AGRICULTURAL RESEARCH IN DROUGHT-AFFECTED AREAS

ETHIOPIA

IRRIGATION AGRONOMY AND SETTLEMENT – WABI SHEBELLE VALLEY

UNITED NATIONS DEVELOPMENT PROGRAMME

FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS

ROME, 1978
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IRRIGATION AGRONOMY AND SETTLEMENT - WABI SHEBELLE VALLEY

Report prepared for
the Government of Ethiopia
by
the Food and Agriculture Organization of the United Nations
acting as executing agency for
the United Nations Development Programme

based on the work of
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Irrigation Agronomist

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
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This report covers two main types of activity in Ethiopia between 1971 and 1977 - irrigation agronomy at Gode Station in the Wabi Shebelle Valley, and the development of settlement irrigation in the Valley area. Irrigation investigations started under the Institute of Agricultural Research and then continued under the UNDP/FAO project 'Agricultural Research in Drought-affected Areas'.

Experiments concerned a number of crops, particularly maize, which covers the largest area under irrigation in the Valley and cotton, the best cash crop. Of the pulses tried, only cowpea aroused any interest among the local farmers. Trials were undertaken with 30 different species of grasses and legumes; of the grasses, Rhodes grass and Guinea grass with Sudan and Napier grass gave the highest yields. The first two can be successfully grown with alfalfa. Twenty-two species of vegetables and some 80 different varieties were tried; the main ones of interest were onion, tomato, peppers, carrots, red garden beet, musk and watermelon and sweet potato.

Crop water use and monetary return studies showed that cotton gave the most profit; cowpea was the most economical, followed by groundnut and cotton. Assessment of crop water requirements is recorded for cotton, sesame and groundnut.

Results of experimentation were applied through a training scheme in irrigation practices started in 1972 for local farmers of nomadic origin. Each farmer was given 2 ha of land, with freedom to crop. An actual settlement project followed in late 1974. Coinciding with its development, a severe drought occurred over most of Ethiopia and relief camps were established. The effect on the settlement programme was that areas and families to be settled increased tenfold. The combined results of harvest at the Gode and Kelafo settlement projects in early 1977 were 37,500 q of grain after the settlement of 25,000 persons. This saved bringing into the area some Birr 1.5 million worth of food.

Investigations concluded that maize, although with its present yields only marginally economic in the Wabi Shebelle and Awash Valleys, will continue to be grown in view of the food shortage. The position of cotton can be further improved by providing ginning facilities in the Wabi Shebelle; proposals are given for a pilot plant in the Ogaden. Sesame is a useful oil crop, but crop establishment methods must be improved. More interest would possibly be shown in groundnut if an oil extraction unit was introduced in the Gode area. The cultivation of cowpea and kenaf should be encouraged. Suitable varieties are suggested for the various crops. To guide seed production activities, isolation distances are suggested by crop.

In irrigation experiments, the split-plot design can be used to aid inexperienced staff. In crop water requirement studies, after experience has been gained, experimentation with varying amounts and intervals should be introduced. Salinity must be carefully monitored. The schistosomiasis problem requires attention.

Detailed recommendations on machinery are given, and a balanced unit for land development is described. Windbreaks should be erected as early as possible in any development area - various tree species are suggested for testing.

It is important that an agreement should exist between Ethiopia, Somalia and Kenya on water rights and use in the Wabi Shebelle, Genale, Weyb and Dawa rivers; this would be of benefit to all three nations. Experience indicates that development blocks should not exceed 300 ha if construction work is to be mainly by hand labour and a minimum of mechanical help. If large-scale development is envisaged, a complete team of international staff using mechanical means is essential, together with national counterpart staff at all levels of technology.
The Food and Agriculture Organization is greatly indebted to all those who assisted in the implementation of the project by providing information, advice and facilities.
# Table of Contents

## List of Abbreviations/Currency

<table>
<thead>
<tr>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>x</td>
</tr>
</tbody>
</table>

## 1. Introduction

- **1.1 Description of activities**
- **1.2 Gode Station**
  - 1.2.1 Site and communications
  - 1.2.2 Facilities and equipment
  - 1.2.3 Physical environment
  - 1.2.4 Organization of activities
  - 1.2.5 The experimental farm

## 2. Crop Research

- **2.1 Field crops**
  - 2.1.1 Maize
  - 2.1.2 Cotton
  - 2.1.3 Sesame
  - 2.1.4 Groundnut
  - 2.1.5 Pulses
  - 2.1.6 Kenaf
  - 2.1.7 Safflower and sunflower
  - 2.1.8 Wheat and barley
  - 2.1.9 Sorghum and millets
  - 2.1.10 Teff
  - 2.1.11 Bambara groundnut and psyllium
- **2.2 Grasses and forage legumes**
- **2.3 Horticultural crops**
  - 2.3.1 Vegetables
  - 2.3.2 Fruits
- **2.4 Crop water use and monetary return**
- **2.5 Seed multiplication**
- **2.6 Windbreaks**
- **2.7 Pump output measurements**

## 3. Settlement Research

- **3.1 Objectives**
- **3.2 Scheme outline**
- **3.3 Capital costs and returns**
- **3.4 Farm labour inputs**

## 4. Settlement Programme

- **4.1 Description**
- **4.2 Staff**
- **4.3 Finance**
- **4.4 Gode RSP scheme**
LIST OF ABBREVIATIONS

CRDA — Christian Relief Development Agency
EUS — External University Students
ORSTOM — Office of Overseas Scientific and Technical Research
RRC — Relief and Rehabilitation Commission
RSP — Relief Settlement Project
SIM — Sudan Interior Mission (now Society of International Missionaries)
USAID — United States Agency for International Development
WADA — Valleys Agricultural Development Agency
WFP — World Food Programme
WHO — World Health Organization

CURRENCY

US$ 1 = Birr 2.0545 (as at 15 February 1971)
1. INTRODUCTION

1.1 DESCRIPTION OF ACTIVITIES

The UNDP/FAO project on 'Agricultural Research in Drought-affected Areas' (ETH/74/004) began in January 1975, with activities closely linked to the third phase (1975-79) of development of the Institute of Agricultural Research (ETH/74/002). The Institute (IAR) is responsible for formulating national policy in agricultural research and for implementing this policy through coordinated programmes of applied research. The central research station is at Holetta, with other stations at Jimma, Melka Werer, Bako, Nazareth, Mekele and Gode (see frontispiece). Although ETH/74/004 has been extended through 1978, the two types of activity covered in this report - irrigation agronomy at Gode Station in the Wabi Shebelle Valley, and the development of settlement irrigation in the Valley area - finished in August 1977.

Irrigation agronomy at Gode is described from 1971, when the IAR took over the Station from the College of Agriculture, Alemaya. The main work in the first three years was the development of the Station from 50 to 200 ha, and the expansion of the experimental investigations already in progress. A settlement research programme was also started, including the training of local nomadic farmers in irrigation agriculture. Coinciding with this pilot project development, a severe drought occurred over most of Ethiopia, and relief camps were set up with assistance provided by relief agencies from both inside and outside Ethiopia. The IAR was at first entirely responsible to the newly-formed Relief and Rehabilitation Commission (RRC) for work along the Wabi Shebelle, until September 1975 when other arrangements were made. Although such activities are outside the normal terms of reference of a research institute, no other government body was considered to have the necessary experience or staff to supervise this programme.

Activities on behalf of the UNDP/FAO were directed by an irrigation agronomist, Mr. J.P. Dallyn, appointed officer-in-charge of Gode Station in 1971 and responsible for the development and administration of the station pending a takeover by national staff. In October 1974, the irrigation agronomist was designated senior officer-in-charge of both research and settlement programmes. In May 1976 he was transferred to Melka Werer Station in the Awash Valley. The Relief Settlement Project (RSP) had by that time taken over the running of the programme in Gode and Kelafo, but his duties included supervision and advice in both valleys.

1/ Investigations in irrigation agronomy from 1971 to 1974 have been summarized in the Institute's Interim Report 1975 (6). A more detailed account is given here.
The Food and Agriculture Organization of the United Nations is the appointed executing agency for the project on Agricultural Research in Drought-affected Areas, the Ministry of Agriculture being the counterpart agency.

Appendix 1 gives the terms of reference of the irrigation agronomist. Visits he made to various IAR stations and institutions, usually as part of a team with other UNDP/FAO staff, to discuss such technical matters as irrigation design and layout, pump sites, irrigation agronomy and research, machinery use in the field and settlements and extension, are detailed in Appendix 2.

1.2 CODE STATION

1.2.1 Site and communications

Gode Station is geographically located 650 km southeast of Addis Ababa, in the Wabi Shebelle plain, at approximately 6°N Lat. and 43°E Long. By road, the distance from Addis Ababa is 1,200 km, via Dire Dawa, Harar, Jijiga and Kebre Dahar - from 1971 to 1973, due to bad surface conditions, the journey by Land Rover took three days. After 1973, with improved road conditions, two days of 12-hour non-stop driving were still needed. Large trucks bringing in supplies required still more time and usually had to travel back empty. There is no public fuel supply over the last 600 km. A weekly air service Addis Ababa/Dire Dawa/Gode was scheduled, but sometimes two to four weeks passed without a flight. Originally there were two flights a week including stops at Kebre Dahar and Kelafo; now these towns are rarely included.

The IAR and later the RSP had twice daily radio communication with Addis Ababa; reception was good.

1.2.2 Facilities and equipment

(a) Staff

As Gode Station is so isolated, it was always extremely difficult to fill the establishment posts for technical staff. The housing situation, totally inadequate until the end of 1975 (6), was a further obstacle. In February 1976, with an establishment of four graduates plus full supporting technical staff, there were only two 12th graders on the site. The staff, either graduate or otherwise, had no experience and little training in irrigated agriculture. FAO staff who assisted in their own disciplines came infrequently, owing to the many wasted days involved in travel.

See Appendix 8 for a list of Code Station and RSP staff.
Six EUS (External University Students) personnel from Alemaya College assisted materially in station development experiment investigations and settlement promotion. They supervised at least one irrigation experiment each, and all have since graduated with B.Sc. (Agric.).

(b) Housing and buildings

Housing, office accommodation and stores were inadequate in 1971. Graduate staff shared one small room, as compared with having a two-bedroomed house each on other IAR stations. Married staff had one room to live in. The main store building, some 1 000 m$^3$, had been completely wrecked in a storm and had to be rebuilt. The housing situation was not improved until December 1975 when some prefabricated houses and rooms were completed.

(c) Equipment

Of the two lorries, two Land Rovers, five tractors and three pumps available in 1971, only one Land Rover was on site and in running order. Implements for the tractors were mostly unsuitable for flood irrigation and consisted of one-way disc ploughs, tandem disc harrows, cultivators, a four row ridger-planter, a small land plane and a small crawler tractor with bulldozer. All except one of the disc ploughs and tandem disc were transferred to other IAR stations; the ploughs were not replaced with rollers because it was found that ploughing was not necessary on the station. The tandem-discs were replaced by heavy duty off-set discs and this became the basic cultivation implement. The crawler and bulldozer had been inundated in the Wabi Shebelle and were sent to Addis Ababa for complete overhaul, which took some two years. The engines and irrigation pumps, in Addis Ababa either as new additions or for overhaul, were later transferred to Gode.

The pump site was some 300 m from the main canal, the water being conveyed in single 150 mm diameter pipes. The friction losses reduced output to less than a half, and so twin 150 mm and 200 mm pipes were introduced. Additionally the main canal was extended towards the river, reducing the distance to 84 m. The 150 mm piping saved was used to convey water some 1 200 m from the river to the main residential/administrative area for drinking and environmental improvement purposes; this water had previously been carried by tractor and trailer with water tank, tying up one tractor daily.

By 1976 from FAO and government sources there were seven pumping sets, four Land Rovers, six tractors and a full range of supporting implements on the station in working order.
1.2.3 Physical environment

(a) Climate

Gode has a warm desert climate, the mean daily temperatures fluctuating between 27° to 34°C. Mean annual rainfall is around 400 mm, falling in April-May and October-November. Irrigated crops can be grown virtually throughout the whole year with a very short growing season; cotton for example takes only 4½ months against 7½ in the Awash Valley (Figure 1). Climatically the only adverse condition is the very high winds, heavily sand-laden, occurring between May and September. Without suitable wind-breaks these desiccate and bury all crops up to a metre deep in soil. A meteorological station was established in 1976; previously figures came from the airport and National Water Resources Commission.

(b) Soils

The soils, on the Wabi Shebelle alluvial plain, are mainly deep or moderately deep Chronic Vertisols over a loamy to sandy substratum. Intersecting the plain are several silted-up river meanders, flood channels and their levees; these are Calcaric Fluvisols. The soils are fertile, giving a response to nitrogen but not as yet to phosphate or potash. The soils survey undertaken in 1972 by the Soils Section, Holetta showed that with very little low cost improvements, 77% of the farm would become class 2a land and a further 20% class 3a land 1/ (24).

(c) Hydrology

The water of the Wabi Shebelle is generally of medium salinity hazard according to American classification, with high to very high peaks during the two rainy periods. However, the dominant salt giving the high salinity during these periods comes from local rains only and is gypsum with sodium being very low. Daily salinity figures for the year 1972 are given in Figure 2.

Groundwater conductivity and depth were monitored from only one observation well. This was badly situated at some 12 m from a main canal. Figure 3 gives daily figures for the period March 1972 to July 1973. After this date less frequent records were kept but the conductivity had risen to 14 000 mho (EC 10^6) at 4.5 m depth by the end of 1975. By March 1977 it had fallen to 2 200 mho at 2 m depth.

(d) Vegetation

The area is very sparsely covered by scrub trees mainly of Acacia species together with grasses and some annuals which germinate during the two rainy periods, giving a greater or lesser cover according to rain intensity. Along the river bank large

1/ Class 2 – Irrigable lands which are moderately suitable for irrigated farming after the required land improvements are implemented;
Class 3 – Marginally irrigable lands which are marginally suitable for irrigated farming after the required land improvements have been made;
1 – Indicates any limitations attributed in general to soil characteristics.
Acacia, Tamarix, and Doum palm Hyphaene corraco and Thespesia spp grow well and are the main source of timber for building and firewood (25, 26).

1.2.4 Organization of activities

The main work, over the three years previous to 1971, had been conducted on the left bank of the river. This area was limited to some 6 ha, including 1.4 ha of experimental citrus and other fruits. The area sloped upwards away from the river, so that pumps, engines and irrigation pipes incurred extra capital cost and running expenses. The soils were poor in nutrients and organic matter. Salinity was very high, with some samples giving 1,000 mmho (EC) at 0 to 15 cm and even rising to 10,000 mmho at 40 to 50 cm; the worst patches were in excess of 20,000 mmho.

