South Africa's Citrus Improvement Programme

L. von Broembsen and A. T. C. Lee

ABSTRACT. South Africa's Citrus Improvement Programme (SACIP) was initiated in 1973. Since then more than 3 million certified nursery trees have been produced from SACIP-approved budwood sources. The first phase of the Programme involved the selection of horticulturally superior field trees which were indexed for exocortis, psorosis and other viruses. Depending on the virus status of these selected trees they were entered into the Programme as approved budwood sources or discarded. For several consecutive years these approved budwood source trees were subjected to further horticultural evaluation. Then for each approved cultivar selection, material from the most superior individual tree under went shoot-tip grafting and preinoculation with a mild strain of citrus tristeza virus (CTV). A Foundation Block to house and multiply this preinoculated material and produce seed sources for rootstocks was established in 1980. Today this block constitutes the primary source of budwood for certified trees produced by South African nurseries under the second phase of the Programme called the Superplant Scheme. This is a formal programme falling under the regulatory authority of the Directorate of Plant and Seed Control. By means of a computerized record-keeping system, all certified trees entering the industry can have their budwood origins traced to the specific foundation block mother tree and ultimately to the original field-grown parent tree from which they arose.

HISTORICAL PERSPECTIVE

As with other similar programmes around the world, the purpose of South Africa's Citrus Improvement Programme (SACIP) is to make available to citrus growers citrus trees of the highest possible horticultural quality and disease freedom. This involves the close cooperation of research, administrative, extension and regulatory bodies on the one hand, and citrus nurseries and commercial producers on the other.

The basic guidelines of the SACIP were drafted by Dr. E. C. Calavan of the University of California, Riverside (UCR), after a consulting visit to South Africa in 1972. The programme was to consist of various phases to provide nurserymen disease-free, horticulturally superior plant material. Significant progress during the past 10 yr in shoot-tip grafting, virus indexing and tristeza cross protection has enabled Dr. Calavan's recommendations to be fully exploited.

The implementation of these recommendations entailed an industry-led 'interim' programme followed some 10 yr later by the adaptation of this into a formal 'Superplant' programme with the active participation of the Directorate of Plant and Seed Control as the regulatory agency.

THE INTERIM PROGRAMME

A detailed account of the early stages of development of the Citrus Improvement Programme, subsequently called the Interim Programme, was given by von Broembsen, *et al.* (4). This was subsequently summarised in a paper presented at the first Conference of the International Society of Citrus Nurserymen (3). The most important stages in the early development of the Interim Programme were:

Nurserymen's participation. Application forms for participation in the programme were sent to all registered citrus nurserymen in South Africa in 1973. The first list of participants was drafted from the replies received, and these nurserymen were asked to submit details of the budwood source trees they were using. A list of prospective budwood source trees was compiled from this information.

Selection of budwood source trees. All the prospective budwood source trees mentioned above were evaluated in the field by horticultural criteria. Trees which were obviously superior were listed, marked and mapped and sampled for virus indexing. This field evaluation has been repeated each year on the trees remaining in the programme.

