SOUTH AFRICAN SUGAR INDUSTRY

AGRONOMISTS' ASSOCIATION

ANNUAL GENERAL MEETING

WEDNESDAY, 11TH NOVEMBER, 1970.

PROGRAMME

9.30 - 9.40 a.m.	Chairman's Report and General.
9.40 - 10.20 a.m.	Filterpress cake experiments - Peter Brown.
10.20 - 11.00 a.m.	Sugarcane crop hygiene schemes - Hilton Durandt.
11.00 - 11.30 a.m.	Tea
11.30 - 12.00 noon	Film: "Break thru" - modern management methods in the space programme.
12.00 - 12.45 p.m.	E.R.S. and its implications - Mr. du Toit and Edmund Browne.
12.45 - 2.15 p.m.	Lunch at Huletts Country Club with group of visitors from U.S.A. (Pennsylvania Agricultural Leaders Goodwill Mission).
2.30 - 4.00 p.m.	Symposium on "Sugarcane production problems today" with contributions from: Tony Tucker, Peter Dovey, John Hill.

SOUTH AFRICAN SUGAR INDUSTRY.

AGRONOMISTS' ASSOCIATION

ANNUAL MEETING, 11TH NOVEMBER, 1970

CHAIRMAN'S REPORT

1. We welcome the following guests to our meeting:

Norman King, Technical Officer, A.E. & C.I.
Jan Kritzinger, Lecturer, Crop Science, N.U.
John Lea, Senior Lecturer, Crop Science, N.U.
Chris Odendaal, Technical Officer, Fisons.

2. Membership, 1969/70:

Current membership stands at 53. During the year Mr. W.H. Williams of Mhlume Sugar Co. died.

The following members joined the Association:

Mike Pennefather, N.T.E., Pietermaritzburg.
Bruce Hulett, Huletts, Darnall.
Paddy Strover, R.S.A., Chiredzi.
Glyn James, R.S.A., Chiredzi.
Henk de Vink, Experiment Station.
D. Tyndall-Briscoe, Illovo.

The following members left the Association:

Ron Wyatt, Illovo.
Keith Armstrong, Swaziland Irr. Scheme.
Peter Coignet, Reynolds Bros.
Tony Whitmarsh, Experiment Station.

The composition of the Committee changed as follows:

Charles Pearson replaced Peter Coignet
Cliff Wardle replaced Ron Wyatt

The Committee therefore now consists of:

Gerald Thompson (Chairman)
John Hill
Charles Pearson
Graeme Shuker
Cliff Wardle

3. Activities

3.1 The Association prepared and circulated a manual giving "Standard procedures for conducting variety experiments throughout the South African Sugar Industry".

3.2 The harvest data from 63 crops of 53 experiments were made available in June, 1970.

The heaviest data from 84 crops of 68 experiments have become available in November, 1970.

3.3 No review papers have been published during the year. It is to be hoped that at least 5 reviews will become available during 1970/71.

3.4 It is intended that the Association will revive our earlier habit of visiting places of interest during the year. On 2nd December we are due to visit Hulett's R and D section, and early in 1971 we will visit Tongaat to see and discuss agricultural management methods.

G.D. THOMPSON
COMMITTEE CHAIRMAN

GDT/MH.
9th November, 1970.

SOUTH AFRICAN SUGAR INDUSTRY

AGRONOMISTS' ASSOCIATION

FILTERPRESS CAKE EXPERIMENTS

INTRODUCTION

In a previous paper by Allsopp (1966) preliminary results of filterpress experiments at Doornkop were reported. Indications at the time were that greater responses to filterpress were being obtained on the heavier Sprintz, Inanda and, to a lesser extent, Trevanian clay-loams than on the lighter Cartref sands, which had received most attention up to then. Further, the use of filterpress on these heavier soils (which at Doornkop are situated furthest from the mill) resulted in a more economic return than on the lighter soils, nearer the mill. It also appeared that the response to 22-45 tons filterpress per hectare in the furrow was equivalent to that of 67-90 tons per hectare broadcast.

Subsequent trials have tended to support the above observations and confirmatory results will not be presented here. The intention is rather to review later developments. Also, to discuss some of its effects on the soil and plant in an attempt to isolate the conditions under which a response to filterpress may be expected.

EXPERIMENTAL RESULTS

Presented in Table I are the results of an experiment harvested last season on an Inanda soil.

Table I : Plant crop results of Experiment M6.

TREATMENTS	T/HA. C.	S. % C.	T/HA. S
Control	97.7	15.09	14.74
Filterpress - 67 t/ha, furrow	119.4	14.61	17.45
" - 134 " "	125.0	14.16	17.70
" - 90 " broadcast	119.8	14.38	17.23
" - 179 " "	118.5	14.54	17.23
MEAN	116.1	14.57	16.87
S.E. of Treatment Means	4.88	0.18	0.67
L.S.D. (0.05)	13.89	0.5	1.90
(0.01)	18.59	0.7	2.55
C.V. %	10.2	3.1	9.7

It is interesting to note that, for both furrow and broadcast applications, there was no significant yield difference between rates of application. Previously it has been noted that, at equal rates, furrow application is superior to broadcast; approximately double the quantity being required to be broadcast for equivalent results. And, considering the results of other experiments, it is thought that highly significant yield increases would be obtained with as little as 25 tons filterpress per hectare in the furrow or 40-50 tons per hectare broadcast, on this soil.

Ratoon Treatments

In three of the experiments filterpress was applied to ratooning cane. In two of these experiments (Cat. Nos. 184 and 492), no significant response was obtained when filterpress was applied to a fourth ratoon crop. Experiment No. 296 was laid down on a first ratoon crop and evidence was significant for a positive response to filterpress (See Table II).

TABLE II : Results of Experiment No. 296 on an Inanda Soil.

TREATMENTS	T/HA. C.	S. % C.	T/HA. S.
Control	65.6	15.91	10.44
Filterpress - 22 t/ha.	86.0	15.52	13.35
Nemagon 80 EC - 112 l/ha.	61.8	16.04	9.91
Filterpress + Nemagon	99.0	15.39	15.24
S.E. of Treatment Means	4.95	0.146	0.739
L.S.D. (0.05)	15.9	0.47	2.35
(0.01)	22.8	0.67	3.38
C.V. %	13.9	2.0	13.2

These results would tend to indicate that reduced responses may be expected when filterpress is applied to ratooning cane. Further, the older the crop, the less likely it is that any positive response will result. Comparison with plant crop results of other experiments (See Table V) indicates that greater yield responses may be expected when filterpress is applied to the plant crop than to a ratoon.

However, this effect could vary under the influence of certain conditions to be discussed later.

Residual Effects

Six of the experiments were carried over for at least one further ratoon. In every case there was no significant evidence of any residual treatment effect, although yields appeared slightly higher for filterpress plots than control. Thus it would appear that no lasting benefits accrue to the crop from the usage of filterpress.

DISCUSSION

On consideration it would appear likely that there are three broad ways in which filterpress could affect the soil environment and hence eventual crop yields.

Physical

Through the addition of organic matter and the stimulation of micro-organisms, it would be expected that the soils' crumb structure would be improved. However, results indicate that this has little immediate effect on yields. As already mentioned, responses have been confined to the better structured soils, with no significant responses being obtained where most expected on the poor structured, low organic matter Cartref soils. Likewise, if improvement of physical conditions were a factor, yield responses would be expected to continue into the ratoons. This in fact does not happen so it seems unlikely that physical effects have much immediate effect on yields, although it is not doubted that continued applications would, in the long term, prove beneficial to the soil and the crop.

Biological

It has been speculated that filterpress has some inhibiting effect on the action of nematodes in the soil. Smith and Batista

(1942) claim:

"Applications of organic matter to the soil stimulate microbial action and some micro-organisms produce substances which retard or inhibit the growth of others".

Experiment No. 296 (See Table II) was laid down on a soil with high nematode counts. Unfortunately no response to fumigation was evident, and, although filterpress treatment outyielded fumigation, no valid conclusions may be drawn from these results. Experiment No. 182 was also conducted on a fairly high nematode population soil. Results of this experiment are presented in Table III.

TABLE III : Results of Experiment No. 182 on an Inanda Soil.

TREATMENTS	T/HA. C.	S. % C.	T/HA. S.
Control	81.1	14.12	11.45
Filterpress - 45 t/ha, F.	130.1	13.84	18.01
" -134 " , b/c	132.6	13.82	18.33
E.D.B. (2.25) -450 l/ha	90.7	14.47	13.12
Fumagon -116 kg/ha	80.4	14.14	11.37
MEAN	103.0	14.08	14.46
S.E. of Treatment Means	3.85	0.165	0.551
L.S.D. (0.05)	11.4	0.49	1.64
(0.01)	15.7	0.67	2.24
C.V. %	8.8.	2.6	8.9

Response to E.D.B. was just significant so it seems quite likely that reaction to nematode attack has played some part in obtaining these results for filterpress treatments. This becomes even more likely when the actual nematode counts are considered.

TABLE IV : Nematode counts before and after treatment in Experiment No. 182

Treatments	Pre	Post	% Diff.
Control	252	150	40.5
Filterpress - 45 t/ha	290	95	67.2
" - 134 "	358	59	83.5
E.D.B.	321	54	83.2
Fumagon	309	141	54.4

Totals of Meloidogyne, Pratylenchus, Hoplaims and Trichodorus counts are presented as these were the most important nematode types present. The "Pre" counts were taken just prior to treatment and the "Post" 50 days afterwards.

It is gratifying to note how closely the "Post" counts correlate with yields. The counts probably explain why Fumagon yields were so low. In view of the above results it would appear very likely that nematode attack (and hence crop yield) is influenced by filterpress application.

Chemical

Analysis of filterpress samples reveals that appreciable quantities of nitrogen, phosphorus, calcium and magnesium and trace elements are present. It may be assumed therefore that filterpress constitutes a source of nutrients, to which sugarcane will respond.

In Table V an attempt has been made to define the soil nutrient conditions under which a response to filterpress occurs. Unfortunately this can only be done for the major elements and at present no definite conclusions can be drawn about the effect of minor elements.

TABLE V : Responses to Filterpress as correlated with soil organic matter and phosphorus status

EXPT.	CROP	TREATMENTS	T/HA. C.	T/HA. S.	O.M. %.	P ppm
291	P	22 t/ha - Furrow	18.6**	2.67**	7.95	5
		45 " - "	23.1**	3.06**		
182	P	45 " - "	49.1**	6.56**	15.76	8
M6	P	67 " - "	21.7**	2.71**	6.70	21
292	P	22 " - "	19.9	3.05	7.30	29
		45 " - "	10.8	0.74		
293	P	22 " - "	-13.0	-2.22	1.0[illegible]	63
		45 " - "	- 6.9	-0.87		
296	1R	22 " - Line	20.4*	2.91*	12.83	8
184	4R	22 " - "	0.7	-0.02	5.92	24
492	4R	22 " - "	- 1.1	0.31	6.43	30
		45 " - "	5.8	1.14		

Of the factors considered organic matter and phosphorus status seemed most closely related to yield response. Generally response to filterpress was only obtained at a soil organic matter content of greater than 6.5 percent. (Although it was not significant, Expt. 292 gave a large, positive response). Likewise, comparison with phosphorus level reveals no significant responses to filterpress above the 20 ppm level. In view of the fairly close correlation between these factors and yield it would appear likely that part, at least, of the responses obtained may be attributable to a response to phosphorus and/or some negative effect of the organic matter in the filterpress.

It is perhaps significant that in the only case where a response was obtained on a ratoon crop, the organic matter content was very much higher and the phosphorus lower than the "threshold levels". These levels in fact cannot be regarded as normal and may explain why any response was obtained on this ratoon crop at all.

REFERENCES

ALLSOPP, L. (1966). Filterpress cake trials. Proc. S.A.S.I.A.A.

SMITH, F.B. and BATISTA, J.W.(1942). The Nematode problem from the soil microbiological standpoint. Proc. Soil Sci. Soc. Fla. 4 - B : 144 - 147.

P.W. BROWN

31.10.1970

SOUTH AFRICAN SUGAR INDUSTRY

AGRONOMISTS' ASSOCIATION

A REVIEW OF EXISTING CROP HYGIENE SCHEMES IN SWAZILAND AND SOUTH AFRICA AND THE PRACTICAL IMPLEMENTATION AND FEASIBILITY OF THESE SCHEMES

INTRODUCTION

Crop hygiene is a very important facet of sound economic farm management, but one that is too frequently overlooked or under-emphasized. It was for this reason that the South African Sugar Association, through their Experiment Station, launched a campaign designed to improve and promote the health and vigour of the cane crop. The result of this campaign has been:

(a) the introduction of a scheme by the Swaziland Sugar Association to control diseases,

(b) a seedcane approval scheme for the South African Sugar Industry.

There can be no doubt that the time and money spent in bringing home to growers the need for crop hygiene are fully justified. The implementation of crop hygiene in theory is quite straight forward, but to be practical the scheme must be simple, workable and easily controlled.

DISEASE PICTURE IN SOUTH AFRICA

More than 20 diseases of sugarcane have been recorded in Southern Africa, but fortunately the majority of these are of relatively minor importance. The most important, classified into groups, are:-

(i) those caused by viruses e.g. mosaic and R.S.D.

(ii) those caused by bacteria e.g. gumming and leaf scald

(iii) those caused by fungi e.g. smut.

Distribution:

(i)	R.S.D.	-	Widespread
	Mosaic	-	Widespread, less prevalent in the northern hot irrigated areas.
(ii)	Gumming	-	Widespread
	Leaf Scald	-	Recently identified. If left uncontrolled can become widespread.
(iii)	Smut	-	Widespread, particularly prevalent in the northern hot irrigated areas.

Control

The most important control measures recommended are:-

(i) Breeding and growing of resistant varieties.

(ii) Careful selection of seedcane material from nurseries planted with hot water treated material.

THE NEED FOR CROP HYGIENE

In 1968, Pearson, in a paper entitled "Why are your yields so low? Is disease the cause", stated that if growers:

(a) conserved water on their cane fields,

(b) cut their crops earlier,

and (c) developed nurseries and eliminated diseases, then they could either double their quota tonnage or produce their mean peak from half the area of land.

It has been shown that R.S.D., under dryland conditions, can cause yield losses of up to 90% during periods of drought.

In Swaziland an observation trial on Ubombo Ranches, under fully irrigated conditions, showed that the yield losses due to R.S.D. were approximately 43% (N.Co376); 42% (N.Co334); 30% (N.55/805) and 28% (N.Co310). This trial was a comparison of known R.S.D.-infected seed material and healthy "first from H.W.T." material harvested at eight months of age.

Field trials to determine yield losses due to smut are not practical due to the ease with which smut spores are spread. However observations in the field clearly indicate that yield losses are substantial.

FACTORS OF IMPORTANCE IN IMPLEMENTING A CROP HYGIENE SCHEME

(i) Ratoon Stunting disease:-

a) All varieties are susceptible to R.S.D.

b) The disease is spread in infected seedcane and mechanically on cane knives, implements, etc.

c) Control is by the hot water treatment of seedcane at 50.5°C for two hours prior to planting into seedbeds.

(ii) Smut:-

a) Varieties differ in their degree of susceptibility to the disease.

b) Spread is by wind, water, man and in infected seed material.

c) Control is by the hot water treatment of seedcane at 50.5°C for two hours, prior to planting into seedbeds; the breeding and growing of resistant varieties; and roguing and destroying infected stools found in the field.

