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Contents

ECONOMIC CONSEQUENCES OF PLANT DISEASES AND PESTS IN COMMERCIAL CROPS*

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1. INTRODUCTION

The existence of plant diseases and pests which destroy crops or lower their marketability has important economic consequences, apart from the social and/or political consequences arising from the reduced availability of food in a world with a fast-growing population.

The economic consequences have various components:

1. Market effects arise because a smaller volume of products and/or products of lower quality are marketed. In this way customers' want satisfaction and producers' income are influenced.
2. Producers incur expenses to combat pests and plant diseases. This involves resources being applied for the manufacture and distribution of pest control materials and equipment.
3. Both authorities and private groups devote funds to research and extension on pest control
4. The existence of such pests and plant diseases makes it necessary for authorities to draw up and maintain phytosanitary and quality standards. This often complicates the marketing of products.
5. Pest control practices are often accompanied by dangers of environmental pollution.
6. The health of the nation can be influenced by certain types of plant diseases or by residues of pest control materials on the product. Certain pest control practices are also dangerous to the people who do the work.
7. The occurrence of pests and plant diseases sometimes influences the structure of agricultural production. A recent example of this was that important citrus production areas in South Africa had to be taken out of production because of greening disease[1].

In this article certain components of the economic consequences of plant diseases and insect pests in the South African citrus industry will be spotlighted.

2. METHODOLOGICAL ASPECTS OF THE CALCULATION OF ECONOMIC CONSEQUENCES

2.1 The naive approach

Ordish[2] discusses this approach in detail and points out that crop losses are often interpreted incorrectly or naively and that this results in wrong estimates of their extent. The following problems are important in this connection:

(i) Crop losses caused by various insect pests and/or diseases are often simply summed regardless of possible duplication. For excample, it may happen that 10 per cent of the crop, on estimate, is lost because of false codling moth infestation and there is also a 5 per cent loss as a result of fungus diseases. Naively seen, a total crop loss of 15 per cent is therefore expected. The total loss may, however, be lower than 15 per cent because there is fruit that is affected by both.

Alternatively it may happen that only the main cause of loss of a particular fruit is recorded.

*Based on an M.Sc.(Agric.) thesis by J.P. Carstens at the University of Pretoria. The authors thank Prof. J.M. Kotze of the University of Pretoria for his valuable advice and suggestions.

1. Carstens, J.P. 1974. *Die ekonomiese belangrikheid van insekpeste en siektes in die Suid-Afrikaanse sitrusbedryf.* M.Sc.(Agric.) thesis, University of Pretoria, pp. 98-103.
2. Ordish, F.G. 1952. *Untaken Harvest.* Constable and Co., Ltd, London, pp. 11-44.

In such a case it may happen that the total loss (in physical terms) is given correctly, but that the relative contribution of different causes is shown incorrectly. It may happen that the contribution of fungus infection to a loss of 15 per cent is fixed at 10 per cent and 5 per cent put down to codling moth. The conclusion may therefore be drawn that fungus infection is the most serious problem and that attention should be concentrated largely on its control. However, should it be the case that 90 per cent of the fruit showing fungus infection was previously damaged by false codling moth, it would mean that false codling moth infestation in fact contributes the following percentage: 5 + (0,9 x 10) = 13 per cent. So the main problem was wrongly diagnosed by the naive approach.

(ii) It often happens that losses, expressed in monetary terms, reach astronomical figures. This often involves a big miscalculation of the economic importance of losses because it is accepted that all fruit that is not marketed because of damage could, without such damage, have been marketed at the same price as the fruit that was in fact sold on the market. This miscalculation arises from the fact that the price elasticity of demand is ignored[3]. Agricultural prices are to a large extent dependent on the supply of products at a given time on the market. A loss that is put at 15 per cent of the crop results in the remaining fruit fetching a higher price. This price is often used in the calculation of the financial loss whereas the real average price would be lower if the losses had not occurred. Calculations based purely on average market prices will therefore, for the industry as a whole, amount to an over-estimate of the financial extent of damage.

The lower the price elasticity of the demand for the product, the more serious the results of such an approach may be. This argument is not equally valid for the individual producer and for the industry as a whole. The average producer's share of the total market is so small that it does not influence the prices. For the average individual producer such an estimate would therefore be fairly realistic.

2.2 The nature of the content of losses

The real nature of losses is expressed in actual quantity losses, calculable quality losses, changes in resource allocations and market factors.

3. Kohls, R.L. 1964. *Marketing of Agricultural Products.* The MacMillan Co., New York, p. 121.

2.2.1 Quantity losses

These are the physical volume of fruit left unharvested as a result of the occurrence of insect pests and diseases. They are that part of the crop that has to be written off completely.

