IMPROVING HOST PLANT RESISTANCE WITHOUT SACRIFICING YIELD AND QUALITY IN ZIMBABWE

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INTRODUCTION

The Cotton Research Institute (CRI) which falls under Agricultural Ministry carries out Cotton variety improvement in Zimbabwe. The Institute started as a Cotton Breeding Station in 1925 and the present programme of cotton production research includes cotton breeding and pathology, cotton agronomy and cotton pest research. The breeding programme includes the development of medium staple and long staple varieties, adapted to different climatic conditions and production requirements, and the incorporation of disease and pest-resistant characteristics into these varieties.

Cotton is grown by large scale commercial growers where the levels of inputs and management are high and where the crop may be grown under irrigated or rainfed conditions. It is also grown by small-scale commercial and communal growers, primarily under rainfed conditions and usually at lower input and management levels. Altitude where cotton is grown varies form 300m above sea level to 1200m above sea level. While the bulk of the cotton produced in Zimbabwe is medium staple, some long staple cotton is also produced. Over 98% of the Zimbabwean cotton are hand picked.

Host plant resistance refers to any inherited characteristics of a host plant which lessens the effect of parasitism that is to say resistant plants are less damaged by parasites than are susceptible plants. In Zimbabwe host plant resistance has been improved over the years successfully for the control of jassid (pest) and the diseases bacterial blight and verticillium wilt to some extent. Currently all varieties grown in Zimbabwe have good tolerance to Bacterial blight and have good jassid resistance.

Improvement of host plant resistance to jassid, bacterial blight and verticillium wilt takes place along side other characters that are evaluated during the overall variety improvement/breeding programme.

THE BREEDING PROGRAMME

The aim of the breeding programme is to develop, evaluate and maintain cotton varieties that satisfy the needs of farmers, ginners and marketeers in Zimbabwe. The needs of these stakeholders can be summarised under field and fibre characteristics:

FIELD CHARACTERS	QUALITY CHARACTERS
Adaptability	Colour
Seed cotton yield	Fibre length
Lint yield (high ginning %)	Uniformity
Boll mass	Strength
Plant habit	Elongation
Stress tolerance	Maturity
Growth pattern	Fineness
Spray penetration	Seedcoat attachment
Pickability	

Disease resistance:
- **Bacterial blight**
- **Verticillium wilt**
- Alternaria leaf spot

Insect resistance:
- **Jassid**
- Aphid
- Bollworms

The priority of individual characters vary as circumstances change but will largely be determined by the needs of the grower, ginnery, marketer and spinner. As such all sections of the cotton industry are consulted at regular intervals to ensure that breeding objectives are up to date and that they reflect the industry's requirements. Since it takes up to 12 years or more from the time of single plant selection to commercial variety release, it is essential that the programme is able to anticipate future requirements by carrying a sufficiently broad genetic base to enable it to react quickly to changing needs.

In order for the breeding programme to respond to industry needs the breeding programme is divided into six parts:

1. **The Medium Staple Middleveld Programme** aims at developing medium staple Albar cotton varieties for the traditional cotton growing areas that lie between 600m and 1200m a.s.l. The emphasis is to produce good quality varieties capable of giving a satisfactory return over a wide range of growing conditions.

2. **The Medium Staple Lowveld Programme** is designed to develop Albar varieties for the southeast lowveld areas that lie between 300 and 600m a.s.l. where cotton is grown by both low input and high input farmers.

3. **The Long Staple Programme** caters for high quality, long staple varieties that can be grown under a range of input levels to meet local and overseas

requirements. Despite their lower yield potential, long staple varieties can be favoured by the premium paid for their high quality.

4. **The Highveld Programme** whose main emphasis is the development of Albar varieties which are sufficiently adapted to cooler growing environments and which complete their growing cycle before the risk of frost becomes high.

5. **The Mechanical Harvesting Programme** which aims at developing varieties that are machine harvestable with minimum input use. The programme was started in response to shortage of labour for hand picking of cotton on large commercial farms.

6. **The Verticillium Wilt Programme** whose aim is to improve host plant resistance to verticillium wilt.

It is important to note that improvement of jassid and blight resistance is paramount in all of the breeding programmes above except the Mechanical harvesting programme . This is because leaf hairiness, which imparts jassid resistance, constitutes trash for machine picked cotton and in order to reduce trash contamination glabrous varieties are prefered Blight resistance is however important even for machine picked cotton.

