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Strategies and Selection Criteria for Participatory Cotton Breeding in Uganda

A Diagnostic Study

M.Sc. Thesis Report Plant Breeding and Genetic Resources

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I hope that with all the before mentioned contributions and my own efforts, this thesis will be an interesting reading and help to initiate participatory variety improvement to the benefits of the hard-working Ugandan cotton producers.

Content

Abbreviations

AELBI	AgroEco – Louis Bolk Institute
ANOVA	Analysis of Variance
BPA	Bukalasa Pedigree Albar, Ugandan cotton variety
Bt-Cotton	Genetically modified cotton expressing a gene from *Bacillus thuringiensis*
CDO	Cotton Development Organization of Uganda
CLIP	Collaboration or Conflict, Legitimacy, Interests and Power, a social analysis technique
CCIU	Cotton Conservation Initiative Uganda
DAP	Days after planting
DDT	Dichlorodiphenyltrichloroethane, highly persistent insecticide
GM	Genetically modified
LOFP	Lango Organic Farming Promotion
NARO	National Agricultural Research Organization of Uganda
NaSARRI	National Semi-Arid Resources Research Institute
NBCC	North Bukedi Cotton Company
NGO	Non-Governmental organization
NOGAMU	National Organic Agriculture Movement of Uganda
SATU	Serere Albar Type Uganda, Ugandan cotton variety
UNACOFF	Ugandan National Cotton Farmers Federation
UGCEA	Uganda cotton Ginners and Exporters Association
USA	United States of America
UGX	Ugandan Shilling (1 Euro = 3,532 UGX; 1 UGX = 0.0002831 Euro)

Executive Summary

Organic cotton production has the potential to generate environmental benefits and to provide small-scale farmers in developing countries an access to a dynamically growing global niche market. In the 2009/10 season, 275 300 organic cotton farmers produced 1.1% of the global cotton production worldwide. However, the lack of suitable varieties and the shortage of organically multiplied seed constrain the development of the sector. Large breeding companies concentrate on genetically modified varieties, cotton breeders are hardly experienced in organic breeding requirements, and selection for and under conventional, high-input conditions creates not necessarily the best adapted varieties for organic production.

To address the availability of suitable varieties in the long term, the international organic cotton community initiated organic cotton breeding in India and Burkina Faso, and the Louis Bolk Institute is developing a project in Uganda, Africa's largest organic cotton producer. A participatory approach in which organic farmers select in their fields was chosen, to gain insights into agronomical traits, and make the release of a cotton variety for organic agriculture economical. To review the aims and underlying assumptions of this project, a diagnostic study was conducted. The objectives were to analyse the Ugandan cotton sector and its stakeholders, to investigate the cotton production system and main constraints, to identify the plant traits that organic and conventional small-scale producers prefer, and to explore the possibilities to breed for resistance to the lygus bug (*Lygus vosseleri* R., *Miridae*), suspected to be the major pest in organic cotton production.

Next to literature analysis, data were collected through interviews with 21 stakeholders, including researchers, government authorities, the organic sector, and other involved organisations. Participatory group discussions, cotton selection exercises, and 46 individual interviews were conducted with seven producer groups, four organic producer groups situated in the Northern region and three groups of conventional producers in the Northeast of Uganda. This spatial separation was a result of the specific working areas of organic cotton projects. In a participatory workshop, producers furthermore selected entries out of a germplasm collection and prioritized identified traits together with researchers. Lastly, morphological traits of cotton and lygus damage were explored at the research station.

Sector Description and Stakeholder Analysis

Cotton is a strategic crop for the Ugandan government, which regulates the cotton sector through the Cotton Development Organization (CDO). The CDO targets a five-fold production increase by 2014 through the promotion of intensified agronomic practices, although similar production targets have proven unrealistic in the past. The promotion strategy relies on incentives (subsidized inputs and prices) and a state-controlled input supply. The CDO organizes the treatment, multiplication (by farmers), and distribution of cotton seed.

The National Semi-Arid Resources Research Institute (NaSARRI) conducts all cotton related research, including germplasm conservation, setting breeding targets, and variety development. In order to export cotton of guaranteed uniform quality, only one variety, the Bukalasa Pedigree Albar (BPA) may be grown in Uganda. This variety is continuously improved through breeding and newly released every few years. Introducing genetically modified cotton is considered and scientists are enthusiastic about the Bt and herbicide tolerant traits. However, yield trials in Uganda and economical studies have not predicted immediate benefits.

Three organic cotton projects were certified in Uganda in 2010. Several organizations temporarily stopped or reduced their operations due to multi-faceted conflicts with governmental bodies. These include, among others, an anti-malarial indoor DDT spraying program affecting cotton storage, and an on-going scientific and public debate on the profitability and productivity of organic cotton, based on lacking and in-transparent data. The organic sub-sector was held responsible for production failures in a dispute that peaked in 2008 with anti-organic newspaper campaigns, and continuing direct pressure to stop or reduce the organic operations.

Except for the organic projects, cotton farmers are not organized, and a few cotton plantation owners control farmer representation in official boards.

The initial ideas for a future organic breeding project would touch many critical issues such as introducing more cotton varieties, organizing an independent seed system, developing the organic sub-sector, and participatory breeding, and could easily be affected by already prevailing conflicts. This thesis reveals that the CDO and the research station are the most legitimate and powerful actors in cotton breeding and seed supply. Together with different allies, they would form a block opposed to giving up the varietal uniformity, specificly organic breeding activities, and handing over research responsibilities to farmers. On the other hand, stakeholders from the organic sector, including the marginalized producers, differ in their level of power and form a second block largely in favour of the proposed project.

The project would be more feasible if the marginalized conventional cotton producers are involved and it concentrates on further developing the existing BPA variety to suit better the needs of small-scale farmers, under the condition that organic and conventional small-scale producers share similar production constraints and variety requirements. Besides not being specifically organic, this adaptation would involve additional stakeholders that are neutral to the pre-existing conflicts, maintain the varietal uniformity, and require a closer collaboration with the public breeders. The collaboration could improve the trust between the two blocks in the long term.

The Cotton Production System

All cotton production in Uganda is rain-fed and part of a wide crop rotation. Cotton may be grown from May to November, which is promoted by most experts because it produces the highest yieds, but occupies the fields for both rainy seasons. Most producers instead grow a short-cycle food crop such as beans during the first rainy season, and plant cotton after its harvest around July. Although this later planting option yields less and requires planting during the peak labour period, the return per field and year is higher in combination with the first crop. Most participants grow 0.4-0.6 hectares of cotton. Overall, there were no clear differences between the constraint perceptions of organic and conventional producers, but large differences between individual locations and fields. Socio-economic constraints, weed and pest control were the most relevant to the producers.

Weed control was considered the main limiting factor to produce more cotton, especially because of its high labour demand, which is not offset by the cotton prices prevailing in the past (the second largest constraint). For weed control, farmers plough twice and weed on average four times, which amounts to 140 man-days per ha by hand or 90 man-days with hired ox-ploughs. The costs for hiring labour and ox-ploughs and the opportunity costs for family labour amount to 90% of the total production costs.

Pests were altogether the next severely rated production constraints, indifferent of production system or time of planting. Producers have very limited organic control options against most pests, and organic pesticide distribution is often irregular, late, or insufficient. Aphids ranked highest in contrast to expert opinions, because they are considered to cause growth retardations with a long-term effect on yield. Lygus, bollworms and cotton stainers overall ranked 4th, 5th, and 6th, respectively, because the infestation differs between individual locations and fields.

Droughts and soil fertility, although considered highly problematic by some experts, were rated as medium to minor constraints, ranking 8th and 11th overall, respectively. Through increased irradiation, short droughts can improve cotton growth. Producers time cotton planting to avoid expected droughts during the sensitive flowering period, and select fields of moderate fertility. However, droughts were more problematic in the southeastern locations, especially in Pallisa where they ranked second. Soil fertility was somewhat problematic in locations with sandy soils and land shortages, where these factors can also lead to fungal wilt diseases (overall rank 13th).

Lastly, constraints connected to the seed distribution system, namely low germination, late supply and insufficient supply of seed, ranked 7th, 9th and 10th highest constraints, respectively. Excessive vegetative growth caused by within-field differences in soil fertility, flooding, monkeys, and termites played important roles in some locations.

Participatory Exploration of Cotton Breeding Targets

Public breeders have so far selected cotton under intensive management and without any involvement of (small-holder) cotton producers. Table A summarizes the approach of breeders and farmers interviewed in this project towards different selection goals.

Table A: Comparison of (both organic and conventional) small-holder farmers' and breeders considerations in cotton selection. Source this thesis.

Goal	Farmers' considerations	Breeders' considerations
High Yield	Large boll size High boll number (twinning trait) High vigour (thick stems)	Large boll size High boll number High vigour (large growth)
High Quality	Fibre quality (visual appearance) Seed quality Uniform and early maturity Easy and clean harvesting	Fibre quality (laboratory assessments) *Not considered* Early maturity *hardly considered* *Not considered*
Stress resistance	Insect resistance Good performance under adverse conditions	Wilt and bacterial blight resistance *Other assessments precluded by selection environment*
Plant habit	Open shape Short and determinate habit Wide and long branching	Semi-compact shape *hardly considered* Semi-determinate habit *hardly considered*

For farmers just as for breeders, high yield and quality are the main selection goals. However, farmers emphasize a large range of stress resistance and morphological traits that breeders hardly assess. These may increase yields under their farming conditions, while past achievements of breeders in increasing yield potential have not increased actual cotton yields in Uganda under the current agricultural practice. Furthermore, farmers newly identified and highly prioritized a twinning trait, i.e. two fruiting points located at one node, to increase boll numbers. The farmers also assess a high quality more broadly than breeders do, including high seed quality, uniform and early maturity, and a habit that allows for easy and clean harvesting.

From the interviews with the breeders we learned that they hardly assess morphological traits during selection, but their preferences slighty disagree with those of farmers. Farmers prioritized very open plants that allow for light and air penetration, a shorter and more determinate habit than the Ugandan varieties, and vigour that translates into a wide growth and many and long fruiting branches with short internodes, rather than tall and more vegetative growth. This habit is supposed to enable easier harvesting and pesticide application, reduce pest pressure, improve the quality ripening of bolls, and support a more uniform maturity. Futhermore, farmers aimed to select for insect resistance, which is not possible under the tight spray regime practiced at the research station. The resistance and the morphological traits interact with environmental factors and the farmers' practices to support high actual yield and quality beyond the genetic yield and quality potential of a genotype.

Farmers showed during the field visits that they were aware of the heritability of most traits, but some farmers selected for a good (heritable) performance under adverse growing conditions, while others preferred to select under optimum conditions that would improve seed vigour exclusively in the following generation.

Altogether, the farmers invited to the breeders' fields considerably appreciated Ugandan germplasm, showing that the breeders have been relatively successful in breeding farmer-acceptable varieties. However, Indian and American varieties were also valued for their determinate habit and higher yield potential. West African germplasm was not preferred by farmers but used much by breeders, underlining the difference in selection goals between West African and Ugandan farmers.

The farmers' assessment of the variety BPA 2008 illustrated that their morphological criteria can predict a low-yielding cultivar at a point when breeders were not aware of its yielding ability. To clarify the yield and quality effect of the farmers' selection criteria, farmers should be given the chance to prove these by selecting over a number of years. During the workshop, farmers and scientists communicated freely and scientists showed great interest in and respect for the farmers' opinions.

Lygus Resistance

Lygus is a sap-sucking capsid bug feeding on cotton and several wild and cultivated plants in Uganda. Due to the shortage of cultural control measures and the ineffectivity of genetically modified Bt-cotton against lygus their control relies on insecticides.

Until the 1960's, lygus was considered the major cotton pest in Uganda. Next to obvious leaf damage and growth retardation, shedding of young fruiting points due to lygus infestation was long suspected to affect cotton yields. However, research and the experiences with introducing insecticides in the 1950's showed that plants compensate the loss of young fruiting points through continued fruiting. Still, this leads to a prolongued fruiting and harvesting period. In the 1950's to 1970's, researchers in Uganda tried to breed for lygus resistance, rule out environmental effects and identify reliable resistance criteria, but all without success.

In literature, the absence of leaf nectaries, a high abundance of gossypol pigmentation and a high leaf pubescence are considered possible lygus resistance criteria. Own observations on the NaSARRI germplasm found a wide variation of pubescence (hair density, length, and tactile hairiness) on upper and lower leaf sides and bracts, but this could not be correlated to lygus damage. This can be explained by the patchy distribution of lygus damage in the germplasm field, and large differences between three replications of the same variety in an organic variety trial. Furthermore, lygus bugs mostly feed on the upper side of the leaves and may thus be less affected by pubescence and its variation, which is more prominent on the lower leaf side.

Thus, lygus resistance is not a recommendable breeding target because a reliable screening method for a variety's resistance would require large experimental efforts, an easily selectable resistance criterion has not been identified, and the yield effects of lygus are neither sufficiently large nor sufficiently proven to justify such efforts.

Conclusion and Recommendations

In conclusion, this diagnostic study was crucial to ensure the relevance of the envisioned future participatory breeding project and adapt problem perceptions. It analysed the complicated Ugandan cotton stakeholder situation, similarities between organic and conventional small-holder farmers with respect to perceived cotton production constraints and desired breeding goals. The study also showed that farmers and breeders have complimentary knowledge and sometimes different perceptions on traits to select for, and that they can cooperate well in on-station selection. Therefore, such joint selection should be given a chance to prove its worth. However, lygus resistance was identified as a non-recommendable breeding target.

Therefore, we recommend that a future breeding project should aim at improving the broadly adapted Ugandan cotton variety BPA to better suit the needs of both organic and conventional, small-scale cotton producers through the following activities. 1) Workshops in which cotton producers discuss suitable germplasm and involve in the on-station selection at the central breeding station. 2) A low-input selection environment needs to be included at the station to allow the farmers to select according to their environmental knowledge, to enable selection for pest resistance, and to increase the correlation to the target environment. 3) Advanced lines could be tested in farmer-managed plots in different production regions through mother-baby trial designs to identify broadly adapted lines. 4) Lastly, farmers could select and self-pollinate superior plants out of their cultivated fields, to be used as additional source germplasm.

Next to the importance of farmers' participation in breeding, the recommended activities hold opportunities to further study the less explicit selection targets of the farmers and assess the possible benefits of breeding for specific adaptation (region specific or to organic production). Such research could be complemented with scaling up studies on the production systems and on the link between the farmers' perceptions and priorities of different constraints.

The recommended activities can be conducted individually or in combination, and the study showed that those activities are desired by both farmers and breeders. In comparison to scientific literature on participatory breeding, the recommended cotton breeding project is unusual with its orientation on mainly centralized breeding, a one-variety system, and a widely grown crop of public interest without a farmer-led seed system. It remains important to consider that participatory breeding is a social product that emerges from and develops through interaction in practice. The resulting breeding strategy allows for farmer participation at all stages of the breeding program, with different forms of collaboration and elements of decentralization to complement the current Ugandan breeding activities.

1 Introduction

Organic cotton production is promoted worldwide in order to generate environmental benefits in the production of one of the most agrochemical-intensive crops (EJF 2007). Furthermore, organic cotton production has the potential to generate development impacts by providing small-scale farmers in developing countries an access to international niche markets (e.g. Bolwig et al. 2009, UNCTAD/UNEP 2008). In the 2009/10 season, 275,300 organic cotton farmers in 23 countries produced 241 697 tonnes of organic cotton fibre, amounting to 1.1% of the global cotton production (Textile Exchange 2010). The organic cotton niche market experienced a dynamic, 40 per cent average annual growth since 2001, a growth rate that was even stable in response to the global recession (Textile Exchange 2010). However, the lack of suitable varieties and the shortage of organically multiplied seed constrain the development of the sector (Organic Exchange 2009).

Therefore, the international organic cotton community started a concerted effort to address the availability of suitable varieties in the long term. While organic cotton breeding initiatives have started in India and Burkina Faso (Organic Exchange 2009), the Louis Bolk Institute is developing a project to improve the availability of cotton varieties suited to organic production in Uganda. Uganda has been Africa's largest organic cotton producer since 2005/06. The total production of 1 550 tonnes still makes it a minor player at the global scale, supplying only 0.64% of the world's organic cotton in 2009/10 (Textile Exchange 2010). A detailed description of the Ugandan cotton sector and the organic sub-sector will be given in Chapter 2. The organic cotton sector is referred to as sub-sector because it is a part of the cotton sector of Uganda.

1.1 Problem Statement and Assumptions

Cotton varieties are mostly selected for and under conventional, high-input conditions and are thus not necessarily the best adapted to organic production and low-input conventional production. Furthermore, the concentration of large breeding companies on genetically modified (GM) varieties, especially Lepidoptera-resistant Bt-cotton, affects negatively the further improvement and seed availability of non-GM varieties needed in organic production. The availability and further improvement of non-GM cotton varieties is of paramount importance for the organic cotton sector, and similarly important for conventional cotton production where non-lepidopteran pests play a major role. Hardly any cotton breeder is trained or experienced in organic cotton production and its breeding requirements, which is also not the case for the governmental cotton breeders in Uganda.

In an AgroEco pilot project to evaluate eight cotton varieties under organic conditions for high-quality production in Uganda, in 2008/2010, serious damage by the Heteroptera bug *Lygus vosseleri* R. was observed in one of the three trial locations, Bulindi (AgroEco Louis Bolk 2010). Some experts consider Lygus as the worst cotton pest in some seasons and a major reason for applying insecticides (Sekamatte 2010, personal communication; Horna et al. 2009). Since lygus is mostly considered a secondary pest in conventional production, and the usually calendar-sprayed broadband insecticides control it, no breeding efforts had been directed at lygus resistance since unsuccessful attempts from the 1940's to the 1970's. It was therefore assumed that lygus damage might be a major cause for low organic cotton yields. The variable performance of the cultivars in Bulindi (95 to 165 kg ha-1) was considered an indication for differences in lygus resistance, although that was not specifically tested.

Consequently, the development of a suitable variety for organic production with some degree of lygus resistance was considered crucial for improving the productivity of organic cotton in Uganda. The productivity of organic cotton in Uganda will be discussed in Chapter 2.3.1; the sub-sector had long been concerned about low yields (van Elzakker 2010, personal communication).

Organic cotton is still a niche in the Ugandan cotton sector; it covers only 0.55% of the total cotton production area (253,000 hectares). It was assumed that a participatory approach with selection by farmers in their fields could make breeding cotton for organic agriculture economically feasible. Farmer involvement was assumed to provide new ideas and insights into important agronomical cotton traits. The needs and preferences of cotton growers in Uganda have never been assessed; rather formal breeders have set objectives without any direct farmer involvement. Research by Lançon et al. (2004) further supported this assumption. They have undertaken a participatory cotton-breeding project in Benin and showed that within four years, farmers were able to create phenotypically and genotypically distinct varieties with considerable improvements. One of the developed varieties even out-yielded all controls in all locations. The crop type developed by the farmer breeders differed greatly from that preferred by the formal breeder and available commercial varieties: it had indeterminate, more vegetative growth, larger numbers of smaller bolls and was highly pubescent. Molecular marker analysis revealed that farmers had specifically selected for alleles that characterized African germplasm included in the initial cross. Lançon et al. also concluded that farmers are able to undertake pedigree selection and achieve greater improvements than with the tested mass selection method.

1.2 Original Aim and Research Objectives

Due to the described situation, assumptions, and questions, it was aimed to start a participatory breeding project for a cotton variety specifically adapted to Uganda's organic growing conditions, with special emphasis on increased resistance to lygus damage. For the preparation of such a project, this study aimed to test the underlying assumptions and the feasibility. In order to target an intervention efficiently, a diagnostic study to assess the need for organic cotton varieties in Uganda, examine the stakeholders in organic cotton breeding, and develop strategies to address this need was conducted.

The specific objectives of the presented report are:

1. To analyse the Ugandan cotton sector and its stakeholders with respect to a proposed breeding project, in order to identify the institutional space, the stakeholders that need to be involved, and their roles.
2. To investigate the cotton production system, identify the main constraints from a small-scale farmers' perspective, and explore possible differences between locations and organic and conventional producers.
3. To identify the plant traits that organic and conventional small-scale producers prefer.
4. To characterize the available germplasm for morphological traits that may confer phenotypic lygus resistance

Through these objectives, the study will compare the variety requirements of organic and conventional farmers and determine whether a separate breeding program for organic varieties needs to be developed or a concerted effort benefiting organic and conventional farmers is applicable. Furthermore, knowing the important breeding goals of farmers and characterizing available germplasm will help to identify appropriate parent material.

1.3 Overall Project Methodology and Thesis Outline

In this section, the overall approach of the study is presented. Details of the specific methods are described in the individual chapters.

Over many years, the experience of low "adoption" of agricultural research outcomes by farmers has proven that agricultural research needs to be grounded in what farmers, as the research beneficiaries, perceive as relevant or problematic issues. Röling et al. (2004) argued, „Anchoring research in the needs and opportunities of farmers is as important as it is to anchor the research in the international scientific literature".

However, the formal research process forces researchers to make PRE-ANALYTICAL CHOICES (Röling et al. 2004). Pre-analytical choices are the choices laid down in the formulation of the research proposal. A researcher's expertise and personal interest and the mandate of the institution will determine the type of project a researcher pursues. The research project then begins with a research proposal to acquire funds, in which the problem perceptions and research priorities and design are defined. Those decisions clearly limit the degrees of freedom of a research project, but they are taken before there are funds to actually study the actual research area and interact with stakeholders, and they are not made explicit (ibid).

Röling et al. (2004) proposed DIAGNOSTIC STUDIES as a means to ground the pre-analytical choices in the perceptions of stakeholders and make them explicit. Diagnostic studies are an ex-ante analysis method that deliberately tries to ground research in farmers' needs. They can comprise different sets of participatory, farming systems research and interactive research techniques. They take a holistic approach and try to answer the following questions:

1. What can work in the (socio-economic and agro-ecological) context?
2. What can work in the farming system?
3. What can be acceptable to stakeholders?
4. How can outcomes be scaled up (have an institutional impact)?

Naturally, pre-analytical choices cannot be avoided completely. In this thesis, the interests, expertise and mandates of the author, the supervisor and the involved organizations (Wageningen University and Louis Bolk Institute), and previous experiences and discourses in literature lead to the pre-analytical assumptions outlined earlier (Section 1.1). These assumptions were a starting point for the research.

However, this study is laid out as a diagnostic study and aims to crosscheck the originally perceived problems with the beneficiaries (farmers) and stakeholders (breeders and cotton sector institutions) of the research. I.e. to identify and prioritize the problems involving stakeholders and explore obstacles and opportunities to make the pre-analytical choices for the design of the envisioned breeding project more explicit (compare Nederlof 2006).

It is important to stress that the outcomes of the diagnostic study are not static and should not lead to a blueprint approach in the later research phase. Rather, in the course of a project, perceptions can change and new ideas come up, that require continuous adaptation of the research design (Nederlof 2006).

As cotton is a crop of public interest, the government and a public research and extension system are heavily involved in the cotton sector. Therefore, the organization of the sector, its stakeholders and their positions towards the project where considered of special importance for the feasibility and possible scaling-up of the project (Questions 1, 3 and 4). In Chapter 2, the study first describes the Ugandan cotton sector and its stakeholders based on literature, document analysis, and interviews. A social analysis then explores the position of the stakeholders towards the proposed breeding project, in order to reach research objective 1.

The further approach was inspired by Weltzien and Christinck (2009) who have described the steps and methodologies involved in setting priorities in a breeding program. They argue that the views of farmers need to be considered to come to a deeper understanding about how yield and value can be increased within the local production system and its specific risk management strategies. Among others, they emphasize that a detailed analysis of the production system is required, including the major constraints and farmers' preferences. Taking into account regional and social differences if applicable, the target regions and target producers can be defined.

An investigation of the organic and conventional cotton production systems with their main constraints from the producers' perspective through producer interviews forms Chapter 3 to reach research objective 2. The plant traits preferred by organic and conventional producers were identified through selection exercises and are the content of Chapter 4 (research objective 3). Although Weltzien and Christinck (2009) emphasize to consider the diverse functions of a crop, including agronomic properties, processing quality and role in the farming system, the study concentrates on agronomic characteristics because it was assumed that the formal breeders have sufficiently considered the fibre qualities. Furthermore, the focus on agronomic properties fits the capacity of farmers and thereby the envisioned organization of the breeding program.

The selection criteria defined in a participatory manner form the basis for selecting germplasm that contains variation for these criteria (Weltzien & Christinck 2009). This study focuses preliminarily on lygus resistance as an assumed breeding target. The importance and feasibility of lygus resistance breeding is investigated through literature research and germplasm characterization in Appendix I (research objective 4).

In the conclusion (Chapter 6), the implications of the findings for the proposed breeding project are discussed and adaptations to its aim and focus will be recommended.

2 Sector Description and Stakeholder Analysis

The following Chapter will describe the Ugandan cotton sector in detail, including trends and conflict areas, and analyse the relations of its stakeholders. The aim is to analyse the sector and its stakeholders with respect to a proposed breeding project, in order to identify the institutional space, the stakeholders that need to be involved, and their roles.