TABLE 1
CERTIFIED BUDS CUT PER CULTIVAR IN THE INTERIM CITRUS IMPROVEMENT PROGRAMME 1976 TO 1985

CULTIVAR	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
GRAPEFRUIT										
Marsh	57 181	37 921	63 823	33 960	55 159	20 375	6 060	10 215	10 908	18 300
Redblush	15 500	3 000	25 925	11 000	33 310	14 955	11 000	1 000	—	9 700
McClean	100	—	—	—	—	—	—	—	—	—
Nartia	182	4 400	6 453	12 674	—	—	170	902	—	—
TOTAL	72 963	45 321	96 211	57 634	88 469	35 330	17 230	12 117	10 908	28 000
VALENCIAS										
Olinda	54 580	61 148	149 883	84 895	81 317	75 560	24 430	19 600	19 400	11 100
Amanzi	27 587	40 373	36 041	30 974	45 290	33 655	24 000	30 465	39 000	23 415
Du Roi	—	—	1 000	13 180	19 703	25 755	8 180	—	6 600	19 646
McClean	7 507	15 710	11 390	26 045	31 620	24 100	10 770	21 280	6 700	13 300
Delta	4 403	22 927	29 713	37 978	105 253	71 313	55 335	25 520	21 118	58 460
Excelsior	2 000	1 840	6 200	7 600	4 060	1 780	2 200	—	—	—
Late	100	3 310	40 075	122 988	79 076	61 044	33 800	9 291	58 809	62 192
TOTAL	96 177	145 308	274 302	323 660	366 319	293 207	158 715	106 156	151 627	188 113
NAVELS										
Palmer	43 848	67 724	80 407	145 059	408 832	429 343	396 701	230 396	245 447	290 836
Bahianina	2 200	—	2 330	12 600	—	3 600	11 200	17 100	5 700	6 120
McClean	8 050	16 700	16 500	24 790	12 520	29 070	36 099	19 450	36 180	15 180
Robyn	—	—	—	—	—	—	19 605	138 924	125 203	91 799
TOTAL	54 098	84 424	99 237	182 449	421 352	462 013	463 605	405 870	412 530	403 935
MIDSEASONS										
Tomango	8 750	—	—	8 920	6 200	—	—	—	—	—
Midknight	2 525	—	—	—	—	—	—	—	130	5 000
Gem	40	—	—	—	—	—	—	—	—	3 700
Clanor	—	—	—	—	26 113	13 820	20 100	4 800	—	15 176
TOTAL	11 315	—	—	8 920	32 313	13 820	20 100	4 800	130	23 876

SOFT CITRUS										
Clementine	—	—	—	—	—	—	—	3 490	6 442	5 608
Tangerine	2 100	2 500	—	—	—	—	—	—	—	—
Satsuma	45	6 105	2 810	15 355	56 727	5 295	18 393	19 301	9 505	9 674
Minneola tang.	—	—	—	—	—	4 300	14 540	9 330	15 032	41 683
Ellendale	—	—	—	—	—	—	—	3 467	840	—
TOTAL	2 145	8 606	2 810	15 355	56 727	9 595	32 933	35 588	31 819	56 965
Eureka lemons	27 561	68 416	70 637	91 049	132 288	179 750	109 214	18 410	17 510	23 460
Lisbon lemons	—	2 800	—	—	—	—	—	310	—	—
TOTAL	27 561	71 216	70 637	91 049	132 288	179 750	109 214	18 720	17 510	23 460
TOTAL BUDS CUT	264 260	354 875	543 197	679 067	1097 468	993 715	801 797	583 251	624 524	724 349

Indexing of horticulturally superior budwood source trees. Regular indexing for exocortis, psorosis and on occasions impietratura and cachexia viruses was conducted in the glasshouses of the Citrus and Subtropical Fruit Research Institute (CSFRI) on these horticulturally selected sources. Mr. Chester Roistacher of the University of California (Riverside) visited South Africa as a guest of the Citrus Exchange in 1977, and contributed significantly to the adoption of sound indexing techniques at this facility.

Approval of budwood source trees. Those field-located, horticulturally superior and successfully (negatively) indexed budwood source trees were given approval for use as budwood parents in the programme. All nurserymen were given a list of the approved parents and these were the only sources which were subsequently recognised for the production of certified trees.

Nursery extension and publicity. An active research and extension programme was launched by the Citrus Exchange and the CSFRI to assist nurserymen to improve their production practices. Particular attention was paid to the control of *Phytophthora* and the effective use of tunnels, shadehouses and various potting mixes. This effort was given impetus by the formation of the South African Citrus Nurserymen's Association (SACNA) in 1974. An annual Conference has been held by SACNA ever since. These conferences have served the important function of providing a forum for personal contact between citrus nurserymen and the relevant research and extension workers.

A general improvement in nursery practices was almost immediately evident following SACNA's formation. This, and the availability of approved budwood sources, gave stimulus to the initiation of a publicity campaign aimed at educating citrus growers about the importance of purchasing only those nursery trees qualifying for certification under the programme.

Budwood cutting and nursery tree certification. Budwood cutting from approved field trees on a commercial scale commenced in 1975. In the following year, a total of 264,260 buds were cut under the personal supervision of authorized witnesses (table 1). This annual quantity grew steadily to 1,097,468 buds in the midst of the 1980 planting boom and has since stabilized at about 700,000 buds per annum (2).

The first trees were certified under the programme in 1976 from budwood cut in 1975 (table 2). The shift in emphasis from Valencias, grapefruit and lemons to navels and to a lesser degree the soft citrus cultivars can clearly be seen (tables 1 and 2). These figures portray trends in overseas market preferences and the response of growers towards consumer preference.

