <i>Guignardia citricarpa</i>	343
4.5.15	Determine the curative action of different chemicals regarding citrus black spot infection	345
4.5.16	Long term effect of different chemical spray programmes on inoculum potential in a citrus black spot infected orchard	345
4.5.17	Determine the incidence and importance of <i>Guignardia citricarpa</i> on nursery trees	347
4.6	Project: Post-harvest Pathology	348
4.6.1	Project summary	348
4.6.2	2,4-D Efficacy trials and Residue Analyses to establish compliance with EU MRL of 1.0 mg/kg	351
4.6.3	The screening of sanitizing agents, new chemicals and potential new fungicides <i>in vitro</i> and <i>in vivo</i> against the post-harvest citrus pathogens	354
4.6.3.1	The screening of a product, Citri A and Citri B as possible alternatives to 2,4-D (Deccomone)	354
4.6.3.2	The <i>in vivo</i> screening of three generic formulations of the post-harvest fungicide imazalil	355
4.6.3.3	The <i>in vivo</i> screening of a genetic formulation of the post-harvest fungicide, guazatine	356
4.6.3.4	The <i>in vivo</i> evaluation of two new generic formulations of the already registered post-harvest fungicide UltraCure (guazatine)	357
4.6.3.5	The screening of two new formulations of the quaternary ammonium compound Quattro Kill as well as F10 and Terminator against post-harvest fungal spores causing disease of citrus fruit	359
4.6.4	The evaluation of three Carnauba (Natural) citrus waxes incorporating post-harvest fungicides for efficacy against postharvest infections	366
4.6.5	The spread of <i>Phytophthora</i> brown rot infection in stored cartons of healthy citrus fruit	367
4.6.6	The <i>in vivo</i> evaluation of the post-harvest fungicide, Prochloraz, from AgChem Africa, against the <i>Penicillium</i> organisms for the purpose of registration in adip treatment	369
4.6.7	Screening of <i>Penicillium</i> spore samples for resistance to the post-harvest fungicide imazalil	370
4.6.8	Evaluation of prochloraz for the control of CBS	371
4.6.9	Evaluation of a fumigation chamber system for the application of alternative post-harvest disease control gas such as chlorine dioxide	372

**CRI GROUP ANNUAL RESEARCH REPORT 2003/4
TABLE OF CONTENTS**

		Page
5	PROGRAMME: CROP LOAD AND FRUIT QUALITY MANAGEMENT	375
5.1	Programme summary	375
5.2	Project: Fruit Quality Enhancement	375
	5.2.1 Project summary	375
	5.2.2 Reduction of acidity of high acid citrus cultivars using alternatives to calcium arsenate	377
	5.2.3 Lemon fruit shape	379
	5.2.4 Role of auxins in rind colour enhancement	380
	5.2.5 Physiological aspects of rind colour development	383
	5.2.6 Post-harvest manipulation of rind colour	384
	5.2.7 Effect of tree nutrition and post-harvest treatments on concentration of the most important colour imparting carotenoids in physiologically mature citrus fruit	394
5.3	Project: CropLoad Management	394
	5.3.1 Project summary	394
	5.3.2 Ecophysiological responses and changes in sugar accumulation due to altered plant water relations of <i>Citrus</i> trees	395
	5.3.3 Physiological responses of <i>Citrus</i> trees to altered plant water relations	402
5.4	Project: Rind condition	407
	5.4.1 Project summary	407
	5.4.2 Rind breakdown of 'Nules Clementine' mandarins	408
	5.4.3 Controlled atmosphere storage trial	413
	5.4.4 Testing agrochemicals for their effectiveness in calyx retention of citrus fruit when applied as a post-harvest treatment	417
	5.4.5 Role of rind mineral content in post-harvest rind pitting and stem end rind breakdown of citrus fruit	425
	5.4.6 Evaluation of methods aimed at reducing chilling injury in grapefruit	428
	5.4.7 Factors influencing Rind Breakdown in citrus fruit	431
6	PROGRAMME: CULTIVAR AND ROOTSTOCK DEVELOPMENT	470
6.1	Programme summary	470
6.2	Project: Evaluations	470
	6.2.1 Project summary	470
	6.2.2 Sub-Project: Cultivar and rootstock evaluation in the Cape region	472
	6.2.2.1 Sub-Project summary	472
	6.2.2.2 Evaluation of Satsuma mandarins in the Cape areas	472
	6.2.2.3 Evaluation of Clementine mandarins in the Cape areas	476
	6.2.2.4 Evaluation of Mandarin hybrids in the Cape areas	484
	6.2.2.5 Evaluation of navels in the Cape areas	491
	6.2.2.6 Evaluation of Midseason oranges in the Cape areas	496
	6.2.2.7 Evaluation of Valencia oranges in the Cape areas	500
	6.2.2.8 Evaluation of Genoa Lemon on various rootstocks in Citrusdal	503
	6.2.2.9 Establishment of new and evaluation of existing cultivars at Lancewood, Knysna area	506
	6.2.2.10 Evaluation of Turkey Valencias on different rootstocks	510
	6.2.2.11 Establishment of new cultivar trials	511
	6.2.2.12 Navel Rootstock trial	513

**CRI GROUP ANNUAL RESEARCH REPORT 2003/4
TABLE OF CONTENTS**

		Page
6.2.3	Sub-Project: Cultivar evaluation in the Northern and inland region	514
6.2.3.1	Sub-Project summary	514
6.2.3.2	Evaluation of Clementine mandarins in Mpumalanga	515
6.2.3.3	Evaluation of late maturing mandarins in the inland areas	517
6.2.3.4	Evaluation of navels in the intermediate and cool inland areas	519
6.2.3.5	Evaluation of Valencia selections in the inland areas	522
6.2.3.6	Evaluation of midseason oranges in the inland areas	528
6.2.3.7	Evaluation of lemons in the inland areas	532
6.2.4	Sub-Project: Rootstock evaluation in the Northern and inland region	534
6.2.4.1	Sub-Project summary	534
6.2.4.2	Evaluation of Delta Valencia rootstocks at Moosrivier Estates, Groblersdal, Mpumalanga	536
6.2.4.3	Evaluation of Star Ruby grapefruit and Delta Valencia in Limpopo Province	542
6.2.4.4	Evaluation of Valencia and navel varieties on different rootstocks in the Vaalharts area	548
6.2.4.5	Evaluation of Valencia and grapefruit varieties on new imported rootstocks in the Malelane and Swaziland area	552
7	CITRUS IMPROVEMENT PROGRAMME (CIP)	556
7.1	Summary	556
8	INTERNATIONAL VISITS	564
8.1 V.	Hattingh	564
8.1.1	Visit to Brussels	564
8.1.2	Visit to UK and Spain	564
8.2	S.D. Moore	567
8.3	Report on a scientific visit to the sterile insect release programme in Canada at the invitation of the International Atomic Energy Agency	569
9	KNOWLEDGE TRANSFER	573
9.1	Summary	573
10	PUBLICATIONS IN 2003	577

**CRI GROUP ANNUAL RESEARCH REPORT 2004/5
TABLE OF CONTENTS**

		Page
1	INTRODUCTION	1
2	PROGRAMME: MARKET ACCESS TECHNICAL CO-ORDINATION	2
	2.1 Programme summary	2
	2.2 China	4
	2.3 Europe	4
	2.4 Japan	5
	2.5 USA	5
	2.6 South Korea	6
	2.7 Thailand	6
	2.8 Other Market Access issues	6
	2.9 Residues and Food Safety	7
	2.10 Survey of Citrus Black Spot in the Northern Cape and Free State Provinces	7
3	PROGRAMME: INTEGRATED PEST MANAGEMENT	21
	3.1 Programme summary	21
	3.2 Project: Biocontrol Disruption	21
	3.2.1 Project summary	21
	3.2.2 Determine the non-target effects of key pesticides used in citrus to the soil predator of citrus thrips, <i>Androlaelaps</i> sp.	22
	3.3 Project: Cosmetic Pests	24
	3.3.1 Project summary	24
	3.3.2 Determining the developmental thresholds for citrus thrips	
	3.3.3 Determine the ability of citrus thrips to switch hosts and development of a rearing technique on <i>Bryophyllum delagoense</i>	25
	3.3.4 OP alternatives for citrus thrips, compatible with biointensive IPM or organic production	27
	3.3.5 The status and control of new moth pests on lemons	32
	3.3.6 Developing a molecular database for <i>Scirtothrips aurantii</i> from different host plants in southern Africa	35
	3.3.7 Development of a rearing technique for the thrips predator, <i>Franklinothrips megalops</i>	35
	3.3.8 Evaluation of the <i>Helicoverpa armigera</i> nucleopolyhedrovirus (HearNPV) for control of bollworm on citrus	37
	3.4 Projek: Valskodlingmot	40
	3.4.1 Projekopsomming	40
	3.4.2 Evaluation of the efficacy of a granulovirus (GV) for the control of False Codling Moth	41
	3.4.3 Evaluation of a genetically modified pathogen for control of False Codling Moth	53
	3.4.4 Development of semiochemical odorants for the attraction and repulsion of false codling moth in citrus	55
	3.4.5 Control of False Codling Moth with sterile insect releases	63
	3.4.5.1 Distinguishing between fluorescent powders of different colours	64
	3.4.5.2 Effect of irradiation rate on FCM males attracted to female moths under orchard conditions	65
	3.4.5.3 Testing release rate and release pattern of FCM for use under commercial SIR conditions	68

**CRI GROUP ANNUAL RESEARCH REPORT 2004/5
TABLE OF CONTENTS**

	Page
3.4.5.4 The dispersal distance and lifespan of irradiated FCM males and their recapture in the presence or absence of released FCM females	70
3.4.5.5 Additional assessment of irradiated FCM quality under orchard conditions	74
3.4.5.6 The dispersal distance and lifespan of irradiated FCM males	77
3.4.5.7 Competitiveness of FCM males of different ages	80
3.4.5.8 Colouring false codling moth for mark and release experiments	83
3.4.5.9 The effect of cold storage on the competitiveness of false codling moth males	85
3.4.5.10 The augmentative effect of egg parasitoids in a sterile insect release programme	89
3.4.5.11 The ovicidal activity of the fungicides Sporekill and Virkon S	91
3.4.5.12 The effect of egg age on the production of false codling moth in artificial diet	92
3.4.5.13 The lifespan and parasitization potential of the egg parasitoid, <i>Trichogrammatoidea cryptophlebiae</i>	93
3.4.5.14 False codling moth population fluctuations in proposed pilot project site	94
3.4.5.15 Comparison of the cold storage capabilities of different cool boxes	95
3.4.5.16 Preparing the infrastructure necessary for a proposed Sterile Insect Release pilot project	97
3.4.5.17 Influence of temperature on recapture rate and lifespan of released false codling moths in orchards	108
3.4.5.18 Parasitization of Codling Moth, <i>Cydia pomonella</i> , eggs by the egg parasitoid, <i>Trichogrammatoidea cryptophlebiae</i>	110
3.4.6 Development of a technique for mass rearing of FCM for SIT purposes	112
3.4.7 Understanding and improving biological control of false codling moth larvae	121
3.4.8 Investigation of alternative hosts for FCM	125
3.4.9 Some morphological features of the immature stages of the false codling moth, <i>Cryptophlebia leucotreta</i> (Meyrick), and comparison with related <i>Cryptophlebia</i> spp. (Lepidoptera: Tortricidae)	132
3.4.10 Surveys of host plants for false codling moth (<i>Cryptophlebia leucotreta</i>) in the Citrusdal area	141
3.4.11 Gamma irradiation of false codling moth larvae for the disinfestation of packed export fruit	143
3.5 Project: Fruit Fly	146
3.5.1 Project summary	146
3.5.2 Rearing of fruit flies	147
3.5.3 Fruit Fly bait sprays – alternatives to Organophosphates	148
3.5.4 Sensitivity of Mediterranean Fruit Fly larvae in mandarins, lemons, grapefruit and oranges to cold treatment of 1°C	150
3.5.5 Cold disinfestation of Mediterranean (<i>Ceratitis capitata</i> [Wiedemann]) and Natal (<i>Ceratitis rosa</i> Karsch) fruit fly-infested litchis (<i>Litchi Chinensis</i> Sonn.)	168
3.5.6 Cold disinfestation of Medfly- and Natalfly-infested Persimmons (Phases 1 and 2)	172
3.5.7 Natal fruit fly monitoring	177
3.5.8 Maputo Corridor Fruit Fly Survey	181
3.5.9 Modifications to the M3 bait station	182

**CRI GROUP ANNUAL RESEARCH REPORT 2004/5
TABLE OF CONTENTS**

		Page
	3.5.9.1 The use of absorbent paper	182
	3.5.9.2 Replacement fungicide for the M3 bait station	186
3.6	Project: Mealybug and other phytosanitary pests	188
	3.6.1 Project summary	188
	3.6.2 Investigating biocontrol agents of mealybug species other than citrus mealybug	188
	3.6.3 Preventive and corrective chemical treatments for control of mealybug on citrus	191
3.7	Project: Production Pests	194
	3.7.1 Project summary	194
	3.7.2 Control of red scale with mayonnaise oil	194
	3.7.3 IPM-compatible treatment options for citrus psylla, <i>Trioza erytrae</i>	196
4	PROGRAMME: DISEASE MANAGEMENT	198
4.1	Programme summary	198
4.2	Project: Graft Transmissible Diseases	199
	4.2.1 Project summary	199
	4.2.2 Research by new Virologist	202
	4.2.3 Citrus virus-free gene source	209
	4.2.4 Cross-protection of Marsh and Star Ruby grapefruit using Beltsville sub-isolates of Nartia mild strain	212
	4.2.5 Cross-protection of Marsh and Star Ruby using Beltsville subisolates of Nartia mild strain for the Orange River Valley	213
	4.2.6 Cross-protection of Marsh and Star Ruby by using the best field isolates collected in the different grapefruit production areas of southern Africa	214
	4.2.7 The response of Star Ruby to different CTV isolates	216
	4.2.8 Field evaluation of promising mild isolates for Star Ruby in two climatic areas	219
	4.2.9 The response of different red grapefruit cultivars to <i>Citrus tristeza virus</i>	221
	4.2.10 Constructing a superior <i>Citrus tristeza virus</i> isolate for crossprotection of grapefruit selections	223
	4.2.11 The effect of CTV pre-immunization on the fruit size of Clementine and Satsuma	225
	4.2.12 Evaluation of CTV isolates in navels	226
	4.2.13 Identification of suitable <i>Citrus tristeza virus</i> isolates for preimmunizing Turkey Valencia	229
	4.2.14 Evaluation of CTV isolates in Valencia	231
	4.2.15 The effect of different CTV isolates in Valencias on different rootstock combinations for the Orange River Valley	233
	4.2.16 Screening of rootstocks for Citrus Blight tolerance	234
	4.2.17 The effect of pruning and graft transmissible isolates on Huanglongbing (greening) infection	238
	4.2.18 The Association of Group III Viroids with Gum Pocket Disease in South Africa	240
4.3	Project: Fruit and Foliar Diseases	247
	4.3.1 Project summary	247
	4.3.2 Screening of new mandarin and mandarin hybrids for their susceptibility/resistance towards <i>Alternaria</i> brown spot	248
	4.3.3 Investigation into die-back of Clementines in the Eastern Cape	252

**CRI GROUP ANNUAL RESEARCH REPORT 2004/5
TABLE OF CONTENTS**

	Page
4.3.4 The pros and cons of a monoclonal antibody developed for <i>Botrytis cinerea</i> to be used with the Quest spore trap	255
4.4 Project: Soilborne Diseases	256
4.4.1 Project summary	256
4.4.2 Assessment of citrus rootstocks for citrus nematode resistance	259
4.4.3 Stimulation of egg hatching of <i>Tylenchulus semipenetrans</i> eggs	265
4.4.4 Evaluation of biological control agents against <i>Tylenchulus semipenetrans</i>	267
4.4.5 Rootstock evaluation against <i>Hemicycliphora</i> in the Gamtoos River Valley	269
4.4.6 Biological control of the citrus nematode under a drip irrigation system	271
4.4.7 To evaluate enhancing products for the control of <i>Phytophthora</i> root rot diseases in citrus nurseries	272
4.4.8 Evaluation of cadusafos on citrus trees in nematode infested soils	274
4.4.9 Evaluation of Crop Guard against the citrus nematode, <i>Tylenchulus penetrans</i>	274
4.4.10 <i>Phytophthora</i> root rot control – determining the long term effect of phosphorous acid equivalent products in soil applied system	274
4.4.11 Resistance of citrus rootstocks to root pathogens	276
4.5 Project: Citrus Black Spot	283
4.5.1 Project summary	283
4.5.2 Detection of <i>Guignardia</i> from soil ecosystems	284
4.5.3 Inoculation of leaves with <i>Guignardia citricarpa</i> pycnidiospores	287
4.5.4 Seasonal availability of ascospore inoculum of <i>Guignardia citricarpa</i>	288
4.5.5 Breaking the life cycle of <i>Guignardia citricarpa</i> : Removal or confinement of inoculum	291
4.5.6 Biological control of <i>Guignardia citricarpa</i>	292
4.5.7 Positioning of a single benomyl application in a strobilurin spray programme	294
4.5.8 <i>In vitro</i> and <i>in vivo</i> evaluation of maneb (Trimangol and Manager) and mancozeb (Sancozeb) against pathogenic <i>Guignardia citricarpa</i> isolates, the cause of citrus black spot on Valencias	298
4.5.9 Evaluation of spray programmes using copper fungicides alternated with mancozeb as well as combinations of copper fungicides with other fungicides for the control of citrus black spot in South Africa	306
4.5.10 Correlation between leaf drop and production of ascospore inoculum in citrus orchards	319
4.5.11 Determining if citrus leaves, naturally infected with <i>Guignardia citricarpa</i> , can produce inoculum while still positioned in a tree	323
4.5.12 Developing a protocol for detecting CBS in citrus nurseries	324
4.5.13 The evaluation of several chemical programmes for the control of Citrus Black Spot	327
4.5.14 Determine the correlation between increasing fruit age and resistance to infection by <i>Guignardia citricarpa</i>	329
4.6 Project: Post-Harvest Pathology	331
4.6.1 Project summary	331
4.6.2 The evaluation of three formulations of the post-harvest fungicide, imazalil, against post-harvest diseases for the purpose of registration	332

**CRI GROUP ANNUAL RESEARCH REPORT 2004/5
TABLE OF CONTENTS**

	Page
4.6.3 The evaluation of the post-harvest fungicide Prochloraz against the <i>Penicillium</i> organisms for the purpose of registration as a postharvest dip treatment	336
4.6.4 The evaluation of three formulations of the post-harvest fungicide, thiabendazole, against post-harvest diseases for the purpose of registration	338
4.6.5 The evaluation of the potentially new post-harvest fungicide Fludioxonil against post-harvest citrus pathogen, <i>P. digitatum</i>	343
4.6.6 The screening of organic compounds, Citofresh, DM31 and KanLife, against post-harvest fungal pathogens causing diseases of citrus fruits	345
4.6.7 The <i>in vitro</i> and <i>in vivo</i> screening of the quaternary ammonium compounds, Sanicide and Ambicide, against the post-harvest diseases of citrus green mould, <i>Penicillium digitatum</i> , and sour rot, <i>Geotrichum candidum</i> , to determine the efficacy of the compound in killing the fungal spores	347
4.6.8 Evaluation of the two sanitizing agents, Sterifect and Prasin (a quaternary ammonium compound) in a hot water fungicide bath	351
4.6.9 The effect of citrus waxes applied post-harvest to citrus sprayed with Kaolin in the orchards for the prevention of sunburn	353
4.6.10 The evaluation of the efficacy of guazatine formulated into citrus waxes (i.e. CitriWax and Deccowax)	354
4.6.11 The <i>in vivo</i> screening of <i>P. digitatum</i> (green mould) spores for resistance to the post-harvest fungicide imazalil	355
4.6.12 CRI Diagnostic Centre	357
5 PROGRAMME: CROP LOAD AND FRUIT QUALITY MANAGEMENT	358
5.1 Programme summary	358
5.2 Project: Fruit Quality Enhancement	359
5.2.1 Project summary	359
5.2.2 Reduction in sunburn incidence of Satsuma mandarin	361
5.2.3 Reduction of acidity of high acid citrus cultivars using alternatives to calcium arsenate	365
5.2.4 Lemon fruit shape	369
5.2.5 Physiological aspects of rind colour development	371
5.2.6 Effects of tree nutrition and post-harvest treatments on concentration of the most important colour-imparting carotenoids in physiologically mature citrus fruit	372
5.3 Project: CropLoad Management	374
5.3.1 Project summary	374
5.3.2 Ecophysiological responses and changes in sugar accumulation due to altered plant water relations of <i>Citrus</i> trees	374
5.4 Project: Rind Condition	381
5.4.1 Project summary	381
5.4.2 Citrus creasing	383
5.4.3 The effect of light and competition on the development of rind disorders	395
5.4.4 Comparison between inside (shaded) and outside (non-shaded) 'Nules' Clementine mandarin fruit regarding physiological and biological properties of the rind as well as on the occurrence of chilling injury and rind breakdown after storage	399
5.4.5 Comparison between 'Nules' and 'Oroval' Clementine mandarins on selected physiological and biochemical rind properties as well as on the occurrence of rind breakdown after storage	405

**CRI GROUP ANNUAL RESEARCH REPORT 2004/5
TABLE OF CONTENTS**

		Page
5.4.6	Postharvest conditions possibly influencing rind disorders	413
5.4.7	Chilling injury to Valencia type oranges	421
5.4.8	Effect of CO ₂ on rind condition of Clementine mandarin	423
6	PROGRAMME: CULTIVAR AND ROOTSTOCK DEVELOPMENT	427
6.1	Programme summary	427
6.2	Project: Evaluations	427
6.2.1	Project summary	427
6.2.2	Sub-Project: Evaluation of cultivars in the Cape region	429
6.2.2.1	Sub-Project summary	429
6.2.2.2	Evaluation of Satsuma mandarins in the Cape areas	429
6.2.2.3	Evaluation of Clementine mandarins in the Cape areas	432
6.2.2.4	Evaluation of mandarin hybrids in the Cape areas	441
6.2.2.5	Evaluation of navel oranges in the Cape areas	449
6.2.2.6	Evaluation of Midseason oranges in the Cape areas	456
6.2.2.7	Evaluation of Valencia oranges in the Cape areas	462
6.2.2.8	Evaluation of Genoa Lemon on various rootstocks in Citrusdal	466
6.2.2.9	Establishment of new and evaluation of existing cultivars at Lancewood, Knysna area	469
6.2.2.10	Evaluation of Turkey Valencias on different rootstocks	472
6.2.2.11	Establishment of new cultivar trials	474
6.2.2.12	Navel rootstock trial	475
6.2.3	Sub-Project: Cultivar evaluation in the Northern and inland region	476
6.2.3.1	Sub-Project summary	476
6.2.3.2	Evaluation of Clementine mandarins in Mpumalanga	476
6.2.3.3	Evaluation of late maturing Mandarins in the inland areas	479
6.2.3.4	Evaluation of navels in the intermediate and cool inland areas	481
6.2.3.5	Evaluation of Valencia selections in the inland areas	484
6.2.3.6	Evaluation of Midseason oranges in the inland areas	487
6.2.3.7	Evaluation of lemons in the inland areas	488
6.2.4	Sub-Project: Evaluation of citrus rootstocks in the Northern and inland areas	490
6.2.4.1	Sub-Project summary	490
6.2.4.2	Evaluation of Delta Valencia rootstocks at Moosrivier Estates, Groblersdal, Mpumalanga	492
6.2.4.3	Evaluation of Star Ruby grapefruit, Midnight and Delta Valencias in the Limpopo Province	500
6.2.4.4	Evaluation of Valencia and navel varieties on different rootstocks in the Vaalharts area	508
6.2.4.5	Evaluation of Valencia and grapefruit varieties on new imported rootstocks in the Malelane and Swaziland area	509
6.2.4.6	Evaluation of various new Valencia and navel varieties on different rootstocks at Marble Hall and Komatipoort	513
7	CITRUS IMPROVEMENT PROGRAMME (CIP)	515
7.1	Programme summary	515

**CRI GROUP ANNUAL RESEARCH REPORT 2004/5
TABLE OF CONTENTS**

	Page
8	INTERNATIONAL VISITS 520
8.1	T.G. Grout - Morocco 520
8.2	H.F. le Roux – Morocco 526
8.3	G.H. Barry – Morocco 532
8.4	W. Kirkman – Canada 534
8.5	V. Hattingh – Canada, Australia & Turkey 537
8.6	A.B. Ware – Australia 548
8.7	P. Cronjé – United Kingdom 551
8.8	H.F. le Roux, S.P. van Vuuren & G. Pietersen – Brazil 552
8.9	G. Pietersen – Mexico 561
9	KNOWLEDGE TRANSFER 564
9.1	Knowledge Transfer Groups (KTGs) 564
10	PUBLICATIONS IN 2004 576
11	PRESENTATIONS AT SOCIETAL AND INTERNATIONAL CONGRESSES 577

**CRI GROUP ANNUAL RESEARCH REPORT 2005/6
TABLE OF CONTENTS**

Page

1	INTRODUCTION	1
2	PROGRAMME: MARKET ACCESS TECHNICAL CO-ORDINATION	3
	2.1 Programme Summary	3
	2.2 China	5
	2.3 Europe	6
	2.4 Japan	7
	2.5 USA	7
	2.6 South Korea	8
	2.7 Thailand	9
	2.8 Israel	9
	2.9 Australia	9
	2.10 Iran	9
	2.11 Pakistan	9
	2.12 Other Market Access and Food Safety Issues	9
3	PROGRAMME: INTEGRATED PEST MANAGEMENT	10
	3.1 Programme Summary	10
	3.2 Projek: Valskodlingmot	11
	3.2.1 Projekopsomming	11
	3.2.2 Evaluation of the efficacy of a granulovirus (GV) for the control of False codling moth	13
	3.2.3 Development of semiochemical odorants for the attraction and repellence of false codling moth in citrus	19
	3.2.4 Bestryding van valskodlingmot deur middel van Steriele Insekloslatings	33
	3.2.5 Development of a technique for mass rearing of FCM for SIT purposes	41
	3.2.6 Understanding and improving biological control of false codling moth larvae	50
	3.2.7 Gammabestrating van VKM-larwes vir die disinfestasië van verpakte sitrusvrugte	57
	3.2.8 Investigation of alternative hosts for FCM	60
	3.2.9 Investigating and improving field persistence of Cryptogran	70
	3.2.10 Entomopathogenic nematodes for control of FCM	76
	3.2.11 The host status of lemons for FCM	81
	3.2.12 Evaluation of a cold treatment for the disinfestation of export citrus from false codling moth, <i>Cryptophlebia leucotreta</i>	87
	3.2.13 Genetic variation in false codling moth populations	94
	3.2.14 Reduction of crop losses due to false codling moth, <i>Cryptophlebia leucotreta</i> , on navel orange trees with EXP105 120 SC	97
	3.3 Project: Fruit Flies	99
	3.3.1 Project summary	99
	3.3.2 Sensitivity of Mediterranean fruit fly eggs and larvae in lemons, grapefruit and oranges to cold treatment of 1°C	100
	3.3.3 Fruit fly bait sprays – alternatives to organophosphates	106
	3.3.4 Development of a rapid diagnostic test to distinguish Medfly larvae from other larvae	109
	3.3.5 Establishing developmental thresholds for different life stages of Natal fruit fly and Marula fruit fly for climate modelling purposes	109
	3.3.6 Natal fruit fly – Field control other than OP substitutes	110
	3.3.7 Verification of Cold Treatment Disinfestation of Medfly-infested Clementines destined for Japan	117
	3.4 Project: Cosmetic Pests	123

**CRI GROUP ANNUAL RESEARCH REPORT 2005/6
TABLE OF CONTENTS**

		Page
	3.4.1 Project summary	123
	3.4.2 OP alternatives for citrus thrips, compatible with bio-intensive IPM or organic production	124
	3.4.3 Develop a rearing technique for the citrus thrips parasitoid, <i>Goetheana incerta</i>	126
	3.4.4 Evaluation of the <i>Helicoverpa armigera</i> nuclear polyhedrovirus (HearNPV) for control of bollworm on citrus	126
	3.4.5 Identify the pest piercing fruit and causing fruit drop near Burgersfort	130
3.5	Project: Biocontrol Disruption	133
	3.5.1 Project summary	133
	3.5.2 To develop an ant repellent that will keep ants out of citrus trees without destroying their nest	133
	3.5.3 Determine the non-target effects of key pesticides used in citrus to lacewing predators of citrus thrips	136
3.6	Project: Mealybug and other phytosanitary pests	136
	3.6.1 Project summary	136
	3.6.2 Investigating biocontrol agents of mealybug species other than citrus mealybug	137
	3.6.3 Preventative and corrective chemical treatments for control of mealybug on citrus	139
	3.6.4 A survey of the mealybug species complex on citrus throughout South Africa	141
	3.6.5 A survey of grain chinch bug in fruit orchards in the Western Cape	143
	3.6.6 Post-harvest chemical control of grain chinch bug	146
3.7	Project: Production Pests	147
	3.7.1 Project summary	147
	3.7.2 IPM-compatible treatment options for citrus psylla <i>Trioza erytreae</i>	148
	3.7.3 Development of an attract-and-kill system for citrus psylla	150
4	PROGRAMME: DISEASE MANAGEMENT	156
4.1	Programme summary	156
4.2	Project: Graft Transmissible Diseases	157
	4.2.1 Projekopsomming	157
	4.2.2 Establish diagnostic capabilities to graft transmissible pathogens of Citrus at CRI-UP, with emphasis on <i>Citrus Tristeza Virus</i> variants	159
	4.2.3 Diagnostic services for graft transmissible diseases	172
	4.2.4 Citrus virus-free gene source	175
	4.2.5 Cross-protection of Marsh and Star Ruby grapefruit using Beltsville sub-isolates of Nartia mild strain	177
	4.2.6 Cross-protection of Marsh and Star Ruby using Beltsville sub-isolates of Nartia mild strain for the Orange River Valley	179
	4.2.7 Cross-protection of Marsh and Star Ruby by using the best field isolates collected in the different grapefruit production areas of southern Africa	180
	4.2.8 The response of Star Ruby to different CTV isolates	182
	4.2.9 The response of different red grapefruit cultivars to <i>Citrus Tristeza Virus</i>	185
	4.2.10 Constructing a superior <i>Citrus Tristeza Virus</i> isolate for cross-protection of grapefruit selections	188
	4.2.11 The effect of CTV pre-immunization on the fruit size of Clementines and Satsuma	191

**CRI GROUP ANNUAL RESEARCH REPORT 2005/6
TABLE OF CONTENTS**

	Page
4.2.12 Evaluation of CTV isolates in navel	193
4.2.13 Identification of suitable <i>Citrus Tristeza Virus</i> isolates for pre-immunizing Turkey Valencia	196
4.2.14 Evaluation of CTV isolates in Valencia	197
4.2.15 The effect of different CTV isolates in Valencias on different rootstock combinations for the Orange River Valley	199
4.2.16 Screening of rootstocks for Citrus Blight tolerance	200
4.2.17 Genetic modification of citrus material for greening resistance – A literature survey	204
4.2.18 Evaluation of citrus material for greening resistance	225
4.2.19 Eradication of citrus greening infections in existing orchards	228
4.3 Project: Citrus Black Spot	230
4.3.1 Project summary	230
4.3.2 Positioning of a single benomyl application in a strobilurin spray programme	231
4.3.3 Evaluation of warm water and fungicide dip treatments for the elimination of endophytic <i>Guignardia citricarpa</i> in budwood	237
4.3.4 Determining the age and decomposition rate of citrus leaves using different irrigation methods	240
4.3.5 Further development of spray programmes consisting of registered fungicides in tank mixtures with Sporekill for the control of citrus Black Spot on Valencia oranges	244
4.3.6 The evaluation of several chemical programmes for the control of Citrus Black Spot	248
4.3.7 Determine the effect of increasing fruit age on resistance to infection by <i>Guignardia citricarpa</i>	252
4.3.8 The correlation between leaf drop and production of ascospore inoculum in citrus orchards	256
4.3.9 <i>In vitro</i> production of <i>Guignardia citricarpa</i> ascospores	267
4.3.10 Detection of <i>Guignardia</i> from leaf litter and symptomless leaves and fruit with CBS PCR	270
4.3.11 Seasonal availability of ascospore inoculum of <i>Guignardia citricarpa</i>	272
4.3.12 Breaking the life cycle of <i>Guignardia citricarpa</i> : Removal or confinement of inoculum	273
4.3.13 Development of a Citrus Black Spot (CBS) disease forecasting model	275
4.3.14 A preliminary survey of the Critical Infection Period (CIP) of Citrus Black Spot in Limpopo, Eastern Cape and Western Cape	283
4.3.15 An empirical “wet-dry” technique to detect CBS in nurseries and production areas with low disease pressure	290
4.3.16 Draft recommendation to monitor for CBS in citrus nurseries	293
4.3.17 Market Access: CRI survey of Citrus Black Spot in the Western Cape districts of Knysna and Mosselbay	294
4.4 Project: Soilborne Diseases	297
4.4.1 Project summary	297
4.4.2 Rootstock evaluation against <i>Hemicycliphora</i> in the Gamtoos River Valley	299
4.4.3 Biological control of the citrus nematode under a drip irrigation system	303
4.4.4 To evaluate alternative nematode control products, i.e. Biofumigants, as part of an integrated nematode control approach in citrus replant situations	304
4.4.5 Evaluation of cadusafos on citrus trees in nematode infested soils	305

**CRI GROUP ANNUAL RESEARCH REPORT 2005/6
TABLE OF CONTENTS**

	Page
4.4.6 Evaluation of Crop Guard against the citrus nematode, <i>Tylenchulus semipenetrans</i>	305
4.4.7 The evaluation of enhancing products for the control of <i>Phytophthora</i> root rot disease in citrus nurseries	305
4.4.8 Application of the phosphonates in combination with other chemicals at lower concentrations for <i>Phytophthora</i> brown rot control	310
4.4.9 <i>Phytophthora</i> root rot control – Determining the long term effect of phosphorous acid equivalent products in soil applied systems	318
4.5 Project: Post-Harvest Pathology	320
4.5.1 Project summary	320
4.5.2 The evaluation of a new 500 EC formulation of imazalil against postharvest diseases for the purpose of registration	322
4.5.3 The evaluation of Guazalil, a new formulation of a combination of imazalil and guazatine, for efficacy against post-harvest diseases	323
4.5.4 Evaluation of “Philabuster 400 SC” from Janssen Pharmaceutica for efficacy against the post-harvest citrus pathogen, green mould	325
4.5.5 The evaluation of Sylitt (a.i. dodine) for efficacy against post-harvest diseases	327
4.5.6 The evaluation of the efficacy of guazatine formulated into citrus waxes (i.e. CitriWax and Deccowax)	328
4.5.7 Evaluation of the sanitizing agents, SteriHarvest, Aseptrol and G-cide, in a simulated packhouse dumptank washing system for efficacy of sterilisation of the system and possible infection of injured fruit moving through the system	330
4.5.8 Evaluation of Erador and Xterminator for compatibility with the postharvest fungicides in a post-harvest dip treatment for the control of chinch bug	331
4.5.9 Kaolin – citrus wax packhouse trial conducted on lemons and mangos for prevention of sunburn	333
4.5.10 High imazalil residue on Star Ruby grapefruit from Neonovo (Lowveld) in Japan	334
4.5.11 Residue levels of the post-harvest fungicide imazalil on South African citrus fruit	336
4.5.12 The <i>in vivo</i> screening of Penicillium spore samples for resistance to the post-harvest fungicide imazalil	337
4.5.13 The screening of South African isolates of Penicillium fungal spores from all citrus production areas for resistance to the post-harvest fungicides imazalil and guazatine	339
4.5.14 The evaluation of plant growth regulators (PGRs), applied postharvest as alternatives to 2,4-D sodium salt (Deccomone) for calyx retention on citrus fruit	342
4.6 Project: Fruit and Foliar Diseases	346
4.6.1 Project summary	346
4.6.2 Evaluation of new spray programmes for the control of <i>Alternaria</i> brown spot in the winter rainfall region of South Africa	347
4.6.3 Positioning and evaluation of new spray programmes consisting of strobilurins for the control of <i>Alternaria</i> brown spot in the summer rainfall regions of South Africa	350
4.6.4 Investigation into die-back of Clementines in the Eastern Cape	355
5 PROGRAMME: CROP LOAD AND FRUIT QUALITY MANAGEMENT	361
5.1 Programme summary	361
5.2 Project: Rind Condition	361

**CRI GROUP ANNUAL RESEARCH REPORT 2005/6
TABLE OF CONTENTS**

		Page
5.2.1	Project summary	361
5.2.2	Effect of timing of calcium salts and micronutrients on creasing of navels	364
5.2.3	Evaluation of alternative means of controlling creasing (albedo breakdown)	367
5.2.4	Preharvest conditions influencing rind conditions: determining the role of mineral nutrients on rind breakdown of 'Nules Clementine' mandarin	368
5.2.5	Chilling injury of Valencia type oranges	373
5.2.6	Intermittent warming of citrus during storage	375
5.2.7	Effect of CO ₂ on rind condition of Clementine mandarin	384
5.2.8	Variation in Post Storage Quality of 'Nules Clementine' Mandarin and 'Oroval Clementine' Mandarin fruit (<i>Citrus reticulata</i> Blanco) with special reference to rind breakdown incidence	387
5.2.9	Effect of canopy position on harvest and post-storage quality of 'Nules Clementine' Mandarin (<i>Citrus reticulata</i> Blanco) fruit	394
5.2.10	The effect of different citrus wax applications on the development of peteca spot on lemons	399
5.2.11	'Eureka' lemon physiological profile: Storage temperature and storage duration response curves for 'Eureka' lemon harvested at different physiological maturities with special reference to peteca spot	403
5.3	Project: Fruit Quality Enhancement	414
5.3.1	Project summary	414
5.3.2	Reduction in sunburn incidence of Satsuma mandarin	415
5.3.3	Reduction of acidity of high acid citrus cultivars using alternatives to calcium arsenate	421
5.3.4	Physiological aspects of rind colour development and enhancement of rind colour, with emphasis on early cultivars	423
5.3.5	Effects of tree nutrition and post-harvest treatments on concentration of the most important colour-imparting carotenoids in physiologically mature citrus fruit	436
5.4	Project: Crop Load Management	440
5.4.1	Project summary	440
5.4.2	Fruit set enhancement of seedless citrus cultivars by reducing heat stress and increasing natural plant defence mechanisms	441
5.4.3	Determining the number of fruit per tree (crop load) that would give optimal yield and fruit size	443
5.4.4	Water use efficiency of navel orange trees under partial root zone drying irrigation	444
6	PROGRAMME: CULTIVAR AND ROOTSTOCK EVALUATION	447
6.1	Programme summary	447
6.2	Programme introduction	447
6.3	Project: Cultivar evaluation	449
6.3.1	Project summary: Cape areas	449
6.3.2	Project summary: Inland areas	452
6.3.3	Evaluation of Satsuma mandarins and Primosole in the Cape areas	453
6.3.4	Evaluation of Clementine mandarins in the Cape areas	458
6.3.5	Evaluation of Mandarin hybrids in the Cape areas	467
6.3.6	Evaluation of navel oranges in the Cape areas	475
6.3.7	Evaluation of Midseason oranges in the Cape areas	489

**CRI GROUP ANNUAL RESEARCH REPORT 2005/6
TABLE OF CONTENTS**

	Page
6.3.8	Evaluation of Valencia oranges in the Cape areas 495
6.3.9	Evaluation of existing cultivars at Lancewood, Knysna area 501
6.3.10	Evaluation of Clementine mandarins in the cool inland areas 504
6.3.11	Evaluation of Mandarin hybrids in the cool inland areas 506
6.3.12	Evaluation of navels in the cool inland areas 508
6.3.13	Evaluation of navels in the intermediate inland areas 511
6.3.14	Evaluation of Valencia selections in the inland areas (Onderberg) 513
6.3.15	Evaluation of lemon selections in the inland areas 515
6.4	Project: Rootstock Evaluation 516
6.4.1	Project summary 516
6.4.2	Summary: Cape and Inland areas 518
6.4.3	Evaluation of Turkey Valencia on different rootstocks 521
6.4.4	Evaluation of Genoa Lemon on various rootstocks in Citrusdal 522
6.4.5	Evaluation of Delta Valencia rootstock trial at Moosrivier Estate 526
6.4.6	Evaluation of Midnight and Delta Valencia rootstock trial at Letaba Estates 531
6.4.7	Evaluation of Star Ruby rootstock trial at Letaba Estates 535
6.4.8	Evaluation of navel orange rootstock trial at Vaalharts 538
6.4.9	Evaluation of Valencia orange rootstock trial at Vaalharts 539
6.4.10	Evaluation of Valencias on new imported rootstocks in the Malelane area 539
6.4.11	Evaluation of grapefruit varieties on new imported rootstocks in the Swaziland area 541
6.4.12	Evaluation of various Valencia selections on different rootstocks in the Komatipoort area 544
7	CITRUS IMPROVEMENT PROGRAMME (CIP) 549
7.1	Programme summary 549
8	INTERNATIONAL VISITS 554
8.1	H.F. le Roux 554
8.2	M.M.N. du Toit 556
8.3	T.G. Grout 559
8.4	G.C. Schutte 563
8.5	V. Hattingh 566
9	TECHNOLOGY TRANSFER 584
9.1	Extension Report 2005 584
9.1.1	Research priorities for 2006 584
9.1.2	Program: Siektebestuur 584
9.1.3	Programme: Integrated Pest Control 588
9.1.4	Program: Oesopbrengs en Vrugkwaliteitsbestuur 590
9.1.5	Programme: Cultivar and Rootstock Evaluation 593
9.2	Technology Transfer Groups (TTG's) 599
9.3	The relative funding support for research programmes and projects for 2005 600
9.4	Extension presentations by CRI Group researchers in 2005 603
9.5	Other means of technology transfer 605
9.5.1	S.A. Fruit Journal 605
9.5.2	CRIInet 605
9.5.3	Cutting Edge 606

CRI GROUP ANNUAL RESEARCH REPORT 2005/6
TABLE OF CONTENTS

	Page
9.5.4 CRI Website	606
6.5.5 Citrus Research Symposium	607
9.6 Transformation	607
9.7 Liaison with Export Agents	608
10 PUBLICATIONS IN 2005	608
10.1 Refereed publication (or ISI ranked journals)	608
10.2 Semi-scientific publications	608
11 Presentations at Societal and International Congresses	609

CRI GROUP ANNUAL RESEARCH REPORT 2006/7
TABLE OF CONTENTS

		Page
1	INTRODUCTION	1
2	PROGRAMME: MARKET ACCESS TECHNICAL CO-ORDINATION	4
	2.1 Programme summary	4
	2.2 China	6
	2.3 Europe	7
	2.4 Japan	8
	2.5 USA	8
	2.6 South Korea	9
	2.7 Thailand	9
	2.8 Israel	10
	2.9 Australia	10
	2.10 Other Market Access and Food Safety Issues	10
3	PROGRAMME: INTEGRATED PEST MANAGEMENT	11
	3.1 Programme summary	11
	3.2 Project: False Codling Moth	12
	3.2.1 Project summary	12
	3.2.2 Development of semiochemical odorants for the attraction and repellence of false codling moth in citrus	14
	3.2.3 Bestryding van valskodlingmot deur middel van Steriele Insekloslatings	22
	3.2.4 Development of a technique for mass rearing of FCM for SIT purposes	41
	3.2.5 Understanding and improving biological control of false codling moth larvae	46
	3.2.6 Investigation of alternative hosts for FCM	54
	3.2.7 Investigating and improving field persistence of Cryptogran	65
	3.2.8 Entomopathogenic nematodes for control of FCM	77
	3.2.9 Globale verspreiding van valskodlingmot	82
	3.2.10 The host status of lemons for FCM	83
	3.2.11 Improvement of cold treatment conditions for the disinfestation of False Codling Moth in citrus fruit, using a potentiating CO ₂ shock treatment	86
	3.2.12 An investigation into the details of FCM population dynamics across time and space	90
	3.3 Project: Fruit Fly	98
	3.3.1 Project summary	98
	3.3.2 Fruit fly rearing	99
	3.3.2.1 Rearing of Natal Fruit fly <i>Ceratitits rosa</i> Karsch	99
	3.3.3 Cold disinfestation of Medfly infested lemons, grapefruit, oranges and Clementines using temperatures above 0°C	103
	3.3.4 Fruit fly bait sprays – alternatives to organophosphates	107
	3.3.5 Development of a rapid diagnostic test to distinguish Medfly larvae from other larvae	108
	3.3.6 Comparative development at constant temperatures of three economically important <i>Ceratitits</i> spp. (Diptera: Tephritidae) from southern Africa	108
	3.3.7 Fruit fly – Field control other than OP substitutes	117
	3.3.8 Global distribution of Natal fruit fly	129
	3.4 Project: Cosmetic Pests	131
	3.4.1 Project summary	131
	3.4.2 Evaluation of the <i>Helicoverpa armigera</i> nuclearpolyhedrovirus (HearNPV) for control of bollworm on citrus	131