2.2.2 Quality losses

Quality losses are here defined in terms of the consumer demand. In the citrus industry, for example, they are in direct relationship to specific export standards contained in the Government Gazette of 3 April 1970[4]. These standards are concerned mainly with the external appearance and internal quality of the fruit. Various authors have already made estimates of the economic consequences of certain pests and diseases in the South African citrus industry. In most such cases market effect, as influenced by the price elasticity of demand, is not taken into account[5].

2.2.3 Resource allocation

As already mentioned, resources are used to counteract the consequences of plant diseases. Examples are the investment in pest control equipment, labour used for pest control, cost of pest control materials and the transportation of new planting material over long distances. Land, labour, capital and management are held back from alternative productive application. Ordish[6] regards this wastage that accompanies the untaken harvest as one of the most important components of the economic effect. Wardle[7] even earlier took note of the economic advantages that can follow changes in resource allocation in respect of the elimination of the untaken harvest. It has also been contended that the marginal value product per R1,00 spent on pest and disease control is among the highest in farming[8].

2.2.4 Market factors

Yield and quality loss results in both direct and indirect loss effects. On the market the direct effect implies the higher or lower trend of the price. Before the economic effect of a certain quantity loss can be calcu-

4. Republic of South Africa. 1970. Government Printer, Pretoria, Government Gazette 2682, 5-13.
5. Among others:
   Kotzé, J.M. 1963. *Studies on black spot disease of citrus caused by Guignardia Citricarpa Kiely, with particular reference to its epiphythology and control at Letaba.* D.Sc.(Agric.) dissertation, University of Pretoria, Pretoria, p. 8.
   Schwartz, A. 1972. Die ekonomiese belangrikheid en bestryding van sitrusroesmyt. *The Citrus Grower & Subtropical Fruit J.* No. 468, pp. 17, 19 and 26.
6. Ordish, F.G., *op. cit.*, p.18.
7. Wardle, R.A., 1929, *Problems of Applied Entomology.*
8. Ordish, F.G., *op. cit.*, p. 19.

lated an estimate must be made of what price would have been realised if the crop loss had not occurred. This will depend on the price elasticity of demand for the product. Where certain effects result in a shift of terminal markets, the relative price levels on the markets and the differences in price elasticity of demand are therefore important[9].

The South African citrus industry depends to a large extent (between 45 and 60 per cent of the total crop) on the export markets, on which higher prices are normally realised than on the local market[10].

In view of this fact the more indirect losses are also very important. An increase in the quality of citrus fruit through more effective control of insects and diseases may result in a higher income for the industry. Not only will the export percentage be raised, but foreign sales may be increased so that ruling incomes are maintained or increased.

Good external as well internal quality is a prerequisite for profitable prices. The chief overseas export officer of the Citrus Exchange states that: "People are prepared to buy citrus even when there is a lot of other competitive fruit and they are prepared to pay the prices for the right quality." This statement is borne out by the success of the pink Texas grapefruit on a saturated European market in 1973[11].

2.3 Pest control and economic losses

Many alternative actions may be taken on the existence of pests and diseases.

The four most important alternatives are the following[12]:

(i) Passiveness. No action is taken and what remains of the crop is marketed.
(ii) Replacement of an affected crop with others.
(iii) The cultivation of crop varieties or cultivars that are resistant to the diseases and/or insects concerned.
(iv) Pest control, which may be chemical or biological or an integrated programme consisting of both chemical and biological control.

All these approaches may be interpreted economically in terms of the alternative cost principle. The replacement of crops or the choice of resistant cultivars holds clear alternative cost aspects in the sense that there are alternative uses for resources and that the cost of this therefore consists of the highest value product which would result from alternative application[13].

Pest control, like any other production activity, is subject to diminishing marginal product and there is an optimum at which the marginal value product of pest control is equal to the marginal cost.

Ideally speaking, a complete and accurate determination of the economic effect of the occurrence of pests and diseases would consist of a comparison of the present condition (income from the harvested product minus pest control cost, minus structural losses, minus research and administrative expenditure) with the optimum condition. The calculation of this optimum would be an extremely complicated process. Many input-output, input-input and output-output relationships and also certain types of market information which would be necessary are at present simply not obtainable.

3. EMPIRICAL DETERMINATION OF EFFECTS IN THE SOUTH AFRICAN CITRUS INDUSTRY

From the above it follows that a complete analysis of the economic effects of pests and plant diseases in the citrus industry cannot be made in this article.

The approach which will be followed will be first to estimate what quantity losses do occur. Because it is impossible with the information available at present to arrive at estimates of the optimum expenditure on pest control action, the present total realisation will be compared only with what the realisation would have been if certain percentages of losses were eliminated. This will be followed by estimates of expenses which arose from the occurrence of pests and diseases and expenses given for pest control.