The move towards later-maturing navel selections is also apparent (table 1). The Robyn navel, which matures 3 to 5 weeks later than the Palmer, made up just over 30% of the total navel buds cut during 1984.

All nursery trees certified through the programme are required to meet certain minimum size and appearance standards in addition to having been derived from approved propagation material. A certificate is issued by the Citrus Exchange for each consignment of nursery trees delivered by a participating nursery. The budwood source tree used for the production of these trees can be traced from a reference number that appears on each certificate. This has made it possible for a record to be kept of the exact parentage of new commercial orchards. This unique system of traceable parentage is considered one of the major strengths of the programme and has on a number of occasions helped in tracing genetic and disease problems to their sources.

Shoot-tip grafting. In 1977 Dr. J.

H. de Lange of the CSFRI introduced the shoot-tip grafting of citrus to South Africa. This followed a visit to California where he learned the technique from Mr. C. Roistacher of the University of California, Riverside. This technique has been used to remove pathogens from a wide range of citrus cultivars, including individual trees which had repeatedly performed outstandingly in the annual horticultural evaluation of the interim programme's budwood source trees. In this way, selected sources which had shown their production and quality superiority under field conditions have been freed of viruses, indexed and then held under insect-free conditions in the Institute's nucleus block glasshouse in Nelspruit.

THE FORMAL CITRUS IMPROVEMENT PROGRAMME (SUPERPLANT PROGRAMME)

The interim programme was preparatory to the establishment of the formal Citrus Improvement Programme or Superplant Scheme which is based on the general principles of plant improvement and conforms to similar schemes being introduced for all the major fruit crops in South Africa. During the interim phase the Citrus Exchange was responsible for all horticultural, administrative and most regulatory aspects of the South Africa Citrus Improvement Programme while the CSFRI was responsible for shoot-tip grafting and virus indexing. With the implementation of the first stages of the formal programme in 1981, the CSFRI retained its previous responsibilities but also became involved in policy decisions and administration. The Directorate of Plant and Seed Control assumed the regulatory functions and the Citrus Exchange undertook responsibility for the multiplication and distribution of registered budwood and seed to those nurseries approved by the Directorate Plant and Seed Control. In the meantime, the interim programme is being gradually phased out as increasing amounts of propagation material are made available from the Outspan Foundation Block (see later) to meet the needs of the formal programme. Figure 1 provides a flow diagram showing the four phases of the formal programme as depicted by Burger (1).

Phase I. This comprises the selection, virus elimination by shoot-tip grafting and preinoculation with mild CTV for cross protection of material to be used in the formal programme. The selection of the cultivars for shoot-tip grafting is done by a joint committee of CSFRI and South African Co-operative Citrus Exchange researchers while all other aspects of Phase I are handled entirely by the CSFRI. The decision to inoculate all Foundation Block budwood sources with a known and tested mild strain of CTV for cross protection was taken by the Citrus Improvement Programme Committee in 1982 on the recommendation of Dr. J. Moll, CSFRI. A single universal mild and protective strain was used to cross-protect all stionic combinations because, by shoot-tip grafting, the plant material had been entirely freed of CTV. Thus any severe CTV strains introduced by aphids in the field would enter a totally unprotected plant. This was a new situation in South African citrus production, since in the past all citrus trees had carried mixtures of CTV strains which may have served to cross-protect them from the effects of more severe strains.

Even prior to the introduction of the SACIP, nurserymen had customarily used healthy-appearing field trees as sources of budwood thus resulting in an ongoing process of protective strain selection.

The search for a suitable mild and protective strain of CTV with which to inoculate all stionic combinations in the Foundation Block yielded the so-called 'Nartia' strain. Attention was first drawn to this strain by the fact that three of four grapefruit trees, planted in an orchard in Wellington,