**CRI GROUP ANNUAL RESEARCH REPORT 2006/7
TABLE OF CONTENTS**

	Page	
3.4.3	Develop a rearing technique for the citrus thrips parasitoid <i>Goetheana incerta</i>	137
3.4.4	Efficacy evaluation of abamectin formulations against citrus thrips	138
3.4.5	Evaluation of Solitaire and BreakThru in combination with abamectin against citrus thrips	139
3.4.6	Improving management of citrus grey mite, <i>Calacarus citrifolii</i>	140
3.5	Project: Biocontrol Disruption	141
3.5.1	Project summary	141
3.5.2	To develop an ant repellent that will keep ants out of citrus trees without destroying their nest	141
3.5.3	Rearing of the lacewing predator <i>Chrysoperla pudica</i> and its susceptibility to key pesticides used on citrus	144
3.5.4	Development of ant baits and the use of bait stations	146
3.6	Project: Mealybug and other Phytosanitary pests	150
3.6.1	Project summary	150
3.6.2	Investigating biocontrol agents of mealybug species other than citrus mealybug	151
3.6.3	A survey of the mealybug species complex on citrus throughout SA	153
3.6.4	Evaluation of <i>Planococcus citri</i> pheromone traps for monitoring infestation levels	156
3.6.5	Postharvest control of grain chinch bug (Heteroptera: Lygaeidae) on citrus using pyrethrum	160
3.6.6	Using BreakThru to improve corrective control of mealybug on citrus	163
3.7	Project: Production Pests	165
3.7.1	Project summary	165
3.7.2	IPM-compatible treatment options for citrus psylla <i>Trioza erytreae</i>	166
3.7.3	Development of an attract-and-kill system for citrus psylla	169
3.8	Project: Residue Trials for PHI and MRL development	171
3.8.1	Project summary	171
	3.8.1.1 Methamidophos residue trials	171
	3.8.1.2 Triflumuron residue trials	176
	3.8.1.3 Propargite residue trials	180
	3.8.1.4 Malathion residue trials	182
	3.8.1.5 Applaud residue trials	185
4	PROGRAMME: DISEASE MANAGEMENT	187
4.1	Programme summary	187
4.2	Project: Graft Transmissible Diseases	188
	4.2.1 Projekopsomming	188
	4.2.2 Establish diagnostic capabilities to graft transmissible pathogens of Citrus at CRI-UP with emphasis on <i>Citrus tristeza virus</i> variants	192
	4.2.3 Diagnostic services for graft transmissible diseases	205
	4.2.4 Citrus virus-free gene source	209
	4.2.5 Cross-protection of Marsh and Star Ruby grapefruit using Beltsville sub-isolates of Nartia mild strain	223
	4.2.6 Cross-protection of Marsh and Star Ruby using Beltsville sub-isolates of Nartia mild strain for the Orange River Valley	225

**CRI GROUP ANNUAL RESEARCH REPORT 2006/7
TABLE OF CONTENTS**

	Page
4.2.7	Cross-protection of Marsh and Star Ruby using the best field isolates collected in the different grapefruit production areas of southern Africa 227
4.2.8	The response of different red grapefruit cultivars to <i>Citrus tristeza virus</i> 228
4.2.9	The effect of CTV pre-immunization of the fruit size of Clementine and Satsuma 232
4.2.10	Evaluation of CTV isolates in navel 234
4.2.11	Identification of suitable <i>Citrus tristeza virus</i> isolates for pre-immunizing Turkey Valencia 237
4.2.12	Evaluation of CTV isolates in Valencia 239
4.2.13	The effect of different CTV isolates in Valencias on different rootstock combinations for the Orange River Valley 241
4.2.14	Screening of rootstocks for Citrus Blight tolerance 242
4.2.15	Evaluation of citrus material for greening resistance 246
4.2.16	Eradication of citrus greening infections in existing orchards 249
4.3	Project: Citrus Black Spot 252
4.3.1	Project summary 252
4.3.2	Leaf wilting to enhance detection of <i>Guignardia</i> spp. in symptomless green leaves 253
4.3.3	Selective medium for <i>Guignardia citricarpa</i> 256
4.3.4	Evaluation of a protocol for detecting <i>Guignardia</i> spp. on citrus nursery trees 260
4.3.5	<i>In vitro</i> infection of plants (Preliminary report) 265
4.3.6	Further developments of spray programmes consisting of registered fungicides in tank mixtures with Sporekill for the control of citrus black spot 268
4.3.7	Evaluation of a guanidine fungicide, new copper and mancozeb formulations and a surfactant for the control of citrus black spot on Valencias 273
4.3.8	Determining when fruit becomes resistant to black spot infection with increasing maturity 283
4.3.9	Evaluation of leaf litter inoculum potential on the orchard floor as affected by the irrigation system (Preliminary report) 288
4.3.10	Reducing the inoculum potential in leaves by applying fungicides to citrus trees in the orchard (Preliminary report) 290
4.3.11	Development of a reliable Citrus Black Spot (CBS) disease forecasting model for the South African citrus producer 291
4.4	Project: Soilborne Diseases 295
4.4.1	Project summary 295
4.4.2	Evaluation of a new biological control product for the control of the citrus nematode 297
4.4.3	Evaluation of Crop Guard against the citrus nematode, <i>Tylenchulus semipenetrans</i> 298
4.4.4	Stimulation of egg hatching of <i>Tylenchulus semipenetrans</i> eggs 298
4.4.5	To determine the most effective control measures for <i>Armillaria</i> die-back of citrus 303
4.4.6	Evaluation of phosphonate-adjuvant mixtures to reduce the problem with possible phytotoxic damage to citrus fruit when applying a phosphonate for the control of <i>Phytophthora</i> brown rot on citrus 306
4.4.7	Screening of nursery isolates of <i>Phytophthora</i> for resistance to metalaxyl 309
4.4.8	Evaluate the efficacy of phosphonates applied through the irrigation system on citrus in the Letsitele area for control of <i>Phytophthora</i> root rot 313
4.5	Project: Post-harvest Pathology 315
4.5.1	Project summary 315
4.5.2	The evaluation of a new post-harvest fungicide Philabuster from Janssen Pharmaceutica against post-harvest disease for the purpose of registration 317

CRI GROUP ANNUAL RESEARCH REPORT 2006/7
TABLE OF CONTENTS

		Page
4.5.3	Residue analyses on fruit samples treated with imazalil sulphate WSP and Fungazil 500 EC for sporulation inhibition	750 319
4.5.4	Imazalil residue "ring test" to determine if the test procedure is standardized at all accredited test laboratories	320
4.5.5	The evaluation of Citrofresh in a citrus packhouse dumptank washing system as a sanitizing agent against post-harvest disease	321
4.5.6	The evaluation of Citrex and Ozone in a citrus packhouse dumptank washing system as sanitizing agents	323
4.5.7	The evaluation of Citrex and Croplife <i>in vivo</i> against post-harvest citrus diseases	325
4.5.8	The evaluation of Wetcit against the control of post-harvest disease	326
4.5.9	The evaluation of the post-harvest fungicide Ortocil (ortho-phenylphenate) for the control of post-harvest diseases	327
4.5.10	The evaluation of a yeast antagonist against the possible control of post-harvest diseases	329
4.5.11	The screening of South African isolates of <i>Penicillium</i> fungal spores from all citrus production areas for resistance to the post-harvest fungicides imazalil and guazatine	331
4.5.12	The evaluation of plant growth regulators (PGRs), applied post-harvest, as possible alternatives to 2,4-D sodium salt (Deccomone) for calyx retention on citrus fruit	334
4.6	Project: Fruit and Foliar Diseases	336
4.6.1	Project summary	336
4.6.2	Evaluation of new spray programmes for the control of <i>Alternaria</i> brown spot in the winter rainfall regions of South Africa	337
4.6.3	Positioning and evaluation of new spray programmes consisting of strobilurins for the control of <i>Alternaria</i> brown spot in the summer rainfall regions of South Africa	341
4.6.4	Evaluation of spray programmes for the control of <i>Phytophthora citrophthora</i> on Clementines in the Western Cape	346
4.6.5	Susceptibility of different Clementine cultivars to <i>Phytophthora citrophthora</i>	355
4.7	CRI Diagnostic Centre	363
5	PROGRAMME: CROP LOAD AND FRUIT QUALITY MANAGEMENT	364
5.1	Programme summary	364
5.2	Project: Rind condition	364
5.2.1	Project summary	364
5.2.2	Evaluation of alternative means of controlling creasing (albedo breakdown)	365
5.2.3	Relationship of bearing position on a tree and the incidence and severity of creasing/albedo breakdown	370
5.2.4	Effect of manipulation of carbohydrate and mineral nutrient allocation in the tree on creasing incidence	381
5.2.5	Effect of elevated ethylene and CO ₂ levels on rind condition of Clementine mandarin	381
5.2.6	Ontwikkeling van voor en na-oes strategië wat die voorkoms van koueskade kan verminder in verskeie sitrus kultivars	386
5.2.7	Preharvest conditions influencing rind condition: determining the role of preharvest carbohydrate levels on rind breakdown of Nules Clementine mandarin	392
5.2.8	The influence of cold disinfestation and duration of storage on the condition of Orobancos/Sweeties exported to Japan	398
5.2.9	Hot water dip treatments to prevent chilling injury on early and late season harvested lemons exported to Japan	401

CRI GROUP ANNUAL RESEARCH REPORT 2006/7
TABLE OF CONTENTS

		Page
5.2.10	Eureka lemon physiological profile: Storage temperature and storage duration response curves for Eureka lemon harvested at different physiological maturities, with special reference to Peteca spot	402
5.2.11	Effect of changes in relative humidity and rind water status during handling of Eureka lemon on the development of Peteca spot	413
5.2.12	Effect of fruit wilting and rind water status on the development of Peteca spot in Eureka lemon fruit	416
5.2.13	Effect of different preharvest chemical treatments and wax applications on the development of Peteca spot in lemons	421
5.2.14	The effect of different citrus wax applications on the development of Peteca spot on lemons	422
5.2.15	Measuring CO ₂ and temperature during a citrus shipment to the USA	424
5.3	Project: Fruit Quality Enhancement	424
5.3.1	Project summary	424
5.3.2	Vegetative growth responses of citrus nursery trees to various growth retardants	425
5.3.3	Preharvest manipulation of chloro-chromoplast transformation by gibberellin biosynthesis inhibitor prohexadione-calcium	431
5.3.4	Improving colour of physiologically mature citrus fruit	465
5.3.5	Reduction of acidity of high acid citrus cultivars using alternatives to calcium arsenate	482
6	PROGRAMME: CULTIVAR AND ROOTSTOCK EVALUATION	489
6.1	Programme summary	489
6.2	Programme Introduction	489
6.3	Project: Cultivar evaluation	493
6.3.1	Project summary: Cape areas	493
6.3.2	Project summary: Inland areas	496
6.3.3	Evaluation of Satsuma mandarins and Primosole in the Cape areas	498
6.3.4	Evaluation of Clementine Mandarins in the Cape areas	501
6.3.5	Evaluation of Mandarin hybrids in the Cape areas	505
6.3.6	Evaluation of navel oranges in the Cape areas	509
6.3.7	Evaluation of Midseason oranges in the Cape areas	524
6.3.8	Evaluation of Valencia oranges in the Cape areas	528
6.3.9	Evaluation of existing cultivars at Lancewood, Knysna area	531
6.3.10	Evaluation of Clementine mandarins in the cool inland areas	534
6.3.11	Evaluation of Mandarin hybrids in the cool inland areas	536
6.3.12	Evaluation of Mandarin hybrids in the cool inland areas	537
6.3.13	Evaluation of navels in the cool inland areas	538
6.3.14	Evaluation of navels in the intermediate inland areas	540
6.3.15	Evaluation of Valencia selections in the inland areas (Onderberg)	542
6.3.16	Evaluation of Valencia selections in the hot inland areas (Swaziland)	544
6.3.17	Evaluation of lemon selections in the inland areas	545
6.4	Project: Rootstock evaluation	547
6.4.1	Project summary	547
6.4.2	Project summary: Cape and inland areas	549
6.4.3	Evaluation of Genoa lemon on various rootstocks in Citrusdal	552
6.4.4	Evaluation of Delta Valencia rootstock trial at Moosrivier Estate	557
6.4.5	Evaluation of Midnight and Delta Valencia rootstock trial at Letaba Estates	562
6.4.6	Evaluation of Star Ruby rootstock trial at Letaba Estates	567
6.4.7	Evaluation of navel orange rootstock trial at Vaalharts	569
6.4.8	Evaluation of Valencia orange rootstock trial at Vaalharts	574

CRI GROUP ANNUAL RESEARCH REPORT 2006/7
TABLE OF CONTENTS

		Page
	6.4.9 Evaluation of Valencias on new imported rootstocks in the Malelane area	576
	6.4.10 Evaluation of grapefruit varieties on new imported rootstocks in the Swaziland area	578
	6.4.11 Evaluation of various Valencia selections on different rootstocks in the Komatipoort area	583
7	CITRUS IMPROVEMENT PROGRAMME 2006	590
	7.1 Programme summary	590
8	INTERNATIONAL VISITS	603
	8.1 S.D. Moore - Switzerland	603
	- China and Australia	609
	8.2 G. Pietersen & H.F. le Roux - Brazil	616
	8.3 P.J.R. Cronjé - USA	619
	8.4 H.F. le Roux - USA	622
	- Zimbabwe	624
9	TECHNOLOGY TRANSFER	626
	9.1 Navorsingsprioriteite/Research Priorities 2007	626
	9.2 Tegnologie Oordragingsgroepe – TOGs (Sitrusstudiegroepe)	658
	9.3 The Relative Funding support for research programmes and projects for 2006-7	660
	9.4 Extension presentation by CRI Group researchers in 2006	662
	9.5 Other means of Technology Transfer	670
	9.5.1 S.A. Fruit Journal	670
	9.5.2 CRI website	671
	9.5.3 CRInet	671
	9.5.4 Cutting Edge	671
	9.5.5 4de Sitrusnavorsingsimposium	672
	9.6 Industrie-verwante Vergaderings	679
	9.7 Siekte- en plaagbeheer	679
	9.8 Tuinboukundige en kultivar aspekte	680
	9.9 Fitosanitêr en ekonomies	680
	9.10 Algemeen	680
10	PUBLICATIONS IN 2006	681
	10.1 Refereed publications	681
	10.2 Semi-scientific publications	681
11	PRESENTATIONS AT SOCIETAL AND INTERNATIONAL CONGRESSES	681

**CRI GROUP ANNUAL RESEARCH REPORT 2007/8
TABLE OF CONTENTS**

		Page
1	INTRODUCTION	1
2	PROGRAMME: MARKET ACCESS TECHNICAL COORDINATION	3
	2.1 Programme Summary	3
	2.2 China	4
	2.3 Europe	4
	2.4 Japan	5
	2.5 USA	6
	2.6 South Korea	7
	2.7 Thailand	8
	2.8 Israel	8
	2.9 Australia	9
	2.10 Other markets	9
3	PROGRAMME: INTEGRATED PEST MANAGEMENT	9
	3.1 Programme summary	9
	3.2 Project: False Codling Moth	11
	3.2.1 Project summary	11
	3.2.2 Final Report: Development of semiochemical odorants for the attraction and repellence of false codling moth in citrus	12
	3.2.3 Vorderingsverslag: Bestryding van VKM met Steriele Insekloslatings (SIL)	22
	3.2.4 Final Report: Understanding and improving biological control of False codling moth larvae	50
	3.2.5 Progress Report: Investigating and improving field persistence of Cryptogran	60
	3.2.6 Progress Report: The use of entomopathogenic nematodes for the control of false codling moth	82
	3.2.7 Progress Report: Determine the potential global distribution for false codling moth	87
	3.2.8 Final Progress Report: The host status of lemons for FCM	90
	3.2.9 Final Report: Spatial and temporal distribution of False Codling Moth across landscapes in the Citrusdal area (Western Cape province, South Africa)	92
	3.2.10 Progress Report: Geographic variation in the susceptibility of FCM populations to a granulovirus, CrleGV-SA (Cryptogran®)	104
	3.2.11 Final Report: Investigating post-harvest control of FCM using Xterminator and Break-Thru	111
	3.2.12 Progress Report: Monitoring the efficacy of Sterile Insect Technique to control false codling moth in the Citrusdal area (Western Cape Province, South Africa)	113
	3.2.13 Final Report: The genetic characterisation and biological activity of the South African <i>Cryptophlebia leucotreta</i> granulovirus (CrleGV-SA) in two biopesticides, Cryptogran® and Cryptex®	124
	3.3 Project: Fruit Fly	139
	3.3.1 Project summary	139
	3.3.2 Progress Report: Rearing of fruit fly	140
	3.3.3 Final Progress Report: Cold disinfestation of Medfly-infested lemons, grapefruit, oranges and Clementines using temperatures above 0°C	142
	3.3.4 Final Report: Fruit fly baits – Organophosphate alternatives	149
	3.3.5 Final Progress Report: Development of a rapid diagnostic test to distinguish Medfly larvae from other larvae	156
	3.3.6 Final Progress Report: Will fruit fly bait applications be effective if applied to the tree trunk to avoid fruit residues? In: Fruit fly – Field control other than OP substitutes	157

**CRI GROUP ANNUAL RESEARCH REPORT 2007/8
TABLE OF CONTENTS**

	Page	
3.3.7	Final Report: Differences between lures used for fruit fly monitoring. In: Fruit fly – Field control other than OP substitutes	163
3.3.8	Progress Report: Determine the potential global distributions for Natal fruit fly	174
3.3.9	Final Report: Fruit fly recovery from fruit inspected by PPECB	178
3.3.10	Final Report: Marula fruit fly survival in citrus fruit and bait efficacy	180
3.3.11	Final Report: Fruit fly damage reduction and management of male fruit fly numbers	182
3.4	Project: Cosmetic Pests	185
3.4.1	Project summary	185
3.4.2	Final Progress Report: Evaluation of the <i>Helicoverpa armigera</i> nuclearpolyhedrovirus (HearNPV) for control of bollworm on citrus	186
3.4.3	Final Progress Report: Develop a rearing technique for the citrus thrips parasitoid <i>Goetheana incerta</i>	191
3.4.4	Progress Report: Investigation of entomopathogenic fungi for control of citrus thrips	192
3.4.5	Progress Report: Improving management of citrus grey mite, <i>Calacarus citrifolii</i>	194
3.4.6	Progress Report: Alternative chemicals for citrus bud mite control	194
3.5	Project: Mealybug and other phytosanitary pests	198
3.5.1	Project summary	198
3.5.2	Final Report: Investigating biocontrol agents of mealybug species other than citrus mealybug	198
3.5.3	Final Report: Evaluation of <i>Planococcus citri</i> pheromone traps for monitoring infestation levels	201
3.5.4	Final Report: Using Break-Thru to improve corrective control of mealybug on citrus	208
3.5.5	Progress Report: Biology of the oleander mealybug, <i>Planococcus burnerae</i>	211
3.5.6	Final Report: Development of laboratory culture methods for grain chinch bug, <i>Macchiademus diplopterus</i> and initial assessment of irradiation as a post harvest control treatment against this pest	213
3.6	Project: Biocontrol Disruption	215
3.6.1	Project summary	215
3.6.2	Final Progress Report: To develop an ant repellent that will keep ants out of citrus trees without destroying their nest	215
3.6.3	Progress Report: Development of ant baits and the use of bait stations	216
3.7	Project: Production Pests	221
3.7.1	Project summary	221
3.7.2	Evaluation of the efficacy of oil with Break-Thru for red scale control	222
3.8	Project: Residue trials for PHI and MRL Development	224
3.8.1	Project summary	224
3.8.2	Final Progress Report: Methamidophos residue trials	224
3.8.3	Final Progress Report: Triflumuron residue trials	227
3.8.4	Final Progress Report: Malathion residue trials	231
3.8.5	Final Progress Report: Buprofezin residue trials	235
3.8.6	Final Report: Methiocarb residue trials	239
3.8.7	Final Report: Tetradifon residue trials	242

**CRI GROUP ANNUAL RESEARCH REPORT 2007/8
TABLE OF CONTENTS**

		Page
4	PROGRAMME: DISEASE MANAGEMENT	246
4.1	Programme summary	246
4.2	Project: Graft Transmissible Diseases	249
4.2.1	Projekopsomming	249
4.2.2	Progress Report: Diagnostic services for graft transmissible diseases	251
4.2.3	Progress Report: Citrus virus-free gene source	256
4.2.4	Progress Report: Dynamics of <i>Citrus tristeza virus</i> mild and severe strains in mild strain cross-protection strategies	259
4.2.5	Progress Report: The response of different red grapefruit cultivars to <i>Citrus tristeza virus</i>	265
4.2.6	Progress Report: Cross-pollination of Marsh and Star Ruby grapefruit using Beltsville sub-isolates of Nartia mild strain	270
4.2.7	Progress Report: Cross-protection of Marsh and Star Ruby using Beltsville sub-isolates of Nartia mild strain for the Orange River Valley	274
4.2.8	Progress Report: Cross-protection of Marsh and Star Ruby by using the best field isolates collected in the different grapefruit production areas of southern Africa	276
4.2.9	Progress Report: The effect of CTV pre-immunisation on the fruit size of Clementine and Satsuma	277
4.2.10	Progress Report: Identification of suitable <i>Citrus tristeza virus</i> sources for pre-immunising Turkey Valencia	281
4.2.11	Progress Report: Evaluation of CTV sources in Valencia	283
4.2.12	Progress Report: The effect of different CTV sources in Valencias on different rootstock combinations for the Orange River Valley	287
4.2.13	Final Report: Screening of rootstocks for Citrus Blight tolerance	288
4.2.14	Progress Report: Evaluation of citrus material for greening resistance	294
4.2.15	Progress Report: Eradication of citrus greening infections in existing orchards	299
4.2.16	Progress Report: Epidemiology of greening disease – alternate hosts and spread	305
4.2.17	Progress Report: Epidemiology of greening disease-variability	309
4.3	Project: Citrus Black Spot	312
4.3.1	Project summary	312
4.3.2	Final Report: Evaluation of a newly developed fungicide, new copper and mancozeb formulations, tank mixtures of strobilurins with copper fungicides and several different adjuvants for the control of citrus black spot on Valencias	314
4.3.3	Final Report: Reducing the inoculum potential in leaves by applying fungicides to citrus trees in the orchard	324
4.3.4	Final Report: The status of strobilurin resistance in citrus orchards	329
4.3.5	Final Report: Evaluation of leaf litter inoculum potential on the orchard floor as affected by the irrigation systems	336
4.3.6	Final Report: Determining the role of <i>Guignardia citricarpa</i> and <i>Guignardia mangiferae</i> in the CBS complex	341
4.3.7	Final Report: Development of a protocol for the accreditation of nurseries and orchards	343
4.3.8	Progress Report: Epiphytic and endophytic occurrence of <i>Guignardia citricarpa</i> on twigs	345
4.3.9	Progress Report: Development of a Citrus Black Spot (CBS) Disease Forecasting model	347
4.4	Project: Soilborne Diseases	347
4.4.1	Projekopsomming	347

**CRI GROUP ANNUAL RESEARCH REPORT 2007/8
TABLE OF CONTENTS**

		Page
4.4.2	Progress Report: Evaluation of a new organic product for the control of the citrus nematode	349
4.4.3	Progress Report: To evaluate alternative nematode control products as part of an integrated nematode control approach in citrus replant situations	349
4.4.4	Final Progress Report: Synchronizing egg hatching in citrus nematodes	350
4.4.5	Final Report: Evaluation of a combination of different chemical compounds, a biological control product, silicon and non-toxic products for the control of nematodes in citrus	357
4.4.6	Progress Report: Characterization of <i>Phytophthora</i> species from various South African citrus production regions	365
4.4.7	Progress Report: Control of <i>Phytophthora</i> trunk and branch canker on Clementines in the Western Cape	370
4.4.8	Update: Susceptibility of citrus cultivars to <i>Phytophthora citrophthora</i>	381
4.4.9	Progress Report: Determine the efficacy of phosphonates applied through the irrigation system on citrus for control of <i>Phytophthora</i> root rot	384
4.5	Project; Post-harvest Pathology	393
4.5.1	Project summary	393
4.5.2	Progress Report: Provision of an industry service whereby new packhouse treatments are comparatively evaluated, fungicide resistance is monitored and standardised recommendations are provided	395
4.5.3	Progress Report: The evaluation of plant growth regulators (PGR's), applied post-harvest, as possible alternatives to 2,4-D sodium salt (Deccomone) for calyx retention on citrus fruit	417
4.5.4	Progress Report: Occurrence of <i>Penicillium</i> spp. in the citrus supply chain	419
4.5.5	Progress Report: Development of alternative disease control products	422
4.5.6	Progress Report: Imazalil and guazatine fungicide resistance screening of dominant <i>Penicillium</i> species isolated from all citrus producing regions in South Africa	430
4.6	Project: Fruit and Foliar Diseases	434
4.6.1	Projekopsomming	434
4.6.2	Progress Report: New spray programmes for the control of <i>Alternaria</i> brown spot in the winter rainfall region of South Africa	435
4.6.3	Progress Report: Positioning and evaluation of new spray programmes consisting of strobilurins for the control of <i>Alternaria</i> brown spot in the summer rainfall regions of South Africa	437
4.6.4	Progress Report: Optimisation of fungicide spray applications in citrus orchards	447
4.7	CRI Diagnostic Centre	459
5	PROGRAMME: CROP AND FRUIT QUALITY MANAGEMENT	461
5.1	Programme summary	461
5.2	Project: Rind Condition	462
5.2.1	Project summary	462
5.2.2	Progress Report: Evaluation of alternative means of controlling creasing (albedo breakdown)	464

**CRI GROUP ANNUAL RESEARCH REPORT 2007/8
TABLE OF CONTENTS**

	Page
5.2.3	470
5.2.4	470
5.2.5	476
5.2.6	480
5.2.7	483
5.2.8	485
5.2.9	489
5.2.10	492
5.3	494
5.3.1	494
5.3.2	496
5.3.3	508
5.3.4	518
5.3.5	525
5.3.6	530
6	551
6.1	551
6.2	551
6.2.1	551
6.2.2	554
6.2.3	556
6.2.4	558
6.2.5	562
6.2.6	564
6.2.7	566
6.2.8	571
6.3	573
6.3.1	573
6.3.2	574
6.3.3	578
6.3.4	586
6.3.5	589

**CRI GROUP ANNUAL RESEARCH REPORT 2007/8
TABLE OF CONTENTS**

		Page
	6.3.6 Evaluation of Grapefruit varieties on new imported rootstocks in the Swaziland area	592
	6.3.7 Evaluation of various Valencia selections on different rootstocks in the Komatipoort area	600
	6.3.8 Colour charts for Star Ruby, Rosé and lemons. Sheepnose charts for Star Ruby and rind quality charts for lemons	606
	6.3.9 Other activities	607
7	CITRUS IMPROVEMENT PROGRAMME	609
	7.1 Programme Summary	609
8	INTERNATIONAL VISITS	621
	8.1 G.C. Schutte (Brazil)	621
	8.2 G. Pietersen and S.P. van Vuuren (Turkey)	631
	8.3 S.D. Moore (Switzerland)	647
	8.4 K.H. Lesar (Italy)	652
	8.5 P.H. Fourie (Australia)	659
9	TECHNOLOGY TRANSFER	665
	9.1 Navorsingsprioriteite / Research priorities – 2008	665
	9.2 Tegnologie Oordragingsgroepe (TOG's)	721
	9.3 Die relatiewe befondsingsondersteuning vir navorsingsprogramme en projekte vir 2007	723
	9.4 Voorligtingsaanbiedings deur CRI groep navorsers in 2007	725
	9.5 Ander maniere van tegnologie oordraging	741
	9.6 Industrie-verwante vergaderings	743
	9.7 Siekte- en plaagbeheer	744
	9.8 Tuinboukundige en kultivar aspekte	744
	9.9 Fitosanitêr	745
	9.10 Transformasie	745
10	PUBLICATIONS IN 2007-8	749
	10.1 Refereed publications (or ISI ranked journals)	749
	10.2 Semi-scientific publications	749
11	PRESENTATIONS AT SOCIETAL AND INTERNATIONAL CONGRESSES	750

**CRI GROUP ANNUAL RESEARCH REPORT 2008/9
TABLE OF CONTENTS**

		Page
1	INTRODUCTION	1
2	PROGRAMME: MARKET ACCESS TECHNICAL COORDINATION & BIOSECURITY	4
	2.1 Programme summary	4
	2.2 Biosecurity	5
	2.3 Europe	5
	2.4 Japan	6
	2.5 USA	7
	2.6 South Korea	7
	2.7 China	8
	2.8 Thailand	8
	2.9 Australia	8
	2.10 Other markets	8
	2.10.1 Vietnam	8
	2.10.2 Lebanon	8
	2.10.3 Malaysia	8
	2.10.4 Philippines and Syria	8
3	PROGRAMME: INTEGRATED PEST MANAGEMENT	9
	3.1 Programme summary	9
	3.2 Project: False Codling Moth	11
	3.2.1 Project summary	11
	3.2.2 Vorderingsverslag: Bestryding van VKM met Steriele Insekloslatings	12
	3.2.3 Final report: Understanding and improving biological control of false codling moth larvae	42
	3.2.4 Vorderingsverslag: Ontwikkeling van 'n uitvoerprotokol vir die bestryding van valskodlingmotlarwes in verpakte vrugte met behulp van gammabestraling	45
	3.2.5 Progress report: Investigating and improving field persistence of Cryptogran	46
	3.2.6 Progress report: The use of entomopathogenic nematodes for the control of false codling moth	70
	3.2.7 Progress report: Improvement of cold treatment conditions for the disinfestation of false codling moth in citrus fruit, using a potentiating CO ₂ shock treatment	74
	3.2.8 Final report: Geographic variation in the susceptibility of FCM populations to a granulovirus, CRleGV-SA	78
	3.2.9 Vorderingsverslag: Die ontwikkeling van middels wat as lok- of afdryfmiddels teen VKM-wyfies en mannetjies gebruik kan word	91
	3.2.10 Progress report: Monitoring the efficacy of Sterile Insect Technique to control false codling moth in the Citrusdal area (Western Cape Province, South Africa)	91
	3.2.11 Vorderingsverslag: Doeltreffendheid van die insekdoder EXP5225 (200 g/l SC) in kombinasie met 'n Steriele-Insek Loslaatprogram	116
	3.2.12 Progress report: The efficacy of the insecticide EXP5225 (200 g/l SC) for control of false codling moth in the Eastern Cape	119
	3.2.13 Progress report: Development of bioassay techniques, genetic characterization and biological activity of South African <i>Cryptophlebia leucotreta</i> Granulovirus (CrleGV-SA) in biopesticides, Cryptex® and Cryptogran®	123
	3.3 Project: Fruit Flies	132
	3.3.1 Project summary	132
	3.3.2 Progress report: Fruit fly rearing	134

CRI GROUP ANNUAL RESEARCH REPORT 2008/9
TABLE OF CONTENTS

		Page
3.3.3	Progress report: Determine the potential global distributions for Natal fruit fly and false codling moth	139
3.3.4	Progress report: A new bait for more effective control of all <i>Ceratitis</i> fruit flies	143
3.3.5	Final report: Fewer fruit fly bait stations for larger areas	152
3.3.6	Progress report: Fruit fly damage reduction and management of male fruit fly numbers	158
3.3.7	Progress report: Cold disinfestation of <i>Bactrocera invadens</i> in citrus	164
3.3.8	Progress report: Feasibility of using male annihilation techniques for suppression of <i>Bactrocera invadens</i> and <i>Ceratitis</i> spp in mango orchards in northern Benin	169
3.3.9	Progress report: Ethyl formate as a fumigant for fruit fly and other phytosanitary pests	173
3.3.10	Progress report: The role of interspecific competition in regulating populations of <i>C. capitata</i> and <i>C. rosa</i>	174
3.3.11	Progress report: Cold tolerance of Natal fruit fly (<i>Ceratitis rosa</i>): geographic distribution and overwintering physiology	176
3.3.12	Progress report: Investigation of entomopathogenic fungi for control of false codling moth and fruit flies	186
3.4	Project: Cosmetic Pests	202
3.4.1	Project summary	202
3.4.2	Progress report: Improving management of citrus grey mite, <i>Calacarus citrifolii</i>	202
3.4.3	Progress report: Investigation of entomopathogenic fungi for control of citrus thrips	206
3.4.4	Progress report: Alternative chemicals for citrus bud mite control	206
3.4.5	Final report: Control options for the lemon borer moth	207
3.4.6	Progress report: Treatments for the control of leafhoppers on citrus	213
3.5	Project: Mealybug and other Phytosanitary pests	215
3.5.1	Project summary	215
3.5.2	Progress report: Biology of the oleander mealybug, <i>Paracoccus burnerae</i>	215
3.5.3	Progress report: <i>Leptomastix</i> spp. as biocontrol agents for control of mealybug, with particular reference to oleander mealybug, <i>Paracoccus burnerae</i>	223
3.6	Project: Biocontrol Disruption	226
3.6.1	Project summary	226
3.6.2	Progress report: Development of ant baits and the use of bait stations	227
3.6.3	Progress report: Non-target effect testing for RJU37PY, a new acaricide for citrus bud mite control	234
3.7	Project: Production Pests	244
3.7.1	Project summary	244
3.7.2	Final report: Development of a bee repellent to prevent cross-pollination of seedless cultivars	245
4	PROGRAMME: DISEASE MANAGEMENT	249
4.1	Programme summary	249
4.2	Project: Graft Transmissible Diseases	252
4.2.1	Project summary	252

**CRI GROUP ANNUAL RESEARCH REPORT 2008/9
TABLE OF CONTENTS**

	Page	
4.2.2	Progress report: Cross-protection of Marsh and Star Ruby grapefruit using Beltsville sub-isolates of Nartia mild strain	254
4.2.3	Progress report: Cross-protection of Star Ruby using Beltsville subisolates of Nartia mild strain for the Orange River Valley	258
4.2.4	Progress report: The effect of different CTV sources in Valencias on different rootstock combinations for the Orange River Valley	260
4.2.5	Progress report: Cross-protection of Marsh and Star Ruby by using the best field isolates collected in the different grapefruit production areas of southern Africa	262
4.2.6	Final report: The response of different red grapefruit cultivars to <i>Citrus tristeza</i> virus	265
4.2.7	Progress report: Evaluation of <i>Citrus tristeza</i> virus sources in Valencia	271
4.2.8	Progress report: Identification of suitable <i>Citrus tristeza</i> virus sources for pre-immunizing Turkey Valencia	275
4.2.9	Final report: The effect of CTV pre-immunisation on the fruit size of Clementine and Satsuma	277
4.2.10	Progress report: Dynamics of citrus <i>tristeza</i> virus mild and severe strains in mild strain cross-protection strategies	281
4.2.11	Progress report: Recovering and evaluation of embryo rescued plants for genetic greening resistance	296
4.2.12	Progress report: Eradication of citrus greening infections in existing orchards	300
4.2.13	Progress report: Epidemiology of greening disease – alternate hosts and spread	305
4.2.14	Progress report: Epidemiology of greening disease – variability	309
4.2.15	Progress report: Epidemiology of greening disease – seed transmission	313
4.3	Project: Fruit and Foliar Diseases	316
4.3.1	Project summary	316
4.3.2	Progress report: Evaluation of new spray programmes for the control of <i>Alternaria</i> brown spot in the summer rainfall regions of South Africa	317
4.3.3	Progress report: Evaluation of a Spanish prediction model for <i>Alternaria</i> brown spot of mandarins	324
4.3.4	Progress report: Optimisation of fungicide spray applications in citrus orchards	331
4.4	Projek: Grondgedraagdesiektes	344
4.4.1	Projekopsomming	344
4.4.2	Progress report: To evaluate alternative nematode control products, i.e. Biofumigants, as part of an integrated nematode control approach in citrus replant situations	345
4.4.3	Progress report: An integrated approach to ensure root and plant health	347
4.4.4	Progress report: Characterization of <i>Phytophthora</i> species from various South African citrus production regions	353
4.4.5	Progress report: Control of <i>Phytophthora</i> trunk and branch canker on Clementines in the Western Cape	364
4.4.6	Final report: Determine the efficacy of phosphonates applied through the irrigation systems in citrus for control of <i>Phytophthora</i> root rot	370
4.4.7	Progress report: The effect of compost, amended with beneficial organisms, applied as soil treatments, on tree condition and general disease resistance	378
4.4.8	Evaluation of a new biological control product for the control of the citrus nematode	381
4.4.9	Evaluation of a new nematicide for the control of the citrus nematode	381
4.4.10	Evaluation of a new safer nematicide for the control of the citrus nematode	382

**CRI GROUP ANNUAL RESEARCH REPORT 2008/9
TABLE OF CONTENTS**

	Page	
4.5	Project: Post-harvest Pathology	382
4.5.1	Project summary	382
4.5.2	Progress report: Provision of an industry service whereby new packhouse treatments are comparatively evaluated, fungicide resistance is monitored and standardized recommendations are provided	384
4.5.3	Progress report: The screening of potential alternative products as replacements for 2,4-D as a post-harvest treatment in citrus packhouses	398
4.5.4	Progress report: The synergistic use of GRAS chemicals for citrus postharvest disease control	400
4.5.5	Progress report: Practical guidelines for good post-harvest handling of citrus fruit	405
4.5.6	Progress report: Optimisation of fungicide application in citrus packhouses	415
4.5.7	Progress report: Occurrence of <i>Penicillium</i> spp. in the citrus supply chain and improving the citrus export chain through determining critical control points	429
4.5.8	Final report: Development of alternative disease control products	434
4.5.9	Progress report: Screening of South African <i>Penicillium</i> isolates from citrus producing regions for resistance to the postharvest fungicides imazalil and guazatine	446
4.6	Projek: Swartvlek	452
4.6.1	Projekopsomming	452
4.6.2	Final report: Evaluation of a newly developed fungicide, new copper and mancozeb formulations, tank mixtures of strobilurins with copper fungicides and several different adjuvants for the control of citrus black spot on Valencias	455
4.6.3	Final report: Further developments of spray programmes consisting of registered fungicides in tank mixtures with didecyldimethylammonium chloride (DDAC) for the control of citrus black spot in South Africa, Brazil and Argentina	461
4.6.4	Progress report: Determining the persistency of copper fungicides as sprayed under natural conditions for the control of citrus black spot	468
4.6.5	Monitoring ascospore releases in the Eastern Cape to determine the critical period for CBS infection	475
4.6.6	Progress report: A holistic approach for the reduction of <i>Guignardia citricarpa</i> ascospore inoculums	479
5	PROGRAMME: CROP LOAD AND FRUIT QUALITY MANAGEMENT	485
5.1	Programme summary	485
5.2	Project: Rind condition	486
5.2.1	Project summary	486
5.2.2	Progress report: Evaluation of alternative means of controlling creasing (albedo breakdown)	487
5.2.3	Progress report: Relationship of bearing position of fruit on a tree and creasing incidence	491
5.2.4	Progress report: Effect of the manipulation of light, carbohydrate and mineral nutrient allocation in the tree on creasing incidence	500
5.2.5	Progress report: The evaluation of alternative methods of uptake of products and plant growth regulators to reduce the incidence of creasing	506
5.2.6	Progress report: Effect of different products on root activity and creasing incidence	510
5.2.7	Progress report: Hot water dip treatments to prevent chilling injury (CI) on early season harvested lemons, grapefruit and Oroblancos exported to Japan	511
5.2.8	Progress report: The influence of citrus waxes on rind defects on sensitive citrus cultivars during shipping	514
5.2.9	Progress report: Peteca spot of lemons	517
5.2.10	The evaluation of postharvest operational issues and the effect of different citrus wax applications on the development of peteca spot on lemons	519

**CRI GROUP ANNUAL RESEARCH REPORT 2008/9
TABLE OF CONTENTS**

	Page
5.2.11 Final report: The effect of light and competition on the development of rind disorders	522
5.2.11.3 Accumulation of K, Mg and Ca during 'Nules Clementine' mandarin flavour development as influenced by canopy position	522
5.2.11.4 Canopy position affects reducing and nonreducing sugar accumulation in the flavedo of 'Nules Clementine' mandarin fruit	537
5.2.11.5 The incidence of rind breakdown of 'Nules Clementine' mandarin fruit is influenced by exposure to sunlight	552
5.2.11.6 Foliar applications of Mg and Ca reduces the incidence of rind breakdown of 'Nules Clementine' mandarin fruit	566
5.2.11.7 Postharvest pigment and carbohydrate changes in relation to the incidence of rind breakdown of 'Nules Clementine' mandarin fruit	577
5.3 Project: Fruit Production and Quality	612
5.3.1 Project summary	612
5.3.2 Final report: Economic benefit of hand thinning	613
5.3.3 Progress report: Effect of 2,4-dichlorophenoxyacetic acid (2,4-D) on the size of the navel end opening of navel oranges	621
5.3.4 Progress report: Monitoring irrigation, nitrogen stress and phenology of citrus trees using physiological and remote sensing approaches	630
6 PROGRAMME: CULTIVAR AND ROOTSTOCK EVALUATION	640
6.1 Programme summary	640
6.2 Project: Cultivar Evaluations	640
6.2.1 Project summary	640
6.2.2 Evaluation of Valencia selections in the inland areas (Onderberg)	644
6.2.3 Evaluation of Valencia selections in the inland areas (Letsitele)	647
6.2.4 Evaluation of lemon selections in the inland areas	651
6.2.5 Evaluation of Valencia selections in the hot inland areas (Swaziland)	655
6.3 Project: Rootstock Evaluations	658
6.3.1 Project summary	658
6.3.2 Evaluation of Valencias on new imported rootstocks in the Malelane area	660
6.3.3 Evaluation of Grapefruit varieties on new imported rootstocks in the Swaziland area	663
6.3.4 Evaluation of various Valencia selections on different rootstocks in the Komatipoort area	669
6.3.5 Evaluation of Limpopo Seedless Valencia on four different rootstocks in the Weipe area	680
6.3.6 Evaluation of Genoa lemon on various rootstocks in Citrusdal, Western Cape	683
6.3.7 Cultivar characteristics and climatic suitability of Navel oranges in the cold production regions	686
6.3.8 Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region	695
6.3.9 Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region	695
6.3.10 Cultivar characteristics and climatic suitability of Oranges in a cold production region	696
6.3.11 Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region	696
6.3.12 Cultivar characteristics and climatic suitability of Midseason oranges in a cold production region	702

**CRI GROUP ANNUAL RESEARCH REPORT 2008/9
TABLE OF CONTENTS**

		Page
	6.3.13 Cultivar characteristics and climatic suitability of Valencia oranges in a cold production region	702
7	CITRUS IMPROVEMENT SCHEME (CIS)	711
	7.1 Programme summary	711
8	INTERNATIONAL VISITS	726
	8.1 Combined report on visit to Wuhan, China	726
	8.2 M.M.N. du Toit (China)	747
	8.3 P.H. Fourie (Chile)	756
	8.4 G.C. Schutte (Italy and Argentine/Uruguay)	763
	8.5 G. Pietersen (Florida, USA)	783
	8.6 M.C. Pretorius (Australia, USA & Ghana)	789
	8.7 J.J. Bester (Spain)	823
9	VOORLIGTINGSDEPARTEMENT	832
	9.1 Tegnologieoordraging	832
	9.2 Extension Coordinator	840
	9.3 PHIP/CRI Citrus Rind Condition Workshop	842
	9.4 Relative funding support for research programmes and projects for 2008-09	844
	9.5 Extension presentations by CRI Group Researchers in 2008-9	846
	9.6 Other means of Technology Transfer	857
	9.6.1 SA Fruit Journal	857
	9.6.2 CRI website	857
	9.6.3 CRInet	858
	9.6.4 Cutting Edge	858
10	PUBLICATIONS IN 2008-9	859
	10.1 Refereed publications (or ISI ranked journals)	859
	10.2 Semi-scientific publications	859
11	PRESENTATIONS AT SOCIETAL AND INTERNATIONAL CONGRESSES	860