3.1 Quantity losses

Quantity losses consist of pre-harvest losses which occur in the orchard because fruit cannot be harvested and losses which occur during and after the harvesting and packing process.

The latter consist of products that are harvested but are unsuitable for marketing and are therefore rejected in packhouses; fruit which degenerates in transit to the harbours and is therefore rejected before export; and fruit which spoils during marketing and therefore also has to be rejected.

It was extremely difficult to obtain reliable information about pre-harvest losses. During a survey, however, it appeared that certain of the larger estates that produce oranges carry out sampling in orchards and analyse the figures carefully. In other cases respondents could give an estimate of quantities of fruit removed during orchard sanitation. It was evident from the survey that about 2,3 per cent of all oranges are lost before the harvest. No reliable figures could be obtained in respect of grapefruit and lemons. Experts

9. Haley, Bernard F. 1948. Value and distribution. In: Ellis, Howard S, *A survey of contemporary economics*. Richard D. Irwin, Homewood, Illinois, pp. 20-24.
10. Carstens, J.P., *op. cit.*, pp. 3-9.
11. Republic of South Africa. Annual Report of the South African Co-operative Citrus Exchange, 1971-72, Pretoria, p. 6.
12. Ordish, F.G., and Dufour, David. 1969. Economic basis for protection against plant diseases. *Ann. Rev. Phyt.* 7, 37.
13. Samuelson, Paul A. 1964. *Economics, Sixth Edition*. McGraw-Hill, New York, pp. 456-459.

approached about this[14], however, are of the opinion that pre-harvest losses are considerably greater with grapefruit and that such losses are even greater with lemons. It was therefore accepted that the annual pre-harvest losses of grapefruit and lemons amount to 2,75 per cent and 3,0 per cent, respectively. These percentages mean that the fruit that does reach the packhouses amounts to 97,7, 97,25 and 97,0 per cent, respectively, of the total amount of fruit. These average figures were then applied to annual packhouse intake in order to estimate the annual pre-harvest quantity losses.

The procedure followed in calculating packhouse rejection losses was as follows:

The calculation of the percentage rejection of oranges is based on information gathered in production areas which provide 80 per cent of the country's marketable oranges and applies to the three-year period from 1970 to 1972. The results were obtained by means of a representative survey at packhouses in the Eastern Transvaal, Central Transvaal, Northern Transvaal and Western Transvaal.

This information was correlated with reports and records of the South African Co-operative Citrus Exchange. According to the results 2,2 per cent of the total crop of oranges is lost through rejection.

Rejection losses of grapefruit were calculated at 3,25 per cent of the total crop. The figure is based only on the Eastern Transvaal, where 3,3 per cent of the marketable grapefruit is produced.

Although the estimate probably cannot be regarded as representative of the whole industry, figures were available only for this production area and oral information in every case gives the impression that grapefruit is also subject to similar packhouse rejection in other production areas. In the absence of sufficient information, and considering the above, a probable minimum percentage of 2,5 per cent rejection losses was made applicable to the entire production.

Estimates for rejection losses of lemons are based on three production areas which together supply 63 per cent of the marketable production. The percentage rejection fluctuates little from year to year, namely: 2,2: 2,4 and 2,1 per cent in three consecutive years.

In Table 2, in which the same procedure is followed as in Table 1, the estimate of the annual packhouse rejection is shown.

Fruit in transit to the export harbours begins to spoil mainly as a result of earlier damage, particularly by false codling moth. On estimate 0,7 per cent of all export fruit is repacked at the harbours by the Co-operative Shipping Services Organisation. During the period 1967-1972 an annual average of 940 995 export units were rejected.

14. Among others, people at the Field Services Division of the South African Co-operative Citrus Exchange and the Citrus and Subtropical Fruit Research Institute at Nelspruit and entomologists and packhouse managers.

TABLE 1[15] — The annual average pre-harvest losses of South African citrus fruit resulting from pests and plant diseases: 1967-72

	Quantity after packhouse (tons)	Packhouse plus orchard loss (tons)	Quantity of orchard loss (tons)
Oranges (2,3%)*	(= 97,7 %)		
1967	433 736	443 947	10 211
1968	445 901	456 398	10 497
1969	403 211	412 703	9 492
1970	481 712	493 052	11 340
1971	417 464	427 292	9 828
1972	506 347	518 267	11 920
Average	448 061	458 609	10 548
Grapefruit (2,75%)	(= 97,25%)		
1967	87 788	90 270	2 482
1968	85 178	87 587	2 409
1969	71 011	73 019	2 008
1970	97 859	100 626	2 767
1971	104 779	107 742	2 963
1972	124 909	128 441	3 532
Average	95 254	97 948	2 694
Lemons (3,0%)	(= 97%)		
1967	10 744	11 076	332
1968	10 849	11 185	336
1969	13 556	13 975	419
1970	11 613	11 972	359
1971	14 828	15 287	459
1972	16 914	17 437	523
Average	13 084	13 489	405
Total average	556 399	570 046	13 647

* Percentage pre-harvest loss

Calculated at the average repacking cost of 17 per cent per unit, this means an annual additional cost to the industry of R160 000.