Additionally, the pH at 1 to 15 cm averaged around 8.2 rising to 9.5 in some samples, creating an even worse hazard to economical irrigated agriculture than the high salinity (8).

The experimental site was changed to the right bank of the river which was totally devoid of vegetation except during the rain, evenly sloped and consisted of some 20,000 ha of reasonable to very good soils. When the IAR took over, some 50 ha had been developed by the Aleema College of Agriculture.

The activities of the station cover:
- determination of suitable crops, including forage crops, for the Wabi Shebelle plain, to be grown under irrigation;
- developing suitable irrigation and cultural practices adapted to the crops and local conditions;
- carrying out agricultural research as required for development of the area;
- investigating the production potential and economics of irrigated settlement for local nomad farmers (as from end 1972);
- providing advisory services and technical support to farmers from Iml over 100 km upstream, to Mustahil–Bukure some 200 km downstream.

1.2.5 The experimental farm

An extension of 400 ha, in addition to the original 50 ha, was surveyed and designed to accommodate future work; it was 1,000 m wide by 4,000 m long, thus giving the greater variation in soil types necessary for an experimental programme. Actual development ceased at 1,500 m long as this was considered sufficient to accommodate the work. In addition, technical staff were never up to establishment, and this limited the area that could be supervised for cropping. The standard layout was to have final tertiary canals of 500 m with 200 m long furrow or border strip irrigation. For most experimental work, field channels were run down the 200 m length with
plots 9.6 m x 10 m on either side of the field channel; one block was put in with a 400 m run to investigate greater lengths. Drainage ditches were put in between 2-ha blocks but were rarely used; they later became filled with wind-blown sand. Roads were run along the bottom 500 m length of each block and windbreaks established on the windward side of main canals (see Figure 4a).

The actual 10-ha blocks used for experiments, other than irrigation experiments, in any one season were also to a standard layout (Figure 4b). Down the 200 m length, 62 ridges at 80 cm were made to form one block, a 4 m strip left for an access road and then another 62 ridges established for the next block; this was continued across the field giving nine blocks in all in the 500 m, allowing for roads and windbreaks at the ends. With a disc-binder two ridges were put into one, leaving plots with 12 ridges in each and a field channel between each pair of plots. Cross bunds were then made at 10 m intervals down the field, making 16 plots in all. The advantages of this standard layout were many:

(a) The standard plot size for irrigation was about 96 m², the same as in irrigation experiments. Irrigation crews were able, with experience gained from irrigation experiments, to apply nearly exact amounts of water without measurement.

(b) Experiments were superimposed upon the standard layout; the irrigation plots could be subdivided if necessary into many combinations - 2 x 6 ridges, 3 x 4 ridges, 4 x 3 ridges, 2 x 5 ridges leaving two blank; if required, the 10 m length could be made into 2 x 5 m. Often full-sized plots were used for each treatment.

(c) With sixteen plots down the field this proved a useful number to bring in required replications, etc. At Gods, three replications and less were classified as observations and four replications upwards as experiments or trials.

(d) The actual time in laying-out the field was minimal because virtually no measuring was done - only marking out two ridges with stakes at 10 m intervals, the tractor driven then going across all other ridges; a skilled operator can, in two days, put in 576 ridged plots of full size, or up to 6,912 plots of minimum size, three ridges 80 cm x 5 m long.

(e) By using an irrigation plot size of 96 m², flows of 20 to 40 l/sec could be used in the field channels without washouts, giving quick and even irrigation.

Irrigation experiments required a special layout to stop any sideways movement of water between plots and also to minimize any leakage through cracks, rodent holes, etc.
For water measurement, 7.5 cm wide Parshall flumes were constructed locally from sheet metal reinforced with angle-iron. Right-angled or 60°V notches were not suitable, owing to the very low heads of water available in the experimental fields.

Parshall flumes were difficult to get accurately constructed locally, indeed it was found that measurements given in some publications were incorrect. It is suggested that out-throat flumes developed at Colorado State University are much simpler to construct, just as accurate (see Appendix 3), and should be used in future.

Siphons can be used in all measurements on a field scale, the two standard sizes available in Ethiopia being 4.3 and 6.7 cm diameter. Details of construction and flows are given in Appendix 4.

A gross plot size of 110 to 130 m² meant that, with a flow of 15 to 22 l/sec, the time taken to irrigate a plot to a depth of 15 cm was between 4 min 10 sec and 7 min 13 sec. These water flows and plot sizes gave sufficient total time of measurement per plot so that, if the set time was decreased or exceeded by 10 to 20 seconds, the percentage margin of error per plot was very small. It also allowed plot bunds and irrigation channels to be constructed by tractor and disc bundler, and the flow agreed with the usual amount of water one man can handle when being introduced to irrigated farming; i.e., 15 to 25 l/sec.

Irrigation channels were all double-bundled on both sides, as were plots with differing intervals of irrigation. Where different amounts of water were applied to adjacent plots at the same interval, single bunds sufficed. This split-plot design made supervision easier for the technical staff, to whom the work was new.

A typical experimental layout, covering two replications, is seen in Figure 5.

When the crop could be ridged, e.g. cotton, groundnut or maize, even with the lowest amount of water (5 cm at - the largest interval - 28 days), the water could be distributed evenly throughout the plot. Crops, such as sesame, grown on the flat, suffered from uneven water distribution within plots at the largest intervals and least amounts.

In the first series of experiments, two Parshall flumes were used in each experiment of four replications, the plot furthest from the Parshall flume being 80 m distant. In the second series another experiment was sited below the first, the furthest plot being 170 m from the Parshall flume. Even at this distance, accurate water measurement was possible, and highly significant differences were obtained between treatments, significant at 0.001% for most experiments.
2. CROP RESEARCH

Until 1976 the annual research programmes were formulated by sections at the individual research stations; these were then submitted to the management and interested parties from other disciplines by the officer-in-charge, finalized and confirmed as projects for budgeting and implementation. In 1977 the different disciplines were divided into sections, field crops being by far the largest. Each section then held meetings covering all stations, finalized the research programme after which the crop coordinators submitted the projects to the management for approval.

The research findings of 1971-1977 are briefly discussed here. Full details are in the Gode annual reports (7).

2.1 FIELD CROPS

2.1.1 Maize

Maize (Zea mays) covers the largest area under irrigation in the Wabi Shebelle - this includes both pumped and flood irrigation. The local population insist upon growing sufficient food crops to cover at least one year's supply for their families before they will turn to cash crops. Maize growing under pumped irrigation with the present varieties is extremely marginal economically; yields obtained on a field scale can reach 50 q/ha but the average on the settlement schemes is around 25 to 30 q; yields must rise to a minimum of 70 q to be economical at the average price paid in the area.

Of some 80 varieties tested, Regular White 170 has not been significantly out-yielded and being open-pollinated is the standard variety for the area. Maize is the only major crop responding to fertilizer application, nitrogen only. In combined irrigation and nitrogen trials there was a very marked interaction, nitrogen only giving large increases in yield in the presence of adequate water. An economical application of 80-100 kg/N/ha gives an increased yield of 15-25 q/ha, with a watering interval of 10 days. The application must be split, half at sowing and half at 40 days. Increasing the watering interval to 20 days dropped the yield to a third.

To the local population, feeding their animals comes second to themselves and is more important than cash. Normal practice in maize growing is to thin down to one plant at 25 cm height; experiments at Gode gave exactly the same yield (52 q/ha) when plants were thinned in three stages of growth at 25, 50 and 75 cm height, yielding 17 t of forage as against normal practice only yielding 1.5 t of fodder.
By far the worst pest of maize is the spotted stalk borer (*Chilo portellus*), which has on occasions dessicated farmers' crops. A close season has not been possible to implement covering maize and sorghums to help control the pest; but under experimental conditions and very close supervision, spraying with DDT, carbaryl or endosulfan has given excellent control.

In the Awash Valley, up to 50% reduction in yield can result from the attacks of the weaver bird *Ploceus cuculatus* or *Quelea quelea*, and wart hogs.

### 2.1.2 Cotton

Even after deducting full transport costs Gode-Addis Ababa for ginning, cotton (*Gossypium hirsutum*) is by far the best cash crop to grow in the Valley. Experiments have yielded up to 57 q/ha in only 4½ months growing period; one settler obtained 66 q/ha from two seasons' crops in one year.

Some 40 varieties were tested over nine seasons, the most promising being AMSI 34, AMSI 39 and P 121.8:

<table>
<thead>
<tr>
<th>Variety</th>
<th>Yield (q/ha)</th>
<th>Ginning (%)</th>
<th>Boll weight (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMSI 34</td>
<td>42.4</td>
<td>40.7</td>
<td>9.1</td>
</tr>
<tr>
<td>AMSI 39</td>
<td>41.8</td>
<td>40.9</td>
<td>8.8</td>
</tr>
<tr>
<td>P 121.8</td>
<td>49.4 1/</td>
<td>39.4</td>
<td>6.4</td>
</tr>
</tbody>
</table>

1/ Grown only twice.

Ginning percentages were excellent, while boll weights differed markedly. The AMSI selections, which are bacterial blight (*Xanthomonas malvacearum*) resistant are recommended as standard varieties.

No consistent results were obtained in NPK fertilizer trials.

Cotton water requirements differed from maize in so far as heavy waterings (15 cm) at 7 day intervals reduced yields by half as against 14 day intervals. The same yield was obtained with only 5 cm at 7 day intervals but obviously the longer interval is to be recommended.

When expressed as mm/day the lower values at which yield increases with the amount of water given, are obtained from the long interval; and the highest, which are depressive, at the short interval (see Figure 6). The optimum range is between 7 mm to 14 mm/day, but as yield differences obtained within this range are small the lower water duty is recommended.

Cotton planted in the April season averaged some 10 q/ha less than that planted in October in all experiments.
Cotton pests are not serious and can be controlled with two to three sprayings per season. Jassids (Empoasca spp) are a serious pest and may mean introducing a jassid resistant variety; stainers (Dysdercus cardinalis) are bad in some seasons. Among the bollworms, American bollworm (Heliothis armigera) is the most common; spiny bollworm (Earias mexicana) is fairly abundant; Sudan bollworm (Diparopsis watersi) is very rare, if present at all; pink bollworm (Pectinophora gossypiella) is not very abundant, possibly because the settlers allow their cattle to graze all crop residues, after harvest, virtually to the ground.

Wild cotton (Gossypium arboreum) grows along the banks of the river, and there are some Hesperis spp also acting as alternative hosts. DDT, endosulfan and carbaryl are used for bollworm control, dimethoate for sucking pests and phenthoate for stainers.

2.1.3 Sesame

Sesame (Sesamum indicum) has been grown around Kelafo in small patches for many years. Oil is extracted by large wooden pestles and mortars, motive power coming from a blind-folded camel.

Twenty-five varieties have been tested at Gode, the top three being Kelafo local, T05 and Selection 76.48 R34 averaging around 12 q/ha. Unfortunately Kelafo selection is of mixed seed colour, but selecting out for white seed, which commands a higher price on the world market, is being done at Gode and Melka Werer.

Like cotton, sesame has given no consistent results from fertilizer trials. It is very sensitive to both amount and intervals in water application as seen in the following table.

<table>
<thead>
<tr>
<th>Interval days</th>
<th>Water Duty (cm)</th>
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<tbody>
<tr>
<td>Mean</td>
<td>8.7</td>
</tr>
<tr>
<td>5</td>
<td>8.2</td>
</tr>
<tr>
<td>10</td>
<td>6.7</td>
</tr>
<tr>
<td>15</td>
<td></td>
</tr>
<tr>
<td>7</td>
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<tr>
<td>21</td>
<td>0.9</td>
</tr>
<tr>
<td>28</td>
<td>0.7</td>
</tr>
<tr>
<td>Mean</td>
<td>4.4</td>
</tr>
<tr>
<td>7</td>
<td>8.7</td>
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<tr>
<td>14</td>
<td>10.7</td>
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<td>28</td>
<td>2.8</td>
</tr>
<tr>
<td>Mean</td>
<td>6.6</td>
</tr>
</tbody>
</table>

L.S.D. Interval ± 2.0***

Too much water at 7 day intervals reduces yield to nearly half, and any interval over 21 days is too long. From this and other trials, sesame requires about 7.5 mm a day which can be given as 10 cm every 15 days or 15 cm at 21 days, as shown in Figure 7.
Sebame has been comparatively free of pests except for web worm (Antigastra catalaunalis) and chafer beetle grubs (Sohizonycha spp). Spraying with ULV malathion against web worm and a seed dressing of 40% aldrin WP at 50 g per 10 kg seed controls these pests.

2.1.4 Groundnut

Although groundnut (Arachis hypogaea) grows well in the area with yields of up to 60 q/ha pods, little interest has been shown by the local farmers.

Of the 21 varieties tested, N.C.2 gave the highest consistent yields. Virginia Bumah and Ashford are also good varieties.

No consistent results were obtained from the fertilizer trials.

Groundnut is not so sensitive to irrigation practices as other crops and varying intervals and amounts can be used to give around 8 mm day, the interval not exceeding 10 days (see Figure 8).

Pests have not been serious on groundnut except for sporadic chafer beetle grub attack. Some aphids Aphis craccivora and thrips, probably Caliothrips audenensis, need spraying occasionally.

2.1.5 Pulses

Of the pulses tried only cowpea (Vigna unguiculata) aroused any interest amongst local farmers. Mung bean (Vigna radiata), haricot bean (Phaseolus vulgaris) and soybean (Glycine max) produced very low yields. Small areas of a local cowpea are grown around Kelafo and being dark-coloured the farmers prefer TVu 335 variety over the black-eyed white types. In trials, White Wonder Trailing was also used being a spreader against the upright TVu 335.

Some 35 varieties have been tested, with yields of up to 39 q/ha from TVu 335. TVu 201, TVu 37 and White Wonder Trailing are the other top yielders.

The irrigation trials indicated that, as long as sufficient water is applied (12-15 cm), then the interval can go up to 20 to 24 days without reducing yield. The growing period at Gode is only 60 days from planting to harvest so only two to three irrigations are required. Of the pulses grown, only cowpea and mung bean (with groundnut) acquired good nodulation. A trial with rhizobium inoculation did not give any results.

American bollworm (Heliothis armigera) sometimes causes damage.