**CRI GROUP ANNUAL RESEARCH REPORT 2009/10
TABLE OF CONTENTS**

		Page
1	INTRODUCTION	1
2	MARKET ACCESS TECHNICAL COORDINATION & BIOSECURITY	2
	2.1 Summary	2
	2.2 Europe (EU)	3
	2.3 Japan	4
	2.4 USA	5
	2.5 China	6
	2.6 South Korea	6
	2.7 New Markets	6
	2.8 Biosecurity	7
3	PROGRAMME: INTEGRATED PEST MANAGEMENT	7
	3.1 Programme summary	7
	3.2 Project: False Codling Moth	9
	3.2.1 Project summary 9	
	3.2.2 Vorderingsverslag: Bestryding van Valskodlingmot met Steriele Insekloslatings	11
	3.2.3 Vorderingsverslag: Ontwikkeling van 'n uitvoerprotokol vir die bestryding van Valskodlingmotlarwes in verpakte vrugte met behulp van gammabestraling	20
	3.2.4 Progress report: Investigating and improving field persistence of <i>Cryptogran</i>	21
	3.2.5 Progress report: The use of entomopathogenic nematodes for the control of false codling moth	30
	3.2.6 Progress report: Monitoring the efficacy of Sterile Insect Technique to control false codling moth in the Citrusdal area (Western Cape Province, South Africa)	33
	3.2.7 Progress summary: Investigation of the potential for the development of a locally produced mating disruption system	65
	3.2.8 Final report: Comparative fitness of laboratory reared false codling moth (FCM) from different regions of South Africa	65
	3.2.9 Progress report: Studies on existing and new isolates of <i>Cryptophlebia leucotreta</i> granulovirus (CrleGV) on FCM populations from a range of geographic regions in South Africa	75
	3.2.10 Progress summary: Amelioration of the post-harvest cold treatment regime for FCM with the use of carbon dioxide	82
	3.2.11 Finale verslag: Evaluasie van EXP5225 (200 g/liter) teen valskodlingmotlarwes en eiers in laboratoriumproewe	82
	3.2.12 Progress report: The efficacy of the insecticide EXP5225 for control of false codling moth in the Eastern Cape	85
	3.2.13 Progress report: Evaluation of Checkmate FCM-F for the control of false codling moth	91
	3.3 Project: Fruit Flies	96
	3.3.1 Project summary	96
	3.3.2 Progress report: Fruit fly rearing 98	
	3.3.3 Final report: Determine the potential global distributions for Natal fruit fly and false codling moth	102
	3.3.4 Progress summary: A new bait for more effective control of all <i>Ceratitis</i> fruit flies	111
	3.3.5 Final report: Fruit fly damage reduction and management of male fruit fly numbers	111
	3.3.6 Progress summary: Cold disinfestation of <i>Bactrocera invadens</i> in citrus	118
	3.3.7 Progress summary: Male annihilation technique and baiting for field control of <i>Bactrocera invadens</i>	119
	3.3.8 Progress summary: Ethyl formate as a fumigant for fruit fly and other phytosanitary pests	119

**CRI GROUP ANNUAL RESEARCH REPORT 2009/10
TABLE OF CONTENTS**

	Page
3.3.9	Progress summary: The role of interspecific competition in regulating populations of <i>C. capitata</i> and <i>C. rosa</i> 120
3.3.10	Final report: Investigation of entomopathogenic fungi for control of false codling moth, <i>Thaumatotibia leucotreta</i> , Mediterranean fruit fly, <i>Ceratitis capitata</i> and Natal fruit fly, <i>C. rosa</i> in South African citrus 120
3.3.11	Progress summary: Cold tolerance of Natal fruit fly (<i>Ceratitis rosa</i>): geographic distribution and overwintering physiology 151
3.3.12	Progress report: Surveillance of <i>B. invadens</i> in commercial citrus orchards in South Africa 152
3.4	Project: Cosmetic Pests 156
3.4.1	Project summary 156
3.4.2	Progress report: Improving management of citrus grey mite, <i>Calacarus citrifolii</i> 157
3.4.3	Final report: Alternative chemicals for citrus bud mite control 159
3.4.4	Final report: Preventing contamination of packed fruit by beetle mites (Oribatida) 164
3.4.5	Progress report: Treatments for the control of leafhoppers on citrus 166
3.5	Project: Mealybug and other Phytosanitary pests 167
3.5.1	Project summary 167
3.5.2	Final report: <i>Leptomastix</i> spp. as biocontrol agents for control of mealybug, with particular reference to oleander mealybug, <i>Paracoccus burnerae</i> 168
3.5.3	Progress report: The impact of 2,4-D induced navel end size reduction on pest infestation of fruit 171
3.5.4	Vorderingsverslag: Evaluasie van gammabestraling as 'n na-oesbehandeling vir sitruswitluis, <i>Planococcus citri</i> (Risso) 179
3.5.5	Progress report: Determination of Buprofezin residues on soft citrus and lemons for residue decline study 183
3.5.6	Final report: Biology of the oleander mealybug, <i>Paracoccus burnerae</i> 186
3.6	Project: Biocontrol disruption 198
3.6.1	Project summary 198
3.6.2	Progress report: Development of ant baits and the use of bait stations 198
3.6.3	Progress summary: Contract non-target effect testing of two new plant protection products 201
4	PROGRAMME: DISEASE MANAGEMENT 203
4.1	Programme summary 203
4.2	Project: Graft Transmissible Diseases 206
4.2.1	Project summary 206
4.2.2	Progress summary: Dynamics of citrus tristeza virus mild and severe strains in mild strain cross-protection strategies 208
4.2.3	Progress summary: Cross-protection of Marsh and Star Ruby grapefruit using Beltsville sub-isolates of Nartia mild strain 209
4.2.4	Progress summary: Cross-protection of Star Ruby using Beltsville sub-isolates of Nartia mild strain for the Orange River Valley 210
4.2.5	Progress summary: Cross-protection of Marsh and Star Ruby by using the best field isolates collected in the different grapefruit production areas of southern Africa 210
4.2.6	Final report: Evaluation of <i>Citrus tristeza virus</i> sources in Valencia 211
4.2.7	Progress summary: The effect of different CTV sources in Valencias on different rootstock combinations for the Orange River Valley 216
4.2.8	Progress summary: Identification of suitable <i>Citrus tristeza virus</i> sources for pre-immunising Turkey Valencia 216

**CRI GROUP ANNUAL RESEARCH REPORT 2009/10
TABLE OF CONTENTS**

	Page
4.2.9 Progress summary: Searching for a <i>Citrus tristeza virus</i> source suitable for cross protecting soft citrus	217
4.2.10 Final report: Epidemiology of greening disease-variability	217
4.2.11 Progress summary: Epidemiology of greening disease – alternate hosts and spread	228
4.2.12 Progress summary: Epidemiology of greening disease – seed transmission	228
4.2.13 Progress summary: Evaluation of citrus material for greening resistance	229
4.2.14 Progress summary: Eradication of citrus greening infections in existing orchards	230
4.3 Project: Fruit and Foliar Diseases	230
4.3.1 Projekopsomming	230
4.3.2 Progress report: Evaluation of new spray programmes for the control of <i>Alternaria</i> brown spot in the summer rainfall regions of South Africa	231
4.3.3 Final report: Evaluation of a Spanish prediction model for <i>Alternaria</i> brown spot in mandarins	239
4.3.4 Progress summary: Optimisation of fungicide spray applications in citrus orchards	253
4.3.5 Final report: Evaluation of selected adjuvants for application in southern African citrus orchards	253
4.4 Project: Soilborne Diseases	268
4.4.1 Project summary	268
4.4.2 Progress summary: The evaluation of different pre-plant products for the control of the citrus nematode, as part of an integrated nematode control approach in citrus replant situations	270
4.4.3 Progress summary: An integrated approach to ensure root and plant health	271
4.4.4 Progress summary: Characterization of <i>Phytophthora</i> species from various South African citrus production regions	272
4.4.5 Progress summary: Rootstock resistance against <i>Phytophthora</i> root rot	272
4.4.6 Progress summary: The effect of compost, amended with beneficial organisms, applied as soil treatments, on tree conditions and general disease resistance	273
4.4.7 Progress summary: Control of <i>Phytophthora</i> trunk and branch canker on Clementines in the Western Cape	274
4.4.8 Contract research: Evaluation of a new nematicide for the control of the citrus nematode	274
4.4.9 Contract research: Evaluation of a new safer nematicide for the control of the citrus nematode	275
4.4.10 Contract research: Evaluation of a product with possible SAR characteristics for the control of citrus greening bacteria in citrus orchards	275
4.5 Project: Post-Harvest Pathology	275
4.5.1 Project summary	275
4.5.2 Progress report: Provision of an industry service whereby new packhouse treatments are comparatively evaluated, fungicide resistance is monitored and standardised recommendations are provided	277
4.5.3 Progress report: The synergistic use of GRAS chemicals for citrus postharvest disease control	289
4.5.4 Progress summary: Practical guidelines for good postharvest handling of citrus fruit	294
4.5.5 Progress summary: Optimisation of fungicide application in citrus orchards	294
4.5.6 Progress summary: Practical resistance evaluation of imazalil and guazatine resistant <i>Penicillium</i> isolates in simulated trials	295

**CRI GROUP ANNUAL RESEARCH REPORT 2009/10
TABLE OF CONTENTS**

		Page
4.5.7	Final report: Screening of South African <i>Penicillium</i> isolates from citrus producing regions for resistance to the postharvest fungicides imazalil, guazatine and thiabendazole	296
4.5.8	Progress summary: Occurrence of <i>Penicillium</i> spp. in the citrus supply chain and improving the citrus export chain through determining critical control points	307
4.5.9	Progress summary: Alternative measures for control of postharvest diseases	308
4.5.10	Progress report: The screening of potential alternative products as Replacements for 2,4-D as a post-harvest treatment in citrus packhouses	309
4.6	Project: Citrus Black Spot	311
4.6.1	Projekopsomming	311
4.6.2	Progress summary: Development of new spray programmes for the control of citrus black spot	312
4.6.3	Progress summary: Monitoring ascospore releases in the Eastern Cape to Determine the critical period of CBS infection	312
4.6.4	Progress summary: A holistic approach for the reduction of <i>Guignardia Citricarpa</i> ascospore inoculums	313
4.6.5	Final report: Retention and persistence of copper fungicides on Valencia and navel orange fruit and leaves by fluorescent pigment deposition analyses	313
4.6.6	Final report: <i>In vitro</i> ascospore production of <i>Guignardia citricarpa</i>	323
5	PROGRAMME: CROP AND FRUIT QUALITY MANAGEMENT	327
5.1	Programme summary	327
5.2	Project: Rind Condition	327
5.2.1	Project summary	327
5.2.2	Final report: Evaluation of alternative means of controlling creasing (albedo Breakdown): determination of the most effective timing of gibberellic acid (GA3) application to reduce the incidence of creasing	329
5.2.3	Final report: Relationship of bearing position of fruit on a tree and creasing incidence	334
5.2.4	Final report: Effect of the manipulation of light, carbohydrate and mineral nutrient allocation in the tree on creasing incidence	351
5.2.5	Final report: The evaluation of alternative methods of uptake of products and plant growth regulators to reduce the incidence of creasing	357
5.2.6	Final report: Effect of different root biostimulants on the incidence on the incidence and severity of creasing	362
5.2.7	Progress report: Development of post-harvest treatments to prevent the incidence of chilling injury in citrus	366
5.2.8	Final report: Hot water dip treatments to prevent chilling injury (CI) on early season harvested lemons, grapefruit and Oroblancos exported to Japan	371
5.2.9	Progress report: Development of laboratory based biochemical methods to determine the physiological condition of the flavedo	375
5.2.10	Progress report: Preliminary studies on aspects concerning rind pitting/ staining of Valencia fruit	384
5.2.11	Progress report: Peteca spot of lemons	387
5.2.12	Final report: The evaluation of postharvest operational issues and the effect of different citrus wax applications on the development of peteca spot on lemons	390
5.3	Project: Fruit Production and Quality	393
5.3.1	Project summary	393
5.3.2	Progress report (Part 1): Effect of 2,4-dichlorophenoxyacetic acid (2,4-D) on the size of the navel end opening of navel oranges	395

**CRI GROUP ANNUAL RESEARCH REPORT 2009/10
TABLE OF CONTENTS**

		Page
5.3.2	Progress report (Part 2): Effect of 2,4-dichlorophenoxyacetic acid (2,4-D) on fruit splitting and fruit quality of Marisol Clementine mandarin (<i>Citrus reticulata</i>)	433
5.3.3	Progress report: Monitoring drought stress and the phenology of citrus trees using physiological and remote sensing approaches	441
5.3.4	Progress report: Improving the uptake and effectivity of foliar nutrient applications	444
5.3.5	Progress summary: The evaluation of silicon absorption in citrus	452
6	PROGRAMME: CULTIVAR AND ROOTSTOCK EVALUATION	454
6.1	Programme summary	454
6.2	Project: Cultivar Evaluations	454
6.2.1	Project summary	454
6.2.2	Evaluation of Valencia selections in the inland areas (Onderberg)	461
6.2.3	Evaluation of Valencia selections in the inland areas (Letsitele)	463
6.2.4	Evaluation of lemon selections in the inland areas	466
6.2.5	Evaluation of Valencia selections in the hot inland areas (Swaziland)	468
6.2.6	Cultivar characteristics and climatic suitability of navel oranges in cold production regions	471
6.2.7	Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region	480
6.2.8	Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region	482
6.2.9	Cultivar characteristics and climatic suitability of oranges in a cold production region	483
6.2.10	Cultivar characteristics and climatic suitability of mandarin hybrids in cold production regions	483
6.2.11	Cultivar characteristics and climatic suitability of Taroccos in cold production regions	487
6.2.12	Cultivar characteristics and climatic suitability of Valencia oranges in cold production regions	487
6.3	Project: Rootstocks	489
6.3.1	Project summary	489
6.3.2	Evaluation of Valencias on new imported rootstocks in the Malelane area	490
6.3.3	Evaluation of grapefruit varieties on new imported rootstocks in the Swaziland area	492
6.3.4	Evaluation of various Valencia selections on different rootstocks in the Komatipoort area	495
6.3.5	Evaluation of Limpopo Seedless Valencia on four different rootstocks in the Weipe area	502
6.3.6	Cultivar Fact Sheets	504
6.3.7	Fukumoto navel Incompatibility report – preliminary survey	505
7	SITRUSVERBETERINGSKEMA (SVS) 2009	508
7.1	Opsomming en Okuleerhout Verskaffing Januarie tot Desember 2009	508
7.2	Saad verskaffing van Januarie tot Desember 2009	512
7.3	Produksie by die Sitrus Grondvesblok	514
7.4	Boom sertifisering vanaf Januarie tot Desember 2009	514
7.5	Kwekery Sertifisering	516
7.6	Statutêre Sitrus Verbeteringskema	517
7.7	Beskermde sone rondom die Sitrus Grondvesblok	517
7.8	Citrus virus-free gene source	517
7.9	Diagnostic services for graft transmissible diseases	521
7.10	Amended procedure following compromised phytosanitary status of CIS material	528

**CRI GROUP ANNUAL RESEARCH REPORT 2009/10
TABLE OF CONTENTS**

		Page
8	INTERNATIONAL VISITS	529
	8.1 J S Verreyne	529
	8.2 P H Fourie	530
	8.3 S D Moore	533
9	VOORLIGTINGSDEPARTEMENT 2009-10	539
	9.1 Tegnologieoordraging	539
	9.2 Navorsingsprioriteit samevatting	543
	9.3 Transformation Extension	561
	9.3.1 Transformation Extension (North)	561
	9.3.2 Transformation Extension (South)	571
	9.4 The relative funding support for research programmes and projects for 2009-10	582
	9.5 Extension presentations by CRI group researchers in 2009-10	584
	9.6 Other means of Technology Transfer	585
	9.6.1 SA Fruit Journal	585
	9.6.2 CRI website	586
	9.6.3 CRInet	587
	9.6.4 Cutting Edge	587
10	PUBLICATIONS IN 2009-10	588
	10.1 Refereed publications (or ISI ranked)	588
	10.2 Semi-scientific publications	588
11	PRESENTATIONS AT SOCIETAL AND INTERNATIONAL CONGRESSES	588

**CRI GROUP ANNUAL RESEARCH REPORT 2010/11
TABLE OF CONTENTS**

		Page
1	INTRODUCTION	1
2	MARKET ACCESS TECHNICAL COORDINATION & BIOSECURITY	1
	2.1 Summary	1
	2.2 Europe (EU)	2
	2.3 Japan	3
	2.4 USA	4
	2.5 China	5
	2.6 South Korea	5
	2.7 New Markets	5
	2.8 Biosecurity	6
3	PROGRAMME: INTEGRATED PEST MANAGEMENT 6	
	3.1 Programme summary	6
	3.2 Project: False Codling Moth	7
	3.2.1 Project summary 7	
	3.2.2 Progress report: Control of false codling moth with sterile insect releases	8
	3.2.3 Progress report: Development of a protocol for control of false codling moth in packed fruit using gamma irradiation	8
	3.2.4 Progress report: Investigating and improving field persistence of Cryptogran	9
	3.2.5 Progress report: The use of entomopathogenic nematodes for the control of false codling moth	9
	3.2.6 Progress report: Monitoring the efficacy of Sterile Insect Technique to control false codling moth in the Citrusdal area (Western Cape Province, South Africa)	9
	3.2.7 Progress report: Investigation of the potential for the development of a locally produced mating disruption system	10
	3.2.8 Final report: Comparative fitness of laboratory reared false codling moth (FCM) from different regions of South Africa	10
	3.2.9 Progress report: Studies on existing and new isolates of <i>Cryptophlebia leucotreta</i> granulovirus (CrleGV) on FCM populations from a range of geographic regions in South Africa	10
	3.2.10 Progress summary: Amelioration of the post-harvest cold treatment regime for FCM with the use of carbon dioxide	11
	3.2.11 Final report: Evaluation of EXP5225 (200 g/litre SC) against false codling moth larvae and eggs in laboratory trials	11
	3.2.12 Progress report: The efficacy of the insecticide EXP5225 for control of false codling moth in the Eastern Cape	11
	3.2.13 Progress report: Evaluation of Checkmate FCM-F for the control of false codling moth	12
	3.3 Project; Fruit Flies	12
	3.3.1 Project summary	12
	3.3.2 Progress report: Fruit fly rearing	13
	3.3.3 Final report: Determine the potential global distributions for Natal fruit fly and false codling moth	13
	3.3.4 Progress summary: A new bait for more effective control of all <i>Ceratitis</i> fruit flies	13
	3.3.5 Final report: Fruit fly damage reduction and management of male fruit fly numbers	14
	3.3.6 Progress summary: Cold disinfestation of <i>Bactrocera invadens</i> in citrus	14

**CRI GROUP ANNUAL RESEARCH REPORT 2010/11
TABLE OF CONTENTS**

	Page
3.3.7 Progress summary: Male annihilation technique and baiting for field control of <i>Bactrocera invadens</i>	14
3.3.8 Progress summary: Ethyl formate as a fumigant for fruit fly and other phytosanitary pests	15
3.3.9 Progress summary: The role of interspecific competition in regulating populations of <i>C. capitata</i> and <i>C. rosa</i>	15
3.3.10 Final report: Investigation of entomopathogenic fungi for control of false codling moth, <i>Thaumatotibia leucotreta</i> , Mediterranean fruit fly, <i>Ceratitis capitata</i> and Natal fruit fly, <i>C. rosa</i> in South African citrus	15
3.3.11 Progress summary: Cold tolerance of Natal fruit fly (<i>Ceratitis rosa</i>): geographic distribution and overwintering physiology	16
3.3.12 Progress report: Surveillance of <i>B. invadens</i> in commercial citrus orchards in South Africa	16
3.4 Project: Cosmetic Pests	16
3.4.1 Project summary	16
3.4.2 Progress report: Improving management of citrus grey mite, <i>Calacarus citrifolii</i>	17
3.4.3 Final report: Alternative chemicals for citrus bud mite control	17
3.4.4 Final report: Preventing contamination of packed fruit by beetle mites (Oribatida)	17
3.4.5 Progress report: Treatments for the control of leafhoppers on citrus	17
3.5 Project: Mealybug and other phytosanitary pests	18
3.5.1 Project summary	18
3.5.2 Final report: <i>Leptomastix</i> spp. as biocontrol agents for control of mealybug, with particular reference to oleander mealybug, <i>Paracoccus burnerae</i>	18
3.5.3 Progress report: The impact of 2,4-D induced navel-end size reduction on pest infestation of fruit	18
3.5.4 Progress report: Evaluation of gamma-irradiation as a post-harvest treatment for citrus mealybug, <i>Planococcus citri</i> (Risso)	19
3.5.5 Progress report: Determination of Buprofezin residues on soft citrus and lemons for residue decline study	19
3.5.6 Final report: Biology of the oleander mealybug, <i>Paracoccus burnerae</i>	19
3.6 Project: Biocontrol disruption	19
3.6.1 Project summary	19
3.6.2 Progress report: Development of ant baits and the use of bait stations	20
3.6.3 Progress summary: Contract non-target effect testing of two new plant protection products	20
4 Programme: Disease Management	20
4.1 Programme summary	20
4.2 Project: Graft Transmissible Diseases	22
4.2.1 Project summary	22
4.2.2 Progress report: Dynamics of citrus tristeza virus mild and severe strains in mild strain cross-protection strategies	23
4.2.3 Progress report: Cross-protection of Marsh and Star Ruby grapefruit using Beltsville sub-isolates of <i>Nartia</i> mild strain	23
4.2.4 Progress report: Cross-protection of Star Ruby using Beltsville sub isolates of <i>Nartia</i> mild strain for the Orange River Valley	24

**CRI GROUP ANNUAL RESEARCH REPORT 2010/11
TABLE OF CONTENTS**

	Page	
4.2.5	Progress report: Cross-protection of Marsh and Star Ruby by using the best field isolates collected in the different grapefruit production areas of southern Africa	24
4.2.6	Final report: Evaluation of Citrus tristeza virus sources in Valencia	24
4.2.7	Progress report: The effect of different CTV sources in Valencias on different rootstock combinations for the Orange Rivier Valley	25
4.2.8	Progress report: Identification of suitable Citrus tristeza virus sources for pre-immunising Turkey Valencia	25
4.2.9	Progress report: Searching for a Citrus tristeza virus source suitable for cross protecting soft citrus	25
4.2.10	Final report: Epidemiology of greening disease-variability	25
4.2.11	Progress report: Epidemiology of greening disease – alternate hosts and spread	26
4.2.12	Progress report: Epidemiology of greening disease – seed transmission	26
4.2.13	Progress report: Evaluation of citrus material for greening resistance	26
4.2.14	Progress report: Eradication of citrus greening infections in existing orchards	27
4.3	Project: Fruit and Foliar diseases	27
4.3.1	Project summary	27
4.3.2	Progress report: Evaluation of new spray programmes for the control of Alternaria brown spot in the summer rainfall regions of South Africa	28
4.3.3	Progress report: Evaluation of a Spanish prediction model for Alternaria brown spot of Mandarins	28
4.3.4	Final report: Optimisation of fungicide spray applications in citrus citrus orchards	28
4.3.5	Final report: Evaluation of selected adjuvants for application in southern African citrus orchards	29
4.4	Project: Soilborne diseases	29
4.4.1	Project summary	29
4.4.2	Progress report: The evaluation of different pre-plant products for the control of the citrus nematode, as part of an integrated nematode control approach in citrus replant situations	30
4.4.3	Progress report: An integrated approach to ensure root and plant health	30
4.4.4	Progress report: Characterization of Phytophthora species from various South African citrus production regions	31
4.4.5	Progress report: Rootstock resistance against Phytophthora root rot	31
4.4.6	Progress report: The effect of compost, amended with beneficial organisms, applied as soil treatments, on tree condition and general disease resistance	31
4.4.7	Progress report: Control of Phytophthora trunk and branch canker on Clementines in the Western Cape	32
4.4.8	Contract research: Evaluation of a new nematicide for the control of the citrus nematode (Israel)	32
4.4.9	Contract research: Evaluation of a new safer nematicide for the control of the citrus nematode (Belgium)	32
4.4.10	Contract research: Evaluation of a product with possible SAR characteristics for the control of citrus greening bacteria in citrus trees	32
4.5	Project: Post-harvest Pathology	32
4.5.1	Project summary	32
4.5.2	Progress report: Provision of an industry service whereby new pack house treatments are comparatively evaluated, fungicide resistance is monitored and standardised recommendations are provided	33

**CRI GROUP ANNUAL RESEARCH REPORT 2010/11
TABLE OF CONTENTS**

		Page
4.5.3	Progress report: The synergistic use of GRAS chemicals for citrus post-harvest disease control	34
4.5.4	Progress report: Practical guidelines for good post-harvest handling of citrus fruit	34
4.5.5	Progress report: Optimisation of fungicide application in citrus packhouses	34
4.5.6	Progress report: Practical resistance evaluation of imazalil and guazatine resistant <i>Penicillium</i> isolates in simulated trials	35
4.5.7	Final report: Screening of South African <i>Penicillium</i> isolates from citrus producing regions for resistance to the post-harvest fungicides imazalil, guazatine and thiabendazole	35
4.5.8	Progress report: Occurrence of <i>Penicillium</i> spp. in the citrus supply chain and improving the citrus export chain through determining critical control points	35
4.5.9	Progress report: Alternative measures for control of post-harvest diseases	35
4.5.10	Progress report: The screening of potential alternative products as replacements for 2,4-D as a post-harvest treatment in citrus packhouses	36
4.6	Project: Citrus Black Spot	36
4.6.1	Project summary	36
4.6.2	Progress report: Development of new spray programmes for the control of citrus black spot	36
4.6.3	Progress report: Monitoring ascospore releases in the Eastern Cape to determine the critical period for CBS infection	37
4.6.4	Progress report: A holistic approach for the reduction of <i>Guignardia Citricarpa</i> ascospore inoculums	37
4.6.5	Final report: Retention and persistence of copper fungicides on Valencia and navel orange fruit and leaves by fluorescent pigment deposition analysis	37
4.6.6	Final report: In vitro ascospore production of <i>Guignardia citricarpa</i>	37
4.7	CRI Diagnostic Centre	38
5	PROGRAMME: CROP AND FRUIT QUALITY MANAGEMENT	39
5.1	Programme summary	39
5.2	Project: Rind condition	39
5.2.1	Project summary	39
5.2.2	Final report: Evaluation of alternative means of controlling creasing (albedo breakdown): determination of the most effective timing of gibberellic acid (GA3) application to reduce the incidence of creasing	40
5.2.3	Final report: Relationship of bearing position of fruit on a tree and creasing incidence	40
5.2.4	Final report: Effect of the manipulation of light, carbohydrate and mineral nutrient allocation in the tree on creasing incidence	41
5.2.5	Final report: The evaluation of alternative methods of uptake of products and plant growth regulators to reduce the incidence of creasing	41
5.2.6	Final report: Effect of different root biostimulants on the incidence and severity of creasing	41
5.2.7	Progress report: Development of post-harvest treatments to prevent the incidence of chilling injury in citrus	42
5.2.8	Final report: Hot water dip treatments to prevent chilling injury (CI) on early season harvested lemons, grapefruit and Oroblancos exported to Japan	42

**CRI GROUP ANNUAL RESEARCH REPORT 2010/11
TABLE OF CONTENTS**

		Page
5.2.9	Progress report: Development of laboratory based biochemical methods to determine the physiological condition of the flavedo	42
5.2.10	Progress report: Preliminary studies on aspects concerning rind pitting/staining of Valencia fruit	42
5.2.11	Progress report: Peteca spot of lemons	43
5.2.12	Final report: The evaluation of post-harvest operational issues and the effect of different citrus wax applications on the development of Peteca spot on lemons	43
5.3	Project: Fruit Production and Quality	43
5.3.1	Project summary	43
5.3.2	Progress report: Effect of 2,4-Dichlorophenoxyacetic acid (2,4-D) on the size of the navel-end opening of navel oranges (Part 1) 44 Progress report: Effect of 2,4-Dichlorophenoxyacetic acid (2,4-D) on fruit splitting and fruit quality of Marisol Clementine mandarin (Citrus reticulata) (Part 2)	44
5.3.3	Progress report: Monitoring drought stress and the phenology of citrus trees using physiological and remote sensing approaches	45
5.3.4	Progress report: Improving the uptake and effectivity of foliar nutrient applications	45
5.3.5	Progress report: The evaluation of silicon absorption in citrus	45
6	PROGRAMME: CULTIVAR AND ROOTSTOCK EVALUATION	46
6.1	Programme summary	46
6.2	Project: Cultivar Evaluations	46
6.2.1	Project summary	46
6.2.2	Evaluation of Valencia selections in the inland areas (Onderberg)	49
6.2.3	Evaluation of Valencia selections in the inland areas (Letsitele)	49
6.2.4	Evaluation of lemon selections in the inland areas	49
6.2.5	Evaluation of Valencia selections in the hot inland areas (Swaziland)	50
6.2.6	Cultivar characteristics and climatic suitability of navel oranges in cold production regions	50
6.2.7	Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region	50
6.2.8	Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region	50
6.2.9	Cultivar characteristics and climatic suitability of oranges in a cold production region	50
6.2.10	Cultivar characteristics and climatic suitability of mandarin hybrids in cold production regions	51
6.2.11	Cultivar characteristics and climatic suitability of Taroccos in cold Production regions	51
6.2.12	Cultivar characteristics and climatic suitability of Valencia oranges in cold production regions	51
6.3	Project: Rootstock Evaluations	51
6.3.1	Project summary	51
6.3.2	Evaluation of Valencias on new imported rootstocks in the Malalene area	52
6.3.3	Evaluation of grapefruit varieties on new imported rootstocks in the Swaziland area	52
6.3.4	Evaluation of various Valencia selections on different rootstocks in the Komatipoort area	52

**CRI GROUP ANNUAL RESEARCH REPORT 2010/11
TABLE OF CONTENTS**

		Page
	6.3.5 Evaluation of Limpopo Seedless Valencia on four different rootstocks in the Weipe area	53
	Cultivar Fact Sheets	53
	Summarized Fukumoto navel incompatibility report	54
7	CITRUS IMPROVEMENT SCHEME (CIS) 2009-10	55
	7.1 Summary	55
8	INTERNATIONAL VISITS	56
	8.1 J S Verreyne	56
	8.2 P H Fourie	57
	8.3 S D Moore	57
9	VOORLIGTINGSDEPARTMENT 2009-10	59
	9.1 Tegnologieoordraging	59
	9.2 Navorsingsprioriteit samevatting van hoogste prioriteite	62
	9.3 Transformation Extension	67
	9.3.1 Transformation Extension (North)	67
	9.3.2 Transformation Extension (South)	69
	9.4 The relative funding support for research programmes and projects for 2009-10	71
	9.5 Extension presentations by CRI Group researchers in 2009-10	73
	9.6 Other means of Technology Transfer	74
	9.6.1 SA Fruit Journal	74
	9.6.2 CRI website	75
	9.6.3 CRInet	76
	9.6.4 Cutting Edge	76
10	PUBLICATIONS IN 2009-10	77
	10.1 Refereed publications (or ISI ranked journals)	77
	10.2 Semi-scientific publications	77
11	PRESENTATIONS AT SOCIETAL AND INTERNATIONAL CONGRESSES	77

**CRI GROUP ANNUAL RESEARCH REPORT 2011/12
TABLE OF CONTENTS**

		Page
1	INTRODUCTION	1
2	MARKET ACCESS TECHNICAL COORDINATION	4
	2.1 Summary	4
	2.2 Europe (EU)	5
	2.3 Japan	5
	2.4 USA	5
	2.5 China	6
	2.6 South Korea	6
	2.7 New Markets	6
	2.7.1 Thailand	6
	2.7.2 Cambodia, Kazakhstan and Syria	7
	2.7.3 Australia, Lebanon and Philippines	7
	2.8 Biosecurity and Regulations	7
3	PROGRAMME: INTEGRATED PEST MANAGEMENT	8
	3.1 Programme summary	8
	3.2 Project: False Codling Moth	11
	3.2.1 Project summary	11
	3.2.2 Final report: Development of a technique for control of false codling moth larvae in packed fruit using gamma irradiation	14
	3.2.3 Final report: Investigating and improving field persistence of <i>Cryptogran</i>	25
	3.2.4 Progress report: Entomopathogenic nematodes for the control of false codling moth in citrus orchards	29
	3.2.5 Progress report: Investigation of the potential for the development of a locally produced mating disruption system	30
	3.2.6 Final report: Studies on existing and new isolates of <i>Cryptophlebia leucotreta</i> granulovirus (CrleGV) on FCM populations from a range of geographic regions in South Africa	31
	3.2.7 Progress report: Amelioration of the post-harvest cold treatment regime for FCM with the use of carbon dioxide	41
	3.2.8 Final report: The efficacy of Coragen for control of false codling moth in the Eastern Cape	43
	3.2.9 Progress report: Development of mechanisms for the postharvest detection of cryptic pests in citrus fruit	55
	3.2.10 Final report: <i>In vivo</i> mass culture of <i>Heterorhabditis zealandica</i> and <i>H. bacteriophora</i>	56
	3.2.11 Progress report: <i>In vitro</i> culture of <i>Heterorhabditis zealandica</i>	68
	3.2.12 Final report: Relative attractiveness of virgin female FCM from different regions to sterile FCM males	68
	3.2.13 Progress report: Identifying volative emissions associated with false codling moth infestation of citrus fruit	75
	3.2.14 Progress report: Entomopathogenic fungi for the control of soilborne life stages of FCM	75
	3.2.15 Progress report: Morphological and molecular identification of moths associated with citrus in the Western Cape Province	76
	3.2.16 Progress report: Large scale field trials with entomopathogenic nematodes for control of FCM, fruit fly and thrips	77
	3.3 Project: Fruit Fly	78
	3.3.1 Project summary	78
	3.3.2 Progress report: Fruit fly rearing	79

**CRI GROUP ANNUAL RESEARCH REPORT 2011/12
TABLE OF CONTENTS**

		Page
3.3.3	Progress report: A new bait for more effective control of all <i>Ceratitis</i> Fruit Flies	80
3.3.4	Final report: Efficacy of formulated entomopathogenic nematodes against <i>Cetatitis capitata</i> and <i>Ceratitis rosa</i> in citrus orchards	81
3.3.5	Final report: Cold tolerance of Natal fruit fly (<i>Ceratitis rosa</i>): geographic distribution and overwintering physiology	85
3.3.6	Progress report: Surveillance of <i>B. invadens</i> in commercial citrus orchards in South Africa	103
3.3.7	Progress report: Field control of <i>Bactrocera invadens</i> with MAT and bait	104
3.3.8	Progress report: Determine the potential global distribution for <i>Bactrocera invadens</i> using CLIMEX	105
3.3.9	Progress report: Evaluating a GRAS post-harvest fumigant for fruit fly and other phytosanitary pests	105
3.4	Project: Cosmetic Pests	106
3.4.1	Project summary	106
3.4.2	Final report: Residue trials for fenpyroximate used for citrus budmite control	107
3.4.3	Progress report: Treatments for the control of leafhoppers on citrus	109
3.4.4	Progress report: The effect of systemically-applied imidacloprid on lepidopteran pests of citrus	109
3.4.5	Final report: The effect of adjuvants, shade and increased concentration on pre-harvest intervals of insecticides	110
3.4.6	Final report: Evaluation of commercial entomopathogenic fungi against thrips and mealybug	115
3.5	Project: Mealybug and Other market access pests	119
3.5.1	Project summary	119
3.5.2	Progress report: The impact of 2,4-D induced navel end size reduction on pest infestation of fruit	120
3.5.3	Progress report: Evaluation of gamma irradiation as a post-harvest control measure for citrus mealybug, <i>Planococcus citri</i> (Risso)	131
3.5.4	Progress report: The use of entomopathogenic nematodes to control <i>Planococcus citri</i> and <i>Paracoccus burnerae</i>	132
3.5.5	Progress report: Assessment of the potential of <i>Anagyrus</i> sp. as a biocontrol agent for mealybug	169
3.6	Project: Biocontrol disruption	169
3.6.1	Project summary	169
3.6.2	Progress report: Development of ant baits	170
3.7	Project: Production Pests	170
3.7.1	Project summary	170
3.7.2	Progress report: Managing Woolly Whitefly, <i>Aleurothrixus floccosus</i>	171
3.7.3	Final report: Monitoring attraction of fruit-feeding moths in citrus orchards to different fruit baits in the Eastern Cape Province, South Africa	171
4	PROGRAMME: DISEASE MANAGEMENT	182
4.1	Programme summary	182
4.2	Project: Graft Transmissible Diseases	185
4.2.1	Project summary	185
4.2.2	Progress report: Cross-protection of Star Ruby grapefruit using Beltsville sub-isolates of Nartia mild strain	186

**CRI GROUP ANNUAL RESEARCH REPORT 2011/12
TABLE OF CONTENTS**

	Page	
4.2.3	Progress report: Cross-protection of Star Ruby using Beltsville sub-isolates of Nartia mild strain for the Orange River Valley	187
4.2.4	Progress report: The effect of different CTV sources in Valencias on different rootstock combinations for the Orange River Valley	187
4.2.5	Progress report: Cross-protection of Marsh and Star Ruby by using the best field isolates collected in the different grapefruit production areas of southern Africa	188
4.2.6	Progress report: Identification of suitable <i>Citrus tristeza virus</i> sources for pre-immunising Turkey Valencia	189
4.2.7	Progress report: Searching for a <i>Citrus tristeza virus</i> source suitable for cross-protecting soft citrus	189
4.2.8	Progress report: Dynamics of citrus tristeza virus mild and severe strains in mild strain cross-protection strategies	190
4.2.9	Progress report: Epidemiology of greening disease – alternate hosts and spread	190
4.2.10	Progress report: Investigation into the seasonal population fluctuation of <i>Trioza erytreae</i> and infection with the greening organism, <i>Candidatus Liberibacter africanus</i>	191
4.2.11	Progress report: Evaluation of citrus material for greening resistance	192
4.3	Project: Fruit and Foliar Diseases	193
4.3.1	Project summary	193
4.3.2	Progress report: Evaluation of new spray programmes for the control of <i>Alternaria</i> brown spot in the summer rainfall regions of South Africa	194
4.3.3	Progress report: Optimisation of fungicide spray applications in citrus orchards	199
4.3.4	Progress report: Control of <i>Botrytis cinerea</i> Pers. on lemons	200
4.4	Project: Soilborne Diseases	201
4.4.1	Project summary	201
4.4.2	Progress report: Investigation into edaphic factors and their interactions on citrus tree decline	202
4.4.3	Progress report: The evaluation of different pre-plant products for the control of the citrus nematode, as part of an integrated nematode control approach in citrus replant situations	203
4.4.4	Progress report: Evaluation of alternative products for control of citrus nematode and <i>Phytophthora</i> spp. in citrus	204
4.4.5	Final report: The effect of compost, amended with beneficial organisms, applied as soil treatments, on tree condition and general disease resistance	204
4.4.6	Progress report: Rootstock resistance against <i>Phytophthora nicotianae</i> root rot	215
4.4.7	Contract research: Evaluation of a new nematicide for the control of the citrus nematode	216
4.4.8	Contract research: Evaluation of a new safer nematicide for the control of the citrus nematode	216
4.4.9	Contract research: Evaluation of a product with possible SAR characteristics for the control of citrus greening bacteria in citrus trees	217
4.5	Project: Post-Harvest Pathology	217
4.5.1	Project summary	217
4.5.2	Progress report: Optimisation of fungicide application in citrus packhouses	218
4.5.3	Final report: Screening of South African <i>Penicillium</i> isolates from citrus producing regions for resistance to the postharvest fungicides imazalil, guazatine and thiabendazole	219
4.5.4	Progress report: Use of potassium silicate and biocontrol agents to reduce postharvest disease and chilling injury in citrus fruit	237
4.5.5	Progress report: Practical impact of fungicide resistance on control of postharvest citrus green and blue mould	238

**CRI GROUP ANNUAL RESEARCH REPORT 2011/12
TABLE OF CONTENTS**

		Page
	4.5.6 Progress report: Provision of an industry service whereby new packhouse treatments are comparatively evaluated, fungicide resistance is monitored and standardised recommendations are provided	238
4.6	Project: Citrus Black Spot	252
	4.6.1 Project summary	252
	4.6.2 Progress report: Monitoring ascospore releases in the Eastern Cape to determine the critical period for CBS infection	253
	4.6.3 Progress report: Development of new spray programmes for the control of citrus black spot	254
	4.6.4 Progress report: The global population structure and reproductive biology of the fungal pathogen, <i>Guignardia citricarpa</i> Kiely	256
	4.6.5 Progress report: Improving the retention of suspension liquid phosphonate fungicides on citrus fruit and leaves	256
	4.6.6 Final report: A holistic approach to the control of citrus black spot with the emphasis on the reduction of <i>Guignardia citricarpa</i> ascospore inoculum	257
	4.6.7 Progress report: Epidemiology and pest risk assessment of <i>Guignardia citricarpa</i>	269
4.7	CRI Diagnostic Centre	269
5	PROGRAMME: HORTICULTURE	272
	5.1 Programme summary	272
	5.2 Project: Rind Condition	272
	5.2.1 Project summary	272
	5.2.2 Progress report: Development of postharvest treatments to prevent chilling injury in various citrus species	273
	5.2.3 Progress report: Effect of different chemical applications on development of peteca spot in lemons	274
	5.2.4 Progress report: Studies on aspects concerning rind pitting/staining citrus fruit	275
	5.2.5 Progress report: Development of laboratory-based biochemical methods to determine the physiological condition of the citrus fruit flavedo	275
	5.2.6 Progress report: Increasing Ca and Mg content in the flavedo using novel techniques	276
	5.2.7 Final report: Influence of calcium foliar sprays on creasing (albedo breakdown)	276
5.3	Project: Fruit Production and Quality	281
	5.3.1 Project summary	281
	5.3.2 Final report: Effect of 2,4-D dichlorophenoxyacetic acid (2,4-D) on the size of the navel end opening of navel oranges	282
	5.3.3 Progress report: The evaluation of silicon absorption in citrus	290
	5.3.4 Progress report: Effect of leaf carbohydrate concentrations on flowering and fruit set of alternate bearing late mandarins	290
	5.3.5 Progress report: A novel approach to water and nutrient management in citrus	291
	5.3.6 Progress report: Effect of 2,4-D on fruit splitting and fruit size of citrus	292
	5.3.7 Progress report: Preliminary study on the effect of humic acids on fertilizer application in citrus	292

**CRI GROUP ANNUAL RESEARCH REPORT 2011/12
TABLE OF CONTENTS**

	Page	
5.4	Project: Cold Chain Management and Packaging	293
5.4.1	Project summary	293
5.4.2	Progress report: Energy and temperature optimisation in refrigerated shipping containers	294
5.5	Project: Cultivar and Rootstock Evaluations	294
5.5.1	Project summary	294
5.5.2	Progress report: Evaluation of Valencia selections in the hot humid inland areas (Onderberg)	295
5.5.3	Progress report: Evaluation of Valencia selections in the hot dry inland areas (Letsitele)	296
5.5.4	Progress report: Evaluation of Valencia selections in the hot humid inland areas (Swaziland)	296
5.5.5	Progress report: Evaluation of Valencias on new imported rootstocks in the Malelane area	297
5.5.6	Progress report: Evaluation of Grapefruit varieties on different rootstocks in the Swaziland area	297
5.5.7	Progress report: Evaluation of various Valencia selections on different rootstocks in the Komatipoort area	298
5.5.8	Final report: Evaluation of Limpopo seedless Valencia on four different rootstocks in the Weipe area	299
5.5.9	Progress report: Cultivar characteristics and climatic suitability of Satsuma Mandarins in a cold production region (East Cape Midlands)	299
5.5.10	Progress report: Cultivar characteristics and climatic suitability of Satsuma Mandarins in a cold production region (Western Cape)	300
5.5.11	Progress report: Cultivar characteristics and climatic suitability of Clementine Mandarins in a cold production region (Western Cape)	300
5.5.12	Progress report: Cultivar characteristics and climatic suitability of Valencia oranges in a cold production region (Sundays River Valley)	301
5.5.13	Progress report: Cultivar characteristics and climatic suitability of Valencia oranges in a cold production region (Western Cape)	301
5.5.14	Progress report: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (East Cape Midlands)	302
5.5.15	Progress report: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Sundays River Valley)	302
5.5.16	Progress report: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Gamtoos River Valley)	302
5.5.17	Progress report: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (South Western Cape)	303
5.5.18	Progress report: Cultivar characteristics and climatic suitability of Navel oranges in a cold production region (Sundays River Valley)	303
5.5.19	Progress report: Cultivar characteristics and climatic suitability of Navel oranges in a cold production region (Western Cape)	304
5.5.20	Progress report: Cultivar characteristics and climatic suitability of experimental navel oranges in a cold production region (Sundays River Valley)	304
5.5.21	Progress report: Cultivar characteristics and climatic suitability of experimental navel oranges in a cold production region (Gamtoos River Valley)	305
6	CITRUS IMPROVEMENT SCHEME (CIS)	306
	Summary	306
6.1	Budwood	309
6.2	Seed	312
6.3	Production	312
6.4	Tree Certification	313