Waste losses on the foreign markets have already caused considerable damage to the industry. Fruit which after repacking is externally unblemished is exposed to normal temperatures in the ships' holds after the period of cold storage. The almost invisible surface

15. For the causes of these and all other losses see Carstens, J.P., *op. cit.*, pp. 32-46, 74-84.

TABLE 2 — The annual quantity of packhouse rejection of citrus fruit

	Quantity marketed (tons)	Marketed plus rejected (tons)	Quantity rejected (tons)
Oranges (2,2%)*	(= 97,8 %)		
1967	424 194	433 736	9 542
1968	436 091	445 901	9 810
1969	394 340	403 211	8 871
1970	471 114	481 712	10 598
1971	408 280	417 464	9 148
1972	495 207	506 347	11 140
Average	438 204	448 061	9 857
Grapefruit (2,25%)*	(= 97,5%)		
1967	85 593	87 788	2 195
1968	83 049	85 178	2 129
1969	69 236	71 011	1 775
1970	95 413	97 859	2 446
1971	102 160	104 779	2 619
1972	121 786	124 909	3 123
Average	92 873	95 254	2 381
Lemons (2,3%)*	(= 2,3%)		
1967	10 497	10 744	247
1968	10 599	10 849	250
1969	13 244	13 556	312
1970	11 346	11 613	267
1971	14 487	14 828	341
1972	16 525	16 914	389
Average	12 783	13 084	301
Average total	543 860	556 399	12 539

*Percentage rejection

damage, such as that often caused by false codling moth and fruit fly, is susceptible to fungus infection. If the fruit is not disposed of quickly, spoilage therefore occurs.

In order to be able to debit exporters with the losses so arising, a sample from each exporter's consignment is stored at a central point in Europe. On the grounds of the percentage of spoilage in the sample, the producer is debited with an amount per carton supplied and the remainder is written off against the export pool. This sampling procedure has been in operation since 1970.

Although it is not known how many units are involved, an estimate can be made from the export prices obtained. In this way it is deduced from the average annual loss of R1 008 977 that an estimated 367 289 export units of 15 kg each are involved annually in waste losses on the foreign markets, in other words, 5 509 tons[16].

3.2 Quality losses

Quality losses are suffered when citrus fruit is rejected for the export market and channelled to the local markets and juice factories. The reasons for rejection in the packhouse are numerous and are summarised in a series of rejection factors[17].

As far as the effect of pests and plant diseases is concerned, these rejection factors are largely a matter of the external appearance of fruit.

Table 3 shows the percentages of fruit that was rejected for export in the packhouses and therefore had to be marketed locally.

TABLE 3 — Percentages of citrus fruit rejected for export in South African packhouses*

Period	Oranges		Grapefruit		Lemons	
	Percentage	Quantity (tons)	Percentage	Quantity (tons)	Percentage	Quantity (tons)
1966/67	20,3	-	16,1	-	28,1	-
1970/71/72	12,1	-	5,3	-	5,3	-
average	16,6	602	10,7	91	16,7	23

*Source: Two unpublished studies by the South African Co-operative Citrus Exchange

In addition, fruit is rejected in the harbours for the same reasons. A considerable quantity of fruit consequently also had to be repacked. A careful cost analysis by McOnie and Van der Ryst of the South African Co-operative Citrus Exchange[18] serves as a basis for the calculation of packing costs. They calculated the cost for 1969 and at the same time made a projection for 1971.

According to this, the packing cost is estimated at 40 cents (export) and 13,4 cents (local) per unit of 15 kg. Based on this, extra packing costs are as shown in Table 4.

16. For the figures this estimate is based on, see *Ibid.*, p. 79.
17. *Ibid.*, pp. 82-85.
18. McOnie, K.C. and Van der Ryst, D.S. 1971. *A South African Co-operative Citrus Exchange report.* Pretoria.

TABLE 4 — The units of citrus fruit rejected at the export harbours and the total cost of repacking

	Oranges	Grapefruit	Lemons	Total
Units	40 152	6 067	1 510	47 729
Tonnage	602	91	23	716
Cost	R10 680	R1 613	R401	R12 694

Apart from the fact that marketing at the lower domestic free on rail price results in quality losses, the cost of repacking that accompanies the rejections at the harbours must also be seen as a further quality loss.