2.1.6 Kenaf

Kenaf (Hibiscus cannabinus) has given yields of up to 30 q/ha retted fibre; the locals much prefer the fibre to that of the Doum palm (Hyphaene corrhoea) as it is some three times longer.
2.1.7  **Safflower and sunflower**

Safflower (*Carthamus tinctorius*) and sunflower (*Helianthus annuus*) give yields of 15 and 30 q/ha respectively, but the oil extraction mills at Nazareth will not accept quantities of less than 500 q.

2.1.8  **Wheat and barley**

Wheat (*Triticum spp*) and barley (*Hordeum vulgare*) gave very low yields (20 q/ha) and were attacked by *Quelea quelea* and Egyptian geese.

2.1.9  **Sorghum and millets**

Sorghum (*Sorghum vulgare*) and millets (*Panicum spp*) can give reasonable yields (35 q/ha), but are devastated by *Quelea quelea* when grown on a large scale.

2.1.10  **Teff**

Teff (*Eragrostis tef*) gave yields of 13 q/ha which might be economical depending upon the price.

2.1.11  **Bambara groundnut and psyllium**

Bambara groundnut (*Voandzeia subterranea*) and psyllium (*Plantago psyllium*) were both failures.

2.2  **Grasses and forage legumes**

Although no senior staff were appointed for forage and pasture work or animal husbandry, some preliminary work was begun in 1972. Over 30 different species of grasses and legumes were tried, many of them producing very high rates of growth.

Alfalfa (*Medicago sativa*) produced a cut a month of about 22 t green matter or 0.75 t/day.

Rhodes grass (*Chloris gayana*) averaged 42 t/cut/month and, in combination with alfalfa, 50 t/month.

Sudan grass (*Sorghum sudanense*) gave a first cut of 88 t but rapidly dropped to 55 t after 33 days, and was down to 28 t after a further 48 days' growth.

Guinea grass (*Panicum maximum* and *P. coloratum*) produced 40 and 35 t respectively in monthly cuts.

Bonavist (*Do. chos lablab*) gave cuts of 26 t at 60 day intervals.

Establishment of grasses and legumes both at Gode and Melka Werer required very careful control when done on a large-scale mechanically. The land had to have a very even slope and was pre-irrigated; after weeds emerged they were killed by cultivation at a maximum depth of 5 cm, preferably by a cultivator with large 40-50 cm sweep blades. It was essential that no new weed seeds were brought up by deeper cultivation.
The grass/legume seed was then broadcast and very lightly harrowed in again, not going deeper than 3 to 4 cm; the land was then irrigated. If any weeds appeared the area was topped by a mower when they were some 30 cm high or before flowering. Sesame and teff were grown by the same method on a large scale but not topped by mower.

Grassing of alfalfa produced some bloat and deaths to cows if no maize stover was fed before hand. An area of regrowth sorghum was grazed and four animals died within two hours from hydrocyanic acid poisoning. Only 3.5 kg of young green regrowth sorghum is required to kill a cow. These investigations were undertaken in conjunction with the combined Medical Services Project.

2.3 HORTICULTURAL CROPS

2.3.1 Vegetables

A great variety of vegetables has been tried, covering 22 species and some 80 different varieties. Many were not accepted by the local population and only the main ones are mentioned here.

Onions (*Allium cepa*) are used in virtually all local cooking but must have a very high pungency. Red Creole and Bombay Red were the best varieties with yields of up to 250 q/ha.

The two best varieties of tomato (*Lycopersicon esculentum*) were Amateur and Real V.F. hybrid, with yields of 180 and 530 q/ha respectively.

Peppers (*Capsicum spp*) like onions must be extremely hot, sweet peppers being unacceptable. Yields were up to 37 q/ha of a local variety.

Carrots (*Daucus carota*) were mostly eaten raw, with Tip Top, Da la Holla and Chantenay yielding up to 226 q/ha.

Red garden beet (*Beta vulgaris*) is eaten cooked; no yield difference in varieties was found.

Both musk melon (*Cucumis melo*) and watermelon (*Citrullus vulgaris*) were accepted in time, with yields of 200 and 400 q/ha.

Sweet potato (*Ipomoea batatas*), new to the area, is readily acceptable.

Vegetables have been remarkably free of pests, except for peppers and tomatoes which were attacked by American bollworm. Melons can be heavily attacked by *Dacus app.*

2.3.2 Fruits

At present, 182 citrus trees comprising 21 different varieties budded onto seven different rootstocks in 37 combinations are under trial. All the trifoliate (*Poncirus trifoliate*) rootstocks have died off. Grapefruit, lemon and lime have produced excellent fruits as have a few orange varieties; tangerine and mandarine have been dry, woody and unetable. No important pests have been observed. Papaya, guava, pomegranate and banana all produce good fruits.
A banana fertiliser experiment (nitrogen) combined with suckers being controlled to three at any one time against no restriction, was carried out in 1972/73. Free suckering against three per stand gave variable results, although the overall average yield for controlled suckering was 575 q/ha against 543. Nitrogen at 800 g/tree every six months gave an increase in yield of 37%, to 700 q/ha.

2.4 CROP WATER USE AND MONETARY RETURN

The optimal use of irrigation water may not necessarily correspond to the highest yields per hectare. In the Wadi Shebelle basin, as in virtually all irrigation areas, good land usually far exceeds the amount of water available to crop it. The basin has some 300,000 ha of good land but until water control measures are introduced upstream by hydro-electric dam(s), barrage(s), etc., cropped area would be some 2,000 ha during October-March and 10,000 ha during April-September. These figures are mandatory and can be changed with cropping patterns, etc., for instance cowpea takes 60-70 days to maturity, cotton 135 days; they are based upon twelve hour pumping only (10).

From the irrigation experiments carried out at Gode, Table 1 gives gross crop returns and m³ water used to produce 1 kg of grain, and cents return per m³ water. Yields are divided into the two main planting seasons of April and October, October giving the highest yields.

No crop approaches cotton in gross return and even with higher production costs it still give the most profit. On the other hand, cowpea gives the most economical return based on m³ water used and also the highest gross monetary return per m³ water. A fuller analysis would take into account production costs, feasibility of growing large areas of the most profitable crop, its effect on succeeding crops and other relevant considerations.

In Table 2, yields from the irrigation trials that have given the most economical use of water are recorded.

Cowpea showed most economical with only 0.4 m³ water/kg, followed by groundnut and cotton at 1.4 m³ water. The prices per quintal are reasonable but can change from year to year; it is not however, thought that the ratio one with the other would fluctuate greatly.

2.5 SEED MULTIPLICATION

The unique climate at Gode coupled with irrigation facilities permits a large variety of crops to be grown virtually all the year round. This led to the IAR being asked to produce or multiply seed in "off seasons" for planting elsewhere in Ethiopia.
Additionally the station was used to produce a second crop in any one year, cutting by half the time taken in breeding and crossing of variety programmes. The IAR also supplied all the seed for first plantings at the numerous settlement projects in the valley.

Crops involved were cotton, maize, hybrid maize, grasses and legumes, cowpea, mung bean, sorghums and sesame.

2.6 WINDBREAKS

Windbreaks were essential to protect crops during May to September when strong sand-laden winds blow continually from the southwest. During this period, surveying and laying out of canals was often stopped when visibility fell to between 5 and 10 m.

The windbreaks consisted of four lines of *Tamarix* and/or *Parkinsonia* spp planted 30 cm apart with one metre between rows. *Tamarix* was propagated from cuttings and *Parkinsonia* from seeds which had been dropped into boiling water the evening before and allowed to soak all night with the water gradually cooling off. Some 500 000 trees were grown. Although eminently suitable for windbreaks, neither species was suitable as timber for house construction so other trees were put under test. *Populus* spp proved satisfactory growing from cuttings and ten species of *Eucalyptus* were seeded in a nursery. Persian lilac (*Melia azadorah*) and neem (*Melia azadirachta*) grew well but depressed crop yields in their vicinity by evaporating too much water.

Once the trees became 1 to 2 m high they received no more irrigation, getting their water from nearby irrigation canals. This was essential as once the high winds began in May the channels in which the trees were planted were filled in with sand. To obtain maximum growth before May, planting should be done as soon as the winds cease in September.

The effectiveness of the windbreaks was tested using a cup anemometer at 2 m above ground. The windbreak consisted of three rows of *Tamarix* some 4-6-7 m in height at 3½ years old. Readings were taken five times in each location, returning to the open plain between each set of readings to check on the unaffected wind speed. The following wind speeds were recorded:

<table>
<thead>
<tr>
<th>Site</th>
<th>km/h</th>
</tr>
</thead>
<tbody>
<tr>
<td>Open plain</td>
<td>35.3</td>
</tr>
<tr>
<td>Five metres to windward of windbreak</td>
<td>28.4</td>
</tr>
<tr>
<td>Five metres in lee of windbreak</td>
<td>2.6</td>
</tr>
<tr>
<td>In maize field, 100 m leeward of windbreak</td>
<td>11.8</td>
</tr>
<tr>
<td>In cotton field, 150 m leeward of windbreak</td>
<td>22.1</td>
</tr>
<tr>
<td>In alfalfa field, 200 m leeward of windbreak</td>
<td>22.8</td>
</tr>
</tbody>
</table>
The windbreak effect of the trees was assisted by some 1 to 2 m depth of sand which had deposited itself around the trees over previous years.

2.7 PUMP OUTPUT MEASUREMENTS

Under varying conditions, pump outputs were measured using a 300 mm diameter Kent irrigation metre. For some tests a 150 mm stopcock was inserted in one pipe of a double outlet of 200 mm diameter. This increased the reading, as seen in records of pump No. 1, from 156 l/sec to 186 l/sec (Table 3). Other pump outputs were adjusted in the ratio 156/186. Increases in flow from the use of two outlets varied from 7 l/sec to 31 l/sec at Code.

From pumps 9, 10, 11 recorded at Melka Werer no increase was obtained by using double outlets at less than half the total metric head as compared with Code. In May 1976 all pump sites and pumps at Code, both IAR and BSP, were flooded. The pumps had to be completely stripped down, cleaned and reassembled. The IAR pump site was totally destroyed and another one was built.
3. SETTLEMENT RESEARCH

3.1 OBJECTIVES

Part of any research programme should be the application of its results, to the betterment of local farmer's practices and conditions. At Gode there were no local farmers producing crops under irrigation. In anticipation of the expected development of this type of agriculture in the Wabi Shebelle a farmer training scheme was started in October 1972 which had the following objectives:

1) To train local farmers of nomadic origin in irrigated farming practices.
2) To ascertain whether positive results from experiments give the same increases in yield under small farmer conditions.
3) To study the economic application of experimental results.
4) To collect data as to labour requirements, costs and returns under small farmer conditions.
5) To investigate the area of irrigated land that is manageable but also large enough to give a reasonable standard of living to one family.

3.2 SCHEME OUTLINE

Each farmer was given 2 ha of land to which water was supplied free of charge. The two basic cultivations for the area, once-over with heavy duty off-set disc harrows followed by ridging where required, were also done free. Fertilizers, insecticides, seeds, etc. were made available but were paid for in full at harvest.

Transport to Addis Ababa for cotton was undertaken by the IAR but charged for in full.

During their first three to four months of training, the farmers were made to work on the experimental farm as labourers for three or four days a week. This gave them sufficient money to live on before their first crop was harvested and also allowed further training in all aspects of irrigation and crop protection.

The first five farmers planted in October 1972, and a further six in December. In March-April of 1973 another eight trainees were added. The first five planted their second crop in April-May of 1973, and the second six, in May. Freedom of cropping was given to each farmer but advice and pressure was brought to bear as thought necessary.
Yields and net return per group of farmers are shown in Table 4. Certain price variations are noticed. Maize rose from Birr 10/q to Birr 30/q; cotton was Birr 68/q delivered to Addis Ababa, but has now risen to over Birr 100/q; sesame began at Birr 30/q, rose to Birr 50/q and is now Birr 70/q.

The lower yields and returns from the last eight farmers was because their holdings were fully exposed to the winds of May-September, whilst the first eleven farmers were fully protected by windbreaks.

3.3 CAPITAL COSTS AND RETURNS

To settle 50 farmers on 100 ha, the capital outlay in mechanical equipment is Birr 80 000 or around Birr 1 600 per farmer (1977 prices):

- 4 irrigation pumps 60/70 l/sec at Birr 10 000 each allowing 20-25% reserve 40 000
- 65 hp tractor 20 000
- Off-set disc harrow 4 000
- Disc bumer 3 000
- Sprayers, etc. 2 000
- Bipher 3 000
- Tools, etc. 2 000
- Contingencies 6 000

Birr 80 000

If each farmer planted 1.25 ha cotton, 0.5 maize and 0.25 ha vegetables, per annum double-cropped, he should produce enough food for his family and have 2.5 ha of cotton for cash to cover water costs, cultivations and other expenses at a minimum of Birr 6 000 gross.

3.4 FARM LABOUR INPUTS

Although 2 ha per family appears small, in practice it gave about the correct amount of land under intensive irrigation covering two cropping seasons per year. In Ethiopia, as in most parts of Africa, a family group is very closely knit and in farming is invariably an extended family. Table 5 shows that each family of the first eleven farmers consisted of 5.5 adults and 7.4 children; additionally there were 0.5 labourers employed. These figures were taken in the first six months of the investigation and increased subsequently. Of these family groups, adult workers averaged 5.2 and children 2.3 per unit; this labour force did everything except the basic cultivation and ridging — including sowing, weeding, fertiliser application, spraying, harvesting and disposal of crop residues.

The natural development from this favourable investigation was an actual settlement scheme which started in October 1974.
4. SETTLEMENT PROGRAMME

4.1 DESCRIPTION

The natural development from the settlement investigations undertaken by the IAR during 1972-74 was a localized pilot settlement project expanding in size and numbers as know-how increased and as more national staff became available and experienced. As there was no other government body in the area with sufficient technical knowledge and experience, the IAR was asked to supervise such work until a settlement authority was formed; obviously this work is outside the normal terms of reference of a research institute.

However, coinciding with this pilot project a severe drought occurred covering most of Ethiopia; relief camps were set-up with food supplies, medical teams, water supplies and other requirements being provided by relief agencies both from inside and outside Ethiopia.

The effect on the proposed settlement programme was that acreages and families to be settled doubled—trebled—increased tenfold almost overnight. IAR involvement was 100%, at first being entirely responsible to the newly-formed RRC for the work along the Wabi Shebelle.