**CRI GROUP ANNUAL RESEARCH REPORT 2011/12
TABLE OF CONTENTS**

		Page
6.5	Nursery Certification	314
6.6	Statutory Improvement Scheme	315
6.7	Protective zone surrounding the Citrus Foundation Block	315
6.8	Establish and maintain a virus-free gene source at CRI	315
6.9	Diagnostic services for graft transmissible diseases	319
6.10	Restructuring of the Citrus Improvement Scheme	327
7	INTERNATIONAL VISITS	328
7.1	P.J.R. Cronjé (Valencia, Spain)	328
7.2	G.C. Schutte (Brazil and Argentina)	333
7.3	S.D. Moore (Kenya)	338
7.4	P.H. Fourie (Hawaii)	344
8	EXTENSION 2011-12	345
8.1	Tegnologieoordraging	345
8.2	Studiegroepvoorsitters vir 2011-12	352
8.3	Transformasie	353
8.4	Biosekuriteit	357
8.5	Research priorities	379
8.6	The relative funding support for research programmes and projects for 2011-12	386
8.7	Extension presentations by CRI researchers in 2011-12	388
8.8	Other means of Technology Transfer	390
	8.8.1 SA Fruit Journal	390
	8.8.2 CRI Website	391
	8.8.3 CRInet	391
	8.8.4 Cutting Edge	391
9	PUBLICATIONS IN 2011-12	392
9.1	Refereed publications (or ISI ranked journals)	392
9.2	Semi-Scientific publications	393
10	PRESENTATIONS AT SOCIETAL AND INTERNATIONAL CONGRESSES	393

**CRI GROUP ANNUAL RESEARCH REPORT 2012/13
TABLE OF CONTENTS**

		Page
1	INTRODUCTION	1
2	MARKET ACCESS TECHNICAL COORDINATION	3
	2.1 Summary	3
	2.2 Europe (EU)	3
	2.3 Japan	4
	2.4 USA	4
	2.5 China	5
	2.6 South Korea	5
	2.7 Thailand	5
	2.8 Reunion	5
	2.9 New Markets	5
	2.9.1 The Philippines	5
	2.9.2 Cambodia, Kazakhstan and Syria	6
	2.9.3 Australia and Lebanon	6
	2.10 Imports	6
	2.10.1 Brazil	6
	2.10.2 Egypt	6
	2.10.3 Import conditions	6
	2.11 Biosecurity and Regulations	6
3	PORTFOLIO: INTEGRATED PEST MANAGEMENT	7
	3.1 Portfolio summary	7
	3.2 Programme: False Codling Moth	11
	3.2.1 Programme summary	11
	3.2.2 Final report: Assessment of Ionizing Radiation for the Phytosanitary disinfestation of False Codling Moth, <i>Thaumatotibia leucotreta</i> (Meyrick) (Lepidoptera: Tortricidae) on citrus in South Africa: Validation of a Post-harvest treatment	14
	3.2.3 Final report: The use of entomopathogenic nematodes to control codling moth	19
	3.2.4 Progress report: Investigation of the potential for the development of a locally produced mating disruption system	50
	3.2.5 Final report: Amelioration of the post-harvest cold treatment regime for FCM with the use of carbon dioxide	51
	3.2.6 Progress report: Development of mechanisms for the postharvest detection of cryptic pests in citrus fruit	73
	3.2.7 Final report: Characterisation of nematode symbiotic bacteria and the <i>in vitro</i> liquid culture of <i>Heterorhabditis zealandica</i> and <i>Steinernema yirgalemense</i>	74
	3.2.8 Final report: FCM infestation of lemons in the field	77
	3.2.9 Progress report: Late season releases of <i>Trichogrammatoidea cryptophlebiae</i> for suppression of FCM	79
	3.2.10 Progress report: Suppression of false codling moth (<i>Thaumatotibia leucotreta</i>) larvae with a combination of suboptimal temperature and ionising radiation	80
	3.2.11 Final report: Identifying volatile emissions associated with false codling moth infestation of citrus fruit	80
	3.2.12 Progress report: The use of entomopathogenic fungi to control the soil-dwelling life stages of false codling moth	86
	3.2.13 Final report: Morphology and taxonomy of tortricid moth pests attacking deciduous fruit and citrus	86
	3.2.14 Progress report: Impact of abbreviated and complete cold-treatment on survival and fitness of FCM larvae	112

**CRI GROUP ANNUAL RESEARCH REPORT 2012/13
TABLE OF CONTENTS**

	Page
3.2.15 Final report: Ovipositional preferences and differences in host susceptibility of navel orange varieties by false codling moth, <i>Thaumatotibia leucotreta</i> Meyrick (Lepidoptera: Tortricidae) in South Africa	112
3.2.16 Progress report: Large scale field trials with entomopathogenic nematodes for control of FCM and Fruit Fly	126
3.2.17 Progress report: Gene expression analysis of <i>Thaumatotibia leucotreta</i> as result of different isolates of <i>Cryptophlebia leucotreta</i> granulosis virus	127
3.2.18 Final report: A comparison of late-season FCM control options	128
3.3 Programme: Fruit Fly	130
3.3.1 Programme summary	130
3.3.2 Progress report: Fruit fly rearing	132
3.3.3 Progress report: A new bait for more effective control of all <i>Ceratitis</i> fruit flies	132
3.3.4 Progress report: Surveillance of <i>B. invadens</i> in commercial citrus orchards in South Africa	133
3.3.5 Final report: Field control of <i>Bactrocera invadens</i> with MAT and bait	134
3.3.6 Final report: Determine the potential global distribution for <i>Bactrocera invadens</i> using CLIMEX	145
3.3.7 Progress report: Evaluating a GRAS post-harvest fumigant for fruit fly and other phytosanitary pests	156
3.3.8 Progress report: Determine the least susceptible immature life stage of Medfly to cold disinfestation at 1°C	156
3.3.9 Final report: Use of molecular techniques to distinguish between <i>Bactrocera invadens</i> and local fruit fly pest species	157
3.3.10 Final report: Determining the sensitivity of <i>Bactrocera invadens</i> to methyl eugenol	162
3.4 Programme: Mealybug and other Market Access pests	165
3.4.1 Programme summary	165
3.4.2 Progress report: Evaluation of gamma irradiation as a post-harvest control measure for citrus mealybug, <i>Planococcus citri</i> (Risso)	166
3.4.3 Final report: Assessment of the potential of <i>Anagyrus</i> sp. as a biocontrol agent for mealybug	167
3.4.4 Progress report: Screening of entomopathogenic fungi against citrus mealybug and citrus thrips	176
3.4.5 Progress report: The morphology and ecology of the Carob moth in citrus orchards	177
3.5 Programme: Minor Pests and Mites	178
3.5.1 Programme summary	178
3.5.2 Final report: Managing woolly whitefly	178
3.5.3 Final report: Treatments for the control of leafhoppers on citrus	186
3.5.4 Final report: Evaluation of a Villa Metaldehyde/Carbaryl snail bait pellet formulation and Nordox (Metallic copper) 86 WG against the brown garden snail, the white dune snail and the small pointed snail in citrus	187
3.6 Programme: Non-Phytosanitary Key Pests	197
3.6.1 Programme summary	197
3.6.2 Final report: Development of ant baits	198
3.6.3 Progress report: The effect of systemically-applied imidacloprid on Lepidopteran pests of citrus	223

**CRI GROUP ANNUAL RESEARCH REPORT 2012/13
TABLE OF CONTENTS**

		Page
4	PORTFOLIO: DISEASE MANAGEMENT	225
4.1	Portfolio summary	225
4.2	Programme: Graft Transmissible Diseases	227
4.2.1	Programme summary	227
4.2.2	Final report: Dynamics of citrus tristeza virus mild and severe strains in mild strain cross-protection strategies	229
4.2.3	Progress report: Evaluation of citrus material for greening resistance	231
4.2.4	Final report: CTV Cross-protection of Star Ruby grapefruit using Beltsville sub-isolates of Nartia mild strain	232
4.2.5	Progress report: CTV Cross-protection of Star Ruby using Beltsville sub-isolates of Nartia mild strain for the Orange River Valley	236
4.2.6	Progress report: The effect of different CTV sources in Valencias on different rootstock combinations in the Orange River Valley	236
4.2.7	Progress report: Cross-protection of Marsh and Star Ruby by using the best field isolates collected in the different grapefruit production areas of southern Africa	237
4.2.8	Progress report: Identification of suitable <i>Citrus tristeza virus</i> sources for cross-protecting Turkey Valencia	238
4.2.9	Progress report: Searching for a <i>Citrus tristeza virus</i> source suitable for cross-protecting soft citrus	238
4.2.10	Final report: Investigation into the seasonal population fluctuation of <i>Trioza erytreae</i> and infection with the greening organism, <i>Candidatus Liberibacter africanus</i>	239
4.2.11	Final report: Epidemiology of greening disease- alternate hosts and spread	247
4.2.12	Progress report: Differential cultivar selection or suppression of <i>Citrus tristeza virus</i> (CTV) genotypes	262
4.3	Programme: Fruit and Foliar diseases	263
4.3.1	Programme summary	263
4.3.2	Progress report: Evaluation of new spray programmes for the control of <i>Alternaria</i> brown spot in the summer rainfall regions of South Africa	264
4.3.3	Final report: Optimisation of fungicide spray applications in citrus orchards	264
4.3.4	Progress report: Control of <i>Botrytis cinerea</i> Pers. on lemons	287
4.4	Programme: Soilborne Diseases	288
4.4.1	Programme summary	288
4.4.2	Final report: Investigation into edaphic factors and their interactions on citrus tree decline	290
4.4.3	Progress report: The evaluation of different pre-plant products for the control of the citrus nematode, as part of an integrated nematode control approach in citrus replant situations	297
4.4.4	Progress report: Evaluation of alternative products for control of citrus nematode and <i>Phytophthora</i> spp. in citrus	298
4.4.5	Progress report: Rootstock resistance against <i>Phytophthora nicotianae</i> root rot	298
4.4.6	Contract research: Evaluation of a new nematicide for the control of the citrus nematode	299
4.4.7	Contract research: Evaluation of a new safer nematicide for the control of the citrus nematode	299
4.4.8	Contract research: Evaluation of a product with possible SAR characteristics for the control of citrus greening bacteria in citrus trees	299

**CRI GROUP ANNUAL RESEARCH REPORT 2012/13
TABLE OF CONTENTS**

		Page
4.5	Programme: Post-Harvest Pathology	299
4.5.1	Programme summary	299
4.5.2	Progress report: Provision of an industry service whereby new packhouse treatments are comparatively evaluated, fungicide resistance is monitored and standardised recommendations are provided	300
4.5.3	Progress report: Use of potassium silicate and biocontrol agents to reduce postharvest disease and chilling injury in citrus fruit	335
4.5.4	Final report: Optimisation of fungicide application in citrus packhouses	336
4.5.5	Final report: The JBT heated flooder as an alternative application method for fungicides in citrus packhouses	383
4.5.6	Final report: Practical impact of fungicide resistance on control of postharvest citrus green and blue mould	383
4.6	Programme: Citrus Black Spot	384
4.6.1	Programme summary	384
4.6.2	Progress report: Monitoring ascospore releases in the Eastern Cape to determine the critical period for CBS infection	385
4.6.3	Progress report: The global population structure and reproductive biology of the fungal pathogen, <i>Guignardia citricarpa</i> Kiely	386
4.6.4	Progress report: Development of new spray programmes for the control of citrus black spot	387
4.6.5	Progress report: Improving the retention of suspension liquid phosphonate fungicides on citrus fruit and leaves	394
4.6.6	Progress report: Epidemiology and pest risk assessment of <i>Guignardia citricarpa</i>	395
4.6.7	Final report: Retention of suspension concentrate fungicides versus wettable powder copper hydroxide and mancozeb formulations on citrus fruit and leaves as determined by fluorescent pigment deposition analyses	395
4.7	CRI Diagnostic Centre	404
5	PORTFOLIO: HORTICULTURE	406
5.1	Portfolio summary	406
5.2	Programme: Rind condition	407
5.2.1	Programme summary	407
5.2.2	Progress report: Development of postharvest treatments to prevent chilling injury in various citrus species	407
5.2.3	Progress report: Effect of different chemical applications on development of Peteca spot in lemons	409
5.2.4	Progress report: Studies on aspects concerning rind pitting/staining citrus fruit	409
5.2.5	Final report: Development of laboratory based biochemical methods to determine the physiological condition of the citrus fruit flavedo	410
5.2.6	Final report: Increasing CA and Mg content in the flavedo using novel techniques	413
5.2.7	Progress report: Non-destructive monitoring and prediction of postharvest rind quality of Nules Clementine Mandarin and Valencia orange fruit	415
5.3	Programme: Fruit Production and Quality	416
5.3.1	Programme summary	416
5.3.2	Final report: Effect of leaf carbohydrate concentrations on flowering and fruit set of alternate bearing late mandarins	417
5.3.3	Progress report: A novel approach to water and nutrient management in citrus	421

**CRI GROUP ANNUAL RESEARCH REPORT 2012/13
TABLE OF CONTENTS**

	Page	
5.3.4	Final report: Effect of 2,4-D on fruit splitting and fruit size of citrus	422
5.3.5	Progress report: Study on the effect of humic and fulvic acids on fertilizer application in citrus	427
5.3.6	Progress report: The evaluation of different formulations of micronutrients on foliar uptake	428
5.3.7	Progress report: The influence of silicon on brown spot (<i>Alternaria alternata</i>) control	428
5.4	Programme: Cold Chain Management and Packaging	429
5.4.1	Programme summary	429
5.4.2	Progress report: Energy optimisation of refrigerated shipping containers and the measurement of temperature and humidity throughout the supply chain	429
5.4.3	Progress report: Using higher 'Steri' temperatures for specialised reefer vessels bound for Japan to reduce landside costs	430
5.4.4	Progress report: Using Radio Frequency Identification Technology (RFID) to get an understanding of the storage air and fruit pulp temperatures and relative humidity in a typical South African fruit export supply chain from the very beginning to very end over two seasons	430
5.5	Programme: Cultivar Evaluation	431
5.5.1	Programme summary	431
5.5.2	Progress report: Evaluation of Valencia selections in hot humid inland areas (Onderberg)	432
5.5.3	Progress report: Evaluation of Valencia selections in the hot dry inland areas (Letsitele)	436
5.5.4	Progress report: Evaluation of Valencia selections in the hot inland areas (Swaziland)	440
5.5.5	Progress report: Evaluation of Valencias on new imported rootstocks in the Malelane area	443
5.5.6	Progress report: Evaluation of Grapefruit varieties on different rootstocks in the Swaziland area	445
5.5.7	Progress report: Evaluation of various Valencia selections on different rootstocks in the Komatipoort area	449
5.5.8	Progress report: Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region (East Cape Midlands)	457
5.5.9	Progress report: Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region (Western Cape)	459
5.5.10	Progress report: Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region (Western Cape)	460
5.5.11	Progress report: Cultivar characteristics and climatic suitability of Valencia oranges in a cold production region (Sundays River Valley)	462
5.5.12	Progress report: Cultivar characteristics and climatic suitability of Valencia oranges in a cold production region (Western Cape)	463
5.5.13	Progress report: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (East Cape Midlands)	465
5.5.14	Progress report: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Sundays River Valley)	468
5.5.15	Progress report: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Gamtoos River Valley)	470
5.5.16	Progress report: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (South Western Cape)	471
5.5.17	Progress report: Cultivar characteristics and climatic suitability of Navel oranges in a cold production region (Sundays River Valley)	473
5.5.18	Progress report: Cultivar characteristics and climatic suitability of Navel oranges in a cold production region (Western Cape)	476
5.5.19	Progress report: Cultivar characteristics and climatic suitability of experimental Navel oranges in a cold production region (Sundays River Valley)	478

**CRI GROUP ANNUAL RESEARCH REPORT 2012/13
TABLE OF CONTENTS**

		Page
5.5.20	Progress report: Cultivar characteristics and climatic suitability of experimental Navel oranges in a cold production region (Gamtoos River Valley)	480
5.5.21	Progress report : Establishment of a molecular citrus genotype reference database for citrus cultivar verification within the Citrus Improvement Scheme	483
5.6	Climatic Regions of Southern Africa and cultivars being evaluated	484
5.7	Approximate maturity periods	487
6	CITRUS IMPROVEMENT SCHEME (CIS)	495
6.1	Budwood	495
6.2	Seed	495
6.3	Production	495
6.4	Tree certification	495
6.5	Nursery registration	495
6.6	Statutory Improvement Scheme	496
6.7	Protective zone surrounding the Citrus Foundation Block	496
6.8	Establish and maintain a virus-free gene source at CRI: Project 790	496 + 506
6.9	Diagnostic services for graft transmissible diseases: Project 796	496 + 510
7	INTERNATIONAL VISITS	517
7.1	Report on the XII International Citrus Congress in Valencia, Spain - 18-23 Nov 2012	517
7.2	S.D. Moore – Report on a visit to Italy and France, 12-17 November 2012	546
7.3	A. Manrakhan – Report on IAEA Expert Mission, Madagascar, 3-7 September 2012	550
7.4	T.G. Grout – International Conference on Pesticidal Plants, Nairobi, Kenya, 21-23 January 2013	552
8	VOORLIGTING 2012-13	561
8.1	Transformation: Extension Coordinators' Report	586
8.2	Research Priorities 2012-13	602
8.3	Study Group Chairmen for 2012-13	616
8.4	Relative funding support for Research Portfolios and Programmes for 2012-13	617
8.5	Extension Presentations by CRI Researchers in 2012-13	620
8.6	Other means of Technology Transfer	623
8.6.1	SA Fruit Journal	623
8.6.2	CRI Website	623
8.6.3	CRInet	624
8.6.4	Cutting Edge	624
8.6.5	CRI Production Guidelines	625
8.6.6	SASCCON interaction	625
9	PUBLICATIONS IN 2012-13	
9.1	Refereed publications (or ISI ranked journals)	626
9.2	Semi-scientific publications other than SA Fruit Journal	627
10	Presentations at Societal and International Congresses	627

**CRI GROUP ANNUAL RESEARCH REPORT 2013/14
TABLE OF CONTENTS**

		Page
1	INTRODUCTION	1
2	MARKET ACCESS TECHNICAL COORDINATION	3
	2.1 Summary	3
	2.2 Europe (EU)	4
	2.3 Japan	4
	2.4 USA	4
	2.5 China	5
	2.6 South Korea	5
	2.7 Thailand	5
	2.8 Vietnam	6
	2.9 India	6
	2.10 New Markets	6
	2.10.1 The Philippines	6
	2.10.2 Australia and Lebanon	6
	2.11 Imports	6
	2.11.1 Egypt	6
	2.11.2 Import conditions	6
	2.12 Biosecurity and regulations	6
3	PORTFOLIO: INTEGRATED PEST MANAGEMENT	7
	3.1 Portfolio summary	7
	3.2 Programme: False Codling Moth	11
	3.2.1 Programme summary	11
	3.2.2 Final report: Investigation of the potential for the development of a locally produced mating disruption system	14
	3.2.3 Progress report: Development of mechanisms for the postharvest detection of cryptic pests in citrus fruit	30
	3.2.4 Progress report: Late season releases of <i>Trichogrammatoidea cryptophlebiae</i> for suppression of FCM	31
	3.2.5 Final report: Postharvest phytosanitary disinfestation of False Codling Moth, <i>Thaumatotibia leucotreta</i> (Meyrick) (Lepidoptera: Tortricidae) in export citrus fruit from South Africa: Validation of a cold and Ionizing radiation combination treatment	32
	3.2.6 Progress report: The use of entomopathogenic fungi to control the soil-dwelling life stages of false codling moth	40
	3.2.7 Progress report: Impact of abbreviated and complete cold-treatment on survival and fitness of FCM larvae	41
	3.2.8 Progress report: Large scale field trials with entomopathogenic nematodes for control of FCM, fruit fly and thrips	41
	3.2.9 Progress report: Gene expression analysis of <i>Thaumatotibia leucotreta</i> as result of different isolates of <i>Cryptophlebia leucotreta</i> granulosis virus	42
	3.2.10 Progress report: Behaviour, biology and survival of pupating false codling moth	43
	3.2.11 Progress report: A feasibility study of postharvest vapour heat for FCM control	43
	3.2.12 Progress report: Evaluation of 7-Vinyl-Decyl Acetate 1 for mating inhibition in FCM	44
	3.2.13 Progress report: Determination of reapplication frequency of the <i>Cryptophlebia leucotreta</i> granulovirus to provide protection against FCM infestation of citrus	45
	3.2.14 Progress report: Using the larval parasitoid, <i>Agathis bishopi</i> , for detection of FCM infested fruit	45

**CRI GROUP ANNUAL RESEARCH REPORT 2013/14
TABLE OF CONTENTS**

	Page	
3.2.15	Final report: Effect of molasses as a baculovirus additive on the behaviour of neonate false codling moth, <i>Thaumatotibia leucotreta</i> (Meyrick) (Lepidoptera: Tortricidae) larvae	46
3.2.16	Progress report: Classical biocontrol introduction of <i>Agathis bishopi</i> into the Western Cape	55
3.2.17	Progress report: Novel approaches to mating disruption of FCM	55
3.2.18	Progress report: Movement of false codling moth (FCM) and fruit flies (FF) in multi-crop (citrus, stone fruit, grape, pomegranate) systems	56
3.2.19	Progress report: Verification of proposed inspections standards within an FCM systems approach	57
3.2.20	Progress report: FCM infestation of packed lemons destined for export	58
3.2.21	Final report: A comparison of late-season FCM control options	58
3.3	Programme: Fruit Fly	61
3.3.1	Programme summary	61
3.3.2	Progress report: Fruit Fly rearing	62
3.3.3	Progress report: A new bait for more effective control of all <i>Ceratitis</i> fruit flies	62
3.3.4	Progress report: Surveillance of <i>B. invadens</i> in commercial citrus orchards in South Africa	63
3.3.5	Progress report: Developmental threshold and critical thermal limits for two <i>Ceratitis rosa</i> types in South Africa	63
3.3.6	Final report: Determining the sensitivity of immature <i>Ceratitis capitata</i> to a temperature of 1°C in various <i>Citrus</i> species according to a protocol received from MAFF, Japan in 2011	64
3.3.7	Progress report: Develop a yeast autolysate attractant for fruit fly bait that is safe with copper and more palatable than hydrolysate	77
3.3.8	Progress report: Dispersal capacity of <i>Bactrocera invadens</i>	78
3.4	Programme: Mealybug and other Market Access pests	79
3.4.1	Programme summary	79
3.4.2	Final report: Evaluation of gamma irradiation as a postharvest control measure for citrus mealybug, <i>Planococcus citri</i> (Risso)	80
3.4.3	Final report: Screening of entomopathogenic fungi against citrus mealybug (<i>Planococcus citri</i>) (Risso) and citrus thrips (<i>Scirtothrips aurantii</i> [Faure])	84
3.4.4	Progress report: The morphology and ecology of the Carob moth in citrus orchards	88
3.4.5	Progress report: Evaluating GRAS postharvest fumigants for phytosanitary pests	88
3.4.6	Progress report: The association of a lepidopteran borer complex between pecan nuts (<i>Carya illinoensis</i>) and citrus (<i>Citrus sinensis</i>) in the Vaalharts region	89
3.5	Programme: Minor Pests and Mites	90
3.5.1	Programme summary	90
3.5.2	Progress report: Using banana odour as an attractant for monitoring fruit piercing moths in citrus orchards	90
3.6	Programme: Non-Phytosanitary Key Pests	91
3.6.1	Programme summary	91
3.6.2	Progress report: Evaluation of entomopathogenic fungi against thrips and mealybug	92
3.6.3	Final report: The potential of several isolates of entomopathogenic fungi for the control of California red scale (<i>Aonidiella aurantii</i> Maskell [Hemiptera: Diapsidae]), a pest of citrus in South Africa	93

**CRI GROUP ANNUAL RESEARCH REPORT 2013/14
TABLE OF CONTENTS**

		Page
	3.6.4 Progress report: Short residual treatments for thrips, psylla, leafhoppers and Woolly whitefly for late season usage	93
4	PORTFOLIO: DISEASE MANAGEMENT	94
4.1	Portfolio summary	94
4.2	Programme: Graft Transmissible Diseases	96
	4.2.1 Programme summary	96
	4.2.2 Final report: CTV cross protection of Star Ruby grapefruit using Beltsville sub-isolates of Nartia mild strain	98
	4.2.3 Progress report: CTV cross protection of Star Ruby using Beltsville sub-isolates of Nartia mild strain for the Orange River Valley	104
	4.2.4 Progress report: The effect of different CTV sources in Valencias on different rootstock combinations in the Orange River Valley	105
	4.2.5 Progress report: Cross protection of Marsh and Star Ruby by using the best field isolates collected in the different grapefruit production areas of SA	105
	4.2.6 Progress report: Identification of suitable <i>Citrus tristeza virus</i> sources for cross-protecting Turkey Valencia	106
	4.2.7 Progress report: Searching for a <i>Citrus tristeza virus</i> source suitable for cross-protecting soft citrus	107
	4.2.8 Progress report: Dynamics of <i>Citrus tristeza virus</i> mild and severe strains in mild strain cross-protection strategies	108
	4.2.9 Progress report: Differential cultivar selection or suppression of <i>Citrus tristeza virus</i> (CTV) genotypes	109
	4.2.10 Progress report: Evaluation of citrus material for greening resistance	110
	4.2.11 Progress report: Epidemiology of greening disease – alternate hosts and spread	110
	4.2.12 Progress report: Comparison of shoot tip grafted citrus with old clone material	111
4.3	Programme: Fruit and Foliar Diseases	112
	4.3.1 Programme summary	112
	4.3.2 Progress report: Evaluation of new spray programmes for the control of <i>Alternaria</i> brown spot in the summer rainfall regions of South Africa	112
	4.3.3 Progress report: Optimisation of fungicide spray applications in citrus orchards	126
	4.3.4 Progress report: Control of <i>Botrytis cinerea</i> pers. on lemons	127
4.4	Programme: Soilborne Diseases	127
	4.4.1 Programme summary	127
	4.4.2 Progress report: The evaluation of different pre-plant products for the control of the citrus nematode, as part of an integrated nematode control approach in citrus replant situations	129
	4.4.3 Progress report: Evaluation of alternative products for control of citrus nematode and <i>Phytophthora</i> spp. in citrus	130
	4.4.4 Progress report: The status of Armillaria root rot and its management in SA citrus orchards	130
	4.4.5 Progress report: Investigation into edaphic factors and their interactions on citrus tree decline	131
	4.4.6 Final report: Rootstock resistance against <i>Phytophthora nicotiane</i> root rot	132
	4.4.7 Progress report: Evaluation of a new nematicide for the control of the citrus nematode	148

**CRI GROUP ANNUAL RESEARCH REPORT 2013/14
TABLE OF CONTENTS**

		Page
4.5	Programme: Postharvest Pathology	148
4.5.1	Programme summary	148
4.5.2	Progress report: Provision of an industry service whereby new packhouse treatments are comparatively evaluated, fungicide resistance is monitored and standardised recommendations are provided	149
4.5.3	Final report: Optimisation of fungicide application in citrus packhouses	166
4.5.4	Final report: Practical impact of imazalil resistance on control of postharvest citrus green and blue mould	177
4.5.5	Progress report: The JBT heated flooder as an alternative application method for fungicides in citrus packhouses	196
4.5.6	Progress report: Identification and modelling of postharvest decay risk indicators	197
4.5.7	Progress report: Use of hot water, potassium silicate and biological control agents to reduce postharvest disease and chilling injury in citrus fruit	198
4.6	Programme: Citrus Black Spot	199
4.6.1	Programme summary	199
4.6.2	Progress report: Monitoring ascospore releases in the Eastern Cape to determine the critical period for CBS infection	200
4.6.3	Progress report: Development of a new spray programmes for the control of Citrus black spot	201
4.6.4	Progress report: The global population structure and reproductive biology of the fungal pathogen, <i>Phyllosticta citricarpa</i> Kiely	201
4.6.5	Progress report: Improving the retention of suspension liquid phosphonate fungicides on citrus fruit and leaves	201
4.6.6	Progress report: Epidemiology and pest risk assessment of <i>Guignardia citricarpa</i>	202
4.7	CRI Diagnostic Centre	202
5	PORTFOLIO: HORTICULTURE	205
5.1	Programme summary	205
5.2	Programme: Rind condition	206
5.2.1	Programme summary	206
5.2.2	Final report: Development of postharvest treatments to prevent chilling injury in various citrus species	206
5.2.3	Progress report: Effect of different chemical applications on development of Peteca spot in lemons	261
5.2.4	Progress report: Studies on aspects concerning rind pitting/staining citrus fruit	261
5.2.5	Final report: Non-destructive monitoring and prediction of postharvest rind quality of 'Nules Clementine' Mandarin and Valencia orange fruit	262
5.3	Programme: Fruit Production and Quality	271
5.3.1	Programme summary	271
5.3.2	Progress report: A novel approach to water and nutrient management in citrus	271
5.3.3	Progress report: Study on the effect of humic and fulvic acids on fertilizer application in citrus	272
5.3.4	Final report: The evaluation of different formulations of micronutrients on foliar uptake	273
5.3.5	Final report: The role of silicon in the control of brown spot (<i>Alternaria alternata</i>) under laboratory conditions and black spot (<i>Phyllosticta citricarpa</i>) in an orchard	279

**CRI GROUP ANNUAL RESEARCH REPORT 2013/14
TABLE OF CONTENTS**

		Page
5.4	Programme: Cold Chain Management and Packaging	286
5.4.1	Programme summary	286
5.4.2	Final report: Energy and temperature optimization in refrigerated shipping containers	286
5.4.3	Progress report: Using Radio Frequency Identification Technology (RFIT) to get an understanding of the storage air and fruit pulp temperatures and relative humidity in a typical SA citrus fruit export supply chain from the very beginning to the very end over two seasons	314
5.5	Programme: Cultivar Evaluation	315
5.5.1	Programme summary	315
5.5.2	Progress report: Evaluation of Valencia selections in hot humid inland areas (Onderberg)	315
5.5.3	Progress report: Evaluation of Valencia selections in the hot dry inland areas (Letsitele)	320
5.5.4	Progress report: Evaluation of Mandarin hybrid selections in the hot inland areas (Letsitele & Malelane)	326
5.5.5	Progress report: Evaluation of Valencia selections in the hot inland areas (Swaziland)	329
5.5.6	Progress report: Evaluation of Valencia selections in the intermediate areas (Tom Burke)	332
5.5.7	Progress report: Evaluation of Mandarin hybrid selections in the hot dry inland areas (Tom Burke & Tshipise)	333
5.5.8	Progress report: Evaluation of Mandarin hybrid selections in the cool inland areas (Burgersfort)	337
5.5.9	Progress report: Evaluation of Delta Valencia on new imported rootstocks in the Marble Hall area	340
5.5.10	Progress report: Evaluation of Valencias on new imported rootstocks in the Malelane area	346
5.5.11	Progress report: Evaluation of grapefruit varieties on different rootstocks in the Swaziland area	349
5.5.12	Progress report: Evaluation of various navel selections on different rootstocks in the Burgersfort & Marble Hall area	352
5.5.13	Progress report: Evaluation of various Valencia selections on different rootstocks in the Komatipoort area	359
5.5.14	Progress report: Cultivar characteristics and climatic suitability of Satsuma Mandarins in a cold production region (Western Cape)	366
5.5.15	Progress report: Cultivar characteristics and climatic suitability of Clementine Mandarins in a cold production region (Western Cape)	367
5.5.16	Progress report: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (East Cape midlands)	369
5.5.17	Progress report: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Sundays River Valley)	371
5.5.18	Progress report: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Gamtoos River Valley)	373
5.5.19	Progress report: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Western Cape)	375
5.5.20	Progress report: Cultivar characteristics and climatic suitability of navel oranges in a cold production region (Sundays River Valley)	378
5.5.21	Progress report: Cultivar characteristics and climatic suitability of experimental navel oranges in a cold production region (Sundays River Valley)	380
5.5.22	Progress report: Cultivar characteristics and climatic suitability of experimental navel oranges in a cold production region (Gamtoos River Valley)	381
5.5.23	Progress report: Establishment of a molecular citrus genotype reference data-base for citrus cultivar verification within the Citrus Improvement Scheme	383

**CRI GROUP ANNUAL RESEARCH REPORT 2013/14
TABLE OF CONTENTS**

	Page
5.6	Climatic regions of southern Africa and cultivars being evaluated 385
5.7	Approximate maturity periods 388
6	CITRUS IMPROVEMENT SCHEME (CIS) 396
6.1	Budwood 396
6.2	Seed 396
6.3	Production 396
6.4	Tree Certification 396
6.5	Nursery registration 396
6.6	Statutory Improvement Scheme 397
6.7	Protective zone surrounding the Citrus Foundation Block 397
6.8	Establish and maintain a virus-free gene source at CRI 408
6.9	Diagnostic services for graft transmissible diseases 413
6.10	Citrus Biosecurity activities 423
7	INTERNATIONAL VISITS 426
7.1	S.D. Moore (Croatia) 426
7.2	A. Manrakhan (Mauritius) 432
7.3	J.G. van Zyl (Spain) 445
7.4	P.H. Fourie (Mexico) 452
7.5	J.J. Bester & P.J.R. Cronjé (California) 459
8	EXTENSION 468
8.1	Transformation: Extension Coordinators Report 475
8.2	Research Priorities 480
8.3	Study Group Chairmen 493
8.4	The relative funding support for research portfolios and programmes 494
8.5	Extension presentations by CRI researchers 496
8.6	Other means of Technology Transfer 498
	8.6.1 SA Fruit Journal 498
	8.6.2 CRI website 498
	8.6.3 CRInet 499
	8.6.4 Cutting Edge 499
9	PUBLICATIONS IN 2013-14 500
9.1	Refereed publications (or ISI ranked journals) 500
9.2	Semi-scientific publications 502
10	PRESENTATIONS AT SOCIETAL AND INTERNATIONAL CONGRESSES 502

**CRI GROUP ANNUAL RESEARCH REPORT 2014/15
TABLE OF CONTENTS**

		Page
1	MARKET ACCESS TECHNICAL COORDINATION	1
	1.2 Japan	2
	1.3 USA	2
	1.4 China	3
	1.5 South Korea	3
	1.6 Vietnam	3
	1.7 Indonesia	3
	1.8 India	4
	1.9 Malaysia	4
	1.10 New Markets	4
	1.10.1 The Philippines	4
	1.10.2 Australia and Lebanon	4
	1.10.3 Imports	4
	1.10.3.1 Import conditions	4
2	BIOSECURITY AND REGULATIONS	4
3	PORTFOLIO: INTEGRATED PEST MANAGEMENT	5
	3.1 Portfolio summary	5
	3.2 Programme: False Codling Moth	8
	3.2.1 Programme summary	8
	3.2.2 Progress report: Development of mechanisms for the postharvest detection of cryptic pests in citrus fruit	12
	3.2.3 FINAL REPORT: Late season releases of <i>Trichogrammatoidea cryptophlebiae</i> for suppression of FCM	12
	3.2.4 PROGRESS REPORT: The use of entomopathogenic fungi to control the soil-dwelling life stages of false codling moth	27
	3.2.5 PROGRESS REPORT: Impact of abbreviated and complete cold-treatment on survival and fitness of FCM larvae	29
	3.2.6 PROGRESS REPORT: Large scale field trials with entomopathogenic nematodes for control of FCM, fruit fly and thrips	29
	3.2.7 FINAL REPORT: Gene expression analysis of <i>Thaumatotibia leucotreta</i> as result of different isolates of <i>Cryptophlebia leucotreta</i> granulosis virus	30
	3.2.8 FINAL REPORT: Behaviour, biology and survival of pupating false codling moth	34
	3.2.9 PROGRESS REPORT: Evaluation of 7-Vinyl-Decyl Acetate 1 for mating inhibition in FCM	38
	3.2.10 Final report: A survey of Lepidoptera infesting citrus fruit in the C. Cape Midlands	39
	3.2.11 FINAL REPORT: Determination of reapplication frequency of the <i>Cryptophlebia leucotreta</i> granulovirus to provide protection against FCM infestation of citrus	46
	3.2.12 FINAL REPORT: Using the larval parasitoid, <i>Agathis bishopi</i> , for detection of FCM infested fruit	48
	3.2.13 PROGRESS REPORT: A feasibility study on the use of sniffer dogs for detecting FCM infested fruit post-harvest	50
	3.2.14 PROGRESS REPORT: Classical biocontrol introduction of <i>Agathis bishopi</i> into the Western Cape	50
	3.2.15 PROGRESS REPORT: Laboratory handling and quality control for SIT: an experimental assessment of FCM chilling and flight performance with respect to the improvement of moth production parameters, particularly pertaining to improved cold-tolerance	51

**CRI GROUP ANNUAL RESEARCH REPORT 2014/15
TABLE OF CONTENTS**

	Page
3.2.16 PROGRESS REPORT: Novel approaches to mating disruption of FCM	51
3.2.17 PROGRESS REPORT: Movement of false codling moth (FCM) and fruit flies (FF) in multi-crop (citrus, stone fruit, grape, pomegranate) systems	52
3.2.18 PROGRESS REPORT: Improving the cold tolerance of false codling moth (<i>Thaumatotibia leucotreta</i>) for improved performance in a sterile insect release Programme	53
3.2.19 PROGRESS REPORT: Verification of proposed inspections standards within an FCM systems approach	54
3.2.20 FINAL REPORT: FCM infestation of packed lemons destined for export	55
3.2.21 PROGRESS REPORT: Identifying volatile emissions associated with false codling moth infestation of citrus fruit	62
3.2.22 FINAL REPORT: An audit of the efficacy of the sterile insect technique programme for false codling moth, <i>Thaumatotibia leucotreta</i> (Meyrick) (Lepidoptera: Tortricidae), in the Sundays River Valley	63
3.3 Programme: Fruit Fly	73
3.3.1 Programme summary	73
3.3.2 Progress report: Fruit fly rearing	75
3.3.3 PROGRESS REPORT: A new bait for more effective control of all <i>Ceratitidis</i> fruit flies	76
3.3.4 FINAL REPORT: Surveillance of <i>Bactrocera dorsalis</i> in commercial citrus orchards in South Africa	77
3.3.5 FINAL REPORT: Developmental threshold and critical thermal limits for two <i>Ceratitidis</i> <i>rosa</i> types in South Africa	90
3.3.6 FINAL REPORT: Develop a yeast autolysate attractant for fruit fly bait that is safe with copper and more palatable than hydrolysate	99
3.3.7 PROGRESS REPORT: Dispersal capacity of <i>Bactrocera dorsalis</i>	103
3.3.8 Progress report: Invasion and expansion of <i>Bactrocera dorsalis</i> in South Africa: a genetic analysis	104
3.3.9 PROGRESS REPORT: Utilisation of citrus and other fruit grown in South Africa by <i>Bactrocera dorsalis</i> previously recognized as <i>B. invadens</i>	104
3.3.10 PROGRESS REPORT: Detection methods for fruit flies of economic significance to fruit and vegetable production in Africa and Indian Ocean islands	105
3.3.11 PROGRESS REPORT: Evaluation of male annihilation treatments for control of <i>Bactrocera dorsalis</i>	106
3.4 Programme: Mealybug and other Market Access pests	106
3.4.1 Programme summary	106
3.4.2 FINAL REPORT: The morphology and ecology of the Carob moth in citrus orchards	107
3.4.3 PROGRESS REPORT: Evaluating GRAS post-harvest fumigants for phytosanitary pests	114
3.4.4 PROGRESS REPORT: The association of a lepidopteran borer complex between pecan nuts (<i>Carya illinoensis</i>) and citrus (<i>Citrus sinensis</i>) in the Vaalharts region	115
3.4.5 PROGRESS REPORT: Establishment of a monitoring system and control practices for carob moth on citrus	116
3.5 Programme: Non-Phytosanitary Key Pests	117
3.5.1 Programme summary	117
3.5.2 PROGRESS REPORT: Evaluation of entomopathogenic fungi against thrips and mealybug	117
3.5.3 PROGRESS REPORT: Short residual treatments for thrips, psylla, leafhoppers and woolly whitefly for late season usage	118
3.5.4 PROGRESS REPORT: Mating disruption for red scale control	119

**CRI GROUP ANNUAL RESEARCH REPORT 2014/15
TABLE OF CONTENTS**

	Page
3.6 Programme: Minor Pests and Mites	120
3.6.1 Programme summary	120
3.6.2 PROGRESS REPORT: Importing and releasing <i>Cales noacki</i> for the control of woolly whitefly	120
3.6.3 FINAL REPORT: Non-target effect updates	121
3.6.4 PROGRESS REPORT: Using banana odour as an attractant for monitoring fruit piercing moth in citrus orchards	130
4 PORTFOLIO: DISEASE MANAGEMENT	131
4.1 Portfolio summary	131
4.2 Programme: Graft Transmissible Diseases	133
4.2.1 Programme summary	133
4.2.2 PROGRESS REPORT: Cross-protection of Star Ruby using Beltsville sub-isolates of Nartia mild strain for the Orange River Valley	135
4.2.3 PROGRESS REPORT: The effect of different CTV sources in Valencias on different rootstock combinations for the Orange River Valley	136
4.2.4 PROGRESS REPORT: Cross-protection of Marsh and Star Ruby grapefruit by using the best field isolates collected in the different grapefruit production areas of southern Africa	136
4.2.5 PROGRESS REPORT: Identification of suitable <i>Citrus tristeza virus</i> sources for pre- immunising Turkey Valencia	137
4.2.6 PROGRESS REPORT: Searching for a <i>Citrus tristeza virus</i> source suitable for cross-protecting soft citrus	138
4.2.7 PROGRESS REPORT: Dynamics of <i>citrus tristeza virus</i> mild and severe strains in mild strain cross-protection strategies	138
4.2.8 FINAL REPORT: Differential cultivar selection or suppression of <i>Citrus tristeza virus</i> (CTV) genotypes	139
4.2.9 PROGRESS REPORT: Characterisation of <i>Citrus tristeza virus</i> variants and their influence on the symptom expression in the grapefruit host	160
4.2.10 PROGRESS REPORT: Evaluation of citrus material for greening resistance	161
4.2.11 PROGRESS REPORT: Further studies on alternative hosts of “ <i>Candidatus Liberibacter africanus</i> ” and related Liberibacters on tree members of indigenous Rutaceae	162
4.2.12 PROGRESS REPORT: Comparison of shoot tip grafted citrus with old clone Material	162
4.3 Programme: Fruit and Foliar Diseases	163
4.3.1 Programme summary	163
4.3.2 PROGRESS REPORT: Evaluation of new spray programmes for the control of <i>Alternaria</i> brown spot in the summer rainfall regions of South Africa	165
4.3.3 FINAL REPORT: Optimisation of fungicide spray applications in citrus orchards	165
4.3.4 FINAL REPORT: Control of <i>Botrytis cinerea</i> Pers. on lemons	202
4.3.5 PROGRESS REPORT: Development of a tree canopy characteristic calibration formula for reduced volume fungicide application in citrus orchards	218
4.3.6 PROGRESS REPORT: The use of adjuvants to improve fungicide foliar spray deposition and control of <i>Alternaria</i> brown spot on citrus	218
4.4 Programme: Soilborne Diseases	219
4.4.1 Programme summary	219
4.4.2 PROGRESS REPORT: The evaluation of different pre-plant products for the control of the citrus nematode, as part of an integrated nematode control approach in citrus replant situations	221

CRI GROUP ANNUAL RESEARCH REPORT 2014/15
TABLE OF CONTENTS

		Page
4.4.3	FINAL REPORT: Investigation into edaphic factors and their interactions on citrus tree decline	221
4.4.4	PROGRESS REPORT: Evaluation of alternative products for control of citrus nematode and <i>Phytophthora</i> spp. in citrus	235
4.4.5	PROGRESS REPORT: The status of Armillaria root rot and its management in South African citrus orchards	241
4.4.6	PROGRESS REPORT: Preventative and curative management of soilborne pathogens in citrus nurseries	242
4.5	Programme: Postharvest Pathology	242
4.5.1	Programme summary	242
4.5.2	FINAL REPORT: The JBT heated flooder as an alternative application method for fungicides in citrus packhouses	243
4.5.3	PROGRESS REPORT: Further optimisation of in-line aqueous fungicide application in citrus packhouses	255
4.5.4	PROGRESS REPORT: Optimisation of postharvest drench application of fungicides on citrus fruit	256
4.5.5	FINAL REPORT: Quantification of imazalil resistance in <i>Penicillium digitatum</i> populations in citrus packhouses	257
4.5.6	FINAL REPORT: Use of hot water, potassium silicate and biological control agents to reduce postharvest disease and chilling injury in citrus fruit	268
4.5.7	PROGRESS REPORT: Provision of an industry service whereby new packhouse treatments are comparatively evaluated, fungicide resistance is monitored and standardised recommendations are provided	269
4.5.8	FINAL REPORT: Identification and modelling of postharvest decay risk Indicators	289
4.6	Programme: Citrus Black Spot	297
4.6.1	Programme summary	297
4.6.2	FINAL REPORT: Monitoring ascospore releases in the Eastern Cape to determine the critical period for CBS infection	299
4.6.3	PROGRESS REPORT: Development of new spray programmes for the control of citrus black spot	313
4.6.4	FINAL REPORT: The global population structure and reproductive biology of the fungal pathogen, <i>Phyllosticta citricarpa</i> Kiely	317
4.6.5	FINAL REPORT: Improving the retention of suspension liquid phosphonate fungicides on citrus fruit and leaves	321
4.6.6	PROGRESS REPORT: Epidemiology and pest risk assessment of <i>Phyllosticta citricarpa</i>	327
4.6.7	FINAL REPORT: Identifying the fungi that cause CBS-like disease symptoms on citrus fruit	334
4.7	CRI Diagnostic Centre	339
5	PORTFOLIO: HORTICULTURE	340
5.1	Portfolio summary	340
5.2	Programme: Rind condition	340
5.2.1	Programme summary	340
5.2.2	PROGRESS REPORT: Studies on aspects concerning rind pitting/staining citrus fruit	341
5.2.3	PROGRESS REPORT: Effect of different chemical applications on development of Peteca spot in lemons	341
5.2.4	FINAL REPORT: The development of a rind disorder prediction model for citrus fruits based on climatic conditions	342