2.1 Materials and Methods

For a comprehensive sector description, literature and newspaper articles (collected by Josephine Akia of NOGAMU) were analysed and identified stakeholders interviewed with semi-structured interviews (Table 1).

Table 1. Interviewed stakeholders.

Organization	Field	Number of Interviewees
National Agricultural Research Organization NARO	Research organization	4
Cotton Development Organization CDO	Government Authority	4
Lango Organic Farming Promotion	Organic Cotton Producer Organization	1
BoWeevil Cotton Conservation Initiative North Bukedi Cotton Corporation	Organic Cotton Ginners & Exporters	3
AgroEco	Organic Agriculture Consultancy	3
NOGAMU	Organic Agriculture Umbrella Organization	3
UNACOFF	Cotton Producer Organization	2
Guru Nanak Oil Mills	Cotton Seed Processor	1
Cotton Producers belonging to - Lango Organic Farming Promotion - North Bukedi Cotton Corporation - Not affiliated	Producer groups	46 producers in 7 locations

First, the cotton sector, its stakeholders, and their relations to one another are described. For a more in depth stakeholder analysis, the Social Analysis CLIP technique (Collaboration or Conflict, Legitimacy, Interests and Power) of the initiative ‘Social Analysis Systems (SAS[2])’ (Chevalier 2008) was used. Social Analysis CLIP is a method to analyse the position of stakeholders to a proposed action, which made it especially meaningful for this thesis. The CLIP technique adds depth to purely descriptive stakeholder analysis by exploring:

- **C**ollaboration or Conflicts between stakeholders that affect the proposed action
- **L**egitimacy: The legal or customary/subjective recognition of a stakeholder’s rights and responsibilities;
- **I**nterest: a stakeholder’s objective and subjective gains and losses in access to power, legitimacy, or social relationships; and

– **P**ower: a stakeholder's ability to influence others through economic resources, authority, force, access to information and/or communication means.

Stakeholders are defined as the parties who can influence the proposed action or may be affected by it, drawing on Long's concept of a SOCIAL ACTOR as an active figure in shaping social processes (Long 1997). The social actor is furthermore seen as a part of social networks (ibid), which is why the CLIP technique explores the ties of collaboration and conflicts among actors. A CONFLICT is here defined as "a direct and conscious struggle" between two actors, in which reaching the common goal is secondary to defeating the other party (the opposite is true for competition, Theodorson & Theodorson 1970). Furthermore, the method draws on Max Weber's idea that POWER is basic to the organization of social action and the pursuit of INTEREST. If the power of an actor is accepted as LEGITIMATE, that actor is an AUTHORITY that does not need to apply its power (Calhoun 2002). Weber took a constructivist perspective on power, legitimacy and interests, emphasizing the subjective meaning that individuals attach to their actions (ibid).

In this thesis, the stakeholders are analysed around a proposed participatory, producer-based cotton-breeding project for organic production. By rating each stakeholder with respect to the before mentioned factors, they are categorized into the pre-defined categories dominant, forceful, influential, dormant, respected, vulnerable or marginalized. This results in a CLIP-figure illustrating the stakeholder scenario. The scenario helps to define possible strategies to fit a given project into the stakeholder situation. Based on the scenario, an adaptation to the initially outlined breeding project is proposed and its effect on the CLIP analysis shown.

2.2 Sector Description

Cotton is produced in Uganda since 1903 and was the most important export crop in colonial times, although under forced labour conditions. In 1974, production reached a peak of 400,000 bales (Baffes 2009). However, production was minimal during times of political instabilities in the late 1970's and the 1980's. Since the cotton sector liberalization in 1994, which created the current set-up of the sector (You & Chamberlain 2004), the production recovered to an average 107,000 bales annually (CDO, average since 1994/95, see Figure 1). A major five-year Cotton Sub-Sector Development Project worth more than 30 million USD aimed to diversify the country's export earnings from the dependency on coffee (Serunjogi et al. 2001). Cotton contributed 2.2% of total export earnings in 1995/96 when production was half of the average (Serunjogi et al. 2001), and became the fifth largest export commodity during peak production in 2005 (Baffes 2009). The constant quality of Ugandan cotton has a high reputation and led to 2-8% quality price premiums on the world market from 2004-2007 (Baffes 2009). There are no reliable figures on average yields, but generally a perceived failure to increase cotton productivity is a concern to the sector now as it has been in the past (e.g. Bowden & Thomas 1970a).

The Uganda government considers cotton a strategic crop. Cotton production diversifies the country's export earnings, it provides employment in agriculture and processing, and the crop has a positive effect on the soil (CDO 2010). Uganda has over 45 ginneries, 15 oil mills, 3 vertically integrated textile mills, and 25 textiles and apparels enterprises (Daily Monitor 13.10.2009). Cotton is seen as having high potential for helping to reduce poverty in rural areas, because there is a large proportion of low- to medium-income households and seasonally food-insecure households among the approximately 300,000 to 400,000 cotton producers (You & Chamberlain 2004, Bahiigwa 1999, Gordon and Goodland 2000, in Poulton et al. 2004).

Untypical for a traditional cash crop, women play an important role in cotton production. Women, who represent only 3-9% of the household heads, manage 30-40% of all cotton plots (Horna et al. 2009).

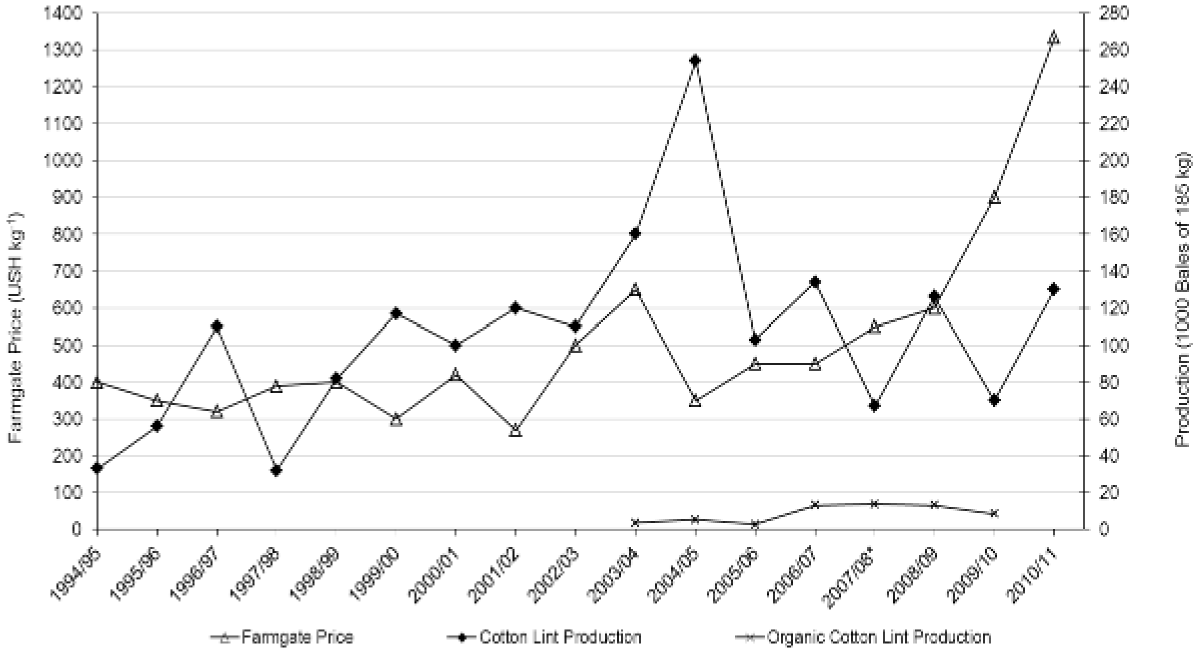

Figure 1. Conventional and organic cotton production and producer prices in Uganda since liberalization. Sources: Production 1994-2006 and prices 1994-2008: CDO 2011b. Production 2007-2008 and organic production 2003- 2007: CDO report to ICAC 2008, in: UIA 2009. Price 2009: Fibre2Fashion 29.6.2010. Production 2009-2010 (estimate): Fibre2Fashion 11.1.2011. Organic Production 2008: Organic Exchange 2009. Organic production 2009: Textile Exchange 2010. Price 2010: (average of early-, mid- and late-season price) own data and Fibre2Fashion 11.1.2011.

In spite of the government's aim to increase production greatly, the figures show no constant production increase, and which strategies can help to achieve such increase remains a highly contested debate. Instead, annual production fluctuates between 30,000 and 250,000 bales, mainly as a reaction to the previous years' price, i.e. the production shows high price elasticity (compare Figure 1, Baffes 2009). The prices fluctuated between 300 and 600 UGX per kg seed cotton, except for drastic increases in the last two years due to a governmental subsidy of 150 UGX per kg and high world market prices.

Considering that 90% of Ugandan farm households cultivate between 1 and 5 hectares of land and about 60% of cotton producers rely solely on hand labour, different crops compete for those limited resources (Serunjogi et al. 2001, Elepu & Ekere 2010). Horna et al. (2009) and Baffes (2009) cite a lack of alternative cash crops, but with the commercialization of sunflowers, soybeans, sesame and chilli, the introduction of upland rice and the rising prices for locally marketed food crops, alternatives in the growing areas have developed during the last years (Elepu & Ekere 2010). In terms of profitability, cotton compares negatively to most alternatives:

– From 1990 to 2003, the price for cotton had tripled while that for most food crops had increased by 5-12 times (Baffes 2009)

- From 1988 to 1994, producers recovered from 52 to 100% of the production costs, but the total recovery was only achieved in one of the ten years (Serunjogi et al. 2002)
- Cotton ranked last of 26 alternative crop enterprises in terms of net profit per unit output in a NARO study (You & Chamberlain 2004)
- Calculations based on the IFPRI Household Survey (2000) and Walusimbi (2002) (in: You & Chamberlain 2004) found that per area margins of cotton were the third lowest, followed by maize and sorghum. However, the per-family labour productivity was second highest, following maize. This may be due to the high use of hired labour in cotton production.
- Elepu & Ekere (2010), whose calculations are based on overly high labour costs, found that organic and conventional cotton, with 7% and -11% gross margins, respectively, were less profitable than eight alternative, partly marketed food crops when their own consumption was valued at market prices. Not valuing own consumption, sunflowers and rice were the only alternative cash crops with positive margins.
- Cotton profitability is very sensitive to price changes, e.g. Table 2 shows that if farmers received the indicative prices that prevailed in the last two seasons, considerable gross margins could be achieved.

Figure 3 shows the six main production regions designated by the CDO, which has also been identified as suitable production area with respect to agro-climatic conditions and ginnery access by You and Chamberlain (2004). However, the production area is decreasing. In the humid central region, cotton was produced when cultivating export crops was forced by the colonial administration (Baffes 2009), but it was replaced by coffee in the 1940's to 1950's. The share in total production of the remaining regions was relatively equal with 20-33%, but since then, the share of the West Nile, Western and South Eastern Region declined continuously, down to 10, 10 and 11% of total production in 200/01, respectively (Serunjogi et al. 2001, Baffes 2009). The share of the North-Eastern Region increased to 27%, and that of the North stayed constantly high near 37% (in 2001, ibid)

Regional production figures of 1963/64 show that a large part of the difference in total production between then and now is due to the replacement by other cash crops in formerly important production areas (Bowden & Thomas 1970a). If the trends since 1994 continue, cotton production will concentrate more and more on the Northeast and Northern Region, although they generally achieve lower yields and suffer higher pest pressure than the other locations (Serunjogi et al. 2001, Horna et al. 2009).

In conclusion, cotton is easily out-competed by other crops, leading to a very price-elastic production. Although the potential cotton production area of Uganda is large, cotton is only grown in few, mostly in lower-yielding areas. Producers must grow cotton also for other than profitability reasons, such as certainty about the market, higher price stability than for local market crops, the convenient time of cash payment (Christmas, school fees, taxes etc.), and its use as a good land opening crop (Horna et al. 2009, Walusimbi 2002). Where cotton is grown thus depends on where a) it is profitable enough compared to alternative crops and b) it fits into a profitable cropping system.

Table 2. Profitability of cotton production according to different sources and under the indicative prices prevailing in the last two seasons (900 UGX in 2009/10, and 1333 UGX in 2010/11).

Price (UGX)	Gross Margin (1000 UGX ha^{-1})	Source
Conventional Cotton		
652	-53	Horna et al. 2009
900	187	Own calculation based on costs and yields in
1333	604	Horna et al. (2009)
545	-94	Elepu & Ekere 2010
900	887	Own calculation based on costs and yields in
1333	1477	Elepu & Ekere 2010
Organic Cotton		
650	20	Horna et al. 2009
900	237	Own calculation based on costs and yields in
1333	611	Horna et al. (2009)
749	54	Elepu & Ekere 2010
900	712	Own calculation based on costs and yields in
1333	1211	Elepu & Ekere 2010

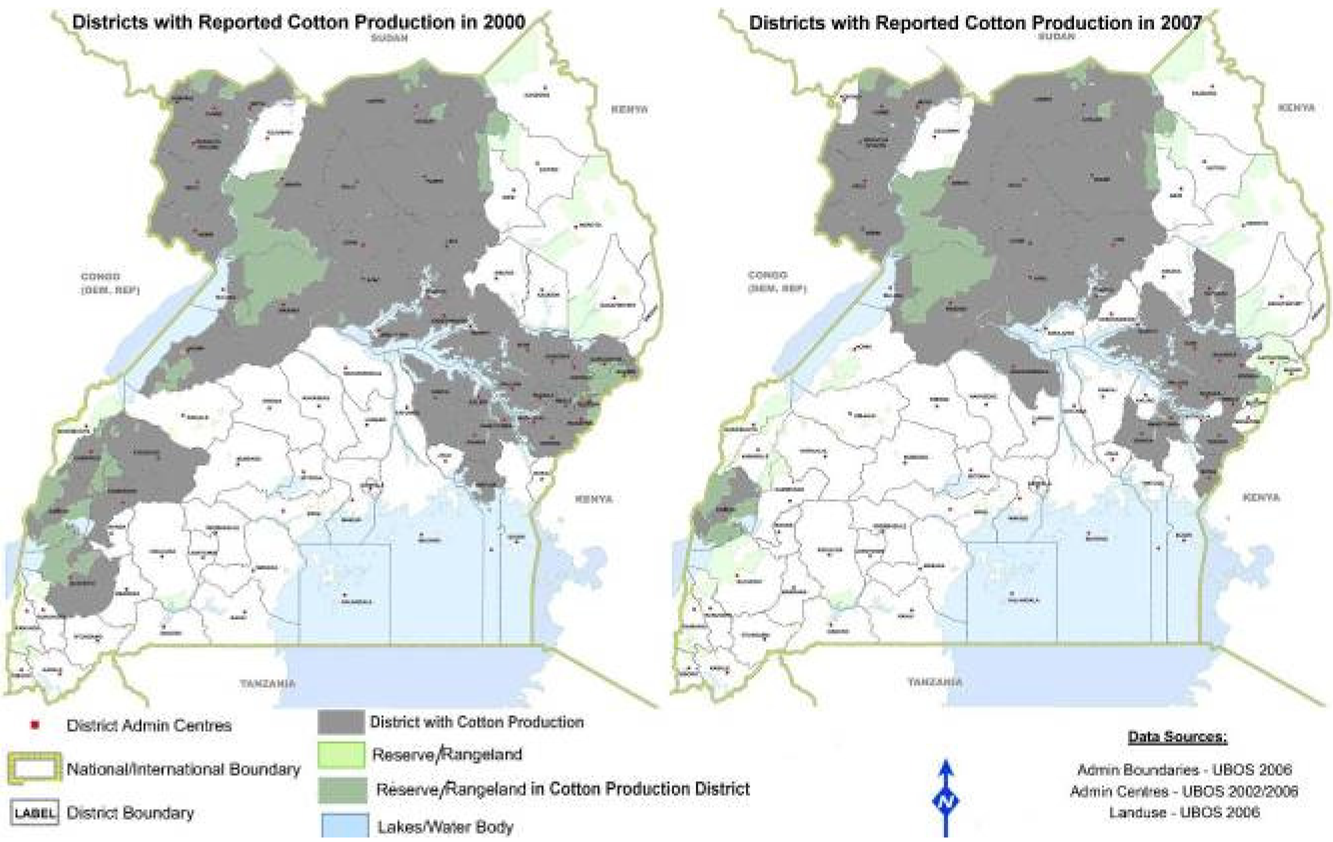

Figure 3. Cotton Production Area in Uganda designated by the CDO and Districts with reported Cotton Production in different years.
Sources: Designated production area: CDO 2010, personal communication; 2000 figures: CDO/Ministry of Agriculture in: You & Chamberlain 2004; 2007 figures: UIA 2009. Map Source: UN/OCHA June 2010.

The North- and South-Eastern regions are generally known to be less fertile and drier than other regions. In the Northern region, political insecurity disturbed production until recently. In the West Nile, the yields and the ginning outturn (percentage ginned fibre per boll) are somewhat higher. In the Western region, with its very fertile volcanic soils and a more input-intensive production system, the highest yields are achieved.

2.3 Role of the Organic Sub-Sector

Uganda is the country with the second-largest number of organic producers worldwide (following India) (Willer & Kilcher 2010), whose main export product in terms of quantities is cotton (8,400 bales or 1 550 tonnes in 2009/10). Organic cotton made up nine to 21% of the fluctuating total Ugandan cotton production in the last four years (see Figure 1). The organic agricultural sector of Uganda is considered as one of the most developed in Africa, in terms of its professional institutional network and high growth rates (Willer & Kilcher 2010). The umbrella-organization National Organic Agriculture Movement of Uganda (NOGAMU), in which all organic producer organizations and numerous organic exporters are members, coordinates the sub-sector. Uganda is an interesting site for organic cotton production also in future, because genetically modified crops are so far not permitted, and GM-cotton varieties are unlikely to be approved in the near future due to low expected economic benefits (Horna et al. 2009).

Originally, development aid supported organic cotton production in Uganda as a means to improve the livelihood of cotton producers. Especially around Lira, where most organic cotton producers are located, the population suffered from political insecurity, leading to their displacement. For the slowly resettling producers, organic cotton production is an important pillar of their livelihoods. NGO’s and governmental development aid agencies such as SIDA, Helvetas, and HIVOS have continuously supported the development of the sector with the aim to improve producer incomes while protecting the environment. Today, consultants from AgroEco Louis Bolk Institute, GroLink, Kulika, NOGAMU, and individual private consultants support the sector. In the Uganda Martyrs University, short courses and a B.Sc. program Organic Agriculture train professionals for the sector.

However, Uganda’s organic cotton sector has not yet developed its full potential for contributing to rural development. Organic cotton production is frequently expected to be more profitable because with lower input use, production costs are expected to be lower while the price is higher. In Uganda where conventional producers hardly ever use fertilizers and little insecticides, the difference in input use is small (Ton & Tulip 2002, RATES 2003, Horna et al. 2009). Elepu & Ekere (2010) found that organic production costs were only 4% lower than those in conventional agriculture were. The higher profitability of organic cotton found by Horna et al. (2009) and Elepu & Ekere (2010) was solely due to the organic price premiums and more price sensitive than in conventional production (see Table 2). The price premiums ranging 10-35% over the conventional market price were also found to be the main motivation of producers to convert to organic production (1994/95 to 2000/01 and 2010, Ton & Tulip 2002, Elepu & Ekere 2010). Still, after seven years of organic cotton production in Uganda there was no measurable difference in the living standards of organic versus non-organic cotton producers, because small quantities of produce were purchased from each certified producer. E.g., LOFP bought only 15% of all produce of their registered producers at organic premiums in 2002, while still increasing the number of producers. Organic projects that deal in additional organic export crops, such as chilli and sesame, created a higher economic impact per farmer, because farmers could sell a larger proportion of their produce at premium prices (Ton & Tulip 2002).

In addition to the higher prices, producers convert to organic production to reduce the need for input capital and health risks (from chemical inputs) and to access extension group membership, whereas conventional producer groups are rare since most former cooperatives are not operating any more, are affected by fraud and partly excluded women (Ton & Tulip 2002). Furthermore, the organic projects paid more reliably than conventional ginneries.

Organic cotton export companies or farmer organizations contract, organize, and certify the organic producers through the local certifier UGOcert or international certification bodies. In 2010, the following exporters and producer organizations were active in organic cotton production:

- BoWeevil – a Netherlands-based pioneer organic export company. Up to recently, they were a regular client of LOFP (Elepu & Ekere 2010). Now they certified own farmers. After the government conducted anti-malarial indoor DDT spraying in the whole certified area, BoWeevil temporarily stopped organic cotton trade in 2010 (BoWeevil).
- Dunavant – formerly purchased from LOFP (Elepu & Ekere 2010), had up to 100,000 certified farmers in Gulu and Pader districts. Reportedly, Dunavant reduced the number of farmers to 30,000 in 2010, partly due to major conflicts with the CDO, but this number and Dunavant's continued involvement in export of organic cotton could not be verified.
- Lango Organic Farming Promotion (LOFP) – founded and owned by the Lango Cooperative Union in 1994 on the initiative of Swedish development cooperation, it was the country's first organic cotton project (Tulip & Ton 2002, Elepu & Ekere 2010). The only farmer organization involved in organic cotton deals with 17,000 organic cotton farmers plus more organic non-cotton farmers. A part of the 17,000 farmers is certified through NBCC and a part through BoWeevil. For the LOFP-certified farmers, certification for the 2010/11 season was not acquired in time for buying due to organizational problems.
- North Bukedi Cotton Company (NBCC) – exports the organic cotton of all LOFP cotton farmers, and trains & certifies LOFP farmers in two sub-counties.
- Cotton Conservation Initiative (CCIU) – Initiative funded by Edun Apparel, Wildlife Conservation Society, and Invisible Children Uganda. It works with 3500 farmers in Gulu and Amuru, who are under conversion after their area had been sprayed with anti-malarial DDT.
- Other organic exporters have been Twin Brothers, South Base, Copcot from Zimbabwe, Olam, and Rhineheart (Elepu & Ekere 2010), but they are currently not active.

Consequently, NBCC and possibly Dunavant were the only two organizations active in organic cotton export in 2010/11. Figure 4 shows the locations of the organic farmers.

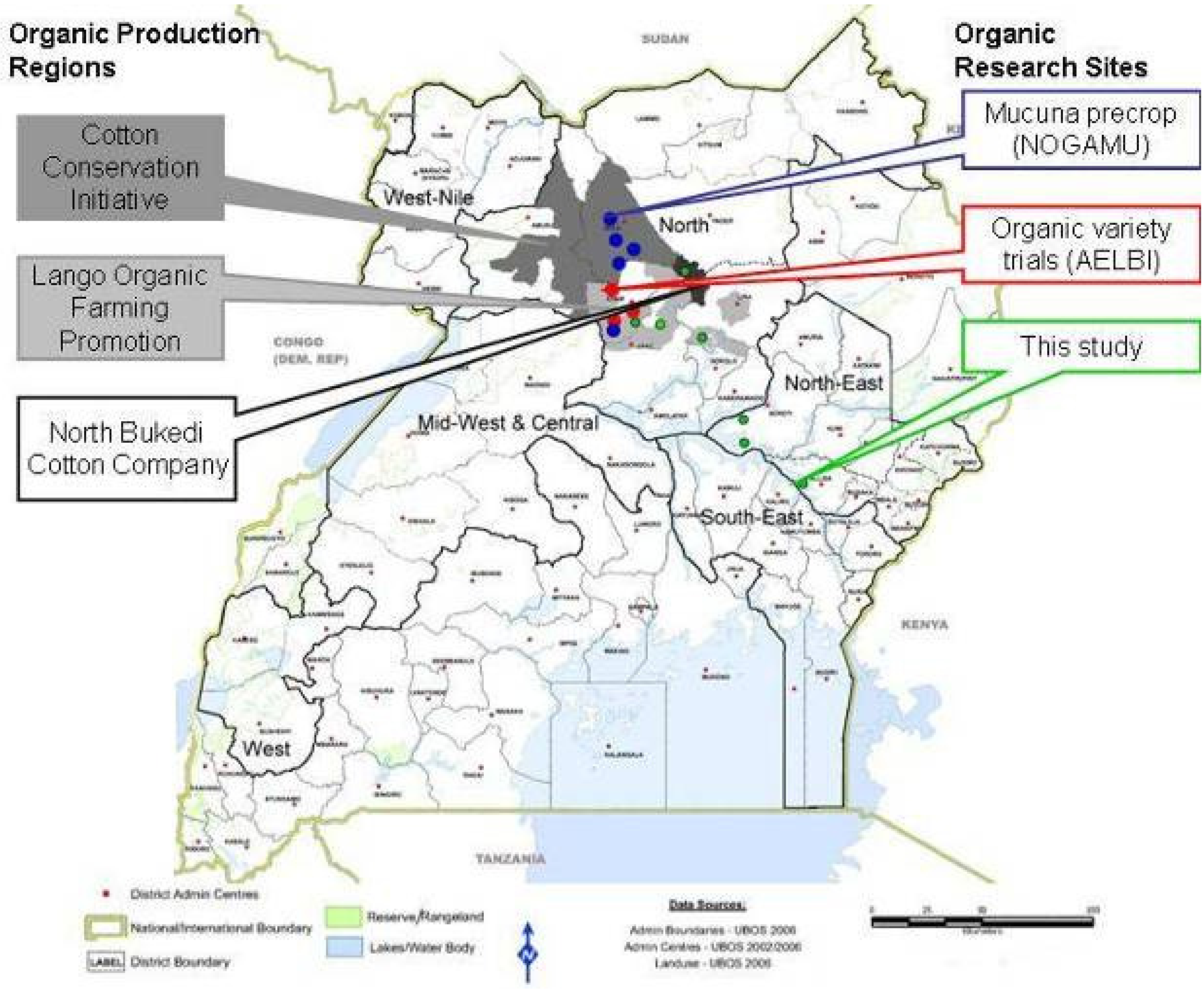

Figure 4. Organic Cotton Production Regions in Uganda in 2010 and Research Sites. The Production Region of the Dunavant Company could not be obtained. Sources: Personal communication for this study. Map Source: UN/OCHA June 2010.