4.2 STAFF

At the beginning of the settlement programme in October 1974, the only staff available were four IAR personnel seconded to the RSP. At the same time, all IAR technical staff devoted part of their time to settlement work. Ato Umata Waktolie, auditor with the IAR in Addis Ababa, was transferred to the RSP as administrator and ran the RSP office there with a minimal staff of finance officer, purchaser and storeman. In September 1975 a general manager, Major Mulugata Kebede, was appointed to the RSP for the Gode-Kelafo work, and he and his staff gradually took over from the IAR. The irrigation agronomist continued to assist and advise until June—July 1977, when the settlement projects had to be temporarily abandoned.

An FAO associate expert, Mr. C.H. Fields, helped in relief settlement work from July 1975 into 1976, when he was transferred to Gambella Station. He carried out his duties successfully under difficult conditions. Further assistance was provided through the FAO project 'Aid to Settlement' and by other international agencies.
For Qode and Kelafo it was not possible to obtain trained and experienced national staff in any field, and so 12th grade students who could speak Somali were engaged. The irrigation agronomist contacted the Christian Relief Development Agency (CRDA) and other agencies through the RRC; expatriate staff were recruited for an interim period until they could train local staff to replace them.

In February-March 1977 a three-week course was given to approximately half of the 12th grade field assistants. A second course was planned for the remaining staff but the area was evacuated before this could take place.

An international team led by Dr. Aklilu Lemma, Director of the Institute of Pathobiology, Addis Ababa, carried out a survey covering schistosomiasis in the Wabi Shebelle Valley (14).

4.3 FINANCE

The first settlement areas in Qode and later some in Kelafo were financed by the United States Agency for International Development (USAID) under an agreement signed between USAID and the RRC with the IAR as the instigating agency.

The IAR agreed to develop 800 ha of land and settle 400 families over a two-year period. For this, USAID put up some Birr 1.5 million of a total of Birr 2.4 million. The IAR was given Birr 7 000 by UNDP personnel in Ethiopia and then approached the CRDA who gave another Birr 23 000; with these monies three pumps were purchased for three pilot village areas at Kelafo beginning in February 1976.

The staff of the Ethiopian Airlines contributed some Birr 750 000 from their salaries to develop and settle a further 400 ha at Qode; this was later reduced to some Birr 550 000.

The final picture was as follows:

<table>
<thead>
<tr>
<th>Initial Financing of Qode-Kelafo Settlement</th>
<th>(Birr)</th>
</tr>
</thead>
<tbody>
<tr>
<td>USAID</td>
<td>1 438 129.00</td>
</tr>
<tr>
<td>Ministry of Agriculture</td>
<td>1 250 000.00</td>
</tr>
<tr>
<td>Ethiopian Airlines</td>
<td>753 000.00</td>
</tr>
<tr>
<td>Ethiopian Government (housing, technical</td>
<td>822 000.00</td>
</tr>
<tr>
<td>assistance and research inputs)</td>
<td></td>
</tr>
<tr>
<td>UNDP/FAO (technical assistance and</td>
<td>125 000.00</td>
</tr>
<tr>
<td>services)</td>
<td></td>
</tr>
<tr>
<td>UNDP Personnel</td>
<td>7 000.00</td>
</tr>
<tr>
<td>CRDA</td>
<td>23 000.00</td>
</tr>
<tr>
<td></td>
<td>4 418 129.00</td>
</tr>
</tbody>
</table>
Additional finance came from the Valleys Agricultural Development Agency (VADA) for a further 1,000 ha at Gode, 1,600 ha at Gode West and such additional areas around Kelafo as was practical. In practice it was not possible, nor desirable to keep these funds separate. Settlement development must be considered as a whole and not piece-meal.

4.4 CODE RSP SCHEME

4.4.1 Development Programme

(a) First 140 hectares

Field work on the settlement project by settlers began in October 1974. The area had already been topographically surveyed and designed by the IAR. The site was adjacent to the IAR farm, lying on the northern boundary. This was an actual settlement project rather than a drought relief settlement. Settlers were chosen by ballot from some dozen local tribes, including highlanders, and added to the original 19, making up 70 families in all. They were to develop 140 ha in three phases, each phase to be planted as completed. The whole area was finished in September 1975, some of it having been cropped once. In September 1976, a further 70 settlers were added to comply with the policy of each family having one hectare.

(b) First 400 hectares

The second selection of 200 settlers began in 1975; 150 settlers came from Muskoki, the Gode Relief Camp and 50 from the Danan camp some 70 km inland from Gode. Included in the selection were highlanders and also widows with families. They began work on their canals in March; again the design layout was for development in three stages so that crops could be produced before completion of the whole area. In 1976 these families were also "doubled-up", in theory making 400 in all; in practice it was somewhat difficult to keep an accurate check on exact numbers as being nomads, individuals disappeared from time to time to graze their cattle, etc. By December 1975, 150 ha had been planted to virtually 100% maize; for the October 1976 planting, 330 ha were finished and planted, again nearly all maize but with some sesame, cotton, cowpea and vegetables.

(c) Second 400 hectares

Selection of settlers for the second 400 ha was on the same basis as the first 200 and they began work in June 1975. They were doubled up in 1976 and their first planting was in October of some 320 ha.
(d) Second 140 hectares

This second 140 ha area was the old cooperative farm, and to the 13 labourers originally working there, were added a further 127 persons from Muskoki camp. The enlargement of the farm started in April 1976 and was finished and planted by November.

(e) The 1 000 hectares site

The 1 000 ha site is outside the IAR's direct responsibility but is included to complete the picture of Gods. The area was surveyed in 1975 and the first canal lines laid out by January 1976. Final selection of settlers was delayed and then the balance of drought victims, 1 000 plus families, were moved on block to this area in 1976. By November 1976 some 135 ha were planted, 100% to maize.

4.4.2 Method of work

On the farm one-over disking followed by ridging was carried out by tractors and machines of the RSP. No further help was given to settlers who then planted, weeded, sprayed, harvested and cleared their areas of crop residues ready for the next plantings, all by hand.

For canal construction, two old second-hand caterpillar D8s with dozer blades were available but on average only one was in working condition. They were virtually essential for assisting in the large canal construction and also at the pump sites. A new caterpillar D5 and dozer blade worked on smaller canals. The smaller canals and field channels were constructed entirely by hand but the soil was loosened by wheeled tractors and disc ploughs. Pumps actually on site for the November 1976 plantings totalled 23 of the Rotes X 250, CF E, NA 20 or NA 25 types.

4.4.3 Results achieved

Up to the time the pump sites were flooded in April 1976 and taking only the drought relief settlement areas into account, some 7 500 q of maize were harvested with small quantities of sesame, sorghum, oupea and cotton. Vegetables depended very much upon the individual farmer's inclination but one settler reported that he made over Birr 500 from vegetables sales. For the second harvest it was estimated that some 25 000 q of maize would be harvested by April 1977, with very small quantities of other crops. On the first 140 ha during February-April 1976, a count made of cattle, sheep and goats grazing on crop residues showed 4 000 head. At the end of the February-March 1977 harvest it was estimated that some 20 000 head were grazing crop residues.
Description of programme

Initially the Kelafo settlement was entirely different from Gode. In the Kelafo area large areas of land are flooded bimannually in May-June or August-September when the river overflows its banks. Additionally rain in April-May and October-November adds to the water available for crop production. According to the amount of rain plus the flooding, the area under crops can alter drastically in total hectares from year to year. Generally, downstream of Kelafo has good crops in most years, upstream very limited. The areas under flood cropping are those some 1 to 2 km away from the river as the land slopes gently down in that direction. Local practice has been to dig canals into the river bank so taking flood water to these low-lying areas.

The IAR decided in early 1975 to put in four pumps, one each in a pilot village area, some 15 km upstream of Kelafo where no river flood had occurred for some eight to ten years. The pumps were small, 60-70 l/sec driven by 2-cylinder Deutz hand-started motors. The first pump was installed at Mouseldon in February and the other three added in neighbouring villages at monthly intervals. The area irrigated was that close to the river which was too high ever to be irrigated by flood. As this was only supplementary help (the villagers usually harvesting some rainfed/flood crops), 90 families were registered per village and cultivated an area of some 40/45 ha. All work was done communally and the produce shared after harvest. The village supplied two men as pump operators. They were instructed in starting, stopping and maintenance for one month and then took charge, with only maintenance visits and checks from IAR staff. This accounted for the one month delay in installing pumps at the next village site.

When the four original pilot sites proved successful, drought relief camps were set up. A further five sites were added by April 1976, and two more after that date by RSP. These sites were continually involved in moving personnel out of the relief camps. The previous cooperative farm was taken over and some 400 families moved out of the Kelafo camp into this area. Other villages had families who were drought victims, added to their areas; if they refused, they got no pump.

The families in these villages, unlike those of Gode, had experience in irrigation. The land was uneven and so irrigation was into basins varying around 500 m², whilst at Gode it was in border strips of 200 to 300 m lengths.

Results achieved

At the first four pilot villages, the first harvest per site averaged nearly 1 000 q of maize, at that time fetching over Birr 35/q. The pump unit had cost only Birr 10 000 and relief grain to the area was said to be costing Birr 34 to 40 q
delivered; these figures testify to the complete economic viability of the scheme. For their second crop these villages again planted maize, against the advice of the IAR staff who recommended sesame. The result was a virtual failure owing to stem borer attack. However, advice was then heeded and sesame planted, one village obtaining over 200 q which was sold at Birr 75/q. 2500 q of maize were harvested at the Gum site relief settlement farm but it was not distributed amongst the settlers and considerable amounts were spoilt by the heavy rains in April 1976.

4.6 OVERALL RESULTS

The combined harvests from Gode and Kelafo produced some 37500 q of grain in early 1977 after the settlement of 25000 persons. This saved bringing into the area some Birr 1.5 million worth of food.
5. CONCLUSIONS AND RECOMMENDATIONS

5.1 FIELD CROPS

5.1.1 Maize

Although with the present yields, maize is only marginally economic in the Awash and Wabi Shebelle valleys, it will continue to be grown in view of the food shortage in Ethiopia. The present open-pollinated variety Regular White 170, should be used in both valleys and may be improved by selection; hybrids should not be introduced as the maintenance and production of seed is not feasible.

Irrigation, if at regular intervals, should not exceed 10 days, and up to 100 kg/N can be applied in two dressings. Late thinning shows advantages locally for cattle fodder but further experimentation is required.

5.1.2 Cotton

Cotton well surpasses all crops in profitable return. This position could be further improved by providing ginning facilities in or nearer both valleys, especially the Wabi Shebelle. Additionally, suitable oil extraction machinery covering both cotton seed and other oil crops would allow extracted cake to be fed to local cattle and would minimize on transport costs of the final products out of the area.

For Gode several AMS I selections, 34 and 39 being the highest yielders, are recommended. These are also resistant to bacterial blight (Xanthomonas malvacearum). A hairy type may have to be introduced to assist against jassid attack.

Planting should preferably take place in October at Gode, the irrigation interval being two weeks. No fertilizer is recommended at present.

The previous irrigation practices recommended for the Awash Valley, irrigating at two week intervals for 150 days at approximately 10 cm water per application, proved wrong in 1975, which had a very high August rainfall, 169.0 mm in 1975 as against only 28.8 mm in 1974. With no further irrigation after crop establishment the same yield was obtained as with any other regime, and high amounts of water at small intervals drastically reduced yields. These results should be confirmed by continuation of the work.

Although pests at present are not serious, with the expansion of areas they could build up and so a closed season is a requirement. The practice of grazing cotton and maize stover virtually into the ground should be encouraged. Both of these practices should be introduced into the Awash Valley.
Sesame

Sesame is a useful oil crop in both valleys but crop establishment methods must be improved. Present experimental procedures are extremely tedious, time consuming and labour expensive, and are unsuitable in large-scale production. The local method of sowing around Kelafo is in large clumps of 15 to 20 seeds at some 60 cm apart — this enables easy weeding by hoes or mechanically and yields of 10 to 12 q/ha are obtained. This method should be tested experimentally.

There are three varieties to choose from, Selection 76, T85 and Kelafo local; T85 is quicker maturing than the other two. Selecting out for white/orange coloured seed types is essential to command the highest price on the world market. Irrigation interval should be 14 days, no fertiliser.

Groundnut

More interest may be shown in groundnuts if a suitable oil extraction unit is introduced into the Code area. The best recommended variety is H.0.2, a large-seeded confectionary type eminently suitable for export. Groundnuts at Code require frequent irrigation at weekly intervals of at least 10 cm water; they have no response to fertiliser applications.

Cowpea

Cowpea is grown in limited qualities but should be encouraged, firstly because of its high protein content as a human food and secondly its very low water requirement (Table 1) as compared with other crops. Work just begun, and showing promise is growing cowpea with maize. The best combination planting date has not as yet been fixed.

TVu 335 is the best variety having a dark seed coat colour, but White Wonder Trailing is used as a spreading type. There are now some 200 more selections at Melka Werer and the best of these should be screened for Code conditions. Irrigation can be of up to three week intervals with a total of only three irrigations. No fertiliser is recommended at present.

Kenaf

Kenaf growing even on a small scale alongside field channels should be encouraged for small-scale local rope production. Ethiopia imports considerable amounts of fibre but the mills would have to offer higher prices than at present if kenaf is to complete with cotton. With abundant water for retting it can be grown in both valleys, but being of the same family as cotton Malvaceae it could harbour and sustain cotton pests if grown in a different season.
Safflower and sunflower

Both safflower and sunflower have given good yields and can be grown on a larger scale to introduce crop rotation and variation. With the establishment of an oil extraction unit at Gode they should be included.

Safflower is not too well liked for harvesting owing to its persistent prickles.

GRASSES AND LEGUMES

Of the grasses Rhodes grass, Guinea grass with Sudan and Napier give the highest yields. The two former can be grown successfully with alfalfa. The latter two might be tried with some climbing Phaseolus spp to improve protein content.

HORTICULTURAL CROPS

For most horticultural crops it is essential to buy first class seed. Seed should not be locally produced for use unless one is prepared to isolate and spray regularly.

Citrus distribution should be restricted to budded grapefruit, lemon and lime.

SEED PRODUCTION

The IAR every year produced large quantities of seed varying from elite seed for breeding programmes to seed for supply to settlers. Additionally, from its many variety trials it uses again or gives out these seeds for multiplication, other variety trials and so on. This is very bad practice in nearly all cases as crossing amongst varieties or with farm weeds growing in the vicinity can and does occur. On receipt of varieties from abroad small quantities must be grown in isolation for future work. It is noticeable that all the recently imported kenaf varieties are now full of rogues (off types).