CRI GROUP ANNUAL RESEARCH REPORT 2014/15
TABLE OF CONTENTS

	Page
5.2.5 PROGRESS REPORT: Investigating cold storage potential of new mandarin citrus selections/cultivars and the effect of ethylene degreening on rind disorders	345
5.3 Programme: Fruit Production and Quality	345
5.3.1 Programme summary	345
5.3.2 PROGRESS REPORT: A novel approach to water and nutrient management in citrus	346
5.3.3 FINAL REPORT: Study on the effect of humic and fulvic acids on fertiliser application in citrus	347
5.3.4 PROGRESS REPORT: Determining the time and duration of flower induction in early vs late mandarin cultivars and evaluating the effect of hand thinning, pruning and girdling on leaf and root carbohydrate levels, fruit size, vegetative regrowth and alternate bearing in Nadorcott mandarin	355
5.3.5 PROGRESS REPORT: Effect of shade net on fruit production of mandarin Citrus	356
5.3.6 PROGRESS REPORT: Effect of pruning on fruit production of Nadorcott mandarin	357
5.4 PROGRAMME: CULTIVAR EVALUATION	340
5.4.1 Programme summary	340
5.4.2 PROGRESS REPORT: Evaluation of Valencia selections in hot humid inland areas (Onderberg)	341
5.4.3 PROGRESS REPORT: Evaluation of Valencia selections in the hot dry inland areas (Letsitele & Hoedspruit)	345
5.4.4 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the hot inland areas (Letsitele & Malelane)	354
5.4.5 PROGRESS REPORT: Evaluation of Valencia selections in the hot inland areas (Swaziland)	359
5.4.6 PROGRESS REPORT: Evaluation of Valencia selections in the intermediate production areas (Tom Burke)	362
5.4.7 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the intermediate production areas (Marble Hall & Tom Burke)	363
5.4.8 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the hot dry inland areas (Tshipise)	367
5.4.9 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the cool inland areas (Burgersfort)	369
5.4.10 PROGRESS REPORT: Evaluation of Delta Valencia on new imported rootstocks in the Marble Hall area	372
5.4.11 PROGRESS REPORT: Evaluation of Valencias on new imported rootstocks in the Malelane area	378
5.4.12 PROGRESS REPORT: Evaluation of various Navel selections on different rootstocks in the Burgersfort and Marble Hall area	381
5.4.13 PROGRESS REPORT: Evaluation of various Valencia selections on different rootstocks in the Komatipoort area	384
5.4.14 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region (Western Cape)	390
5.4.15 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region (Western Cape)	393
5.4.16 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (East Cape Midlands)	394
5.4.17 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Sundays River Valley)	396
5.4.18 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Gamtoos River Valley)	398
5.4.19 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Western Cape)	403

CRI GROUP ANNUAL RESEARCH REPORT 2014/15
TABLE OF CONTENTS

	Page
5.4.20 PROGRESS REPORT: Cultivar characteristics and climatic suitability of navel oranges in a cold production region (Sundays River Valley)	407
5.4.21 PROGRESS REPORT: Cultivar characteristics and climatic suitability of experimental navel oranges in a cold production region (Gamtoos River Valley)	409
5.4.22 PROGRESS REPORT: Evaluation of Valencia selections in a semi-desert production area (Kakamas)	411
5.4.23 PROGRESS REPORT: Cultivar characteristics and climatic suitability of experimental Navel oranges in a semi-desert region (Kakamas)	413
5.4.24 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a semi-desert production region (Kakamas)	414
5.4.25 PROGRESS REPORT: Cultivar characteristics and climatic suitability of lemons in a semi-desert production region (Kakamas)	416
5.4.26 FINAL REPORT: Establishment of a molecular citrus genotype reference database for citrus cultivar verification within the Citrus Improvement Scheme	418
5.5 Climatic Regions of Southern Africa and cultivars being evaluated	470
5.6 Approximate maturity periods	473
6 CITRUS IMPROVEMENT SCHEME (CIS)	481
6.1 Budwood	481
6.2 Seed	487
6.3 Production	488
6.4 Tree Certification	488
6.5 Nursery Certification	491
6.6 Statutory Improvement Scheme	493
6.7 Protective zone surrounding the Citrus Foundation Block	493
6.8 Shoot tip grafting (STG), pre-immunisation and nucleus block management	493
6.9 Diagnostic services for graft transmissible diseases	497
6.10 Citrus Biosecurity Activities	507
6.10.1 African Greening Citrus surveys	507
6.10.2 Asiatic Citrus Greening (HLB) and Asian Citrus Psyllid (ACP) surveys	507
6.10.3 Citrus Biosecurity in Africa	508
7 INTERNATIONAL VISITS	509
7.1 G.C. Schutte	509
7.2 A. Manrakhan	523
8 VOORLIGTING / EXTENSION	537
8.1 Transformation Managers' Annual Report	540
8.2 Research Priorities	543
8.3 Study Group Chairmen 2014-15	556
8.4 The relative funding support for research Portfolios and Programmes for 2014-15	557
8.5 Extension presentations by CRI researchers in 2014-15	559
8.6 Other means of Technology Transfer	563
8.6.1 S.A. Fruit Journal	563
8.6.2 CRI Website	563
8.6.3 CRInet	564
8.6.4 CRI Cutting Edge	564
9 PUBLICATIONS IN 2014-15	565
9.1 Refereed Publications (or ISI ranked journals)	565

**CRI GROUP ANNUAL RESEARCH REPORT 2014/15
TABLE OF CONTENTS**

	Page
9.2 Semi-scientific publications	566
10 PRESENTATIONS AT SOCIETAL AND INTERNATIONAL CONGRESSES	566

**CRI GROUP ANNUAL RESEARCH REPORT 2015/16
TABLE OF CONTENTS**

1	MARKET ACCESS TECHNICAL COORDINATION	1
1.1	Summary	1
1.2	Europe (UK)	1
1.3	Japan	2
1.4	USA	3
1.5	China	3
1.6	South Korea	3
1.7	Vietnam	3
1.8	Indonesia	4
1.9	Reunion	4
1.10	New Markets	4
	1.10.1 The Philippines	4
1.11	Imports	
	1.11.1 Import conditions	4
1.12	Regulations	4
2	BIOSECURITY AND REGULATIONS	5
3	PORTFOLIO: INTEGRATED PEST MANAGEMENT	6
3.1	Portfolio summary	6
3.2	Programme: False Codling Moth	8
	3.2.1 Programme summary	8
	3.2.2 FINAL REPORT: Development of mechanisms for the postharvest detection of cryptic pests in citrus fruit	12
	3.2.3 FINAL REPORT: Large scale field trials with entomopathogenic nematodes for control of FCM, fruit fly and thrips	32
	3.2.4 FINAL REPORT: A feasibility study on the use of sniffer dogs for detecting FCM infested fruit post-harvest	63
	3.2.5 FINAL REPORT: Classical biocontrol introduction of <i>Agathis bishopi</i> into the Western Cape	69
	3.2.6 PROGRESS REPORT: Laboratory handling and quality control for SIT: an experimental assessment of FCM chilling and flight performance with respect to the improvement of moth production parameters, particularly pertaining to improved cold-tolerance	70
	3.2.7 PROGRESS REPORT: Assessment of the pest status of FCM on citrus in various southern African production regions	71
	3.2.8 PROGRESS REPORT: Entomopathogenic fungi for control of soil-borne life stages of FCM	72
	3.2.9 PROGRESS REPORT: Impact of abbreviated and complete cold-treatment on survival and fitness of FCM larvae	72
	3.2.10 PROGRESS REPORT: Evaluating hot air treatments for postharvest FCM control	73
	3.2.11 PROGRESS REPORT: Evaluation of 7-Vinyl-Decyl Acetate for mating inhibition in FCM	74
	3.2.12 PROGRESS REPORT: Novel approaches to mating disruption of FCM	74
	3.2.13 Progress Report: Movement of false codling moth (FCM) and fruit flies (FF) in multi-crop (citrus, stone fruit, grape, pomegranate) systems	75
	3.2.14 PROGRESS REPORT: Improving the cold tolerance of false codling moth (<i>Thaumatotibia leucotreta</i>) for improved performance in a sterile insect release programme	76
	3.2.15 PROJECT REPORT: Verification of proposed inspections standards within an FCM systems approach	77

**CRI GROUP ANNUAL RESEARCH REPORT 2015/16
TABLE OF CONTENTS**

		Page
3.2.16	PROGRESS REPORT: Identifying volatile emissions associated with false codling moth infestation of citrus fruit	78
3.2.17	PROJECT REPORT: The efficacy of registered treatments for FCM control in Limpopo	79
3.2.18	PROGRESS REPORT: FCM population ecology in citrus orchards: the influence of orchard age	79
3.2.19	PROGRESS REPORT: Assessment of pheromone specificity in FCM populations with focus on pest monitoring and regional rollout of SIT	80
3.2.20	PROGRESS REPORT: Development of UV-resistant CrleGV-SA for use as an enhanced biopesticide for FCM control on citrus	81
3.2.21	PROGRESS REPORT: Developing and optimising automatic sorting equipment with focus on online detection of FCM	82
3.2.22	PROGRESS REPORT: Genetic and biological characterization of a novel nucleopolyhedrovirus from the false codling moth (FCM), <i>Thaumatotibia leucotreta</i> , for improved control of FCM	84
3.3	Programme: Fruit Fly	84
3.3.1	Programme summary	83
3.3.2	PROGRESS REPORT: Fruit fly rearing	86
3.3.3	PROGRESS REPORT: A new bait for more effective control of all <i>Ceratitis</i> fruit flies	86
3.3.4	PROGRESS REPORT: Dispersal capacity of <i>Bactrocera dorsalis</i>	87
3.3.5	PROGRESS REPORT: Invasion and expansion of <i>Bactrocera dorsalis</i> in South Africa: a genetic analysis	88
3.3.6	PROGRESS REPORT: Utilisation of citrus and other fruit grown in South Africa by <i>B. dorsalis</i> previously recognized as <i>B. invadens</i>	89
3.3.7	PROGRESS REPORT: Detection methods for fruit flies of economic significance to fruit and vegetable production in Africa and Indian Ocean islands	90
3.3.8	PROGRESS REPORT: Evaluation of male annihilation treatments for control of <i>Bactrocera dorsalis</i>	91
3.4	Programme: Mealybug and other Market Access Pests	92
3.4.1	Programme summary	92
3.4.2	PROGRESS REPORT: Evaluating GRAS post-harvest fumigants for phytosanitary pests	93
3.4.3	PROGRESS REPORT: Establishment of a monitoring system and control practices for carob moth on citrus	94
3.4.4	PROGRESS REPORT: The natural enemies and biological control of <i>Delottococcus aberiae</i>	94
3.5	Programme: Non-Phytosanitary Key Pests	95
3.5.1	Programme summary	95
3.5.2	FINAL REPORT: Evaluation of entomopathogenic fungi against thrips and mealybug	96
3.5.3	FINAL REPORT: Mating disruption for red scale control	106
3.5.4	PROGRESS REPORT: Short residual treatments for thrips, psylla, leafhoppers and woolly whitefly for late season usage	114
3.6	Programme: Minor Pests and Mites	114
3.6.1	Programme summary	114
3.6.2	FINAL REPORT: Using banana odour as an attractant for monitoring fruit piercing moth in citrus orchards	115
3.6.3	PROGRESS REPORT: Importing and releasing <i>Cales noacki</i> for the control of woolly whitefly	129

**CRI GROUP ANNUAL RESEARCH REPORT 2015/16
TABLE OF CONTENTS**

		Page
4	PORTFOLIO: DISEASE MANAGEMENT	130
4.1	Portfolio summary	131
4.2	Programme: Graft Transmissible Diseases	133
4.2.1	Programme summary	133
4.2.2	FINAL REPORT: <i>Citrus tristeza virus</i> cross-protection of Star Ruby using Beltsville sub-isolates of Nartia mild strain for the Orange River Valley	134
4.2.3	FINAL REPORT: Evaluation of citrus material for greening resistance	138
4.2.4	FINAL REPORT: Dynamics of <i>Citrus tristeza virus</i> mild and severe strains in mild strain cross-protection strategies	145
4.2.5	FINAL REPORT: Further studies on alternative hosts of “ <i>Candidatus Liberibacter africanus</i> ” and related Liberibacters on tree members of indigenous Rutaceae	150
4.2.6	PROGRESS REPORT: The effect of different CTV sources in Valencias on different rootstock combinations for the Orange River Valley	162
4.2.7	PROGRESS REPORT: Identification of suitable <i>Citrus tristeza virus</i> sources for pre-immunising Turkey Valencia	163
4.2.8	PROGRESS REPORT: Characterisation of <i>Citrus tristeza virus</i> variants and their influence on the symptom expression in the grapefruit host	164
4.2.9	PROGRESS REPORT: <i>Citrus tristeza virus</i> cross-protection of Marsh and Star Ruby grapefruit using the best field isolates collected in the different grapefruit production areas in southern Africa	164
4.2.10	PROGRESS REPORT: Searching for a <i>Citrus tristeza virus</i> source suitable for cross-protecting soft citrus	165
4.2.11	PROGRESS REPORT: Comparison of shoot tip grafted citrus with old clone material	166
4.3	Programme: Fruit and Foliar Diseases	167
4.3.1	Programme summary	167
4.3.2	PROGRESS REPORT: Evaluation of new spray programmes for the control of <i>Alternaria</i> brown spot in the summer rainfall regions of South Africa	168
4.3.3	PROGRESS REPORT: Development of a tree canopy characteristic calibration formula for reduced volume fungicide application in citrus orchards	168
4.3.4	PROGRESS REPORT: The use of adjuvants to improve fungicide foliar spray deposition and control of <i>Alternaria</i> brown spot on citrus	169
4.4	Programme: Soilborne Diseases	169
4.4.1	Programme summary	169
4.4.2	PROGRESS REPORT: The evaluation of different pre-plant products for the control of the citrus nematode, as part of an integrated nematode control approach in citrus replant situations	171
4.4.3	PROGRESS REPORT: Evaluation of alternative products for control of citrus nematode and <i>Phytophthora</i> spp. in citrus	171
4.4.4	PROGRESS REPORT: The status of Armillaria root rot and its management in South African citrus orchards	172
4.4.5	PROGRESS REPORT: Diachronic study of abiotic and biotic factors associated with citrus decline	173
4.4.6	PROGRESS REPORT: Preventative and curative management of soilborne pathogens in citrus nurseries	173
4.5	Programme: Postharvest Pathology	174
4.5.1	Programme summary	174
4.5.2	FINAL REPORT: Optimisation of postharvest drench application of fungicides on citrus fruit	175

**CRI GROUP ANNUAL RESEARCH REPORT 2015/16
TABLE OF CONTENTS**

		Page
4.5.3	FINAL REPORT: Further optimisation of in-line aqueous fungicide application in citrus packhouses	175
4.5.4	PROGRESS REPORT: Provision of an industry service whereby new packhouse treatments are comparatively evaluated, fungicide resistance is monitored and standardised recommendations are provided	175
4.5.5	PROGRESS REPORT: Singular and combined effects of postharvest treatments on viability and reproductive ability of <i>Phyllosticta citricarpa</i> infections	191
4.5.6	PROGRESS REPORT: Precision fungicide application for the control of postharvest diseases on citrus	191
4.5.7	PROGRESS REPORT: Application of nanotechnology to decrease the volatility of effective essential oils in different applications against citrus postharvest fungi	192
4.6	Programme: Citrus Black Spot	192
4.6.1	Programme summary	192
4.6.2	PROGRESS REPORT: Development of new spray programmes for the control of citrus black spot	195
4.6.3	PROGRESS REPORT: Epidemiology and pest risk assessment of <i>Phyllosticta citricarpa</i>	200
4.6.4	PROGRESS REPORT: The global population structure and reproductive biology of the fungal pathogen, <i>Phyllosticta citricarpa</i> Kiely	200
4.6.5	FINAL REPORT: Improving the retention of suspension liquid phosphonate fungicides on citrus fruit and leaves	201
4.6.6	FINAL REPORT: Identifying the fungi that cause CBS-like disease symptoms on citrus fruit	216
4.6.7	PROGRESS REPORT: Evaluation of reduced volume fungicide and pesticide sprays for control of citrus black spot and false codling moth	224
4.6.8	PROGRESS REPORT: Epidemiology, inoculum potential and infection parameters of Citrus Black Spot	225
4.6.9	Improved Citrus Black Spot management through web-based information systems	226
4.6.10	PROGRESS REPORT: Epidemiology of CBS in different geographic areas and development of a risk management system for Citrus Black Spot	226
4.6.11	PROGRESS REPORT: Detection and spread of Citrus Black Spot pathogens	227
4.7	CRI Diagnostic Centre	228
5	PORTFOLIO: HORTICULTURE	230
5.1	Portfolio summary	230
5.2	Programme: Rind condition	231
5.2.1	Programme summary	231
5.2.2	FINAL REPORT: Effect of different chemical applications on development of Peteca spot in lemons	232
5.2.3	PROGRESS REPORT: Studies on aspects concerning rind pitting/staining citrus fruit	238
5.2.4	PROGRESS REPORT: Investigating cold storage potential of new mandarin citrus selections/cultivars and the effect of ethylene degreening on rind disorders	240
5.2.5	PROGRESS REPORT: Effect of irradiation levels on internal and external citrus fruit quality	241
5.2.6	PROGRESS REPORT: Non-destructive prediction and monitoring of post-harvest rind quality of citrus fruit using Vis/NIR spectroscopy	242
5.3	Programme: Fruit Production and Quality	242
5.3.1	Programme summary	242

**CRI GROUP ANNUAL RESEARCH REPORT 2015/16
TABLE OF CONTENTS**

	Page	
5.3.2	PROGRESS REPORT: A novel approach to water and nutrient management in citrus	243
5.3.3	PROGRESS REPORT: Determining the time and duration of flower induction in early vs late mandarin cultivars and evaluating the effect of hand thinning, pruning and girdling on leaf and root carbohydrate levels, fruit size, vegetative regrowth and alternate bearing in Nadorcott mandarin	244
5.3.4	PROGRESS REPORT: Effect of shade net on fruit production and pruning requirements of mandarin citrus	244
5.3.5	PROGRESS REPORT: Effect of pruning on fruit production of Nadorcott mandarin	245
5.3.6	PROGRESS REPORT: Potential of 2,4-D as commercial solution to Alternaria black core rot (ABCR) in Navel oranges	247
5.3.7	PROGRESS REPORT: Studies on the reproductive development of 'Nadorcott' mandarin (<i>C. reticulata</i> Blanco)	247
5.3.8	PROGRESS REPORT: The benefits of shade netting for citrus fruit quality	248
5.3.9	PROGRESS REPORT: Nitrogen release from organic soil amendments	248
5.4	COLD CHAIN & PACKAGING	249
5.4.1	Programme summary	249
5.4.2	PROGRESS REPORT: Pre-cooling: ambient loading and forced air cooling of citrus fruit for cold sterilization markets	249
5.5	PROGRAMME: CULTIVAR EVALUATION	250
5.5.1	Programme summary	250
5.5.2	PROGRESS REPORT: Evaluation of Valencia selections in hot humid inland areas (Onderberg)	251
5.5.3	PROGRESS REPORT: Evaluation of Valencia selections in the hot dry inland areas (Letsitele & Hoedspruit)	256
5.5.4	PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the hot inland areas (Letsitele & Malelane)	263
5.5.5	PROGRESS REPORT: Evaluation of Valencia selections in the intermediate production areas (Tom Burke)	269
5.5.6	PROGRESS REPORT: Evaluation of Valencia selections in the hot dry production areas (Wiepe)	271
5.5.7	PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the intermediate production areas (Marble Hall & Tom Burke)	272
5.5.8	PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the hot dry inland areas (Tshipise)	277
5.5.9	PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the cool inland areas (Burgersfort)	281
5.5.10	PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the intermediate production areas (Karino)	283
5.5.11	PROGRESS REPORT: Evaluation of Navel selections in the intermediate production areas (Karino)	285
5.5.12	PROGRESS REPORT: Evaluation of Navel selections in the intermediate production areas (Marble Hall)	289
5.5.13	PROGRESS REPORT: Evaluation of Lemon selections in the intermediate production areas (Tom Burke)	291
5.5.14	PROGRESS REPORT: Evaluation of Valencias on new imported rootstocks in the Malelane area	292
5.5.15	PROGRESS REPORT: Evaluation of various Navel selections on different rootstocks in the Marble Hall area	295
5.5.16	PROGRESS REPORT: Evaluation of various Valencia selections on different rootstocks in the Komatipoort area	298
5.5.17	PROGRESS REPORT: Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region (Western Cape)	305

**CRI GROUP ANNUAL RESEARCH REPORT 2015/16
TABLE OF CONTENTS**

	Page
5.5.18 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region (Western Cape)	307
5.5.19 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (East Cape Midlands)	309
5.5.20 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Sundays River Valley)	311
5.5.21 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Gamtoos River Valley)	315
5.5.22 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Western Cape)	318
5.5.23 PROGRESS REPORT: Cultivar characteristics and climatic suitability of navel oranges in a cold production region (Sundays River Valley)	323
5.4.24 PROGRESS REPORT: Cultivar characteristics and climatic suitability of experimental navel oranges in a cold production region (Gamtoos River Valley)	326
5.4.25 PROGRESS REPORT: Evaluation of Valencia selections in a semi-desert production area (Kakamas)	328
5.4.26 PROGRESS REPORT: Cultivar characteristics and climatic suitability of experimental Navel oranges in a semi-desert region (Kakamas)	330
5.4.27 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a semi-desert production region (Kakamas)	332
5.4.28 PROGRESS REPORT: Cultivar characteristics and climatic suitability of lemons in a semi-desert production region (Kakamas)	337
5.6 Climatic Regions of Southern Africa and cultivars being evaluated	339
5.7 Approximate maturity periods	343
6 CITRUS IMPROVEMENT SCHEME (CIS)	351
6.1 Summary	351
6.2 Budwood	352
6.3 Seed	357
6.4 Production	357
6.5 Tree Certification	358
6.6 Nursery Certification	358
6.7 Statutory Improvement Scheme	361
6.8 Protective zone surrounding the Citrus Foundation Block	361
6.9 Shoot tip grafting (STG), pre-immunisation and nucleus block management	361
6.10 Diagnostic services for graft transmissible diseases	361
7 INTERNATIONAL VISITS	362
7.1 J. Joubert	362
8 VOORLIGTING / EXTENSION	368
8.1 Voorligtingoorsig	368
8.1.1 Die 2015 Seisoen	368
8.1.2 Die 2016 seisoen	368
8.1.3 CRI-PTF	368
8.1.4 No-oes voorligting	370
8.1.5 Noordelike produksiegebiede – (Groblersdal/Marble Hall, Burgersfort en Ohrigstad, Letsitele, Tshipise en Weipe asook Hoedspruit)	371
8.1.6 Sitrus-Koueketting	372
8.1.7 Sitrusverbeteringskema	372
8.1.8 CRI Na-oes Werkswinkels	372
8.2 Transformation Extension Officers' Annual Report	385

**CRI GROUP ANNUAL RESEARCH REPORT 2015/16
TABLE OF CONTENTS**

		Page
	8.2.1 The Citrus Study Groups	385
	8.2.2 Information Days	386
	8.2.3 Workshops	388
	8.2.4 Female Farmer of the Year Competition	389
	8.2.5 The Citrus Growers Development Chamber (CGDC)	390
	8.2.6 Launch of the CGA Grower Development Company	390
	8.2.7 The CGA Roadshows	390
	8.2.8 Commodity Project Allocation Committee (CPAC)	390
	8.2.9 Greening Committee	390
	8.2.10 CGA Mentorship Programme	390
	8.2.11 Government Grant and Recap Funding	391
	8.2.12 Challenges	391
	8.2.13 Summary of Transformation Extension Officers' Activities	391
8.3	Research Priorities	402
	8.3.1 Integrated Pest Management	402
	8.3.2 Disease Management	403
	8.3.3 Horticulture	404
	8.3.4 Cultivar Evaluation	406
8.4	Study Group Chairmen 2015-16	408
8.5	The relative funding support for research Portfolios and Programmes for 2015-16	409
8.6	Other means of Technology Transfer	411
	8.6.1 S.A. Fruit Journal	411
	8.6.2 CRI Website	412
	8.6.3 CRInet	413
	8.6.4 CRI Cutting Edge	413
9	PUBLICATIONS IN 2014-15	414
	9.1 Refereed Publications (or ISI ranked journals)	414
	9.2 Semi-scientific publications	415
10	PRESENTATIONS AT SOCIETAL AND INTERNATIONAL CONGRESSES	416

**CRI GROUP ANNUAL RESEARCH REPORT 2016/17
TABLE OF CONTENTS**

		Page
1	MARKET ACCESS TECHNICAL COORDINATION	1
1.1	Summary	1
1.2	Europe (UK)	1
1.3	Japan	2
1.4	USA	2
1.5	China	3
1.6	India	4
1.7	Vietnam	4
1.8	New Markets	4
	1.8.1 The Philippines	4
	1.8.2 Myanmar	4
1.9	Regulations	5
2	PORTFOLIO: INTEGRATED PEST MANAGEMENT	5
2.1	Portfolio summary	5
2.2	Programme: False Codling Moth	7
	2.2.1 Programme summary	7
	2.2.2 FINAL REPORT: Developing and optimising automatic sorting equipment with focus on online detection of FCM	10
	2.2.3 PROGRESS REPORT: Assessment of pheromone specificity in <i>Thaumatotibia leucotreta</i> (Meyrick) populations with focus on pest monitoring and the regional rollout of the sterile insect technique in citrus	15
	2.2.4 PROGRESS REPORT: Genetic and biological characterization of a novel nucleopolyhedrovirus from the false codling moth (FCM), <i>Thaumatotibia leucotreta</i> , for improved control of FCM	17
	2.2.5 PROGRESS REPORT: Development of UV-resistant CrleGV-SA for use as an enhanced biopesticide for FCM control on citrus	17
	2.2.6 PROGRESS REPORT: FCM population ecology in citrus orchards: the influence of orchard age	18
	2.2.7 PROGRESS REPORT: The efficacy of registered treatments for FCM control in Limpopo	19
	2.2.8 PROGRESS REPORT: Assessment of the pest status of FCM on citrus in various southern African production regions	19
	2.2.9 PROGRESS REPORT: Identifying volatile emissions associated with false codling moth infestation of citrus fruit	20
	2.2.10 PROGRESS REPORT: Verification of proposed inspections standards within an FCM systems approach	21
	2.2.11 PROGRESS REPORT: Evaluation of 7-Vinyl-Decyl Acetate for mating inhibition in FCM	22
	2.2.12 PROGRESS REPORT: Evaluating hot air treatments for postharvest FCM control	22
	2.2.13 PROGRESS REPORT: Impact of abbreviated and complete cold-treatment on survival and fitness of FCM larvae	23
	2.2.14 PROGRESS REPORT: Entomopathogenic fungi for control of soil-borne life stages of FCM	24
	2.2.15 PROGRESS REPORT: Movement of false codling moth (FCM) and fruit flies (FF) in multi-crop (citrus, stone fruit, grape, pomegranate) systems	25
	2.2.16 PROGRESS REPORT: Novel approaches to mating disruption of FCM	26
2.3	Programme: Fruit Fly	27
	2.3.1 Programme summary	27

CRI GROUP ANNUAL RESEARCH REPORT 2016/17
TABLE OF CONTENTS

	Page
2.3.2 FINAL REPORT: Evaluation of male annihilation treatments for control of <i>Bactrocera dorsalis</i>	28
2.3.3 FINAL REPORT: Invasion and expansion of <i>Bactrocera dorsalis</i> in South Africa: a genetic analysis	40
2.3.4 PROGRESS REPORT: Dispersal capacity of <i>Bactrocera dorsalis</i>	50
2.3.5 PROGRESS REPORT: Detection methods for fruit flies of economic significance to fruit and vegetable production in Africa and Indian Ocean islands	51
2.3.6 PROGRESS REPORT: Utilisation of citrus and other fruit grown in South Africa by <i>B. dorsalis</i> previously recognized as <i>B. invadens</i>	52
2.3.7 PROGRESS REPORT: Determination of non-host status of lemon to Natal fly, Medfly and Oriental fruit fly	53
2.3.8 PROGRESS REPORT: Fruit fly rearing	53
2.3.9 PROGRESS REPORT: A new bait for more effective control of all <i>Ceratitidis</i> fruit flies	53
2.3.10 PROGRESS REPORT: Determining phytotoxicity of fruit fly baits on citrus with previous exposure to copper sprays	54
2.3.11 PROGRESS REPORT: Biology and ecology of <i>Ceratitidis rosa</i> and <i>Ceratitidis quilicii</i> (Diptera: Tephritidae) in citrus	55
2.4 Programme: Mealybug and other Market Access Pests	56
2.4.1 Programme summary	56
2.4.2 FINAL REPORT: Development of a cold sterilisation treatment for carob moth	56
2.4.3 FINAL REPORT: Establishment of a monitoring system and control practices for carob moth on citrus	66
2.4.4 PROGRESS REPORT: Evaluating GRAS post-harvest fumigants for phytosanitary pests	71
2.4.5 PROGRESS REPORT: Trunk sprays for Fuller's rose beetle control	71
2.4.6 PROGRESS REPORT: The natural enemies and biological control of <i>Delottococcus aberiae</i>	72
2.4.7 PROGRESS REPORT: Suitability of entomopathogenic fungal isolates for microbial control of citrus pests: biological traits and effects of formulation	72
2.5 Programme: Non-Phytosanitary Key Pests	73
2.5.1 Programme summary	73
2.5.2 PROGRESS REPORT: Short residual treatments for thrips, psylla, leafhoppers and woolly whitefly for late season usage	73
2.5.3 PROGRESS REPORT: New systemic insecticides for citrus	74
2.5.4 PROGRESS REPORT: Control of Asian Citrus Psyllid, vector of Huanglongbing	74
2.6 Programme: Minor Pests and Mites	75
2.6.1 Programme summary	75
2.6.2 PROGRESS REPORT: Importing and releasing <i>Cales noacki</i> for the control of woolly whitefly	75
3 PORTFOLIO: DISEASE MANAGEMENT	76
3.1 Portfolio summary	76
3.2 Programme: Graft Transmissible Diseases	80
3.2.1 Programme summary	80
3.2.2 FINAL REPORT: <i>Citrus tristeza virus</i> cross-protection of Star Ruby using Beltsville sub-isolates of Nartia mild strain for the Orange River Valley	81
3.2.3 FINAL REPORT: The effect of different CTV sources on 3 Valencia cultivars in the Orange River Valley	86

**CRI GROUP ANNUAL RESEARCH REPORT 2016/17
TABLE OF CONTENTS**

	Page
3.2.4 FINAL REPORT: Identification of suitable <i>Citrus tristeza virus</i> sources for pre-immunising Turkey Valencia	90
3.2.5 PROGRESS REPORT: <i>Citrus tristeza virus</i> cross-protection of Marsh and Star Ruby grapefruit using the best field isolates collected in the different grapefruit production areas in southern Africa	93
3.2.6 PROGRESS REPORT: Characterisation of <i>Citrus tristeza virus</i> variants and their influence on the symptom expression in the grapefruit host	93
3.2.7 PROGRESS REPORT: Detection of ‘ <i>Candidatus Liberibacter asiaticus</i> ’ and biological characterization of <i>Liberibacter</i> species from South Africa	94
3.2.8 PROGRESS REPORT: Searching for a <i>Citrus tristeza virus</i> source suitable for cross-protecting soft citrus	95
3.2.9 PROGRESS REPORT: Comparison of shoot tip grafted citrus with old clone material	96
3.2.10 PROGRESS REPORT: Field testing of commercial or potentially important rootstock selections for viroid sensitivity	96
3.3 Programme: Soilborne Diseases	97
3.3.1 Programme summary	97
3.3.2 FINAL REPORT: Training of dogs for the detection of citrus trunk and branch canker	99
3.3.3 PROGRESS REPORT: The evaluation of different pre-plant products for the control of the citrus nematode, as part of an integrated nematode control approach in citrus replant situations	102
3.3.4 PROGRESS REPORT: Evaluation of alternative products for control of citrus nematode and <i>Phytophthora</i> spp. in citrus	102
3.3.5 PROGRESS REPORT: The status of <i>Armillaria</i> root rot and its management in South African citrus orchards	111
3.3.6 PROGRESS REPORT: Preventative and curative management of soilborne pathogens in citrus nurseries	111
3.3.7 PROGRESS REPORT: Factors associated with citrus decline and spatial tempo distribution	112
3.3.8 PROGRESS REPORT: Understanding citrus replant disease in South Africa with the aim of developing a methyl bromide free management strategy.	112
3.4 Programme: Fruit and Foliar Diseases (with CBS)	113
3.4.1 Programme summary	113
3.4.2 PROGRESS REPORT: Evaluation of new spray programmes for the control of <i>Alternaria</i> brown spot in the summer rainfall regions of South Africa	115
3.4.3 PROGRESS REPORT: Development of new spray programmes for the control of citrus black spot	119
3.4.4 PROGRESS REPORT: The global population structure and reproductive biology of the fungal pathogen, <i>Phyllosticta citricarpa</i> Kiely	119
3.4.5 PROGRESS REPORT: Development of a tree canopy characteristic calibration formula for reduced volume fungicide application in citrus orchards	120
3.4.6 PROGRESS REPORT: Evaluation of reduced volume fungicide and pesticide sprays for control of citrus black spot and false codling moth	120
3.4.7 PROGRESS REPORT: Epidemiology, inoculum potential and infection parameters of Citrus Black Spot	121
3.4.8 PROGRESS REPORT: Improved Citrus Black Spot management through web-based information systems	122
3.4.9 PROGRESS REPORT: Epidemiology of CBS in different geographic areas and development of a risk management system for Citrus Black Spot	122
3.4.10 PROGRESS REPORT: Detection and spread of Citrus Black Spot pathogens	123
3.5 Programme: Postharvest Diseases	123

**CRI GROUP ANNUAL RESEARCH REPORT 2016/17
TABLE OF CONTENTS**

	Page
3.5.1 Programme summary	123
3.5.2 FINAL REPORT: Singular and combined effects of postharvest treatments on viability and reproductive ability of <i>Phyllosticta citricarpa</i> infections	126
3.5.3 PROGRESS REPORT: Provision of an industry service whereby new packhouse treatments are comparatively evaluated, fungicide resistance is monitored and standardised recommendations are provided	160
3.5.4 PROGRESS REPORT: Precision fungicide application for the control of postharvest diseases on citrus	162
3.5.5 PROGRESS REPORT: Epicuticular wax composition of CBS resistant and susceptible citrus cultivars	163
3.5.6 PROGRESS REPORT: Studies on the management of sour rot and green mould with propiconazole	163
3.5.7 PROGRESS REPORT: Fungal degradation of wood pallets used in export of citrus fruit	164
3.5.8 Application of nanotechnology to decrease the volatility of effective essential oils in different applications	164
3.6 CRI Diagnostic Centre	165
4 PORTFOLIO: CITRICULTURE	167
4.1 Portfolio summary	167
4.2 Programme: Rind condition	168
4.2.1 Programme summary	168
4.2.2 FINAL REPORT: Effect of irradiation levels on internal and external citrus fruit quality	168
4.2.3 FINAL REPORT: Studies on aspects concerning rind pitting/staining citrus fruit	183
4.2.4 FINAL REPORT: Non-destructive prediction and monitoring of postharvest rind quality of citrus fruit using Vis/NIR spectroscopy	199
4.2.5 FINAL REPORT: Investigating cold storage potential of new mandarin citrus selections/cultivars and the effect of ethylene degreening on rind disorders	211
4.3 Programme: Flowering and fruit set	219
4.3.1 Programme summary	220
4.3.2 FINAL REPORT: Potential of 2,4-D as commercial solution to Alternaria black core rot (ABCR) in Navel oranges	221
4.3.3 PROGRESS REPORT: Studies on the reproductive development of 'Nadorcott' mandarin (<i>C. reticulata</i> Blanco)	225
4.3.4 PROGRESS REPORT: Determining the time and duration of flower induction in early vs late mandarin cultivars and evaluating the effect of hand thinning, pruning and girdling on leaf and root carbohydrate levels, fruit size, vegetative regrowth and alternate bearing in 'nadorcott' mandarin	226
4.3.5 PROGRESS REPORT: Effect of pruning on fruit production of Nadorcott mandarin	226
4.3.6 PROGRESS REPORT: Effect of shade net on fruit production of mandarin citrus	228
4.3.7 PROGRESS REPORT: Benefits of shade netting for citrus fruit quality	229
4.4 Programme: Cold chain & packaging	229
4.4.1 Programme summary	229
4.4.2 FINAL REPORT: Pre-cooling of citrus – manual and practical guidelines	230
4.4.3 PROGRESS REPORT: Pre-cooling: ambient loading and forced air cooling of citrus for cold sterilization markets	231

**CRI GROUP ANNUAL RESEARCH REPORT 2016/17
TABLE OF CONTENTS**

		Page
4.5	Programme: Nutrition and water management	232
4.5.1	Programme summary	232
4.5.2	PROGRESS REPORT: A novel approach to water and nutrient management in citrus	232
4.5.3	PROGRESS REPORT: Nitrogen and Potassium release from organic soil amendments over time	233
4.5.4	PROGRESS REPORT: Foliar uptake of urea and micronutrients in mandarins grown under shade net in different climatic regions	234
4.6	PROGRAMME: CULTIVAR EVALUATION	234
4.6.1	PROGRESS REPORT: Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region (East Cape Midlands)	234
4.6.2	PROGRESS REPORT: Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region (Sundays River Valley)	236
4.6.3	PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (East Cape Midlands)	238
4.6.4	PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Sundays River Valley)	241
4.6.5	PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Gamtoos River Valley)	246
4.6.6	PROGRESS REPORT: Cultivar characteristics and climatic suitability of mandarin hybrids in a cold production region (Western Cape)	251
4.6.7	PROGRESS REPORT: Cultivar characteristics and climatic suitability of navel oranges in a cold production region (Sundays River Valley)	254
4.6.8	PROGRESS REPORT: Cultivar characteristics and climatic suitability of experimental navel oranges in a cold production region (Gamtoos River Valley)	257
4.6.9	PROGRESS REPORT: Cultivar characteristics and climatic suitability of navel oranges in a cold production region (East Cape Midlands)	260
4.6.10	PROGRESS REPORT: Cultivar characteristics and climatic suitability of Valencia oranges in a cold production region (Sundays River Valley)	261
4.6.11	PROGRESS REPORT: Evaluation of Valencia selections in a semi-desert production area (Kakamas)	265
4.6.12	PROGRESS REPORT: Cultivar characteristics and climatic suitability of mandarin hybrids in a semi-desert production region (Kakamas)	268
5	CITRUS IMPROVEMENT SCHEME (CIS)	271
5.1	Summary	271
5.2	Budwood	273
5.3	Seed	279
5.4	Production	280
5.5	Tree Certification	280
5.6	Nursery Certification	282
5.7	Statutory Improvement Scheme	283
5.8	Protective zone surrounding the Citrus Foundation Block	283
5.9	Shoot tip grafting (STG), pre-immunisation and nucleus block management	283
6	INTERNATIONAL VISITS	294
6.1	20th conference of the international organization of citrus virologists (IOCV) in Chongqing, China	294
6.2	International Citrus Congress at Foz do Iguaçu, Brazil,	299
6.3	Technical visit to Brazil citrus nurseries and growers	315
6.4	International Congress of Entomology (ICE), Orlando, USA	336
6.5	Citrus production practices in Queensland, South Australia and Victoria	342

**CRI GROUP ANNUAL RESEARCH REPORT 2016/17
TABLE OF CONTENTS**

	Page	
6.6	5th International Research Conference on Huanglongbing in Orlando Florida	349
6.7	Visit to Steritech, a commercial gamma irradiation plant, in Narangba, Queensland, Australia	353
7	VOORLIGTING / EXTENSION	357
7.1	Voorligtingoorsig	357
7.1.1	Die 2016 Seisoen	357
7.1.2	Die 2017 Seisoen	358
7.1.3	CRI-PTF	358
7.1.4	Na-oes voorligting	360
7.1.5	9de Sitrus Navorsings Simposium	361
7.1.6	Biosekuriteit	361
7.1.7	Sitrus-koueketting	362
7.1.8	Voorligtingsbehoefes	362
7.2	Other means of Technology Transfer	372
7.2.1	S.A. Fruit Journal	372
7.2.2	CRI Website	373
7.2.3	CRInet	373
7.2.4	CRI Cutting Edge	373
8	PUBLICATIONS IN 2016-17	374
8.1	Refereed Publications (or ISI ranked journals)	374
8.2	Semi-scientific publications	375
9	PRESENTATIONS AT SOCIETAL AND INTERNATIONAL CONGRESSES	375

**CRI GROUP ANNUAL RESEARCH REPORT 2017/18
TABLE OF CONTENTS**

		Page
1	MARKET ACCESS TECHNICAL COORDINATION	1
1.1	Summary	1
1.2	Europe (UK)	2
1.3	Japan	4
1.4	USA	5
1.5	China	6
1.6	India	6
1.7	Vietnam	7
1.8	New Markets	7
1.8.1	The Philippines	7
1.8.2	Myanmar	8
1.9	FCM cold treatment changes related to multiple markets	8
1.10	Regulations	8
2	PORTFOLIO: INTEGRATED PEST MANAGEMENT	9
2.1	Portfolio summary	9
2.2	Programme: False Codling Moth	11
2.2.1	Programme summary	12
2.2.2	FINAL REPORT: Movement of false codling moth (FCM) and fruit flies (FF) in multi-crop (citrus, pome and stone fruit, grape, pomegranate) systems	15
2.2.3	FINAL REPORT: Entomopathogenic fungi for control of soil-borne life stages of FCM	33
2.2.4	FINAL REPORT: The efficacy of registered treatments for FCM control in Limpopo	51
2.2.5	FINAL REPORT: Assessment of pheromone specificity in FCM populations with focus on pest monitoring and regional rollout of SIT	55
2.2.6	FINAL REPORT: Verification of proposed inspections standards within an FCM systems approach	61
2.2.7	FINAL REPORT: FCM population ecology in citrus orchards: the influence of orchard age.	80
2.2.8	FINAL REPORT: Genetic and biological characterization of a novel nucleopolyhedrovirus from the false codling moth (FCM), <i>Thaumatotibia leucotreta</i> , for improved control of FCM	87
2.2.9	FINAL REPORT: Degreening of satsumas for identification of FCM infested fruit	105
2.2.10	PROGRESS REPORT: Impact of abbreviated and complete cold-treatment on survival and fitness of FCM larvae	108
2.2.11	PROGRESS REPORT: Evaluation of 7-Vinyl-Decyl Acetate for mating inhibition FCM	109
2.2.12	PROGRESS REPORT: Evaluating hot air treatments for postharvest FCM control	101
2.2.13	PROGRESS REPORT: Identifying volatile emissions associated with false codling moth infestation of citrus fruit	110

**CRI GROUP ANNUAL RESEARCH REPORT 2017/18
TABLE OF CONTENTS**

	Page
2.2.14 PROGRESS REPORT: Development of UV-resistant CrleGV-SA for use as an enhanced biopesticide for FCM control on citrus stages of FCM	111
2.2.15 PROGRESS REPORT: Potential of novel products, including a novel nucleopolyhedrovirus, for control of FCM	112
2.2.16 PROGRESS REPORT: Identification and development of an attractant for monitoring FCM adult females	113
2.2.17 PROGRESS REPORT: Improvement of the quality and quality control testing of sterile moths for FCM SIT	113
2.2.18 PROGRESS REPORT: Development of a remote vapour detection system using a trained sniffer dog to detect FCM infested fruit	114
2.2.19 PROGRESS REPORT: FCM control under nets – is pest-freedom possible?	116
2.2.20 PROGRESS REPORT: Using Carbon dioxide to shorten cold disinfestation treatments for internal pests of citrus fruit destined for Europe	116
2.2.21 PROGRESS REPORT: Yeast-baculovirus synergism: Investigating mixed infections for improved management of the false codling moth, <i>Thaumatotibia leucotreta</i>	116
2.2.22 PROGRESS REPORT: Novel approaches to mating disruption of FCM	117
 2.3 Programme: Fruit Fly	 118
2.3.1 Programme summary	118
2.3.2 FINAL REPORT: Dispersal capacity of <i>Bactrocera dorsalis</i>	120
2.3.3 FINAL REPORT: Detection methods for fruit flies of economic significance to fruit and vegetable production in Africa and Indian Ocean islands	133
2.3.4 FINAL REPORT: Determination of non-host status of lemon to Natal fly, Medfly and Oriental fruit fly	152
2.3.5 PROGRESS REPORT: Fruit fly rearing	164
2.3.6 PROGRESS REPORT: Utilisation of citrus and other fruit grown in South Africa by <i>B. dorsalis</i>	165
2.3.7 PROGRESS REPORT: A new bait for more effective control of all <i>Ceratitidis</i> fruit flies	166
2.3.8 PROGRESS REPORT: Determining phytotoxicity of fruit fly baits on citrus fruit with previous exposure to copper sprays	167
2.3.9 PROGRESS REPORT: Biology and ecology of <i>Ceratitidis rosa</i> and <i>Ceratitidis quilicii</i> (Diptera: Tephritidae) in citrus	168
2.3.10 PROGRESS REPORT: Efficacy of FCM partial cold treatments for fruit fly pests of citrus	168
2.3.11 PROGRESS REPORT: The assessment of control and monitoring for fruit fly in the Western Cape	169
2.3.12 PROGRESS REPORT: Cold tolerance of immature stages of <i>Ceratitidis capitata</i> (Wiedemann) and <i>Bactrocera dorsalis</i> (Hendel) (Diptera: Tephritidae) in artificial diet	170
 2.4 Programme: Mealybug and other Market Access Pests	 170
2.4.1 Programme summary	170