The information given above is summarised in Table 5.

price. A decrease in quality losses would also result in more fruit being sold on the export markets and less on local markets. Consequently prices will rise at home and drop on export markets. The size of the price and income changes will depend on the quantities involved and the price elasticity of demand.

The domestic demand is subdivided into two markets: the Witwatersrand market and the Cape market. A demand analysis indicates that the price elasticity on the Witwatersrand market is -1,5578 and that on the Cape market is -1,9700[19].

No calculated price elasticity of demand for citrus fruit in Europe could be traced in literature. However, American analyses[20], particularly taking into account the relative incomes of Europe — the most important export market — and the U.S.A., show that a price

TABLE 5 — Combined analysis of quantity and quality losses of citrus in South Africa: 1967-1972

	Oranges	Grapefruit	Lemons	Total
		Units of 15 kg each		
1. Ouantity losses of harvested citrus:				
(a) Packhouse rejection	558 676	133 241	17 058	708 975
(b) Spoilage at harbours	3 409	394	536	4 339
(c) Spoilage on foreign markets	288 057	72 471	6 761	367 289
Total	850 100	206 100	24 400	1 080 600
2. Quantity losses before the harvest stage:	703 300	179 600	27 000	909 900
Total quantity losses (1 + 2)	1 553 500	385 700	51 400	1 990 500
3. Quality losses:				
(a) Packhouse rejections lead to loss of export*	(40 152)	(6 067)	(1 510)	(48 729)
(b) Harbour rejection leads to loss of export and repacking	(28 082)	(637)	(936)	(29 653)
Total	(68 200)	(6 700)	(2 400)	(78 400)
Total (1 +2 +3)	1 553 300	385 700	51 400	1 990 500
Tonnage	23 300	5 786	771	29 857

*These figures are given in brackets because this fruit was not entirely lost, but had to be sold at lower prices because of downgrading.

3.3 Market effects

As already mentioned, an increase in the total quantity of fruit marketed will result in a lower average

19. Carstens, J.P., *op. cit.*, pp. 30-31.
20 Powell, L.A. and Jodium, M.R. 1955. *Economic relations involved in retailing citrus products.* Florida Ag. Exp. Sta., Bul. 567.

elasticity of about -1,6 can be accepted as reasonable for the export market.

With the help of a computer programme an annual analysis was made of the change in the level of earnings in accordance with this elasticity of demand[21]. The potential change in earnings was measured at four possible levels of quantity losses eliminated and within each of these levels also four levels of quality losses eliminated, namely: 100; 75; 50 and 25 percentage levels, respectively. The local marketing was divided between the Cape and Rand markets. The share of factories of the locally marketed fruit was not included in the calculations, because fixed prices are determined by the Citrus Board in this case. Table 6 shows the calculated value of the factories' share of the crop.

Where two different definite quantity-price combinations are compared, the relevant formula is the formula for the arc elasticity, as follows:

TABLE 6 — Factory share of South African citrus fruit

	1967	1968	1969	1970	1971	1972
Oranges						
% share of domestic turnover	55	53	52	52	51	57
Gross price (cents/unit)	17,49	17,10	16,63	14,64	19,24	19.83
Quantity to factories:						
Packhouse rejection (13,6 kg)	145 547	127 210	127 624	165 696	136 144	216 740
Pre-harvest losses (13,6 kg)	155 752	136 188	136 558	177 297	145 690	231 915
Total (13,6 kg)	301 299	263 398	264 182	342 993	281 834	448 655
Gross value of supply to factories	R 52 697	45 041	43 933	50 214	54 225	88 968
Grapefruit						
% share of domestic turnover	84	86	90	85	82	85
Gross price (cents/unit)	16,14	17,57	17,63	17,40	16,35	11.74
Quantity to factories:						
Packhouse rejection (13,6 kg)	45 234	42 657	45 795	59 323	58 271	82 821
Pre-harvest losses (13,6 kg)	51 149	48 202	51 807	67 109	65 925	93 910
Total (13,6 kg)	96 383	90 859	97 602	126 432	124 196	176 731
Gross value of supply to factories	R 15 556	15 964	17 207	21 999	20 306	20 748
Lemons						
% share of domestic turnover	60	56	63	63	65	64
Gross price (cents/unit)	26,07	17,59	25,00	25,94	30,89	23,96
Quantity to factories:						
Packhouse rejection (13,6 kg)	4 753	5 834	6 984	6 650	8 260	5 363
Pre-harvest losses (13,6 kg)	6 388	7 840	9 379	8 941	11 118	7 211
Total (13,6 kg)	11 041	13 674	13 363	15 591	19 378	12 574
Gross value of supply to factories	R 96 383	90 859	97 602	126 432	124 196	176 731

$$\eta = \frac{H_0 - H_1}{H_0 + H_1} \Big/ \frac{P_0 - P_1}{P_0 + P_1}$$ [22]

Where: η = elasticity of demand
H_0 = existing quantity
H_1 = new quantity
P_0 = existing price
P_1 = new price

For the purposes of the calculations the new price (P_1) will be deduced from the new quantity (H_1) and the elasticity of demand.