Isolation distances vary from country to country and increase with the importance of the seed grown. In some cases barrier crops can be grown to reduce the distances but not always; as an extreme example for complete isolation of hemp (Cannabis sativa) in the U.S.A., small plots of monoecious varieties require 4.8 km and dioecious varieties 19 km separation. Appendix 5 indicates reasonable isolation distances between varieties, to give pure seed (for more detailed information, see (20)).

WINDBREAKS

Windbreaks should be put in as early as possible in any development area, for the Gode plain probably at 200 to 300 m apart according to the irrigation layout. The first consideration is to stop the sand-laden wind from hitting and burying the crops, especially in the young stage of growth.
After stopping damage by wind the other effects of windbreaks which are directly important in any irrigation scheme must also be considered in planning:

(a) Soil temperature is probably increased with the presence of windbreaks, not wanted at Gode.
(b) Relative humidity is usually increased and this should improve crop growth at Gode.
(c) Air temperature should be lowered in the hot afternoons and slightly raised in the morning, both being advantageous.
(d) Evaporation is invariably reduced by windbreaks particularly at the higher wind speeds.
(e) Soil moisture is increased, although with bigger and better crops increased evapotranspiration occurs.
(f) Soils will not be lifted below wind speeds of 12-15 kph depending upon the soil type.

Depending upon the denseness, height and thickness of the windbreak there is a reduction in wind speed 10 times the height of the windbreak in distance, to windward of the windbreak; to leeward it will give some protection up to 30 x height in distance (21).

In addition to the tree species already tried at Gode, the following should be tested:

Acacia oyanophylla
Albizia lebbek
Casuarina glauca
Cupressus sempervirens
Dalbergia sissoo
Elagagnus augustifolia
Eucalyptus oesmaldelensis
Eucalyptus sideroxylon
Ficus sycomorus
Fraxinus syriaca
Gleditsia triacanthus
Halaxylus persicarm
Pinus brutia
Prosopis alba
Prosopis spioigera
Salix spp
Tetraclinis articulata
Zisiphus jujuba.
At Melka Werer Station, dust laden winds are increasing every year as more land is cleared of trees for development. The station itself is protected by nearby hills and old trees left around the station, and is not truly representative of other farms in the valley which are much more open. An investigation on windbreaks should be undertaken by the IAR or some other body.

5.6 RESEARCH AND EXPERIMENTAL METHODS

5.6.1 Organization

On some IAR stations experimental practices at certain times leave much to be desired. This has not been helped over the last few years by the extreme shortage of trained and experienced staff.

At Gode several experiments were written-off because, over some 40 to 50 plots, perhaps eight plots gave exactly the same yield, another five the same, followed by another three and two x four the same. At Melka Werer in one experiment, eight plot records were "mislaid", several treatments were not represented in some replications while others were repeated two or three times.

Field work should not be delegated to field assistants with no supervision from graduate staff. When it is admitted that a mistake has been made, extreme caution is required in any disciplinary action. This should not go beyond a frank discussion of what could be the result if it is not reported - otherwise it is extremely likely that next time it won't be.

Research personnel should train themselves to see, notice and record differences even although these are not specifically listed as "observations to be taken".

In planting variety trials or distributing fertilizer, labourers should not be allowed to walk across plots but around the edge, as sooner or later a man slips or a bag bursts and one plot or more becomes missing from the experiment.

5.6.2 Irrigation experiments

Irrigation experiments require special treatment, as discussed in Section 1.2.5. The split-plot design can be used to aid inexperienced staff in water control and to lose less area from buffer zones. This should take the form of treatments with the same interval, grouped together as "main plots" with amounts of water as "subplots". On analysis it is generally agreed that the subplots will give more precise information; but in this case, in practice, it is easier to recommend to farmers to vary their interval rather than their amount.
At both Gode and Melka Werer, Parshall flumes have been used in water measurement but in some seasons the flumes were not placed high enough in relation to the highest plot being irrigated. Back-up water developed, reducing the actual flow of water without adjustment being made in time, so less water was applied than recorded. Care should be taken to place the flumes correctly.

5.6.3 Crop water requirements

The crop water requirement experiments carried out at Gode were based upon fixed amounts and fixed intervals covering the growing period of the crop. The reasons for this simplified approach were that no senior staff had any experience in irrigation experimental work nor field staff any experience in water measurement, distribution or control. Similarly, when the settlement programme was started, fixed amounts and intervals were very much easier to organise and administer; new settlers, never having grown crops under irrigation, can be taught to judge on a certain amount of water and apply it at a certain number of days' interval, preferably on the same day of the week, be it weekly, fortnightly or at three weekly intervals.

It was fully intended, once some experience had been gained, that the work would naturally evolve into the correct pattern of crop water requirements generally allowing for greater amounts of water at lesser intervals over the flowering-fruiting period, with lesser amounts at longer intervals at seeding-harvesting; in fact, some work was started in 1976-77 along these lines. Such investigations were not possible before, as the fairly rapid change-over of technical staff leaving for fellowships, etc., necessitated the training of new inexperienced personnel; this was further aggravated by personnel on fellowships not returning to the station on completion of their training.

The recommendations given for crop water requirements are therefore based on this simple method of assessment where in fact the crop receives more water than necessary at the beginning and finishing of its growing period and possibly insufficient during the vital flowering-fruiting stage. Once sufficient experience is gained by staff, then experimentation into varying amounts and intervals should be carried out, bearing in mind that results also have to be put into practice by experienced extension staff and farmers.

5.6.4 Experimental design

The use of sophisticated experimental designs, coupled with mini-plot techniques, should be discouraged. This practice is often introduced by personnel returning from training abroad, where they have learned these techniques on experimental stations which have been running, in many cases, for 50 to a 100 years, and where all grades of qualified staff are available. The use of mini-plots can possibly increase the
number of replications and so probably increase accuracy, but with inexperienced labour a slight error in gross or net plot size at harvest can have disastrous results. On one station, a 25% variation was recorded.

5.7 MACHINERY

5.7.1 Tractor implements

(a) Plough

Most of the tractor implements found at Gode Station were not suitable for surface irrigation cultivations as they did not leave the land level after passing. Ploughs were ordinary 3-4 furrow discs which leave a high ridge upon opening-up a field and a depression when finishing. Additionally they do not bury surface weeds or trash but leave them on the soil surface acting as a mulch. If planting machinery is subsequently used then blockages will occur. It is possible by very careful setting out to use ordinary ploughs following lines of water flow in border strips, etc., but time lost in running empty will be great.

Reversible ploughs should always be used, leaving a level surface according to the original design. If mould-board ploughs are used, then weeds and trash can be buried as long as skin coulters are correctly set. Disc coulters are preferable to knife coulters chopping through crop residues where a knife coulter tends push them along in front of it.

Ploughs, if set as for opening up a field for normal ploughing, can be used to construct small field irrigation channels or border strip bunds.

By ploughing across the slope and turning the soil downhill over a number of years, land can be put into broad or narrow based terraces assisting in even water distribution.

(b) Disc harrows

Disc harrows should always be of the off-set type and not tandem, again leaving the land level as per the original surface design. The positioning of the tractor in distance from the previous bout depends upon the forward speed to avoid throwing up small ridges between bouts.

(c) Cultivators and harrows

Cultivators and harrows are all suitable for surface irrigation cultivations as they leave the land level, and in fact over a period improve land levels.
(d) **Disc bunders**

Disc bunders for making field channels and border strip bunds are extremely useful. They can also be used to construct large ridges suitable for sweet potato and similar crops.

(e) **Mould board furrower**

A mould board furrower can be used for constructing channels in which to plant windbreaks and also for making broad top beds suitable for watermelon and other cucurbits.

(f) **Mould board ridgers**

Mould board ridgers are suitable for ridge and furrow irrigation but must be used correctly for subsequent planting or inter-row cultivations. If a five-row ridger is used, the opening run will leave four ridges made with two halves on either side. On the return run, four ridges can again be made by running the outside ridging body in the previous half ridge but this leaves the machine slightly off the horizontal if it is set level with the tractor. If the tractor is driven to leave five ridges, then on either side of the work there will be a run of four ridges only, the first and last runs. If the tractor is driven round and round on a central bout with one ridging body running in the previous half furrow, then the ridger can be levelled off to give exact work.

It is possible to purchase disc ridgers and these leave the same number of ridges at each pass; they have the advantage of riding over or cutting through trash or tree roots without damage, but it is not often that such obstacles are found on irrigation land.

(g) **Rolling cultivators**

Limestone rolling cultivators can be used for weed control or for incorporating herbicides on ridged land and still maintain the ridge formation; they do not penetrate into the soil between ridges and, if this is required to increase water penetration, then tined cultivators should be used.

(h) **Bed formers**

Bed formers combined with planters, inter-row cultivators, etc., leave a perfectly shaped ridge and furrow, particularly useful for ridges below 70 cm width and for the growing vegetables which require more exact irrigation than the major crops.

Tractors can be of almost any type but usually some high clearance models are required for inter-row cultivations; these may be fitted with row-crop wheels. The use of mechanical means for basic cultivations is virtually essential on any large
irrigation project, land development is expensive, water distribution must be timely and efficiently used, often the period for cultivations is short; for these reasons individual farmers cultivating with bullocks, etc., always results in adjacent areas not being ready in time for planting and irrigating.

5.7.2 Marrying of machines

Where tractors and implements are used for inter-row work, then all machines must be married to suit each other. If a four-row planter is used, then all subsequent operations should be undertaken with implements covering the same four rows. For inter-row cultivations, the machine must completely work the three areas between the four rows, plus two-thirds of the areas on the outside of the two outside rows. Additionally, the tractor should always be driven in the same direction as in the first operation be it ridging, or ridging and planting, etc. By this method if any inaccuracies occur in the setting up of the first machine, then subsequent implements can be set to follow the same inaccuracies. Variations in distances between bouts do not interfere with complete weeding operations.

If harvesting machinery is used, and it is often found that these machines only operate at a few row widths, then all other machinery should be married backwards from the harvester.

5.7.3 Land development machinery

Both in the Awash Valley and the Wabi Shebelle development, efficient use of large machines is very poor. Machines purchased are often of the wrong type or size for the job, fitted with the wrong implements and invariably incorrectly set for the job in hand; with the very large capital cost involved, such machines must always be on shift work of at least 12 hours per day.

Several machines of varying types making up a unit must be grouped so that no machine is idle, waiting for an operation to finish before it can start in its own work.

The crawler tractor of 100 to 400 hp is invariably the best machine for agricultural land development as it can be used for varying operations when fitted with different implements. Additionally it can on occasions be adopted for normal farm cultivations; this does not apply to specialist machines such as motorized scrapers, etc.

A balanced unit for land development is suggested as follows:

(a) Two crawler tractors fitted with bulldozer blades for either tree clearing and/or push loading. If land has to be levelled over very short distances (up to 50-60 m), then bulldozers can be used. One machine should have a ripper attached for loosing hard compacted soils for the scraper-carriers to pick-up. If continual back and forward movement is involved, then automatic transmission is an advantage.
(b) Two crawler tractors with towed four-wheeled rubber-tyred scrapers of 12 to 15 m³ capacity. These should be used for canal construction - land levelling with hauls of 50 to 300 m. Above 300 m, motorised scrapers become the most efficient to operate - they are not as versatile as crawler tractors and it is not usual for such long hauls to be found in agricultural development.

(c) One smaller hp tractor fitted with rear-mounted heavy duty cultivator to loosen the soil after the scrapers, making it suitable for land planning. This tractor will also be used for pulling the land plane. The land plane should have a minimal size of 20 m length, and bucket width of around 4 m.

Tractors making up the unit will be very efficiently used in such places as the Awash Valley. In the Wabi Shebelle area, one less tractor and bulldozer would make the unit as there is no tree clearing to be done.

In operation, it is essential that the scraper work is of a high-standard - if it is badly done then no amount of subsequent land planning will correct it. Land plane operators in Ethiopia should not be allowed to change the setting of the machine, either mechanically or hydraulically, between passes. For the first pass, the bucket will invariably be between a quarter and half full, sometimes even nearly empty; when this happens, it was observed that the operator invariably lowers the bucket, so completely nullifying his work by creating "waves" over the ground.

Depressions should be cultivated or ripped as deep as possible before filling, or perched water tables may result.

Land levelling and planning should be highly accurate the first time and not repeated yearly. The work destroys soil structure and the first crop following always suffers. In the second year after development, some minor levelling/land planning is usually required owing to sinkage of filled areas after irrigation. In the Awash Valley, many areas were noted being land planed annually - a very bad practice.

5.7.4 Pumps and engines

The standard pumping unit both for Melka Werer and Gode was a Rotos XB250 driven by a 4 cylinder Deutz engine. At Gode the original pumps and engines purchased in November 1971 were still working in May 1977. Except for the stripping and cleaning after the inundation by flood water, very little overhaul has proved necessary. Impellers and some broken main shafts were replaced on the pumps and three injector pumps overhauled on the engines; no other major work has been necessary. Spring starters were fitted to all pumping sets, replacing battery, dynamo and starter motors. This practice should continue.
It was found that pumping units on other irrigation projects were not suitable for the work planned. Sometimes when additional hectares were brought into production, larger lengths of pipes were added to existing systems and the extra friction losses greatly reduced output. On many farms outlet pipes were too small, again resulting in excess head loss. Very few farm managers understood that by say increasing pipe size from 150 mm to 200 mm, friction losses fell from 30 m/100 to 8 m/100 at 125 l/sec or that a reduction of 14 m/100 could result from doubling the outlet pipes to 2 x 150 mm diameter. Friction losses for normal pipes used in Ethiopia are given in Appendix 6. In future an experienced mechanical engineer should be consulted whenever possible.

Pumping costs, although not charged to the settlers at Gode, were worked out from actual measurements at about 1.5 c/m³. These costs are similar to those calculated for Melka Werer Station (15).

5.7.5 Cotton ginnery and oil extractor - Gode

The future expansion of irrigation in the Wabi Shebelle will necessitate a cotton ginnery in the Valley allowing the pressed ginned cotton to be transported to Dire Dawa for spinning. The present transport of seed cotton is limited by bulk area to some 50 q on a lorry - this quantity could be doubled or trebled by baled lint. The economics of installing an oil expelling plant with only small quantities of crops available is doubtful, but it will come in the future.

A quotation for small gins is given in Appendix 7.

5.7.6 Machinery in rainfed areas

The irrigation agronomist visited stations and institutions under rainfed agricultural to advise on machinery use. Besides the normal incorrect settings and use of machines noted, it is impossible to understand why local farmers and cooperatives are advised to buy tractors and ploughs to replace their bullocks and local plough. The local "plough" is not a plough in the English sense except that it resembles a "chisel plough". It is a single cultivator tine with usually extended wings on the shear.