**CRI GROUP ANNUAL RESEARCH REPORT 2017/18
TABLE OF CONTENTS**

	Page
2.4.2 FINAL REPORT: Evaluating GRAS post-harvest fumigants for phytosanitary pests	171
2.4.3 FINAL REPORT: Carbon dioxide as a shock treatment to shorten cold disinfestation treatments for internal pests of citrus fruit	193
2.4.4 PROGRESS REPORT: The natural enemies and biological control of <i>Delottococcus aberiae</i>	213
2.4.5 PROGRESS REPORT: Suitability of entomopathogenic fungal isolates for microbial control of citrus pests: biological traits and effects of formulation	216
2.4.6 PROGRESS REPORT: The efficacy of commercial entomopathogenic fungi products for control of citrus pests	217
2.5 Programme: Non-Phytosanitary Key Pests	218
2.5.1 Programme summary	218
2.5.2 PROGRESS REPORT: Short residual treatments for thrips, psylla, leafhoppers and woolly whitefly for late season usage	219
2.5.3 PROGRESS REPORT: New systemic insecticides for citrus	219
2.5.4 PROGRESS REPORT: Control of Asian Citrus Psyllid, vector of Huanglongbing	220
2.6 Programme: Minor Pests and Mites	221
2.6.1 Programme summary	221
2.6.2 FINAL REPORT: Importing and releasing <i>Cales noacki</i> for the control of woolly whitefly	221
2.6.3 PROGRESS REPORT: Preharvest management of oribatulid mites on citrus in KwaZulu-Natal	224
3 PORTFOLIO: DISEASE MANAGEMENT	225
3.1 Portfolio summary	225
3.2 Programme: Graft Transmissible Diseases	230
3.2.1 Programme summary	231
3.2.2 FINAL REPORT: <i>Citrus tristeza virus</i> cross-protection of Marsh and Star Ruby by using the best field isolates collected in the different grapefruit production areas of southern Africa	232
3.2.3 FINAL REPORT: Detection of ' <i>Candidatus Liberibacter asiaticus</i> ' and biological characterization of <i>Liberibacter</i> species from South Africa	256
3.2.4 PROGRESS REPORT: Searching for a <i>Citrus tristeza virus</i> source suitable for cross-protecting soft citrus	254
3.2.5 PROGRESS REPORT: Characterisation of <i>Citrus tristeza virus</i> variants and their influence on the symptom expression in the grapefruit host	257
3.2.6 PROGRESS REPORT: Comparison of shoot tip grafted citrus with old clone material	258
3.2.7 PROGRESS REPORT: Field testing of commercial or potentially important rootstock selections for viroid sensitivity	259

**CRI GROUP ANNUAL RESEARCH REPORT 2017/18
TABLE OF CONTENTS**

	Page
3.2.8 PROGRESS REPORT: Application of CTV infectious clones to combat HLB	260
3.2.9 PROGRESS REPORT: Field evaluation of three single-strain CTV isolates on Grapefruit, Valencia and Navel varieties	261
3.2.10 PROGRESS REPORT: Training of dogs for the detection of African greening and Huanglongbing	262
3.3 Programme: Soilborne Diseases	263
3.3.1 Programme summary	263
3.3.2 FINAL REPORT: Understanding citrus replant disease in South Africa with the aim of developing a methyl bromide free management strategy	265
3.3.3 PROGRESS REPORT: Evaluation of alternative products for control of citrus nematode and <i>Phytophthora</i> spp. in citrus	304
3.3.4 PROGRESS REPORT: The evaluation of different pre-plant products for the control of the citrus nematode, as part of an integrated nematode control approach in citrus replant situations	316
3.3.5 PROGRESS REPORT: The status of Armillaria root rot and its management in South African citrus orchards	316
3.3.6 PROGRESS REPORT: Preventative and curative management of soilborne pathogens in citrus nurseries	317
3.3.7 PROGRESS REPORT: Factors associated with citrus decline and spatial tempo distribution	317
3.4 Programme: Fruit and Foliar Diseases (with CBS)	318
3.4.1 Programme summary	318
3.4.2 PROGRESS REPORT: An independent model comparison for evaluating predictions of climate suitability of citrus black spot in Europe	323
3.4.3 FINAL REPORT: Distribution and genetics of Citrus pathogens	324
3.4.4 FINAL REPORT: The global population structure and reproductive biology of the fungal pathogen, <i>Phyllosticta citricarpa</i> Kiely	331
3.4.5 PROGRESS REPORT: Development of new spray programmes for the control of citrus black spot	346
3.4.6 PROGRESS REPORT: Evaluation of new spray programmes for the control of Alternaria brown spot in the summer rainfall regions of South Africa	351
3.4.7 PROGRESS REPORT: Epidemiology, inoculum potential and infection parameters of Citrus Black Spot	357
3.4.8 PROGRESS REPORT: Improved Citrus Black Spot management through web-based information systems	358
3.4.9 PROGRESS REPORT: Epidemiology of CBS in different geographic areas and development of a risk management system for Citrus Black Spot	358
3.4.10 PROGRESS REPORT: Evaluation of reduced volume fungicide and pesticide sprays for control of citrus black spot and false codling moth	359
3.4.11 PROGRESS REPORT: Development of a tree canopy characteristic calibration formula for reduced volume fungicide application in citrus orchards	360

**CRI GROUP ANNUAL RESEARCH REPORT 2017/18
TABLE OF CONTENTS**

	Page
3.4.12 PROGRESS REPORT: Influence of shade nets on Alternaria brown spot and citrus black spot: comparing epidemiological model output for covered (under shade nets) and uncovered (normal/open) orchards' weather datasets	360
3.4.13 PROGRESS REPORT: Susceptibility period of sweet orange fruit to <i>Phyllosticta citricarpa</i> in commercial orchards	361
3.5 Programme: Postharvest Diseases	362
3.5.1 Programme summary	362
3.5.2 FINAL REPORT: Application of nanotechnology to decrease the volatility of effective essential oils in different applications against citrus postharvest fungi	365
3.5.3 FINAL REPORT: Precision fungicide application for the control of postharvest diseases on citrus	401
3.5.4 PROGRESS REPORT: Provision of an industry service whereby new packhouse treatments are comparatively evaluated, fungicide resistance is monitored and standardised recommendations are provided	451
3.5.5 PROGRESS REPORT: Epicuticular wax composition of CBS resistant and susceptible citrus cultivars	464
3.5.6 PROGRESS REPORT: Studies on the management of sour rot and green mould with propiconazole	465
3.5.7 PROGRESS REPORT: Fungal degradation of wood pallets used in export of citrus fruit	466
3.6 CRI Diagnostic Centre	466
4 PORTFOLIO: CITRICULTURE	467
4.1 Portfolio summary	467
4.2 Programme: Rind condition	468
4.2.1 PROGRESS REPORT: Chilling injury of lemon fruit	468
4.3 Programme: Flowering and fruit set	473
4.3.1 Programme summary	473
4.3.2 FINAL REPORT: Effect of pruning on fruit production of Nadorcott mandarin	474
4.3.3 FINAL REPORT: Determining the time and duration of flower induction in early vs late mandarin cultivars and evaluating the effect of hand thinning, pruning and girdling on leaf and root carbohydrate levels, fruit size, vegetative regrowth and alternate bearing in 'Nadorcott' mandarin	496
4.3.4 FINAL REPORT: Studies on the reproductive development of 'Nadorcott' mandarin (<i>C. reticulata</i> Blanco)	510
4.3.5 FINAL REPORT: The benefits of shade netting for citrus fruit quality	534
4.4 Programme: Cold chain & packaging	549

**CRI GROUP ANNUAL RESEARCH REPORT 2017/18
TABLE OF CONTENTS**

	Page
4.4.1 PROGRESS REPORT: Precooling: ambient loading and forced air cooling of citrus for cold sterilisation markets	550
4.5 Programme: Nutrition and water management	556
4.5.1 FINAL REPORT: A novel approach to water and nutrient management in citrus	556
4.5.2 PROGRESS REPORT: Nitrogen and Potassium release from organic soil amendments over time	581
4.5.3 PROGRESS REPORT: Foliar uptake of urea and micronutrients in mandarins grown under shade net in different climatic regions	582
4.6 PROGRAMME: CULTIVAR EVALUATION	583
4.6.1 Programme summary	
4.6.2 PROGRESS REPORT: Evaluation of Valencia selections in hot humid inland areas (Onderberg)	584
4.6.3 PROGRESS REPORT: Evaluation of Valencia selections in the hot dry inland areas (Letsitele & Hoedspruit)	589
4.6.4 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the hot inland areas (Letsitele & Malelane)	598
4.6.5 PROGRESS REPORT: Evaluation of Valencia selections in the hot dry production areas (Weipe and Tshipise)	605
4.6.6 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the intermediate production areas (Marble Hall & Groblersdal)	610
4.6.7 PROGRESS REPROT: Evaluation of Mandarin hybrid selections in the hot dry inland areas (Tshipise and Weipe)	616
4.6.8 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the intermediate production areas (Karino)	621
4.6.9 PROGRESS REPORT: Evaluation of Navel selections in the intermediate production areas (Karino)	624
4.6.10 PROGRESS REPORT: Evaluation of Navel selections in the intermediate production areas (Marble Hall and Groblersdal)	627
4.6.11 PROGRESS REPORT: Evaluation of Lemon selections in the intermediate production areas (Marble Hall)	628
4.6.12 PROGRESS REPORT: Evaluation of Lemon selections in the intermediate production areas (Letsitele)	630
4.6.13 PROGRESS REPORT: Evaluation of Grapefruit on different rootstocks in a semi-desert production area (Kakamas)	632
4.6.14 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region (East Cape Midlands)	636
4.6.15 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region (Sundays River Valley)	638
4.6.16 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (East Cape Midlands)	641
4.6.17 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Sundays River Valley)	643
4.6.18 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Gamtoos River Valley)	651

**CRI GROUP ANNUAL RESEARCH REPORT 2017/18
TABLE OF CONTENTS**

	Page
4.6.19 PROGRESS REPORT: Cultivar characteristics and climatic suitability of mandarin hybrids in a cold production region (Western Cape)	655
4.6.20 PROGRESS REPORT: Cultivar characteristics and climatic suitability of mandarin hybrids in a cold production region (South West Cape)	663
4.6.21 PROGRESS REPORT: Cultivar characteristics and climatic suitability of navel oranges in a cold production region (Sundays River Valley)	667
4.6.22 PROGRESS REPORT: Cultivar characteristics and climatic suitability of experimental navel oranges in a cold production region (Gamtoos River Valley)	670
4.6.23 PROGRESS REPORT: Cultivar characteristics and climatic suitability of experimental navel oranges in a cold production region (Western Cape)	673
4.6.24 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Valencia oranges in a cold production region (Sundays River Valley)	677
4.6.25 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Valencia oranges in a cold production region (Citrusdal)	681
4.6.26 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region (Sundays River Valley)	684
4.6.27 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region (Western Cape)	686
4.6.28 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region (South West Cape)	690
4.6.29 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region (Western Cape)	692
4.6.30 Climatic Regions of Southern Africa and cultivars being evaluated	695
4.6.31 FINAL REPORT: Fine-tuning of molecular genotype reference database for mandarins, lemons and limes	698
4.6.32 FINAL REPORT: Validation of the established citrus molecular genotype reference database for grapefruit, pummelo and rootstocks	703
 5 CITRUS IMPROVEMENT SCHEME (CIS)	 714
5.1 Introduction	715
5.2 Budwood	715
5.3 Seed	724
5.4 Production	725
5.5 Tree Certification	726
5.6 Nursery Certification	729
5.7 Statutory Improvement Scheme	729
5.8 Protective zone surrounding the Citrus Foundation Block	730
5.9 PROGRESS REPORT: Citrus Improvement Scheme: Shoot tip grafting and diagnostic services	730
 6 INTERNATIONAL VISITS	 737
6.1 Technical visit to citrus shoot tip grafting laboratories in Florida and California (USA)	737
6.2 Third FAO/IAEA International conference on Area-wide Management of insect pests: Integrating the sterile insect and related nuclear and other techniques	749 763
6.3 Report on attendance of the 11 th Congress of the International Society for Citrus Nurserymen	753

**CRI GROUP ANNUAL RESEARCH REPORT 2017/18
TABLE OF CONTENTS**

		Page
6.4	A report on the Norman E. Borlaug international agricultural science and technology fellowship program at the department of Botany and Plant Sciences at the University of California Riverside (UCR) in California, USA	
7	VOORLIGTING / EXTENSION	796
7.1	Voorligtingoorsig	796
7.1.1	Die 2017 Seisoen	796
7.1.2	Die 2018 Seisoen	797
7.1.3	CRI-PTF	797
7.1.4	Produksie areas	799
7.1.5	Na-oes voorligting	801
7.1.6	CRI Produksiewerkswinkel	803
7.1.7	CRI Geïntegreerde Plaagbeheer en Siektebestuur Werkswinkels	803
7.1.8	CRI Na-oes Werkswinkels 2018	803
7.1.9	10de CRI Sitrusnavorsingsimposium 2018	804
7.1.20	Opsomming van aktiwiteite	804
7.2	Other means of Technology Transfer	831
7.2.1	S.A. Fruit Journal	831
7.2.2	CRI Website	832
7.2.3	CRInet	833
7.2.4	CRI Cutting Edge	833
8	PUBLICATIONS IN 2017-18	834
8.1	Refereed Publications (or ISI ranked journals)	834
9	PRESENTATIONS AT SOCIETAL AND INTERNATIONAL CONGRESSES	836

**CRI GROUP ANNUAL RESEARCH REPORT 2018/19
TABLE OF CONTENTS**

	Page
1 MARKET ACCESS TECHNICAL COORDINATION	2
1.1 Summary	2
1.2 Europe (UK)	3
1.3 Japan	4
1.4 USA	5
1.5 China	6
1.6 India	7
1.7 Vietnam	7
1.8 The Philippines	7
1.9 Indonesia	8
2 BIOSECURITY AND REGULATIONS	8
2.1 Summary	8
2.2 Develop and maintain a comprehensive Citrus industry biosecurity plan - to ensure overall mitigation of the Southern African Citrus industry's biosecurity risks	10
2.2.1 Project 1: Develop a Southern Africa Citrus industry biosecurity master plan	10
2.3 Biosecurity portfolio: Design, develop and oversee the implementation and operation of appropriate biosecurity structures, engagements, procedures, co-operations, resources, projects and other appropriate actions	10
2.3.1 Project 2: Identify, assess and initiate engagement with international funding providers, for future support of Southern African biosecurity projects	10
2.4 Networking and awareness: Obtain supportive participation of relevant stakeholders and interested parties	10
2.5 Ensure successful implementation of processes, procedures and interactions to ensure the timely identification and assessment of biosecurity threats facing the Southern African Citrus industry	11
2.5.1 Project 3: Develop and oversee implementation of Southern African Citrus industry pest-specific action plans for priority biosecurity pests	11
2.6 Ensure that there is a comprehensive and up to date list of Citrus pests and diseases perceived to hold a biosecurity risk for the industry	11
2.7 Ensure effective implementation of processes, procedures, interactions to advance actions required to successfully mitigate the risks and consequences of biosecurity incursions	11
2.7.1 Project 4: Develop and oversee implementation of a Southern African Citrus industry HLB action plan and safe tree production system	11
2.7.2 Project 5: Ensure that HLB and ACP surveillance is undertaken in Eastern Africa	12
2.7.3 Project 6: Facilitate initiation of an HLB eradication plan in Ethiopia	12
2.7.4 Project 7: Ensure, in close collaboration with relevant government officials, that regulations of relevance to biosecurity risk mitigation are appropriately updated and compliance effectively implemented	13
2.7.5 Project 8: Monitoring and control of Leprosis	13
2.7.6 Project 9: Phytosanitary Risk Forum	15
2.7.7 Project 10: Greening surveys (African greening - <i>candidatus liberibacter Africanus</i> & asiatic greening - <i>candidatus liberibacter asiaticus</i>)	15
2.7.8 Project 11: Citrus Free Zone (5 km) outside the Citrus Foundation Block (CFB) in the Eastern Cape Province in the magisterial district of	

**CRI GROUP ANNUAL RESEARCH REPORT 2018/19
TABLE OF CONTENTS**

	Page
Uitenhage	16
3 PORTFOLIO: INTEGRATED PEST MANAGEMENT	
3.1 Portfolio summary	16
3.2 Programme: False Codling Moth	19
3.2.1 Programme summary	19
3.2.2 FINAL REPORT: Evaluation of 7-Vinyl-Decyl Acetate for mating inhibition in FCM	22
3.2.3 FINAL REPORT: Potential of novel products, including a novel nucleopolyhedrovirus, for control of FCM	40
3.2.4 FINAL REPORT: Novel approaches to mating disruption of FCM	50
3.2.5 PROGRESS REPORT: Evaluating hot air treatments for postharvest FCM control	60
3.2.6 PROGRESS REPORT: Semi-commercial control of FCM using sequential CO ₂ fumigation and a short cold treatment	60
3.2.7 PROGRESS REPORT: Impact of abbreviated and complete cold-treatment on survival and fitness of FCM larvae	61
3.2.8 PROGRESS REPORT: Identifying volatile emissions associated with false codling moth infestation of citrus fruit	63
3.2.9 PROGRESS REPORT: Development of UV-resistant CrleGV for use as an enhanced biopesticide for FCM control on citrus	64
3.2.10 PROGRESS REPORT: Identification and development of an attractant for monitoring FCM adult females	65
3.2.11 PROGRESS REPORT: Improvement of the quality and quality control testing of sterile moths for FCM SIT	66
3.2.12 PROGRESS REPORT: Development of a remote vapour detection system using a trained sniffer dog to detect FCM infested fruit	67
3.2.13 PROGRESS REPORT: FCM control under nets – is pest-freedom possible?	68
3.2.14 PROGRESS REPORT: Selection for improved virulence to FCM or resistance by FCM using a homologous and a heterologous baculovirus	68
3.2.15 PROGRESS REPORT: Sexual attraction and mating compatibility between FCM populations and the potential impact on the sterile insect technique	69
3.2.16 PROGRESS REPORT: Yeast-baculovirus synergism: Investigating mixed infections for improved management of the false codling moth, <i>Thaumatotibia leucotreta</i>	70
3.2.17 PROGRESS REPORT: Improvement of the quality of sterile moths for FCM SIT	71
3.3 Programme: Fruit Fly	72
3.3.1 Programme summary	72
3.3.2 FINAL REPORT: A new bait for more effective control of all <i>Ceratitis</i> fruit flies	74
3.3.3 FINAL REPORT: Determining phytotoxicity of fruit fly baits on citrus fruit with previous exposure to copper sprays	100
3.3.4 PROGRESS REPORT: Fruit fly rearing	108
3.3.5 PROGRESS REPORT: Biology and ecology of <i>Ceratitis rosa</i> and <i>Ceratitis quilicii</i> (Diptera: Tephritidae) in citrus	109
3.3.6 PROGRESS REPORT: Efficacy of FCM partial cold treatments for fruit fly pests of citrus	110
3.3.7 PROGRESS REPORT: The assessment of control and monitoring for fruit fly in the Western Cape	111
3.3.8 PROGRESS REPORT: The impact of interruptions on Medfly cold treatment efficacy	112
3.3.9 PROGRESS REPORT: Attract and kill methods for fruit flies: efficacy and application	

CRI GROUP ANNUAL RESEARCH REPORT 2018/19
TABLE OF CONTENTS

	Page
of new and registered products	112
3.3.10 PROGRESS REPORT: Cold tolerance of immature stages of <i>Ceratitis capitata</i> (Wiedemann) and <i>Bactrocera dorsalis</i> (Hendel) (Diptera: Tephritidae)	113
3.3.11 PROGRESS REPORT: Laboratory bioassays on AVIMA's bait stations for control of Medfly and Oriental fruit fly	114
3.4 Programme: Other Pests	115
3.4.1 Programme summary	115
3.4.2 FINAL REPORT: Short residual treatments for thrips, psylla, leafhoppers and woolly whitefly for late season usage	117
3.4.3 FINAL REPORT: Preharvest management of oribatulid mites on citrus in KwaZulu-Natal	123
3.4.4 FINAL REPORT: Augmentation of <i>Orius thripoborus</i> for citrus thrips control	131
3.4.5 FINAL REPORT: Control of Asian Citrus Psyllid, vector of Huanglongbing	140
3.4.6 FINAL REPORT: Suitability of entomopathogenic fungal isolates for microbial control of citrus pests: biological control and effects of formulation	151
3.4.7 PROGRESS REPORT: The efficacy of commercial entomopathogenic fungi products for control of citrus pests	166
3.4.8 PROGRESS REPORT: Synergism and formulation of entomopathogenic fungi for foliar control of various citrus pests	167
3.4.9 PROGRESS REPORT: IPM under nets in Mpumalanga Province	168
3.4.10 PROGRESS REPORT: Determine the primary cause for mealybug repercussions under netting	169
3.4.11 PROGRESS REPORT: Improving biocontrol of woolly whitefly in the Western and Eastern Cape regions	170
3.4.12 PROGRESS REPORT: New systemic insecticides for citrus	171
3.4.13 PROGRESS REPORT: Controlling mites on budwood	172
4 PORTFOLIO: DISEASE MANAGEMENT	172
4.1 Portfolio summary	172
4.2 Programme: Graft Transmissible Diseases	177
4.2.1 Programme summary	177
4.2.2 FINAL REPORT: Characterisation of Citrus tristeza virus variants and their influence on the symptom expression in the grapefruit host.	179
4.2.3 FINAL REPORT: Searching for a citrus tristeza virus source suitable for cross-protecting soft citrus	190
4.2.4 FINAL REPORT: Training of dogs for the detection of African greening and Huanglongbing	195
4.2.5 PROGRESS REPORT: Field evaluation of three single-strain CTV isolates on Navel and Soft Citrus cultivars	200
4.2.6 PROGRESS REPORT: Comparison of shoot tip grafted citrus with field-cut (old clone) material	201
4.2.7 PROGRESS REPORT: Field testing of commercial or potentially important rootstock selections for viroid sensitivity	202
4.2.8 PROGRESS REPORT: Validation of primer regions used for the differentiation of Asian HLB, African greening and its subspecies	202
4.2.9 PROGRESS REPORT: Application of CTV infectious clones to combat HLB	204
4.3 Programme: Preharvest Diseases	205
4.3.1 Programme summary	205

**CRI GROUP ANNUAL RESEARCH REPORT 2018/19
TABLE OF CONTENTS**

		Page
4.3.2	FINAL REPORT: Preventative and curative management of soilborne pathogens in citrus nurseries.	210
4.3.3	PROGRESS REPORT: Evaluation of alternative products for control of citrus nematode and <i>Phytophthora</i> spp. in citrus	240
4.3.4	PROGRESS REPORT: Evaluation of new spray programmes for the control of Alternaria brown spot in the summer rainfall regions of South Africa	250
4.3.5	PROGRESS REPORT: The evaluation of different pre-plant products for the control of the citrus nematode, as part of an integrated nematode control approach in citrus replant situations	254
4.3.6	PROGRESS REPORT: The status of Armillaria root rot and its management in South African citrus orchards	254
4.3.7	PROGRESS REPORT: Potential biocontrol agents and host/pathogen interaction of citrus replant pathogens	255
4.4	Programme: Postharvest Diseases	257
4.4.1	Programme summary	257
4.4.2	FINAL REPORT: Epicuticular wax composition of CBS resistant and susceptible citrus cultivars.	260
4.4.3	FINAL REPORT: Studies on the management of sour rot and green mould with propiconazole	271
4.4.4	PROGRESS REPORT: Provision of an industry service whereby new packhouse treatments are comparatively evaluated, fungicide resistance is monitored and standardised recommendations are provided	280
4.4.5	PROGRESS REPORT: Fungal degradation of wood pallets used in export of citrus fruit	294
4.4.6	PROGRESS REPORT: Evaluation of new postharvest fungicides for the control of <i>Phytophthora</i> brown rot	295
4.4.7	PROGRESS REPORT: Comparison of the rind phytochemistry and wax composition of CBS resistant and susceptible citrus cultivars.	296
4.5	CRI Diagnostic Centre	298
5	PORTFOLIO: CITRICULTURE	300
5.1	Portfolio summary	300
5.2	Programme: Rind condition and cold chain	301
5.2.1	Programme summary	301
5.2.2	FINAL REPORT: Chilling injury of lemon fruit	302
5.2.3	PROGRESS REPORT: Postharvest fruit quality in mandarin, lemons and navels oranges under shade netting	397
5.2.4	PROGRESS REPORT: Ambient loading and forced air cooling of citrus for cold sterilisation markets. Including: Validation of ambient loading in the False codling moth Management System (FMS) for citrus export to the EU (PHI 3 extension)	398
5.3	Programme: Production and quality	399
5.3.1	Programme summary	399
5.3.2	FINAL REPORT: Nitrogen and potassium release from organic soil amendments over time	401
5.3.3	FINAL REPORT: The benefits of shade netting for citrus fruit quality	410
5.3.4	PROGRESS REPORT: The use of novel soil conditioners to improve citrus P nutrition and tree performance	444
5.4	Programme: Cultivar evaluation	445

**CRI GROUP ANNUAL RESEARCH REPORT 2018/19
TABLE OF CONTENTS**

	Page
5.4.1 Programme summary	445
5.4.2 PROGRESS REPORT: Evaluation of Valencia selections in hot humid inland areas (Onderberg)	447
5.4.3 PROGRESS REPORT: Evaluation of Valencia selections in the hot dry inland areas (Letsitele and Hoedspruit)	451
5.4.4 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the hot inland areas (Letsitele and Malelane)	461
5.4.5 PROGRESS REPORT: Evaluation of Valencia selections in the hot dry production areas (Weipe and Tshipise)	469
5.4.6 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the intermediate production areas (Marble Hall)	475
5.4.7 PROGRESS REPROT: Evaluation of Mandarin hybrid selections in the hot dry inland areas (Tshipise and Weipe)	481
5.4.8 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the intermediate production areas (Karino)	488
5.4.9 PROGRESS REPORT: Evaluation of Navel selections in the intermediate production areas (Karino)	493
5.4.10 PROGRESS REPORT: Evaluation of Lemon selections in the intermediate production areas (Marble Hall)	495
5.4.11 PROGRESS REPORT: Evaluation of Lemon selections in the intermediate production areas (Letsitele)	497
5.4.12 PROGRESS REPORT: Evaluation of Grapefruit on different rootstocks in a semi-desert production area (Kakamas)	498
5.4.13 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region (East Cape Midlands)	503
5.4.14 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region (Sundays River Valley)	505
5.4.15 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Sundays River Valley)	507
5.4.16 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Gamtoos River Valley)	511
5.4.17 PROGRESS REPORT: Cultivar characteristics and climatic suitability of mandarin hybrids in a cold production region (Western Cape)	514
5.4.18 PROGRESS REPORT: Cultivar characteristics and climatic suitability of mandarin hybrids in a cold production region (South West Cape)	519
5.4.19 PROGRESS REPORT: Cultivar characteristics and climatic suitability of navel oranges in a cold production region (Sundays River Valley)	522
5.4.20 PROGRESS REPORT: Cultivar characteristics and climatic suitability of experimental navel oranges in a cold production region (Gamtoos River Valley)	530
5.4.21 PROGRESS REPORT: Cultivar characteristics and climatic suitability of experimental navel oranges in a cold production region (Western Cape)	532
5.4.22 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Valencia oranges in a cold production region (Sundays River Valley)	537
5.4.23 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Valencia oranges in a cold production region (Citrusdal)	540
5.4.24 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region (Sundays River Valley)	544
5.4.25 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region (Western Cape)	546
5.4.26 PROGRESS REPORT: Cultivar characteristics and climatic suitability of	

**CRI GROUP ANNUAL RESEARCH REPORT 2018/19
TABLE OF CONTENTS**

	Page
Clementine mandarins in a cold production region (South West Cape)	549
5.4.27 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region (Western Cape)	550
6 CITRUS IMPROVEMENT SCHEME (CIS)	553
6.1 Introduction	554
6.2 Budwood	554
6.3 Seed	563
6.4 Production	564
6.5 Tree Certification	565
6.6 Nursery Certification	569
6.7 Statutory Improvement Scheme	571
6.8 Protective zone surrounding the Citrus Foundation Block	571
6.9 PROGRESS REPORT: Citrus Improvement Scheme: Shoot tip grafting and diagnostic services	571
6.10 PROGRESS REPORT: Diagnostic and technical services for the Citrus Improvement Scheme by the ARC-TSC	580
7 INTERNATIONAL VISITS	581
7.1 Attendance of the Joint Conference of the 21st International organization of Citrus Virologists and the 6th International Research Conference on Huanglongbing. March 10-15, 2019, Riverside, California, USA	581
7.2 10th International Symposium on Fruit Flies of Economic Importance, Tapachula, Chiapas, Mexico, 23 - 27 April 2018	598
8 VOORLIGTING / EXTENSION	607
8.1 Voorligtingoorsig	607
8.1.1 Die 2018 Seisoen	607
8.1.2 Die 2019 Seisoen	607
8.1.3 CRI Postharvest Technical Forum	608
8.1.4 Produksiestreke	610
8.1.5 Na-oes voorligting	613
8.1.6 10de CRI Sitrusnavorsingsimposium	615
8.1.7 CRI Geïntegreerde Plaagbeheer (IPM) en Siektebestuur (DM) werksinkels	615
8.1.8 Sitrusverbeteringskema	615
8.1.9 CRI Na-oes werksinkels	616
8.1.10 Biosekuriteit	616
8.1.11 Opsomming van aktiwiteite	616
8.2 Other means of Technology Transfer	630
8.2.1 S.A. Fruit Journal	630
8.2.2 CRI Website	631
8.2.3 CRInet	632
8.2.4 CRI Cutting Edge	632

CRI GROUP ANNUAL RESEARCH REPORT 2019/20
TABLE OF CONTENTS

		Page
1	MARKET ACCESS TECHNICAL COORDINATION	1
1.1	Summary	1
1.2	Europe (EU)	1
1.3	Japan	3
1.4	USA	3
1.5	China	3
1.6	South Korea	4
1.7	India	5
1.8	Vietnam	5
1.9	The Philippines	5
1.10	eSwatini	6
1.11	Zimbabwe	6
2	BIOSECURITY AND REGULATIONS	7
2.1	Summary	7
2.2	Develop and maintain a comprehensive Citrus industry biosecurity plan - to ensure overall mitigation of the Southern African Citrus industry's biosecurity risks	8
2.2.1	Project 1: Develop a Southern Africa Citrus industry biosecurity master plan	8
2.3	Biosecurity portfolio: Design, develop and oversee the implementation and operation of appropriate biosecurity structures, engagements, procedures, co-operations, resources, projects and other appropriate actions	9
2.3.1	Project 2: Identify, assess and initiate engagement with international funding providers, for future support of Southern African biosecurity projects	9
2.4	Networking and awareness: Obtain supportive participation of relevant stakeholders and interested parties	9
2.5	Ensure successful implementation of processes, procedures and interactions to ensure the timely identification and assessment of biosecurity threats facing the Southern African Citrus industry	9
2.5.1	Project 3: Develop and oversee implementation of Southern African Citrus industry pest-specific action plans for priority biosecurity pests	9
2.6	Ensure effective implementation of processes, procedures, interactions to advance actions required to successfully mitigate the risks and consequences of biosecurity incursions	10
2.6.1	Project 4: Develop and oversee implementation of a Southern African Citrus industry HLB action plan and safe tree production system	10
2.6.2	Project 5: Ensure that HLB and ACP surveillance is undertaken in Eastern Africa	10
2.6.3	Project 6: Facilitate initiation of an HLB eradication plan in Ethiopia	12
2.6.4	Project 7: Ensure, in close collaboration with relevant government officials, that regulations of relevance to biosecurity risk mitigation are appropriately updated and compliance effectively implemented	12
2.6.5	Project 8: Monitoring and control of Leprosis	13
2.6.6	Project 9: Phytosanitary Risk Forum	14
2.6.7	Project 10: Greening surveys (African greening - <i>candidatus liberibacter Africanus</i> & Asiatic greening - <i>candidatus liberibacter asiaticus</i>)	14
2.6.8	Project 11: Citrus Free Zone (5 km) outside the Citrus Foundation Block (CFB) in the Eastern Cape Province in the magisterial district of Uitenhage	14

CRI GROUP ANNUAL RESEARCH REPORT 2019/20
TABLE OF CONTENTS

		Page
3	PORTFOLIO: INTEGRATED PEST MANAGEMENT	15
3.1	Portfolio summary	15
3.2	Programme: False Codling Moth	18
3.2.1	Programme summary	18
3.2.2	FINAL REPORT: Development of UV-resistant CrleGV for use as an enhanced biopesticide for FCM control on citrus	21
3.2.3	FINAL REPORT: FCM control under nets – is pest-freedom possible?	30
3.2.4	FINAL REPORT: Semi-commercial control of FCM using sequential CO ₂ fumigation and a short cold treatment	45
3.2.5	FINAL REPORT: Sexual attraction and mating compatibility between FCM populations and the potential impact on the sterile insect technique	52
3.2.6	FINAL REPORT: Development of a remote vapour detection system using a trained sniffer dog to detect FCM infested fruit	57
3.2.7	PROGRESS REPORT: Impact of abbreviated and complete cold-treatment on survival and fitness of FCM larvae	60
3.2.8	PROGRESS REPORT: Evaluating hot air treatments for postharvest FCM control	61
3.2.9	PROGRESS REPORT: Identifying volatile emissions associated with false codling moth infestation of citrus fruit	61
3.2.10	PROGRESS REPORT: Identification and development of an attractant for monitoring FCM adult females	62
3.2.11	PROGRESS REPORT: Improvement of the quality and quality control testing of sterile moths for FCM SIT	63
3.2.12	PROGRESS REPORT: Improvement of the quality of sterile moths for FCM SIT	64
3.2.13	PROGRESS REPORT: Field trials for control of FCM	65
3.2.14	PROGRESS REPORT: Synergism between insecticides for improved control of FCM	66
3.2.15	PROGRESS REPORT: FCM population phenology in the warm northern citrus production regions and implications for management practices	67
3.2.16	PROGRESS REPORT: An assessment of the reasons for lower FCM infestation in organic versus conventional citrus orchards	68
3.2.17	PROGRESS REPORT: Yeast-baculovirus synergism: Investigating mixed infections for improved management of the false codling moth, <i>Thaumatotibia leucotreta</i> .	69
3.2.18	PROGRESS REPORT: Improving baculovirus virulence against the false codling moth by repeated passage and virus combinations.	70
3.3	Programme: Fruit Fly	71
3.3.1	Programme summary	71
3.3.2	FINAL REPORT: Cold tolerance of immature stages of <i>Ceratitis capitata</i> (Wiedemann) and <i>Bactrocera dorsalis</i> (Hendel) (Diptera: Tephritidae)	73
3.3.3	FINAL REPORT: Biology and ecology of <i>Ceratitis rosa</i> and <i>Ceratitis quilicii</i> (Diptera: Tephritidae) in citrus	105
3.3.4	PROGRESS REPORT: Fruit fly rearing	134
3.3.5	PROGRESS REPORT: Efficacy of FCM partial cold treatments for fruit fly pests of citrus	135
3.3.6	PROGRESS REPORT: The impact of interruptions on Medfly cold treatment efficacy	136
3.3.7	PROGRESS REPORT: Attract and kill methods for fruit flies: efficacy and application of new and registered products	137
3.3.8	PROGRESS REPORT: Development of new cold disinfestation treatments for fruit fly pests on citrus	138

CRI GROUP ANNUAL RESEARCH REPORT 2019/20
TABLE OF CONTENTS

	Page
3.3.9 PROGRESS REPORT: Redefining dispersal potential for adequate fruit fly pest management (Diptera, Tephritidae)	138
3.3.10 PROGRESS REPORT: In-silico boosted, pest prevention and off-season focussed IPM against new and emerging fruit flies	139
3.3.11 PROGRESS REPORT: Field performance of a new AVIMA bait station for fruit fly control in citrus.	140
3.3.12 PROGRESS REPORT: The assessment of control and monitoring for fruit fly in the Western Cape	141
3.3.13 PROGRESS REPORT: Understanding fruit fly trap efficiency: the role of physical and biotic variables	141
3.4 Programme: Other Pests	142
3.4.1 Programme summary	142
3.4.2 FINAL REPORT: Suitability of entomopathogenic fungal isolates for microbial control of citrus pests: biological control and effects of formulation	143
3.4.3 FINAL REPORT: Controlling flat mite as a vector of Leprosis	157
3.4.4 FINAL REPORT: New systemic insecticides for citrus	160
3.4.5 PROGRESS REPORT: The efficacy of commercial entomopathogenic fungi products for control of citrus pests	161
3.4.6 PROGRESS REPORT: Determine the primary cause for mealybug repercussions under netting	162
3.4.7 PROGRESS REPORT: Controlling mites on budwood	162
3.4.8 PROGRESS REPORT: Surveying for Oleander scale, <i>Aspidiotus nerii</i>	163
3.4.9 PROGRESS REPORT: Chemical control of mealybug on citrus	163
3.4.10 PROGRESS REPORT: IPM under Nets in the Western Cape	164
3.4.11 PROGRESS REPORT: Synergism and formulation of entomopathogenic fungi for foliar control of various citrus pests	165
3.4.12 PROGRESS REPORT: IPM under nets in Mpumalanga Province	166
4 PORTFOLIO: DISEASE MANAGEMENT	167
4.1 Portfolio summary	167
4.2 Programme: Graft Transmissible Diseases	171
4.2.1 Programme summary	171
4.2.2 PROGRESS REPORT: Comparison of shoot tip grafted citrus with field-cut (old clone) material	172
4.2.3 PROGRESS REPORT: Field testing of commercial or potentially important rootstock selections for viroid sensitivity	173
4.2.4 PROGRESS REPORT: Application of CTV infectious clones to combat HLB	174
4.2.5 PROGRESS REPORT: Field evaluation of three single-strain CTV isolates on Navel and Soft Citrus cultivars	175
4.2.6 PROGRESS REPORT: Validation of primer regions used for the differentiation of Asian HLB, African greening and its subspecies	176
4.2.7 PROGRESS REPORT: Application of high-throughput sequencing (HTS) for routine virus and viroid detection in high value accessions.	177
4.3 Programme: Preharvest Diseases	178
4.3.1 Programme summary	178
4.3.2 PROGRESS REPORT: Evaluation of alternative products for control of citrus nematode and <i>Phytophthora</i> spp. in citrus	181
4.3.3 PROGRESS REPORT: Unravelling the clonal distribution of <i>Phyllosticta citricarpa</i> through a Genotyping-By-Sequencing approach	191

CRI GROUP ANNUAL RESEARCH REPORT 2019/20
TABLE OF CONTENTS

		Page
4.3.4	PROGRESS REPORT: Epidemiology and management of <i>Botrytis cinerea</i> in citrus	192
4.3.5	PROGRESS REPORT: The evaluation of different pre-plant products for the control of the citrus nematode, as part of an integrated nematode control approach in citrus replant situations	192
4.3.6	PROGRESS REPORT: Characterization and management of Valley Bushveld citrus decline	193
4.3.7	PROGRESS REPORT: Evaluation of reduced volume fungicide and pesticide sprays for control of citrus black spot and false codling moth.	194
4.3.8	PROGRESS REPORT: Potential biocontrol agents and host/pathogen interaction of citrus replant pathogens	194
4.3.9	PROGRESS REPORT: Evaluation of new spray programmes for the control of Alternaria brown spot in the summer rainfall regions of South Africa	195
4.3.10	PROGRESS REPORT: Development of new spray programmes for the control of citrus black spot	198
4.3.11	PROGRESS REPORT: Susceptibility period of sweet orange fruit to <i>Phyllosticta citricarpa</i> in commercial orchards	205
4.3.12	PROGRESS REPORT: Influence of shade nets on Alternaria brown spot and citrus black spot: comparing epidemiological model output for covered (under shade nets) and uncovered (normal/open) orchards' weather datasets	206
4.3.13	PROGRESS REPORT: Management of pruning debris as part of citrus black spot control strategy	206
4.3.14	PROGRESS REPORT: Further validation and improvements of CRI-PhytRisk	207
4.3.15	PROGRESS REPORT: Comparison of the rind phytochemistry and wax composition of CBS resistant and susceptible citrus cultivars	207
4.3.16	PROGRESS REPORT: Epidemiology, inoculum potential and infection parameters of Citrus Black Spot	208
4.4	Programme: Postharvest Diseases	209
4.4.1	Programme summary	209
4.4.2	PROGRESS REPORT: Provision of an industry service whereby new packhouse treatments are comparatively evaluated, fungicide resistance is monitored and standardised recommendations are provided	212
4.4.3	PROGRESS REPORT: Evaluation of new postharvest fungicides for the control of <i>Phytophthora</i> brown rot	229
4.4.4	PROGRESS REPORT: Fungal degradation of wood pallets used in export of citrus fruit	229
4.4.5	PROGRESS REPORT: Optimising available alternative postharvest remedies as replacement for imazalil use on citrus exported to Europe	231
4.4.6	PROGRESS REPORT: The use of alternative fungicides in wax to control citrus green mould caused by <i>Penicillium digitatum</i>	232
4.5	CRI Diagnostic Centre	233
5	PORTFOLIO: CITRICULTURE	235
5.1	Portfolio summary	235
5.2	Programme: Rind condition and cold chain	236
5.2.1	Programme summary	236
5.2.2	PROGRESS REPORT: Ambient loading and forced air cooling of citrus for cold sterilisation markets.	236
5.2.3	PROGRESS REPORT: An investigation into aspects affecting chilling injury in	

CRI GROUP ANNUAL RESEARCH REPORT 2019/20
TABLE OF CONTENTS

		Page
	Citrus fruit	249
5.2.4	PROGRESS REPORT: Integration of pallet bases and carton designs to improve ventilation of citrus exports	252
5.2.5	PROGRESS REPORT: Investigation of factors contributing towards the non-conformance of in-transit citrus container shipments to cold protocol markets	253
5.3	Programme: Production and quality	254
5.3.1	Programme summary	254
5.3.2	FINAL REPORT: The use of novel soil conditioners to improve citrus P nutrition and tree performance	256
5.3.3	PROGRESS REPORT: Evaluation of aerial application and adjuvants of micronutrients	274
5.3.4	PROGRESS REPORT: Adaptive Nutrition Management Strategies for Improved Fruit Quality	275
5.3.5	PROGRESS REPORT: Handbook for Citrus Nutrition in Southern Africa	276
5.3.6	PROGRESS REPORT: Studies to improve seed production of rootstock trees	276
5.3.7	PROGRESS REPORT: Re-evaluating fruit set strategies for seedless 'Valencia' in the Letsitele region	277
5.4	Programme: Cultivar evaluation	278
5.4.1	Programme summary	278
5.4.2	PROGRESS REPORT: Evaluation of Valencia selections in hot humid inland areas (Onderberg)	280
5.4.3	PROGRESS REPORT: Evaluation of Valencia selections in the hot dry inland areas (Letsitele and Hoedspruit)	285
5.4.4	PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the hot inland areas (Letsitele and Malelane)	294
5.4.5	PROGRESS REPORT: Evaluation of Valencia selections in the hot dry production areas (Weipe and Tshipise)	302
5.4.6	PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the intermediate production areas (Marble Hall)	308
5.4.7	PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the hot dry inland areas (Tshipise and Weipe)	313
5.4.8	PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the intermediate production areas (Karino and Ngonini)	319
5.4.9	PROGRESS REPORT: Evaluation of Navel selections in the intermediate production areas (Karino)	325
5.4.10	PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the cool-inland production areas (Orighstad and Burgersfort)	327
5.4.11	PROGRESS REPORT: Evaluation of Valencia selections in the intermediate production areas (Nelspruit)	333
5.4.12	PROGRESS REPORT: Evaluation of Grapefruit on different rootstocks in a semi-desert production area (Kakamas)	336
5.4.13	PROGRESS REPORT: Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region (Sundays River Valley)	341
5.4.14	PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarins in a cold production region (Sundays River Valley)	343
5.4.15	PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Gamtoos River Valley)	348
5.4.16	PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Gamtoos River Valley)	351
5.4.17	PROGRESS REPORT: Cultivar characteristics and climatic suitability of	