Variety Improvement trials are conducted in all major and potential cotton producing areas of Zimbabwe. On average 200 breeding trials are conducted annually on about 80 sites of which at least 50% are in the communal dryland areas. Over 80% of the trials are on-farm and are managed by cotton farmers (both communal and large scale) under the guidance of research personnel.

The Problem of Jassid in Zimbabwe

Jassids have been a serious threat to cotton production in Zimbabwe since as far back as 1925 where the commercial variety then, improved Bancroft, was described as "generally susceptible to jassid attack. Leaf hairiness - a combination of hair density and hair length, particularly on the underside of leaves imparts resistance to jassid attack. The mechanism of resistance is that the leaf hairs interfere physically with the feeding, movement and oviposition of the jassids. Unlike many other characters which confer resistance to cotton pests the breeding of jassid - resistant varieties does not conflict unduly with the need to maintain yields and quality.

Jassid is a very important for the communal farmer who often does not have money to buy chemicals to spray. Only those varieties assessed for at least three seasons and found to have enough jassid tolerance to avoid economic yield loss are recommended for dryland production in the communal areas

In the breeding programme a number of hairy exotic varieties mostly West Africa have been used in the crossing programme with the locally adapted varieties. Single plants are selected for among other characteristics, hairiness. Screening of varieties for resistance to jassid starts from the second season of testing onwards. All varieties in the programmes mentioned before are assessed for jassid resistance. Varieties found to be too susceptible to jassid are discarded if they are not suitable for machine picking.

Jassid Screening:

During the jassid screening programme varieties from the second stage of testing onwards from all the breeding programmes are grown under the unsprayed conditions. No chemicals are sprayed for the control of any pest except aphids in which case a selective aphicide is used. The aphids are only sprayed when their counts are so high that they make the cotton leaves unattractive to jassids and this is usually early in the season before the jasside counts are high.

To encourage jassid built up the cotton selections are planted with cow peas at a regular intervals. The cow peas are more attractive to the jassids and so attract the jassids early on in the season. When the jassid have built up in the cow peas, the cow peas are then uprooted to dry and as the cow peas dry the jassids migrate to the cotton plants. In resistant varieties the leaves are not visibly affected or in very severe attack the leaf margins turn pale yellow while in susceptible varieties, leaves become badly curled and reddened and plant growth is severely stunted.

In Zimbabwe over 80% of the crop is produced by communal farmers. Jassid is a particular problem in these areas where pesticide use is often limited by availability or cost. Therefore, all dryland varieties are selected for good jassid resistance which drastically reduces yield loss from this particular pest. Large scale commercial farmers on the other hand have the capacity to spray for pests when and as the need arises and as such some high yielding varieties which are not necessarily resistant to jassid can be recommended. This is because the regular pesticides applied to control other pests inadvertently control jassid in most cases.

It is however, important to note that several adverse factors are associated with hairy or pubescent varieties. White flies can be more abundant and heliothis moths prefer to lay eggs on pubescent varieties compared with glabrous ones. So here there is a conflict and a decision has to be made about which pests can be controlled with resistant cotton varieties and which have to be controlled by other methods, usually insecticides. In Zimbabwe while white fly is a problem in some seasons under high input conditions it is not serious under dryland growing conditions where the bulk of the crop comes from.

Bacterial Blight in Zimbabwe

Bacterial blight is a very important cotton foliar disease in Zimbabwe. The disease is caused by *Xanthomonas campestris* and yield losses can range from 10 - 70% depending on severity of epidemic and well as variety susceptibility to the disease.

All Albar varieties grown in Zimbabwe commercially have good levels of resistance to bacterial blight and as a result the disease is rarely seen.

Bacterial Blight Screening Programme

The bacterial blight programme is concerned with screening for host plant resistance within the main pedigree breeding programme. Routine screening is carried out annually on introductions, crosses, hybrid pools, population development programmes, non-replicated progeny rows and in the preliminary and advanced variety trials.

Bacterial blight resistance is one of the characteristics on which single plant selection (SPS) is based at the very beginning of the pedigree breeding programme. Breeding material is inoculated each season from the SPS stage onwards, with susceptible material being rogued. Once the material reaches the strain stage of selection, evaluation for blight resistance is conducted in replicated trial where roguing is not practiced.