If farmers wish to extend their operations by mechanization they should replace their bullocks and "ploughs" with a tractor and cultivator with suitable points. The advantages are many:

(a) The work produced would exactly resemble that which is done by bullocks and so the farmers would understand the techniques involved.

(b) A smaller tractor could be purchased than that which is now used with the disc plough, and capital investment would be less.
(c) Rate of work, depending upon the number of passes, would be greater than with a disc plough.

(d) With a disc plough, the farmer ploughs as deep as possible moving large quantities of earth; on hillsides with heavy rain the effect is disastrous, as farm soil is washed into the valley below. This would not happen with a cultivator.

(e) Once mechanised a farmer tends to cultivate more land in any one season, leaving less land for fallow; this would have to be counterbalanced by improved husbandry methods.

(f) Once a farmer has obtained some years experience with a tractor and cultivator, he could decide for himself whether he wished to purchase a plough. In the drier areas it probably should be a disc plough as at present, the discs leaving a rough mulched area assisting in erosion control and exposing weeds to hot sun and wind to die.

In the higher rainfall areas a mould-board plough would be more suitable, fitted with disc and skin coulters which, when correctly adjusted, would bury all weeds and trash. This would greatly assist in the control of weeds, one of the big problems in these areas.

5.8 STAFF

5.8.1 Irrigation sections

If the present national staff away on irrigation fellowships return, they can carry on the further investigations necessary without external assistance. However, several are now considerably overdue and it is recommended that an international agronomist covering irrigation practices should be based either at Melka Werer or Nazareth, and cover both stations. At Code it may be necessary to employ a second international expert, depending upon the local staff situation when the station reopens.

5.8.2 Farm management section

The farm management section is one of the weakest links on all stations of the IAR in respect to the day-to-day running. Activities are confined to economics, collecting input/output data, etc., on which an excellent job is done.

The farm manager’s post on the stations should rank next to the officer-in-charge in importance and salary; the person filling the post would be a graduate with a wide and long experience. In particular he should know a wide variety of crops, be experienced in machinery use and cultivations and, when necessary be familiar with various methods of irrigation, cut-back, flows, etc.
5.8.3 Statistical services

As recommended in the Interim Report 1975 (6) and again emphasized by Ohlander (9), a statistical section must be formed in the IAR.

Many experiments are inadequately formulated to obtain the information required; and much information obtained from experiments is not published both because of the work load of general staff and because they are not fully conversant with the means and methods of obtaining the information.

5.8.4 Artisans

Artisans - tractor drivers and masons, carpenters, etc. - are generally of a low standard. It is not their fault as very few if any senior staff can show them what to do and their salaries do not attract persons with the required background.

Such personnel should receive a bigger salary than at present, and in time it should be equal to a graduate's during his first three to five years out of university.

5.9 RELIEF SETTLEMENT PROGRAMME

5.9.1 Water rights

In the Wabi Shebelle, before any settlement or development is again re-started, agreement must exist between Ethiopia, Somalia and Kenya over water rights and use in the area. This should cover all rivers - the Wabi Shebelle is the largest but the Genale, the Weyb and the Dawa must also be included. Once this is achieved, then international institutions would come forth with the necessary monies to control the rivers by dams, barrages, etc. producing electricity and increasing the total irrigable area five-fold or more, to the benefit of all three nations and their peoples.

The above advice was given by the FAO Staff at all the important meetings held with the government concerning Wabi Shebelle Development.

5.9.2 Future development

After the initial pilot settlement area of 140 ha was developed, future blocks were designed for 400 ha. In practice this proved somewhat too large for satisfactory development and 300 ha-blocks are recommended; this only applies if construction work is undertaken almost entirely by hand labour with a minimum of mechanical help. When re-settlement begins again there will be a shortage of trained experienced staff at all levels and it will take at least two years before technical assistants are fully conversant with all aspects of water distribution and control. It is far less damaging if mistakes are made involving small canals and irrigable areas; with smaller areas it will be found that a proportion of the area being developed can be planted within four or five months of starting, so giving encouragement to the would-be settlers and offering experience both to them and to the control staff.
If on the other hand large-scale development is envisaged, then a complete team of international staff using mechanical means of construction is vital, but national counterpart staff must provided from the beginning covering all levels of technology. It is thought extremely likely, after the past troubles, that future settlers will have to be "imported" into the area, at least for the initial development.

Although no salinity problems have been encountered to date, the total area under irrigation is neither large enough nor has it been under irrigation sufficiently long to give rise to trouble. Nevertheless, the salinity figures obtained from the one observation well, coupled with the rapid rise of water-table, indicated that future development areas should be carefully monitored by the establishment of observation wells (piezometers) throughout the area. During the local rain periods of April-May and October-November it may be necessary to stop irrigation when the salinity in the Wabi Shebelle rises above 750 mho.

5.9.3 Mechanisation

In the Awash valley, water distribution is entirely an Ethiopian matter and so should cause only local problems. The settlement schemes however must be drastically changed, with increasing emphasis on the settler doing the work; very little, if anything should be done beyond basic cultivators— at present some "settlers" do very little except collect the money at the end of the season.

On the minimum mechanisation experiment it is correct to investigate the feasibility of using bullocks, camels, etc., but such methods have no place in an economic irrigation project for basic cultivations. These must be done mechanically so that timely sowing and organised water distribution is possible; once sowing is completed, then such methods may have a place, in e.g., weed control.

5.9.4 Schistosomiasis control

On any irrigation project, bilharzia or schistosomiasis will almost certainly become a problem in the tropics. An initial survey in the Wabe Shebelle (14) showed that going downstream from Imi the disease progressively increased from under 1% at Imi and Gode, to 2% at Kelafo and 40% at Mustahil. The Kelafo and Mustahil areas have always had irrigation from river flooding which is reflected in the schistosomiasis figures.

With irrigation works expanding around Gode, precautions must be taken to ensure that the disease does not expand. Appendix 8 gives the known position at Gode and suggestions as to preventive measures.
### Table 1
**CROP WATER USE AND MONETARY RETURN**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Price (Birr/q)</th>
<th>Planting (month)</th>
<th>Yield (q/ha)</th>
<th>Gross return (Birr/q)</th>
<th>Water use (m³/kg crop)</th>
<th>Return (₩/m³ water)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>15</td>
<td>April, October</td>
<td>36, 57</td>
<td>540, 855</td>
<td>4.5, 2.1</td>
<td>3.3, 7.1</td>
</tr>
<tr>
<td>Cotton</td>
<td>75</td>
<td>April, October</td>
<td>24, 58</td>
<td>1 800, 4 350</td>
<td>4.4, 4.0</td>
<td>15.9, 17.5</td>
</tr>
<tr>
<td>Sesame</td>
<td>40</td>
<td>April, October</td>
<td>14, 15</td>
<td>540, 600</td>
<td>6.6, 7.2</td>
<td>6.7, 5.6</td>
</tr>
<tr>
<td>Groundnut</td>
<td>40</td>
<td>April, October</td>
<td>34, 36</td>
<td>1 340, 1 440</td>
<td>9.7, 3.1</td>
<td>4.1, 12.9</td>
</tr>
<tr>
<td>Cowpea</td>
<td>40</td>
<td>April, October</td>
<td>27, 32</td>
<td>1 080, 1 280</td>
<td>1.6, 1.4</td>
<td>24.4, 28.4</td>
</tr>
</tbody>
</table>

### Table 2
**CROP YIELDS AND RETURNS FROM THE MOST ECONOMICAL USE OF WATER**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Price (Birr/q)</th>
<th>Yield (q/ha)</th>
<th>Gross return (Birr)</th>
<th>Water use (m³/kg crop)</th>
<th>Return (₩/m³ water)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Maize</td>
<td>15</td>
<td>57</td>
<td>855</td>
<td>2.1</td>
<td>7.1</td>
</tr>
<tr>
<td>Cotton</td>
<td>75</td>
<td>18</td>
<td>1 350</td>
<td>1.4</td>
<td>50.0</td>
</tr>
<tr>
<td>Sesame</td>
<td>40</td>
<td>13</td>
<td>520</td>
<td>5.5</td>
<td>7.3</td>
</tr>
<tr>
<td>Groundnut</td>
<td>40</td>
<td>18</td>
<td>720</td>
<td>1.4</td>
<td>28.6</td>
</tr>
<tr>
<td>Cowpea</td>
<td>40</td>
<td>26</td>
<td>1 040</td>
<td>0.4</td>
<td>102.8</td>
</tr>
<tr>
<td>No.</td>
<td>Engine</td>
<td>Pump</td>
<td>IN-LET</td>
<td></td>
<td>Friction loss</td>
</tr>
<tr>
<td>-----</td>
<td>-----------------</td>
<td>------</td>
<td>--------</td>
<td>----------</td>
<td>---------------</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Pipe</td>
<td>Vert.</td>
<td>Flow</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>Size (mm)</td>
<td>head (m)</td>
<td>1/ sec</td>
</tr>
<tr>
<td>1</td>
<td>Deutz 4 cylinder</td>
<td>XB 250</td>
<td>200</td>
<td>2</td>
<td>1.3</td>
</tr>
<tr>
<td>2</td>
<td>Deutz 5 cylinder</td>
<td>HA 25</td>
<td>250</td>
<td>1</td>
<td>1.8</td>
</tr>
<tr>
<td>3</td>
<td>Deutz 4 cylinder</td>
<td>XB 250</td>
<td>200</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>4</td>
<td>Deutz 4 cylinder</td>
<td>XB 250</td>
<td>200</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>5</td>
<td>Deutz 4 cylinder</td>
<td>HA 20</td>
<td>200</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>6</td>
<td>Deutz 4 cylinder</td>
<td>HA 20</td>
<td>200</td>
<td>2</td>
<td>1.8</td>
</tr>
<tr>
<td>7</td>
<td>Deutz 4 cylinder</td>
<td>XB 250</td>
<td>200</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>8</td>
<td>Deutz 4 cylinder</td>
<td>XB 250</td>
<td>200</td>
<td>2</td>
<td>2</td>
</tr>
<tr>
<td>9</td>
<td>Deutz 4 cylinder</td>
<td>XB 250</td>
<td>250</td>
<td>1</td>
<td>4.2</td>
</tr>
<tr>
<td>10</td>
<td>Deutz 4 cylinder</td>
<td>XB 250</td>
<td>250</td>
<td>1</td>
<td>4.2</td>
</tr>
<tr>
<td>11</td>
<td>Deutz 4 cylinder</td>
<td>XB 250</td>
<td>250</td>
<td>1</td>
<td>4.2</td>
</tr>
</tbody>
</table>

1/ Adjusted flow. Pumps 6, 10, 11 recorded 1/2 head drop.
### Table 4
**SETTLEMENT SCHEME – YIELDS AND RETURNS – 19 TRAINEE FARMERS**

<table>
<thead>
<tr>
<th>Farmers</th>
<th>Planting date</th>
<th>Maize</th>
<th>Cotton</th>
<th>Sesame</th>
<th>Sorghum</th>
<th>Groundnut</th>
<th>Returns (Birr)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Area</td>
<td>Yield</td>
<td>Area</td>
<td>Yield</td>
<td>Area</td>
<td>Yield</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Yield</td>
<td>Birr</td>
<td>Yield</td>
<td>Birr</td>
<td>Yield</td>
<td>Birr</td>
</tr>
<tr>
<td>A 1 - 5</td>
<td>October 1972</td>
<td>0.5</td>
<td>21.2</td>
<td>272</td>
<td>0.8</td>
<td>20.9</td>
<td>1 170</td>
</tr>
<tr>
<td></td>
<td>April 1973</td>
<td>0.25</td>
<td>8.1</td>
<td>243</td>
<td>0.75</td>
<td>23.8</td>
<td>1 666</td>
</tr>
<tr>
<td></td>
<td>Annual return</td>
<td>0.75</td>
<td>29.3</td>
<td>455</td>
<td>1.55</td>
<td>44.7</td>
<td>2 836</td>
</tr>
<tr>
<td>A 6 - 11</td>
<td>December 1972</td>
<td>0.3</td>
<td>9.7</td>
<td>97</td>
<td>0.80</td>
<td>18.9</td>
<td>1 058</td>
</tr>
<tr>
<td></td>
<td>May 1973</td>
<td>0.50</td>
<td>13.5</td>
<td>211</td>
<td>1.60</td>
<td>33.9</td>
<td>2 108</td>
</tr>
<tr>
<td></td>
<td>Annual return</td>
<td>0.50</td>
<td>13.5</td>
<td>211</td>
<td>1.60</td>
<td>33.9</td>
<td>2 108</td>
</tr>
<tr>
<td>E 1 - 2</td>
<td>April 1973</td>
<td>0.36</td>
<td>14.5</td>
<td>435</td>
<td>0.54</td>
<td>11.0</td>
<td>770</td>
</tr>
<tr>
<td>E 3 - 8</td>
<td>April 1973</td>
<td>0.36</td>
<td>1.23</td>
<td>369</td>
<td>0.75</td>
<td>9.6</td>
<td>672</td>
</tr>
</tbody>
</table>

1/ Costs do not include family labour or pumping costs. Tractor Birr 10/hour, plus transport fertilizer, seed, insecticides, etc. included.

2/ Yields for the first eleven farms were cotton 50.7, maize 63.1 and sesame 9 q/ha/year.
<table>
<thead>
<tr>
<th>Farmer: place of origin and number of years in Geds</th>
<th>Number of workers</th>
<th>Children</th>
<th>Relatives</th>
<th>Labourers</th>
<th>Total workers</th>
<th>Livestock</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Number of wives</td>
<td></td>
<td>Adult</td>
<td></td>
<td>Part time</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Farm work</td>
<td>Farm work</td>
<td>Farm work</td>
<td>Farm work</td>
<td>Farm work</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Gede</td>
<td>-</td>
<td>1</td>
<td>2</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>2. Imd</td>
<td>-</td>
<td>1</td>
<td>3</td>
<td>7</td>
<td>1</td>
<td>8</td>
</tr>
<tr>
<td>(3 years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>3. Gede</td>
<td>-</td>
<td>1</td>
<td>3</td>
<td>-</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>4. Gede</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>-</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>5. Gede</td>
<td>1</td>
<td>1</td>
<td>7</td>
<td>5</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>6. Kelafo</td>
<td>-</td>
<td>3</td>
<td>8</td>
<td>2</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>(5 years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>7. Degah bar</td>
<td>1</td>
<td>1</td>
<td>5</td>
<td>2</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>(4 years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>8. Gede</td>
<td>2</td>
<td>-</td>
<td>2</td>
<td>1</td>
<td>4</td>
<td>3</td>
</tr>
<tr>
<td>9. Gede</td>
<td>-</td>
<td>1</td>
<td>4</td>
<td>-</td>
<td>2</td>
<td>3</td>
</tr>
<tr>
<td>10. Kelafo</td>
<td>-</td>
<td>1</td>
<td>4</td>
<td>2</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>(9 years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>11. Kelafo</td>
<td>-</td>
<td>2</td>
<td>2</td>
<td>3</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td>(8 years)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total 22 ha</td>
<td>5</td>
<td>13</td>
<td>45</td>
<td>22</td>
<td>4</td>
<td>27</td>
</tr>
</tbody>
</table>
Appendix 1

TERMS OF REFERENCE OF IRRIGATION AGRONOMIST

The terms of reference of the Irrigation Agronomist over the period October 1971 to August 1977 are given below:

(a) October 1971 – October 1974

The Irrigation Agronomist will be stationed at Addis Ababa or Holetta, but his main duties will be at the Gode Experimental Station in the Wabi Shebelle. Under the general guidance of the Project Manager, Institute of Agricultural Research, Ethiopia, and in cooperation with other IAR staff members, he will:

1. Act as Officer-in-Charge of the Gode Station until such a time as a suitably qualified national is available to take over these duties.