CRI GROUP ANNUAL RESEARCH REPORT 2019/20
TABLE OF CONTENTS

	Page
mandarin hybrids in a cold production region (South West Cape)	356
5.4.18 PROGRESS REPORT: Cultivar characteristics and climatic suitability of navel oranges in a cold production region (Sundays River Valley)	359
5.4.19 PROGRESS REPORT: Cultivar characteristics and climatic suitability of experimental navel oranges in a cold production region (Gamtoos River Valley)	366
5.4.20 PROGRESS REPORT: Cultivar characteristics and climatic suitability of experimental navel oranges in a cold production region (Western Cape)	369
5.4.21 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Valencia oranges in a cold production region (Sundays River Valley)	374
5.4.22 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Valencia oranges in a cold production region (Citrusdal)	378
5.4.23 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region (Sundays River Valley)	382
5.4.24 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region (Western Cape)	384
5.4.25 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region (South West Cape)	388
5.4.26 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region (Western Cape)	389
5.4.27 PROGRESS REPORT: Evaluation of new University of Florida (UF) rootstocks	392
5.4.28 PROGRESS REPORT: Studies into the high incidence of chimeras of Valencia orange cultivars, specifically Valencia Late.	392
6 CITRUS IMPROVEMENT SCHEME (CIS)	393
6.1 Introduction	394
6.2 Budwood	394
6.3 Seed	400
6.4 Production	405
6.5 Tree Certification	406
6.6 Nursery Certification	410
6.7 Statutory Improvement Scheme	411
6.8 Protective zone surrounding the Citrus Foundation Block	412
6.9 PROGRESS REPORT: Shoot tip grafting and CIS diagnostic services at CRI-Nelspruit	412
6.10 PROGRESS REPORT: Diagnostic and technical services for the Citrus Improvement Scheme by the ARC-TSC	423
7 INTERNATIONAL VISITS	431
7.1 Report on the kick-off meeting of the FF-IPM project (H2020), Volos, Greece, 16-20 September 2019	431
8 VOORLIGTING / EXTENSION	436
8.1 Voorligtingoorsig	436
8.1.1 Die 2019 Seisoen	436
8.1.2 Die 2019 Seisoen	436
8.1.3 CRI Postharvest Technical Forum	437
8.1.4 Produksiestreke	439

CRI GROUP ANNUAL RESEARCH REPORT 2019/20
TABLE OF CONTENTS

	Page
8.1.5 Postharvest extension	441
8.1.6 Research priorities	443
8.1.7 CRI Na-oes werksinkels vir 2020	443
8.1.8 Biosekuriteit	444
8.1.9 Geïntegreerde Plaag en Siektebestuur werksinkels	444
8.1.10 11de Sitrusnavorsingsimposium	444
8.2 Other means of Technology Transfer	459
8.2.1 S.A. Fruit Journal	459
8.2.2 CRI Website	460
8.2.3 CRInet	461
8.2.4 CRI Cutting Edge	461
9 PUBLICATIONS IN 2019-20	462
9.1 Refereed Publications (or ISI ranked journals)	462

**CRI GROUP ANNUAL RESEARCH REPORT 2020/21
TABLE OF CONTENTS**

		Page
1	MARKET ACCESS TECHNICAL COORDINATION	1
1.1	Summary	1
1.2	European Union (EU)	1
1.3	Japan	2
1.4	USA	3
1.5	China	3
1.6	South Korea	3
1.7	India	4
1.8	Vietnam	4
1.9	The Philippines	5
1.10	Australia	5
1.11	eSwatini	5
1.12	Citrus one pagers	6
2	BIOSECURITY AND REGULATIONS	6
2.1	Summary	6
2.2	Develop and maintain a comprehensive Citrus industry biosecurity plan - to ensure overall mitigation of the Southern African Citrus industry's biosecurity risks	7
2.2.1	Project 1: Develop a Southern Africa Citrus industry biosecurity master plan	7
2.3	Biosecurity portfolio: Design, develop and oversee the implementation and operation of appropriate biosecurity structures, engagements, procedures, co-operations, resources, projects and other appropriate actions	8
2.3.1	Project 2: Identify, assess and initiate engagement with international funding providers, for future support of Southern African biosecurity projects	8
2.4	Networking and awareness: Obtain supportive participation of relevant stakeholders and interested parties	8
2.5	Ensure successful implementation of processes, procedures and interactions to ensure the timely identification and assessment of biosecurity threats facing the Southern African Citrus industry	9
2.5.1	Project 3: Develop and oversee implementation of Southern African Citrus industry pest-specific action plans for priority biosecurity pests	9
2.6	Ensure effective implementation of processes, procedures, interactions to advance actions required to successfully mitigate the risks and consequences of biosecurity incursions	9
2.6.1	Project 4: Develop and oversee implementation of a Southern African Citrus industry HLB action plan and safe tree production system	9
2.6.2	Project 5: Ensure that HLB and ACP surveillance is undertaken in Eastern Africa	10
2.6.3	Project 6: Facilitate initiation of an HLB eradication plan in Ethiopia	12
2.6.4	Project 7: Ensure, in close collaboration with relevant government officials, that regulations of relevance to biosecurity risk mitigation are appropriately updated and compliance effectively implemented	12
2.6.5	Project 8: Monitoring and control of Leprosis	13
2.6.6	Project 9: Phytosanitary Risk Forum	13
2.6.7	Project 10: Greening surveys (African greening - <i>candidatus liberibacter Africanus</i> & Asiatic greening - <i>candidatus liberibacter asiaticus</i>)	14
2.6.8	Project 11: Citrus Free Zone (5 km) outside the Citrus Foundation Block (CFB) in the Eastern Cape Province in the magisterial district of Uitenhage	14

**CRI GROUP ANNUAL RESEARCH REPORT 2020/21
TABLE OF CONTENTS**

		Page
3	PORTFOLIO: INTEGRATED PEST MANAGEMENT	14
3.1	Portfolio summary	14
3.2	Programme: False Codling Moth	17
3.2.1	Programme summary	17
3.2.2	FINAL REPORT: Yeast-baculovirus synergism: Investigating mixed infections for improved management of the false codling moth, <i>Thaumatotibia leucotreta</i>	20
3.2.3	FINAL REPORT: Improvement of the quality and quality control testing of sterile moths for FCM SIT	32
3.2.4	FINAL REPORT: Improving baculovirus virulence against the false codling moth by repeated passage and virus combinations.	45
3.2.5	FINAL REPORT: FCM population phenology in the warm northern citrus production regions and implications for management practices	61
3.2.6	FINAL REPORT: Improvement of the quality of sterile moths for FCM SIT	66
3.2.7	FINAL REPORT: Identifying volatile emissions associated with false codling moth infestation of citrus fruit	69
3.2.8	PROGRESS REPORT: Impact of abbreviated and complete cold-treatment on survival and fitness of FCM larvae	89
3.2.9	PROGRESS REPORT: Evaluating hot air treatments for postharvest FCM control	90
3.2.10	PROGRESS REPORT: Identification and development of an attractant for monitoring FCM adult females	91
3.2.11	PROGRESS REPORT: Synergism between insecticides for improved control of FCM	91
3.2.12	PROGRESS REPORT: Identification and evaluation of male false codling moth pheromones and an investigation of the usefulness for monitoring of female moths	92
3.2.13	PROGRESS REPORT: Using the antennal response of the FCM larval parasitoid, <i>Agathis bishopi</i> , for identifying key volatiles indicative of FCM fruit infestation	92
3.2.14	PROGRESS REPORT: Improving understanding of mating disruption	93
3.2.15	PROGRESS REPORT: Sterile Insect Technique and Mating Disruption in the control of FCM	94
3.2.16	PROGRESS REPORT: Comparing the performance of mating disruption for false codling moth control in netted and open orchards	94
3.2.17	PROGRESS REPORT: An assessment of the reasons for lower FCM infestation in organic versus conventional citrus orchards.	95
3.2.18	PROGRESS REPORT: Field trials for control of FCM	96
3.2.19	PROGRESS REPORT: Genetic analysis and field application of a UV-resistant strain of CrleGV for improved control of <i>Thaumatotibia leucotreta</i>	97
3.3	Programme: Fruit Fly	98
3.3.1	Programme summary	98
3.3.2	FINAL REPORT: Attract and kill methods for fruit flies: efficacy and application of new and registered products	98
3.3.3	FINAL REPORT: Development of new cold disinfestation treatments for fruit fly pests on citrus	121
3.3.4	PROGRESS REPORT: Fruit fly rearing	133
3.3.5	PROGRESS REPORT: Efficacy of FCM partial cold treatments for fruit fly pests of citrus	134
3.3.6	PROGRESS REPORT: The impact of interruptions on Medfly cold treatment efficacy	135
3.3.7	PROGRESS REPORT: Understanding fruit fly trap efficiency: the role of physical	

**CRI GROUP ANNUAL RESEARCH REPORT 2020/21
TABLE OF CONTENTS**

		Page
	and biotic variables	135
3.3.8	PROGRESS REPORT: Redefining dispersal potential for adequate fruit fly pest management (Diptera, Tephritidae)	136
3.3.9	PROGRESS REPORT: In-silico boosted, pest prevention and off-season focussed IPM against new and emerging fruit flies	137
3.4	Programme: Other Pests	138
3.4.1	Programme summary	138
3.4.2	FINAL REPORT: The efficacy of commercial entomopathogenic fungi products for control of citrus pests	139
3.4.3	FINAL REPORT: Surveying for Oleander scale, <i>Aspidiotus nerii</i>	147
3.4.4	FINAL REPORT: Potential Synergism between Entomopathogenic Fungi and Entomopathogenic Nematodes for the control of false codling moth (<i>Thaumatotibia leucotreta</i>)	157
3.4.5	FINAL REPORT: Improving biocontrol of woolly whitefly in the Western and Eastern Cape regions.	170
3.4.6	PROGRESS REPORT: New systemic insecticides for citrus	172
3.4.7	PROGRESS REPORT: Determine the primary cause for mealybug repercussions under netting	173
3.4.8	PROGRESS REPORT: Controlling mites on budwood	174
3.4.9	PROGRESS REPORT: Augmentation of <i>Aphytis melinus</i> DeBach (Hymenoptera: Aphelinidae) for the control of California red scale (Hemiptera: Diaspididae) in citrus	175
3.4.10	PROGRESS REPORT: IPM under Nets in the Western Cape	176
3.4.11	PROGRESS REPORT: IPM under nets in Mpumalanga Province	177
3.4.12	PROGRESS REPORT: The influence of systemic phenology (citrus, mealybug and parasitoids) on the efficacy of <i>Anagyrus</i> augmentation for mealybug control	178
4	PORTFOLIO: DISEASE MANAGEMENT	179
4.1	Portfolio summary	179
4.2	Programme: Graft Transmissible Diseases	182
4.2.1	Programme summary	182
4.2.2	FINAL REPORT: Validation of primer regions used for the differentiation of Asian HLB, African greening and its subspecies.	184
4.2.3	PROGRESS REPORT: Comparison of shoot tip grafted citrus with field-cut (old clone) material	191
4.2.4	PROGRESS REPORT: Field testing of commercial or potentially important rootstock selections for viroid sensitivity	192
4.2.5	PROGRESS REPORT: Field evaluation of three single-strain CTV isolates on navel and soft citrus cultivars	193
4.2.6	PROGRESS REPORT: Application of CTV infectious clones to combat HLB	194
4.2.7	PROGRESS REPORT: Application of high-throughput sequencing (HTS) for routine virus and viroid detection in high value accessions.	195
4.3	Programme: Preharvest Diseases	196
4.3.1	Programme summary	196
4.3.2	FINAL REPORT: Potential biocontrol agents and host/pathogen interaction of citrus replant pathogens	200
4.3.3	PROGRESS REPORT: Evaluation of alternative products for control of citrus nematode and <i>Phytophthora</i> spp. in citrus	254
4.3.4	PROGRESS REPORT: Evaluation of new spray programmes for the control of Alternaria brown spot in the summer rainfall regions of South Africa	271

**CRI GROUP ANNUAL RESEARCH REPORT 2020/21
TABLE OF CONTENTS**

		Page
4.3.5	PROGRESS REPORT: Development of new spray programmes for the control of citrus black spot	275
4.3.6	PROGRESS REPORT: Susceptibility period of sweet orange fruit to <i>Phyllosticta citricarpa</i> in commercial orchards	283
4.3.7	PROGRESS REPORT: Influence of shade nets on Alternaria brown spot and citrus black spot: comparing epidemiological model output for covered (under shade nets) and uncovered (normal/open) orchards' weather datasets	284
4.3.8	PROGRESS REPORT: Management of pruning debris as part of citrus black spot control strategy	285
4.3.9	PROGRESS REPORT: Further validation and improvements of CRI-Phytrisk	286
4.3.10	PROGRESS REPORT: Epidemiology, inoculum potential and infection parameters of Citrus Black Spot	287
4.3.11	PROGRESS REPORT: Characterization and management of Valley Bushveld citrus decline	287
4.3.12	PROGRESS REPORT: Unravelling the clonal distribution of <i>Phyllosticta citricarpa</i> through a Genotyping-By-Sequencing approach	288
4.3.13	PROGRESS REPORT: The evaluation of different pre-plant products for the control of the citrus nematode, as part of an integrated nematode control approach in citrus replant situations	290
4.3.14	PROGRESS REPORT: Comparison of the rind phytochemistry and wax composition of CBS resistant and susceptible citrus cultivars	290
4.3.15	PROGRESS REPORT: Epidemiology and management of <i>Botrytis cinerea</i> in citrus	292
4.3.16	FINAL REPORT: Evaluation of reduced volume fungicide and pesticide sprays for control of citrus black spot and false codling moth	293
4.4	Programme: Postharvest Diseases	295
4.4.1	Programme summary	295
4.4.2	FINAL REPORT: Fungal degradation of wooden pallet bases used in containerised export of citrus fruit	298
4.4.3	FINAL REPORT: Evaluation of new postharvest fungicides for the control of Phytophthora brown rot	321
4.4.4	FINAL REPORT: Optimising available alternative postharvest remedies as replacement for imazalil use on citrus exported to Europe	348
4.4.5	PROGRESS REPORT: Provision of an industry service whereby new packhouse treatments are comparatively evaluated, fungicide resistance is monitored and standardised recommendations are provided	356
4.4.6	FINAL REPORT: The use of alternative fungicides in wax to control citrus green mould caused by <i>Penicillium digitatum</i>	368
4.5	Programme: Huanglongbing	378
4.5.1	Programme summary	378
4.5.2	PROGRESS REPORT: New systemic insecticides for citrus	381
4.5.3	PROGRESS REPORT: Application of CTV infectious clones to combat HLB	381
4.5.4	PROGRESS REPORT: Distinguishing <i>Diaphorina</i> spp. and <i>Trioza</i> spp. from other psyllids likely to be caught on yellow traps	382
4.5.5	PROGRESS REPORT: Evaluation of new University of Florida (UF) rootstocks	384
4.5.6	PROGRESS REPORT: Studies to improving seed production of rootstock trees	384
4.5.7	PROGRESS REPORT: Validation of LAMP diagnostics for in-field detection of HLB	385
4.6	CRI Diagnostic Centre	386
5	PORTFOLIO: CITRICULTURE	388

**CRI GROUP ANNUAL RESEARCH REPORT 2020/21
TABLE OF CONTENTS**

		Page
5.1	Portfolio summary	388
5.2	Programme: Rind condition and cold chain	389
	5.2.1 Programme summary	389
	5.2.2 FINAL REPORT: Integration of pallet bases and carton designs to improve ventilation of citrus exports	390
	5.2.3 FINAL REPORT: Optimising container loading methods for improved cooling performance	420
	5.2.4 PROGRESS REPORT: An investigation into aspects affecting chilling injury of citrus	441
	5.2.5 PROGRESS REPORT: Investigation of factors contributing towards the non-conformance of in-transit citrus container shipments to cold protocol markets	442
5.3	Programme: Production and quality	443
	5.3.1 Programme summary	443
	5.3.2 FINAL REPORT: Evaluation of aerial application and adjuvants of micronutrients	445
	5.3.3 FINAL REPORT: Adaptive nutrition management strategies for improved fruit quality	455
	5.3.4 PROGRESS REPORT: Re-evaluating fruit set strategies for seedless 'Valencia' in the Letsitele region	493
	5.3.5 PROGRESS REPORT: Handbook for Citrus Nutrition in Southern Africa	494
5.4	Programme: Cultivar evaluation	494
	5.4.1 Programme summary	494
	5.4.2 PROGRESS REPORT: Evaluation of Valencia selections in hot humid inland areas (Onderberg)	497
	5.4.3 PROGRESS REPORT: Evaluation of Valencia selections in the hot dry inland areas (Letsitele and Hoedspruit)	502
	5.4.4 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the hot inland areas (Letsitele and Hoedspruit)	509
	5.4.5 PROGRESS REPORT: Evaluation of Valencia selections in the hot dry production areas (Tshipise)	515
	5.4.6 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the intermediate production areas (Marble Hall)	522
	5.4.7 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the hot dry inland areas (Tshipise)	525
	5.4.8 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the intermediate production areas (Karino and Ngonini)	529
	5.4.9 PROGRESS REPORT: Evaluation of Navel selections in the intermediate production areas (Karino)	533
	5.4.10 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the cool-inland production areas (Orighstad and Burgersfort)	536
	5.4.11 PROGRESS REPORT: Evaluation of Valencia selections in the intermediate production areas (Nelspruit)	547
	5.4.12 PROGRESS REPORT: Evaluation of Grapefruit on different rootstocks in a semi-desert production area (Kakamas)	551
	5.4.13 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region (Sundays River Valley)	564
	5.4.14 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarins in a cold production region (Sundays River Valley)	557
	5.4.15 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Gamtoos River Valley)	563
	5.4.16 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Western Cape)	566
	5.4.17 PROGRESS REPORT: Cultivar characteristics and climatic suitability of	

**CRI GROUP ANNUAL RESEARCH REPORT 2020/21
TABLE OF CONTENTS**

		Page
	mandarin hybrids in a cold production region (South West Cape)	570
5.4.18	PROGRESS REPORT: Cultivar characteristics and climatic suitability of navel oranges in a cold production region (Sundays River Valley)	574
5.4.19	PROGRESS REPORT: Cultivar characteristics and climatic suitability of experimental navel oranges in a cold production region (Gamtoos River Valley)	581
5.4.20	PROGRESS REPORT: Cultivar characteristics and climatic suitability of experimental navel oranges in a cold production region (Western Cape)	583
5.4.21	PROGRESS REPORT: Cultivar characteristics and climatic suitability of Valencia oranges in a cold production region (Sundays River Valley)	589
5.4.22	PROGRESS REPORT: Cultivar characteristics and climatic suitability of Valencia oranges in a cold production region (Citrusdal)	593
5.4.23	PROGRESS REPORT: Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region (Sundays River Valley)	597
5.4.24	PROGRESS REPORT: Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region (Western Cape)	599
5.4.25	PROGRESS REPORT: Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region (South West Cape)	602
5.4.26	PROGRESS REPORT: Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region (Western Cape)	603
5.4.27	PROGRESS REPORT: Studies into the high incidence of chimeras of Valencia orange cultivars, specifically Valencia Late	606
6	CITRUS IMPROVEMENT SCHEME (CIS)	610
6.1	Introduction	611
6.2	Budwood	611
6.3	Seed	621
6.4	Production	622
6.5	Tree Certification	624
6.6	Nursery Certification	624
6.7	Statutory Improvement Scheme	629
6.8	Protective zone surrounding the Citrus Foundation Block	629
6.9	PROGRESS REPORT: Shoot tip grafting and CIS diagnostic services at CRI-Nelspruit	629
6.10	PROGRESS REPORT: Diagnostic and technical services for the Citrus Improvement Scheme by the ARC-TSC	637
7	VOORLIGTING / EXTENSION	644
7.1	Voorligtingoorsig	644
7.1.1	Die 2020 Seisoen	644
7.2	CRI-PTF	645
7.2.1	Akkreditasie van kartonvervaardigers	645
7.2.2	Klagtes oor kartonne	645
7.2.3	Palette	646
7.2.4	Everest Packaging	646
7.2.5	CRI-Packaging Material Specifications and Palletisation Protocols for the 2021 Citrus Export Season.	647
7.2.6	Disruptive Packaging	647
7.2.7	Navorsing- en ontwikkelingswerk op meer koste-effektiewe kartonne	647
7.2.8	Fruit Technical Services and Support Ltd	647

**CRI GROUP ANNUAL RESEARCH REPORT 2020/21
TABLE OF CONTENTS**

		Page
	7.2.9 Versoeke van Morrisons en Lidl	647
	7.2.10 Versoek vanuit Japan vir 'n 18Kg teleskopiese karton vir Suurlemoene	648
	7.2.11 CRI Na-oes Werkwinkels 2021	648
7.3	Postharvest	648
	7.3.1 COVID-19	648
	7.3.2 Decay concerns	649
	7.3.3 Fungicide Concerns	649
7.4	Extension - Key Events	649
	7.4.1 CRI Symposium	649
	7.4.2 CRI Biosekuriteit/Voorligting vergroening-opleiding	649
	7.4.3 IPM en Scouting opleiding met LAC Nelspruit	650
	7.4.4 CRI Werkswinkels	650
	7.4.5 CRI Postharvest Workshops 2021	650
	7.4.6 Packaging Working Group meeting	650
	7.4.7 Exporters Technical Panel and Cooling Working Group meeting	650
	7.4.8 Integrated Pest Management Course	650
7.5	Produksiestreke	651
	7.5.1 Suidelike Produksiestreek	651
	7.5.2 Sentrale Produksiestreek	651
	7.5.3 Noordelike Produksiestreek	653
7.6	Other means of Technology Transfers	665
	7.6.1 CRI website	665
	7.6.2 CRInet	666
	7.6.3 X2 CRM System	666
	7.6.4 CRI Cutting Edge	666
8	PUBLICATIONS IN 2020-21	668
8.1	Refereed Publications (or ISI ranked journals)	668

**CRI GROUP ANNUAL RESEARCH REPORT 2021/22
TABLE OF CONTENTS**

		Page
1	MARKET ACCESS TECHNICAL COORDINATION	1
1.1	Summary	1
1.2	European Union (EU)	1
1.3	Japan	3
1.4	USA	4
1.5	China	4
1.6	South Korea	5
1.7	India	5
1.8	Thailand	5
1.9	Vietnam	6
1.10	The Philippines	6
1.11	eSwatini	6
1.12	Zimbabwe	6
1.13	Citrus one-pagers	7
1.14	Deviation for fruit age compliance on citrus that is intended for export	7
2	BIOSECURITY AND REGULATIONS	7
2.1	Summary	7
2.2	Develop and maintain a comprehensive Citrus industry biosecurity plan - to ensure overall mitigation of the Southern African Citrus industry's biosecurity risks	9
2.2.1	Project 1: Develop a Southern Africa Citrus industry biosecurity master plan	9
2.3	Biosecurity portfolio: Design, develop and oversee the implementation and operation of appropriate biosecurity structures, engagements, procedures, co-operations, resources, projects and other appropriate actions	9
2.3.1	Project 2: Identify, assess and initiate engagement with international funding providers, for future support of Southern African biosecurity projects	9
2.4	Networking and awareness: Obtain supportive participation of relevant stakeholders and interested parties	9
2.5	Ensure successful implementation of processes, procedures and interactions to ensure the timely identification and assessment of biosecurity threats facing the Southern African Citrus industry	10
2.5.1	Project 3: Develop and oversee implementation of Southern African Citrus industry pest-specific action plans for priority biosecurity pests	10
2.6	Ensure effective implementation of processes, procedures, interactions to advance actions required to successfully mitigate the risks and consequences of biosecurity incursions	10
2.6.1	Project 4: Develop and oversee implementation of a Southern African Citrus industry HLB action plan and safe tree production system	10
2.6.2	Project 5: Ensure that HLB and ACP surveillance is undertaken in Eastern Africa	11
2.6.3	Project 6: Facilitate initiation of an HLB eradication plan in Ethiopia	12
2.6.4	Project 7: Ensure, in close collaboration with relevant government officials, that regulations of relevance to biosecurity risk mitigation are appropriately updated and compliance effectively implemented	12
2.6.5	Project 8: Monitoring and control of Leprosis	13
2.6.6	Project 9: Phytosanitary Risk Forum	13
2.6.7	Project 10: Greening surveys (African greening - <i>Candidatus Liberibacter africanus</i> & Asiatic greening - <i>Candidatus Liberibacter asiaticus</i>)	13

**CRI GROUP ANNUAL RESEARCH REPORT 2021/22
TABLE OF CONTENTS**

		Page
3	PORTFOLIO: INTEGRATED PEST MANAGEMENT	15
3.1	Portfolio summary	15
3.2	Programme: False Codling Moth	18
3.2.1	Programme summary	18
3.2.2	FINAL REPORT: A comparison of <i>Thaumatotibia leucotreta</i> (Meyrick) (Lepidoptera: Tortricidae) in organic versus conventional citrus orchards	22
3.2.3	FINAL REPORT: Genetic analysis and field application of a UV-tolerant strain of CrleGV for improved control of <i>Thaumatotibia leucotreta</i>	42
3.2.4	PROGRESS REPORT: Impact of abbreviated and complete cold-treatment on survival and fitness of FCM larvae	76
3.2.5	PROGRESS REPORT: Identification and development of an attractant for monitoring FCM adult females	78
3.2.6	PROGRESS REPORT: Field trials for control of FCM	79
3.2.7	PROGRESS REPORT: Synergism between insecticides for improved control of FCM	80
3.2.8	PROGRESS REPORT: Identification and evaluation of male false codling moth pheromones and an investigation of the usefulness for monitoring of female moths	80
3.2.9	PROGRESS REPORT: Using the antennal response of the FCM larval parasitoid, <i>Agathis bishopi</i> , for identifying key volatiles indicative of FCM fruit infestation	81
3.2.10	PROGRESS REPORT: Improving understanding of mating disruption	82
3.2.11	PROGRESS REPORT: Sterile insect technique (SIT) and mating disruption (MD) in the control of FCM	83
3.2.12	PROGRESS REPORT: Comparing the performance of and mating disruption (MD) for FCM control in netted and open orchards	84
3.2.13	PROGRESS REPORT: Evaluation of potential repellents for false codling moth, <i>Thaumatotibia leucotreta</i> (Meyrick) (Lepidoptera: Tortricidae)	85
3.2.14	PROGRESS REPORT: Selected Ion Flow Tube Mass Spectrometry for postharvest detection of FCM infested fruit	86
3.2.15	PROGRESS REPORT: Investigating the appropriate timing for initiation of mating disruption against FCM in Limpopo Province	87
3.2.16	PROGRESS REPORT: Selection for a UV-resistant isolate of a nucleopolyhedrovirus for improved field persistence and efficacy against FCM	88
3.2.17	PROGRESS REPORT: Regional differences in sex pheromones and sexual attractiveness in FCM	89
3.2.18	PROGRESS REPORT: An investigation into the biological and genetic stability of UV-tolerant baculoviruses for improved control of FCM	90
3.2.19	PROGRESS REPORT: Accurate monitoring of FCM fruit infestation	91
3.2.20	PROGRESS REPORT: Evaluating hot air treatments for postharvest FCM control	92
3.3	Programme: Fruit Fly	92
3.3.1	Programme summary	92
3.3.2	FINAL REPORT: Efficacy of FCM partial cold treatments for fruit fly pests of citrus	94
3.3.3	FINAL REPORT: Understanding fruit fly trap efficiency: the role of physical and biotic variables	118
3.3.4	PROGRESS REPORT: The impact of interruptions on Medfly cold treatment efficacy	127
3.3.5	PROGRESS REPORT: Alternate hosts of the Oriental Fruit Fly, <i>Bactrocera dorsalis</i> , in the Sundays River Valley	127
3.3.6	PROGRESS REPORT: Fruit fly rearing	128

CRI GROUP ANNUAL RESEARCH REPORT 2021/22
TABLE OF CONTENTS

		Page
	3.3.7 PROGRESS REPORT: Redefining dispersal potential for adequate fruit fly pest management (Diptera, Tephritidae)	129
	3.3.8 PROGRESS REPORT: In-silico boosted, pest prevention and off-season focussed IPM against new and emerging fruit flies	130
	3.3.9 PROGRESS REPORT: Rearing technology and taxonomy of the Cape fly <i>Ceratitits quilicii</i>	131
	3.3.10 PROGRESS REPORT: Efficacy of fruit fly systems approach for export of citrus to EU	131
	3.3.11 PROGRESS REPORT: Host status of citrus for <i>C. cosyra</i>	132
	3.3.12 PROGRESS REPORT: F ³ (Fruit fly free)	133
	3.3.13 PROGRESS REPORT: Utilization of <i>Fopius arisanus</i> for control of Oriental fruit fly	134
3.4	Programme: Other Pests	135
	3.4.1 Programme summary	135
	3.4.2 FINAL REPORT: Determine the primary cause for mealybug repercussions under netting	137
	3.4.3 FINAL REPORT: Determining the LC ₅₀ and LC ₉₀ values for spinetoram on <i>Scirtothrips aurantii</i>	154
	3.4.4 PROGRESS REPORT: Controlling mites on budwood	164
	3.4.5 PROGRESS REPORT: IPM under nets in Mpumalanga Province	165
	3.4.6 PROGRESS REPORT: Integrated pest management under nets in the Western Cape	166
	3.4.7 PROGRESS REPORT: Chemical control of mealybug on Citrus	167
	3.4.8 PROGRESS REPORT: Augmentation of <i>Aphytis melinus</i> DeBach (Hymenoptera: Aphelinidae) for the control of California red scale (Hemiptera: Diaspididae) in citrus	167
	3.4.9 PROGRESS REPORT: A comparison of control of key citrus pests in orchards under nets, in a biointensive IPM programme and a conventional programme	168
	3.4.10 PROGRESS REPORT: Investigating delivery systems for formulation and application of microbial control agents	170
	3.4.11 PROGRESS REPORT: Identification and management of new lepidopteran pests on citrus	171
	3.4.12 PROGRESS REPORT: Development of molecular detection tools for the identification of citrus pests and natural enemies.	173
	3.4.13 PROGRESS REPORT: Monitoring and control techniques for Australian bug	174
	3.4.14 PROGRESS REPORT: The influence of timing, insecticide residues and hyperparasitism on the efficacy of <i>Anagyrus vladimiri</i> augmentation for mealybug control	175
	3.4.15 PROGRESS REPORT: New systemic insecticides for citrus	176
	3.4.16 PROGRESS REPORT: Distinguishing <i>Diaphorina</i> spp. and <i>Trioza</i> spp. from other psyllids likely to be caught on yellow traps	177
	3.4.14 PROGRESS REPORT: Development of novel monitoring and control tools for citrus psyllids	178
4	PORTFOLIO: DISEASE MANAGEMENT	179
	4.1 Portfolio summary	179
	4.2 Programme: Graft Transmissible Diseases	184
	4.2.1 Programme summary	184
	4.2.2 FINAL REPORT: Application of high-throughput sequencing (HTS) for routine virus and viroid detection in high value accessions.	185
	4.2.3 FINAL REPORT: Comparison of shoot tip grafted citrus with field-cut (old clone) material	193

**CRI GROUP ANNUAL RESEARCH REPORT 2021/22
TABLE OF CONTENTS**

		Page
4.2.4	PROGRESS REPORT: Field testing of commercial or potentially important rootstock selections for viroid sensitivity	193
4.2.5	PROGRESS REPORT: Field evaluation of three single-strain CTV isolates on navel and soft citrus cultivars	194
4.2.6	PROGRESS REPORT: Field evaluation of two approved cross-protection sources for Grapefruit	195
4.3	Programme: Preharvest Diseases	196
4.3.1	Programme summary	196
4.3.2	FINAL REPORT: Epidemiology and management of <i>Botrytis cinerea</i> in citrus	202
4.3.3	FINAL REPORT: Influence of shade nets on Alternaria brown spot and citrus black spot: comparing epidemiological model output for covered (under shade nets) and uncovered (normal/open) orchards' weather datasets	216
4.3.4	FINAL REPORT: Management of pruning debris as part of the citrus black spot control strategy	225
4.3.5	FINAL REPORT: Epidemiology, inoculum potential and infection parameters of Citrus Black Spot	231
4.3.6	FINAL REPORT: Development of a rapid molecular tool to detect benzimidazole resistance in field-collected <i>Phyllosticta citricarpa</i> isolates	239
4.3.7	FINAL REPORT: Unravelling the clonal distribution of <i>Phyllosticta citricarpa</i> through a Genotyping-By-Sequencing approach	250
4.3.8	PROGRESS REPORT: Evaluation of new spray programmes for the control of Alternaria brown spot in the summer rainfall regions of South Africa	270
4.3.9	PROGRESS REPORT: Development of new spray programmes for the control of citrus black spot	274
4.3.10	PROGRESS REPORT: The evaluation of different pre-plant products for the control of the citrus nematode, as part of an integrated nematode control approach in citrus replant situations	284
4.3.11	PROGRESS REPORT: Evaluation of alternative products for control of citrus nematode and <i>Phytophthora</i> spp. in citrus	285
4.3.12	PROGRESS REPORT: Characterization and management of Valley Bushveld Citrus Decline	301
4.3.13	PROGRESS REPORT: Further validation and improvements of CRI-Phytrisk	302
4.3.14	PROGRESS REPORT: New oomycete fungicide-based approaches for managing <i>Phytophthora nicotianae</i> in citrus orchards	303
4.3.15	PROGRESS REPORT: Effect of citrus rootstocks on phosphonate applications for Phytophthora disease management in citrus	303
4.3.16	PROGRESS REPORT: Sources of <i>Phytophthora</i> spp. infestation in citrus Nurseries	304
4.3.17	PROGRESS REPORT: Phosphonate sensitivity of <i>Phytophthora nicotianae</i> in South African citrus orchards and nurseries	305
4.3.18	PROGRESS REPORT: Epidemiology and control of <i>Colletotrichum</i> species associated with anthracnose on citrus in South Africa	306
4.3.19	PROGRESS REPORT: Factors affecting results of citrus nursery <i>Phytophthora</i> Testing	307
4.3.20	PROGRESS REPORT: Further validation of the current CBS diagnostic protocols	308
4.3.21	PROGRESS REPORT: Sensitivity profiles of <i>Phyllosticta citricarpa</i> to quinone outside inhibitors and methyl benzimidazole carbamates	308
4.4	Programme: Postharvest Diseases	309
4.4.1	Programme summary	309

CRI GROUP ANNUAL RESEARCH REPORT 2021/22
TABLE OF CONTENTS

		Page
4.4.2	PROGRESS REPORT: Provision of an industry service whereby new packhouse treatments are comparatively evaluated, fungicide resistance is monitored and standardised recommendations are provided	311
4.4.3	PROGRESS REPORT: Optimising available alternative postharvest remedies as replacement for imazalil use on citrus exported to Europe	319
4.4.4	PROGRESS REPORT: Investigating rind aspects of mandarins, an important commercial citrus type, which affects efficacy of chemical application during postharvest treatments	317
4.4.5	PROGRESS REPORT: Increasing occurrence of saprophytic stem end growth - investigating the causes and species involved	318
4.4.6	PROGRESS REPORT: Management of postharvest diseases in the near-harvest period	319
4.4.7	PROGRESS REPORT: Evaluation of essential oil volatiles in degreening chambers for the management of <i>Penicillium</i> decay and Sour rot	319
4.5	Programme: Huanglongbing	320
4.5.1	Programme summary	320
4.5.2	FINAL REPORT: Application of CTV infectious clones to combat HLB	326
4.5.3	FINAL REPORT: Validation of LAMP diagnostics for in-field detection of HLB	336
4.5.4	FINAL REPORT: Studies to improve seed production of rootstock trees	343
4.5.5	PROGRESS REPORT: New systemic insecticides for citrus	405
4.5.6	PROGRESS REPORT: Evaluation of new University of Florida (UF) rootstocks	405
4.5.7	PROGRESS REPORT: Distinguishing <i>Diaphorina</i> spp. and <i>Trioza</i> spp. from other psyllids likely to be caught on yellow traps	406
4.5.8	PROGRESS REPORT: Development of novel monitoring and control tools for citrus psyllids	407
4.5.9	PROGRESS REPORT: Determination of genome diversity of citrus infecting ' <i>Candidatus Liberibacter africanus</i> ' species and subspecies	408
4.5.10	PROGRESS REPORT: Evaluation of the influence of CTV infection on ' <i>Candidatus Liberibacter africanus</i> ' titre	409
4.6	CRI Diagnostic Centre	410
5	PORTFOLIO: CITRICULTURE	413
5.1	Portfolio summary	413
5.2	Programme: Rind condition and cold chain	413
5.2.1	Programme summary	413
5.2.2	PROGRESS REPORT: Investigation of factors contributing toward the non-conformance of in-transit citrus container shipments to cold protocol markets	414
5.2.3	PROGRESS REPORT: An investigation into aspects affecting chilling injury of citrus	415
5.2.4	PROGRESS REPORT: Optimise 2,4-D applications and investigate alternatives for calyx retention	416
5.2.5	PROGRESS REPORT: Modelling citrus inland supply chains for improved handling practices	417
5.2.6	PROGRESS REPORT: Investigating the relationship between creep testing of corrugated cartons and current industry test methods	418
5.2.7	PROGRESS REPORT: Designing integrated packaging systems for enhanced cold treatments	418
5.2.8	PROGRESS REPORT: Optimisation of pallet base designs for the citrus industry	419

CRI GROUP ANNUAL RESEARCH REPORT 2021/22
TABLE OF CONTENTS

		Page
	5.2.9 PROGRESS REPORT: Enhancing phytosanitary cold treatment capabilities of reefer refrigerated containers during citrus exports	420
5.3	Programme: Production and quality	421
	5.3.1 Programme summary	421
	5.3.2 FINAL REPORT: Studies to improve seed production of rootstock trees	422
	5.3.3 FINAL REPORT: Adaptive nutrition management strategies for improved fruit quality	483
	5.3.4 PROGRESS REPORT: PROGRESS REPORT: The influence of shade netting and rootstock choice on the oleocellosis incidence of citrus varieties, Navel oranges, and Eureka lemons	514
	5.3.5 PROGRESS REPORT: The use of root growth restricting soil management practices to improve Valencia tree vigour, yield and fruit quality	515
	5.3.6 PROGRESS REPORT: Evaluation of strategies to improve water use efficiencies in citrus production	516
	5.3.7 PROGRESS REPORT: Water stress at different phenological stages of Nadorcott Mandarin trees in combination with two irrigation systems to mitigate water shortages in citrus growing areas	517
5.4	Programme: Cultivar evaluation	518
	5.4.1 Programme summary	518
	5.4.2 PROGRESS REPORT: Evaluation of Valencia selections in hot humid inland areas (Onderberg)	520
	5.4.3 PROGRESS REPORT: Evaluation of Valencia selections in the hot dry inland areas (Letsitele and Hoedspruit)	525
	5.4.4 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the hot inland areas (Letsitele and Hoedspruit)	539
	5.4.5 PROGRESS REPORT: Evaluation of Valencia selections in the hot dry production areas (Tshipise)	545
	5.4.6 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the intermediate production areas (Marble Hall)	554
	5.4.7 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the hot dry inland areas (Tshipise)	557
	5.4.8 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the intermediate production areas (Karino and Ngonini)	561
	5.4.9 PROGRESS REPORT: Evaluation of Navel selections in the intermediate production areas (Karino)	566
	5.4.10 PROGRESS REPORT: Evaluation of Mandarin hybrid selections in the cool-inland production areas (Ngodwana, Orighstad and Burgersfort)	570
	5.4.11 PROGRESS REPORT: Evaluation of Lemon selections in the hot dry production areas (Letsitele and Hoedspruit)	584
	5.4.12 PROGRESS REPORT: Evaluation of Valencia selections in the intermediate production areas (Nelspruit)	586
	5.4.13 PROGRESS REPORT: Evaluation of Mandarin Hybrid on different rootstocks in a cold production area (Buffeljagsrivier)	590
	5.4.14 PROGRESS REPORT: Evaluation of Grapefruit on different rootstocks in a semi-desert production area (Kakamas)	594
	5.4.15 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region (Sundays River Valley)	598
	5.4.16 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Sundays River Valley)	600

**CRI GROUP ANNUAL RESEARCH REPORT 2021/22
TABLE OF CONTENTS**

	Page
5.4.17 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Gamtoos River Valley)	603
5.4.18 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Mandarin hybrids in a cold production region (Western Cape)	605
5.4.19 PROGRESS REPORT: Cultivar characteristics and climatic suitability of mandarin hybrids in a cold production region (South West Cape)	609
5.4.20 PROGRESS REPORT: Cultivar characteristics and climatic suitability of navel oranges in a cold production region (Sundays River Valley)	612
5.4.21 PROGRESS REPORT: Cultivar characteristics and climatic suitability of experimental navel oranges in a cold production region (Gamtoos River Valley)	616
5.4.22 PROGRESS REPORT: Cultivar characteristics and climatic suitability of experimental navel oranges in a cold production region (Western Cape)	619
5.4.23 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Valencia oranges in a cold production region (Sundays River Valley)	623
5.4.24 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Valencia oranges in a cold production region (Citrusdal)	626
5.4.25 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region (Sundays River Valley)	629
5.4.26 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region (Western Cape)	631
5.4.27 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Clementine mandarins in a cold production region (South West Cape)	633
5.4.28 PROGRESS REPORT: Cultivar characteristics and climatic suitability of Satsuma mandarins in a cold production region (Western Cape)	635
5.4.29 PROGRESS REPORT: Studies into the high incidence of chimeras of Valencia orange cultivars, specifically Valencia Late	637
5.4.30 PROGRESS REPORT: Evaluation of new University of Florida (UF) rootstocks	638
6 CITRUS IMPROVEMENT SCHEME (CIS)	639
6.1 Introduction	639
6.2 Budwood	640
6.3 Seed	649
6.4 Production	650
6.5 Tree Certification	653
6.6 Nursery Certification	654
6.7 Statutory Improvement Scheme	655
6.8 Protective zone surrounding the Citrus Foundation Block	656
6.9 FINAL REPORT: Shoot tip grafting and CIS diagnostic services at CRI-Nelspruit	656
6.10 FINAL REPORT: Diagnostic and technical services for the Citrus Improvement Scheme by the ARC-TSC	666
7 VOORLIGTING / EXTENSION	675
7.1 Voorligtingoorsig	675
7.1.1 Terugblik op die 2021 seisoen	675
7.1.2 Blik op die 2022 seisoen	676
7.1.3 CRI Postharvest technical forum	676
7.1.4 Postharvest extension	679
7.1.5 Produksiestreke	680

**CRI GROUP ANNUAL RESEARCH REPORT 2021/22
TABLE OF CONTENTS**

	Page
7.1.5.1 Wes-Kaap Produksiestreek	680
7.1.5.2 Oos-Kaap Produksiestreek	681
7.1.5.3 Sentrale Produksiestreek	683
7.1.5.4 Noordelike Produksiestreek	684
7.1.6 Research priority meetings	686
7.1.7 Simposium terugvoer	687
7.1.8 CRI Geïntegreerde plaag- en siektebestuur werksinkels	687
7.1.9 Tegnieuse besoek aan Namibia	687
7.1.10 CRI Na-oes werksinkels	687
7.1.11 11de CRI Sitrusnavorsings Simposium	688
7.2 VOORLIGTING DIVISIE	688
7.3 OTHER MEANS OF TECHNOLOGY TRANSFER	717
7.3.1 SA Fruit Journal	717
7.3.2 CRI website	718
7.3.3 CRI Cutting Edge	718
8 PUBLICATIONS IN 2021-22	719
8.1 Refereed Publications (or ISI ranked journals)	719