Current research on organic cotton production is minimal. NOGAMU, Textile exchange, Makerere University, NaSARRI, LOFP and CCIU study organic cotton and the effect of a Mucuna pre-crop on demonstration plots, in four sites in Northern Uganda for 3 years. However, the plots are not replicated within locations and can thus not be analysed scientifically.

AgroEco/Louis Bolk Institute and NARO staff conduct replicated variety trials under organic conditions to identify varieties with a superior quality in three locations and seasons. Although the financing stopped after the first season, two of the trials are continued (NARO, CDO). Many perceived these trials as an evaluation of the effectiveness of organic pesticides (NARO). However, the trials were not designed for that purpose and contain no conventional or control variant, instead they allow only for comparisons among the varieties. AgroEco/Louis Bolk Institute furthermore started replicated organic phosphorus-fertilizer trials in three locations in Northern Uganda in 2010, which are planned to continue for one more season.

Collection of acreage, yield, and agronomic data through NARO and LOFP is planned for the 2011/12 season (LOFP, AELBI). The CDO occasionally refers to own comparison trials between organic and conventional cotton, but these are not documented. Collection of reliable organic yield data is urgent for the organic sector but difficult in the currently hot political situation (NOGAMU). For NARO and the CDO, research on organic pest control is most urgent (CDO).

2.4 Stakeholder Relations

The CDO is the statutory board created in 1994, mandated to monitor and regulate the development of the cotton sector. It is financed by a levy imposed on all cotton exports (2% of the FOB), ginning fees, and the government (Tulip & Ton 2002, Baffes 2009, MOF Budget 2009). Its Board of directors consists of the NaSARRI director, representatives for the Ministries of Agriculture, Finance and Trade, the cotton producers, the oil millers, textile millers, ginners, and exporters. The Board appoints the Managing Director. The mandate is to increase production and producer incomes (MOF 2009). The current target is 280,000 bales in 2010 and a steady increase to 500,000 bales in 2014, to be achieved mainly through increased per-area productivity (CDO). However, several similarly optimistic earlier targets have not been met (e.g. MOF 2009, Baffes 2009, Namisango Kamya 2006).

Besides the CDO, the Ministry of Agriculture, Animal Industry and Fisheries (hereafter Ministry of Agriculture) influences the cotton sector policies. It audits the CDO and is represented in the boards of the CDO and NARO. It defines the National Agricultural Policy as a guide for the agricultural development in Uganda. It heads the different Zonal Agricultural Research and Development Institutes, which are involved in some cotton research trials. It does not head the CDO or NARO, rather each organization has its separate budget, which the Ministry of Finance, Planning and Economic Development approves and monitors (MOF 2008). The Uganda Investment Authority recruits and attends to foreign and local investors into the cotton sector, such as ginners, textile millers, and exporters. The National Agricultural Advisory Service NAADS provides extension services to producers, but no cotton-related extension.

The National Semi-Arid Resources Research Institute (NaSARRI) is a NARO institute in Serere and is mandated to conduct all cotton related research. The director of Serere is the senior cotton breeder, while a breeding technician and a number of junior staff carry out the breeding activities. Furthermore, an agronomist, an entomologist, and a plant pathologist involve in cotton research. A major constraint to the research activities is the frequently delayed quarterly release of funds (CDO). Laboratory analyses are done in the National Agricultural Research Laboratories in Kawanda. The Uganda Martyrs University is involved in a program named "Capacitate" under which they train breeders and officials in client oriented breeding. Makerere University is well linked with the Ministry of Agriculture and Makerere researchers have involved in studies with NOGAMU (MOF Budget 2009, NOGAMU).

There is no general cotton producer organization. The only non-organic one, Uganda National Cotton Farmers Federation (UNACOFF) is a company founded by large-scale producers from the West-Nile region in 2007. They supply extension and tractor services to producers and allow those with at least 10 acres cropland (ca. 4 ha) to buy shares in the company. The organization is closely linked to the CDO as three persons, all large cotton producers, are active in leading position of both organizations at a time (UNACOFF, CDO). UNACOFF works "in a top-down manner" and is "not representative" of Uganda's cotton producers (CDO). So far, only a few individuals who produce cotton at the side of their governmental and scientific positions represent the cotton producers, e.g. the two producer representatives in the CDO are Ph.D. holders appointed by the Ministry of Agriculture. However, there is no regular involvement or representation of 'true' cotton producers in the CDO or NaSARRI (CDO, NARO).

The trust in the producers' ability to choose optimal agronomic practices or define the cotton variety they need is small throughout the sector, repeatedly interviewees stated, "Farmers don't know anything" (BoWeevil, UNACOFF). The only interaction of the breeders with farmers is during irregular annual field days and agriculture shows at Jinja. However, researchers in NaSARRI showed a keen interest in such interactions, as well as the producer organization LOFP, who are experienced in data collection and trial set-ups (LOFP).

The Uganda Ginners and Cotton Exporters Organization UGCEA mainly served to coordinate the private sector support programme (see Chapter 2.4.1) and is hardly active today, although it elects two representatives for the CDO board (CDO). Four textile mills, of which one is specialized on organic cotton, process cotton for local consumption (Rates 2003). However, local consumption amounts to only about 5% of total production (CDO 2011b). Cottonseed is milled into the seed cake for animal feed, which is the most valuable part of the seed, 700 UGX/kg and more are paid for the cake (Guru Nanak Oil Mills). The extracted oil is refined, separating the non-edible part, the soap-stock, from the minimal edible part (ibid). The soap-stock is given out for free or at cost price and used for producing washing soaps (ibid). After further purification, the edible oil fetches 3500-4000 UGX per litre (ibid). The quality of the oil and seed cake depends on selecting large, healthy seed, but there are no quality issues for the oil-milling sector (ibid).

The main stakeholders of the organic cotton sub-sector are NGO's, development organizations, a university, consultants, a producer organization, several ginners and exporters and a textile mill, all named in Chapter 2.3.

2.4.1 Regulation through the Cotton Development Organization

The main strategy of the CDO to achieve a higher production has been the promotion of intensified agronomic practices, i.e. higher use of pesticides and fertilizers, efficient agronomy and use of high-quality planting seed in lower quantities. The promotion of these production methods relied heavily on the use of incentives (Parliament of Uganda 2010):

- Free supply of treated seeds
- Pesticides subsidized at 50% (3,000 UGX/treatment sufficient for 1 acre, ca. 0.95 €, and free supply to producers in seed production areas)
- Subsidized fertilizers (for demo plots)
- Subsidized price since 2008/09 (by 150 UGX/kg)
- Also tractors, ox-ploughs and spray-pumps have been distributed

Furthermore, the CDO announces indicative cotton prices in the beginning of the season as a guideline for the producers, however, these indicative prices are communicated like legally binding minimum prices to the producers ("The CDO just raised the price to 1300 UGX, so do not allow anyone to cheat you and pay less for your cotton!").

In earlier years, different input supply schemes involving the ginneries (the Private Sector Support Programme through UGCEA) were tried but failed. The ginneries were meant to distribute inputs for free or at subsidized prices and recover the costs through a reduced cotton price. In spite of a zoning system, excessive side trading by intermediaries to different ginneries led to the ginneries' refusal and the collapse of the programme in 2007. Since 2008, the CDO is the only and direct supplier of cotton seed, subsidized insecticides and extension services (MOF 2009), i.e. the CDO also defines which inputs and seed treatments to be used and which extension messages to be communicated by which communication strategies (radio broadcasts, lead-farmer demo plots). Furthermore, through the packaging and distribution of seeds and insecticides into 1-acre packages, they also determine the dosages to be applied.

The free seed distribution system comes with high costs for seed production and distribution (Ton & Tulip 2002). The free availability lead to irregularities, such as farmers stealing the seed to sell it to others or bunkering large amount of seed. This required close monitoring and detailed documentation. The resulting staff requirements exceed the CDO's capacity (LOFP) such that some farmers receive no or insufficient seed or receive seed too late. Therefore, the CDO cooperates with producer organizations such as the organic projects LOFP and NBCC to collect such data. However, a CDO field officer stated that producers were used to and expected free inputs, such that the CDO has no other chance than following this admittedly complicated system.

It can be summarized that the CDO followed a top-down manner of promoting increased cotton production. The heavy incentive use proved not compatible with a liberalized sector, therefore increasingly more aspects of the cotton sector were brought back under state control, such that the liberalization was partly reversed, with the purchase of 50% of the organic textile mill Phenix as the most recent step in 2009 (BoWeevil) (see Figure 5).

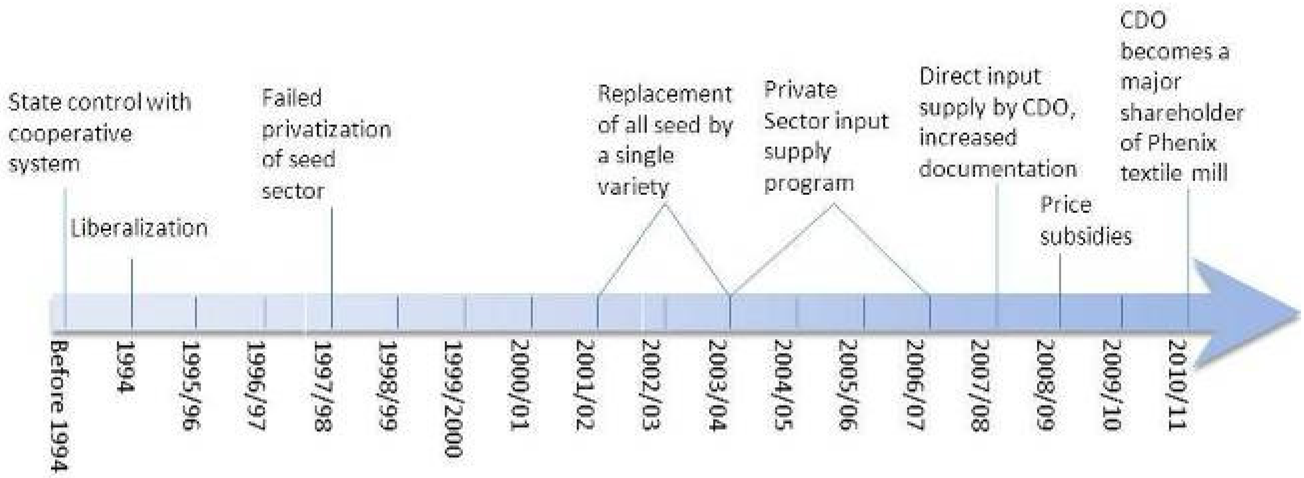

Figure 5. Steps of increasing state control in Uganda's cotton sector since liberalization. Source this project.

2.4.2 Conflicts between the CDO and Organic Stakeholders

The organic sub-sector is in conflict with governmental agencies, because it follows a different vision for the development of the cotton sector: The governmental agencies envision a high-yielding, medium-scale and input-intensive farming system (pesticides, fertilizers and GM cotton varieties) that produces a large quantity of cotton exports, ideally as much as in the early 1970's. The organic actors envision a partly organic, diverse, small-scale farming system that improves export earnings by creating and supplying niche markets. On top of this fundamental difference, the following conflicts form a complex of issues resulting in a general hostility between the CDO and the organic sector.

The atmosphere between the CDO and organic sector players had become hostile in 2007 because Rhineheart and Dunavant had been among the refusing ginneries at the collapse of the Private Sector Support Programme; they withdrew from the obligations of the Private Sector Support Programme by converting to organic (AELBI). This gave the impression that producers were forced to convert to organic production by the two companies (e.g. in New Vision 11.11.2008).

Dunavant has a low legitimacy as a big multinational company owned and managed in every position by Indians, and with a colonial history as LonRho Cotton Company (NOGAMU, AELBI). Since the farmer organization LOFP is partly exempted from the conflict, it becomes apparent that business actors are not legitimate in the eyes of the CDO while farmer organizations are.

The hot debate on the advantages and disadvantages of organic cotton production is mainly centred on comparisons of organic and conventional cotton yields. Critics often cite organic yields as low as 10-20% of the conventional (New Vision 11.11.2008, New Vision 20.1.2010, NOGAMU). However, there are no scientific data on neither organic nor conventional nor overall actual cotton yields in Uganda. The CDO documents the overall production and acreages, but the acreage data are overestimated because producers estimate wrongly (each field equals 1 acre) or overstate the area in order to receive more inputs (CDO). Furthermore, the planting dates are not consistently collected such that one cannot distinguish early- and late-planted cotton with their very different yield potential (ibid). Therefore, CDO staff was not willing to share those data because they would calculate incredibly low overall yields of 126 kg per ha (CDO). The organic exporter Dunavant had apparently similar documentation problems, since the same calculations would lead to only 60 kg per ha yields for their organic producers (New Vision 10.10.2008).

Consequently, many inconsistent yield claims were brought up in the numerous news articles and in literature and discussions by both sides, leading to a wide range of 50-3700 kg per ha for conventional and 60-990 kg per ha for organic yields, based on lacking, inconsistent and in-transparent data. Table 3 compares some of the more transparent figures. The huge differences can therefore be explained by incorrect comparisons e.g. between average figures and demonstration plots, incomplete organic production methods (e.g. when agronomists have no experience in organic agriculture) or differences due to planting date, plant density, regional and other effects. E.g. in CDO demonstration plots, from where yields of 2000-5000 kg per ha were reported, fertilizers and 3-4 insecticide sprays are applied, while the common practice is no fertilizers and 2-3 insecticide sprays (CDO). Moreover, there is a huge variation within each system, a 1994 survey in Eastern Uganda recorded yields from 52 to almost 1500 kg per hectare (Olani et al. 1994). To the experience of LOFP, organic yields are lower than the conventional ones, because of the low use of organic pesticide formulations (LOFP). In the 2010/11 season, the CDO put major efforts into obtaining more realistic and positive data at least in the major production regions for accountability to the Ministry of Agriculture (CDO).

In 2007/08, cotton production fell to 60,000 bales, the lowest value since nine years, partly due to unfavourable weather and low prices. The CDO failed to source sufficient seed for the following season: while they overspent, their approved budget by three times, they obtained only half of the targeted amount of seed and depended on parliamentary support to alleviate the situation (CDO). This caused open criticism and a budget cut of 40% for the CDO (Fibre2Fashion 5.8.2008, Namisango Kamya 2006). The CDO partly made the rapid expansion of organic agriculture responsible for the low production and the shortage of seed (New Vision 18.2.2008, NOGAMU, CDO). Especially Dunavant, which had increased its number of registered farmers from zero to 30.000 to 100.000 in only two years and allowed a large amount of produce to spoil, allegedly in order to pressure the CDO to accept Zimbabwean varieties, was made responsible (AELBI, CDO). The area planted with cotton for seed production did not reach the target, as seed from the now organic area was not obtained. On the other hand, organic sector actors blamed the low production on the CDO's late distribution of low quality seed and the shortage of planting seed on its mismanagement and corruption (BoWeevil, NOGAMU). The situation in 2009/10 supports this view, when production was again similarly low in spite of previously high prices, and the CDO again obtained only 58% of the targeted planting seed, while also the seed production area remained almost one third below the target. Altogether organic stakeholders agree that Dunavant did not behave properly and there were shortcomings in the training and certification of its farmers, which might have caused yield losses (AELBI).

As the conflict between the CDO and the organic cotton export company continued and affected other companies, the Ugandan Investment Authority, the Opposition Party FDC and media involved. They criticized the CDO for over-regulating the cotton sector and scaring off four major investors (EA in Focus 20.9.2009, UGPulse 1.1.2009, BoWeevil) by a shortage of ginned cotton, attributed to the CDO (Reuters 14.8.2008). The debate in the media became as fundamental that some referred to a political corruption affair of the late 1990s (UGPulse 3, New Vision 9.1.2009). Dunavant's registration with the Uganda Investment Authority instead of the CDO aggravated its conflict with the CDO (CDO). The President of Uganda, a "friend" of foreign investors like the organic textile mill Phenix, dismissed the CDO/Organic conflict as "endlessly haggling with peasants being manipulated by cotton merchants or those politicians who do not know what their country needs" (Museveni 2008).

To summarize, a fundamental difference, conflicts around the collapse of the Private Sector Support Programme, the low legitimacy of multi-national companies, a debate about low organic cotton yields, the responsibility for low production in 2007/08 and an overregulation of the cotton sector by the CDO come together into a multi-faceted conflict. Over time, all organic cotton stakeholders, the CDO, NARO, the Uganda Investment Authority, the Ministry of Agriculture, an opposition party, and even the president of Uganda became involved in the conflict. In addition, the government newspaper New Vision became an important and biased platform for the conflict. In 2008, it published 18 articles critical of Dunavant and organic cotton production in general, referring to anti-capitalistic and anti-Indian resentments. Since a single author mostly wrote the critical articles in the business section, where agricultural topics are uncommon, NOGAMU raised concerns that he was financed from outside (NOGAMU). The debate developed up to the point that stakeholders in the organic sector see a "campaign" aiming to "kill organic" (AELBI, NOGAMU).

The arguments brought up against organic agriculture included that only a small amount of the organic certified cotton is bought under organic premium prices, unregistered and ineffective pesticide formulations were promoted by organic projects (CDO), Dunavant rejected CDO policies, and did not provide promised inputs to producers (New Vision 23.6.2008 and 10.10.2008). Further, groundless arguments were that prices were as low as six UGX per bale, a lack of market for organic produce, a lack of contract between organic farmers and the organic farming promoters (without a contract farmers cannot be certified organic) (Daily Monitor 24.8.2010, New Vision 9.1.2009 and 24.2.2010), a bias caused by foreign funding (New Vision 9.1.2009) and others. On the other hand, the organic stakeholders claim that CDO staff are corrupt and involve directly in trading in inputs, cotton, and cotton seed or associate with opportunistic companies (LOFP, BoWeevil, CDO).

However, also in 2009 and 2010, newspaper articles discredited organic cotton production (New Vision 9.1.2009, Daily Monitor published 24.8.2010), showing that the debate has not ended to date. In 2010, CDO representatives, including the senior cotton breeder, pressured LOFP and CCIU to reduce the number of their registered producers dramatically (LOFP, CIIU). For the CCIU, this pressure and free pesticide distribution in their production areas put the future of the project as organic under question, while for LOFP it contributed to the resignation of leading staff. CDO officials find that the debate about organic cotton "is not going to go away any time soon".

Table 3. Organic and Conventional Yield Claims in literature and newspaper articles.

Source	Seed Cotton Yield (kg ha^{-1})		Comments
	Conventional	Organic	
Reported averages			
Daily Monitor (2009)	120	320-400	4 farmer interviews
CDO data	126	-	Reportedly overestimated acreage data
UIA (2009)	170	-	*
You & Chamberlain (2004)	206	-	Based on Uganda National Household Survey 1999-2000
Lundbaek 2002 in: Poulten et al. (2009)	310	-	*
Olani et al. (1994)	250-600	-	Majority of measured yields in Eastern region, overall range 50-1500
Ton & Tulip (2002)	720	600-779	Rough estimate from ICS documentation
Horna (2009)	960	860	Survey 151 farmers, 12 organic, 2007
CDO	990-1240	-	Average out of experience
NARO data	-	175	*
New Vision (Dunavant) 2.12.2008	-	990	80% of the yield estimates above 988
Bowden & Thomas (1970)	445	-	Uganda Census of Agriculture, 1960's figures
Reported maximums			
Elobu (1994)	300-1240	-	Average yield of sowing date trials in 5 research stations
UIA (2009)	1480	-	*In Rwenzori soils
New Vision 11.11.2008	2220	490	*
New Vision 4.11.2008	2470	-	*CDO, in Bulisa
NOGAMU	2970	620	*Reported yields in discussions
New Vision 20.1.2010	3700	370	*
CDO	4940	-	Demonstration plots
Range (averages)	120-1240	175-990	
Range (maximums)	1480-4940		

* original source of data unknown

2.4.3 Organization of the Breeding and Seed Sector

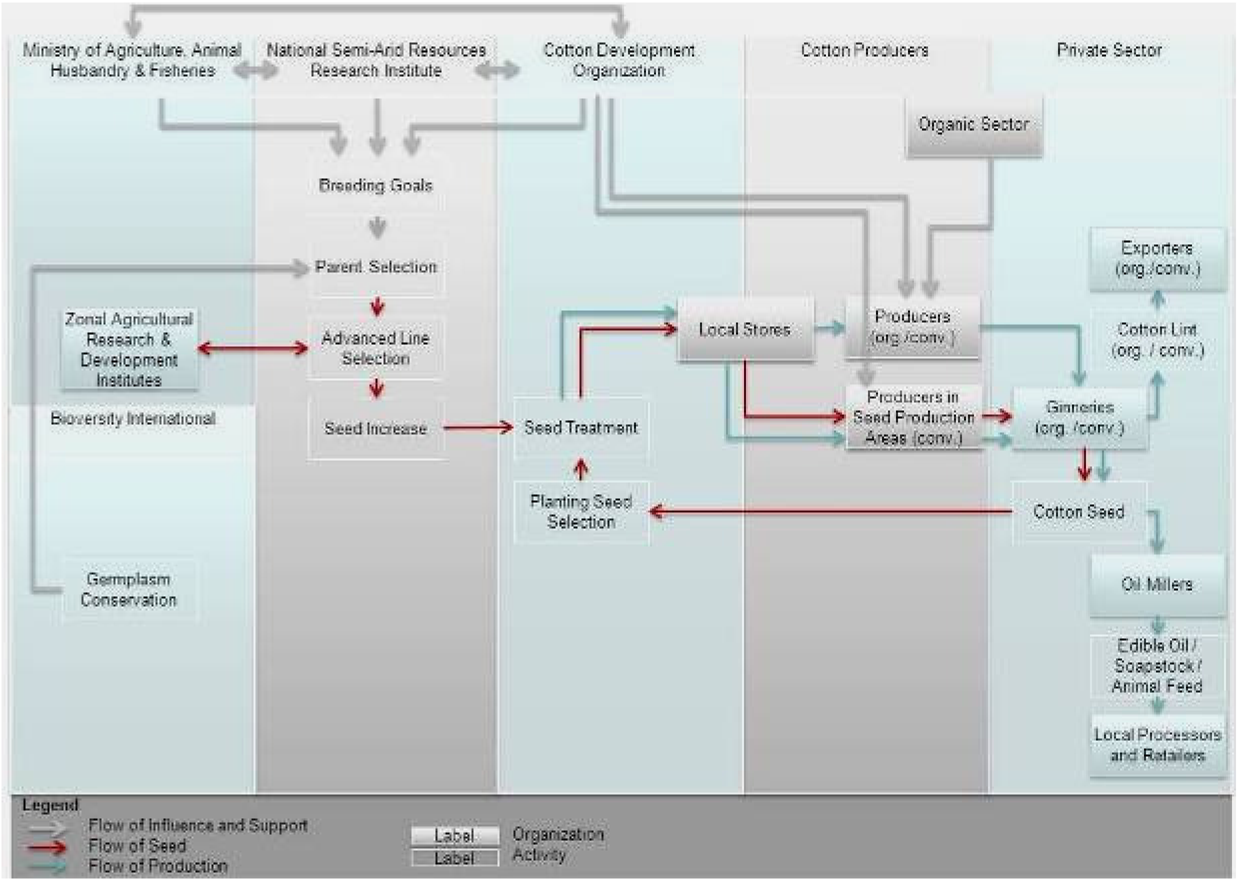

Figure 6. Organization of the cotton breeding and seed sector in Uganda and flows of influence, seed, and production, based on literature review and stakeholder interviews in this study, 2010.

Figure 6 illustrates the organization of the cotton breeding and seed sector and the cotton value chain. The breeding goals for a new variety are influenced by the national agricultural policy of the Ministry of Agriculture, occasional surveys, and research experiences of the research institute, and the CDO that generates breeding targets through reported interaction with producers, private sector organizations, and UNACOFF (CDO). The Ministry of Agriculture approves the breeding goals on request of the CDO.