TABLE 2
TREES CERTIFIED PER CULTIVAR IN THE INTERIM CITRUS IMPROVEMENT PROGRAMME FROM 1976 TO 1985

CULTIVAR	1976	1977	1978	1979	1980	1981	1982	1983	1984	1985
GRAPEFRUIT										
Marsh	15 493	25 747	25 051	38 553	15 140	30 049	9 189	5 470	2 768	7 489
Redblush	10 421	10 284	4 474	12 076	8 155	11 210	12 292	7 025	520	1 250
McClean	—	—	—	—	—	—	—	—	—	—
Nartia	—	—	—	5 974	9 764	515	—	550	1 458	—
TOTAL	25 914	36 031	29 525	56 603	33 059	41 774	21 481	13 045	4 746	8 739
VALENCIAS										
Olinda	22 277	41 270	30 576	63 600	52 336	31 597	28 706	9 191	19 142	9 465
Amanzi	9 507	13 695	13 548	31 672	20 317	24 724	18 789	1 045	2 760	15 304
Du Roi	427	—	—	480	2 992	4 677	11 065	8 749	3 390	6 298
McClean	—	4 924	6 937	6 848	13 425	9 421	3 225	1 681	1 651	9 870
Delta	—	671	3 825	15 877	34 028	57 429	31 520	19 932	30 788	15 660
Late	—	—	478	30 006	21 080	20 063	30 759	16 250	27 870	29 874
Excelsior	—	1 071	2 268	355	3 232	3 606	6 328	32	1 693	—
TOTAL	32 211	61 631	57 633	148 838	147 410	151 517	130 392	56 880	87 294	86 471
NAVELS										
Palmer	11 063	24 794	33 142	49 965	74 001	154 588	258 867	73 921	151 065	141 927
Bahianina	1 680	2 211	—	440	2 700	3 800	1 220	1 950	9 501	37
McClean	—	5 235	10 949	13 497	14 320	21 678	17 455	21 084	16 702	21 892
Robyn	—	—	—	—	—	—	—	20 104	39 821	56 081
TOTAL	12 743	32 240	44 091	63 902	91 021	180 066	277 542	117 059	217 089	219 937
MIDSEASON ORANGES										
Tomango	—	3 391	3 660	250	—	—	—	—	—	—
Clanor	—	—	—	—	—	2 455	6 148	3 502	3 400	596
TOTAL	—	3 391	3 660	250	—	2 455	6 148	3 502	3 400	596

SOFT CITRUS										
Clementine	—	—	—	—	—	—	—	—	377	4 465
Minneola tangelo	—	—	—	—	—	—	3 407	465	4 372	12 071
Satsuma mandarin	—	—	622	3 157	3 534	9 047	9 582	1 186	3 019	3 232
Ellendale	—	—	—	—	—	—	—	117	—	500
TOTAL	—	—	622	3 157	3 534	9 047	12 989	1 768	7 768	20 268
Eureka lemons	6 989	22 770	26 361	42 935	58 573	68 287	99 022	23 331	12 888	17 801
Lisbon lemons	—	—	—	—	—	—	—	—	208	—
TOTAL	6 989	22 770	26 361	42 935	58 573	68 287	99 022	23 331	13 096	17 801
TOTAL CERTIFIED	78 732	156 063	161 892	315 685	333 777	453 146	547 574	215 585	333 393	353 812