In order to do this the above formula is used as follows[23].

$$P_1 = \frac{P_0 \left(1 - \frac{1}{\eta} \frac{H_0 - H_1}{H_0 + H_1}\right)}{1 + \frac{1}{\eta} \frac{H_0 - H_1}{H_0 + H_1}}$$

The calculations are based on the assumption that all the exportable fruit will be exported. This is not necessarily the case and may create the situation in which suboptimal allocation among markets arises, as may happen particularly with minimum loss levels and therefore maximum exports. In such a situation it would be desirable to investigate the principle of market discrimination further. Du Toit gives a comprehensive description of how the theory of market discrimination can be applied in banana marketing in South Africa[24].

In the analysis the following approach was used. A certain percentage of prevention of quantity losses

21. Calculations were also made in respect of a few other possible elasticities. See Carstens, J.P., *op. cit.*, pp. 120-122.
22. Schuman, C.G.W., Franzen, D.G. and De Kock, G. 1952. *Ekonomie, 'n inleidende studie.* Universiteitsuitgewers en Boekhandelaars, Stellenbosch/Grahamstown, p. 138.
23. Carstens, J.P., *op. cit.*, p. 118.
24. Du Toit, J.P.F. 1973. *'n Statistiese evaluering van bemarkingstrategie in die piesangbedryf.* D.Sc.(Agric.) dissertation, University of Pretoria, pp. 150-153.

will result in more fruit being available for marketing. If quality losses are not prevented, this would mean that the same proportional percentages of fruit would be channelled to the local and the export markets. By making use of the elasticity of demand, as mentioned, new prices and therefore new income levels can be calculated in this way. The difference between the new income level and the existing one is then defined as a loss.

The prices used in these analyses were the average net pool realisations on export markets and local markets as published in annual reports of the Citrus Board.

Prevention of a certain percentage of quality losses with the same recovery of quantity losses results in more of the fruit finding its way to the export market and less being marketed locally. This results in a drop in export realisation per unit and an increase in local prices. Because prices on the export markets are higher than local prices, this nevertheless in most cases produces an increase in income. This increase in income may be interpreted as a loss caused by pests and plant diseases.

Because an elasticity of demand higher than -1,0 is used in all cases, a prevention of losses will lead to higher total income realisations in that — by definition — prices will drop proportionately less than quantities marketed increase in such a case. The higher the elasticity of demand, the greater the income-increasing effect of loss prevention. Results are given in Tables 7,8

TABLE 7 — Market effects in the case of oranges according to different levels of quantity and quality losses eliminated at an elasticity of demand of -1,6 on the foreign market: Period 1967-1972

	Quality losses eliminated							
	100%		75%		50%		25%	
Quality losses eliminated = 0%								
Quantity (million)		25,37		25,03	24,69	24,69		24,35
Prices (cents):								
Export	256,8		250,9		248,1		246,7	
Cape	61,4		61,8		62,3		62,7	
Rand	56,6		57,1		57,6		58,1	
Total income (Rm)		49,180		48,940		48,690		48,440
Income loss (Rm)		0,9983		0,7519		0,5034		0,2580
Quality losses eliminated = 25%								
Quantity (million)		25,37		25,03		24,69		24,35
Prices (cents):								
Export	238,0		250,0		252,0		254,0	
Cape	65,8		66,3		66,9		67,4	
Rand	61,8		62,4		63,0		63,7	
Total income (Rm)		49,880		49,640		49,390		49,150
Income loss (Rm)		0,6945		0,7001		0,7066		0,7118
Quality losses eliminated = 50%								
Quantity (million)		25,37		25,03		24,69		24,35
Prices (cents):								
Export	240,0		241,8		243,6		245,5	
Cape	71,4		72,0		72,7		73,4	
Rand	57,0		69,3		70,1		71,0	
Total income (Rm)		50,520		50,280		50,040		49,800
Income loss (Rm)		1,2349		1,3427		1,3528		1,3631
Quality losses eliminated = 75%								
Quantity (million)		25,37		25,03		24,69		24,35
Prices (cents):								
Export	230,3		234,3		236,0		237,7	
Cape	78,5		79,4		80,4		81,3	
Rand	77,4		78,5		79,7		80,9	
Total income (Rm)		51,090		50,850		50,620		50,380
Income loss (Rm)		1,9057		1,9179		1,9302		1,9427
Quality losses eliminated = 100%								
Quantity (million)		25,37		25,03		24,69		24,35
Prices (cents):								
Export	225,9		227,4		228,9		230,5	
Cape	88,3		89,6		90,9		92,3	
Rand	90,1		91,8		93,6		95,5	
Total income (Rm)		51,570		51,340		51,100		50,860
Income loss (Rm)		2,3915		2,4024		2,4141		2,4235