2. In the above capacity he will be responsible for the development and administration of the Station on an interim basis and for evolving appropriate research programmes for the area.

3. Screen and identify a wide range of field, horticultural and perennial crops that are suitable for growing under irrigation in the Wabi Shebelle Valley.

4. Conduct agronomic studies under irrigation aimed at developing a package of recommendations for the selected crops and varieties likely to be conducive to their successful growing, and covering such aspects as responses to sowing date, seed rate, fertilizer requirements and irrigation regimes.

5. Conduct studies on irrigation methods and practices and crop water requirements.

6. Train Ethiopian staff members in all the above aspects.

7. In so far as his duties at Gode allow, advise and assist staff at Melka Werer conducting irrigation studies in the methodology of irrigation agronomy.

(b) October 1974 – May 1976

The Irrigation Agronomist, as Senior Officer-in-charge of Gode Experimental Station and the Relief Settlement Project will be stationed initially at Holetta, but will carry out his main duties at the Gode Experimental Station under field conditions, as well as subsidiary activities at Melka Werer and Jijiga.
Under the general guidance of the Project Manager, IAR, and cooperation with other staff members of the Institute, he will:

1. Be Senior Officer-in-Charge of the Gode Experimental Station responsible for the administration, development and the planning of a suitable research programme covering a wide variety of crops for the future development of irrigated agriculture in the Wabi Shebelle Basin.

2. Be directly responsible for the training and settlement of some 500 families of nomadic origin into a cooperative irrigated farming complex which is being financed from USAID by a grant of Birr 1 400 000, during the two years 1975-76.

3. Assist and advise, when requested, in the planning, development and execution of the combined Medical Services Project, Gode, which has the objective of developing 25 000 ha for the improvement of local cattle and meat production.

4. Assist and advise the staff at Melka Merer Station on irrigation techniques, experimentation and machinery use.

5. Formulate and supervise an experimental programme covering dryland cropping on the Ministry's Seed Production Farm at Jijiga.

6. Train Ethiopian staff members in all aspects of the above work.

May 1976 - August 1977

The Irrigation Agronomist will be stationed at the Melka Merer Research Station, but will be expected to provide assistance both at Melka Merer and other research sites in the Awash Valley, and at Gode Research Station and other research sites in the Wabi Shebelle Valley. His duties in the Wabi Shebelle Valley will be undertaken by visits as required.

In both valleys he will:

1. Assist in the planning and development of research programmes.

2. Assist in the conduct of studies of crop production under irrigation, these to include the production of pasture and forage crops as well as arable crops for human consumption and sale.

3. Assist in the conduct of studies on irrigation methods and practices, and crop water requirements.

4. Work on the integration of crops into viable farming systems.

5. Train Ethiopian staff in all the above aspects.

6. Report on all research work in which he is involved, giving priority initially to the back-log of reporting required for Gode.

In Gode only, he will support the Officer-in-Charge in the development of the Station and its dependent experimental sites.
Appendix 2

ADVISORY WORK AT VARIOUS IAR STATIONS AND OTHER INSTITUTIONS

Advisory visits made to various IAR stations and institutions are listed below.

<table>
<thead>
<tr>
<th>Station/Institution/Area</th>
<th>Advisory activity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tendaho Plantation</td>
<td>Experimental programme, machinery use and suitability, irrigation practices.</td>
</tr>
<tr>
<td>Addis Hiwot Rehabilitation Project</td>
<td>Pump sites, irrigation layout and cropping programmes.</td>
</tr>
<tr>
<td>Bale Province</td>
<td>Evaluation of areas for settlement sites.</td>
</tr>
<tr>
<td>Dolo-Mandera-Gonale River area</td>
<td>Pump sites, irrigation layout, settlement site selection, cropping programme and machinery selection and maintenance.</td>
</tr>
<tr>
<td>Awassa Experimental Station</td>
<td>Water supply and method, pumps and irrigation layout.</td>
</tr>
<tr>
<td>Jimma IAR Farm</td>
<td>Water supply, pumps and irrigation layout, machinery use.</td>
</tr>
<tr>
<td>Dire Dawa</td>
<td>Water supply and quality, pump and areas for horticultural production.</td>
</tr>
<tr>
<td>Jijiga Experimental Farm</td>
<td>Farm layout, experimental programme and machinery use.</td>
</tr>
<tr>
<td>Mekele IAR Experimental Farm</td>
<td>Farm layout, irrigation, well pumps and machinery use.</td>
</tr>
<tr>
<td>Besidemo Leprosy Farm Settlement</td>
<td>Experimental programme and irrigation expansion.</td>
</tr>
<tr>
<td>Nazareth, IAR Horticultural Station</td>
<td>Irrigation layout and methods, machinery use.</td>
</tr>
<tr>
<td>Holetta, IAR Experimental Station</td>
<td>Field use of machinery.</td>
</tr>
<tr>
<td>Dairy Development Agency Livestock and Meat Board</td>
<td>Sprinkler irrigation design, Holetta, for forage production. Station development for horticulture at Adami Tulu, Lakes Ziway, Hellane and Wonji.</td>
</tr>
<tr>
<td>Station/Institution/Area</td>
<td>Advisory/activity</td>
</tr>
<tr>
<td>-------------------------</td>
<td>-------------------</td>
</tr>
<tr>
<td>Melka Werer, IAR experimental programme</td>
<td>Experimental programme, farm machinery use, development and farm expansion.</td>
</tr>
<tr>
<td>Gode and Kelafo farmers' cooperatives</td>
<td>Site selection, irrigation layout, cropping programme, pump and engine selection, machinery selection and use.</td>
</tr>
<tr>
<td>World Vision Settlement, Gode</td>
<td>Site selection, machinery use, cropping.</td>
</tr>
</tbody>
</table>
Appendix 3

CUT-THROAT FLUME

The cut-throat flume is recommended for future water measurements, both in experiments and for field use, as it is much simpler to construct than the Parshall flume used at present.

The cut-throat flume has a flat bottom and vertical walls, the angles of convergence and divergence remain the same for all flumes and therefore rates of flow can be changed merely by moving the walls in or out but increasing the length with increased depth of water.

(a) Dimensions

\[ W = \text{Throat width} \]
\[ L = \text{Length} \]
\[ P_1, P_2 = \text{Piezometer offtake } P_1 \text{ for depth reading.} \]

Ratio water depth: length should be 0.4 or less.

1/ Full details are available from Colorado State University, or from FAO Irrigation Drainage Paper 26/2 (Small hydrologic structures. D.B. Kratz. Rome, 1975).
Water depth (cm) | Discharge (l/sec) | Water depth (cm) | Discharge (l/sec) | Water depth (cm) | Discharge (l/sec)
----------------|-----------------|-----------------|-----------------|-----------------|-----------------|
18.0            | 15              | 23.0            | 24              | 28.0            | 34              |
18.5            | 16              | 23.5            | 25              | 28.5            | 35              |
19.0            | 17              | 24.0            | 26              | 29.0            | 37              |
19.5            | 18              | 24.5            | 27              | 29.5            | 38              |
20.0            | 18              | 25.0            | 28              | 30.0            | 39              |
20.5            | 19              | 25.5            | 29              | 30.5            | 40              |
21.0            | 20              | 26.0            | 30              | 31.0            | 41              |
21.5            | 21              | 26.5            | 31              | 31.5            | 43              |
22.0            | 22              | 27.0            | 32              | 32.0            | 44              |
22.5            | 23              | 27.5            | 33              |                 |                 |
Appendix A

SIPHON FLOWS

Flows for 4.3 cm and 6.7 cm siphons, as tested at Gode and Melka Merer

(a) Siphon - 4.3 cm internal diameter

<table>
<thead>
<tr>
<th>Difference head (cm)</th>
<th>2.5</th>
<th>5</th>
<th>7.5</th>
<th>10</th>
<th>12.5</th>
<th>15</th>
<th>17.5</th>
<th>20</th>
</tr>
</thead>
<tbody>
<tr>
<td>Flow (l/sec)</td>
<td>0.62</td>
<td>0.87</td>
<td>1.06</td>
<td>1.24</td>
<td>1.38</td>
<td>1.51</td>
<td>1.63</td>
<td>1.7</td>
</tr>
</tbody>
</table>

(b) Siphon - 6.7 cm internal diameter

| Difference in head (cm) | 2.5 | 5  | 7.5 | 10  | 12.5 | 15 | 17.5 | 20 | 22 | 24 | 26 | 28 | 30 | 32 | 34 | 36 | 38 | 40 | 45 |
|-------------------------|-----|----|-----|-----|------|----|------|----|----|----|----|----|----|----|----|----|----|----|----|----|
| Flow (l/sec)            | 1.5 | 2.1| 2.6 | 3.0 | 3.3  | 3.6| 4.0  | 4.4| 4.8| 5.1| 5.4 | 5.7 | 5.9 | 6.2 | 6.4| 6.6 | 6.8 | 7.0| 7.5 |
**Appendix 5**

**YIELDS IN THE WADI SHEBELLE BASIN UNDER PRODUCTION CONDITIONS**

<table>
<thead>
<tr>
<th>Crop</th>
<th>Isolation (m)</th>
<th>Root depth</th>
<th>Salinity 2/</th>
<th>Yield (q/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Maize</strong> Zea mays</td>
<td>150-200</td>
<td>D</td>
<td>M</td>
<td>50</td>
</tr>
<tr>
<td><strong>Cotton</strong> Gossypium hirsutum barbadense</td>
<td>50-100</td>
<td>D</td>
<td>H</td>
<td>50</td>
</tr>
<tr>
<td><strong>Sesame</strong> Sesamum indicum</td>
<td>200-350</td>
<td></td>
<td></td>
<td>13</td>
</tr>
<tr>
<td><strong>Groundnut</strong> Arachis hypogaea</td>
<td>15</td>
<td>S</td>
<td>L</td>
<td>60</td>
</tr>
<tr>
<td><strong>Cowpea</strong> Vigna unguiculata</td>
<td>100-150</td>
<td>M</td>
<td>L</td>
<td>33</td>
</tr>
<tr>
<td><strong>Pigeon pea</strong> Cajanus cajan</td>
<td>200-350</td>
<td>L</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Dolichos bean</strong> Dolichos spp</td>
<td>200-350</td>
<td>D</td>
<td>L</td>
<td>-</td>
</tr>
<tr>
<td><strong>Bean</strong> Phaseolus spp</td>
<td>40-60</td>
<td>S</td>
<td>L</td>
<td>-</td>
</tr>
<tr>
<td><strong>Soybean</strong> Glycine max</td>
<td>Nil</td>
<td>M</td>
<td>L</td>
<td>11</td>
</tr>
<tr>
<td><strong>Safflower</strong> Carthamus tinctorius</td>
<td>200-250</td>
<td>D</td>
<td>ML</td>
<td>15</td>
</tr>
<tr>
<td><strong>Sunflower</strong> Helianthus annuus</td>
<td>800</td>
<td>M</td>
<td>ML</td>
<td>30</td>
</tr>
<tr>
<td><strong>Wheat</strong> Tritium aestivum/ durum</td>
<td>2-3</td>
<td>M</td>
<td>M</td>
<td>20</td>
</tr>
<tr>
<td><strong>Barley</strong> Hordeum vulgare</td>
<td>180</td>
<td>M</td>
<td>H</td>
<td>20</td>
</tr>
<tr>
<td><strong>Sorghum</strong> Sorghum vulgare</td>
<td>200</td>
<td>D</td>
<td>M</td>
<td>35</td>
</tr>
<tr>
<td><strong>Millet</strong> Panicum spp</td>
<td>150-250</td>
<td>M</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Rice</strong> Oryza sativa</td>
<td>15-30</td>
<td>M</td>
<td>-</td>
<td></td>
</tr>
<tr>
<td><strong>Teff, Haginz</strong> Eragrostis tef and Tefaddia</td>
<td>Nil</td>
<td>M</td>
<td>-</td>
<td>13</td>
</tr>
</tbody>
</table>

1/ Shallow up to 60 cm
2/ Resistant
M - Medium 60-120 cm
D - Deep 120 cm
H - Medium Resistant
L - Susceptible
<table>
<thead>
<tr>
<th>Crop</th>
<th>Isolation (m)</th>
<th>Root 1/ depth</th>
<th>Salinity 2/ Yield (q/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Bambara groundnut Voandzeia</td>
<td>200-350</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Visitae subterranea</td>
<td></td>
<td>Me</td>
<td></td>
</tr>
<tr>
<td>Tobacco Nicotiana tabacum</td>
<td>50-400</td>
<td></td>
<td>24 flue cured leaf</td>
</tr>
<tr>
<td>rustica</td>
<td></td>
<td>leaf</td>
<td></td>
</tr>
<tr>
<td>Kenaf Hibiscus cannabinus</td>
<td>50-250</td>
<td></td>
<td>30</td>
</tr>
</tbody>
</table>

(b) Vegetable crops

<table>
<thead>
<tr>
<th>Crop</th>
<th>Isolation (m)</th>
<th>Root 1/ depth</th>
<th>Salinity 2/ Yield (q/ha)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tomato Lycopersicum</td>
<td>30-100</td>
<td>D</td>
<td>MH 500</td>
</tr>
<tr>
<td>esculentum</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Carrot Daucus carota</td>
<td>250-1 000</td>
<td>N</td>
<td>NL 2 269</td>
</tr>
<tr>
<td>Radish Raphanus sativus</td>
<td>250-300</td>
<td>S</td>
<td>L</td>
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(c) Fruit crops

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Appendix 6

FRICTION LOSS IN WELDED STEEL PIPE
(in metres per 100 m)

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Appendix 7

ALTERNATIVE COTTON GINNING AND BALING PROPOSALS FOR A PILOT PLANT IN THE GUGIEN, ETHIOPIA

(Quotation provided by Ethiopian Commodities Private Ltd. Co.)