The research station carries out germplasm conservation on behalf of Bioversity International, an international research centre. Out of this germplasm and own lines, parents for the breeding program are selected; crossings made and eventually advanced lines selected. These are tested in different Zonal Agricultural Research Institutes to evaluate the performance in different environments. Yet, a variety of institutional constraints hinders many trials to be carried out by the respective Institutes, such that breeders rely mostly on the data from Serere (NARO). The preferred lines are then combined into a variety.

While for other crops farmers evaluate varieties, this is not done for cotton so far, partly because the breeders feel that producers may overlook important aspects such as invisible resistances and fibre qualities. Originally, two varieties (BPA and SATU) designated to specific production regions were grown in Uganda. After liberalization, BPA spread into parts of the traditional SATU production area because of a higher demand by buyers, demonstrating its ability to yield well in those locations (Serunjogi et al. 2001). From 2001, the SATU variety was phased out such that today, only a single variety may be grown in Uganda; to ensure uniformity and easier quality control measures, and prevent mixing of seed as had happened before liberalization (Daily Monitor 13.10.2009).

Of the approved variety, the research institute increases the breeders' seed for two seasons, obtaining e.g. 500 kg of nucleus seed and then 10 tons on foundation seed in the case of BPA 2002. The foundation seed is treated by the CDO: de-fuzzing and copper treatment to prevent bacterial blight (the normally used product Nodox is approved for organic production). Before the introduction of standard dressing with cuprous oxide in 1950, which resulted in a 9% average annual yield increase, the soil- and seed-borne as well as lygus-transmitted disease was considered the worst cotton disease in Uganda and had caused up to 33% countrywide yield loss in an extreme year (Bowden & Thomas 1970).

Conventional cotton producers in gazetted seed production areas, grow the foundation seed, producing e.g. 150 tons of pure seed (for BPA 2002) for distribution across parts of the country. The CDO specifically gazettes these areas and used to hand out pesticides free, but within the 2010 season, this was changed to the subsidized price as in the other production areas. Ginneries buy the produced seed cotton and separate the lint from the seed, out of which the CDO selects planting seed, according to the estimations documented by the seed distribution stores (involving CDO staff, producers, and producer organizations). The CDO again treats the seed in the dressing station and then distributes it to producers in the seed production areas and beyond, via local, farmer-managed stores. Seed is handed out based on producers' registrations of the area they plan to grow. Conventional producers in all areas receive training and subsidized pesticides from the CDO, while organic producers receive training and occasional inputs from numerous organizations such as the organic cotton exporters, farmer's organizations and consultants, which were omitted for clarity.

The produced organic and conventional seed cotton is handled separately during buying, in the ginneries and by separate lint exporters, with the exception of organic cotton that is side-sold to conventional traders. The cotton seed which is not selected for planting is sold to oil millers which mill it into seed cake (animal feed), edible oil and raw material for making washing soaps. Organic seed products are not marketed separately from conventional. The sector organization and all stakeholders are supervised by the CDO and have to be in accordance to its sector goals.

Currently, allowing GM-cotton is considered by the Uganda government. With support from the USA-financed Program for Biosafety Systems, confined trials are running in NaSARRI since 2009 (Oloka & Sengooba 2008). An economical study came to the conclusion that the costs for weeding and pest control in Uganda do not justify the investment for introducing Bt- or herbicide-tolerant cotton varieties (Horna et al. 2009).

2.5 Social Analysis for a Participatory Cotton Breeding Project

2.5.1 The Original Proposed Breeding Project

This chapter describes which effect the previously described stakeholder relations and sector description would have on a proposed breeding project. The proposed cotton breeding project is based on selection by organic farmers in their fields with the aim to create a variety specifically suited for organic cultivation. Behind the analysis are the following assumptions: The project will successfully develop a variety, this variety increases the productivity and quality of organic cotton. This variety is registered as a second cotton variety, only to be grown in gazetted organic production areas. Therefore, it is not accessible for conventional low-input producers.

Table 4 describes the forms of legitimacy, interests, and power of the stakeholder groups in relation to the proposed project in detail. The criteria in which the stakeholders received a high or medium rating define into which pre-formed stakeholder category (Chevalier 2008) they are classified.

The CDO is the most DOMINANT stakeholder because it has high legitimacy, high net losses, and high power. The research station is also a DOMINANT stakeholder although it has only medium power. The Ministry of Agriculture and the rich cotton producers also have medium power and legitimacy but do not clearly gain or loose through the project, they are therefore rated as INFLUENTIAL. The former organizations collaborate through crosscutting membership. Thereby, they form a block of rather powerful government bodies and advantaged producers who would largely be opposed to the proposed project.

Another party that would mainly experience losses through the project would be the ginneries and exporters, who have interests in a simple buying system and a uniform fibre quality and medium power, but little legitimacy; they are therefore FORCEFUL stakeholders. The organic ginneries and exporters are equally FORCEFUL but, in contrast, they would gain from the increased organic production and productivity. They collaborate with different NGO's that support organic agriculture, have both power and legitimacy, and are therefore INFLUENTIAL. Both the exporters and the NGO's are advocates for the organic producers, who themselves have no power, legitimacy only towards the organic sector but little beyond, but high interests in the project and are thus VULNERABLE. The pro-organic stakeholders consequently form a second block of stakeholders with a differing level of power, which are largely in favour of the proposed project. Moreover, the two blocks are in conflict with each other, especially the CDO with one organic exporter, as the previous sections have shown.

However, there are further stakeholders outside these two blocks: the INFLUENTIAL NGO's and universities who advocate and do research for cotton producers in general and specifically conventional producers. This group could also gain to some extent from the project. Still, the conventional producers do not have as much support from allies as the organic ones and are just barely RESPECTED. Furthermore, two NEUTRAL stakeholders who received low ratings in all categories and were therefore not included in the analysis exist with the Zonal Agricultural research Institutes and Bioversity international.

Figure 7 shows the outcomes of Table 4 by arranging the stakeholders according to their category and illustrating ties of collaboration and conflict. This stakeholder scenario shows that the proposed project will be very difficult to handle since the most powerful stakeholders are opposed to it and not allied with any stakeholders that are in favour of it. The previously described conflicts and hostility would directly be transferred on the proposed project. Options to improve the situation (depicted as dashed lines or arrows) are: to involve and create collaboration with the "neutral stakeholders" (who do not belong to the two conflicting blocks), to empower the stakeholders of the "organic block" to create a better balance of power, and to reduce the negative interests of the opposed stakeholders. An adaptation of the originally proposed breeding project would therefore be desirable to fit better in the given stakeholder situation and create a more positive stakeholder scenario.

Table 4. Social Analysis CLIP for the originally proposed participatory breeding project for an organic cotton variety, based on literature review and stakeholder interviews in this study, 2010.

Stakeholder	Legitimacy (L)	Interests (I)	Power (P)	Category*
CDO	High + Legal regulatory body for cotton sector + Only legal seed supplier	High losses - Loose seed sector control - Loose countrywide variety uniformity - Loose influence on sector development goal towards more input-intensity	High + All sector bodies need CDO approval + Control about production inputs + Political influence, high presence in media - Insufficient field staff	PIL Dominant
Ministry of Agriculture	Medium + Legal governing body of the agricultural sector - Most authority for cotton sector given to CDO	Low interests ?	Medium + Sets the National Agricultural policy + Political Influence	PL Influential
NaSARRI	High + Legally mandated to conduct breeding, research, and give recommendations	Medium losses - Loose control of the breeding goals and process - May loose working field in breeding + May gain legitimacy and collaborations through working with new stakeholders	Medium + High access to knowledge and information + Well equipped breeding station - Regular budget and personal shortages - Low influence on out-of-station activities	PIL Dominant
Zonal Agricultural Research and Development Institutes	Low - Legally mandated to conduct region-specific research and producer education - Known for past corruption and inactivity	Low gains + May gain new working field if involved in the project	Low - Reduced influence due to past low performance	-
UNACOFF and other rich cotton producers	Medium + Well recognized by public bodies because of personal relations - Not representative of cotton producers	Low losses - Loose influence when other producers are consulted by research ? breeding may differ from those of small-scale producers	Medium + Public influence through personal relations, access to information, communication means and economic wealth	PL Influential
Conventional cotton producers	High + Official target group of any sector policy	No gains or losses * cannot access the more prodcer-acceptable cotton variety * are not directly involved to voice their requirements	Low - Low access to information & communication means, economic wealth or authority	L Respected

Stakeholder	Legitimacy (L)	Interests (I)	Power (P)	Category*
Organic Cotton Producers	Medium - Not targeted by public policies + Supported by the organic sector	High gains + gain from a tailor-made cotton variety + gain influence and social relations in research and decision making	Low - Low access to information & communication means, economic wealth or authority	IL Vulnerable
Organic Ginneries and Cotton Exporters	Low - Easily dismissed as multinational corporations with purely economic interests + Economic importance	Medium gains + may gain from a tailor-made cotton variety / improved productivity and quality	Medium + Good access to information, media communication, financial resources	PI Forceful
Ginneries and Cotton Exporters	Low - Easily dismissed as multinational corporations with purely economic interests + Economic importance	Medium losses - Required to handle varieties separately and risk of unintended mix of different cotton qualities causes economic losses	Medium + Good access to information, media communication, financial resources + Power to sabotage export	PI Forceful
NGO's	Medium + Recognized as advocates of the marginalized and vulnerable - Not legitimate for decision making	Low gains + may gain influence and work if involved in a project, otherwise advocates with low own interests	Medium + Good access to information, media communication, financial resources (donors)	PL Influential
Universities	Medium + Legitimate researchers - No mandate for cotton	Low gains + May gain interesting research project if involved + May gain participants in professional education programs	Medium + Good access to information, scientific communication, research funds +Knowledgeable in participatory methods - No cotton experts	PL Influential

* The criteria (P, I, L) in which the stakeholder received a high or medium rating define to which pre-formed stakeholder categories the stakeholders are attributed, according to Chevalier (2008).

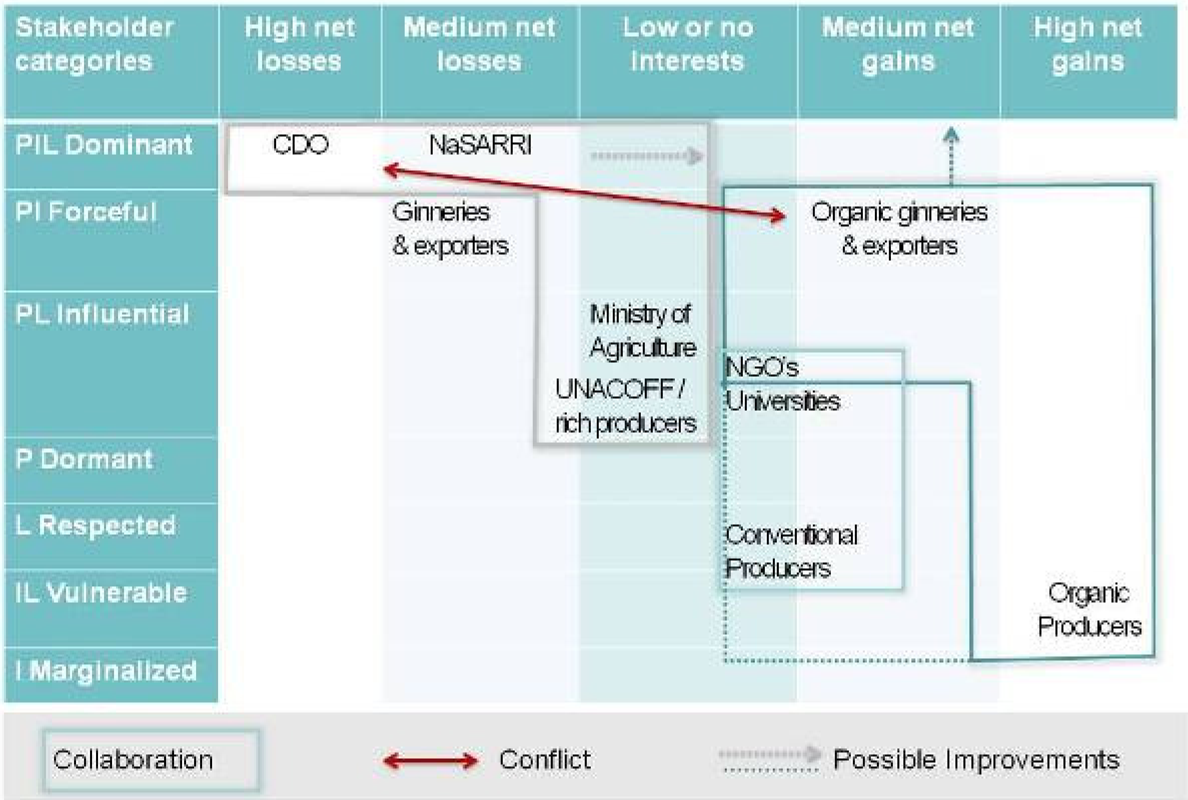

Figure 7. Social Analysis CLIP of a farmer-based participatory organic cotton breeding project, based on literature review and stakeholder interviews in this study, 2010. The format of this figure and the stakeholder categories are based on Chevalier (2008).

2.5.2 The Adapted Breeding Project

The last section concluded that an adaptation to the originally proposed breeding project is desirable. This section suggest such adaptations based on the possible improvements identified in the last section, and shows how these adaptations would change the stakeholder scenario. Options to improve the situation (depicted as dashed lines or arrows) are: to involve and create collaboration with the "neutral stakeholders" (who do not belong to the two conflicting blocks), to empower the stakeholders of the "organic block" to create a better balance of power, and to reduce the negative interests of the opposed stakeholders.

Collaborating with neutral stakeholders, who do not belong to any of the conflicting blocks, could make the project more neutral with respect to the pre-existing conflict. This can be achieved if conventional producers (and the NGO's who are their advocates) are involved in the project. This will improve the whole project's legitimacy and acceptance by the governmental stakeholders. It will furthermore empower the conventional cotton producers who lack a farmer organization and powerful allies. The pre-condition for such an adaptation is that organic and conventional small-scale producers share similar constraints in cotton production and have similar variety requirements. This will be studied in later chapters of this thesis. Ugandan universities are other neutral stakeholders, whose involvement will improve the credibility of research results and make use of their capacities in participatory research.

Increasing the legitimacy, public acceptance, and official recognition of organic agriculture can empower the organic stakeholders, such that the parties that are in favour of the proposed project are on a more equal level with the governmental organizations in terms of power and legitimacy. However, this is a long-term process that is already pursued by NOGAMU. A positive collaboration between organic and non-organic stakeholders in an adapted breeding project could contribute to this long-term goal.

Lastly, the expected negative interests of the dominant stakeholders need to be reduced. To that end, the project could concentrate on the further development of the currently only accepted cotton variety to suit the needs of small-scale producers better, instead of creating a new and second variety. This would resolve most of the hurdles for the CDO and the ginneries and exporters, which have interest in having only one variety. Moreover, work on the current variety would require closer collaboration with the research institute. Since the research institute would then be involved, they would not lose as much influence and working area as in a purely farmer-led project. Through the collaboration, trust can be built and ideas exchanged, such that the relations between the two blocks could improve in the long term. The benefits of diversifying the cotton seed sector and making more than one variety available need first to be evaluated and possibly proven. Convincing the dominant stakeholders of this should be viewed as a long-term vision that would become more possible through such a project.

An adapted proposed action would consequently be a participatory breeding project, in which conventional and organic farmers collaborate with the public breeders to improve the conventionally used cotton variety. A balance between formal and participatory breeding will be maintained and neutral institutions such as universities involved. For example, in Morris & Bellon's (2004) model for "Efficient Participatory Breeding", farmers collaborate with researchers in the selection of source germplasm and varietal evaluation, but the formal breeders pursue the trait- and cultivar development. For that case, the following changes would appear in the Social Analysis CLIP (Table 5 showing only stakeholders with changes, changes highlighted in italics).

Table 5. Changes in the Social Analysis CLIP of an adapted breeding project, based on literature review and stakeholder interviews in this study, 2010.

Stakeholder	Legitimacy	Interests	Power	Category*
CDO	High	*Medium* losses** - Loose influence on sector development goal towards more input-intensity	High	PIL Dominant
NaSARRI	High	Low - Loose *some* control of the breeding goals and process *+ Gain new information, legitimacy and collaborations through working with new stakeholders*	Medium	PL Influential
Small-scale cotton producers *(org./conv.)*	Medium	High gains + gain from a more acceptable cotton variety and involvement in the project	Low	IL Vulnerable
Ginneries and cotton exporters	Low	*Low gains* + may gain from improved productivity and quality	Medium	P Dormant

* The criteria (P, I, L) in which the stakeholder received a high or medium rating define to which pre-formed stakeholder categories the stakeholders are attributed, according to Chevalier (2008).
** Changes compared to Table 4 are highlighted in italics.

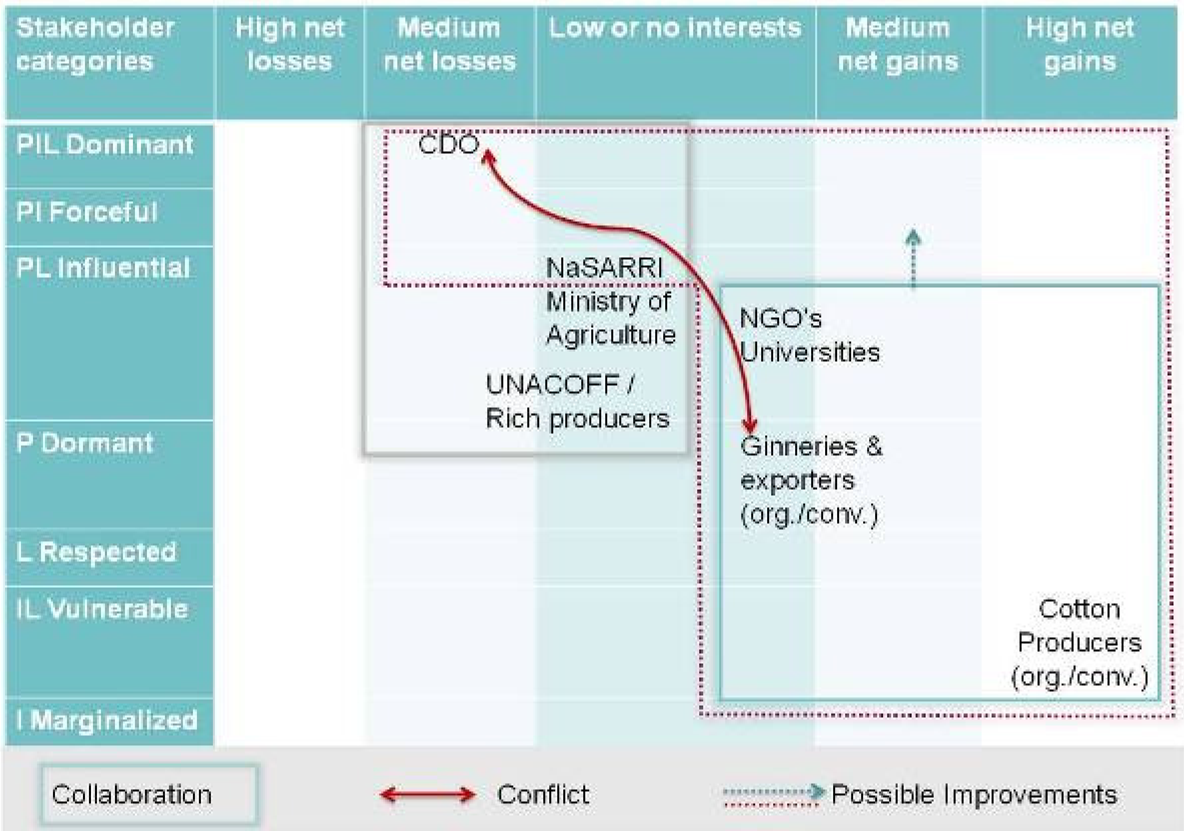

Figure 8. Social Analysis CLIP of an adapted participatory variety improvement project, based on literature review and stakeholder interviews in this study, 2010. Abbreviations: Org. – organic, conv. – conventional. The format of this figure and the stakeholder categories according to Chevalier (2008).

With the adapted breeding project, no stakeholder would suffer high losses (Figure 8). In the adapted stakeholder scenario, two blocks with slightly opposite interests would remain.

However, those blocks do not any more consist only of the same stakeholders who were involved in the pre-existing conflict, which would then become a conflict between individual groups instead of the proponents and opponents of the project. Over time, a collaboration between the stakeholders directly involved in the project can evolve (red dashed box), and thereby the organic stakeholders be empowered. Specifically, their legitimacy, as perceived by the governmental stakeholders, could improve such that they could pursue a stronger policy influence.

2.6 Discussion

The Ugandan cotton sector experiences a relatively low cotton production due to a reduction in the production regions and competition with alternative food and market crops. Improving the productivity is one means of improving the cotton profitability and increasing production, but the governmental policies show little success and require very tight state control over all cotton-related activities. In that situation, alternative approaches such as introducing more cotton varieties, organizing an independent seed system, developing an organic sub-sector, foreign investment and participatory breeding inevitably face conflicts with the governmental agencies.

The initially proposed project would touch all those critical issues and easily be affected by already prevailing conflicts. It would most likely not be feasible institutionally. It is crucial for a project to align with the stakeholder situation. Consequently, an adaptation to the project is proposed: The project should aim at benefiting both organic and conventional small-scale producers, who are equally vulnerable and may share many variety requirements. It should furthermore focus on improving the generally grown BPA cotton variety in close collaboration with the researchers, and not aim at introducing extra varieties. In this project, farmers and state breeders should share responsibilities. Such a project could benefit the stakeholder relations in the long run and open room for discussing further actions in a better atmosphere, while benefiting small-scale producers across the country.

The adaptations proposed are based on solely on the social situation in the cotton sector. To find out whether they are feasible, one needs to know whether organic and conventional small-scale producers actually share enough production constraints and breeding targets to justify breeding a variety for them together. Furthermore, it is important to know whether the differences between the cotton production regions and different producers are small enough to make further investment in a single variety for all of Uganda worth-wile. Therefore, the outcomes of this chapter changed the focus of the further progress of this study. Instead of concentrating on the situation of organic cotton producers in the north only, conventional producers from the eastern region were included in the research to study the extent and nature of the differences between the two groups.

3 The Cotton Production System

The following chapter will investigate the cotton production system in two regions of Uganda, to identify the main constraints from a small-scale farmers perspective and explore possible differences between locations and organic and conventional producers. Especially since the previous chapter has shown that it is desirable for the proposed cotton breeding project to address organic and conventional small-scale producers jointly, this chapter aims to investigate in more detail whether that is worth-wile from an agronomic point of view.

3.1 Introduction

The Ugandan growing conditions differ from those of many other cotton production areas with respect to lower temperatures, lower radiation (due to shorter day-length, more cloudiness and lower atmospheric transmission), varying rainfall patterns and pest pressure of lygus and jassids, which are not problematic as pests in most other regions (Arnold 1970). Jassids (*Empoasca devastans* Dist.) are a species of leafhoppers feeding on cotton leaves. Furthermore, the Ugandan cultivation is part of a wide crop rotation (see Figure 9), therefore, diseases play a lesser role than in regions with continuous monoculture. It is entirely rain-fed, thus the effect of cotton aphids is not as prominent as in irrigated production. Of the average land holding of 4.8 hectares, 1.1 and 0.7 hectares are allocated to cotton by organic and conventional producers, respectively (Elepu & Ekere 2010). In addition, the land is occasionally fallowed and more than half of the cotton crop was planted on new land in 1969, which was considered to give a yield advantage of about 10 per cent (Bowden & Thomas 1970). In a survey of 1994 in Eastern Uganda, one quarter of the participants intercropped cotton with beans, maize and other food crops, but because of an inappropriate spacing the yields of intercropped fields were low (Olani et al. 1994).

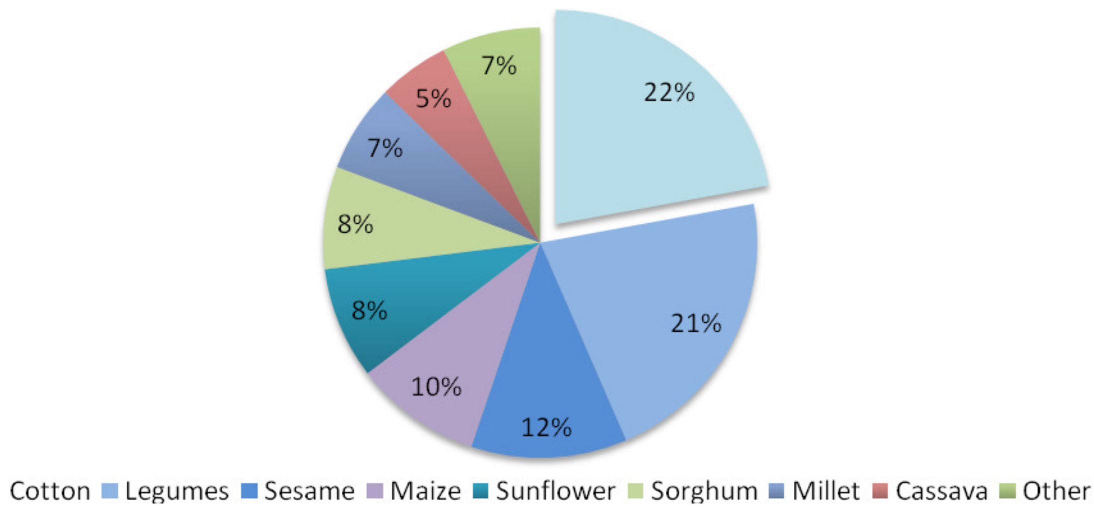

Figure 9. Proportion of areas cropped to different crops of cotton producers in Northern Uganda. Data source: Elepu & Ekere 2010.