Screening is based on stem and boll inoculation. Stem inoculation is made by a puncture at the top most internode of the young plant with a machine needle dipped into the inoculum. This is usually done at 6 weeks post-germination and plants are assessed about 3 and 6 weeks later. Assessment is made by direct measurement of lesion size on the stem. The more variable the material under test, or the more advanced its stage of testing, the larger the amount of plants are inoculated and assessed for reaction to black-arm infection. Natural infection may also be used in seasons favourable to the disease.

The severity of disease reaction in response to innoculation which separates resistance from susceptibility is decided upon in any one season with reference to the controls but generally for SPS a score of 3 or lesion diameter of 3mm or more is considered susceptible for stem inoculation and boll inoculation respectively. In replicated trials the material is categorised as below:

Category of Disease Reaction	**Description**	**Stem Lesion (Score 1 - 6)**	**Boll Lesions (diameter mm)**
RR	Highly resistant	1 (no reaction)	1 (no reaction)
R	Resistant	2	2
I	Intermediate	3	3 - 5
S	Susceptible	4	6 - 9
SS	Highly susceptible	5 - 6	10 or above

Selection of Isolates

Each season isolates of *Xanthomonas malvacearum* are collected infected leaves, stems and bolls from as many different localities as possible. The Isolates are tested in the glasshouse before the start of the new season by inoculating them into the 8 host differentials. An isolate is then selected on the basis of virulence and apparent "race". An isolate corresponding to race 10 is preferred as this race is virulent to a wider range of material then race 6.

Because bacterial blight is very important in Zimbabwe all single plants and varieties under test from all the breeding programmes are assessed for resistance to blight and only the resistant single plants and varieties are selected for further testing.

The Verticillium Wilt problem in Zimbabwe

Verticillium wilt became an important disease of cotton in Zimbabwe, due mainly to the development of commercial varieties which had much improved yield and fibre qualities but which were susceptible to Verticillium. Indications are that Verticillium is becoming distributed over a wider area each season. The development of new commercial varieties which were less resistant to the disease than previous varieties derived from strictly Albar population, allowed Verticillium wilt incidence to increase in areas where it was absent, or present at a very low level in the past.

Wilt incidence in Zimbabwe increased dramatically in 1983 when the variety then called Albar 72B was replaced by Albar K602 whose genetic background involved some non-Albar material.

Sources of resistance

Both Albar G501 and Albar 72B have some resistance to wilt and have been used in the wilt crossing programme. Acala varieties from USA and particularly the MAR germplasm have also been crossed with locally adapted varieties together with Australian varieties. The use of the old varieties like Albar G501 and Albar 72B however compromises fibre quality and yield to some extent. The old varieties have coarse, weaker, shorter and less uniform fibre and do not yield as well as the newer varieties. Wilt resistant varieties with acceptable fibre quality have been used a lot in the breeding programme.

Breeding for resistance

From the strain stage (F5) of the pedigree line breeding programme onwards, when sufficient seed is available for replicated screening trials, material is evaluated for wilt resistance on land heavily infected with the pathogen and where the disease is sufficiently evenly distributed to rely on natural infection. However, because of the risk of disease escape, natural infection is unreliable for single plant selection and artificial inoculation is required. Stem inoculation is used for selection in unreplicated material and in addition, all replicated trials which are screened by natural infection planted in duplicate for stem inoculation. Stem inoculation is successful in the field provided the trials are sown late so that inoculation is carried out in cooler weather.

There appears to be some site to site variation in the expression of resistance to wilt and the aim has therefore been screening material in the geo-climatic zone for which it is intended. Also, at each site there should be two screening areas which are used for trials in alternate years. In the intervening years a susceptible variety is grown to even out the distribution of the pathogen.

Currently two varieties Albar BC 853, a medium staple variety and CY 889, a long staple variety can be grown under wilt conditions in Zimbabwe.