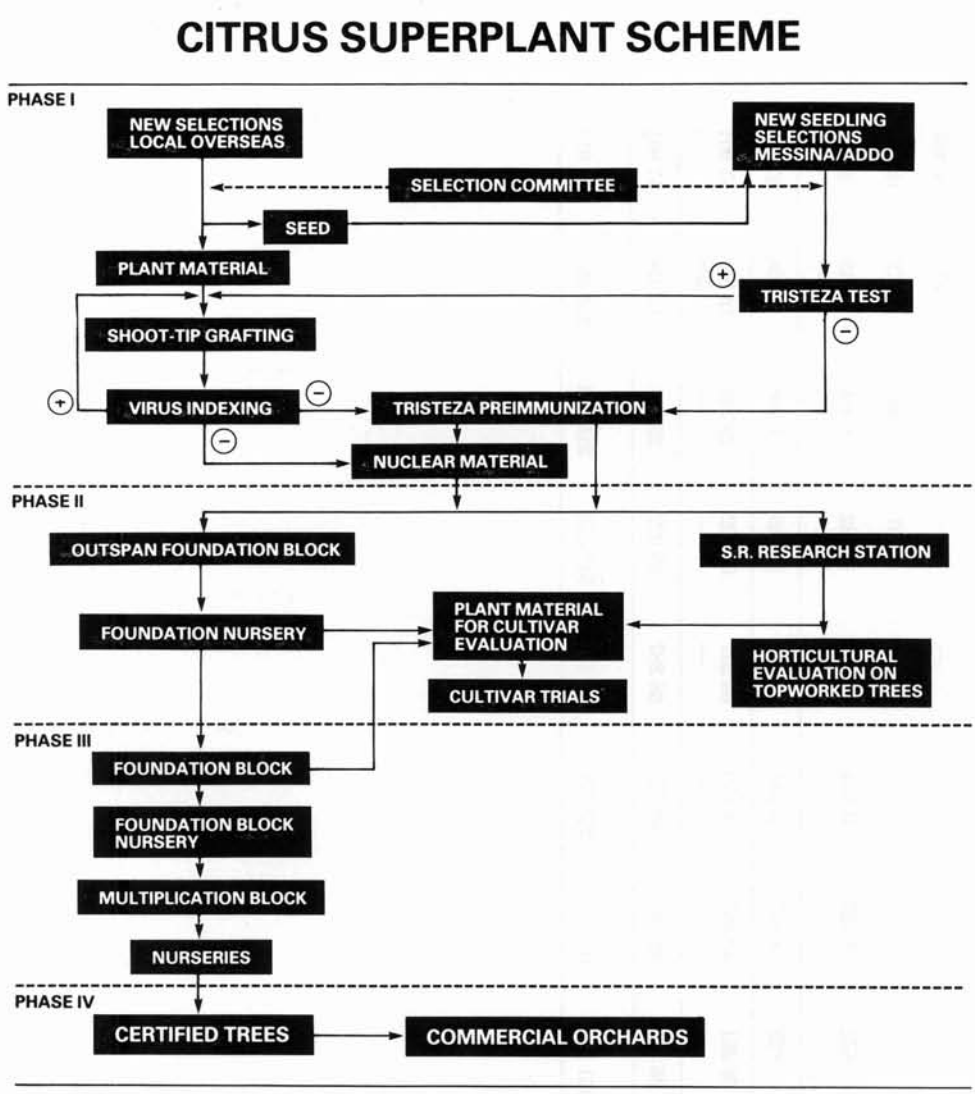

Fig. 1. Schematic representation of the steps involved in the South African Superplant Scheme (after W. P. Burger, Citrus and Subtropical Fruit Research Institute, Nelspruit).

Cape, in 1926, were performing well 50 yr later. Since this discovery was made, Nartia has performed favourably in comparison with a number of other suspected mild strains in glasshouse trials using a range of CTV-sensitive indicator plants (Moll, personal communication). Its cross-protective ability has not been confirmed experimentally, but daughter trees produced with budwood of the original parent source have performed well in commercial field plantings. Trials to compare the cross-protective ability of the Nartia strain with other promising CTV strains are currently in progress at the CSFRI.

Phase II. Here the material made available through Phase I is topworked at the Addo Research Station in the Eastern Cape for subsequent horticultural evaluation. Once the topworks are bearing, the fruit is evaluated by a joint committee of CSFRI and Citrus Exchange horticulturists to ensure trueness to type and that no mutations have been selected during shoot-tip grafting. At the same time identical material is supplied to the Outspan Foundation

Block so that trees can be produced and planted there as future budwood parents. The movement of this material is monitored at all times by the Directorate Plant and Seed Control.

Phase III. This is the final stage in supplying registered propagation material to approved nurserymen. Budwood taken from Foundation Block parent trees is increased in a central multiplication facility located at the Foundation Block. Only buds from behind fruit will be multiplied, and increase trees will expire after a 2-yr period during which time approximately 150 buds will be multiplied from each bud originally supplied. First budwood cutting from the Foundation Block parent trees commenced in October 1986. Until then, budwood for multiplication at the Outspan Foundation Block was taken from the CSFRI's nucleus block (*i.e.*, the same budwood source used to establish the Foundation Block's parent trees).

OUTSPAN FOUNDATION BLOCK

During 1980 the Citrus Exchange acquired a farm in the lower reaches of the Elands River Valley, near Uitenhage in the greening disease-free Eastern Cape, for the establishment of a foundation block. The farm comprises 167 ha of which approximately 25 ha are suitable for citrus cultivation. It is located more than 20 km away from the nearest commercial citrus plantings.

Since January 1983, 16,000 buds have been supplied from the nucleus block at the CSFRI to the Outspan Foundation Block. The majority of these buds are at present being multiplied for release to approved nurserymen during 1986 and 1987. The remaining buds have been used to produce trees for planting in the foundation block orchard, and from October to December 1984, 486 trees were planted there to serve as future budwood parents. Once in bearing, these parent trees will undergo strict horticultural and virological evaluation on a regular basis and will be removed from the Foundation Block orchard should any problems be detected.