Elepu and Ekere furthermore found that the average cotton producer had experience in cotton production of 14 years, 51% relied solely on family labour while the others employed partly to only hired labour. 35% of organic and 44% of conventional producers used ox-ploughs for all or part of the cultivation, in addition 13% of the organic producers had access to tractor services delivered by the organic exporter Dunavant, the remainder relied on hand-hoes for soil cultivation only.

The organic production system has hardly been studied or compared to average conventional practice. Therefore, the following chapter tries to understand both systems and the main agronomic constraints, which need to be considered in a breeding project, in detail. For the definition of target regions and users of a developed variety, it is crucial to understand also the differences between organic and conventional production, different regions or localities and different groups of farmers.

The experts interviewed in the course of the stakeholder analysis and literature on cotton production give diverse opinions about what the most important cotton production constraints in Uganda are. Many see pests and the low use of pesticides as main constraints (e.g. Horna et al. 2009, AGSEC 1999; AGSEC 1994, PMA 2010, most interviewed experts). Mostly bollworms are quoted as the main pests (Horna et al. 2009). Aphids are generally not considered important pests because they infest mostly during dry spells and are sufficiently controlled by predators (e.g. Bowden & Thomas 1970b). Ton (2004) found the false coddling moth (*Cryptophlebia leucotreta*) an additional main pest on organic cotton, although no experts consider this pest.

Similarly, adverse weather conditions are frequently seen as “the single most important determinant of crop yield” (Bowden & Thomas 1970, similarly Serunjogi et al. 2001, PMA 2010, CDO 2011a, most interviewed experts), as both drought and radiation reductions due to excessive rain may become a limiting factor during early vegetative growth and flowering. In contrast, according to Ton & Tulip (2002) Uganda is the most humid of all Sub-Saharan Africa’s organic cotton production areas and insufficient rainfall is no problem on average. Yield losses occur when droughts exceed 4 weeks, while an earlier onset of the dry winter season reduces lint quality because the time for the lint to mature is interrupted.

Some experts cite low soil fertility as a production constraint (NARO, CDO, RATES 2003, CDO 2011a). This constraint refers mainly to the eastern regions, but also the fertility in the north is expected to decline as the population resettles and uses the long fallowed land (van Elzakker 2010, personal communication). Furthermore, while mostly nitrogen fertilizers are promoted, some experts consider the importance of phosphorus as under-estimated (AELBI). In contrast, a 1994 survey in Eastern Uganda could not explain yield variations by a regression of soil fertility parameters over yields, although it classified 19% of the soils as low in phosphorus and all as below critical content of nitrogen. For soil fertilization, Ugandan organic producers rely entirely on crop rotation with no input of fertilisers, while in other countries different organic manures are applied (Ton 2004). According to Mans Lanting, deep soils with optimum pH and high organic carbon, phosphorus, zinc and sulphur were important to high organic cotton yields, while organic carbon and potassium improved the staple length (Lanting 2010, personal communication).

Wilt diseases caused by *verticilium* and *fusarium* have occurred in spatially and temporally localized outbreaks in the 1930’s and 1957 (Bowden & Thomas 1970), but also receive considerable attention in recent years, especially by breeders, due to their occurrence in Pallisa, where a large part of Uganda’s cotton production is located (NARO).

Furthermore, a number of socio-economic constraints such as low price, high labour requirements, reliance on hand labour instead of oxen-driven ploughing and unsatisfactory seed quality and distribution are cited (LOFP, CDO, BoWeevil, UNACOFF, Elepu & Ekere, Lundbaek 2002, COMPETE 2002; CDO 2002; Walusimbi 2002; AGSEC 1999). Moreover, lack of access to credit, equipments, storage facilities, research and others undoubtedly affect cotton production. However, for this study and other agricultural research, the main interest is in agronomic and not institutional constraints.

Lastly, many experts partly blame inappropriate agronomic practices for low cotton yields, since as early as 1970 (e.g. NARO, AEBI, NBCC, Bowden & Thomas 1970). Following scientific recommendations for planting dates, spacing, time for ploughing, thinning, weeding, spraying, and frequent picking is said to enable drastic yield increases. The calculation goes that 1500kg optimum yield can be achieved at recommended spacing, but 300kg are lost with every week of delay in planting (after June 15), 8kg with every day of delay in thinning (after day 12), and 2% of the remainder with insufficient weeding (Dennis Kaijabahoire, agronomist in Daily Monitor 31.3.2010). However, the fact that those recommendations and the producers reported “failure” to adopt them have prevailed over so many years lead the researcher to question what constraints hinder farmers, especially from planting at recommended times. The disagreement among experts and literature about the importance of main production constraints increased doubts of the relevance of extension and research in cotton production and called furthermore for studying the view of producers.

3.2 Materials and Methods

3.2.1 Study Sites

Seven cotton producer groups were visited (Table 6, Figure 10). The Northern and North-Eastern regions are increasing their share in total cotton production in the last years (Section 2.2) and were therefore chosen as study regions. Four locations belonging to the Lango region (North) were under organic production, the three in Teso (Northeast) were under conventional production. The spatial separation of the production systems was necessary because organic production is regionally distributed depending on the working areas of organic projects. The conventional producers in close vicinity of organic producers were not considered representative conventional producers, since they often profit from trainings and organic pesticide distributions from the organic projects. Instead, they often have less access to the conventional extension service and input supply (compare e.g. Elepu & Ekere 2010, 75% of conventional participants had received extension services from one of the nearby organic project and only 25% from the CDO). Both regions have predominantly ferralitic soils in the form of sandy loams and fall into the same climatic category (above 2500 mm per year, mean temperature 23-26°C), and the Teso culture is derived from the Luo culture in Lango region and has similar agricultural traditions. A higher fertility of the soils in the Lango region is frequently quoted to have resulted of the long displacement of the inhabitants to refugee camps during political insecurity, and high natural populations of predatory black ants reportedly control pest problems (Ton & Tulip 2002). This proved not to be true for Bala, which had been the site of a displacement camp itself and rather suffered higher population pressure. Bulongo and Pingire have been gazetted seed production areas since 1929 (Bowden & Thomas 1970). Altogether, the differences between the regions were assumed small, although in the course of the study climatic, soil and ecological differences became apparent.

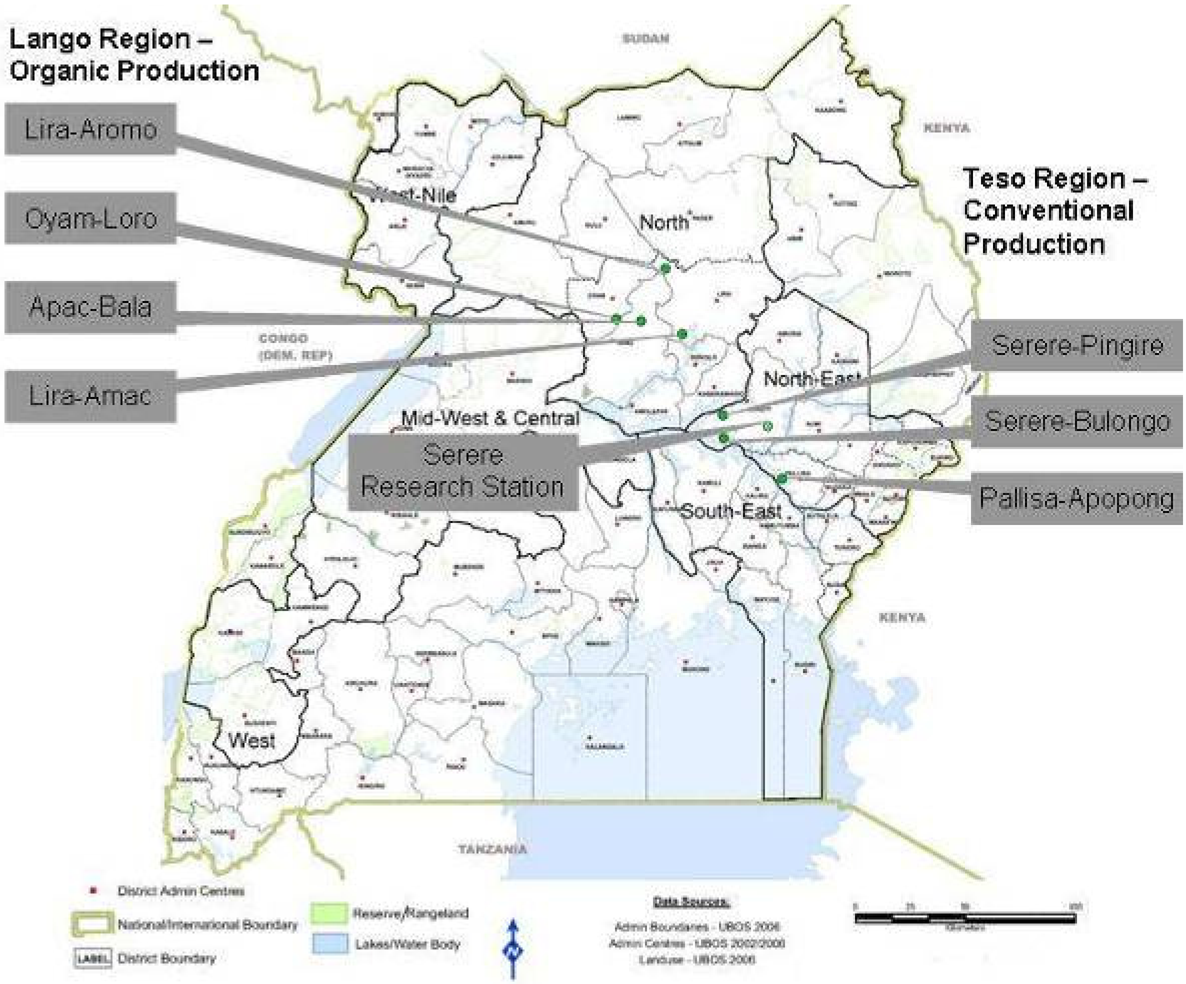

Figure 10. Study Sites. Map Source: UN/OCHA June 2010.

Table 6. Study sites and their main characteristics.

Location	District	Region & Production System	Comments	Gradient
Aromo	Lira	Lango, Organic	Land in use since 6 years after 10 years rest	North-west
Loro	Oyam		Land in use since 4-5 years after 10 years rest	↑
Bala	Apac		Land used continuously, land shortage, high population pressure, sandy soil	
Amach*	Lira		Land in use since 3-5 years after 10 years rest, cotton traditionally grown by every household	
Pingire	Serere	Teso, Conventional	Designated seed production area, used to receive free pesticides	
Bulongo	Serere		Some swampy & clayey lowlands utilized, Designated seed production area, used to receive free pesticides	↓
Pallisa	Pallisa		Infertile and sandy, but some swampy & clayey lowlands utilized	South-east

* - In Amach, only group discussions and no individual interviews were held.

3.2.2 Data Collection

In each location, a group discussion with five to twelve male and female producers (67 in total) was held, to produce a seasonal calendar, showing production steps, labour demand, and pest pressure. The two organic locations Amach and Bala were visited for the purpose of initial group discussions that served to identify the main production constraints and get an overview over the issues to be covered in the other locations.

In six of the seven groups, seven to eight producers per group were interviewed individually, totalling 46 producers. Amach was left out in order to have an equal number of organic and conventional groups, and because it was near Bala. The participants were asked to score the importance of 16 previously identified production constraints for their own fields on a scale from zero (constraint not experienced) to four (major constraint). For this scoring, the participants placed illustrated constraint-cards into boxes representing the scores, and explained their decisions. The participants preferred to decide where to place each card directly after being asked, instead of first getting an overview to all questions. At the end, they were encouraged to adjust the decisions if they wished, especially when no or very many constraint cards were given a specific score. In some cases, that led to a further differentiation of the constraints.

The participants of both the group sessions and the individual interviews were asked to estimate their cotton area and expected minimum, most likely, and maximum cotton yield. Participants who were unable or very insecure to estimate the area or yield were left out, resulting in a total of 61 respondents for area and 57 respondents yields (43 organic and 24 conventional). According to Horna et al. (2009), this method is appropriate to estimate a normal distribution of data when own measurements cannot be taken (for practical reasons). To enable a more reliable estimation, the participants were not asked to estimate kg per acre yields, which was considered an inappropriately abstract question. Rather, they gave the area and expected total yield specifically of their current cotton fields, which was then converted into kg per acre, making the exercise more practical.

For the area estimates, participants were encouraged to use local units, the exact size of which was then determined. Especially in the Lango area, where the organic farmer groups were located, producers measure their land in units of “katala”, the area a hired labourer is expected to hand-plough within one workday, which equals 160-230 square meters, depending on the locality. In the Teso area, where the conventional farmers were located, many farmers estimated the length of the field sides in number of steps, which were measured at 70-80 cm per step. Although these estimates involve many possible conversion errors, they gave a more differentiated picture then when acres are asked, when only round figures like a quarter, half or full acre are given.

In both the group discussions and the individual interviews, a 50% participation of female producers was aimed at. However, males attended in larger numbers and females did not like participating in group discussions that became large. In two group discussions, no females participated, their total number reached 12 of 67 participants (18%). In the individual interviews, additional female producers were visited, but due to practical reasons their total number in the individual interviews reached only 17 of 46 participants (37% of participants). Due to difficulties in estimating the field sizes and yields, females only contributed 15 of the 57 area and yield estimates collected from all participants (26%).

3.2.3 Data Analysis

The results of the group discussions and the explanation for the scoring decisions were summarized and compared to each other with attention to differences between locations.

For each location, the scored constraints were ranked by first grouping them in order of the median, and then sorting the data within each median-group in order of the arithmetic mean. This produced an overview over the relative importance of each constraint per location.

The scores themselves were regarded as absolute importance ratings, since the participants were free to allocate any number of constraints to each score. However, relative considerations also influenced the scoring decisions, when participants compared the importance of different constraints. The scores were analysed statistically using GenStat. The normal distribution of values and residuals were examined graphically in histograms and normal plots produced by an ANOVA. Since the values and residuals were in most cases not normally distributed, the Mann-Whitney-U test was used for a pair-wise comparison of the values of the six locations. This test makes no prior assumption about the distribution of values and residuals and is therefore suited for situations where the conditions for t-tests or analysis of variance are not fulfilled.

The sample size of the survey is rather small with 46 respondents and therefore there remains a risk that found differences are artefacts of the statistical analysis, which would need confirmation of a larger survey. Differences found were therefore interpreted carefully, by comparing them with the participants' explanations of their decisions, the information from group discussions, and the relative ranking of constraints per location.

To determine whether gender influenced the rating of the constraints, the mean male and female scores of each constraint per location were correlated with each other. However, only in one location and for two constraints did the correlation account for more than 70% of the total variance ($R^2>0.7$, data not shown). For that reason, it was concluded that female and male participants did not rate the constraints systematically different, but individual considerations and the situation in one's individual field determined the answers. However, some explainable slight differences will be pointed out.

Since the locations were confounded with the prevailing production system, the values for the two systems were not compared statistically, to avoid attributing location differences (e.g. due to climate, soil type, cropping system…) to organic or conventional management. Instead, the collected descriptions and explanations of the participants were used to explain the origin of location differences and see whether the organic or conventional management played a role.

For the acreage and yield estimations, the values were normally distributed, but since the number of respondents differed greatly between locations, again the Mann-Whitney-U test was used to compare the means between locations.

3.3 Seasonal Calendar and Rotations

3.3.1 Expected Weather Conditions and Cropping Options

According to the seasonal calendars produced by the participants (Figure 1, Appendix II), the year begins with drought and first rainy season sets in mid-February to late March. The first rains last two to four months until mid-May to mid-June, of which maximally two months are heavy rains. In May to June, all locations experience a short drought period of a few weeks to one and a half months. The second rainy season begins in late June to late July and ends in late November. The second rains are heavier than the first, one and a half to three and a half months of heavy rains occur.

Altogether, there is a gradient of decreasing humidity from the northwestern to the southeastern locations. In the north-west, the first rains generally set in and end earlier, and the second rains are long and mostly heavy. In the southeast, especially in Pallisa, the second rains are shorter and lighter, and the summer droughts are longer. In Pallisa, also the first rains are long but light.

The producers were encouraged to include different options of cotton growing and possible delays for specific activities into the seasonal calendars. One option (hereafter called cotton as a single crop or single-crop cotton) is to plant cotton ‘early’, i.e. during the first rainy season, and harvest it towards the end of the second rainy season, thus growing only cotton on the field during one year. The second option (hereafter called cotton as a second crop or second-crop cotton) is to begin the year by growing a short-season food crop during the first rainy season and plant cotton ‘late’, i.e. after harvesting the food crop. An about 1 month earlier planting time is possible in this system if cotton is interplanted into the first season crop about a month before its harvest.

In the northern locations Aromo, Loro, Bala and Amach, second season rains are longer and heavier than the first season and the majority of participants planted cotton as a second crop (in 2010, see Table 7). In the Eastern locations Pingire and Bulongo, the second season rains are unreliable and rather light compared to the first season, so cotton needs to be able to profit from the first season rains. Therefore, second-crop cotton is not preferred in Bulongo and considered impossible in Pingire. Only the combination of two food crops following each other is considered possible. In Pallisa, the second season rains are as light as in the former two locations, but since the first season rains are even lighter, the majority of producers also plants late cotton here.

The participants explained that the earlier-planted single-crop cotton gives higher yields, due to more favourable weather conditions and less pest pressure, while the pests that previously build up in earlier cotton attack the later-planted second-crop cotton. However, producing cotton after a first season crop gives a higher total return per field and year.

The first season crops are not equally suitable for preceding cotton. Beans are the most frequently planted first crop (21 participants) and are considered to facilitate good cotton yields. Soybeans (four participants) are less frequently planted because they cause low cotton yields and bad germination. Groundnuts (one participant) are considered in Bulongo and Pallisa but lead to overly delayed cotton planting. Maize (five participants) is considered to produce the best cotton yields in Aromo, but is rarely planted before cotton in other locations. In Loro and Bulongo participants found that it depletes the soil too much and therefore causes low yields. The same was said about sorghum, which is rarely plated before cotton. Sunflower has been tried in Amach but was experienced to lead to excessive vegetative growth in cotton. Few participants had tried sesame or millet before cotton but found it a good pre-crop, probably this sequence is uncommon because millet is the preferred crop to follow cotton. Cassava was only mentioned in Pallisa.

Table 7. Cotton production options followed by participants of group discussions in seven locations in Uganda. Aromo, Loro, Balan and Amach are in Lango region under organic production, Pingire, Bulongo, and Pallisa are in Teso region under conventional production.

Location	Cotton as a single crop		Cotton as a second crop		
	% of respondents	Planting time	First season crop	% of respondents	Planting time
Lira - Aromo	10	June	Beans, soybeans, maize	90	May-June (i)* June-July
Oyam - Loro	36	May	Beans	63	May (i)
Apach - Bala	40	May-June	Beans, soybeans	40	June-July
			Maize	25	August
Lira - Amac	20	May	Beans	60	June
			Maize	20	July (i) / August
Serere - Pingire	100	April-June	-	0	-
Serere - Bulongo	75	May-July	Groundnuts, millet	25	Late July-early August
Pallisa - Apopong	36	May	Groundnuts	18	July-August
			Maize, millet, sorghum, sesame, cassava	45	July (i) / August
Total (n=67)	43	April-June		57	May-July (i) / June-August

* (i) Indicates the planting time when cotton is intercropped into the ripening first season crop.

3.3.2 Cropping Cycle

3.3.2.1 Land Selection and Preparation

Cotton can follow any previous-year crop, such as maize, millet, sesame, cassava, legumes (soybeans, groundnuts), vegetables, or fallow. Only maize and sorghum are considered less suitable because they deplete the soil. In addition, maize and sorghum are hosts for cotton bollworms, which may also have led to the participants' experience that they cause lower yields. In Pallisa, both single-crop and second-crop cotton always follows a fallow period or the less demanding cassava. This is likely to be an adaptation to the lower soil fertility in Pallisa. In contrast, some participants in other locations experienced excessive vegetative growth if cotton follows fallow. In Aromo, cotton rarely follows a fallow period, because sesame or beans are the preferred crops after fallow.

None of the participants applies any manure in cotton or a previous crop. Rather, they rely on rotation, mulching (especially Bala), incorporating rotten or burnt crop residues, and fallowing to maintain soil fertility. A few participants in Loro plant Mucuna, a green-manure legume, during the fallow period and avoid burning after the fallow. Producers try to maintain a fallow period if land is sufficient, such as all participants in Pallisa and Loro (fallow is a must even if only 1 year), most participants in Aromo (ten of eleven) and many in Pingire and Bulongo (five of eight and five of eleven, respectively). In Bala, fallowing reduced and became less common due to land scarcity. The duration depends on the land availability, between one to five years after two to ten years. However, most participants stated that the current fallow periods are below optimal, which they observe in the form of increased weed infestation, erosion, and reduced fertility.

The cropping cycle begins with thorough ploughing in the dry winter season to prepare the field well for a weed-sensitive crop. For single-crop cotton, producers plough twice in an interval of one month and try to make sure that rain induces weed growth between the first and second ploughing. Either, the first ploughing is done early, during the last rains of the previous year ("back-end ploughing", November & December in Bulongo), or late, such that the spring rains begin before the second ploughing (between late February and early May in other locations). Between the second ploughing and planting lie another two weeks to three months, or even five months in the case of the back-end ploughing in Bulongo, such that the actual seed bed preparation may again contribute to weed control. If the cotton crop is preceded by a first-season crop, the ploughing in most cases takes place completely in the dry season, probably because those crops are planted earlier (mid-January to mid-April) and need less intensive weed control (two to three 3 times weeding as opposed to four to five times). The fields are prepared well in advance of the expected planting, such that if seeds are delivered late, some fields may need an additional hand-clearing and -ploughing. Therefore, late seed delivery can have high labour and/or cost implications.

Ploughing can be done by ox-plough, which takes two times five days per hectare and achieves best weed control. However, ox-ploughs have to be hired expensively (75,000-120,000 UGX per ha) and are not available in every location. Therefore, many participants plough by hand-hoes, which takes two times one man-day (six hours) per katala, which equals, depending of the size of the local unit, 50 to 75 man-days per ha. In Pingire, all participants use an ox-plough for the first and hand-hoes for the second ploughing. In Bulongo, ox-ploughs are most commonly used both times of ploughing. Seedbed preparation is always done by hand hoes.

3.3.2.2 Planting and Early Development

Since both drought and excessive rainfall can negatively affect germination, planting is mostly done when light rainy weather is expected (Table 8). However, the planting weather varies from drought to heavy rainfall, indicating that reliable rainfall during planting time is not the only determinant of the crop timing. Single-crop cotton is mostly planted during the first season rains or just before the summer drought. For cotton as a second crop, the planting dates lie either just before the summer droughts, when cotton is interplanted into a ripening, soon to be harvested first season crop, or at the end of the summer droughts after harvesting the first season crop. In Loro, producers may intercrop cotton with Hibiscus (locally consumed leafy vegetable) or yellow, non-climbing beans. Intercropping is generally considered to reduce yields in other locations, although intercropped fields were seen, and in Pingire and Bulongo, the purchasing ginnery discourages intercropping. The mentioned planting times result either in an escape from the summer drought, or a timing of the drought during the crop's vegetative growth stage (5-53 days after planting, hereafter referred to as DAP). Also light or heavy rains occur.

The first weeding has to follow within two to four weeks after emergence and includes thinning to one to two plants per planting hole, although some only remove small and unhealthy plants. Weeding needs to be done monthly for the first three to four months (Aromo, Loro, Pingire) up to five times (early cotton in Pallisa). Early cotton is weeded more often than late cotton. Each weeding takes one person-day per three katala, which equals 17-25 person-days per hectare.