TABLE 8 — Market effects in the case of grapefruit according to different levels of quantity and quality losses eliminated at an elasticity of demand of -1,6 on the foreign market: Period 1967-1972

	Quality losses eliminated							
	100%		75%		50%		25%	
Quality losses eliminated = 0%								
Quantity (million)		4,21		4,13		4,05		3,98
Prices (cents):								
Export	270,0		274,1		278,4		283,0	
Cape	75,8		76,7		77,7		78,7	
Rand	81,7		83,0		84,3		85,7	
Total income (Rm)		10,410		10,340		10,280		10,200
Income loss (Rm)		0,2797		0,2109		0,1414		0,0711
Quality losses eliminated = 25%								
Quantity (million)		4,21		4,13		4,05		3,98
Prices (cents):								
Export	265,1		268,9		273,0		277,4	
Cape	87,0		88,3		89,7		91,2	
Rand	97,7		99,5		101,5		103,6	
Total income (Rm)		10,480		10,420		10,350		10,280
Income loss (Rm)		0,0743		0,0751		0,0758		0,0766
Quality losses eliminated = 50%								
Quantity (million)		4,21		4,13		4,05		3,98
Prices (cents):								
Export	260,3		264,0		268,8		272,0	
Cape	108,4		111,0		113,8		116,7	
Rand	131,2		135,3		139,7		144,6	
Total income (Rm)		10,540		10,470		10,420		10,330
Income loss (Rm)		0,1288		0,1291		0,1293		0,1295
Quality losses eliminated = 75%								
Quantity (million)		4,21		4,13		4,05		3,98
Prices (cents):								
Export	256,5		261,8		263,1		267,7	
Cape	124,0		127,8		139,7		151,3	
Rand	142,0		168,7		180,4		212,9	
Total income (Rm)		10,570		10,510		10,470		10,430
Income loss (Rm)		0,1671		0,1672		0,1677		0,1681
Quality losses eliminated = 100%								
Quantity (million)		4,21		4,13		4,05		3,98
Prices (cents):								
Export	253,5		256,8		258,4		261,5	
Cape	129,2		137,0		155,0		178,3	
Rand	147,8		181,9		205,4		235,5	
Total income (Rm)		10,610		10,550		10,550		10,470
Income loss (Rm)		0,1960		0,1970		0,2010		0,2070

and 9. If no quality losses are eliminated, then according to Table 7 the total income of the industry from oranges will increase by R0,258 million if 25 per cent of the quantity losses are eliminated, compared with R0,998 million in the case of 100 per cent elimination of such quantity losses. If quantity losses had been completely (100 per cent) eliminated, the increases in income would correspondingly have amounted at 25 per cent and 100 per cent levels of quality loss elimination to R0,7118 million and R2,4235 million, respectively. If increases in income with total elimination of quality and quantity losses were to be interpreted as the total crop loss, it would then be R2,3915 million for oranges, R0,1960 million for grapefruit, R0,0900 million for lemons and R2,6775 million together.

The analyses show that in general prevention of a certain percentage of quality losses would have a greater influence on the increase of income than a corresponding level of prevention of quantity losses. Should it be the case that an expenditure of R1,00 would at the present stage contribute to the same saving in quantities lost or downgraded, it would be possible to deduce that more attention should be devoted to the quality than the quantity aspect. Whether such an assumption is realistic at this stage, however, was not determined in this investigation.

TABLE 9 — Market effects in the case of lemons according to different levels of quantity and quality losses eliminated at an elasticity of demand of -1,6 on the foreign market: Period 1967-1972