1. Cotton production

Assuming that cotton production rises to 1,000 t seed cotton in five years, with an annual progression of 200 t from the first year, these 200 t of Acala type seed cotton with estimated lint percentage out-turn of 38 percent, will produce 76 t lint, equivalent to 425 bales x 400 lb Standard Density.

2. Ginning and baling requirements

(a) The most economic approach to providing ginning capacity in this most remote area, where cotton production will increase at a relatively slow rate, would be to transfer an existing gin from Addis Ababa, and install a low density press. The Addis Ababa gin could be replaced by high capacity gins in Addis or elsewhere.

(b) The alternative, should a separate pilot plant unit be preferable, and if the availability of a second-hand gin from Addis Ababa is in doubt, is the provision of the simplest saw-gin stand and low-density press, which would be the cheapest pilot unit obtainable.

(c) If there was any likelihood of cotton production expanding more rapidly to say 5,000 t in five years, and the possibility of doubling production by the seventh year, it would be prudent to install one high capacity gin immediately, with a high-density baling press, but such a plant would be expensive, the initial cost of machinery alone being in excess of £ 125,000 1/.

1/ £ (U.K.) 1.00 = Birr 3.6.
3. **Ginning and baling specification**

Simplest pilot plant as outlined in 2 (b)

(a) **Output**

One 40-saw Platt's gin with 8-in dia. saws x 750 rpm brush doffing, giving an output between 250 lb and 400 lb lint cotton per hour - depending on type, conditions, and grade of seed cotton. Assuming 1 bale x 400 lb per hour Acala-type cotton, output will be:

- 10 bales per 10-hour day
- 60 bales per 6-day week
- 1,000 – 1,200 bales per 20 week season

1st year crop estimate – 425 bales
2nd year crop estimate – 850 bales
3rd year crop estimate – 1,275 bales

One 40-saw gin would probably meet the required capacity for the first three seasons, then a second could be installed to take capacity up to the 1,000 t seed cotton production estimated in the five-year period.

(b) **Pressing**

A manually-operated baling press is available which would produce about 2 bales x 200 lb per hour "half-pressed", and a bale dimension of 39-in x 25-in x 28-in approximately. This would be suitable for domestic consumption in Ethiopia, but not for export. The small quantity of bales produced does not justify the cost of a high density press costing around £50,000.

(c) **Cleaning and conveying**

To keep cost down, no cleaning equipment need be installed. The cotton will be hand picked and carefully sorted and graded. Prior to ginning it could be spread out in the sun, which will dry and open the seed cotton to some extent. It can then be fed into the 40-saw gin manually. The lint can be collected in a tray or skip from the gin, carried manually to the press and fed manually to the press box.

(d) **Power supply**

It would be simpler to supply a diesel generating unit to supply electric power to drive the equipment, than an engine and transmission shafting.
4. Estimate

Estimate for pilot plant 1

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<td>One 40-saw gin, complete with 5-5 bhp motor and starter and suitable spares</td>
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<td>One seed conveyor and 4-5 hp motor and starter</td>
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<tr>
<td>One Platt's press electrically operated (hand-operated - £ 2 650)</td>
<td>4 500</td>
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<tr>
<td>One diesel generating set - say 52 KVA 40 kW with reserve power for lighting and water pump, etc.</td>
<td>2 800</td>
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<td>To c.i.f. Djibouti - say 12%</td>
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<td>Transport, clearing and forwarding, say 5%</td>
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<td>Duty - say 5%</td>
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<td>Total estimate</td>
<td>15 000</td>
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Building - 30 ft x 20 ft x 23 ft 6 in Blockwall, angle-iron, C.I. roof
Local purchase of material, labour
Miscellaneous erection costs, cable, switchgear, etc.

Total estimate

£20 000

1/ A single high-capacity gin unit - 7 bales/hour - with single box standard density press, could produce 15 000 bales in 22 weeks, 20 hour day x 5 day week. Cost about £ 60 000 f.o.b., generator extra.
Appendix B

NOTE ON SCHISTOSOMIASIS CONTROL MEASURES IN THE WABI SHABELLE IRRIGATION FARMS 1/

It is difficult to suggest effective schistosomiasis control measures, for three main reasons:

1. The snail intermediate host of Schistosoma haematobium (urinary schistosomiasis) in the Wabi Shebelle basin is not known although it is most likely Bulinus abyssinicus which transmits this disease in the irrigation farms of the Somali Republic and the swamps of that country and the Awash Valley (Gewani and the Awash Delta). The Bulinus spp found by Lemma have not been identified.

2. B. abyssinicus has not been found in irrigation canals anywhere in Ethiopia, although B. abyssinicus-containing swamps exist near some of these farms, such as the ones at Barga Farm and Dubti/Dib Bahari farms in the lower Awash Valley. It is not known whether the physico-environmental conditions of the farms on the Ethiopian side of the Ogaden resemble those of the Somali farms, many of which grow banana and sugar-cane, or those of the Awash Valley. Here we are speaking in terms of irrigation schedules, canal outlay, and population size of farms, in addition to topography of the land, soil texture, climate, and crop types.

3. Our knowledge of the ecology of B. abyssinicus, in particular its resistance to dessication and habitat preference, is very limited. Each snail species has different habitat requirements, thus different tolerances to such stresses as dessication and extreme temperatures. Most studies on the ecology of S. haematobium intermediate snail hosts in irrigation canals in Africa come from Egypt where live snails (B. truncatus) have been recovered from more or less dry canals that had not received irrigation water for as long as 6 weeks. Since no detailed information is available on how dry the soil of the canal beds was and if canals where uniformly dry throughout their length, the above information is of limited value.

The only recommendations which can be made, based on field knowledge of B. abyssinicus and other aquatic snails in the Awash Valley, are to:

(a) Ensure that there are no potential snail habitats on or near the farms during the period of non-irrigation, such as ponds, reservoirs, or stagnant drains, because snails may be reintroduced from there to the canals by birds and even by irrigation water current.

1/ Note prepared by H. Kloos, Schistosomiasis Consultant.
(b) Discontinue irrigation in all canals for six to eight weeks once a year. This would presumably be after harvesting the main crop.

(c) Maintain all canals in good working condition, in terms of siltation and vegetation control, seepages, overflows and eroded banks and canal beds. To accomplish this, canals should be cleaned at least once or twice a year, whenever local conditions and the weather (i.e. heavy rains and siltation) make it necessary.

(d) Practice only daytime irrigation, if possible, to provide for significant diurnal water level changes that may kill snail eggs and the adult snails. In general, aim for the highest standards in irrigation efficiency and agricultural practices, as they relate to economizing irrigation water. Some irrigation engineers should be available, at least for consultation. It is recommended that such specialists be consulted in the planning phase of new irrigation schemes.

(e) Plan for a programme of periodic snail surveys, preferably by a visiting specialist who should submit his findings after each survey in the form of a report, and who should make appropriate recommendations to the irrigation engineers and other workers in that field. Irrigation schedules and canal maintenance operations may then be adjusted in a way that could either preclude the colonization of canals by schistosomiasis snails or reduce their numbers.

No definite statements can be made at present on the control of any possible snail intermediate hosts in the Wabi Shebelie irrigation farms. The above recommendations can only be tentative and subject to change, after more has been learned about the local conditions in the Valley and the ecology of the snails.
## Appendix 9

**STAFF**

### STAFF OF CODE AGRICULTURAL RESEARCH STATION

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<tr>
<td>J.P. Dallyn</td>
<td>Officer-in-Charge/ (October 1971 to August 1977) Irrigation Agronomist</td>
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Consultancy visits (International Institute of Agriculture)

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<tr>
<td>N. Fadda</td>
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<tr>
<td>A. Hamersley</td>
<td>Entomologist</td>
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<tr>
<td>J.H. Saunders</td>
<td>Mechanical Engineer</td>
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<tr>
<td>T.J. Crowe</td>
<td>Pulse Agronomist</td>
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<tr>
<td>P. Wesserling</td>
<td>Plant Pathologist</td>
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<tr>
<td>L. Ohlander</td>
<td>Agronomist, Weed Control</td>
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<td>E. Niemann</td>
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<td>J. Moore</td>
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Graduate counterpart staff

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<td>Bisrat Gebre Kalle</td>
<td>Agronomist and Counterpart, Officer-in-Charge to June 1972</td>
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<tr>
<td>Yebio Wolde Mariam</td>
<td>Assistant Research Officer and Counterpart Officer-in-Charge (October 1971 to May 1973). Proceeded on fellowship</td>
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<tr>
<td>Tedele Gebre Selassie</td>
<td>Assistant Research Officer (July 1973 to September 1976). Proceeded on fellowship</td>
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<tr>
<td>Mengiste-Ab Solomon</td>
<td>Assistant Research Officer (July 1973 to October 1974). Transferred to Mekale.</td>
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<tr>
<td>Pikade Selassie Girma</td>
<td>Assistant Research Officer (May 1976) Officer-in-Charge (September 1976 to August 1977)</td>
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**EUS personnel, Alemaya College**

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<td>Altamaw Aytenfisu</td>
<td></td>
</tr>
<tr>
<td>Mengiste-Ab Solomon</td>
<td></td>
</tr>
<tr>
<td>Teoleab Mezghana</td>
<td></td>
</tr>
<tr>
<td>Haissana Solomon</td>
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</tr>
<tr>
<td>Kiflamariam Mengistu</td>
<td></td>
</tr>
<tr>
<td>Asefa Gebre Amlake</td>
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</tbody>
</table>
## RELIEF SETTLEMENT PROJECT

<table>
<thead>
<tr>
<th>Name</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Major Mulugata Kebede</td>
<td>General Manager</td>
</tr>
<tr>
<td>Umeta Waktolie</td>
<td>Administrator</td>
</tr>
<tr>
<td>G. Gilbert (FAO)</td>
<td>Senior Mechanical Engineer, Consultant</td>
</tr>
<tr>
<td>C.R. Fields (FAO)</td>
<td>Associate expert (1975–76)</td>
</tr>
<tr>
<td>A. Joiner (Friends Service Council)</td>
<td>Mechanical Engineer, Kelafo area</td>
</tr>
<tr>
<td>R. Rees (Oxfam)</td>
<td>Agricultural, Kelafo area</td>
</tr>
<tr>
<td>P. Shears (Oxfam)</td>
<td>Irrigation Engineer (part-time in 1975–76)</td>
</tr>
<tr>
<td>R. Fuller (ex-American Peace Corps)</td>
<td>Agronomist, Gode</td>
</tr>
<tr>
<td>L. Klante (German Peace Corps)</td>
<td>Mechanical Engineer, Gode</td>
</tr>
<tr>
<td>C. Tolle ((German Peace Corps)</td>
<td>Agronomist, Gode</td>
</tr>
</tbody>
</table>

**International agencies (experts for short periods):**

USAID, UNICEF, WFP, Oxfam, Norwegian Save the Children, WHO, Concern, Friends Service Council, GRDA, SID, FAO "Aid to Settlement", in particular P. van den Hoven, Irrigation Engineer, who supervised the surveying and designed the 1000 ha area at Gode and Ms. C. Simpson, Consultant.
Appendix 10

REFERENCES


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(20) FAO. Agricultural and horticultural seeds. Rome. FAO Agricultural Studies No. 55.


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CLIMATE DIAGRAM OVER 1967-71

Fig. 1
Fig. 2

CONDUCTIVITY (mmho/cm (E.C. 10^6) DAILY) WABI SHEBELLE, GODE, JANUARY - DECEMBER 1972

American classification (USDA, Agricultural Handbook 60)
GROUNDWATER CONDUCTIVITY (mmho/cm, weekly)

MARCH 1972 - JULY 1973

GROUNDWATER DEPTH (m)

E.C.10^6

-7000
-6000
-5000
-4000
-3000
-2000
-1000
-500
0

Metres

MAR. APR. MAY JUNE JULY AUG. SEPT. OCT. NOV. DEC. JAN. FEB. MAR. APR. MAY JUNE JULY 1972 1973
LAYOUT AT EXPERIMENTAL FARM, GODE

a) DESIGN LAYOUT OF EXPERIMENTAL STATION

b) STANDARD LAYOUT FOR 10 ha EXPERIMENTAL FIELD

---

SLOPE 0.05%

400 m EXPERIMENTAL RUN

16 plots each
11.6 m gross
151.6 m in 200 m run

53.6 m I BLOCK FOR EXPERIMENTS
53.6 x 9 BLOCKS = 492.4 m
IN 500 m LENGTH GROSS

---

CANALS

ROADS BETWEEN CANALS AND DRAINS

FIELD CHANNELS

WINDBREAKS

DRAINS
IRRIGATION EXPERIMENTS - TYPICAL LAYOUT SHOWING TWO REPLICATIONS, SPLIT PLOT DESIGN

PARSHALL FLUME

**Fig. 5**

TO DRAIN OR SECOND EXPERIMENT

REP I

- 5 cm
- 2 weeks
- 15 cm
- 2 weeks
- 10 cm
- 2 weeks

REP II

- 15 cm
- 4 weeks
- 10 cm
- 4 weeks
- 5 cm
- 4 weeks

REP III

- 15 cm
- 3 weeks
- 10 cm
- 3 weeks
- 5 cm
- 3 weeks

REP IV

- 5 cm
- 2 weeks
- 10 cm
- 2 weeks
- 15 cm
- 2 weeks
Fig. 6

COTTON - WATER REQUIREMENTS EXPERIMENT

YIELD (q/ha)

WATER DUTY (mm/day)

OCTOBER TRIAL

Y = 6.8988 + 5.1391x - 0.1313x^2
R^2 = 0.92

APRIL TRAIL

Y = 1.8423 + 3.4014x + 0.1408x^2
R^2 = 0.82
SESAME-WATER REQUIREMENTS EXPERIMENT

Y = -3.47417 + 2.65919x - 0.11218x^2

R^2 = 0.84
GROUNDNUT - WATER REQUIREMENTS EXPERIMENT

\[ Y = 15.0262 + 3.0615x - 0.0998x^2 \]

\[ R^2 = 0.81 \]