3.3.2.3 Pest Control

Aphids are the earliest pest, which appear as early as March to May. They reach peak infestations during flowering around May to June. Participants in Loro, Pingire, and Pallisa found that they disappear around August, with the first pesticide applications (in conventional locations) and stronger rains. In contrast, in Aromo and Bulongo they were found to remain throughout the whole season only slightly reduced by rains and pesticides but recovering quickly. Organic producers dust wood-ash on the plants to control aphids. Lygus bugs attack especially during flowering from June/July until October/November, while in Loro they are reportedly only present in July and August. In Aromo and Pallisa, the infestation remains only on a low level. Conventional producers found pesticide applications not effective. Bollworms attack during the boll formation stage starting from June (early cotton) to September (late cotton) and remain until October-January. In Loro, Pingire, and Bulongo, they reach high infestation levels in September/October, while in the other locations infestation remains low. Cotton stainers infest from boll opening onwards, appearing first in September (in early cotton) to November (in late cotton). They reach peak levels in November/December and remain until the end of harvest in around February. In Loro, Pingire and Bulongo they reach high infestation levels, while in Aromo, Bala, and Pallisa the infestation remains low.

Participants in Pallisa and Bulongo only know pesticides as pest control measures. Insecticides are preferably applied after the second and each following time of weeding, i.e. three to four times in Pallisa, two to five times in Pingire, none to four times in Bulongo. However, at the time of the discussion in Pallisa, one farmer had only sprayed twice, three three times and seven four times; in Pingire they had sprayed two to five times. Mostly, the CDO-subsidized pesticides are applied but because their distribution is frequently delayed and quantities insufficient, additional pesticides are bought. These are about twice as expensive and considered less effective. Especially since the dilution directions differ for each product, producers may experience little effects if they unknowingly diluted too much. E.g., in Bulongo, the CDO field extension worker stated that only 400 out of 700 request units (each meant for spraying one acre one time) were allocated to his work area, and only 324 units remained after other areas and individuals had taken some shares away. These remaining units can only be collected and distributed little by little, which costs much time and effort and brings frequent conflicts. To the date of the interview, participants received a maximum of two applications from the CDO although they intended to spray four times, so they bought on average two applications from agriculture input stores.

In Pingire, participants experienced that thorough weeding and clearing a one step-wide strip around the field from vegetation reduced pest pressure. Organic producers in Loro have good experiences with molasses traps against bollworms and neem as a botanical pesticide, but neem was too expensive to be used after the one-year test. Participants in Loro observe beneficial insects such as praying mantis, wasps, big-eyed bugs, black ants, and ladybird beetles in their field all year round. Black ants are seen effective against all pests to a certain extent. Higher populations are more effective, they can be moved in bones or sweet potato leaves, and they multiply especially in maize. Their populations have reduced in the Lango region with the cutting of trees and are almost absent in the Teso region.

3.3.2.4 Adjusting the Crop to the Weather Conditions

Comparing the growth pattern of the current cotton variety to the expected weather during the respective growth stages reveals that expected rainfall during the flowering and boll filling stage is the main criterion for choosing planting times, to the benefit of which adverse weather conditions in other periods are tolerated (Table 8). The flowering and boll formation stage (54-104 DAP) the weather conditions are the most uniform across planting options: in two thirds of the participant's planting decisions flowering coincides with heavy rains. In Lango area, droughts during flowering only occur when weather patterns differ from the expectations, the same is true for the intermediate planting time in Pingire, the single-crop cotton in Pallisa and the second season cotton in Bulongo. Some of the cropping strategies in Teso area cannot prevent expected drought during flowering, namely the earliest and latest possible planting times in Pingire, the planting as second crop in Pallisa and the planting as pure crop in Bulongo lead to short droughts affecting flowering. This fits with the observation of six participants in Pingire and Pallisa, that droughts may cause square shedding (shedding of flower buds) and thereby affect yield, while in other locations droughts were mainly a problem during planting or not considered a problem.

Table 8. Weather conditions expected during different production stages by numbers of fields of 67 participants in group discussions across seven locations in Uganda.

Weather	Ploughing	Between/after ploughing	Planting	Growth	Flowering	Boll opening	Picking
Heavy rains	16	4	21	32	47	43	12
Light rains	5	21	33	17	14	14	17
Dry weather	51	4	18	23	11	15	43
First Crop		43					

3.3.2.5 Harvest and Following Crops

Boll opening (105 DAP) and harvesting begins in most cases during rainy weather. Under such conditions, one can only harvest in the afternoons of sunny days, when the cotton has dried, and the majority of the work goes into weeding the crops that remain in the fields. Therefore, for the benefit of timely and quality harvesting in the dry season, cotton would need to be planted later. Again, the harvesting conditions are not the only determinant of planting times.

After cotton, millet and legumes (peas, beans, soybeans, groundnuts) are preferred. In Serere and Pallisa, maize and sorghum are also planted. Generally, all crops do well after cotton, but the more demanding crops profit most from the well-prepared soil while planting less demanding ones like cassava is considered a waste of the good land.

3.3.3 Socio-Economic Aspects

Participants indicated their general workload in different months into the calendars. Peak workloads were experienced around the dry seasons in summer, because during this time first season crops need to be harvested, the land again prepared and the second season crops planted and weeded early, all within a short time. However, with the general school holidays in July to August, extra support by schooling children and youth is available. Furthermore, the main planting time in the beginning of the first rainy season and times with excessive rainfall that require frequent weeding were indicated with a high workload. In Bulongo, where most participants plant cotton as a single crop, the land preparation in April is also found a high workload.

Ploughing and insecticide applications mostly involve men, while all other farming activities are carried out by both men and women. In some locations, farmers share the work by working in groups, in Loro also for cotton. Nevertheless, for cotton this is less common, because especially the weeding needs to be done carefully in order not to break branches.

From March onwards, but especially in May, many participants experience a financial and food shortage, because first food crops are harvested and incomes earned in June, while high expenses for ploughing, seeds, and school fees for the first two terms as well as food purchases occur earlier in the year. This may be an additional reason for some producers to plant cotton in the second season instead of May, although in that case also planting has to be done during the peak workload. One can therefore not conclude that socioeconomic constraints govern the planting time of cotton. Also directly during the cotton harvesting season, high expenses are due for Christmas (the traditional time to buy new clothes and a special meal) and the first term school fees.

3.4 Acreages, Yields and Profitability

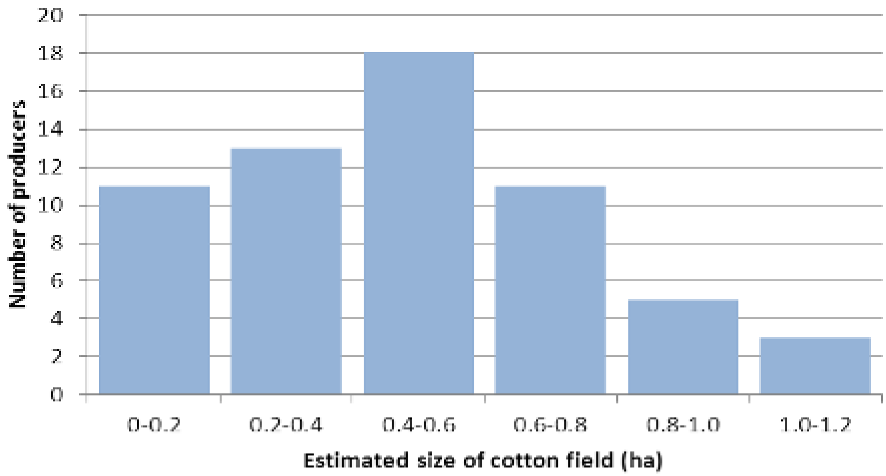

Figure 11. Distribution of estimated cotton field sizes of 61 cotton producers, who participated in grpoup discussions or individual interviews in seven locations of Uganda.

The cotton field sizes ranged from 0.08 to 1.2 hectares per producer, the average being 0.49 hectares. The majority of participants planted 0.4-0.6 hectares with cotton (Figure 11). This field size is not equal to the area per household since different household members may own separate cotton fields. The average field size in Pallisa is significantly smaller than in Bala, Loro and Bulongo ($P<0.001$, $P=0.021$ and $P<0.001$, respectively).

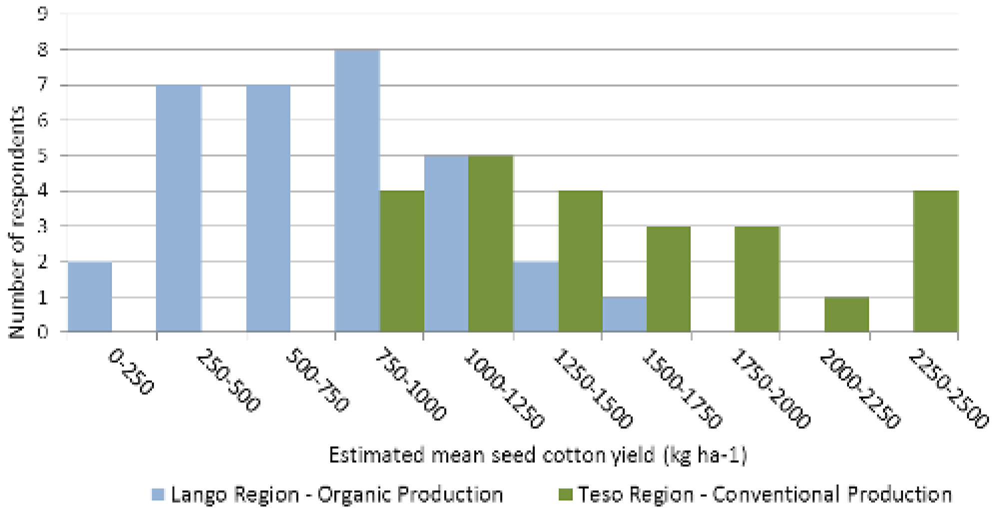

Figure 12. Distribution of estimated yields of 32 organic cotton producers in Lango region and 24 conventional cotton producers in Teso region, who participated in group discussions or individual interviews in seven locations in Uganda.

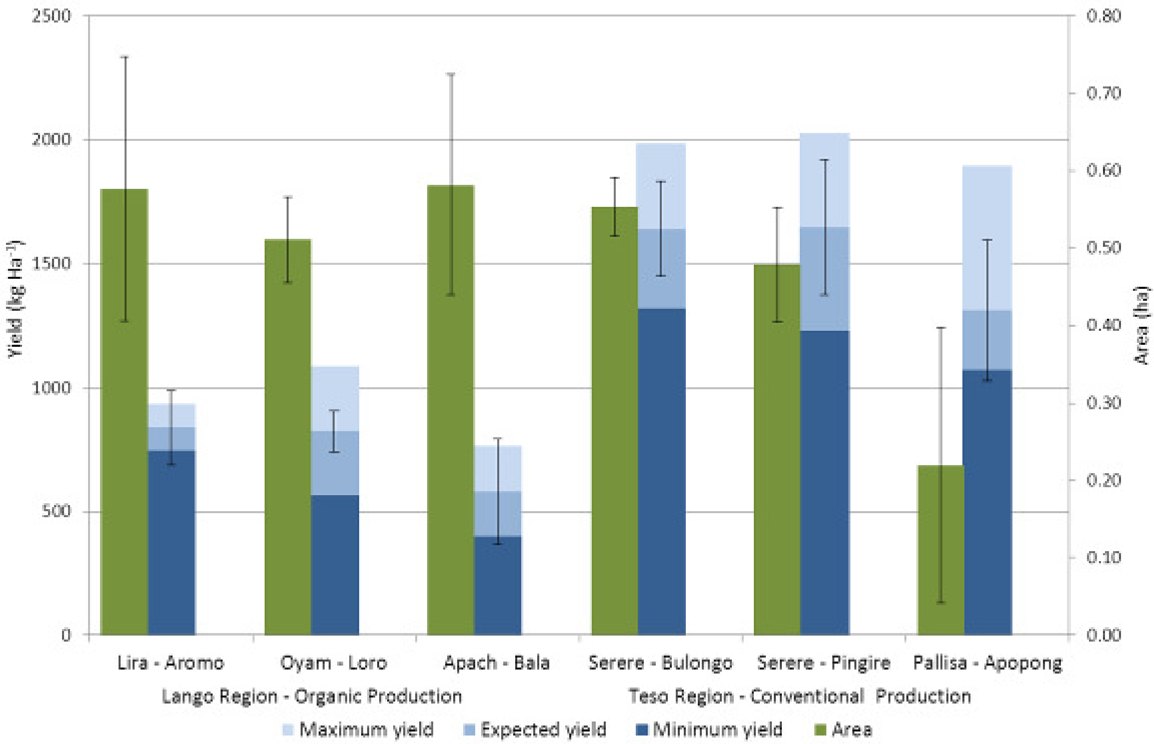

Figure 13. Minimal, average, and maximal seed cotton yields (kg per ha) and area (ha) of cotton fields estimated by 57 cotton producers who participated in group discussions or individual interviews in six locations in Uganda. Error bars indicate the standard deviation of the expected yield and of the area in each location.

The estimated minimum, expectable and maximum yields (Figure 12 and 13) of the organic production sites all differed significantly from those of the conventional production sites (P ranging from P=0.020 to P<0.001), averaging one third to one half of those expected by farmers in conventional growing areas. In the three locations under organic production, yield expectations ranged from 115-1979 kg per hectare, the majority of the expectable yield were 250-1000 kg, averaging 766 kg. In Aromo and Loro, the majority of the yields ranged from

250-100 kg, in Loro they were somewhat higher with 500-1250 kg. Yield expectations in the conventional production sites ranged from 412-3727 kg per hectare, the majority of the expectable yields were 750-1750 kg, averaging 1660 kg. In Pallisa, the majority of the yields ranged from 750-1250 kg and were thus similar to those in Loro. In Bulongo and Pingire, most yield estimates ranged from 1000-1500 kg and there was a secondary peak of four participants with yields above 2250 kg. Since except for the location, no similarities among those four participants could be found, it must be assumed that these outliers resulted from estimation errors or are an artefact of the low number of total participants. There are no consistent differences between the size of male and female landholdings or their expected yields (data not shown).

Table 9. Profitability calculations for one hectare cotton of different model producers valuing all labour at market costs and assuming maximum yields under low investment and average yields in the other cases. Costs and prices are based on group discussions and individual interviews in seven locations in Uganda. Detailed cost calculations are in Tabe 1, Appendix II.

	Conventional high investment	Conventional low investment	Organic with premium (150 UGX)	Organic without premium
Production Costs (1000 UGX)	1053	573	432	432
Yield (kg)	2250	1660	766	766
Unprofitable price (600 UGX)				
Total Revenue (1000 UGX)	1350	996	575	460
Net Revenue (1000 UGX)	297	423	142	27
Cost-Benefit Ratio	1.28	1.74	1.33	1.06
Cost-covering price (1000 UGX)				
Total Revenue (1000 UGX)	2250	1660	881	766
Net Revenue (1000 UGX)	1197	1087	449	334
Cost-Benefit Ratio	2.14	2.90	2.04	1.77
Motivating Price (1300 UGX)				
Total Revenue (1000 UGX)	2925	2158	1111	996
Net Revenue (1000 UGX)	1872	1585	679	564
Cost-Benefit Ratio	2.78	3.77	2.57	2.30

The profitability of cotton production is calculated in Table 9, detailed calculations of production costs are listed in Table 1, Appendix II. For the calculations, all labour was valued at the cost of hired labour (1,000 UGX per person-day), the opportunity cost for family labour. In all cases, labour costs accounted for more than 90% of the total production costs.

Farmers stated they would give up to grow cotton at a price of 500-600 UGX and below, 800-1100 UGX would cover their production costs excluding own labour, while 1300 to 2000 UGX and above would motivate them to plant more cotton. Accordingly, calculations were modelled for three prices, of which the highest is about the average price for the 2010/11 season. The resulting profitability depends greatly on the yields that are assumed based on the yield distributions (Chapter 3.3), but only apply to model producers. However, the main result is that at least at this low labour costs, cotton production produces positive net returns under all price and production options.

Depending on the potential and the decisions of the producer, a high-investment conventional producer can have double the production costs of a low-investment one, however, this does not guarantee achieving the maximum yield as in this calculation. Even if one does, the cost-benefit ratio is smaller than with low investment and average yield. A high investment thus leads to greater total profits, especially considering that it enables cropping larger areas, but is less profitable than low-investment production. Whether organic premiums are paid or not, organic cotton is less profitable than the conventional variants due to the lower average yields. Still, with a cost-covering price and organic premiums, the net revenue is considerable and the cost/benefit ratio with two good. Difficulties in obtaining sufficient and timely seed and pesticides from the CDO lead to extra ploughing and pesticide costs which slightly reduce the net revenue and cost-benefit ratio, plus possible yield losses due to delayed planting, patchy germination or late pest control (not shown).

In summary, the revenue and cost-benefit ratio of different types of organic cotton producers was profitable based on the cost covering and motivating prices, while with 600 UGX per kg, profitability was very low but still positive. However, whether these revenues are truly achieved depends greatly on the yields achieved by the individual producers. Furthermore, a producer who manages to sell later in the buying season when prices usually rise will improve the profitability. In contrast, Elepu & Ekere (2010) found that organic cotton production was profitable with 7% gross margins while conventional with -11% was not. However, without the organic price premiums of 35%, both systems would have produced negative gross margins. If the own consumption of the food-crops was not valued, organic sunflowers and rice were the only other crops with positive gross margins. When the own consumption was valued at market prices, sesame gave the best returns with almost 35%, but also sunflowers, soybeans, pigeon peas, maize and rice were more profitable than cotton. The data are based on the valuing a person-day of work with 5,000 UGX, which is unrealistically high. Also Serunjogi et al. (2001) found that production costs depend greatly on the production methods, because of higher yields, they were lowest computed per kg of seed cotton when ox-ploughs or tractors are used and insecticides applied, somewhat higher when hand-hoes and insecticides were used and highest when using hand-hoes and no insecticides.

3.5 Production Constraints

3.5.1 Ranking of Constraints

The mean and median scores and statistical properties of the constraints per location are listed in Table 2, Appendix II. The mean and median scores lead to the following ranking of production constraints, which indicates the relative importance of the constraints in the different locations (Table 10, also see Table 3, Appendix II for transparency of the ranking).

In total (across locations), weeds and the price of cotton were rated as the most severe production constraints (median score 4, mean scores 3.4 and 3.1, respectively), followed by three of the main pests aphids, lygus and bollworm (median score 3, mean scores 2.8 to 2.9). Medium ratings were given to stainers, low germination due to low seed quality, drought and the timing of seed distribution (median score 2, mean scores 2.4 to 1.7). The quantity of available seed, low soil fertility, tall vegetative growth and the flooding of fields, which played a role in the three conventional production sites, played a minor role with the median score 1 (mean scores 1.0 to 1.6). The locally important pests, monkeys and termites, and cotton wilt diseases were overall of no importance with the median score 0 (mean scores 1.6 to 0.4). The following section will describe the constraints and location differences in more detail, in order of their overall relative importance.

Table 10. Ranking of production constraints by 46 cotton producers in six locations in Uganda. 1- largest constraint. The ranking resulted from a combination of the median and arithmetic mean of each constraint in each site (see Tables 2 and 3, Appendix II).

Constraint	Lango - Organic production			Teso - Conventional production			Total
	Lira-Aromo	Oyam-Loro	Apach-Bala	Serere-Pingire	Serere-Bulongo	Pallisa-Apopong	
Weeds	8	2	2	2	2	1	1
Price	6	3	7	1	1	9	2
Aphids	3	1	5	12	4	4	3
Lygus	7	5/6	1	9	5	6	4
Bollworm	2	10	3	4	3	3	5
Stainer	4/5	4	8/9	10	7/8	5	6
Germination	10	5/6	4	3	7/8	8	7
Drought	9	7	11/12	7	6	2	8
Seed availability (timing)	1	13	8/9	8	9	13	9
Seed availability (quantity)	4/5	8	13	13	12	11	10
Soil fertility	13	9	11/12	14	11	7	11
Tall growth	11	11	6	11	13	14	12
Flooding	?*	?	?	16	14	10	?
Monkeys	?	?	?	5	15	16	?
Termites	?	?	?	6	?	15	?
Disease	12	12	10	15	10	12	13

* Not asked in all locations. The importance of Monkeys and Termites in the locations marked with a '?' was not asked. For Flooding, it is most likely that it does not play a role in the Lango locations.

3.5.2 Scores of Constraints

The mean scores and the significant differences between locations according to the Mann-Whitney test are shown in Figure 14, note that the locations are ordered in a northwest to southeast direction.

The local differences may be explained by locality effects (climate, soil, natural vegetation etc.), the differences between the organic and conventional production system (especially pest control), and different perceptions and local discourses by the participant. E.g. a constraint for which there is no control option may be rated high in spite of its low yield effect, in one village producers may have discussed the importance of a specific pest.

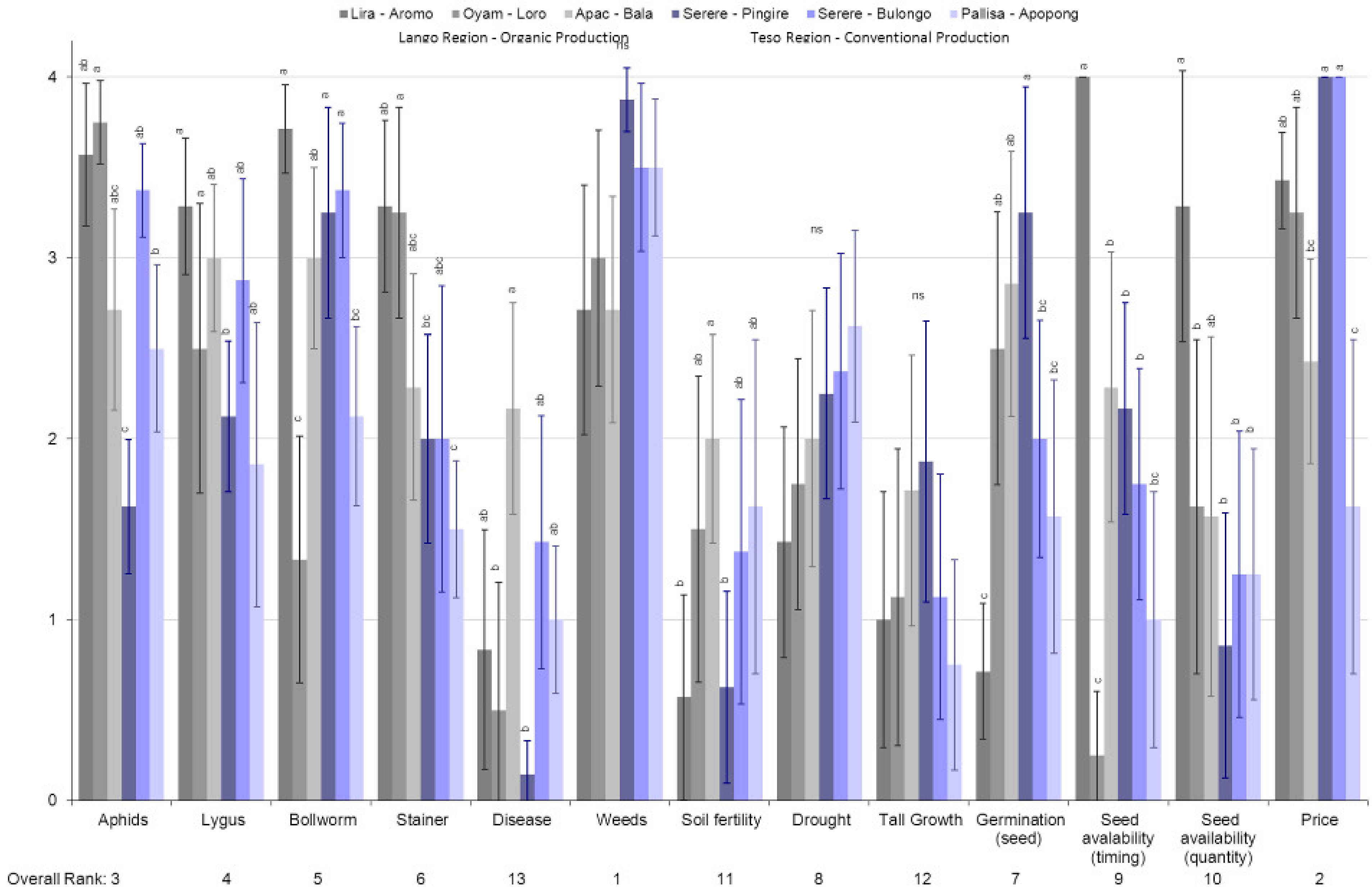

Figure 14. Cotton production constraints rated by 46 producers in six locations in Uganda, on a scale from 0 (no constraint) to 4 (very serious constraint). The first three locations (grey shading) are under organic cotton production, while the last three locations (blue shading) are conventional production areas. Columns marked with the same letters within one constraint do not differ significantly (α>5%) as determined by a two-sided Mann-Whitney-U test.

3.5.2.1 Most Severe Constraints

The absolute scores for weeds showed no significant difference between locations, and they ranked first or second in all locations but in Aromo, with rank eight. The high and low scores for germination problems in Pingire and Aromo could explain the high and low scores for weeds in these locations, respectively, because low seed quality reduces early vigour. However, there is no visible relation between the two scores in the other locations. Participants in Pingire and Pallisa emphasized the importance of obnoxious weed species wandering jew (*Camelina senegalensis*) and citronella grass (*Cymbopogon afronardus*). The rating of the participants largely depended on their family labour availability and whether costs for hired labour incurred. The weeding requirements were a major constraint for farmers not to plant more cotton, and three farmers planted the cotton in intervals to cope with the weeding requirements. Weeds were found more abundant due to having two crops per year and if participants were not able to fallow the land or relied solely on hand-ploughing, which reportedly does not sufficiently suppress weeds. Weeds compete with the crop, but are also found to increase pest incidence.