RESEARCH FINDINGS OF IMPORTANCE

(i) Ratoon Stunting disease:-

a) Normal hot water treatment (50.5°C for 2 hours) does NOT lower yield significantly.

b) Germination of youngest eyes at the top of the stalk is adversely affected by H.W.T.

c) Hot water treatment adversely affects yield if "bad" seed is used.

d) The addition of urea to the water in the heat treatment tank (0.3%) improves the germination of H.W.T. stalks.

(ii) Smut:-

a) The incidence of smut is increased from plant to first ratoon, both in number of stools that develop smut and number of whips produced, proving that smut spores remain viable in the soil.

b) The "whole stool" roguing technique is the best method of smut control in the field. Removing smut whips only and not roguing leads to an increase in the incidence of smut.

c) Smut spores can remain viable in dry soil for at least 64 days. In wet soil, however, few if any, remain viable for longer than 8 days.

CROP HYGIENE SCHEMES IN OPERATION

(i) SWAZILAND: The crop hygiene scheme in operation in Swaziland is attached as Annexure 1. The scheme is aimed at controlling, restricting and preventing the spread of R.S.D. and smut.

Smut is considered to be the disease of major importance because:

a) it is widespread and has reached alarming proportions (20 - 50%) on some estates within the Industry.

b) it is responsible for restricting and limiting the number of varieties released for general cultivation and is endangering continued cultivation of released varieties such as NCo310 and N55/805.

c) it cannot be restricted to an individual field or estate. R.S.D. on the other hand, can be restricted to an individual estate.

(ii) SOUTH AFRICA: The South African Sugar Association has introduced a seedcane approval scheme (Annexure 2) in their attempts at crop hygiene. This scheme differs from the Swaziland scheme in that it is aimed at the production of healthy, clean seed by a limited number of registered seedcane producers. In other words, the scheme may achieve crop hygiene by encouraging growers to plant only certified seed.

PRACTICAL IMPLEMENTATION AND FEASIBILITY OF THESE SCHEMES

In considering the practical implementation and feasibility of crop hygiene in a crop like sugarcane, one must accept that it is practically impossible to control or prevent all sugarcane diseases. At best one can only hope to control and prevent the spread of a selected few diseases.

The Swaziland Sugar Association scheme is aimed at completely eliminating smut and R.S.D. This approach is both practical and feasible because of the geographical layout and climatic uniformity of their industry. Sugarcane production is located round Big Ben in the south and 60 miles further north round Mhlume. The total area under cane is approximately 40,000 acres, divided equally between the north and south. Furthermore, 50% of the acreage in the north and 62% in the south is owned by miller-cum-planters, who are motivated and determined to rid their estates of disease.

The Swaziland Sugar Association has the power to compell a grower to practice crop hygiene, by

a) refusing to accept cane for milling from a grower

b) forcing a grower to plough out any field which is considered to be a danger to neighbouring estates.

Their scheme is not only aimed at attacking the disease position from one aspect. Throughout the life of the crop strict control measures are enforced, aimed at keeping the incidence low, thus safeguarding and prolonging the life of crops which were heat treated prior to planting or planted from heat-treated stock.

Sugar Association disease inspectors visit each grower (including miller-cum-planter) at least once a month. They mark smut infested stools in the field for roguing and destroying by the grower. In addition the incidence of other diseases is noted and reported to the Extension Officer. Priority is given to the inspection of nurseries and commercial fields planted to NCo310 and N55/805.

Reports from growers and observations in the field by the author, indicate that the roguing of whole stools in the field has the following limitations:-

a) Roguing is only possible in the Plant, 1R and 2R due to the difficulty of removing stools. No suitable implement for cane removal is available.

b) The number of stools that can be rogued by one man is limited.

c) Large numbers of empty fertilizer bags are needed to cover stools during roguing.

d) Smut spores are in fact spread, no matter how carefully the stools are removed and carted from the field.

This is the only method available and for want of a better and easier method, it is recommended.

The roguing of volunteer stools of cane in commercial fields is not insisted upon, but left to the discretion of the grower.

In the Swaziland Sugar Industry a seed nursery is defined as any land planted to H.W.T. seed material and approved by the Extension Officer. In other words, provided the grower has pre-irrigated at least 10 days (summer) or 20 days (winter) before planting, and the land is free from volunteers, it will be approved and passed as a nursery. Once the nursery has been planted with H.W.T. seed material it is inspected regularly by the Disease Inspector, and the grower must rogue out any cane not true to type or diseased (except gumming and other leaf spot diseases).

If only the plant crop is to be used as seed material, cane knives which were cleaned prior to entering the nursery can be used. No cleaning of cane knives between stools is insisted upon, but at the end of the day cane knives must be washed in a detergent of left standing overnight in a solution of water and Jeyes fluid.

The fencing of nurseries is not considered practical or necessary. However, 10 ft (2 rows) of cane round the nursery must n9t be used as seed.

If the first ratoon is to be used as seed material, then the plucking of cane in the plant crop is encouraged, but because of the impracticability of this method it is not insisted upon.

The dipping of cane after H.W.T. in Aretan and Dieldrin is not insisted on, as it is not considered necessary:

a) where whole sticks are treated

b) under climatic conditions prevailing in Swaziland where germination is rapid and invariably planting furrows are treated with Dieldrin against Heteronychus licas.

Only seed from a registered nursery may be planted or sold. The issuing of a certificate by the Extension Officer has not been implemented, as conditions governing the registration and inspection of a registered nursery ensures that buyers of seed do obtain practically pure clean seed.

By vesting control of the scheme in the Mill Group Committees and the Extension Officer, growers are continually kept aware of the need for disease control.

It can be concluded that the disease scheme in operation in Swaziland is simple, workable and economically feasible. It forms part of the day to day management on every cane estate, growers are disease orientated, and hence the chances of the scheme achieving its objectives must be ranked very high.

Approximate cost:

To the Industry:	3c per acre under cane per annum or 0.75c per ton sugar per annum.
To the Grower:	50c per acre under cane per annum or 1.2c per ton cane per annum.

SOUTH AFRICA

Theoretically the scheme is impressive. It differs from the Swaziland scheme in that the emphasis is placed on planting certified seed and there can be no doubt that this scheme will, over a period of time, reduce the incidence of ratoon stunting disease. As a means of controlling or restricting smut it cannot suceed due to the ease with which smut is spread.

In the view of the author,the scheme could be made more effective and more practical if:

(i) all growers of sugarcane were compelled to use only approved seed for planting.

(ii) a simpler system of certification were to be introduced, e.g. only one certificate to be issued and that after final inspection.

The following comments may also be pertinent:

(i) 18-month old cane is considered to be too old for planting,

(ii) the changing of knives between stools is impractical. Furthermore, existing methods of knife sterilization (Jeyes Fluid) are not proven to be effective in killing the R.S.D. virus.

The author is of the opinion that a scheme based on the following lines would be more practical and would achieve more in the long run as it embraces grower participation at the administration level:

i) Seedcane Approval Scheme: As outlined, but simplified as suggested above, with the organisation and administration to be an Industry obligation.

ii) De-centralised schemes: aimed at controlling and preventing the spread of a disease that is particularly prevalent in a certain locality. Administration should be vested in the growers themselves, either through Mill Group Committees or Liaison groups. Day to day control should be in the hands of the local Extension Officer, i.e. organised along the lines at present in operation in Swaziland.

The two areas where it is felt essential to start "local schemes" are Pongola and the Eastern Transvaal. Emphasis should be on the control and elimination of smut. Similarly a de-centralised scheme could be started in an area where mosaic is rife.

Discussion and conclusion

The control of only two diseases, namely smut and R.S.D., has been discussed in this paper. It is the author's opinion that all diseases could be controlled by the measures used to control and eliminate smut and R.S.D. (e.g. leaf scald and mosaic), provided that disease inspectors are trained in their identification in the field.

Similarly no mention has been made about weed control - also a facet of "crop hygiene". Weed control is a subject on its own and for the purpose of this paper is simply noted as being of major importance in sugarcane production.

To be effective, any crop hygiene scheme must be uncomplicated, easily controlled and, even if sacrificing academic correctness, practical and easily implemented by the man on the ground. It is not impossible to be academically correct and at the same time to extend this to field practice, but what is involved?

a) For the grower himself:

i) His time: he will have to devote considerable time to supervising, organising and training in the field.

ii) His money: growers will rather pay a little more for a commodity or a service, to safeguard their own independence of the operation/service.

b) For labourers: Cane cutters are usually migratory. The success of any scheme depends to a large extent on these people. Hence these people will have to be trained regularly and made aware of their importance in the scheme.

H.K. DURANDT.

ANNEXURE I

SWAZILAND SUGAR ASSOCIATION

CONTROL OF DISEASES

1. Inspection in the field

Large scale cane growers to employ personnel to inspect and mark diseased stools in each field.

The Sugar Association to employ an inspector for each of the two areas, whose duties will be to inspect and mark the fields of all quota holders. The training and administration of these inspectors to be carried out by the two mill estates with their expenses to be an industry obligation.

2. Eradication in the field

Growers to take out diseased stools as soon as they have been marked. Removal to be effected as recommended by the Extension Officer.

3. Variety purity in the field

Inspectors to investigate and report on the purity of varieties planted in all fields.

4. Reporting and records

Inspectors to report direct to the Extension Officer who will, in turn, report to the Mill Group Committees. It will be the responsibility of the Mill Group Committees to take appropriate action.

Each grower to maintain a "smut file" which will contain for each field, a full record of:

a) the date of an inspector's visit
b) the incidence of smut ascertained
c) the action taken in regard to eradication and the date of such action.

"Smut files" to be made available to inspectors and to the Extension Officer.

5. Control of seed

a) All seed nurseries to be registered in writing with the Sugar Association and to be planted with heat-treated seed only.

b) The Sugar Association to be given advance notice in writing of a grower's intention to sell seed.

c) The prohibition of seed either for planting or for sale unless it has been heat-treated, or is from a registered nursery.

d) Seed for sale to be accompanied by an official Inspection Certificate, issued by the Extension Officer, containing a guarantee only to the fact that an inspection has been made and that the seed appears to be true to type and free from disease.

6. Extension Officer

It being a normal part of the Extension Officer's duties to observe the incidence and location of disease he will, in addition, be required to report periodically to the Sugar Association on the results of the control system and to give his opinion of its efficiency.

7. Control

The Extension Officer to be the person responsible for the day-to-day control of the inspectorate staff and for the maintenance of such records as he considers necessary for the efficient operation of the system.

8. Discipline

In the event of non-co-operation by any grower, the Mill Group Committees to recommend to the Sugar Association such disciplinary action as they consider necessary. They may also draw the attention of the Sugar Association to the sanction contained in the Sugar Industry Agreement, clause 12 (2).

3rd April, 1969.

Annexure II

A SEEDCANE APPROVAL SCHEME

MAY 1970

THE EXPERIMENT STATION OF THE
SOUTH AFRICAN SUGAR ASSOCIATION

THE SOUTH AFRICAN SUGAR ASSOCIATION

SEEDCANE APPROVAL SCHEME

(1) The scheme shall be organised and administered by an industrial committee, comprising 1 grower representative, 1 miller cum planter, 1 seedcane inspector, not less than 2 professional members of the Experiment Station staff and 1 representative of a Seedcane Producers Association, as and when such an Association is formed.

(2) The committee will be advised on all technical matters by the representatives of the Experiment Station.

(3) The committee will actively promote the use by cane growers of healthy, good quality, disease-free seedcane.

(4) The committee shall have full authority to design, implement and control a seedcane approval or certification scheme, provided that it shall not have authority to insist that a commercial producer of cane shall be required to plant with approved "seed".

(5) (a) The scheme envisaged, involves the registration of a number of seedcane producers.

(b) These individuals or organisations, in order to qualify as producers of "Certified Seedcane", would be required to propagate seedcane according to prescribed standards so that, subject to the approval of the committee, it shall be certified reasonably free from disease and acceptably true to type.

(6) It shall be a condition of registration, that the seedcane producer shall accept production standards as laid down, and from time to time amended, by the committee. He will also, at any time, permit access to, and inspection of, his seed nursery, heat treatment plant, and ancillary equipment by seedcane inspectors (hereinafter referred to as "inspectors"). Furthermore, he will be obliged to accept the decision of the committee on the issue or otherwise of an approval certificate.

(7) No ceiling shall be placed on the amount of certified seedcane produced, provided that plans demarcating the limits of the nursery area are lodged with the committee, and the site inspected before planting.

(8) The issue of an "approval certificate" for seedcane will be subject to the following conditions:

(a) adherence to the conditions of site isolation, land preparation, selection of nucleus seed, heat treatment, planting, fertilizer use, management, roguing, harvesting and such other aspects of production as laid down from time to time by the committee, on the advice of the Experiment Station. (Current recommendations are given on page 2.)

(b) The provision of approval vouchers relating to the conditions outlined at (a) above.

(c) Provision of evidence that adequate precautions are being taken to prevent contamination or damage to seedcane during delivery.

(9) An approval certificate may be issued for all or part of the area registered for seed production, at the discretion of the inspector, but subject to approval by the committee (restriction of the area approved for production will be carried out only if some of the cane, or its management, is considered to be substandard).

(10) An inspector may suspend a certificate of approval for seedcane if, in his opinion, the terms of the approval scheme have been violated since issue of the certificate. This decision will be subject to approval by the committee at its absolute discretion, following representation by the registered seedcane producer.

(iv) Fertilizer shall be applied in accordance with, and at levels not less than, the recommendations of the F.A.S.
(v) Frequent and regular inspections should be carried out—rogue stools and plants suspected of harbouring disease being eliminated promptly and ruthlessly.
(vi) An authorised inspector will, at his own discretion, carry out at least two random check inspections. If he is not satisfied with the first inspection, he will notify the producer accordingly, explaining the shortcomings and granting him a specified period in which to comply with his recommendations.

THE INSPECTOR, WHEN HE IS SATISFIED THAT THE SEEDCANE IS ACCEPTABLY TRUE TO TYPE AND FREE FROM DISEASE, WILL ISSUE APPROVAL VOUCHER D.

(d) **Harvesting and disposal**
(i) Seedcane shall comprise only plant cane or a first ratoon crop and it shall be not less than 9 months and not more than 18 months old at the time of harvest.
(ii) The seedcane producer shall give the seedcane inspector not less than one month's notice of his intended date of cutting. He shall not proceed with harvest until his cane has been examined by an inspector, and he has received a certificate of approval.

THE INSPECTOR WILL ISSUE A CERTIFICATE OF APPROVAL FOLLOWING A FINAL INSPECTION OF THE CROP, PROVIDED THE PRODUCER HAS RECEIVED VOUCHER D, AND SATISFIES THE INSPECTOR THAT HE IS AWARE OF THE CONDITIONS GOVERNING HARVESTING, HANDLING AND TRANSPORT.

(iii) Harvesting of certified seedcane shall be conducted carefully, to prevent damage to cane buds.
(iv) The cane should be plucked, but, if cut by hand the harvester shall change knives after cutting each stool. A freshly sterilised knife shall be used for each stool by cleaning each knife with a brush after use and storing it in disinfectant solution.
(v) The inspector shall make at least one unscheduled inspection during harvest. If he, for any reason, is not satisfied with the quality of seedcane being issued or delivered as "certified seed" he is authorised to suspend further disposal as "certified seed". Subject to subsequent authorisation by the seedcane committee, the certificate of approval issued for some or all seed sold that season can be withdrawn, and the onus placed on the seedcane producer to inform his clients accordingly.
(vi) The seedcane producer must ensure that arrangements for transport, where he undertakes delivery, safeguards the seedcane against damage and infection. Failure to do so renders him liable to withdrawal of his seed approval certificate.