In time all commercial cultivars will be available from the Outspan Foundation Block. Some cultivars of particular interest to growers that are already available in limited quantities are the Midknight, the old-line Delta Valencia, the new Clementine selections from Spain and Corsica, and the Kuno and Miho Wase Satsumas from Japan. In the pipeline is a wide variety of cultivars such as the Newhall, Robyn, and Nieuwoudt navels, a number of late lemon selections, the Star Ruby grapefruit, as well as various Temple selections. A full list of cultivar selections so far entered into the formal programme is provided in table 3.

A factor which initially restricted the release of budwood from the Outspan Foundation Block was that this material release could not be approved until fruit borne by the shoot-tip grafted material top-worked at the Addo Research Station had undergone at least one horticultural evaluation. Some of these topworks came into bearing in 1984. Consequently, the first material was not eligible for release from the Outspan Foundation Block until 1985. By January 1986, 231,770 buds had been released from the Outspan Foundation Block, and by the end of 1986, this figure should exceed 1,000,000 buds.

Administration. One of the major strengths of the South African Citrus Improvement Programme is the fact that the parentage of certified trees can be traced. This system itself is quite straightforward and relates all consignments of certified trees through reference numbers to the budwood source, *i.e.* the individual trees from which the buds were cut. The programme administration has also played an important role in keeping track of rootstock trends and in providing a cross-check for the annual tree census, particularly in areas new to citrus.

Although it could be said that the CIP started just after Dr. Calavan's

TABLE 3
LIST OF CULTIVARS AND SELECTIONS ENTERED INTO THE CITRUS IMPROVEMENT PROGRAMME

CLEMENTINE MANDARINS:	Nules	SATSUMA MANDARINS:	Owari
	Oroval		Kuno
	SRA 63 (Corsican)		Miho Wase
	SRA 70		
	SRA 85	VALENCIA ORANGES:	Olinda
	SRA 89		Delta
	SRA 92		Late
	SRA 84		Amanzi
	SRA 88		Midknight
			McClean
ELLENDALE:	CSFRI		Du Roi
	Koster		Margueret
	Herps		Broedershoek
	Leng		Valentine
	Novelty		
	Messina	NAVEL ORANGES:	Palmer
			Bahianina
MANDARIN HYBRIDS:	Temple Sue Linda		McClean
	Temple Thoro		Robyn
	Page		Nieuwoudt
	Nova		Newhall
	Imperial		Leng
	Sunburst		Stiemie
	Bedhlane		Lane Late
	Minneola		Emslie
	Robinson X		Ryan
	Fairchild		Washington
			Zeerust
MIDSEASON ORANGES:	Clanor		Spanish Late
	Tomango		C.J. Navel
	Shamouti		Rautenbach
LEMON:	Eureka	GRAPEFRUIT:	Marsh
	Lisbon		Red Blush
			Nartia
			Star Ruby

visit in 1972, movement of the first budwood was recorded only from 1975, with the first trees being certified in 1976. Over the past 10 yr a great deal of data pertaining to budwood and tree movement has been recorded. However, to date it has only been possible to make restricted use of this information by way of monthly and annual summaries.

This situation is now in the process of being rectified with the computerization of all data; at present all CIP records are being entered into data base files. Once this has been completed, it will be possible to develop a comprehensive monitoring system capable of providing instantaneous summaries of cultivar and rootstock usage on an area basis and to make rapid references to budwood parentage.

LITERATURE CITED

1. Burger, W. P.
1984. S.A. Sitrusverbeteringskema—Riglyne vir Fases 1 tot 4. NISSV Verslag.
2. Lee, A. T. C. and C. J. Alexander
1986. Citrus Improvement Programme—1985 Progress Report. South African Co-operative Citrus Exchange.
3. von Broembsen, L.A., W. P. Burger, and A. T. C. Lee
1984. South Africa's Citrus Improvement Programme Proc. Int. Soc. Citrus Nurserymen.
4. von Broembsen, L.A., J. V. da Graca, A. T. C. Lee, and G. G. Waller.
1978. South Africa's Citrus Improvement Programme after five years. Citrus & Subtropical Fruit J. 532: 11-18.