Prices were overall the second-highest constraint in cotton production. This constraint includes low prices, price fluctuations across and during seasons and cheating by intermediaries. In Loro, Bulongo and Pingire the price scored highest, followed by Aromo and Bala (not significantly different from Loro), and lowest in Pallisa (not significantly different from Bala). The relative importance is similarly distributed across locations. Farmers received 500 to 800 UGX per kg (ca. 30-45 eurocents) in the last three years. Although many farmers found the indicative price of 1100 UGX per kg (ca. 66 eurocents) that prevailed during the interview time acceptable, they expected that during the buying season it would not reach that level, as they were used to be motivated with high price promises during the planting and weeding season. During the interviews in Pallisa, buying had already started and farmers experienced that the 1100 UGX had actually been paid, and an increase to 1300 UGX had just been announced, which explains the much lower rating there. In Bulongo and Pingire, participants complained especially about cheating by intermediaries, and the costs of using of ox-ploughs, which is more common in these two locations, might explain the concern about prices.The high rating for prices fits well with the low profitability of cotton found in literature and the price-sensitivity found in the current study.

3.5.2.2 Severe Constraints

Aphids were the most important pest overall, but the scores and ranking differed between locations. In Loro and Aromo, aphids were ranked as the first and second constraint, and scored a median 4. Although aphids are only experienced for about 4 months in Loro, they reach high infestation levels and were therefore ranked highest. In Bulongo and Bala, they received median score 3 and ranked fourth and fifth, although the scores of the latter four locations did not differ significantly. In Bulongo, producers often received insecticides too late for aphid control. In Pallisa, insecticides were available but not found effective, therefore, aphids received a median 2 and ranked fourth, the scores were significantly lower than in Loro. In Pingire, Aphids received the lowest mean score and ranked only 12th, significantly lower than all locations but Bala. In the seasonal calendars, participants of Pallisa indicated that aphids are only present from June to August because they are controlled by the first pesticide application; and in Pingire only in June and July, while in the other locations they are experienced for four to ten months. Higher ratings in the organic production sites may be explained by the more humid climate there and the lower effectiveness and use of organic pesticides, namely wood-ash (in form of dust or water solution). Aphids received surprisingly high ratings compared to the judgement of experts, who stated that aphids infested cotton only very early in the season, were well controlled either naturally by rain and predators or by single insecticide applications and caused hardly yield loss. In contrast, many farmers found aphids reduced photosynthesis and affected the plant development and branching in the long term, and are problematic for a major part of the growing season and in spite of heavy rains, although they found the infestation worst during dry spells. There is however no relation between the rating for droughts and aphids. The perceived ineffectiveness of pesticides conforms to research experience of increased aphid infestation following insecticide application, due to the reduction of predators (Serunjogi et al. 2001).

Lygus bugs were the second most important pest overall. The scores in Aromo and Loro were significantly higher than those in Pingire, while the other locations showed no significant differences. The differences between locations are inconsistent, with respect to scores, relative rank, and illustration of the severity of infestation in the seasonal calendars. The severity of lygus does not differ as much between locations as it does between individual producers and fields. According to the farmers' explanations, lowland fields, insufficiently weeded fields and fields near bushy areas or pastures are prone to lygus damage. Opinions differed about how easy it is to control, organic farmers opinions ranged from 'easy to prevent through clean weeding' to 'not affected by organic pesticides', while conventional farmers found that at least several insecticide applications were required. Most farmers mainly perceived leaf damage affecting photosynthesis, while some highlighted growth retardation and square shedding. Higher weed incidence may increase lygus problems.

Bollworms were the third most important pest overall and ranked 2nd to 4th. In Loro, they scored significantly less than in the other locations and ranked only 10th. Also in Pallisa they scored lower than in the other locations but Bala. All farmers agreed that it caused the most severe damage since it affects the fruits directly; in addition, many farmers mentioned the damage to growing tips caused by spiny bollworms before boll formation. In Loro and Pallisa, the lower scores were based on perceived lower infestation. In Pallisa, the low score fits the indication of low infestation levels in the seasonal calendar, while in Loro severe infestation in August and September occurs. The agro-ecological effects which caused the lower scores are unknown, such as higher presence of predatory black ants (e.g. in Loro where more fallow is observed), or lower abundance of alternative hosts. Control options for organic farmers were handpicking affected fruits, molasses traps catching the moths, neem application, and black ants were found effective predators. For conventional farmers, bollworms were the reason for continuous spraying of three to five times; however, some farmers complained about the late delivery of CDO-pesticide while the free-market pesticides were not effective.

3.5.2.3 Medium Constraints

Cotton stainers were the least important pest and received a lower median score of 2. They were rated higher in Aromo and Loro than in Pallisa, but received similar relative ranks (4 to 5) in those locations. There seems to be a northwest to southeast pattern in the scores, just as those of drought constraints. Although stainer infestation is not directly connected to climate, the ecology of drier regions may favour stainer damage. Bowden & Thomas (1970b) observed in a comparison between the north and the more humid central region, that a shorter dry season and a more bimodal distribution of rainfall leads to the continuous seed production of wild grasses, the alternative host of cotton stainers. With a more pronounced dry season and more unimodal rainfall, as in the eastern locations, wild grass seed ripen all at once at the beginning of the dry season and stainers migrate from them to cotton when it is most susceptible, when young green bolls grow. Stainers can be controlled by herbal pesticides, early planting, predation by black ants and burning crop residues, while some farmers found clean weeding effective while others did not. Conventional farmers found them easy to control by late pesticide application, if available, although some stated they would not spray after bolls have opened, because the pesticide might affect the cotton fibres. Because they stain cotton yellow, they force farmers to dry and sort their cotton, which often has cost implications, and reduce the amount of marketable fibre.

If one averages the scores for all pests, pests score highest in Aromo (3.5), lower in Bulongo, Bala, Loro, and Pingire (2.9 to 2.3) and least in Pallisa (2.1). They rank the third largest production constraints in all locations but Aromo (rank 2^{nd}) and Pingire (rank 4^{th}), where they are overtaken by germination problems. Surprisingly, although in Pingire and Bulongo all or the majority of cotton producer plant pure, early-planted cotton, which is generally reported to suffer less from pests, and the yields in these locations are highest, they show no lower scores for pests in general.

Low germination due to low seed quality was the seventh highest production constraint overall, but the problems differed greatly between locations. In Loro, Bala and Pingire, germination problems scored highest and ranked 3^{rd} to 5^{th}, while in Aromo, Bulongo and Pallisa, it scored less and ranked 7^{th} to 10^{th}. However, the values for Loro, Bala, Bulongo, and Pallisa did not differ significantly. In Pingire, participants quantified germination even as low as 3-5%. According to the experience of the producers and seed distributors, the low seed quality results mostly from transport and storage and therefore affects only specific batches of seed, explaining the differences between locations. In addition, the cotton breeders suspected a negative effect of machine de-linting, and producers think that some seed multipliers picked immature seed or sold wet cotton (a common malpractice to increase the weight at the time of selling). They requested that only the seed from the first fruits in the lower part of the plant were used, because they found them to be harder and larger. In contrast, only nine farmers mentioned low germination due to drought or excessive rains. Farmers were sure that the low germination was caused by the seed quality when they compared the performance of different seed bags or from different years in the same field and planting time or the performance of one seed bag in different fields or planting times. The seed quality varied between years, lots, and individual bags.

Droughts were ranked eighth overall and values did not differ significantly between locations. However, the data show a clear northwest-southeast gradient that fits the patterns described in the seasonal calendars (see Section 3.2). In Pallisa, the driest location, the higher score also results in a much higher relative rank as the second most problem following weeds, and comes even before the pests. Dry periods can affect germination or cause square and flower shedding when they extend for more than 2 weeks or fall into the flowering stage. However, most dry spells are shorter than that and have a positive effect on cotton growth, probably because of increased irradiation, which is limited in Uganda compared to other cotton production regions.

3.5.2.4 Minor Constraints

The availability of seed was problematic in terms of the timing of seed distribution (rank 9th) and the quantity of seed available (ranked 10th). Especially in Aromo, the timing scored 4.0, i.e. it was rated a severe problem by all participants and ranked the first problem, and the quantity scored 3.3 and had a median of 4, making it the fourth or fifth highest problem. The seed distributor stated that only 138 out of 420 registered farmers received seed, because of a mere insufficient delivery, which causes struggles between different seed stores and even physical fights between farmers for seed. In other locations, at least one of the two had a median of 2 or higher. In Bala, the quantity was problematic, in Pingire the timing and in Bala and Bulongo both. In Pingire, the first seed lot had been delivered in time, but due to very low germination, participants had to wait for the second lot to replant, which was brought in July. In Pallisa, the both seed distribution constraints were rated and ranked lowest. Probably this location profited from the management of a foreign consultant to the CDO. However, some farmers reportedly took large quantities for later resale to those who still needed seed (500 to 2000 UGX per 3 kg of seed, ca. 15-60 eurocent). The timing is especially important in Pingire where cotton is only planted as a single crop and the first season rains are considered crucial for crop growth, and for producers who cultivate lowland fields and need to plant early in order to escape flooding in late October. In general, farmers stated they need the seed in April to plant in early May, to achieve the highest cotton yields. However, only small seed lots are delivered so early, most producers receive in June and some wait up to July. CDO documents in a regional store even showed large numbers of seed delivered to stores but not given out to farmers as late as September. If one wants to plant the early cotton, one has to keep seed for next year. Late seed distribution also has cost implications for the farmers because they need to plough an additional time if planting delays.

The soil fertility was mostly rated as a minor problem, since cotton was stated to require moderate fertility and farmers select their fields for planting cotton accordingly and adjust by planting after fallow (as in Pallisa) or a crop. Furthermore, producers stated that sufficient rainfall was more important to achieve good cotton yields than high soil fertility. In Bala, soil fertility scored highest, because the soils are sandy and the village suffers land shortage (therefore land of any fertility has to be used and less land is fallowed). That the soils there are lighter can also be seen from the size of a katala, which is larger in Bala than in the other locations. In Pallisa, which is known for its poor sandy soils, fertility problems scored significantly higher than in Aromo and Pingire, and ranked seventh while in the other locations it ranked 9th to 14th.

Farmers experienced excess vegetative growth, with cotton plants reaching more than 2 meters in height, while setting few fruits. This was a minor problem overall but ranked 6th and scored a median 3 in Bala, while in Pingire it scored a median of 2 but ranked only 11th. Since soil fertility is low in Bala, and no link to lygus damage can be observed, these problems are unlikely the cause for tall growth as frequently stated by experts. Farmers often found tall growth in fertile parts of the field even if the fields were generally infertile. Plant growth could be as variable as from one-half to two meters height within one field, and farmers viewed this heterogeneity as negative. This shows that the cotton variety is too sensitive to different fertility levels, as farmers cannot be expected to adjust spacing within a field, and needs a broader adaptation.

Flooding, Monkeys, Termites, and diseases played important roles in some locations. Except for diseases, the constraints were highlighted during the course of interviews and then included in the list of constraints; therefore, they had not been covered in the first locations.

Heavy rains and flooding were a problem to six male farmers with lowland fields in Pallisa and Bulongo, and these six scored it on average 2.2, but on average across all participants it scored only 0.6 and 1.4 in these two locations. This problem affects individual fields, which are mostly hired by male producers and are the most productive cotton fields. Although few participants of this survey owned such fields, the overall extent may be large considering the extent of swampy lowland fields in the Lake Kyoga crescent with its large cotton production. Damage occurs when the fields are flooded for more than one week, starting with browning of the leaves, and persistent flooding will cause flower and boll shedding up to total yield loss. It would be interesting to find out how much cotton is produced on such lowland fields, because besides the risk of flooding, these were reported to mature faster, give higher yields with less weed pressure compared to upland fields, and are a major part of the Teso farming system, where a lot of cotton is produced.

Monkeys feeding on the inner part of immature bolls were the fifth largest problem in Pingire, where six participants experienced it and it received an average score of 3.2. Monkeys had also been mentioned in the organic production sites but were only later systematically included into the survey. In Pallisa, monkeys were not present since bushes have been cleared, but were mentioned as a problem in the past.

Termites were found a problem by five participants in Pingire, where they were rated 2.4 and thereby the sixth largest problem. In Pallisa, termites were not experienced as pests but rats were reported to eat ripe cotton bolls in lowland fields (mentioned by three participants).

Diseases (*fusarium* and *verticilium* wilts) were hardly known to most farmers, but played a limited role in Bala, Bulongo and Pallisa where they scored median 1 to 2. Although Pallisa is an area known for the presence of diseases, they were most problematic in Bala, where all farmers were familiar with the specific symptoms. The sandy soils in Bala and Pallisa are prone for such soil-borne diseases, but the highest scores in Bala and Bulongo may be explained by the lack of fallowing in Bala and the strongly reduced fallowing in Bulongo. Since diseases are reportedly common in Pallisa district, where the majority of Uganda’s cotton production is located, wilt resistance was and is the main breeding goal of the public breeding system, although most farmers are not affected by or even aware of them.

In summary, low prices were a concern to all cotton producers in the past seasons. Weed problems are largely determined by socio-economic aspects, when producers have less own workforce or capital for hiring labour, no access to ox-ploughs and fields are affected by obnoxious weed species, or when cotton germination is low. Aphids are most problematic in the organic production sites, while in the conventional production their score depended on the availability and perceived effectiveness of insecticides. Bollworm abundance differs greatly between locations, but the agro-ecological cause is not known. Drought affects producers in the southeastern locations more because it is more likely to affect flowering, and the drier locations suffer less stainer infestations. Germination and seed availability depend on each other (low germination requires more seed for replanting) and the situation in the local seed store or the seed lot received. Soil fertility is for most producers a constraint that can be controlled by selecting appropriate fields and fallowing, but soil fertility and diseases are somewhat problematic where soils are sandy and land in shortage.

Furthermore, within-field differences in soil fertility lead to excessive vegetative growth in specific field parts, but it is not linked to lygus infestation or general soil fertility of the region. In lowland fields, flooding and rats are important constraints, while in "bushy" fields near much natural vegetation, lygus are problematic and monkeys and termites can acquire pest status.

3.5.3 Gender Differences

Female participants were mostly married or single women who owned their own cotton field, separately from male family members, and a few stated that they co-own the fields with their husbands and share the decision-making. Females who worked in cotton fields but did not consider themselves as owners were not interviewed as female cotton producers. Table 11 shows the scores for selected constraints that differed between male and female participants.

Based on the distribution of gender responsibilities, one could assume that females were less involved in acquiring inputs and marketing the produce, and would therefore rate seed distribution and low prices lower than male participants would. In fact, the mean values for these constraints are slightly lower for females, in the case of the timing of seed availability the difference is even significant according to the Mann-Whitney test (P=0.008). However, the assumption cannot be upheld because female participants all stated that they collected seed themselves and even brought seeds for their husbands, and many were able to receive seed from the first batches delivered, were therefore in time for planting, and received any desired quantity. The problems are thus likely lower because female producers are keener on being at the seed stores in time. Furthermore, females did not own swampy lowland fields for which much earlier planting is required to escape late-season floods. Also for the price, the explanations and prices considered profitable did not differ between male and female participants.

The second assumption is that females may use less fertile lands because of the distribution of land within the household by the husband or father and because they are less likely to hire land. Therefore, they might rate drought and soil fertility higher and excessive vegetative growth lower than males. This is true although the values do not differ significantly. Drought was rated worse by females than males in all locations but Loro, where the overall rating for drought was among the lowest, and soil fertility was rated worse in all locations but Aromo, were again the overall rating was among the lowest. It is therefore possible that females are more affected by drought and soil fertility problems, given they are problematic in a specific location.

Lastly, it is often quoted that females perform the main amount of work in the fields, specifically planting and weeding. Therefore, they might rate germination, weeds and pests (which are observed during weeding) higher than males. However, only slight and inconsistent differences exist between the male and female ratings of those constraints. On the one hand, male producers involve just as much in weeding and planting because they consider cotton a weeding-sensitive crop and do not hand over the control about it to their wives, except in a few cases were male producers were involved in non-agricultural work. On the other hand, the interviewed women were field owners and not wives who only help in their husband's cotton crop.

Table 11. Selected cotton production constraints rated differently by 17 male and 29 female participants. Constraints were rated on a scale from 0 (no constraint) to 4 (very serious constraint) in six locations in Uganda.

Constraint	**Male (n=29)**		**Female (n=17)**		**Total**		**P-value (Mann-Whitney test)**
	Mean	Median	Mean	Median	Mean	Median	
Soil fertility	1.0	0.5	1.8	1.5	1.2	1	0.161 (Excluding Aromo 0.089)
Drought	1.9	1	2.5	2	2.1	2	0.098 (Excluding Loro 0.017)
Tall growth	1.4	1	1.0	0	1.3	1	0.243
Seed availability (quantity)	1.8	2	1.3	0	1.6	1	0.307
Seed availability (timing)	2.2	2	0.9	0	1.7	2	0.008
Price	3.3	4	2.8	4	3.1	4	0.379

3.6 Discussion

Several of the findings are supported by other research. The influence of moist waterlies from Congo on the climate from June to August in Northern Uganda may explain the northwest-southeast trend of a reducing of second rains that was marked in the seasonal calendars (Basaliirwa 1995). Bowden & Thomas (1970) confirm that early cotton is sown such that flowering coincides with the second rains. The found field sizes fit older figures from National household surveys (0.1-2 ha range, 0.7 ha average) which also found total farm size to be 3.2 ha (Bowden & Thomas 1970, You & Chamberlain 2004). Horna et al (2009) found that labour costs contribute 50% to the total production costs. The calculations in this study found labour costs even higher than 90%, in spite of the low prices at which labour was valued in the calculations. They underline the conclusion by Baffes (2009) that when chemical inputs are not the main cost factor in cotton production, much of the sector policies that are aimed at reducing input costs are unlikely to have an effect on cotton production.

3.6.1 Different Perceptions on Production Constraints

Earlier planting dates had proven great yield advantages as early as 1958 and have been advocated since. However, already in 1970, little impact was observed: in the Eastern and Northern region, 30-50% and 50-75% of the crop had been planted in July and August, respectively (Bowden & Thomas 1970). This appears not to have changed much, considering that 0-63% and 63-90% of the respondents planted cotton as a second crop in the East and North, respectively, although these figures include a few earlier plantings when cotton was inter-planted in the maturing first crop. The focus of researchers and extensionists on pure, early-season cotton however goes so far, that Bowden & Thomas called for legally prohibiting planting after specific dates (1970). In addition, the planting date trials in 1993 and 1994, which form the basis of recent recommendations, only included

March to June as possible planting times (Elobu 1994), leaving out the common planting months of July and August.

This chapter has shown that producers have clear reasons for planting later which lead to an overall higher productivity. On the one hand, late seed availability constraints early planting, on the other hand, producers deliberately choose to plant late, timing this activity into the peak workload months and into times of expected droughts. That producers accept these difficulties shows that their decision for late planting follows the clear reasons of higher profitability over the year, while they time the planting such that flowering always coincides with optimum rain conditions. In situations of land scarcity and competition of cotton with more profitable cash/food crops, planting cotton as a second crop is for many producers the only niche where cotton can be grown at all. Within each production option, producers indicated a time span of maximally one month within which they have to and do plant cotton. Therefore, "delayed planting" as it is often referred to in literature, implying that the delay was due to lack of knowledge or negligence, is an exception. However, the practice of a minority of participants may be an entry point to promote about one month earlier planting, when cotton is inter-planted in a maturing first season food crop.

The failure of agronomic advice to acknowledge the reasons behind producer's decision may affect more areas than planting times. E.g., narrower plant spacing has been advocated without any impact since the beginning of cotton production (e.g. Olani et al. 1994, Bowden & Thomas 1970), while when asked about the causes of excessive vegetative growth, agronomists blame a too wide spacing by farmers (NARO, CDO). It is reasonable to doubt that the current recommendations, which are based on two years of trials in a few research stations under high-input management, can fit the producers' specific situations, considering the importance of locality, production system, intensity of input use and planting dates (compare contributions to the world cotton research conference 2003).

Furthermore, now the amount of seed allocated to the producers with the connected advice to sow at maximum three seeds per planting hole controls planting practices. Also this advice does not fit the experience of producers about low germination, many termed it that "the government made a mistake". Again, the innovative approach of one participant may be an entry point to adjust to the unreliable germination; he planted first a small test area and decided the amount of seed per hole for the rest of the field based on the observed germination.

On the other hand, the majority of the producers weeds once a month 3-4 times altogether, or try to do so, which fits the agronomic recommendations (Elobu 1994). This proves that farmers do not just generally mismanage and neglect their crop.

Lastly, pest-control advice is based solely on the recommendation of four calendar sprays beginning early in the season with broadband insecticides (cypermethrin). Research from 1957 (McKinley & Geering 1957) had demonstrated in contrast that four sprays during the main bollworm attack gives the highest yield advantages, while early-season sprays against aphids and lygus have no consistent or even a negative effect by reducing predators (ibid, Sekamatte et al. 2004). Under the Smallholder Cotton Rehabilitation Project from 1993-1996, integrated pest management had been researched but the results are not disseminated nowadays (Sekamatte et al. 2004). While the development of scouting techniques and action threshold methods for lygus and bollworm control faced disinterest on the side of the farmers, encouraging results were found about intercropping. Intercropping with common beans or hibiscus attracted some pests away from cotton and predators into the field, and thereby reduced pest-attributed yield losses from 36-58% (Eastern Uganda) to 28-37%. Furthermore, the total yield expressed as land equivalent ratio was shown to be higher when beans or soybeans are intercropped into cotton at the optimal spacing and planting times (Elobu 1994). As a comparison, calendar spraying reduced them to about 7-10%. Optimal planting dates and spacing were determined experimentally, and farmers were very interested in taking up the intercropping methods, although researchers were concerned about the farmers' unwillingness to plant them in rows. On the other hand, experiments found that maize was a less compatible intercrop because of its shading effect, a result that should be included into the organic extension messages.

4 Participatory Exploration of Cotton Breeding Targets

The following chapter will compare the cotton traits selected and breeding targets pursued by farmers and breeders. After describing the methodology in Section 4.1, the breeding targets of the breeders will be described based on the cotton breeding history and current goals (Section 4.2). Sections 4.3 to 4.6 will describe and discuss the results of individual plant selection exercises in farmers' fields, and a variety selection workshop with farmers, and the results of this chapter discussed in Section 4.7.

4.1 Material and Methods

4.1.1 Cotton Varieties

The current cotton variety applied in Uganda is an open pollinated synthetic variety. The common variety currently grown in Uganda was developed in 2002 and since then maintained by farmers without selection. As a partly cross-pollinating crop, this variety therefore contains phenotypic heterogeneity. More details will be described in Chapter 4.2 together with the history of Ugandan cotton breeding.

4.1.2 Exploring Breeding Targets of Breeders

The breeding targets of breeders will be described based on literature on the history of Ugandan cotton breeding and interviews with two current and one former cotton breeder.

4.1.3 Exploring Breeding Targets of Farmers through Farmer Field Visits

In the six study locations described in Chapter 3, a group of four to seven male farmers and another of two to four female farmers were asked to each jointly select five superior plants for retaining seed in their fields. The separation into male and female groups was to enable females to discuss freely and because the competition motivated both groups to do the exercise seriously. Afterwards the author and all participating farmers discussed together which traits farmers select for and why. The fields in which the selection exercises were carried out were ordinary, non-fertilized heterogeneous cotton fields (not demo plots). The organic fields had not received any pesticides, and the conventional ones still showed considerable pest damage in spite of spraying. The cotton was in different development stages from flowering to the first picking time, which lead to a differential emphasis on traits.

4.1.4 On-Station Workshop with Farmers and Scientists

Ten producers, who were previously involved in the group discussions, were selected by the author and invited to NaSARRI breeding station, Serere. They included organic producers from Lango region and conventional producers from Teso region, and male and female producers from each site. They were accompanied by two field officers from LOFP, Lira, and one from CDO, Serere, who also functioned as interpreters where necessary. As a first activity of the workshop, the producers and field officers selected entries (numbered, only the standard variety was marked for reference) from the germplasm collection field. They marked the varieties they liked overall with red cloth pegs on the entry's number-plate, and those of which they liked only specific characters with a blue one. To give female participants an extra chance to voice their opinion in case they were not sufficiently involved in the group discussions, they were given each one yellow peg to mark any variety they liked but the group did not mark.