CONDITIONS GOVERNING THE PRODUCTION OF HEAT-TREATED CERTIFIED SEEDCANE

(a) "Heat treated certified seedcane" is a grade of seed material suitable for the establishment of seedbeds. It is freshly heat treated, and guaranteed to be reasonably free from disease and acceptably true to type. No guarantee is provided of its germinative capacity.
(b) Guaranteed "heat treated certified seedcane" shall be produced and disposed of only by registered seedcane producers.
(c) Guaranteed "heat treated certified seedcane" shall invariably be issued under the name, or the brand name, of the registered seedcane producer.
(d) The seedcane used to produce this grade of seed material shall be certified in terms of the S.A.S.A. Seedcane Approval Scheme. If chopped into setts, either before or after heat treatment, the implements used must be repeatedly washed with disinfectant.
(e) The certified seedcane shall be immersed in hot water in a suitable tank for a period of two hours at a uniform temperature of 50.5°C $\pm$ 0.5°C (123° F $\pm$ 1° F). The tank shall be of approved design and shall be fitted with automatic temperature recording equipment—the temperature records being retained for inspection at any time.
(f) The heat treated cane shall, following heat treatment, be immersed briefly in a tank of cold water containing a defined quantity of an approved fungicide and insecticide.
(g) The registered seedcane producer must provide the inspector with details of the source of his certified "seed" and permit inspection of harvest, purchase, and disposal records for seedcane. He will also inform the inspector of his seedcane preparation and treatment programmes well in advance of actual operations. The inspector shall make at least one unscheduled inspection of the production operation.

THE INSPECTOR, PROVIDED HE IS SATISFIED WITH THE RESULT OF HIS INSPECTIONS, WILL ISSUE A CERTIFICATE, INDICATING THAT A PRESCRIBED TONNAGE OF CANE HAS BEEN RELEASED FOR DISPOSAL AS "HEAT TREATED CERTIFIED SEEDCANE".

CONDITIONS GOVERNING THE PRODUCTION OF CERTIFIED SEEDCANE

I. THE REGISTRATION OF SEEDCANE PRODUCERS

(a) The applicant shall, not less than two months before planting is programmed, provide the industrial seedcane committee with:
   (i) evidence that he can provide facilities sufficient to enable him to comply with the regulations laid down herein;
   (ii) detailed maps, indicating accurately the location and extent of the nursery area;
   (iii) details of the use of the nursery site during the past two years;
   (iv) a signed and witnessed statement, on an approved form, stipulating that he will comply with the conditions laid down at para. 6 of the schedule "Seedcane Approval Scheme".

(b) The applicant shall permit inspection of the nursery site, at a time selected by the inspector, and will place sufficient staff at the inspector's disposal to allow him to check site location, suitability, and freedom from likely volunteer growth.

IF THE INSPECTOR IS SATISFIED THAT THE CONDITIONS LAID DOWN IN SECTION 1 (a) HAVE BEEN COMPLIED WITH, AND THAT THE SITE INSPECTED IS SATISFACTORY*, THEN HE WILL REGISTER THE APPLICANT AS AN AUTHORISED SEEDCANE PRODUCER BY ISSUING APPROVAL VOUCHER A.

* Suitability of site shall be determined by:
(1) its accessibility
(2) its isolation, or the availability of artificial means of providing isolation
(3) its slope
(4) its soil

II. PRODUCTION STANDARDS

(a) **Site and Soil**
   (1) The boundary of the nursery or nurseries shall be clearly demarcated, and surrounded by a fence and by a guard zone which is left fallow, or planted with a crop which will not carry sugarcane diseases.
   (2) Land preparation shall not commence until recommendations have been received from the F.A.S., and minimum requirements complied with. Soil samples submitted for analysis should be labelled "For seed nursery recommendations".
   (3) The site shall be inspected during, or following its preparation.

THE INSPECTOR, IF HE IS SATISFIED WITH ARRANGEMENTS AND THE PREPARATION OF THE SITE, WILL ISSUE APPROVAL VOUCHER B.

(b) **Nucleus seed**
   (i) Care shall be taken to ensure that there is no mixing of varieties during selection, treatment or planting.
   (ii) "Heat Treated Certified Seedcane" a grade of seed material guaranteed in terms of the S.A.S.A. Seed certification Scheme, may be used as planting material without further treatment.
   (iii) Alternatively, and subject to subsequent heat treatment, certified seedcane or, if this is not available, selected cane which has been examined and approved for use by an inspector, shall be used as nucleus material.
   (iv) Certified seedcane, or other approved nucleus seed material, shall be immersed in hot water in a suitable tank for a period of two hours at a uniform temperature of 50.5°C, $\pm$ 0.5°C (123°F $\pm$ 1°F). *The tank shall be of approved design and shall be fitted with automatic temperature recording* equipment—the temperature records being retained for inspection at any time.
   (v) The seedcane producer shall notify the inspector well in advance of his scheduled planting dates.
   (vi) The registered seedcane producer must provide the inspector with details of the source of his nucleus seed, arranging for its inspection if it is not certified seed. He must also notify the inspector of his scheduled heat treatment and planting programmes, so that the inspector can conduct spot checks.

THE INSPECTOR, IF HE IS SATISFIED WITH THE SEED USED, ITS TREATMENT AND PLANTING WILL ISSUE APPROVAL VOUCHER C.

(c) **Management**
   (i) Strict precautions shall at all times be taken to exclude stray animals and unauthorised persons from the nursery.
   (ii) Implements and tools shall always be thoroughly cleaned before being taken into the confines of the nursery.
   (iii) Weeds shall be effectively and regularly controlled.

SOUTH AFRICAN SUGAR INDUSTRY

AGRONOMISTS' ASSOCIATION

ESTIMATED RECOVERABLE SUGAR % CANE

(E.R.S. % cane)

(Extract from Submissions to the Commission of Inquiry into the Sugar Industry, December, 1968)

A condition for a fair payment system is that cane should be evaluated according to its content of recoverable sugar. In this respect it is proposed that this sugar shall be defined as a Standard Sugar of 98.7° pol and 0.23 safety factor.

It is a fact that the yield of sugar which can be recovered from cane (Recoverable Sugar) is based on;

(i) the sucrose content of the cane, as sucrose will render sugar when crystallised;

(ii) the fibre content of the cane, as fibre in the form of bagasse will carry away some sucrose;

(iii) the non-sucrose content, as the non-sucrose causes the formation of molasses which also contains sucrose.

Hence sugar cane having a sucrose content of S%, a fibre content of F%, and a non-sucrose content of N%, will yield a percentage of Recoverable Sugar (E.R.S.) in accordance with the general formula:

Estimated Recoverable Sugar % Cane (E.R.S. % Cane) = $aS - bN - cF$

a, b and c are factors related to direct losses of sucrose, and the effect of non-sucrose and the effect of fibre respectively in cane on the recovery of the Standard Sugar.

In practice, the factors a, b and c can be based on the actual weighted average performance of all factories in the South African Sugar Industry over the last 10 years, and this has been done in the next paragraph to derive the proposed 'van Hengel' formula for cane evaluation. A similar formula can be derived using data relating to the performance of an "ideal" sugar factory and this has in actual fact been done and is available to the Commission, if required. The fact that the 'van Hengel' formula proposed in this report is based on the average performance of sugar factories over ten years is by no means fundamental to the principle involved. In actual fact the millers strongly recommend that the 'van Hengel' formula should be reviewed at regular intervals, say three to four years, in order to ascertain that the various constants used are correct from the point of view of the latest technology and analytical procedures.

The 'van Hengel' formula for cane evaluation

The average factory performance figures over the last ten years resulted in the following data:

Sucrose % cane	=	13.50
Purity of cane juice	=	84.38
Fibre % cane	=	15.50
Sucrose % bagasse	=	2.41
Moisture % bagasse	=	52.96
Purity last expressed juice	=	73.87
Purity of final molasses	=	39.78
Combined loss of sucrose in filter cake and "undetermined"	=	1.85%
Ratio $\frac{\text{non-sucrose final molasses}}{\text{non-sucrose in mixed juice}}$	=	0.82*
Ratio $\frac{\text{non-sucrose in final molasses}}{\text{total non-sucrose in cane}}$	=	0.72

* As the proportion of non-sucrose in sugar is small, it has been justifiably ignored for the purpose of these calculations.

The 'van Hengel' formula is derived from the equation which has been stated above:

E.R.S. % Cane = aS - bN - cF

(i) The factor a is based on the direct losses of sucrose in the filter cake and undetermined losses. From the above data this amounts to 1.85%.

Hence, only 100 - 1.85 = 98.15% of sucrose is recoverable even if no losses occurred in molasses and bagasse.

<u>This means that for each part of sucrose in cane only 0.9815 parts are available for crystallisation.</u>

(ii) The factor b is based on the ratio of the sucrose lost in final molasses to the non-sucrose content of the cane and can be calculated as follows:

Sucrose % non-sucrose in molasses

$$= \frac{\text{Purity of final molasses}}{100 - \text{Purity of final molasses}} \times 100$$

$$= \frac{39.78}{100 - 39.78} \times 100$$

$$= 66.1\%$$

Hence, percentage of sucrose in molasses to non-sucrose in cane

$$= \text{Sucrose \% non-sucrose in molasses} \times \frac{\text{non-sugar in molasses}}{\text{non-sugar in cane}}$$

$$= 66.1 \times 0.72$$

$$= 47.6\%$$

<u>This means that for each part of non-sucrose in cane 0.476 parts of sucrose are lost in molasses.</u>

(iii) The factor c is based on the ratio of the sucrose content in bagasse to the fibre content of cane and can be calculated as follows:

Brix % bagasse $= \frac{2.41}{73.87} \times 100$

$= 3.26\%$

Non-sucrose % bagasse $= 3.26 - 2.41$

$= 0.85\%$

Fibre % bagasse = 100 - moisture % bagasse - brix % bagasse

$= 100 - 52.96 - 3.26$

$= 43.78\%$

Hence, the percentage of the sucrose in bagasse to the fibre in bagasse

$= \frac{2.41}{43.78} \times 100$

$= 5.50\%$

This means that for each part of fibre in cane 0.055 parts of sucrose are lost in bagasse.

On the basis of (i), (ii) and (iii), the percentage of pure sugar crystals recoverable from cane is shown by the equation :

Recoverable Pure Sugar Crystals % Cane

$= 0.9815S - 0.476N - 0.55F$

In practice sucrose is not recovered as pure sugar crystals, but as a Standard Sugar of 98.7° pol and 0.23 safety factor. The percentage of pure sugar crystals in Standard Sugar is 98.039%.

As the Estimated Recoverable Sugar % cane is defined in terms of a Standard Sugar which is equal to pure sugar crystals % cane divided by 0.98039 :

Then E.R.S. % Cane $= \frac{\text{Recoverable Pure Sugar Crystals \% Cane}}{0.98039}$

$= \frac{0.9815S - 0.476N - 0.055F}{0.98039}$

$= 1.0011S - 0.4854N - 0.0561F$

This is the 'van Hengel' formula, where factor a = 1.000, factor b = 0.485 and factor c = 0.0561 which, for the sake of simplicity, and without loss of accuracy can be rewritten as follows :

$$\text{E.R.S. \% Cane} = S - 0.485\left(N + \frac{F}{8.5}\right)$$

SOUTH AFRICAN SUGAR INDUSTRY

AGRONOMISTS' ASSOCIATION

CANE PRODUCTION PROBLEMS TODAY

1. Availability and quality of labour.

Urban and industrial demand put agriculture at a competitive disadvantage on the labour market. Shortages exist of fit and capable young men on the farm.

Working conditions and rates of pay are unattractive.

These conditions are creating a trend towards a farm labour force consisting largely of the old, the young and women, none of which are ideally suited to highly intensive farming systems where skill and application are vital.

The need now exists for comprehensive training schemes (particularly for machine operators) to increase skill and efficiency on the farm.

Improved pay structures with more attractive bonus systems for payment on improved quality and performance of workmanship are inevitable.

The aim must be towards a smaller, more skilled and efficient labour force with favourable working conditions.

2. The poor performance and lack of uniformity on many of our sandy soils.

The problem of poor, patchy growth on a wide variety of basically sandy soils is familiar to us all.

It occurs at high altitude, along the coast and in irrigated valleys, in soils which have only one thing in common - high sand fraction and low clay content.

It is very unlikely to be the result of poor states of N, P or K, and pH is usually within normal accepted limits.

Neither drought conditions nor bad drainage provide a satisfactory solution as the phenomenon is just as marked under conditions of good irrigation on these soils.

Trace elements, with the possible exception of zinc, appear to be in no way limiting growth.

One possible and promising factor now being investigated is the control of nematodes by soil sterilization in these sands.

Initial trials have been quite successful under these conditions.

Could it be, however, that there is a more complex chemical problem involved?

3. Insufficient attention to management problems

Few farmers keep adequate records of field performance and farm finances.

This in time means there is little attention given to advanced planning.

Decisions are frequently made hastily and the lack of sufficient time could mean reduced efficiency.

Better field records should give us more reliable information on adaptation of varieties to particular conditions; length of cutting and replanting cycles; and fertilizer practice.

Careful recording of all financial matters should result in more efficient utilization of labour and machinery; advanced budgeting and planning; and control of costs.

Decisions are then premeditated and reliable.

A.B. TUCKER.

3rd November, 1970
ABT/MH.

SOUTH AFRICAN SUGAR INDUSTRY

AGRONOMISTS ' ASSOCIATION

The agronomist or extension officer and the grower do not always agree as to what are the most important problems of cane production. A recent survey in the Midlands - South Coast district established that the following aspects were considered to be the major problems of cane production by a cross-section of growers:

i) A shortage of labourers or poor quality labour was mentioned by half the growers.

ii) Pests and diseases (primarily R.S.D.) were also mentioned by nearly half the respondents.

iii) Poor and inefficient rainfall and low production.

P. DOVEY.

SOUTH AFRICAN SUGAR INDUSTRY

AGRONOMISTS' ASSOCIATION

CANE PRODUCTION PROBLEMS TODAY

These notes represent the view of one miller-cum-planter on the subject. They are written in the first person by the Agricultural Manager of an estate with 12,000 hectares under cane and smaller areas under alternate crops.

I believe that my biggest problem in cane production today is to put into practice present knowledge. We have a great deal of know-how obtained through research work but a time lag of more than two years is experienced before this knowledge is effective in practice. The problem can be solved by training. Training not only in new methods but also in management principles. One must - overcome resistance to change; motivate the operators into accepting and even enthusing about new methods; and finally train operators to perform their tasks efficiently and effectively. Cane production problems for which the above lag exists at Tongaat are:-

Preparation

(i) Deep tillage principle,

(ii) Eradication of the old crop,

(iii) Conservation in very steep land.

Cultivation

(i) Optimum frequencies of either hand weeding, cultivation and use of herbicide,

(ii) Correct understanding, use and supervision of certain sophisticated operations, such as herbicides and fertilizer application.

Harvesting

(i) Training and motivation of cane cutters to perform to satisfactory standards,

(ii) Planning of harvesting programmes to achieve optimum efficiencies in all post harvest operations as well as satisfying the sucrose/maturity position of individual varieties and fields.