**CRI GROUP ANNUAL RESEARCH REPORT 2022/23
TABLE OF CONTENTS**

		Page
1	MARKET ACCESS TECHNICAL COORDINATION	1
1.1	Summary	1
1.2	European Union (EU)	2
1.3	Japan	3
1.4	USA	3
1.5	China	3
1.6	South Korea	4
1.7	India	4
1.8	Thailand	4
1.9	Vietnam	5
1.10	Botswana	5
1.11	Zimbabwe	5
1.12	Citrus one-pagers	5
2	BIOSECURITY	6
2.1	Summary	6
2.2	Develop and maintain a comprehensive Citrus industry biosecurity plan - to ensure overall mitigation of the Southern African Citrus industry's biosecurity risks	7
2.2.1	Project 1: Develop a Southern Africa Citrus industry biosecurity master plan	7
2.3	Biosecurity portfolio: Design, develop and oversee the implementation and operation of appropriate biosecurity structures, engagements, procedures, co-operations, resources, projects and other appropriate actions	7
2.3.1	Project 2: Identify, assess and initiate engagement with international funding providers, for future support of Southern African biosecurity projects	7
2.4	Networking and awareness: Obtain supportive participation of relevant stakeholders and interested parties	8
2.5	Ensure successful implementation of processes, procedures and interactions to ensure the timely identification and assessment of biosecurity threats facing the Southern African Citrus industry	8
2.5.1	Project 3: Develop and oversee implementation of Southern African Citrus industry pest-specific action plans for priority biosecurity pests	8
2.6	Ensure effective implementation of processes, procedures, interactions to advance actions required to successfully mitigate the risks and consequences of biosecurity incursions	9
2.6.1	Project 4: Develop and oversee implementation of a Southern African Citrus industry HLB action plan and safe tree production system	9
2.6.2	Project 5: Ensure that HLB and ACP surveillance is undertaken in Eastern Africa	9
2.6.3	Project 6: Facilitate initiation of an HLB eradication plan in Ethiopia	10
2.6.4	Project 7: Ensure, in close collaboration with relevant government officials, that regulations of relevance to biosecurity risk mitigation are appropriately updated and compliance effectively implemented	10
2.6.5	Project 8: Monitoring and control of Leprosis	11
2.6.6	Greening surveys (African greening - <i>Candidatus Liberibacter africanus</i> & Asiatic greening - <i>Candidatus Liberibacter asiaticus</i>)	11

**CRI GROUP ANNUAL RESEARCH REPORT 2022/23
TABLE OF CONTENTS**

		Page
3	PORTFOLIO: INTEGRATED PEST MANAGEMENT	12
3.1	Portfolio summary	12
3.2	Programme: False Codling Moth	14
3.2.1	Programme summary	14
3.2.2	FINAL REPORT: Investigating the appropriate timing for initiation of mating disruption against FCM in Limpopo Province	19
3.2.3	FINAL REPORT: Selection for a UV-resistant isolate of a nucleopolyhedro-virus for improved field persistence and efficacy against FCM	27
3.2.4	FINAL REPORT: Regional differences in sex pheromones and sexual attractiveness in FCM	34
3.2.5	FINAL REPORT: An investigation into the biological and genetic stability of UV-tolerant baculoviruses for improved control of <i>Thaumatotibia leucotreta</i>	41
3.2.6	FINAL REPORT: Accurate monitoring of FCM fruit infestation	51
3.2.7	FINAL REPORT: Encapsulation of CrleGV in calcium alginate using a microfluidic device for improved UV resistance	62
3.2.8	FINAL REPORT: Characterisation of the False Codling Moth (<i>Thaumatotibia leucotreta</i>) gut microbiome and its host-microbe physiological interactions	67
3.2.9	PROGRESS REPORT: Impact of abbreviated and complete cold-treatment on survival and fitness of FCM larvae	81
3.2.10	PROGRESS REPORT: Evaluating hot air treatments for postharvest FCM control	83
3.2.11	PROGRESS REPORT: Identification and development of an attractant for monitoring FCM adult females	84
3.2.12	PROGRESS REPORT: Field trials for the control of FCM	85
3.2.13	PROGRESS REPORT: Synergism between insecticides for improved control of FCM	86
3.2.14	PROGRESS REPORT: Identification and evaluation of male false codling moth pheromones and an investigation of their usefulness for monitoring of female moths	87
3.2.15	PROGRESS REPORT: Using the antennal response of the FCM larval parasitoid, <i>Agathis bishopi</i> , for identifying key volatiles indicative of FCM fruit infestation	88
3.2.16	PROGRESS REPORT: Improving understanding of mating disruption	89
3.2.17	PROGRESS REPORT: Comparing the performance of sterile insect technique (SIT) and mating disruption (MD) for FCM control in netted and open orchards	90
3.2.18	PROGRESS REPORT: Evaluation of potential oviposition deterrents for false codling moth, <i>Thaumatotibia leucotreta</i> (Meyrick) (Lepidoptera: Tortricidae)	91
3.2.19	PROGRESS REPORT: Selected Ion Flow Tube Mass Spectrometry for postharvest detection of FCM infested fruit	92
3.2.20	PROGRESS REPORT: Mass culture of <i>Heterorhabditis bacteriophora</i> using <i>in vitro</i> liquid culture techniques	93
3.2.21	PROGRESS REPORT: High concentration formulation of entomopathogenic Nematodes	94
3.2.22	PROGRESS REPORT: Understanding FCM oviposition on citrus: analysis of chemical cues used to locate oranges and nutritional composition of preferred fruits	95
3.2.23	PROGRESS REPORT: Investigating release ratios in an FCM SIT programme	96
3.2.24	PROGRESS REPORT: Evaluating baculovirus mixtures against false codling moth, <i>Thaumatotibia leucotreta</i> Meyrick. (Lepidoptera: Tortricidae)	97
3.2.25	PROGRESS REPORT: The expression and evaluation of CrpeNPV GP37 as a formulation additive for enhanced infectivity with CrleGV and improved <i>Thaumatotibia leucotreta</i> control	98
3.2.26	PROGRESS REPORT: Investigating bats for the biological control of FCM	99

**CRI GROUP ANNUAL RESEARCH REPORT 2022/23
TABLE OF CONTENTS**

		Page
	3.2.24 PROGRESS REPORT: Research and demonstration trials to reposition the false codling moth (FCM) SIT programme as a base of the pyramid approach to FCM integrated pest management in citrus	100
3.3	Programme: Fruit Fly	101
	3.3.1 Programme summary	101
	3.3.2 FINAL REPORT: Rearing technology and taxonomy of the Cape fly <i>Ceratitis quilicii</i>	102
	3.3.3 FINAL REPORT: Alternate hosts of the Oriental Fruit Fly, <i>Bactrocera dorsalis</i> , in the Sundays River Valley	119
	3.3.4 FINAL REPORT: Efficacy of fruit fly systems approach for export of citrus to EU	124
	3.3.5 PROGRESS REPORT: Fruit fly rearing	141
	3.3.6 PROGRESS REPORT: Redefining dispersal potential for adequate fruit fly pest management (Diptera, Tephritidae)	142
	3.3.7 PROGRESS REPORT: In-silico boosted, pest prevention and off-season focussed IPM against new and emerging fruit flies	142
	3.3.8 PROGRESS REPORT: Host status of citrus for <i>C. cosyra</i>	143
	3.3.9 PROGRESS REPORT: F ³ (Fruit fly free)	144
	3.3.10 PROGRESS REPORT: Investigating X-ray technologies for the post-harvest detection of fruit flies in citrus	145
	3.3.11 PROGRESS REPORT: Identification and characterisation of a virus specific to fruit flies affecting citrus	146
	3.3.12 PROGRESS REPORT: Post-harvest cold treatments for fruit flies	146
	3.3.13 PROGRESS REPORT: Patterns of foraging for protein by fruit fly pests in citrus in South Africa	147
	3.3.14 PROGRESS REPORT: Spatio-temporal analysis of fruit fly trap captures and citrus fruit infestation	148
	3.3.15 PROGRESS REPORT: Contribution of the gut microbiome to thermal tolerance of fruit fly larvae	149
	3.3.16 PROGRESS REPORT: Utilization of <i>Fopius arisanus</i> for control of Oriental fruit fly	150
	3.3.17 PROGRESS REPORT: The impact of interruptions on Medfly cold treatment efficacy	151
3.4	Programme: Other Pests	152
	3.4.1 Programme summary	152
	3.4.2 FINAL REPORT: Integrated pest management under nets in the Western Cape	154
	3.4.3 PROGRESS REPORT: New systemic insecticides for citrus	158
	3.4.4 PROGRESS REPORT: Controlling mites on budwood	159
	3.4.5 PROGRESS REPORT: Techniques to distinguish <i>Diaphorina citri</i> and <i>Trioza erytrae</i> from other psylloids likely to be caught on yellow traps	160
	3.4.6 PROGRESS REPORT: Chemical control of mealybug on citrus	161
	3.4.7 PROGRESS REPORT: Augmentation of <i>Aphytis melinus</i> DeBach (Hymenoptera: Aphelinidae) for the control of California red scale (Hemiptera: Diaspididae) in citrus	162
	3.4.8 PROGRESS REPORT: Investigating delivery systems for formulation and application of microbial control agents	163
	3.4.9 PROGRESS REPORT: Identification and management of new lepidopteran pests on citrus	164
	3.4.10 PROGRESS REPORT: Development of molecular detection tools for the identification of citrus pests and natural enemies.	166
	3.4.11 PROGRESS REPORT: Monitoring and control techniques for Australian bug	167
	3.4.12 PROGRESS REPORT: Determination of citrus feeding by indigenous psylloid species colonising commercial citrus environments	168

**CRI GROUP ANNUAL RESEARCH REPORT 2022/23
TABLE OF CONTENTS**

		Page
3.4.13	PROGRESS REPORT: The role of hyperparasitism in the biological control of citrus mealybugs	169
3.4.14	PROGRESS REPORT: Biology and management of the fruit piercing moth, <i>Serrodus partita</i> , in citrus orchards	170
3.4.15	PROGRESS REPORT: Bioprospecting for entomopathogenic fungi against foliar citrus pests	171
3.4.16	PROGRESS REPORT: Post-harvest treatments for mealybugs on citrus	172
3.4.17	PROGRESS REPORT: The isolation, identification, and characterisation of novel baculoviruses for the control of emerging agricultural pests of potential concern for the SA citrus industry	172
3.4.18	PROGRESS REPORT: <i>Brevipalpus</i> diversity and distribution in South Africa	173
3.4.19	PROGRESS REPORT: Predicting the pathways and entry points to the southern African citrus production areas, for the Asian Citrus Psyllid, <i>Diaphorina citri</i>	174
3.4.20	PROGRESS REPORT: Development of novel monitoring and control tools for citrus psyllids	175
3.4.21	PROGRESS REPORT: An assessment of citrus psyllid passage risk through Damaged insect secure structure	176
4	PORTFOLIO: DISEASE MANAGEMENT	177
4.1	Portfolio summary	177
4.2	Programme: Graft Transmissible Diseases	183
4.2.1	Programme summary	183
4.2.2	FINAL REPORT: Field evaluation of three single-strain CTV isolates on navel and soft citrus cultivars	184
4.2.3	PROGRESS REPORT: Comparison of shoot tip grafted citrus with field-cut (old clone) material	189
4.2.4	PROGRESS REPORT: Field testing of commercial or potentially important rootstock selections for viroid sensitivity	190
4.2.5	PROGRESS REPORT: Field evaluation of two approved cross-protection sources for grapefruit	191
4.2.6	PROGRESS REPORT: Identification of early indicators of CTV induced stem pitting to aid the selection of CTV cross protection sources	192
4.2.7	PROGRESS REPORT: Effect of CTV strains on priming plant immunity and disease modulation	193
4.2.8	PROGRESS REPORT: Investigating disease agents of concentric ring blotch of citrus	193
4.3	Programme: Preharvest Diseases	194
4.3.1	Programme summary	194
4.3.2	FINAL REPORT: Sources of <i>Phytophthora</i> spp. infestation in citrus nurseries	202
4.3.3	PROGRESS REPORT: Evaluation of new spray programmes for the control of Alternaria brown spot in the summer rainfall regions of South Africa	207
4.3.4	PROGRESS REPORT: The evaluation of different pre-plant products for the control of the citrus nematode, as part of an integrated nematode control approach in citrus replant situations	214
4.3.5	PROGRESS REPORT: Development of new spray programmes for the control of citrus black spot	214
4.3.6	PROGRESS REPORT: Evaluation of alternative products for control of citrus nematode and <i>Phytophthora</i> spp. in citrus	224

CRI GROUP ANNUAL RESEARCH REPORT 2022/23
TABLE OF CONTENTS

		Page
4.3.7	PROGRESS REPORT: Further validation and improvements of CRI-Phytrisk	240
4.3.8	PROGRESS REPORT: New oomycete fungicide-based approaches for managing <i>Phytophthora nicotianae</i> in citrus orchards	241
4.3.9	PROGRESS REPORT: Effect of citrus rootstocks on phosphonate applications for Phytophthora disease management in citrus	242
4.3.10	PROGRESS REPORT: Phosphonate sensitivity of <i>Phytophthora nicotianae</i> in South African citrus orchards and nurseries	243
4.3.11	PROGRESS REPORT: Epidemiology and control of <i>Colletotrichum</i> species associated with anthracnose on citrus in South Africa	244
4.3.12	PROGRESS REPORT: Further validation of the current CBS diagnostic protocols	245
4.3.13	PROGRESS REPORT: Optimisation of biocontrol agent applications for the management of citrus soilborne pathogens	245
4.3.14	PROGRESS REPORT: Characterisation and detection of mefenoxam sensitivity in South African <i>Phytophthora nicotianae</i> and <i>Phytophthora citrophthora</i> isolates from citrus nurseries	246
4.3.15	PROGRESS REPORT: Potential inoculum sources for the establishment of Citrus Black Spot in new citrus orchards	247
4.3.16	PROGRESS REPORT: Evaluation of tree row volume (TRV)-based spray volumes for pest and disease management in South African citrus	248
4.3.17	PROGRESS REPORT: Etiology and control of Alternaria brown spot and core rot of citrus in South Africa	248
4.3.18	PROGRESS REPORT: Towards the development of a risk-based system for management of CBS: Part 1	249
4.3.19	PROGRESS REPORT: Sensitivity profiles of <i>Phyllosticta citricarpa</i> to quinone outside inhibitors and methyl benzimidazole carbamates	250
4.4	Programme: Postharvest Diseases	250
4.4.1	Programme summary	250
4.4.2	FINAL REPORT: Evaluation of biocontrol agents for pre-packhouse and packhouse drenches to control postharvest <i>Penicillium</i> decay and sour rot of citrus	253
4.4.3	PROGRESS REPORT: Provision of an industry service whereby new packhouse treatments are comparatively evaluated, fungicide resistance is monitored and standardised recommendations are provided	276
4.4.4	PROGRESS REPORT: Investigating rind aspects of mandarins that affects efficacy of postharvest treatments	294
4.4.5	PROGRESS REPORT: Increasing occurrence of saprophytic stem end growth - investigating the causes and species involved	294
4.4.6	PROGRESS REPORT: Management of postharvest diseases in the near-harvest period	295
4.4.7	PROGRESS REPORT: Effect of postharvest sanitisers and fungicide mixtures on citrus <i>Phytophthora</i> brown rot	295
4.4.8	PROGRESS REPORT: Evaluation of essential oil volatiles in degreening chambers for the management of <i>Penicillium</i> decay and sour rot	296
4.4.9	PROGRESS REPORT: Optimising available alternative postharvest remedies as replacement for imazalil use on citrus exported to Europe	297
4.4.10	PROGRESS REPORT: Effect of post-harvest UV light irradiation on the accumulation of secondary metabolites prior to degreening and their ability to control sour rot	298
4.5	Programme: Huanglongbing	298
4.5.1	Programme summary	298
4.5.2	PROGRESS REPORT: New systemic insecticides for citrus	303
4.5.3	PROGRESS REPORT: Techniques to distinguish <i>Diaphorina citri</i> and <i>Trioza erytreae</i> from other psyllids likely to be caught on yellow traps	304

**CRI GROUP ANNUAL RESEARCH REPORT 2022/23
TABLE OF CONTENTS**

		Page
4.5.4	PROGRESS REPORT: Determination of genome diversity of citrus infecting ' <i>Candidatus Liberibacter africanus</i> ' species and subspecies	305
4.5.5	PROGRESS REPORT: Evaluation of the influence of CTV infection on ' <i>Candidatus Liberibacter africanus</i> ' titre	306
4.5.6	PROGRESS REPORT: Determination of citrus feeding by indigenous psyllids species colonising commercial citrus environments	307
4.5.7	PROGRESS REPORT: Development of HLB detection assays	308
4.5.8	PROGRESS REPORT: Greening disease characterisation and mitigation strategies	309
4.5.9	PROGRESS REPORT: Predicting the pathways and entry points to the southern African citrus production areas, for the Asian Citrus Psyllid, <i>Diaphorina citri</i>	310
4.5.10	PROGRESS REPORT: Evaluation of the efficacy of an area wide management strategy for the combined control of a vector and disease, using <i>Trioza erytreae</i> and ' <i>Candidatus Liberibacter africanus</i> ' (CLaf) as an example	311
4.5.11	PROGRESS REPORT: Development of novel monitoring and control tools for citrus psyllids	311
4.5.12	PROGRESS REPORT: An assessment of Citrus psyllid passage risk through damaged insect secure structure	312
4.6	CRI Diagnostic Centre	313
5	PORTFOLIO: CITRICULTURE	315
5.1	Portfolio summary	315
5.2	Programme: Rind condition and cold chain	316
5.2.1	Programme summary	316
5.2.2	FINAL REPORT: The influence of shade netting and rootstock choice on the oleocellosis incidence of citrus varieties, Navel oranges, and Eureka lemons	317
5.2.3	PROGRESS REPORT: Optimise 2,4-D applications and investigate alternatives for calyx retention	341
5.2.4	PROGRESS REPORT: Colour development of citrus: effective degreening	342
5.2.5	PROGRESS REPORT: Fundamental cellular aspects involved in chilling injury	343
5.2.6	PROGRESS REPORT: Modelling citrus inland supply chains for improved handling practices	344
5.2.7	PROGRESS REPORT: Mechanical creep testing: an improved approach to developing stronger low-cost cartons	345
5.2.8	PROGRESS REPORT: Designing integrated packaging systems for enhanced cold treatments	346
5.2.9	PROGRESS REPORT: Optimisation of pallet base designs for the citrus industry	347
5.2.10	PROGRESS REPORT: Container optimisation and characterisation for improved cold sterilisation treatments	347
5.2.11	PROGRESS REPORT: Defining citrus pallet stability and modes of failure: developing tools to make stronger and cheaper cartons	348
5.3	Programme: Preharvest Production and quality	350
5.3.1	Programme summary	350
5.3.2	PROGRESS REPORT: The use of root growth restricting soil management practices to improve Valencia tree vigour, yield and fruit quality	351
5.3.3	PROGRESS REPORT: Evaluation of strategies to improve water use efficiencies in citrus production	352
5.3.4	PROGRESS REPORT: Water stress at different phenological stages of Nadorcott Mandarin trees in combination with two irrigation systems to mitigate water shortages in citrus growing areas	353

**CRI GROUP ANNUAL RESEARCH REPORT 2022/23
TABLE OF CONTENTS**

	Page
5.3.5 PROGRESS REPORT: Digital fruit sizing and yield estimation application development	353
5.3.6 PROGRESS REPORT: Promotion of young tree performance to advance the Period to full production, and enhancing the tree's healthy life span	354
5.3.7 PROGRESS REPORT: Comparison of nutrient use efficiencies between different fertilisation and irrigation management approaches	355
5.3.8 PROGRESS REPORT: The use of cover crops to ensure sustainable citrus orchard performance	355
5.4 Programme: Cultivar evaluation	356
5.4.1 Programme summary	356
5.4.2 PROGRESS REPORT: Studies into the high incidence of chimeras of Valencia orange cultivars, specifically Valencia Late	359
5.4.3 PROGRESS REPORT: Evaluation of new University of Florida (UF) rootstocks	360
5.4.4 PROGRESS REPORT: Valencia Selections for the Letsitele Citrus Production Region	361
5.4.5 PROGRESS REPORT: Satsuma selections for Citrusdal	369
6 CITRUS IMPROVEMENT SCHEME (CIS)	375
6.1 Introduction	376
6.2 Budwood	376
6.3 Seed	386
6.4 Production	387
6.5 Tree Certification	390
6.6 Nursery Certification	391
6.7 Statutory Improvement Scheme	392
6.8 Protective zone surrounding the Citrus Foundation Block	393
6.9 FINAL REPORT: Shoot tip grafting and CIS diagnostic services at CRI-Nelspruit	393
6.10 FINAL REPORT: Diagnostic and technical services for the Citrus Improvement Scheme by the ARC-TSC	403
7 VOORLIGTING / EXTENSION	410
7.1 Oorsig oor die 2022-seisoen	410
7.2 Vooruitskouing op die 2023-seisoen	411
7.3 11de Sitrusnavorsingsimposium	412
7.4 Exporters Technical Panel	412
7.5 Karton-akkrediasiestelsel	412
7.6 CRI Postharvest Technical Forum (CRI-PTF)	413
7.7 Postharvest Extension	416
7.7.1 CRI Na-oes werksinkels	416
7.7.2 Northern region (Catherine Savage)	416
7.7.3 Southern Region (Natasha Bronkhorst)	417
7.7.4 Tegnies (Jan Landman)	417
7.8 Produksiestreke	418
7.8.1 CRI IPM & Disease Management werksinkels	418
7.8.2 Wes- en Noord-Kaap produksiestreke (Coenraad Fraenkel)	418
7.8.3 Eastern Cape production region (André Combrink)	420
7.8.4 Sentrale produksiestreek (MC Pretorius)	422
7.8.5 Northern production region (Wayne Mommsen)	423

CRI GROUP ANNUAL RESEARCH REPORT 2022/23
TABLE OF CONTENTS

	Page
7.9 Other means of technology transfer	456
7.9.1 SA Fruit Journal	456
7.9.2 CRI website	457
7.9.3 CRI Cutting Edge	457
8 INTERNATIONAL VISITS	459
8.1 Report on the 12th Congress on Citrus Nurseries hosted by the International Society of Citrus Nurserymen (ISCN) and the California Citrus Nursery Society during October 2022	459
8.2 The XIV International Citrus Congress in Mersin, Türkiye (6-11 November 2022)	498
8.3 XVI International Congress of Acarology, 1 – 5 December 2022, Auckland, New Zealand	517
8.4 Report on technical visits and meetings: University of Florida, and Wonderful citrus (McAllen) and Texas A&M University, January 2023	519
8.5 Travel report: Australia 2023, by Paul Fourie (CIS-Manager)	527
8.6 Report on the 11 th International Symposium on Fruit Flies of Economic Importance	546
9 PUBLICATIONS IN 2022-23	556
9.1 Refereed Publications (or ISI ranked journals)	556

**CRI GROUP ANNUAL RESEARCH REPORT 2023/24
TABLE OF CONTENTS**

	Page
1 MARKET ACCESS TECHNICAL COORDINATION	1
1.1 Summary	1
1.2 European Union (EU)	2
1.3 Japan	3
1.4 USA	3
1.5 China	3
1.6 South Korea	4
1.7 India	4
1.8 Thailand	4
1.9 Vietnam	5
1.10 Botswana	5
1.11 Zimbabwe	5
1.12 Citrus one-pagers	5
2 BIOSECURITY	6
2.1 Summary	6
2.2 Develop and maintain a comprehensive Citrus industry biosecurity plan - to ensure overall mitigation of the Southern African Citrus industry's biosecurity risks	7
2.2.1 Project 1: Develop a Southern Africa Citrus industry biosecurity master plan	7
2.3 Biosecurity portfolio: Design, develop and oversee the implementation and operation of appropriate biosecurity structures, engagements, procedures, co-operations, resources, projects and other appropriate actions	7
2.3.1 Project 2: Identify, assess and initiate engagement with international funding providers, for future support of Southern African biosecurity projects	7
2.4 Networking and awareness: Obtain supportive participation of relevant stakeholders and interested parties	8
2.5 Ensure successful implementation of processes, procedures and interactions to ensure the timely identification and assessment of biosecurity threats facing the Southern African Citrus industry	8
2.5.1 Project 3: Develop and oversee implementation of Southern African Citrus industry pest-specific action plans for priority biosecurity pests	8
2.6 Ensure effective implementation of processes, procedures, interactions to advance actions required to successfully mitigate the risks and consequences of biosecurity incursions	9
2.6.1 Project 4: Develop and oversee implementation of a Southern African Citrus industry HLB action plan and safe tree production system	9
2.6.2 Project 5: Ensure that HLB and ACP surveillance is undertaken in Eastern Africa	9
2.6.3 Project 6: Facilitate initiation of an HLB eradication plan in Ethiopia	10
2.6.4 Project 7: Ensure, in close collaboration with relevant government officials, that regulations of relevance to biosecurity risk mitigation are appropriately updated and compliance effectively implemented	10
2.6.5 Project 8: Monitoring and control of Leprosis	11
2.6.6 Greening surveys (African greening - <i>Candidatus Liberibacter africanus</i> & Asiatic greening - <i>Candidatus Liberibacter asiaticus</i>)	11

**CRI GROUP ANNUAL RESEARCH REPORT 2023/24
TABLE OF CONTENTS**

		Page
3	PORTFOLIO: INTEGRATED PEST MANAGEMENT	12
3.1	Portfolio summary	12
3.2	Programme: False Codling Moth	14
3.2.1	Programme summary	14
3.2.2	FINAL REPORT: Investigating the appropriate timing for initiation of mating disruption against FCM in Limpopo Province	19
3.2.3	FINAL REPORT: Selection for a UV-resistant isolate of a nucleopolyhedro-virus for improved field persistence and efficacy against FCM	27
3.2.4	FINAL REPORT: Regional differences in sex pheromones and sexual attractiveness in FCM	34
3.2.5	FINAL REPORT: An investigation into the biological and genetic stability of UV-tolerant baculoviruses for improved control of <i>Thaumatotibia leucotreta</i>	41
3.2.6	FINAL REPORT: Accurate monitoring of FCM fruit infestation	51
3.2.7	FINAL REPORT: Encapsulation of CrleGV in calcium alginate using a microfluidic device for improved UV resistance	62
3.2.8	FINAL REPORT: Characterisation of the False Codling Moth (<i>Thaumatotibia leucotreta</i>) gut microbiome and its host-microbe physiological interactions	67
3.2.9	PROGRESS REPORT: Impact of abbreviated and complete cold-treatment on survival and fitness of FCM larvae	81
3.2.10	PROGRESS REPORT: Evaluating hot air treatments for postharvest FCM control	83
3.2.11	PROGRESS REPORT: Identification and development of an attractant for monitoring FCM adult females	84
3.2.12	PROGRESS REPORT: Field trials for the control of FCM	85
3.2.13	PROGRESS REPORT: Synergism between insecticides for improved control of FCM	86
3.2.14	PROGRESS REPORT: Identification and evaluation of male false codling moth pheromones and an investigation of their usefulness for monitoring of female moths	87
3.2.15	PROGRESS REPORT: Using the antennal response of the FCM larval parasitoid, <i>Agathis bishopi</i> , for identifying key volatiles indicative of FCM fruit infestation	88
3.2.16	PROGRESS REPORT: Improving understanding of mating disruption	89
3.2.17	PROGRESS REPORT: Comparing the performance of sterile insect technique (SIT) and mating disruption (MD) for FCM control in netted and open orchards	90
3.2.18	PROGRESS REPORT: Evaluation of potential oviposition deterrents for false codling moth, <i>Thaumatotibia leucotreta</i> (Meyrick) (Lepidoptera: Tortricidae)	91
3.2.19	PROGRESS REPORT: Selected Ion Flow Tube Mass Spectrometry for postharvest detection of FCM infested fruit	92
3.2.20	PROGRESS REPORT: Mass culture of <i>Heterorhabditis bacteriophora</i> using <i>in vitro</i> liquid culture techniques	93
3.2.21	PROGRESS REPORT: High concentration formulation of entomopathogenic Nematodes	94
3.2.22	PROGRESS REPORT: Understanding FCM oviposition on citrus: analysis of chemical cues used to locate oranges and nutritional composition of preferred fruits	95
3.2.23	PROGRESS REPORT: Investigating release ratios in an FCM SIT programme	96
3.2.24	PROGRESS REPORT: Evaluating baculovirus mixtures against false codling moth, <i>Thaumatotibia leucotreta</i> Meyrick. (Lepidoptera: Tortricidae)	97
3.2.25	PROGRESS REPORT: The expression and evaluation of CrpeNPV GP37 as a formulation additive for enhanced infectivity with CrleGV and improved <i>Thaumatotibia leucotreta</i> control	98
3.2.26	PROGRESS REPORT: Investigating bats for the biological control of FCM	99

**CRI GROUP ANNUAL RESEARCH REPORT 2023/24
TABLE OF CONTENTS**

		Page
	3.2.24 PROGRESS REPORT: Research and demonstration trials to reposition the false codling moth (FCM) SIT programme as a base of the pyramid approach to FCM integrated pest management in citrus	100
3.3	Programme: Fruit Fly	101
	3.3.1 Programme summary	101
	3.3.2 FINAL REPORT: Rearing technology and taxonomy of the Cape fly <i>Ceratitis quilicii</i>	102
	3.3.3 FINAL REPORT: Alternate hosts of the Oriental Fruit Fly, <i>Bactrocera dorsalis</i> , in the Sundays River Valley	119
	3.3.4 FINAL REPORT: Efficacy of fruit fly systems approach for export of citrus to EU	124
	3.3.5 PROGRESS REPORT: Fruit fly rearing	141
	3.3.6 PROGRESS REPORT: Redefining dispersal potential for adequate fruit fly pest management (Diptera, Tephritidae)	142
	3.3.7 PROGRESS REPORT: In-silico boosted, pest prevention and off-season focussed IPM against new and emerging fruit flies	142
	3.3.8 PROGRESS REPORT: Host status of citrus for <i>C. cosyra</i>	143
	3.3.9 PROGRESS REPORT: F ³ (Fruit fly free)	144
	3.3.10 PROGRESS REPORT: Investigating X-ray technologies for the post-harvest detection of fruit flies in citrus	145
	3.3.11 PROGRESS REPORT: Identification and characterisation of a virus specific to fruit flies affecting citrus	146
	3.3.12 PROGRESS REPORT: Post-harvest cold treatments for fruit flies	146
	3.3.13 PROGRESS REPORT: Patterns of foraging for protein by fruit fly pests in citrus in South Africa	147
	3.3.14 PROGRESS REPORT: Spatio-temporal analysis of fruit fly trap captures and citrus fruit infestation	148
	3.3.15 PROGRESS REPORT: Contribution of the gut microbiome to thermal tolerance of fruit fly larvae	149
	3.3.16 PROGRESS REPORT: Utilization of <i>Fopius arisanus</i> for control of Oriental fruit fly	150
	3.3.17 PROGRESS REPORT: The impact of interruptions on Medfly cold treatment efficacy	151
3.4	Programme: Other Pests	152
	3.4.1 Programme summary	152
	3.4.2 FINAL REPORT: Integrated pest management under nets in the Western Cape	154
	3.4.3 PROGRESS REPORT: New systemic insecticides for citrus	158
	3.4.4 PROGRESS REPORT: Controlling mites on budwood	159
	3.4.5 PROGRESS REPORT: Techniques to distinguish <i>Diaphorina citri</i> and <i>Trioza erytrae</i> from other psylloids likely to be caught on yellow traps	160
	3.4.6 PROGRESS REPORT: Chemical control of mealybug on citrus	161
	3.4.7 PROGRESS REPORT: Augmentation of <i>Aphytis melinus</i> DeBach (Hymenoptera: Aphelinidae) for the control of California red scale (Hemiptera: Diaspididae) in citrus	162
	3.4.8 PROGRESS REPORT: Investigating delivery systems for formulation and application of microbial control agents	163
	3.4.9 PROGRESS REPORT: Identification and management of new lepidopteran pests on citrus	164
	3.4.10 PROGRESS REPORT: Development of molecular detection tools for the identification of citrus pests and natural enemies.	166
	3.4.11 PROGRESS REPORT: Monitoring and control techniques for Australian bug	167
	3.4.12 PROGRESS REPORT: Determination of citrus feeding by indigenous psylloid species colonising commercial citrus environments	168

**CRI GROUP ANNUAL RESEARCH REPORT 2023/24
TABLE OF CONTENTS**

	Page
3.4.13 PROGRESS REPORT: The role of hyperparasitism in the biological control of citrus mealybugs	169
3.4.14 PROGRESS REPORT: Biology and management of the fruit piercing moth, <i>Serrodus partita</i> , in citrus orchards	170
3.4.15 PROGRESS REPORT: Bioprospecting for entomopathogenic fungi against foliar citrus pests	171
3.4.16 PROGRESS REPORT: Post-harvest treatments for mealybugs on citrus	172
3.4.17 PROGRESS REPORT: The isolation, identification, and characterisation of novel baculoviruses for the control of emerging agricultural pests of potential concern for the SA citrus industry	172
3.4.18 PROGRESS REPORT: <i>Brevipalpus</i> diversity and distribution in South Africa	173
3.4.19 PROGRESS REPORT: Predicting the pathways and entry points to the southern African citrus production areas, for the Asian Citrus Psyllid, <i>Diaphorina citri</i>	174
3.4.20 PROGRESS REPORT: Development of novel monitoring and control tools for citrus psyllids	175
3.4.21 PROGRESS REPORT: An assessment of citrus psyllid passage risk through Damaged insect secure structure	176
4 PORTFOLIO: DISEASE MANAGEMENT	177
4.1 Portfolio summary	177
4.2 Programme: Graft Transmissible Diseases	183
4.2.1 Programme summary	183
4.2.2 FINAL REPORT: Field evaluation of three single-strain CTV isolates on navel and soft citrus cultivars	184
4.2.3 PROGRESS REPORT: Comparison of shoot tip grafted citrus with field-cut (old clone) material	189
4.2.4 PROGRESS REPORT: Field testing of commercial or potentially important rootstock selections for viroid sensitivity	190
4.2.5 PROGRESS REPORT: Field evaluation of two approved cross-protection sources for grapefruit	191
4.2.6 PROGRESS REPORT: Identification of early indicators of CTV induced stem pitting to aid the selection of CTV cross protection sources	192
4.2.7 PROGRESS REPORT: Effect of CTV strains on priming plant immunity and disease modulation	193
4.2.8 PROGRESS REPORT: Investigating disease agents of concentric ring blotch of citrus	193
4.3 Programme: Preharvest Diseases	194
4.3.1 Programme summary	194
4.3.2 FINAL REPORT: Sources of <i>Phytophthora</i> spp. infestation in citrus nurseries	202
4.3.3 PROGRESS REPORT: Evaluation of new spray programmes for the control of Alternaria brown spot in the summer rainfall regions of South Africa	207
4.3.4 PROGRESS REPORT: The evaluation of different pre-plant products for the control of the citrus nematode, as part of an integrated nematode control approach in citrus replant situations	214
4.3.5 PROGRESS REPORT: Development of new spray programmes for the control of citrus black spot	214
4.3.6 PROGRESS REPORT: Evaluation of alternative products for control of citrus nematode and <i>Phytophthora</i> spp. in citrus	224

CRI GROUP ANNUAL RESEARCH REPORT 2023/24
TABLE OF CONTENTS

		Page
4.3.7	PROGRESS REPORT: Further validation and improvements of CRI-Phytrisk	240
4.3.8	PROGRESS REPORT: New oomycete fungicide-based approaches for managing <i>Phytophthora nicotianae</i> in citrus orchards	241
4.3.9	PROGRESS REPORT: Effect of citrus rootstocks on phosphonate applications for Phytophthora disease management in citrus	242
4.3.10	PROGRESS REPORT: Phosphonate sensitivity of <i>Phytophthora nicotianae</i> in South African citrus orchards and nurseries	243
4.3.11	PROGRESS REPORT: Epidemiology and control of <i>Colletotrichum</i> species associated with anthracnose on citrus in South Africa	244
4.3.12	PROGRESS REPORT: Further validation of the current CBS diagnostic protocols	245
4.3.13	PROGRESS REPORT: Optimisation of biocontrol agent applications for the management of citrus soilborne pathogens	245
4.3.14	PROGRESS REPORT: Characterisation and detection of mefenoxam sensitivity in South African <i>Phytophthora nicotianae</i> and <i>Phytophthora citrophthora</i> isolates from citrus nurseries	246
4.3.15	PROGRESS REPORT: Potential inoculum sources for the establishment of Citrus Black Spot in new citrus orchards	247
4.3.16	PROGRESS REPORT: Evaluation of tree row volume (TRV)-based spray volumes for pest and disease management in South African citrus	248
4.3.17	PROGRESS REPORT: Etiology and control of Alternaria brown spot and core rot of citrus in South Africa	248
4.3.18	PROGRESS REPORT: Towards the development of a risk-based system for management of CBS: Part 1	249
4.3.19	PROGRESS REPORT: Sensitivity profiles of <i>Phyllosticta citricarpa</i> to quinone outside inhibitors and methyl benzimidazole carbamates	250
4.4	Programme: Postharvest Diseases	250
4.4.1	Programme summary	250
4.4.2	FINAL REPORT: Evaluation of biocontrol agents for pre-packhouse and packhouse drenches to control postharvest <i>Penicillium</i> decay and sour rot of citrus	253
4.4.3	PROGRESS REPORT: Provision of an industry service whereby new packhouse treatments are comparatively evaluated, fungicide resistance is monitored and standardised recommendations are provided	276
4.4.4	PROGRESS REPORT: Investigating rind aspects of mandarins that affects efficacy of postharvest treatments	294
4.4.5	PROGRESS REPORT: Increasing occurrence of saprophytic stem end growth - investigating the causes and species involved	294
4.4.6	PROGRESS REPORT: Management of postharvest diseases in the near-harvest period	295
4.4.7	PROGRESS REPORT: Effect of postharvest sanitisers and fungicide mixtures on citrus <i>Phytophthora</i> brown rot	295
4.4.8	PROGRESS REPORT: Evaluation of essential oil volatiles in degreening chambers for the management of <i>Penicillium</i> decay and sour rot	296
4.4.9	PROGRESS REPORT: Optimising available alternative postharvest remedies as replacement for imazalil use on citrus exported to Europe	297
4.4.10	PROGRESS REPORT: Effect of post-harvest UV light irradiation on the accumulation of secondary metabolites prior to degreening and their ability to control sour rot	298
4.5	Programme: Huanglongbing	298
4.5.1	Programme summary	298
4.5.2	PROGRESS REPORT: New systemic insecticides for citrus	303

**CRI GROUP ANNUAL RESEARCH REPORT 2023/24
TABLE OF CONTENTS**

		Page
4.5.3	PROGRESS REPORT: Techniques to distinguish <i>Diaphorina citri</i> and <i>Trioza erytreae</i> from other psylloids likely to be caught on yellow traps	304
4.5.4	PROGRESS REPORT: Determination of genome diversity of citrus infecting ' <i>Candidatus Liberibacter africanus</i> ' species and subspecies	305
4.5.5	PROGRESS REPORT: Evaluation of the influence of CTV infection on ' <i>Candidatus Liberibacter africanus</i> ' titre	306
4.5.6	PROGRESS REPORT: Determination of citrus feeding by indigenous psylloids species colonising commercial citrus environments	307
4.5.7	PROGRESS REPORT: Development of HLB detection assays	308
4.5.8	PROGRESS REPORT: Greening disease characterisation and mitigation strategies	309
4.5.9	PROGRESS REPORT: Predicting the pathways and entry points to the southern African citrus production areas, for the Asian Citrus Psyllid, <i>Diaphorina citri</i>	310
4.5.10	PROGRESS REPORT: Evaluation of the efficacy of an area wide management strategy for the combined control of a vector and disease, using <i>Trioza erytreae</i> and ' <i>Candidatus Liberibacter africanus</i> ' (CLaf) as an example	311
4.5.11	PROGRESS REPORT: Development of novel monitoring and control tools for citrus psyllids	311
4.5.12	PROGRESS REPORT: An assessment of Citrus psyllid passage risk through damaged insect secure structure	312
4.6	CRI Diagnostic Centre	313
5	PORTFOLIO: CITRICULTURE	315
5.1	Portfolio summary	315
5.2	Programme: Rind condition and cold chain	316
5.2.1	Programme summary	316
5.2.2	FINAL REPORT: The influence of shade netting and rootstock choice on the oleocellosis incidence of citrus varieties, Navel oranges, and Eureka lemons	317
5.2.3	PROGRESS REPORT: Optimise 2,4-D applications and investigate alternatives for calyx retention	341
5.2.4	PROGRESS REPORT: Colour development of citrus: effective degreening	342
5.2.5	PROGRESS REPORT: Fundamental cellular aspects involved in chilling injury	343
5.2.6	PROGRESS REPORT: Modelling citrus inland supply chains for improved handling practices	344
5.2.7	PROGRESS REPORT: Mechanical creep testing: an improved approach to developing stronger low-cost cartons	345
5.2.8	PROGRESS REPORT: Designing integrated packaging systems for enhanced cold treatments	346
5.2.9	PROGRESS REPORT: Optimisation of pallet base designs for the citrus industry	347
5.2.10	PROGRESS REPORT: Container optimisation and characterisation for improved cold sterilisation treatments	347
5.2.11	PROGRESS REPORT: Defining citrus pallet stability and modes of failure: developing tools to make stronger and cheaper cartons	348
5.3	Programme: Preharvest Production and quality	350
5.3.1	Programme summary	350
5.3.2	PROGRESS REPORT: The use of root growth restricting soil management practices to improve Valencia tree vigour, yield and fruit quality	351
5.3.3	PROGRESS REPORT: Evaluation of strategies to improve water use efficiencies in citrus production	352

**CRI GROUP ANNUAL RESEARCH REPORT 2023/24
TABLE OF CONTENTS**

		Page
5.3.4	PROGRESS REPORT: Water stress at different phenological stages of Nadorcott Mandarin trees in combination with two irrigation systems to mitigate water shortages in citrus growing areas	353
5.3.5	PROGRESS REPORT: Digital fruit sizing and yield estimation application development	353
5.3.6	PROGRESS REPORT: Promotion of young tree performance to advance the Period to full production, and enhancing the tree's healthy life span	354
5.3.7	PROGRESS REPORT: Comparison of nutrient use efficiencies between different fertilisation and irrigation management approaches	355
5.3.8	PROGRESS REPORT: The use of cover crops to ensure sustainable citrus orchard performance	355
5.4	Programme: Cultivar evaluation	356
5.4.1	Programme summary	356
5.4.2	PROGRESS REPORT: Studies into the high incidence of chimeras of Valencia orange cultivars, specifically Valencia Late	359
5.4.3	PROGRESS REPORT: Evaluation of new University of Florida (UF) rootstocks	360
5.4.4	PROGRESS REPORT: Valencia Selections for the Letsitele Citrus Production Region	361
5.4.5	PROGRESS REPORT: Satsuma selections for Citrusdal	369
6	CITRUS IMPROVEMENT SCHEME (CIS)	375
6.1	Introduction	376
6.2	Budwood	376
6.3	Seed	386
6.4	Production	387
6.5	Tree Certification	390
6.6	Nursery Certification	391
6.7	Statutory Improvement Scheme	392
6.8	Protective zone surrounding the Citrus Foundation Block	393
6.9	FINAL REPORT: Shoot tip grafting and CIS diagnostic services at CRI-Nelspruit	393
6.10	FINAL REPORT: Diagnostic and technical services for the Citrus Improvement Scheme by the ARC-TSC	403
7	VOORLIGTING / EXTENSION	410
7.1	Oorsig oor die 2022-seisoen	410
7.2	Vooruitskouing op die 2023-seisoen	411
7.3	11de Sitrusnavorsingsimposium	412
7.4	Exporters Technical Panel	412
7.5	Karton-akkreditasiestelsel	412
7.6	CRI Postharvest Technical Forum (CRI-PTF)	413
7.7	Postharvest Extension	416
7.7.1	CRI Na-oes werksinkels	416
7.7.2	Northern region (Catherine Savage)	416
7.7.3	Southern Region (Natasha Bronkhorst)	417
7.7.4	Tegnies (Jan Landman)	417
7.8	Produksiestreke	418
7.8.1	CRI IPM & Disease Management werksinkels	418
7.8.2	Wes- en Noord-Kaap produksiestreke (Coenraad Fraenkel)	418

CRI GROUP ANNUAL RESEARCH REPORT 2023/24
TABLE OF CONTENTS

	Page
7.8.3 Eastern Cape production region (André Combrink)	420
7.8.4 Sentrale produksiestreek (MC Pretorius)	422
7.8.5 Northern production region (Wayne Mommsen)	423
7.9 Other means of technology transfer	456
7.9.1 SA Fruit Journal	456
7.9.2 CRI website	457
7.9.3 CRI Cutting Edge	457
8 INTERNATIONAL VISITS	459
8.1 Report on the 12th Congress on Citrus Nurseries hosted by the International Society of Citrus Nurserymen (ISCN) and the California Citrus Nursery Society during October 2022	459
8.2 The XIV International Citrus Congress in Mersin, Türkiye (6-11 November 2022)	498
8.3 XVI International Congress of Acarology, 1 – 5 December 2022, Auckland, New Zealand	517
8.4 Report on technical visits and meetings: University of Florida, and Wonderful citrus (McAllen) and Texas A&M University, January 2023	519
8.5 Travel report: Australia 2023, by Paul Fourie (CIS-Manager)	527
8.6 Report on the 11 th International Symposium on Fruit Flies of Economic Importance	546
9 PUBLICATIONS IN 2022-23	556
9.1 Refereed Publications (or ISI ranked journals)	556