ACHIEVEMENTS OF THE PAST 15 YEARS

a) Seed Cotton Yield

Over the past 15 years all new varieties have demonstrated some seed cotton yield improvements over their predecessors with the average level of improvements ranging from about 3% to 20%, depending on the season. A striking feature of the yield performances of more recent varieties is their ability to perform much better than older varieties under stress conditions.

b) Fibre Quality

A major push towards developing higher quality medium staple Albar cottons occurred during the past 10-15 years and this has resulted in the present varieties having superior fibre quality (particularly length, strength and fineness) to that obtained before. The improved quality in the new varieties has been recognised by the various marketing groups who now give growers a 7 - 20% seed cotton price premium for a range of these "improved Albar" varieties:

Table 1: Fibre Characteristics of Zimbabwe varieties

Variety	Staple (inches)	Strength 1/8 gauge gpt	Maturity	Fineness	Micronaire Range
Albar SZ 93 14	1 3/32 to 1 5/32	27-30	82-99	130-175	4,0-4,9
Albar FQ 902	1 3/32 to 1 5/32	27-30	82-99	160-180	3,8-4,8
Albar BC 853	1 3/32 to 1 1/8	27-30	> 80	130-170	3,8-4,6
LS 9219	1 7/32 to 1 5/16	29-33	> 80	160-190	3,5-4,6
CY 889	1 3/16 to 1 ¼	29-33	> 80	160-190	3,5-4,6

c) Ginning % and Lint Yield

The percentage of lint removed from seed cotton during ginning (referred to as ginning % or gin outturn) was between 34% and 36% in the older varieties. However, following a shift in selection priorities and the use of high ginning % foreign varieties in crosses with local material major advances have been made such that our most recent cultivars now have values of around 42% (using a 40 saw gin). Under commercial ginning the newer varieties produce at least 10% more lint than the old varieties.

d) Diseases

The two most important cotton diseases in Zimbabwe are bacterial blight and Verticillium wilt. The former is widespread in all cotton growing areas and it can cause yield losses of around 20% in susceptible varieties. Combined efforts from the pathologists and breeders have ensured that all our current cultivars have sufficient bacterial blight resistance to prevent yield loss from this disease.

Verticillium wilt is largely restricted to heavier soils such as those found in the large scale sector where it can cause substantial yield loss when infection levels are high. Two varieties, medium staple Albar BC 853 and long staple CY 889 were developed and released specifically for farms where the disease is endemic. They combine good wilt tolerance with good fibre quality.

e) Pests

Insect pests are a major cause of yield loss in cotton if preventative measures are not taken. In most cases this requires the use of pesticides but one of our major pests, jassid, can be controlled by variety resistance. Jassid is a particular problem in the communal areas where pesticide use is often limited by availability or cost. Therefore, all our dryland varieties have been selected for good jassid resistance which drastically reduces yield loss from this particular pest.

The drier-than-normal seasons during the first half of the 1990s encouraged widespread aphid build-up and this allowed the breeders to identify material with increased aphid tolerance.

The breeding programme has also improved the chances of better pest control by producing some varieties with an open plant structure which allows better spray penetration into the crop and an increased chance of hitting the target area.

f) Long Staple Cotton

Long staple cotton is a high value crop which was principally grown under high input conditions and which usually produces between 12 000 and 15 000 tonnes of seed cotton per season. The first of Zimbabwe's long staple varieties, called Delmac, was developed in the early 1970's but it had an erratic yield performance and it was very susceptible to bacterial blight. Currently a new look long staple variety called CY 889, which was released in 1994 has since built a good reputation among growers for its reliable yield performance and good disease resistance. Another long staple variety called LS 9219 was further released in 2001 and can be grown under both low input and high input management systems.

g) High Altitude Cotton

In 1996-97 Zimbabwe released its first high altitude cotton cultivar. Traditionally, cotton has been grown in Zimbabwe at altitudes between 300m and

1200m, although efforts to raise the ceiling by producing cool tolerant cultivars have been ongoing since 1976. The release of the new variety, called HAP 1, has enabled the extension of areas suitable for cotton production from 1200m to 1350m and will allow growers at these altitudes to consider cotton as a new option in their farming systems.

CONCLUSION

The present breeding programme contains an extremely broad genetic base which present every opportunity to introduce improvements over existing and imminent varieties. The short to medium term objectives of the breeding programme are to continue improving the yield, drought, pest and disease tolerance as well as the general fibre quality of Zimbabwean varieties with special emphasis on fibre uniformity, strength and elongation. Our long term objective is to reduce the number of varieties grown in the country by introducing broad adaptability genes in our germplasm. We also hope to introduce some genes that confer resistance to a number of bollworm species and specific herbicides into our varieties. The Bt and Round-up Ready genes are top on our priority list.