General Labour

(i) Efficient tasking of labour and machines to achieve satisfactory standards of output.

Note:

1. I feel that most of the above can be solved by a combination of organisational adjustments and training.

2. Several agronomic problems also exist on the estate. These include:-

   (i) Control of trash grub,

   (ii) Specific soil fertility problems, such as weak areas and acid chlorosis,

   (iii) Variety problems (NCo.376 is the only really satisfactory variety growing at present),

   (iv) Cane growth on weak coastal sands.

J.N.S. HILL.

SOME APPLICATIONS OF OPERATIONAL RESEARCH TO AGRICULTURE, WITH SPECIFIC REFERENCE TO THE SUGAR INDUSTRY.

Text of a Lecture given to the S.A. Sugar Industry Agronomists Association - at S.A.S.A. Experiment Station, Mount Edgecombe, on 2nd December, 1970.

R.G. HOEKSTRA
Operational Research Dept.,
Huletts Sugar Limited,
Mount Edgecombe.

SOME APPLICATIONS OF OPERATIONAL RESEARCH TO AGRICULTURE, WITH SPECIFIC REFERENCE TO THE SUGAR INDUSTRY

SUMMARY:

The object of this lecture is to give an idea of what operational research is and how it can be applied to agriculture in general and to the sugar industry in particular. The following subjects are dealt with:-

1. Description and objectives of operational research.

2. General applicability of operational research.

3. Main steps in applying operational research.

4. Some operational research techniques are described by way of illustrative examples, and several examples of their applications are given:-

   i) Monte Carlo simulation.

   ii) Applied mathematical statistics.

   iii) Linear programming.

5. Conclusion.

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1. DESCRIPTION AND OBJECTIVES OF OPERATIONAL RESEARCH

Illustrative Example:

Before attempting a definition of Operational Research, the following example might be helpful in obtaining an understanding of the concept of Operational Research: Refer to Figure 1. A piece of sheet metal ABCD, 2 metres by 2 metres, is to be made into an open box by cutting out the shaded areas, folding on the dotted lines and welding the seams. The objective is to construct a box with the maximum possible volume for the given size of sheet metal. To achieve this, 3 different methods are available:

i) Construct a variety of such sheet metal boxes, all with different dimensions, measure the volume of each by filling with a measured amount of water, and choose the box with the highest volume.

ii) Construct scale models of the boxes out of water proof paper, and again determine the volumes by filling with measured amounts of water.

iii) Letting the height of a side = y, the size of the base of the box would be a square of size (2 - 2y) metres, and the volume will = y(2 - 2y) (2 - 2y).

2/Trying........

Trying various values of y, the volume of the box can be calculated in each case. A better method however is available which will directly give the best value of y. When the expression is multiplied out, we obtain:

$$\text{Volume} = 4y - 8y^2 + 4y^3$$

Differentiating the expression and putting = 0, we have:

$$4 - 16y + 12y^2 = 0$$

For a maximum or minimum, the derivative of volume with respect to y has to be = 0. The value of y which will let the derivative = 0 will be the height of the side which provides the highest volume. The roots of this equation can easily be obtained by factorisation, being y = 1/3 or 1. The latter answer is obviously not possible for a maximum and does in fact give the value of y for minimum volume. The correct answer therefore is y = 1/3, i.e. the height of the side must equal 1/3 metre.

The above three methods can respectively be generalised as:

1. Experimenting with the actual physical situation.

2. Experimenting with a physical model of the situation.

3. Experimenting with a mathematical model of the situation.

It is obvious that, of the three methods listed, the third one is the cheapest and provides results the fastest.

The mathematical model in this case was the equation:

$$\text{Volume} = 4y - 8y^2 + 4y^3.$$

Definitions:

In general a mathematical model of a situation is developed from first principles of physics, chemistry and physiology, etc. and modified where necessary so that, when subjected to the same imaginary environment and operating conditions, i.e. to the same inputs, it will yield approximately the same results as the actual situation.

Naturally, a model should be designed to simulate only those variables which we are interested in, otherwise it would become unnecessarily complicated without serving any useful purpose. In the above example, there would have been no point in introducing the weight of the box as an output variable, or the hardness of the steel as an input variable.

There are many definitions of Operational Research, but one which I like is:- Operational Research is the application of techniques of mathematical analysis to systems, with the objectives of obtaining a better understanding of their operation and/or finding out how the systems can be made to operate in a more favourable manner.

3/This......

This immediately begs the question: What is meant by "system"? This could be defined as:

> A system is the organised interaction of a number of functions within a given environment to produce certain results.

The method of payment for sugar cane; the procedure for progressing an order through an engineering workshop; the method of deciding on the number of ratoons for a cane field are all examples of systems.

Referring to the illustrative example, one can see that the third method most closely corresponds to the definition of Operational Research. The system was the way in which the volume of the box changed with height of side, the objective was to find what value of height of side provided the greatest volume, and mathematical analysis (compiling a mathematical model and finding the optimum by differential calculus) was used to obtain the answer.

At the outset, a word of warning must be given regarding the accuracy of mathematical analyses and modelling. In the above example, the mathematical method is quicker and cheaper, but does not provide a 100% exact answer, as we did not take account of the thickness of the plate nor of the volume of weld metal. In most real life systems or situations which the Operational Research worker encounters it is not possible to obtain a fully accurate mathematical representation, because the exact mathematical relationships are not be known, because there are unpredictable outside disturbances influencing the system, or because the mathematical representation of the system is so complicated that it has to be simplified (thereby sacrificing accuracy) to enable solution of the problem. When deciding whether or not to use Operational Research on a given problem, one has to balance the speed and cheapness of obtaining relatively inaccurate answers by mathematical analysis against the greater cost and delay of using the actual physical system or a physical model of the system to provide more accurate answers.

2. GENERAL APPLICABILITY OF OPERATIONAL RESEARCH:

Operational Research can suitably be applied to systems which are very complicated; in which there are a number of variables, which might often be conflicting; where there are several constraints on the system; and where there are many combinations of alternative courses of action. The larger and the more complex a system is, the more opportunities there will usually be for economising and increasing efficiency, but the harder it will be to find the optimum combination of operating conditions, and this is where Operational Research comes into the picture. On the industrial side, one will usually find it in the larger firms producing several products, having a number of factories, often in different geographical locations, and having a high degree of vertical integration (meaning that many of the processes from raw material to final consumer are controlled by the same firm). Besides providing a greater potential improvement in profitability, their

4/size.....

size also makes it easier to bear the additional overhead costs of an Operational Research Department. It follows that in small, single purpose firms, there will usually be little scope for Operational Research.

On the agricultural side, farming operations are generally done on a relatively small scale, with the farmers all working independently, For this reason, the agricultural applications of Operational Research have been relatively few compared with industrial applications. It is interesting to note that a number of applications have been made in Russia and other communist countries with collective farms, where the large scale integrated operations provide scope for Operational Research. The fact that Russian agricultural output often fails to achieve its target should not be regarded as a failure of Operational Research, but rather as an indication of the disincentives of collective farming.

In the West, forestry has been a good candidate for Operational Research. It is usually governments or large corporate bodies such as paper or lumber companies who own and harvest the tree farms. These plantations represent large investments, which will only be realised in many years' time. The slow response time of the system makes experimentation on the actual physical system very risky, because the consequences of a wrong decision will only become apparent very much later.

Another branch of agriculture where use has been made of Operational Research is sugar cane growing. The sugar milling companies, which usually are large, often possess large areas of their own sugar cane estates, and even where the cane is supplied by private farmers, the economics of sugar growing and milling are such that there is a closer bond and a greater incentive for co-operation between sugar cane growers and millers than is the case with most other grower/processor combinations.

It should be pointed out that mathematical modelling is often used in cases where it is not feasible at all to experiment with the actual physical system. For example, when developing defence systems during peace time, it would not be a good idea to start a war for the sake of testing out the system. In other cases, the response of a system is so slow and the changes in its environment so rapid that simple observation of the outcomes of any action taken will not provide much useful information on how favourably or unfavourably the operational variables affect the results.Analysis of a realistic mathematical model will show which are the important variables. An example of such systems is the performance of a blast furnace in a steelworks, with the quantities, proportions and quality of raw materials varying during the process and all affecting the composition, temperature and output rate of the molten iron coming out several hours later.

3. MAIN STEPS IN DOING OPERATIONAL RESEARCH ON A PROBLEM.

i) Assuming that a problem is known, it must be possible to obtain a mathematical expression or model for the operation of the system. This is easier said than done, and represents the major source of expenditure of time and money in any operational research project. Much effort is spent on collecting the historical operating statistics of the system and in developing a mathematical model which fits the statistics.

5/(ii)As.....

ii) As the objective of Operational Research usually is obtaining the optimum set of operating conditions of a system, this information should be available from the model. First of all, it is necessary to express the result which has to be optimised in a quantitative form, and this expression has the name <u>objective function</u>. In the box example, the result which has to be optimised, namely maximised, is the volume. The objective function is $4y - 8y^2 + 4y^3$. In the case of business enterprises, the objective usually is to maximise total profit, so that the units of measurement of the objective function will be money, once again showing that, although money is not everything, it is way ahead of whatever comes second.

When analysing the future operations of a system which has to operate over a period of several years, such as a tree farm, the objective should be to maximise total nett discounted cash flow into the organisation rather than to maximise total profit over the years, the principle being that possession of a given number of Rands available now is worth more than the same number of Rands at a future date, because their availability can earn additional money when invested, or alternatively save having to pay interest.

In less mercenary applications of Operational Research, such as for sociological purposes, the objective function might be the minimisation of road accidents or the minimisation of unemployment, one of the constraints on the system usually being the amount of money which the poor tax payer has available to finance these noble objectives. On the other hand, in military applications, the objective might be to sink the maximum number of enemy ships.

One should always try to obtain the optimum value of the objective function by direct means, such as by differentiation in the above sheet metal example. Unfortunately, this is not always possible, and methods of trial and error have to be resorted to, designed in such a way that the amount of trial and error calculation is kept to a minimum.

For both the fitting of the data to the mathematical model and the determination of the optimum conditions, a computer is an extremely useful tool. In many applications the amount of manual calculation would have been so great that it would have cost more to perform the optimisation calculations than the savings resulting from optimisation would have been worth, plus the fact that by the time that the answer was available, conditions might have changed so much that it no longer was valid.

4. <u>SOME OPERATIONAL RESEARCH TECHNIQUES</u>:

There is a variety of Operational Research techniques available, but only three of the more important will be discussed. They are:

i) Monte Carlo simulation.

ii) Applied mathematical statistics.

iii) Linear programming.

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The type of technique chosen will depend mainly on the nature of the problem, but sometimes there is a choice, depending on which techniques the researcher is most familiar with and what auxiliary facilities such as computers are available.

i) Monte Carlo simulation:

In real life one finds that in most systems the outputs are not predictable or consistent, because there always are outside influences affecting the variables under consideration, and such influences are either not known or any attempt to take them into account would complicate matters too much.

This type of system is modelled by a technique called Monte Carlo simulation, in which the idea is to deliberately let the variables in the model vary in a random manner, the randomness taking on the same pattern as in real life.

Illustrative Example:

Trucks with sugar cane arrive at a mill in a random manner. The inter-arrival times between trucks can be anything from 1 to 6 minutes, and each inter-arrival time has an equal probability of occurring. There is one crane available at the mill, and the handling time can be anything from 2 to 5 minutes, each with an equal chance of occurring. Furthermore, the two sets of time distributions are independent of each other, and we shall assume that times are rounded off to the nearest minute . . .

The average inter-arrival time of the trucks, therefore is $3\frac{1}{2}$ minutes, and the average handling time for the crane is also $3\frac{1}{2}$ minutes. If it had not been for the element of random variation, the frequency of truck arrivals and the handling time of the crane would have been perfectly matched, and there would have been no queueing of trucks nor idle time of the crane. Due to the unpredictable variations however, these two variables often do not balance, and the result is that queues of trucks sometimes tend to form. In this example, Management have thought of either modifying the crane so that the average handling time is reduced by 1 minute, or obtaining a second crane. Before spending any large amounts of money, they want an idea of by how much the waiting times of the trucks would be reduced. The first step is to simulate the existing system.

In this particular example, the random times can very easily be simulated by throwing a die. The six faces of the die can represent the six possible inter-arrival times. The values 2 to 5 on the die can represent the handling times. If the die is thrown for handling time, and a 1 or a 6 appears, that throw is considered invalid, and the die has to be thrown again. In Figure 2 a tabular representation of the simulation is given. It is assumed that operations commence at the beginning of the first minute, when truck number 1 has just arrived.

The die is thrown to obtain the handling time, and thereafter the inter-arrival time and handling time are alternately determined from the die. The last two columns record when a truck is waiting and being off-loaded respectively.

The process is repeated over and over again, and when the cumulative truck waiting time and the cumulative crane operating time in relation to the total time elapsed tend towards constant values, we know that we have repeated it often enough to obtain reliable values.

The ultimate test of the value of this simulation is to then compare the average truck waiting time and the percentage time utilisation of the crane thus obtained with actual values recorded from the existing system.

If we are satisfied that our model is correct, we can re-run it by simulating the handling times of the modified crane and again re-run it by using two cranes instead of one, in each case determining the average waiting time of the trucks. It then is a simple matter to calculate whether the financial savings in waiting time make the investment in improved handling equipment worth while.

It is obvious that on the one hand, this method could save the unnecessary expenditure of large amounts of capital by pointing out which alternatives are not worth while, and, on the other hand, can show the way to greater efficiency where Management might otherwise have been hesitant to spend capital for fear that the returns might not justify it.

In practice, the simulation problems are not as simple as the above. The frequency distributions of the random variables will usually not be simple rectangular distributions (Figure 3(a)) as in the above example, but the frequency distribution of inter-arrival times might be something like the shape in Figure 3(b), and for crane handling times it might look like in Figure 3(c). Also, the system might be far more complicated. The truck loads might vary, also in a random fashion, and there might be several existing cranes with different handling time frequency distributions and where one has to take account of the cranes getting into each other's way. To perform the simulation by hand becomes an impossible task, but it is an ideal application for a computer. The computer is well suited to perform repetitive processes such as the arrivals of successive trucks, can test for conditions such as whether or not a given crane is available, has sufficiently large storage capacity to record the past and present status of each truck and each crane, and it can be programmed to produce random variables conforming to any given frequency distribution.

Depending on how it is used, simulation does not always provide a direct optimum value, but it can be used to analyse the profitability of different alternatives, as in the above example.

8/The......

The reason for the name of this type of simulation should now be apparent. At gambling places, like the Monte Carlo, extensive use is made of random numbers such as generated by the throwing of dice or the turning of a roulette wheel. Likewise, this method of simulation is also based on random numbers.