	Quality losses eliminated							
	100%		75%		50%		25%	
Quality losses eliminated = 0%								
Quantity (million)		0,72		0,71		0,70		0,69
Prices (cents):								
Export	355,2		358,1		361,1		364,5	
Cape	72,5		73,0		73,5		47,1	
Rand	94,7		95,6		96,5		97,4	
Total income (Rm)		1,9200		1,9100		1,9000		1,89000
Incom loss (Rm)		0,0408		0,0307		0,0206		0,0103
Quality losses eliminated = 25%								
Quantity (million)		0,72		0,71		0,70		0,69
Prices (cents):								
Export	337,7		343,2		346,0		348,9	
Cape	76,4		77,0		77,6		78,2	
Rand	101,3		102,3		103,4		104,5	
Total income (Rm)		1,9500		1,9400		1,9300		1,9200
Income loss (Rm)		0,0276		0,0273		0,0275		0,0277
Quality losses eliminated = 50%								
Quantity (million)		0,72		0,71		0,70		0,69
Prices (cents):								
Export	327,6		330,1		332,7		335,3	
Cape	81,0		81,7		82,5		83,2	
Rand	109,3		110,5		111,8		113,2	
Total income (Rm)		1,9800		1,9700		1,9500		1,9400
Income loss (Rm)		0,0521		0,0522		0,0526		0,0530
Quality losses eliminated = 75%								
Quantity (million)		0,72		0,71		0,70		0,69
Prices (cents):								
Export	316,2		318,5		320,8		323,2	
Cape	86,6		87,6		88,5		89,5	
Rand	119,2		120,3		122,5		124,2	
Total income (Rm)		2,0000		1,9900		1,9800		1,9700
Income loss (Rm)		0,0708		0,0746		0,0751		0,0756
Quality losses eliminated = 100%								
Quantity (million)		0,72		0,71		0,70		0,69
Prices (cents);								
Export	306,0		308,1		310,2		312,4	
Cape	93,7		94,9		96,1		97,4	
Rand	132,1		134,2		136,5		138,8	
Total income (Rm)		2,0200		2,0100		2,0000		1,9900
Income loss (Rm)		0,0900		0,0942		0,0947		0,0952

3.4 Pest control expenses

An attempt was also made by means of questionnaires dispatched by post to producers in various citrus regions in the country to make an estimate of pest control expenses. In some cases the information was incomplete, but cost standards of the Division of Agricultural Production Economics could be used where necessary to fill the gaps. Costs in smaller production regions, where the number of completed questionnaires was insufficient for realistic estimates, were brought into line with those of larger regions which were faced with similar insect pests and diseases and similar intensities[25].

Table 10 gives a general breakdown of pest control expenses for citrus in South Africa.

25. See Carstens, J.P., *op. cit.*, pp. 104 and 123.

TABLE 10 — Summary of pest control expenses by region and in total for the whole citrus industry in 1973

Production region	Total number of trees	Cost per tree	Total control cost
	Trees	Cents	Rand
Eastern Transvaal	2 798 620	74,79	2 093 087,90
Northern Transvaal	2 095 405	73,57	1 541 589,46
Central Transvaal	1 413 188	26,35	372 375,04
Western Transvaal	494 150	24,35	120 226,70
Sundays River Valley	1 257 062	25,56	321 305,05
Eastern Cape Midlands	426 438	± 25,00	106 609,50
Gamtoos River Valley	447 468	± 25,00	111 867,00
Western Cape	628 238	± 25,00	157 059,50
Natal	325 011	- 75,00	243 758,25
Total and weighted average cost per tree	9 885 580	51,26	5 067 878,40

Note: Cape regions equated to Sundays River Valley and Natal equated to Eastern Transvaal[26].

There are striking differences in pest control costs per tree between the hot and moister production regions of the Northern and Eastern Transvaal and Natal, on the one hand, and the less humid and rather arid regions in the Central and Western Transvaal and the Cape Province, on the other hand. In addition, there are reasons to believe that in many cases pest control is carried out inefficiently with a consequently high cost relative to results obtained[27].

4. RESEARCH EXPENDITURE

An attempt was also made to estimate research expenditure on plant diseases and pests in the citrus industry. Naturally it is not possible to make a complete estimate here for the following reasons:

1. In many cases it is difficult to obtain the relevant information and it is also extremely difficult to arrive at an acceptable basis for cost allocation where figures are available.
2. In certain other cases, particularly in the private sector, such information is regarded as confidential and proper data could not be obtained.
3. It is quite probable that considerable research expenditure is also incurred by organisations which were not approached for information.

The calculations given below are therefore a tentative, extremely conservative estimate of research expenditure on plant diseases and pests in the citrus industry[28].

The annual figures calculated according to organisations concerned are as follows:

Department of Agricultural Technical Services	R376 000
South African Co-operative Citrus Exchange	R128 000
Developers of control materials	R150 000
Citrus estates	R 48 000
Total	R702 000

5. SUMMARY

In this article methodological aspects of the calculation of economic consequences of the occurrence of plant diseases and pests in commercial crops were considered. One important problem is the market effects of such plant diseases and pests. There are further difficulties in evaluating realistically the importance and effect of pest control expenses and research in this connection.

Only if more and better information becomes available will it be possible — with the alternative cost principle — to approach the whole matter — including structural aspects — completely realistically.

In this article an estimate was nevertheless made of the market effects of plant diseases and pests in the South African citrus industry and an estimate of pest control expenses and research expenditure.

26. Greorgala, M.B. 1973. Personal communication.
27. Carstens, J.P., *op. cit.*, pp. 105-108.
28. For a fuller exposition see: *Ibid.*, pp. 107-110.