1. EXAMPLES OF SIMULATION:

a) Queues of trucks at grain elevators;

This is essentially the same kind of problem as described in the above example. During harvest time in the U.S.A., especially in wheat growing areas in the Central Great Plains, truck queueing at grain elevators is a problem. The U.S. Department of Agriculature studied truck waiting times for three types of receiving systems at the grain elevators, using information from field studies and performing the simulation through the use of computers. From the information obtained on truck waiting times and costs thereof, the optimal capacities of receiving systems for different ranges of truck receipts were determined. In addition, by experimenting with this simulation model, several methods of improving truck receiving at country elevators were discovered. For example, in some situations it would be worth having more trucks than drivers, and parking the driverless trucks near the combines so that if the bin of the combine became full while the other trucks with their drivers were still waiting at the elevator, the combine could simply release its load into the driverless truck and then continue harvesting, instead of being held up. It was also found worth changing the working hours of the receiving crews at the elevator to fit in better with the harvesting operations. In other cases it was found cheaper to pay disgruntled farmers a waiting time compensation where their harvesting routine was upset because their trucks had to wait too long than to provide additional handling facilities for reducing the probability of such delays.

b) Insect Pest Control in Forestry:

In Canada the approach to controlling insect pests was usually to wait until the insect population reached pest level, and then to kill as many insects as possible. Data on weather conditions and the insect pest populations for over sixty years for the moth Bupalus piniarius was used in this study. The objective function was cumulative defoliation, which had to be minimised. The simulation model took account of variables such as the physiological responses of the insects to weather, the responses to overcrowding and the higher vigour of insects which survive a control programme. Because of the data limitations, variables such as net economic value of protection, prior damage, and timing of control had to be left out.

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In the computer simulation model, three different strategies were compared:

> The usual maximum possible control whenever densities reached pest levels; optimum strategy as suggested by one-stage look-ahead dynamic programming; and optimum strategy as suggested by two-stage look-ahead dynamic programming.

According to the simulation model, the latter two methods were superior to the first. In view of the variables which had to be ignored in this simulation, the investigators could not place sufficient confidence in the results, but further research might yet prove that the existing method of insect control was not the best one.

c) <u>Optimising output of Forestry Nurseries</u>:

The procedure which the British Foresty Commission use in their nurseries is as follows:

> The seed is sown in the nursery, and after one to two years the resulting seedling is transplanted, still within the nursery, and after another one to two years the resulting young plant is planted in the forest. This is shown schematically in Figure 4.

There is thus a delay of between 2 and 4 years from planting the seed in the nursery until the young plant is ready for putting into the forest. It is not easy to decide how much to sow at the beginning of each nursery cycle, because the yields from sowing and transplanting are variable, and the times required for these seedlings and transplants to reach the required sizes vary. Furthermore, the amounts of timber of various species to be harvested will vary according to the ruling market, and so will the demand for young plants to replace the harvested trees. In the past, the policy had been simply to over-produce seedlings and young plants at the nurseries to ensure that there would not be a shortage at planting time. Usually this was wasteful, and the Forest Commission compiled a simulation model of the supply and demand of young plants. A certain amount of flexibility was also available in that each of the two nursery stages could be of either one or two years' duration. In this model the variability of yields in the nursery processes was also simulated.

This model showed by how far the nursery stock levels could safely be reduced, and has led to a significant reduction in production costs.

d) <u>Simulation of Sugar Harvesting Operations</u>:

A very ambitious simulation model has been derived by Sorensen and Gilheany of the Matson Research Corporation, applicable to the Hawaiian Sugar Industry. The setup is that the sugar cane is harvested mechanically in the fields, is taken by road transport to the mills, which then further process it. Harvesting, transport and milling operations are often interrupted by unpredictable disturbances causing delays and under-utilisation of resources.

One of the major problems is rainfall at inopportune times. As part of the overall simulation model, a rainfall model covering the entire sugar producing area under examination of 5 miles by 14 miles was constructed. Not only will the model simulate rainfall at a given point with the same probability of occurrence and amount of rain as in nature, but other points in the neighbourhood show the same probabilistic rainfall correlation as in the actual situation.

The disrupting effect of rainfall is twofold: With moderate rainfalls, the amount of trash harvested with the cane increases (bearing in mind that mechanical methods are used), thereby reducing the effective capacity of the mill due to overloading of the cane cleaning section; and with heavy rainfalls harvesting operations have to cease, one of the reasons being that the soil is damaged through compaction from the harvesting machines. Sub-models were constructed to simulate the increase in trash per ton harvested with increased rainfall, and to simulate the probability of a rain-out in a field when subjected to a given amount of rainfall. Because for ratoon cane the damage resulting from compaction of the soil would be more severe, the rainout threshhold for ratoon fields was lower than for plant cane fields.

The sequence in which fields are harvested depends on their ages, If a field suffers a rainout when its turn comes, harvesting operations where possible, have to be temporarily shifted to the next field in the harvesting sequence. Delays in the transport of cane from the fields to the mill are caused mainly by truck breakdowns, queueing at the loaders and unloaders for cane, and end-of-shift stretching out of cycle times by truck drivers. The probability of a breakdown occurring in a truck is simulated on the computer, and so is the travelling time for each truck on its given route. Because the computer programme keeps track of each vehicle, the queueing at the cane loaders and unloaders can be simulated directly without having to introduce an artificial distribution of inter-arrival times.

The effect of trash in cane on the mill output capacity is taken into account in the mathematical model of the milling operation, and the probability of mill breakdowns occurring is simulated.

This overall model can be used in studies to evaluate alternative manning or equipment policies and rules. For example, one could try adding an additional cane hauler and see by how much that would reduce delays, or alternatively one could try increasing the capacity of the truck repair shop, thereby reducing the downtime of defective trucks.

11/Although....

Although the South African Sugar Industry operates under different conditions to the Hawaiian Sugar Industry, the same general principles could be applied to South African harvesting and transport operations. A start has already been made by analysing the cane yard operations at the Darnall mill, and this will probably eventually be expanded to include truck loading operations in the zones. With a suitable simulation model available, different methods and equipment can be tested and compared before committing the Company to any systems, changes or capital expenditure.

e) Determination of Optimum Crop Life and Number of Ratoons:

In his paper in the 1960 Proceedings of S.A.S.T.A., Mr. J.L. du Toit states that the optimum number of ratoons for a cane field occurs when the accumulated nett income from cane (taking account of planting, harvesting, fertilizer and other costs), divided by the total number of months that have elapsed since planting reaches a maximum. When applying this principle, the problem arises that the yield will not only depend on the weather which that crop received during its life, but also on the time of year that it was harvested. Furthermore, the date of starting a new ratoon crop is necessarily tied to the date of harvesting the previous crop, and the age that a crop reaches is influenced by the fact that, under most South African conditions, one full year is too short and two full years are too long for a good crop, so that the fields will tend to get out of step. If the behaviour of a number of fields can be simulated by the Monte Carlo technique, in which the rainfall is made to vary in the same random pattern as in nature, and if a mathematical model of the fields is available in which they respond to fertilizer application, time of year, age, rainfall and ratoon stage in a reasonably realistic manner, one could try out the effect of different ratooning, age and fertilizer policies. The more the problem of modelling a cane field is examined, the more formidable do the obstacles seem, but we have not yet given up hope.

Fortunately, a large amount of research has already been done by the S.A.S.A. Experiment Station, much of which is useful in our work, particularly as the research officers there have always been extremely helpfull in giving advice and information.

Over 1100 records of crops from our own estates dating back to 1963, have been collected, giving details of fertilizer, soil types, soil analyses, cane yields, sucrose yields, and ages have been collected and stored on computer disc, from where they are easily available for doing statistical analyses. At the same time, we are also doing cane maturity trials on a few selected fields in the Darnall area, where we regularly take samples of the cane, measure, weigh and trisect them and analyse the three segments for sucrose and brix.

One of the lines of attack being considered is to derive a generalised relationship for all fields, and modifying it to fit each individual field on the basis of its past performance.

12/(2)Applied....

2. APPLIED MATHEMATICAL STATISTICS:

Mathematical statistics could be described as "The Science of Probabilities". When applying mathematical statistics to any situation where there is uncertainty of a given event occurring, it does not mean that one can now predict whether it will occur, but one will at least know the probability of that event occurring.

In business life one has to cope with many uncertainties, where either the occurrence or not of an event is uncertain, or its magnitude is unpredictable. One of the main causes of uncertainty is human nature with all its inconsistency and fickleness. War, strikes, accidents, mistakes, absenteeism, consumer preferences all have a profound effect on industrial and commercial operations, but their occurrence or the magnitude of their occurrence cannot be predicted. Under these circumstances, the best thing that Management can do is to organise the enterprise in such a way that it can take maximum advantage of and be least adversely affected by the more probable or likely combinations of events. The enterprise will not be as well prepared to meet the less probable combinations of events, particularly when those combinations are unfavourable, but this is a calculated risk which has to be taken. Through the use of applied mathematical statistics, these probabilities can be calculated and Management formulate its policies accordingly.

Just like the business man, the farmer also has to cope with uncertainties, only in this case the main cause is unpredictability of the elements of nature, such as droughts, hailstorms, frost, insect pests and disease. As in the case of commerce and industry, the occurrence of an event cannot be predicted, but its probability usually can, provided that sufficient historical data is available, and the farmer or the agricultural concern should use this information to formulate the optimum policy.

Two examples of the application of mathematical statistics to agriculture follow:

a) Replacement Policy

One of the very many tribulations the motorist has to contend with is the problem of determining the optimum time to replace his present car with a new one, particularly as advice from car salesmen is not free from bias. The cost of a new car represents a large capital investment, with consequent high interest charges and high depreciation rate.

Against this, as the car gets older, its utility decreases, i.e. it costs more in petrol and oil to perform a given duty and the probability or risk of serious trouble occurring, necessitating expensive repairs or even scrapping the car, increases.

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It is easy enough to see the similarity between the above example and the problem which a farmer has of deciding whether to replace a tractor or a truck. The logic of the situation can however be extended much further to include production assets such as cattle, poultry and timber plantations.

When a dairy cow becomes older, it will deliver less milk and the risk of it contracting disease will probably increase.

If the cow is slaughtered while it still is healthy, the meat on its carcass will be saleable, if somewhat tough, but if the cow were to die from a disease, its "scrap" value will be considerably less.

In the case of a plantation, the rate of growth of timber and therefore growth of potential income will slow down, but when considering the risk of destruction by fire or pests, the amount at stake continues to increase.

To determine the optimum replacement date it therefore is essential to know the probability distribution of equipment failure, death, etc., and combine it with a discounted cash flow analysis. It is in the determination of distributions such as these, that the science of mathematical statistics is used.

Another important application of mathematical statistics is in the determination of the probability distributions necessary for performing Monte Carlo simulations, such as interarrival times, handling times, breakdowns, etc.

b) Probability of Rainfall Occurrence in the Natal Sugar Belt:

With the exception of the Mount Edgecombe area, most of the cane coming into Huletts' mills is dependent on rainfall. The two major factors which can affect the fortunes of sugar companies are the price for sugar and the weather. In the absence of being able to predict weather (long term, at any rate), it nevertheless is very useful to know the probability of a certain weather pattern occurring. Firstly, because it would enable the sugar company to calculate what financial contingencies to allow for in the event of unfavourable weather causing poor harvests, and secondly, because it would enable the company to select those areas which are more suitable for sugar farming from a weather point of view, and to use the less suitable areas for other purposes.

With the objective of obtaining rainfall probability distributions in mind, Dr. Sichel of the Operational Research Bureau analysed the monthly rainfalls for various estates of Huletts, going back over periods as far as 42 years.

When plotting a histogram of the number of times that the rainfall in a given winter month fell between certain limits, a result similar to that in Figure 5 (a) was obtained. For the summer months, a histogram similar to Figure 5 (b) was obtained. It was found that the gamma frequency distribution fitted these histograms very well. The shape of a gamma distribution curve is dependent on two constants, μ and k. μ is the arithmetic mean of the rainfall in that month, and

$$k = \frac{\mu^2}{(\text{Standard deviation of rainfalls})^2}$$

14/These....

These two constants, called parameters of the frequency distribution, can therefore easily be calculated from historical rainfall observations.

It is interesting to note that when k is equal to or bigger than 1, the gamma distribution takes on the asymptotic curve shown in Figure 5(a), and when k is bigger than 1, the hump curve shown in Figure 5(b). This meant that k was less than 1 in the drier winter months and bigger than 1 in the wetter summer months.

Next, the monthly values of u and k for a given estate, as obtained from historical rainfall data, were plotted. Smoothing out the values by a mathematical technique known as Fourier analyses, curves such as shown in Figures 6(a) and 6(b) respectively were obtained. For both μ and k, the minimum is reached in the winter months and the maximum during the summer months, but it should be noted that neither of the curves is sinusoidal. The "summer period" is longer than the "winter period" and whereas the peak for μ leans towards the right, the peak for k leans towards the left.

Having obtained the relevant gamma distribution for each month of a given estate by reading its parameters μ and k from the smoothed curves shown in Figure 6(a) and Figure 6(b), it is possible to calculate the probability that the rainfall in a given month (say September) will be less than a given amount (say 40 mm). In this way it is possible to plot month-by-month curves of constant rainfall (called isohyets) as shown in Figure 7. There is one such family of curves as in Figure 7 for each estate. By following the course of say the "Probability of more than 40 mm" curve, one can see that it is higher in the summer months than in winter, which is what one would expect.

The next step was to investigate whether the rainfalls of successive months were independent. For example, if the rainfall in February is higher than normal, could one expect the March rainfall also to be higher than normal as a result of carry-over effects, or could one expect it to be lower than normal because the heavens have been depleted of water, or will it be unaffected by the previous month's rain? The correlation coefficients for the rainfalls of pairs of successive months, taken over the 30 or 40 years for which data was available, were determined, but no significant correlation, positive or negative, was obtained.

It is therefore safe to say that the probability of a given amount of rainfall occurring in a certain month is independent of the rainfall in any other month.

If, say in August, the agronomist finds that, for the season to be successful, it is necessary to receive at least r_s mm rain in September, r_o mm rain in October, etc., the probability of such a successful season occurring can simply be calculated by reading the respective probabilities from the graph shown in Figure 7, and multiplying the probabilities. Because the rainfall probabilities for the individual months are independent, multiplication of the probabilities is legitimate.

3. LINEAR PROGRAMMING

Linear Programming is an extremely useful technique for deciding on the optimum usage of resources, subject to various constraints, when there are linear relationships governing the interaction of the resources. (Linear means that, when these relationships are expressed algabraically, each variable may only occur to the power 1. For example, $3x + 5y = 9$ is a linear relationship, $4 - 6y + 7y^2 = 0$ and $2x - 3xy = 4$ are non-linear).

Illustrative Example:

A farmer has 100 hectares of farmland available for planting crops. It is suitable for planting two different crops, A and B. There is a limit to the supplies of labour force he can obtain, there is a quota restriction on crop B, and a safety restriction on crop A. Assuming normal yields, and normal crop prices and production costs, the farmer has to decide which combination of crops, under the above restrictions, yields the maximum nett income.

Represent the area (hectares) under crop A by x_A and the area under crop B by x_B. The constraints under which the farmer has to operate will be examined one by one.

Obviously, the farmer cannot plant a bigger total area than the size of his farm. Therefore,

$$x_A + x_B \leq 100$$

If there has only been an = sign, this would have been the equation of a straight line, such as line NM in Figure 8(a). Because there is also a "less than" sign, the above relationship represents the entire area NOM below line NM, and is shown shaded in Figure 8(a) This means that any point (i.e. any combination of x_A and x_B) in the shaded area (including on the boundary lines themselves) will satisfy the above relationship.

The size of the farmer's labour force and the labour requirement of the respective crops are such that, when working only on crop A, the labour force could deal with a maximum of 80 hectares, and when dealing only with crop B, it could deal with a maximum of 120 hectares. Referring to Figure 8(b), these quantities are represented by points P and Q respectively. For any mixture of the two crops, the maximum that the labour force could do would lie somewhere on line PQ. The equation of line PQ is given by:

$$\frac{x_A}{80} + \frac{x_B}{120} = 1$$

This simplifies to $3x_A + 2x_B = 6$

Because the above equation represents the maximum output of the labour force, any amount less than maximum will also be possible (although not necessarily optimal). The equation should therefore be written as an inequality $3x_A + 2x_B \leqq 6$, which on Figure 8(b) will be represented by the area POQ.

Remembering that all feasible combinations of x_A and x_B should satisfy the area constraint (triangle NOM in Figure 8(a), and the labour constraint (triangle POQ in Figure 8(b)), only those points which appear in both areas will be feasible. This feasible area can be obtained by overlaying triangle NOM and POQ as in Figure 8(c). Area NOPR, where they overlap is then the feasible area which simultaneously satisfies the constraints on farm area as well on size of labour force.

There is a quota restriction on crop B, specifying that not more than 80 hectares may be planted. This gives rise to the following inequality:

$$x_B \leqq 80$$

Because crop A is a risky crop, the farmer prefers not to plant more than 60% of his farmland with crop A, i.e. not more than 60 hectares. Hence the following inequality:

$$x_A \leqq 60$$

The feasible area satisfying these two inequalities (disregarding for the moment the previous area and labour constraints) is given by all points below line ST and all points to the left of line TU, i.e. by all points inside rectangle SOUT. Because all feasible combinations of farm area allocations have to satisfy the above quota restriction and self-imposed restriction as well as the farm size and labour constraints, the area of feasible points is obtained by overlaying area NOPR of Figure 8(c) and area SOUT of Figure 8(b), giving SOUWRV, shown in Figure 8(e).

Having taken all restrictions into account, one now wants to find out which feasible combination of x_A and x_B, i.e. which point inside or on the border of SOUWRV, will yield the maximum income for the farmer. If the selling price per hectare produce for products A and B are R5,400 and R4,000 respectively, and the variable costs of production per hectare are R3,200 and R2,200 respectively, the nett income is given by:

$$\text{Nett Income} = (5400 - 3200)x_A + (4000 - 2200)x_B$$

This simplifies to:

$$\text{Nett income} = 2200\ x_A + 1800\ x_B$$

That what we want to optimise (maximum in this case) has been expressed in a mathematical form, i.e. this expression is the objective function.

For a given nett income, the objective function is the equation of a straight line, with

$$\text{Slope} = -\frac{11}{9}$$

Referring to Figure 8(f), one can draw a series of such straight lines, all with slope $= -\frac{11}{9}$. All combinations of x_A and x_B yielding points lying on the same straight line will be equally profitable. Obviously, the higher the values of x_A and x_B that can be put into the equation for nett income, the higher will be the nett income. Referring to Figure 8(f), the further to the upper right one chooses a line, the higher the nett income represented by that line. The logical thing to do is to find a line of slope $= -\frac{11}{9}$ as far as possible to the upper right, but which will still contain a feasible point, i.e. which will still represent a combination of x_A and x_B which will satisfy all the previous constraints. Such a line is C_1D_1 which touches the feasible area at point R. The x_A and x_B co-ordinates of point R therefore represent the sizes of area which the farmer should plant with crops A and B respectively to obtain maximum income.

If however, the selling price per hectare of produce of crop A had only been R4,200 instead of R5,400 the objective function would have been:

$$\text{Nett Income} = (4200 - 3200)x_A + (4000 - 2200)x_B$$

$$= 1000\ x_A + 1800\ x_B$$

The slope would then have been:

$= -\frac{5}{9}$, and the optimum solution would be where line C_2D_2 touched the feasible area at point V.

Such a simple problem could probably have been solved by applying common sense and elementary arithmetic, but when the situation becomes more complicated, such as when the number of alternative crops increases, or the constraints become more complicated, the problem becomes harder to solve intuitively. When there are three variables (say x_A, x_B and x_C), the problem has to be thought of in 3 dimensions instead of 2. The feasible points will now lie inside a flatsided solid body known as a polyhedron (a cube, a pyramid and a cut diamond are special cases of polyhedra, namely symmetrical ones), and the objective function is represented by a plane instead of a straight line. The co-ordinates of the point of the polyhedron which is touched by the objective function plane represent the optimum values of x_A, x_B and x_C.

When there are more than three variables, it is no longer possible to visualise, let alone solve, the problem graphically. Algebraic methods then have to be used, and fortunately the procedure is very well suited for solution by computer.

In Britain, a large supplier of agricultural chemicals has developed a comprehensive computerised program, based on linear programming, which is specially designed to assist farmers in planning their production.

EXAMPLES OF LINEAR PROGRAMMING:

a) Optimisation of production of granular fertilizer mixture:

Most fertilizer mixtures contain the three basic plant food elements, N, P and K. The manufacturers of granular fertilizer produce certain standard mixtures, where each plant food element has to be a minimum weight fraction per unit weight of mixture. As constituents for the mixture, the fertilizer manufacturer has anhydrous ammonia, urea, ammonium nitrate and ammonium sulphate as sources of nitrogen, normal super phosphate and double super phosphate as sources of phosphate, and potassium chloride as a source of potassium. In addition, there are some ammonium salts of phosphoric acids available, containing both nitrogen and phosphate.

These constituents all contain different percentages plant food, and have different prices per unit plant food.

To produce say 100 tons of mixture, the manufacture has to choose his components such that, for each plant food element, the total weight of element in the constituents will be at least equal to that prescribed by law. The amount of inerts (i.e. non-plant food) in the constituents must also add up to the total amount of inerts in the mixture.

An additional constraint is that, although ammonia is the cheapest form of nitrogen per unit plant food, it is volatile, and will only be stable when present in not more than a specified proportion to normal or double super phosphate. There also are similar constraints effecting the stability of the other nitrogen containing constituents. In addition, there might be constraints on the availability of certain of the components, which could include the possibility that where the manufacturer produces his own mixture constituents, his plant capacity might not be adequate.

19/Where.......

Where the size of the market is less than the capacity of the granulation plant, the amount that can be produced of each mixture will be constrained by the size of its potential sales, and the problem is to find the optimum (most profitable) combinations of components to produce the specified marketable products. If however, the output of the plant is the limiting factor, the problem will be to find which combination of products using which combination of components would yield the maximum profit.

The relationships and constraints and the objective function in this problem are all linear, and the problem lends itself very well to solution by linear programming. Several fertilizer manufacturers use this method.

When making cattle or chicken feed mixes, using components available at different prices and with different percentages of the necessary vitamins, minerals, etc.,the resulting mixtures have to conform to certain specifications. The problem of obtaining the optimum mixtures is essentially the same as the fertilizer mixing problem above, and is also ammenable to solution by linear programming.

b) Optimum Cane Diversions :

In the past, use has often been made of cane diversion in the sugar industry, by which the sugar millers economise on transport costs by exchanging growers' quotas among each other, and then sharing in the savings. It is easy enough to spot the obvious candidates for diversion, but there should be other profitable opportunities of diversion which are not so obvious. The possibility of using linear programming to decide on optimum cane diversions is at present examined.

As you may know, the principles involved in cane diversions are the following :

i) The sucrose quota for a farmer shall not be affected by any diversions. That means that, for each farmer, the sum total of all the sucrose diverted to various mills shall still remain equal to the total sucrose quota for that farmer.

ii) The total sucrose quota which any mill (or group of mills, where it is all part of the same company, such as Huletts) shall remain unaffected by diversions.
This means that, for each mill or group of mills, the total amount of sucrose which it receives from the quotas of other mills must equal the toal amount of sucrose which that mill donates to other mills from its own quota. The mills from which the cane is received, and to which the cane is given, will not necessarily be the same, because tri-lateral diversionary agreements will also be possible.

iii) No mill may receive more fibre than its milling capacity can handle. Quotas are based on tons sucrose, but a given amount of sucrose is not always associated with the same amount of fibre, because it can vary for different farmers, varieties of cane and regions grown.
The situation may not arise that the cane which a mill receives from other mills' quotas has a fibre content so much higher than the cane which it has donated to other mills that the total fibre to be milled exceeds the capacity of the milling train.

The objective is to find that set of diversionary agreements which will minimise the total <u>cane</u> (not sucrose) transport costs.

This problem lends itself very well to solution by linear programming. The relationships are all linear. For condition (i) there will be one equation for each farmer under consideration, for condition (ii) there will be one equation for each mill or mill group, and for condition (iii) there will be one "equal to or less than" relationship for each mill or mill group.

The objective function can easily be obtained if distances, transport costs per mile and the estimated sucrose percent cane figure for each farmers' produce is known. The problem can even be refined further to allow for diversions within a mill group from the less efficient to the more efficient mills.
Such a program could be run several times during a season to take account of shortfalls, redistributions of shortfalls, etc.
If this scheme were to be put into operation, many more farmers would be involved in cane diversion than at present, and it would probably be better to wait until the Sugar Industry is on the E.R.S. system of cane payment before implementing it. With the present Java Ratio System of payment, there are sure to be objections from farmers who do not want to send their cane to mills with a lower Java Ratio, and from millers who do not want to receive cane with a lower Sucrose-to-E.R.S. value than the cane which they have donated to other mills.

c) <u>Overall Optimisation Project for Huletts Operations :</u>

When considering that the Huletts group is involved in growing a significant portion of its own sugar cane, transports its own cane as well as that of many private farmers, mills it at five different mills, and is moving into the field of by-product manufacture, a complicated overall picture results.
There is obviously an endless variety of ways in which the system can be operated, but only a limited number of them will provide optimum profitability. Some of the factors which have to be taken into account are the following :

- The sucrose content, and even more so the E.R.S. content of cane varies from month to month during the season.
- The shape of the sucrose curve with time is affected by rainfall, over which one has no control; irrigation, choice of cane variety, and age of cane, over all of which one does have a certain measure of control.

- The capacities of the mills, transport systems and harvesting crews are limited so that not all cane can be harvested at the time of peak sucrose. Expanding the capacities could increase the sucrose yield, but will also increase the fixed costs of larger capacities standing idle for longer periods.

- There are government-imposed quota restrictions under which the system has to operate. If it can be shown that relaxation or modification of these constraints could produce overall benefits, the authorities might be agreeable to change.

- The mills have different recovery efficiencies, thermal efficiencies and variable costs of operation. They have different maximum capacities, and the bottle-necks in the production process will not be the same for each mill. Furthermore, the way in which the efficiencies drop with increase in throughput will also not be the same for all mills.

- Transport costs from a given estate or loading zone to different mills vary, mainly because of different distances.

- The way in which a mill is operated will affect the costs of production as well as the recovery efficiencies. Normally, the one should increase as the other increases, but usually the recoveries will tend to flatten out when the manufacturing costs are still rising. A good example is increasing the amount of imbibition water per unit weight fibre in a milling train.

- As the uses for bagasse as a by-product increase, it is no longer considered a waste product. Bought-out coal and oil will gradually have to take its place for generating steam, and as these fuels are not available free of charge, mill operating variables such as the level of imbibition water will have to be given closer attention.

- With the increasing emphasis on bagasse by-products, it might be worthwhile extending the milling season because the total sugar-plus-bagasse output of the mill plus the economies of not having to stockpile as much bagasse for the shorter off-crop might well offset the lower average sucrose % cane for the season. Also, when the sucrose content of cane is low, the fibre content usually is high, and with fibre becoming more valuable, this would also help to offset the reduction in sucrose yields. The farmers would of course have to be compensated for their loss of sucrose in cane.

To summarise therefore, the maximum profitability of this system depends on the optimum selection of:

i) Cane growing conditions.
ii) Time of harvesting.
iii) Destination of harvested cane.
iv) Operation of the sugar mills.
v) Marketing of the by-products.

The intention is to eventually compile a large linear programme of the entire system. Several sub-models will be needed, one of them being the simulation of yield of sugar cane and sucrose from fields when subjected to given conditions. A large amount of work has already been done on collecting field-to-mill transport data and costs.

Mathematical modelling of the mills is a large project and is expected to take several years. It will have to be done simultaneously with automation of the factory operations, because when the process is not operating steadily or when it is subject to human judgement or "art" of operation, such as pan boiling, it is difficult if not impossible to model the process. Automation will of course also provide side benefits such as more consistent quality, greater throughput of factory, lower manpower requirements, and higher recoveries.

This overall programme will naturally have to be done on computer. It might be run say every two months, when the constraints etc. are updated in conformity with the latest policies and when the sugar cane yield models are adjusted with the latest rainfall and yield statistics.

d) <u>The location of a New Sugar Mill and Pulp Mill for the Huletts Group:</u>

The existing mill at Felixton is very old, and Huletts are looking into the question of building a new mill in the Northern Zululand area. At the same time, thought also has to be given to expansion of the Ngoye Paper Mill at Felixton, as well as the eventual construction of a large new pulp mill. Important considerations in the location of a pulp mill are supplies of bagasse raw material, transport of the product pulp, provision of very large quantities of water and disposal of equally large quantities of effluent. Consideration must also be given to the possibility that the existing Empangeni mill might be expropriated when it gets in the way of urban expansion. Whether to close the Empangeni mill down prematurely, whether to centre all the existing production capacity of the existing Empangeni and Felixton mills at a new mill at Felixton, whether to expand capacity at the Amatikulu and Darnall mills, and where to place the new pulp mill, are all questions which will have to be answered in the near future, and linear programming will be used to assist in making this decision.

CONCLUSION:

Operational Research is still a young discipline, as it came into being during the Second World War, and it was only with the development of easy-to-use programming languages and special applications programmes for computers during the early 60's that Operational Research became a widely recognised technique for improving the operation of systems. One can therefore expect much development to take place in this branch of science, particularly in the applications to agriculture.

One last word of warning: When using Operational Research, one should never expect sensational improvements of the order of, say, 25%. The intuition and "feel for the job" of people who have been operating the system for many years will be so well developed that they will instinctively operate reasonably close to the optimum. The object of Operational Research is to gain that extra one or two percent. In a large organisation such a marginal increase can amount to a significant amount of money, and will well justify the relatively small overhead cost of having an Operational Research Department.

R.G. HOEKSTRA
Operational Research Dept.
Huletts Sugar Limited,
Mount Edgecombe.

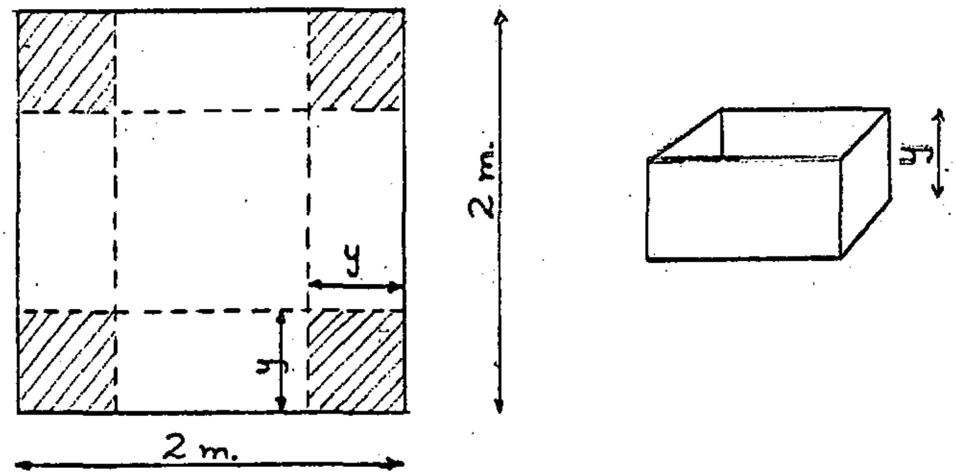


Fig. 1: Determining Optimum Shape of Box

Fig. 2: On Next Page

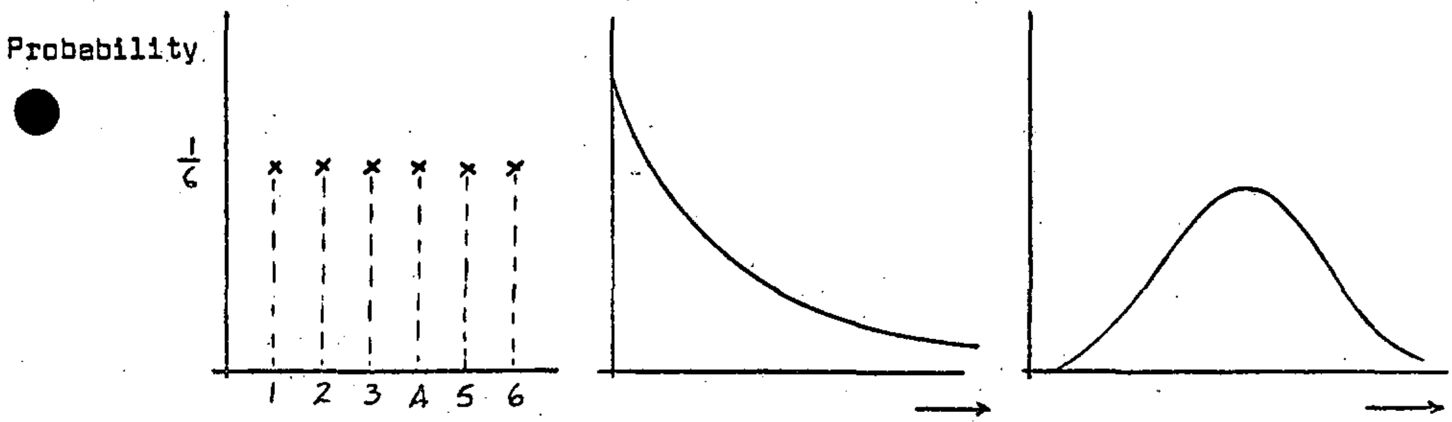


Fig. 3(a) Fig. 3(b) Fig. 3(c)

Different Probability Distributions

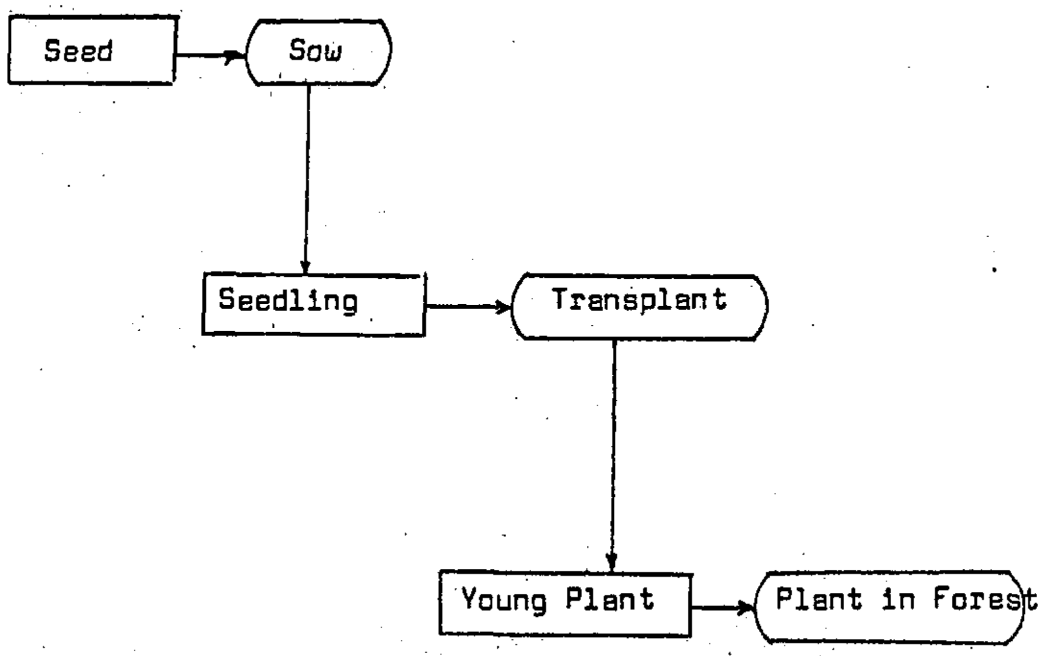


Fig. 4: Flow Diagram of Forestry Nursery Process

Figure 2

Monte Carlo Simulation of Mill Yard Operations

Truck No.	Clock	Int.Arr.Time (Since Previous truck)	Handling Time	Truck Waiting	Crane Working
(1) →	0				
	1		4		x
	2				(1) x
(2) →	3	3			x
	4		3	(2) x	x
	5				x
	6				(2) x
(3) →	7	4			x
	8		2		(3) x
	9				x
	10				
	11				
	12				
(4) →	13	6			
	14		4		x
	15				(4) x
(5) →	16	3			x
	17		5	(5) x	x
(6) →	18	2			x
	19		5	x	x
	20			(6) x	(5) x
(7) →	21	3		x	x
	22		2	x x	x
	23			x	x
	24			(7) x	x
	25			x	(6) x
(8) →	26	5		x	x
	27		3	x	x
	28			(8) x	(7) x
	29			x	x
(9) →	30	4			x
	31		2	(9) x	(8) x
	32			x	x
	33				(9) x
	34				x

No. of Trucks: 9
Total Waiting Time: 16 minutes
Average Waiting Time/Truck: 16/9 = 1.78 minutes
Total Time Elapsed: 34 minutes
Cane Idle Time: 5 minutes
% Crane Idle Time: 1.47%

CLIFTON ESTATE

Fig. 5(a): June

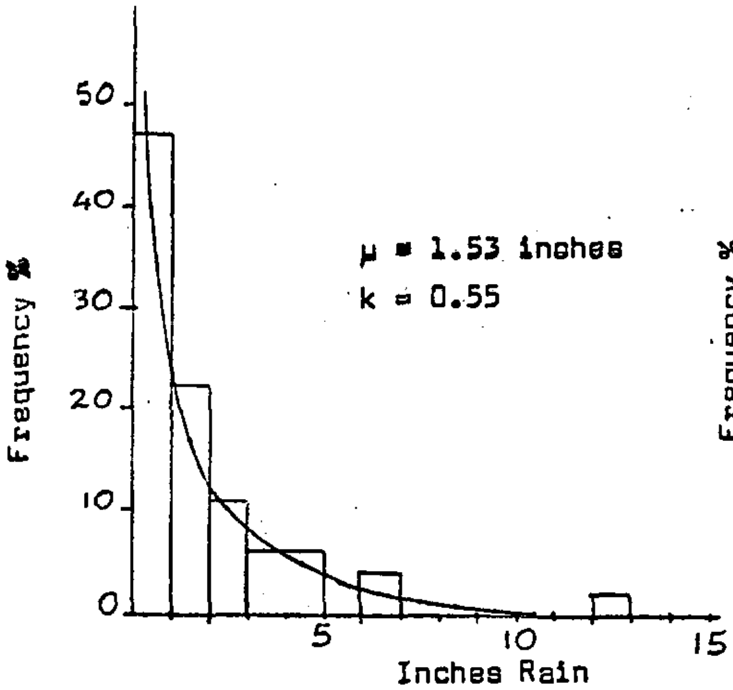


Fig. 5(b): January

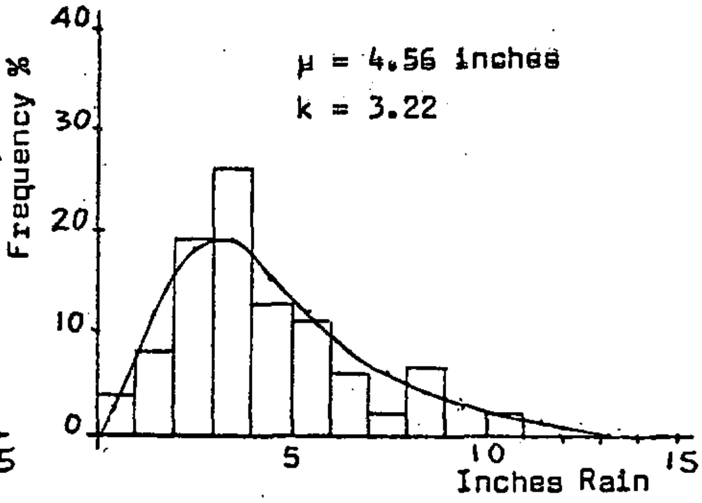


Fig. 5: Rainfall Probability Distributions in a given month

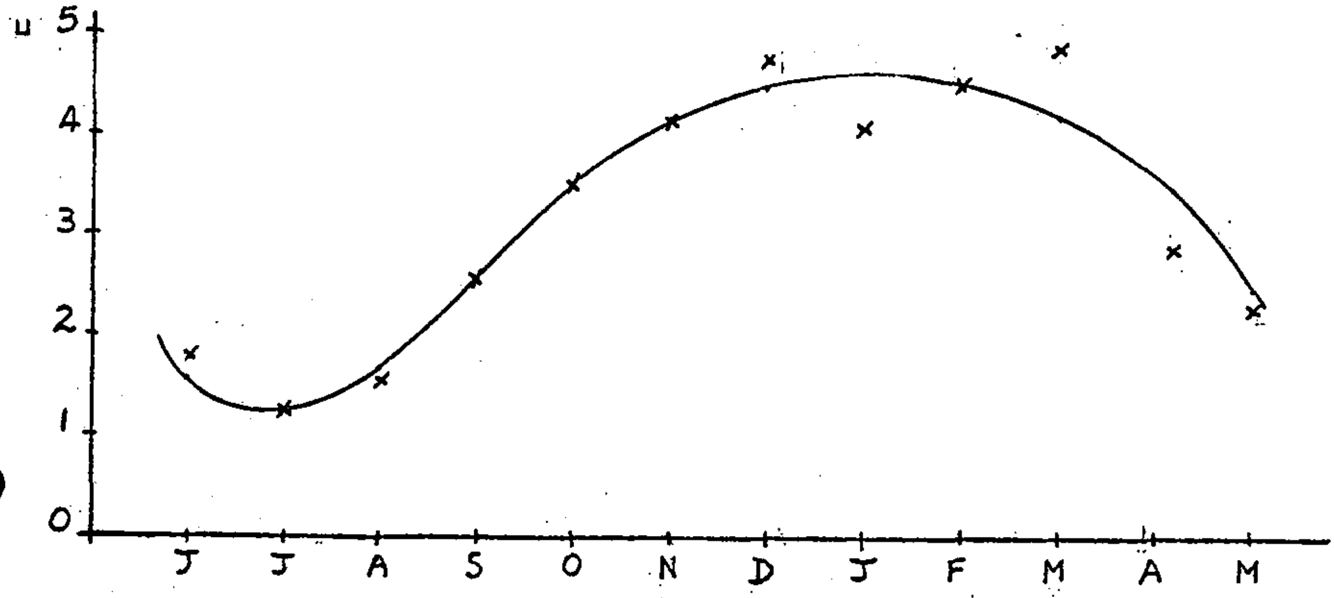


Fig. 6 (a): Monthly values of u

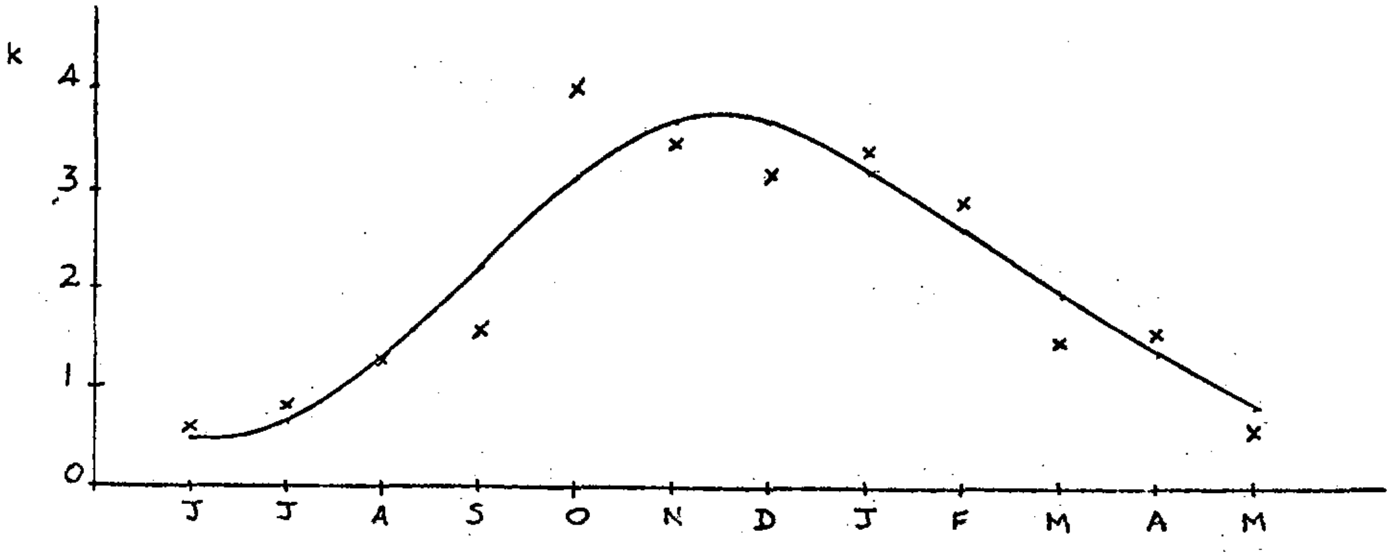
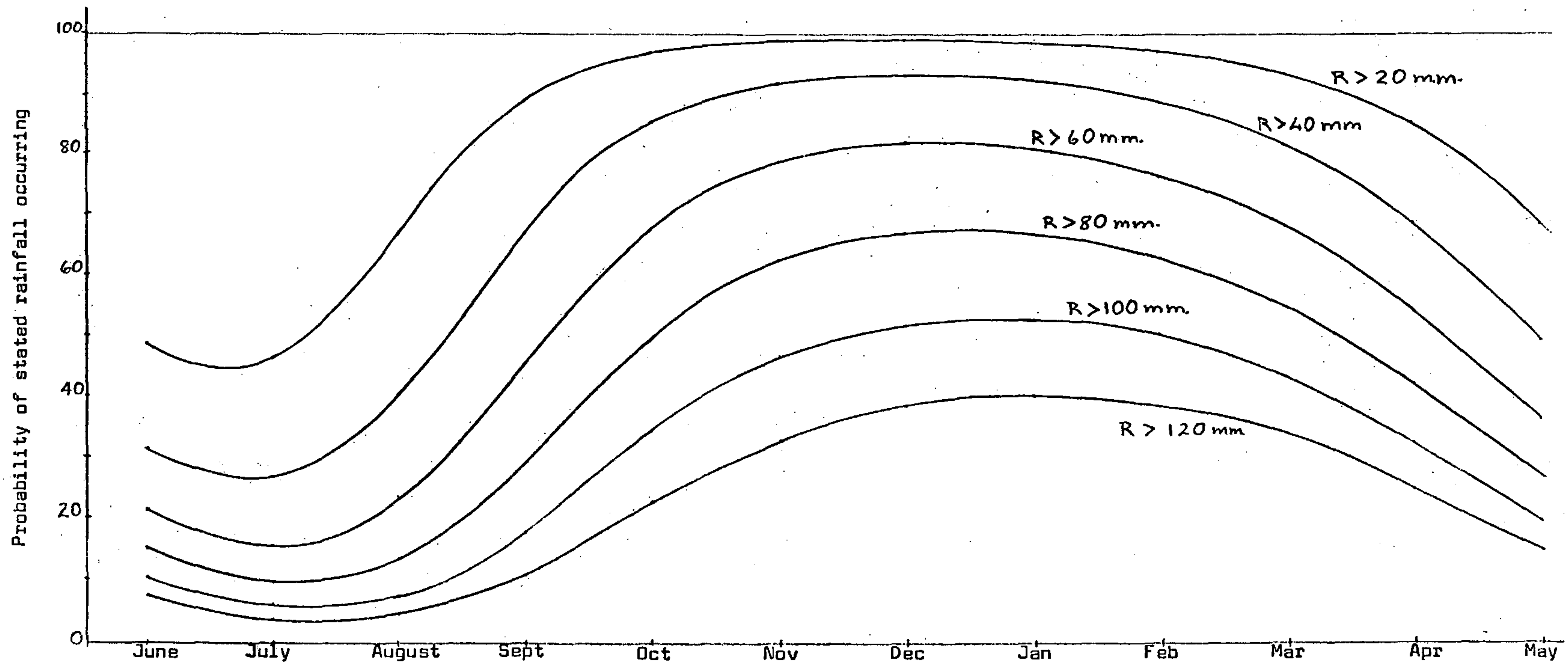


Fig. 6(b): Monthly values of k

Fig. 7: Rainfall Probability Curves for Clifton Estate



LINEAR PROGRAMMING EXAMPLE

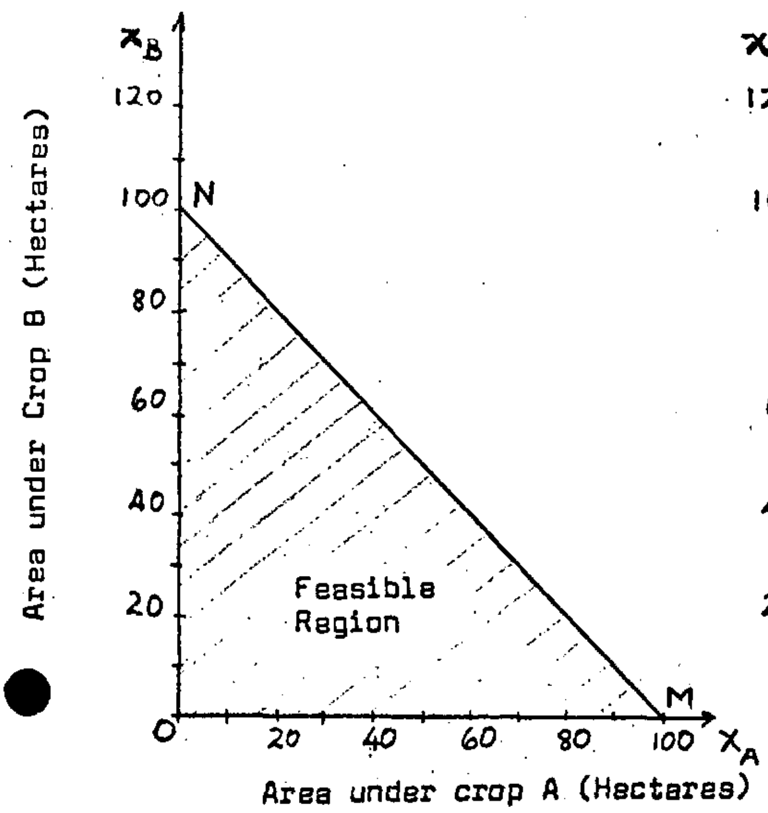


Fig. 8(a): Area Constraint

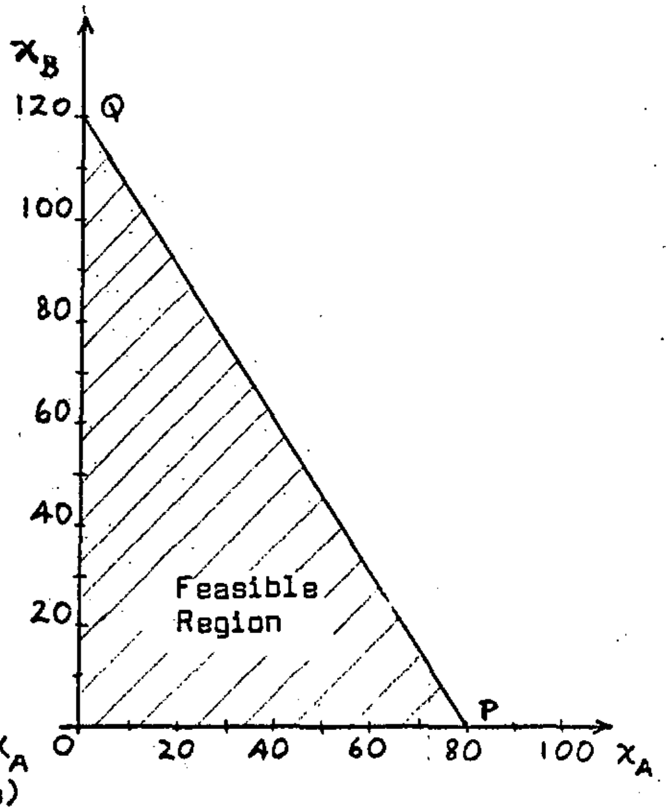


Fig. 8(b): Labour Constraint

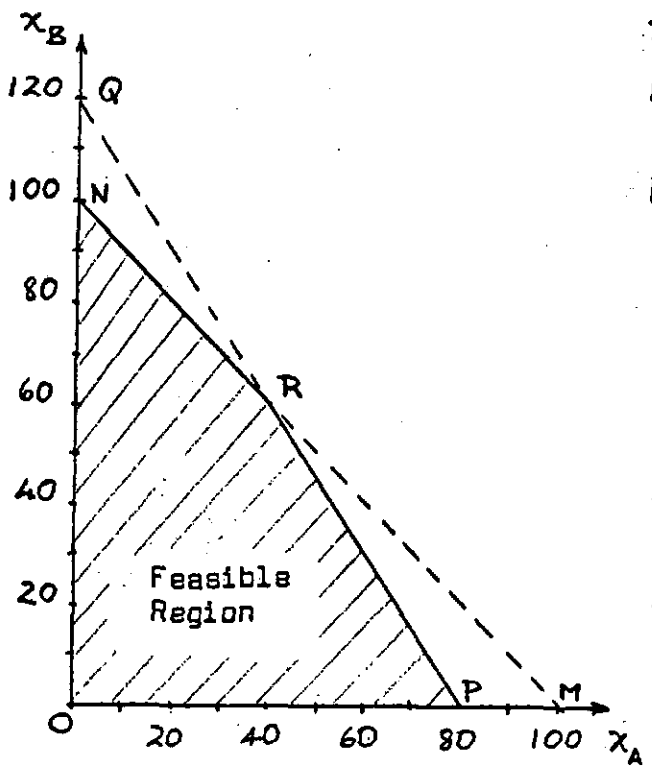


Fig. 8(c): Area and Labour Constraint

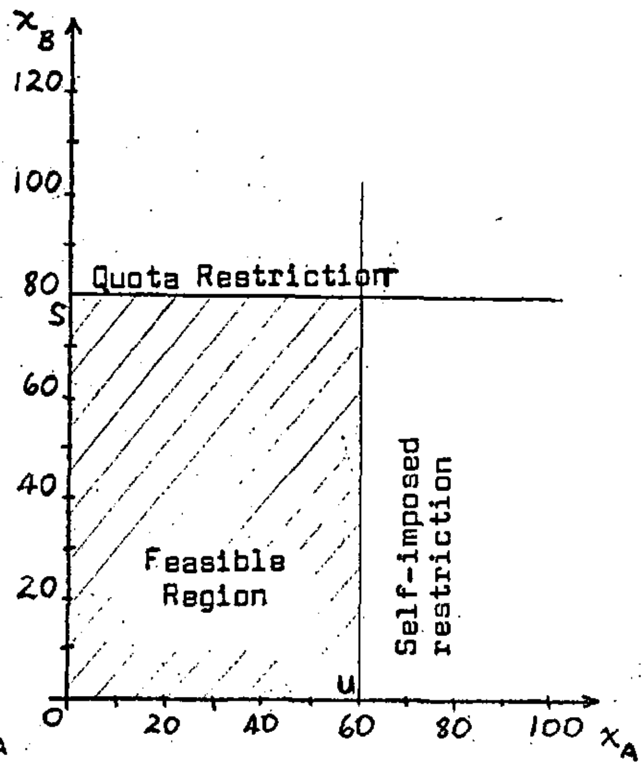


Fig. 8(d): Quota Constraints

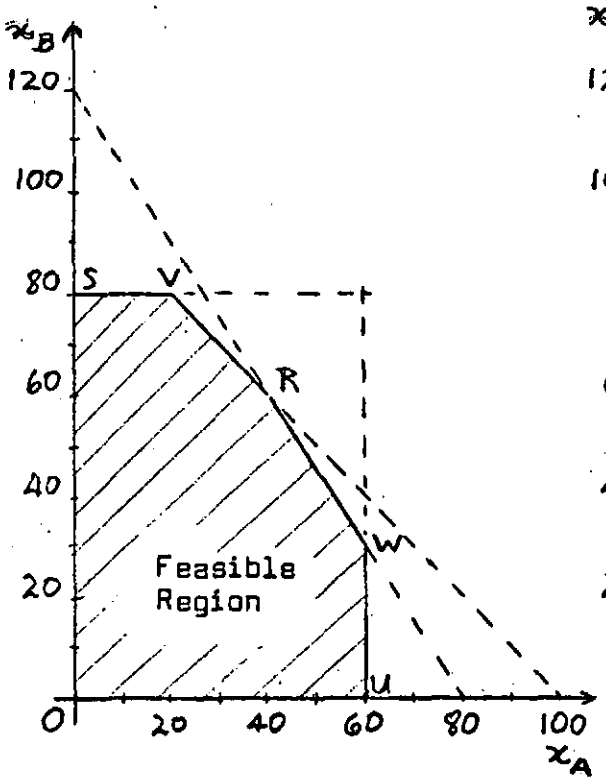


Fig. 8(e): Area, Labour and Quota Constraints

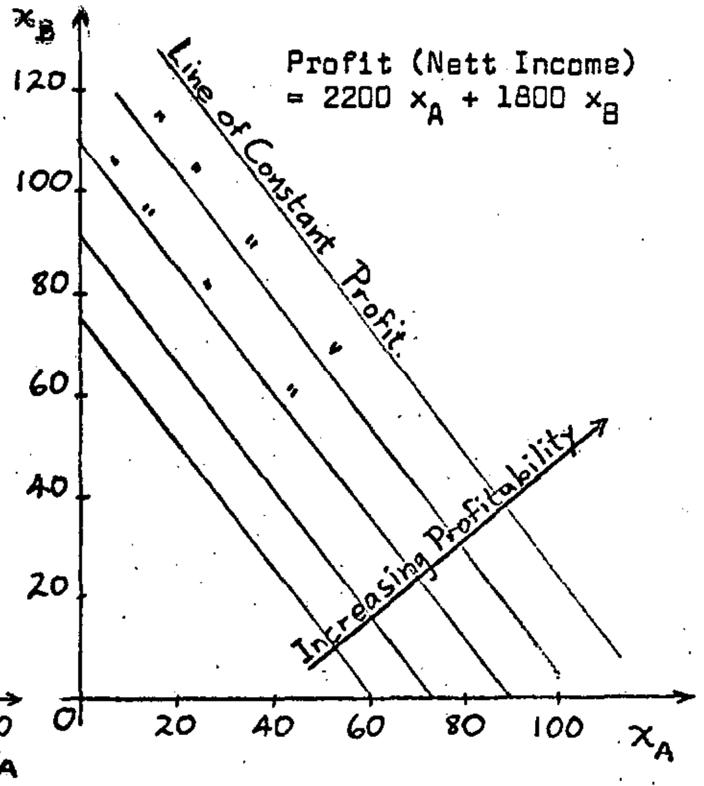
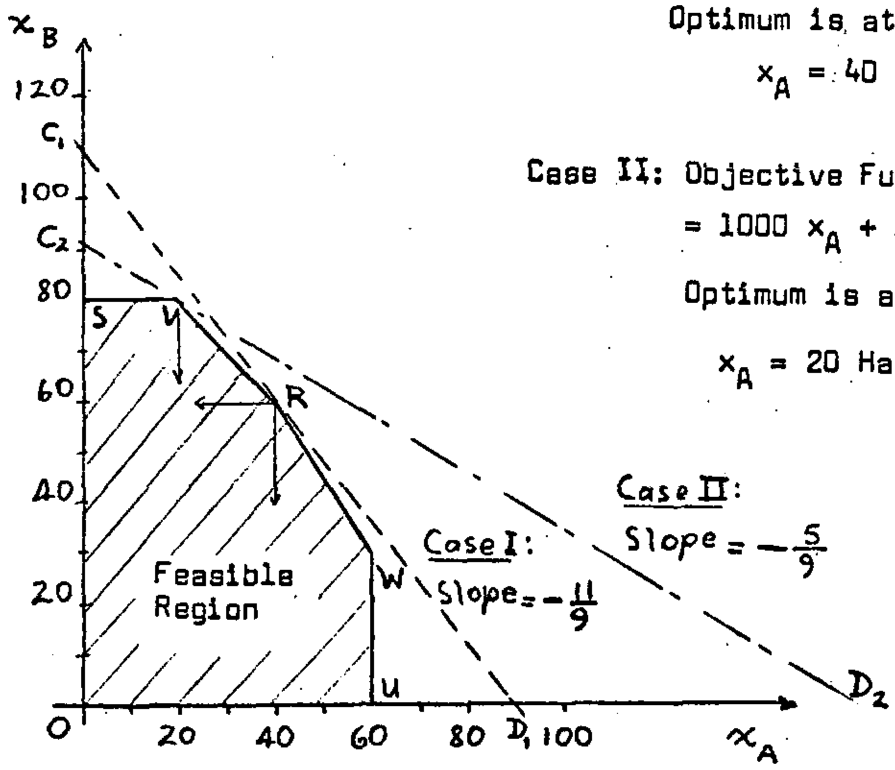


Fig. 8(f): Graphs of Objective Function



Case I: Objective Function

= 2200 x_A + 1800 x_B

Optimum is at point R, i.e.

x_A = 40 Ha, x_B = 60 Ha

Case II: Objective Function

= 1000 x_A + 1800 x_B

Optimum is at point V, i.e.

x_A = 20 Ha, x_B = 80 Ha.

Fig. 8(g): Solution to Linear Programming Problem

Dr. Ziegel
Sichel

(3.9) pH Horseshoe field. (iron chlorosis)

Medical - cows from 1.12.20;
Life cows,