The exercise was carried out without the presence of scientists, except for the author, to make participants feel comfortable and enable a free and uninfluenced discussion. Since the exercise resembled that which had been done before in farmers' fields, participants considered it easy, except for the overwhelming number of germplasm entries to be evaluated. A separation into two groups, one of Langi participants and one of Ateso participants was intended to simplify communication within the groups. However, the participants expressed a strong interest in mixing, therefore two mixed groups were created, and participants promised to translate to those for whom English was a barrier. In each group, one member spontaneously started noting the arguments that participants discussed for marking an entry.

In a later step, the participants revisited the germplasm field accompanied by two breeders and three other researchers and the marked (or noted) entries were discussed together. In the following chapter, the term BREEDER will be used when only the breeders are concerned, while RESEARCHER and SCIENTIST refers to the group of cotton breeders and other cotton researchers. In addition, one cotton breeder had marked a few entries that he wished to discuss together, and the author included a West African entry into the discussion because no variety from this group had been marked. Since farmers had had the chance to discuss the varieties among themselves first, they were now more confident to bring up their arguments. Furthermore, the author had previously encouraged them to be confident and assured them of the importance of their opinions. They were told that they had been invited to the workshop because of their interesting and clever ideas in the earlier meetings.

Through the discussion, the preferred traits and varieties (grouped by origin) were identified. The plants were flowering during the exercise, so traits normally observed in other development stages could not easily be discussed. In the following chapter, the traits will be distinguished into three levels: indicators, traits, and targets. INDICATORS are directly observed characters that indicate a specific TRAIT, e.g. less monopodial branches indicating the trait of high number of fruits. A number of indicators together are selected to reach a certain BREEDING TARGET, such as high number and large size of bolls to select for a high potential yield. The term POTENTIAL YIELD or yield potential will be used to refer to a plant's ability to yield under favourable conditions, while the (actual) YIELD of a variety will also be influenced by other characters, such as its pest resistance.

Lastly, the traits identified both in the farmers' fields and in the breeding station were noted on cards and prioritized. For this, farmers and researchers mixed in two randomly composed groups, which again was at the request of the participants. They were asked to score the importance of the traits on a scale of 0-no importance, to 4-highest importance. The use of the same scale as in the interviews about the production constraints (Chapter 3) was meant to give farmers an advantage, as they already knew the method. However, in one group the researchers had difficulties with the method and tried to force their understanding on the others, which brought considerable confusion into the exercise. In the other group, the method was understood and the group process appeared well balanced, but resulted in all cards either getting score 0 or score 4. Therefore, one researcher suggested to compare the cards through pair-wise comparison, which resulted in a ranking of 1 (highest importance) to 13 (lowest importance), plus the cards that received score 0.

Difficulties in the group process and understanding the method and the resulting different scales (rank 1-13 and score 1-4) may have biased the prioritization. Furthermore, the different items used in the prioritization exercise represented different levels of characters: indicators, traits, and breeding targets. Participants may have rated the latter higher than the former not because of their content but simply due to their level. Therefore, for each group the highest, medium, and lowest priority items were distinguished and the decisions of the two groups summarized, as it will be shown in Table 14 (Section 4.4.2).

4.1.5 Terms Used

The following chapters will refer to a number of terms describing the morphology of the cotton plant. A cotton plant has a bush habit with a main stem and a number of primary and secondary branches (see Figure 15). The branches can be distinguished into sympodial branches, which grow diagonal up and have fruiting points. Vegetative branches that grow upright are called monopodial branches, they only carry fruiting points on secondary branches. The stem is herbaceous and lignifies with plant maturity.

The flower buds, called SQUARES, develop in the leaf axils first in the lower stems. Three to four BRACTS surround each square. A special trait, called FREGO BRACT, leads to twisted bracts that do not cover the flower bud or early developing boll as usual. The squares develop into flowers, which grow into the fruits, called BOLLS, after fertilization. The bolls are organized in a number of sections, called CARPELS, typically four to five for G. hirsutum, which contain a number of seeds. Each seed is surrounded by long fibers, called LINT, and shorter ones, called FUZZ.

A PUBESCENT plant has plant hairs, called TRICHOMES, on the leaf surfaces, stems and bracts. A plant with very few or no trichomes is called GLABROUS.

Cotton tissue may contain GOSSYPOL, a plant compound making the tissue toxic for non-ruminant mammals and some insects. The gossypol, together with other compounds, is located in pigments, dark dots in the plant tissue, and the seed. Furthermore, some trichomes may contain gossypol and other plant compounds and are then called GLANDS.

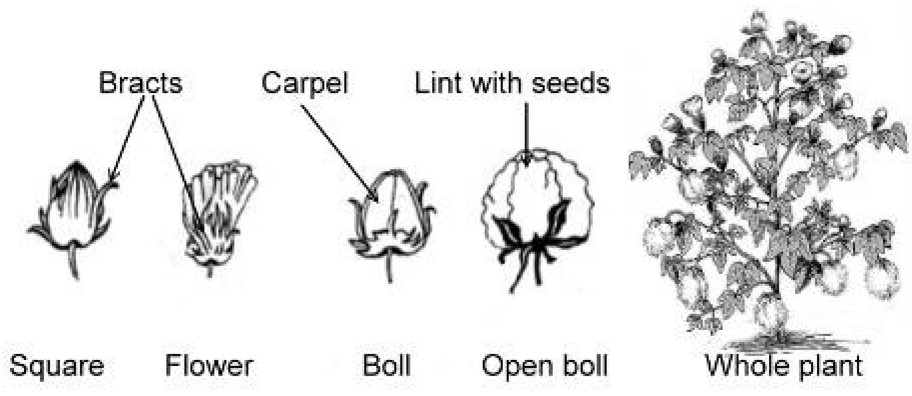

Figure 15. Cotton plant features

4.2 Breeding Targets of Breeders

4.2.1 History of Ugandan Cotton Breeding

The Ugandan cotton varieties owe most of their genetic background to AMERICAN UPLAND varieties, namely 'Allen' and 'Sunflower' (both from the USA) and the later introductions 'Nyasaland Upland' (Tanzania) and 'Albar' (Nigeria) (Arnold 1970). American Upland is a section of *Gossypium hirsutum* race *latifolium. G. barbadense* varieties from Egypt were found less suitable to Ugandan growing conditions. The Ugandan conditions required adaptation to lower temperatures, lower radiation (due to shorter day-length, more cloudiness and lower atmospheric transmission), varying rainfall patterns, and pest pressure of lygus and jassids. These conditions together favoured leaf hairiness and a prolonged fruiting period; and the early breeding for this adaptation gave rise to the AFRICAN UPLAND group of varieties (ibid).

Until 1966-70, the two varieties mainly grown in Uganda were based on the early selections BP50 and BP52 (ibid). BP52 had a higher fibre quality (staple length and silky appearance) due to introgression from *G. barbadense* varieties, and had some resistance to *verticilium* wilts. BP50 was susceptible to wilts, produced higher yields, and had a slightly lower fibre quality. Yield improvements, higher uniformity in fibre length, improved wilt resistance, and resistance to damage of the seed coat during ginning (causing coat residues in the yarn) were important achievements in early breeding (ibid).

In 1949, a Nigerian Allen line was selected for resistance to bacterial blight and produced the Albar varieties grown nowadays (Al-Allen and bar-blackarm resistant) (ibid). These were used in several East African countries and appreciated for their resistance and high yields. The higher yield of the Albar varieties was attributed to a deeper root penetration. However, introduction in Uganda was difficult because of their coarser, although long, fibres. Later, a change in markets allowed the introduction of SATU (Serere Albar Type Uganda) in the North and East (replacing BP50 derived varieties), and BPA (Bukalasa Pedigree Albar) in the West and Central (replacing the BP52 derived varieties) (ibid). Since 1998, SATU has not anymore been improved and all cotton countrywide has been gradually replaced by BPA because of its higher fibre qualities.

The breeding process for Ugandan cotton varieties is a rather short line selection process resulting in a synthetic variety (Figure 16). The process is relatively fast because inbreeding is followed for few years and must not achieve total homozygosity, to avoid inbreeding depression (previously seven years of inbreeding and single plant selection). Beginning with BPA 2002, the breeding process was speeded up further by use of early generation testing, which needed eight generations from the first cross to release of foundation seed (ibid). In this method, replicated tests are already carried out in the F3 stage, reducing the inbreeding and single plant selection process by five years (ibid). In the following generations, breeders can concentrate further evaluations on fewer promising lines (Serunjogi et al. 2004). Cotton varieties are constituted of a mixture of two to six inbred lines, such that natural out-crossing between those lines causes a certain level of hybrid vigour in the variety. Natural out-crossing of cotton in Uganda amounts to roughly 10%, but depends on the circumstances, especially the presence of pollinators (Serunjogi et al. 2004). In addition, back-crossing and recurrent selection methods are occasionally combined with this generalized breeding scheme. Since 1995, a new BPA variety has been released every three to four years, and if the about-to-release BPA 2008 is accepted, it will have taken six years since the last variety.

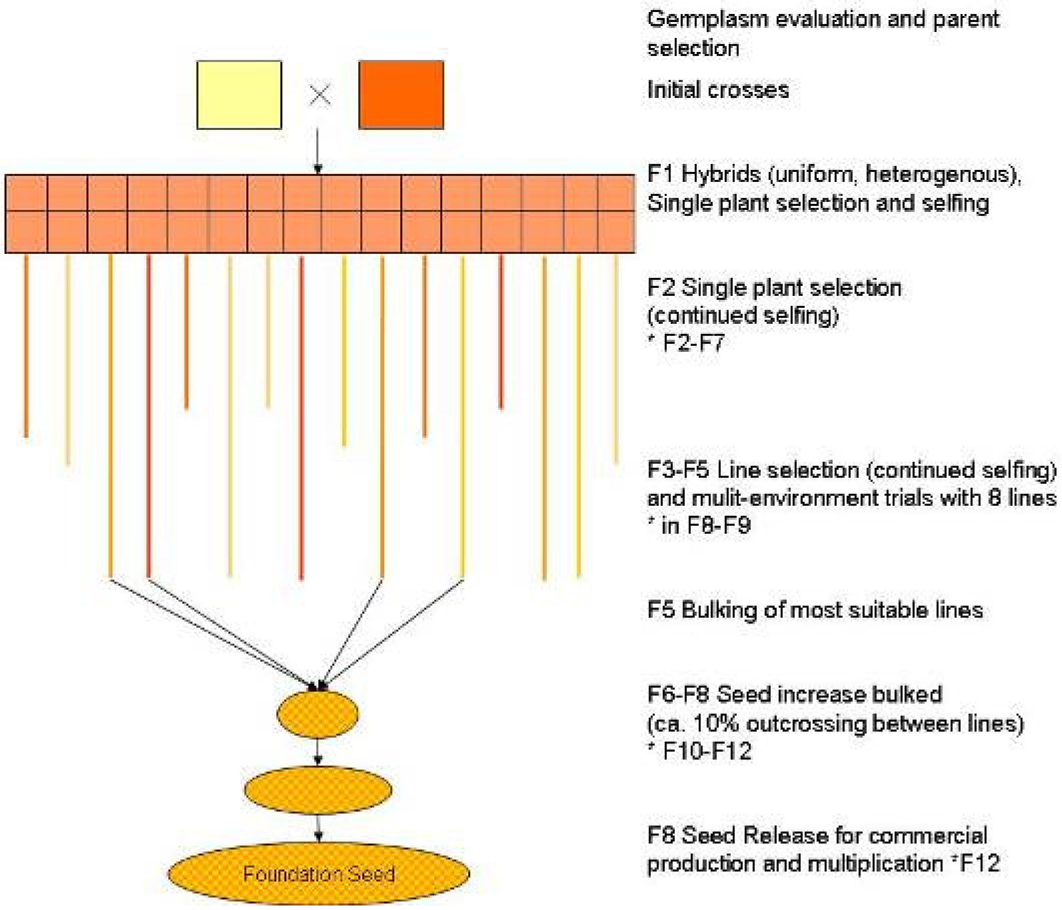

Figure 16. Generalized cotton breeding scheme for a synthetic cotton variety using early generation testing. * - generation under the former breeding scheme.

4.2.2 Breeding Targets of Breeders

The traits breeders select for, their indicators and selection stages are summarized in Table 12 based on interviews with three breeders.

The current breeding activities concentrate on introducing resistance to *fusarium* and *verticilium* wilts from American multiple adversity resistance (MAR) germplasm into BPA (Serunjogi et al. 2004). Early selection of the cross progeny was carried out in wilt-affected locations (out-of-station trials). In the selection of the Ugandan crossing partners, the breeders considered potential yield, fibre qualities and the preferred plant habit. They prefer a semi-determinate habit, which enables the plant to compensate early fruit losses due to pests. They aim at reducing the maturity period to four months. The varieties should be semi-compact and very pubescent. However, the plant habit is not any more assessed or applied during the selection process.

The characteristic morphology of *G. hirsutum* (leaf shape, flower colour, etc.), sufficient germination and bacterial blight resistance are monitored during all stages.

During the line and single plant selection, only the most important selection criteria boll weight, seed weight, ginning out-turn and fibre qualities are systematically assessed and applied (Serunjogi et al. 2001). Advanced lines are tested for yield in two to four testing stations for three years. New varieties are constituted from lines yielding at least 5% more than the current variety over a range of testing stations, while having at least equal fibre qualities (ibid).

For potential yield improvements, larger bolls with larger and heavier seed are preferred, because these produce heavier seed cotton yields, which benefits farmers. Small boll sizes, in contrast, correlate with a higher fibre percentage, higher fibre yields but lower seed cotton yields. Breeders do not prefer this breeding approach because the benefit would be to ginners, who are not expected to pass on the benefit to the producers.

Table 12. Traits selected for by breeders, their indicators, and selection stages. Based on interviews with breeders.

Trait	Indicator	Stage of Selection
Wilt resistance	Resistance in naturally wilt infested locations	Selection of foreign germplasm (one parent) Testing of F2
Early maturity	Four months maturity period	Selection of BPA line (second parent)
Morphology	Semi-determinate habit Semi-compact habit	
Pest resistance	High leaf pubescence	
Characteristic morphology	Leaf shape Flower colour	Monitored annually
Bacterial blight resistance	Resistance after artificial inoculation of breeding field	
Fibre quality	Micronaire Staple length	Single plant selection Line selection
Potential yield	Boll weight Seed weight Ginning out-turn	
	Yield per line	Advanced line selection

Although the formalized breeding process pursued so far produced varieties with growing yield potential, the actual yields in Uganda seem to have stagnated in the eyes of many experts. New approaches that aim at improving actual yields, based on the high potential yields, may have positive impacts on cotton productivity in Uganda. Participatory approaches may help to include farmer knowledge into the target setting and selection and increase actual yields.

4.2.3 Participatory Approaches

Cotton producers and their perceptions of a good variety have so far never been involved in the breeding process. Moreover, selection was always done in bteeding stations under more intensive management than common in Uganda (in terms of fertilizer and insecticide use, denserspacing and others). An exception occurred in the 1970's, when breeders selected outstanding plants from farmers' fields and thereby achieved yield increases, this was also purely breeder-controlled. Farmers do not select their own seed, because the seed is part of the marketable produce and fresh seed has always been given for free, so there was no incentive for own seed selections. Furthermore, cotton producers indicated that only ginned seed could germinate well, while own, un-ginned material would easily rot due to the moisture retention within the fibres. The Ugandan agriculture budget is two thirds donor funded, and scientists mentioned that they were urged by the Ministry of Agriculture, on behalf of the donors, to include participatory approaches into their research.

However, participatory plant breeding is mostly applied for subsistence crops, with own, farmer-based breeding and seed systems and a high biodiversity (E.g. Ceccarelli et al. 2000). Can the approach also contribute in the breeding of a crop of which there is only one variety, farmers have never involved in the breeding and seed system, and which has uniform quality requirements by the industrial processors? Would farmers have any interesting breeding ideas when they have not been able to try own selection or compare different varieties before? These questions motivated the research presented in this chapter.

4.3 Farmers' Preferences for Variety/Origin Groups

Figure 17 shows the number of entries the farmers selected from different origin/variety groups. It distinguishes entries that farmers marked as interesting with respect to one or more characters, and those they marked as preferred, i.e. that were positive in all characters. Farmers marked many Ugandan BPA and, to a lesser extent, SATU varieties, and many of those were preferred. In addition, many Indian varieties and US-American MAR varieties were marked. Two of the MAR varieties were preferred. One entry belonging to US-American Tamcot, one BPAxMAR cross, one West African BPAN, and one South African variety were marked. The latter was also preferred.

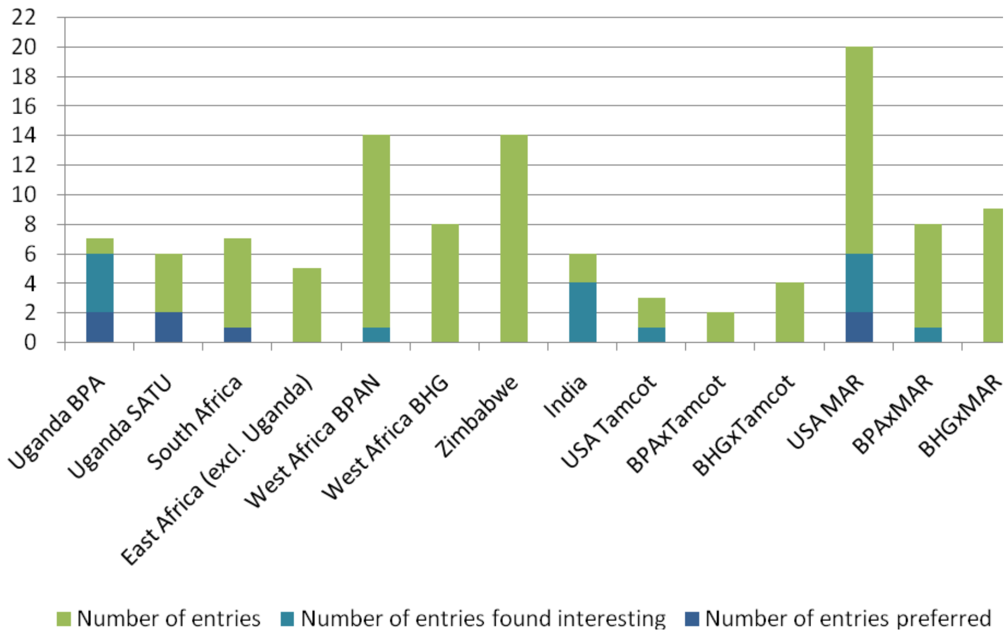

Figure 17. Origin/Variety groups of entries and numbers selected by two groups of farmers in a variety selection exercise in Uganda, 2010.

Altogether, farmers did not prefer African to Indian or American varieties. Rather, their preferences were unrelated to geographic origin and showed a differentiated picture for the entries of African origins: They did not mark any Zimbabwean or East African (including Tanzania, Malawi) varieties, and only one out of 35 West African varieties (BHG and BPAN) and their crosses. For the US-American varieties, farmers marked MAR preferentially over Tamcot varieties.

Farmers were asked about their opinion about one West African BHG variety, and they stated that it had too small bolls, long internodes and had shed many bolls. In contrast to the farmers' disregard, the breeders had crossed BHG varieties with Tamcot and MAR because they considered them promising crossing partners. In addition, they considered BPAN varieties as very promising crossing partners, and they have been involved in the breeding of the last BPA variety. The BPA 2008 variety under development consists of BPAN and BHG lines. Zimbabwean varieties had been introduced into the last BPA varieties because of their superior fibre qualities. One East African variety had been discussed with the farmers, who stated they did not mark it because of its tall growth.

Thus, the farmer decisions show that farmers were overall content with most past and present Ugandan varieties, but their opinions about other suitable germplasm differed greatly from the breeders' strategies.

4.4 Traits Selected by Farmers

Table 13 shows the traits that were considered, the plant characters that indicated the traits and in which development stage of cotton they can be selected for.

At early development stages (squaring and flowering), the farmers used indirect indicators to predict high potential yield, early maturity and short habit, such as thick stems and low branching to predict large boll size and vigorous branching. Pest incidence is also considered mostly during the vegetative stage, while later only fruit retention and fibre discoloration can be observed. From the boll formation stage onwards, the final plant habit, total boll setting and the boll size could be considered directly. The first picking is the best time to select for uniform ripening, good maturity and seed and fibre quality. Farmers preferred to use seed from the first picking, which they find usually large and well matured. Seed quality should not be selected for afterwards.

To consider all identified traits, selection has to be carried out at least at two growth stages. The first selection during the vegetative stage could take place during late flowering, when plant health, vigour, habit and first signs of boll development are visible (as in the workshop). The second selection at the time of first picking can consider boll properties, fibre and seed quality and uniformity and quality of ripening. Still, farmers identified indicators already during the vegetative stage that predict traits that would appear later.

Table 13. Plant traits of relevance to farmers, their indicators and possible selection stage. Based on Selection exercises of single plants in farmers' fields in six locations in Northern and Eastern Uganda, and variety selection exercises with ten farmers in a research station.

Trait	Indicator	Stage of selection
Potential Yield		
High boll number	Many fruiting points per branch (e.g. 3-5) Short internodes, bolls near to each other	Squaring-Boll formation
	Many bolls on all branches to the top (e.g. 35 per plant)	Boll formation - Maturity
	Twinning trait	Squaring - Maturity
Large boll size	Large bolls Later bolls not smaller than early ones	Late Boll formation - Maturity
Vigorous growth	Thick stems and branches	Squaring-Early boll formation
Plant Habit		
Many long fruiting branches	Many branches (e.g.12, or two branches at one node) Long branches Branches at high angle Few monopodial branches	Squaring-Maturity
Short and determinate habit	Shorter than other plants, ca. 80cm[1] Terminal buds form squares (growth about to stop)	Squaring-Early boll formation
	Optimum height (ca. 95 cm) Stopped flowering when bolls mature	Late boll formation-Maturity
Open shape	Light penetrates and air circulates Small leaves First internode of branch long Branches well spaced	Squaring - Maturity
Quality		
High fibre quality	White colour Fluffy appearance	1st Picking
High seed quality	Large seed Hard seed coat White endosperm	1st Picking
	Germinated well, few gaps Germinated uniformly, no late-comers	Germination - Maturity
Early and uniform maturity	1st branch starts low	Squaring-Maturity
	Bolls more developed than on other plants	Boll formation
	Not the first plant to open bolls	1st Opening
	Many bolls opened early Leaves shed early	1st Picking
Easy and clean harvesting	Widely opened bolls	1st Opening - Maturity
	Less pubescence	Squaring – 1st Opening
	Well shed leaves	1st Picking
Stress Resistance		
Robustness	Good overall performance under adverse growing conditions	Squaring-Maturity
Pest resistance	Healthy leaves No aphid infestation, little lygus damage	Squaring-Boll formation
	Retention of fruiting bodies Few bollworm-infested bolls	Squaring-1st Picking
	No discoloration of fibre	1st Picking
Not of interest	Anthocyanin pigmentation Mechanical damage (hail) Animal damage	

[1] - In all locations but Aromo, where plants of average height were selected. Prediction before the final height of the mature plant could be known.

4.4.1 Prioritization of Traits

Table 14 summarizes the priority given to the different traits by the two groups of farmers during the workshop. The scores and ranks of each group were summarized into three categories because exact values were found misleading. The prioritizations will be mentioned along with the following description of selected traits.

Table 14. Prioritization of identified selection traits by two participatory groups. Each group consisted of a random mix of researchers and farmers, male and female and Lango and Teso farmers. One group ranked traits from 1st to 13th, one rated from 0 to 4.

Priority	Trait	Explanation
High priority	Seed quality Fibre quality Plant health	Both groups rated high[1]
Medium-High priority	Open shape Large boll size Twin trait	One group rated high[1] and the other medium[2]
Medium priority	Short internodes High boll number High vigour	Both groups rated medium[2]
Medium-Low priority	Uniform and early maturity Easy and clean harvesting Short habit	One group rated medium[2] and the other low[3]
Low priority	Determinate habit Less monopodial branches Storm resistance	Both groups rated low[3]
Variable priority	Robustness	One group rated high[1] and the other low[3]

[1] rated as 1 or ranked as 1st to 5th
[2] rated as 2-3 or ranked as 6h to 12th
[3] rated as 4 or ranked as 13th

4.4.2 Yield Components

A high potential yield is composed of many bolls (‘prolific’ variety) and large bolls. Furthermore, farmers considered a high plant vigour necessary to nurture the bolls. Of these traits, large bolls were given high priority while many bolls and vigour were given medium priority.

A large boll was considered to contain higher quality fibre and seeds, which explains the higher prioritization of this trait. Farmers disregarded plants that had large bolls in the lower branches but smaller ones in the top. This could be an indicator that the plant was not able to nurture all the initially set bolls. Larger bolls take longer to mature and lead to a later harvest. This indicates that yield and quality are considered more important than early maturity, which fits the higher prioritization of yield and quality traits.

To support a high boll number, the plant needs many long branches with many fruiting points per branch (see also plant habit, Figure 18). The latter means that the internodes are short and many nodes carry fruiting points; this indicator was given medium priority. The 22 marked entries had on average 14.7 cm long internodes, while those of six entries explicitly not preferred for internode length measured 16.2 cm. Ugandan BPA and SATU and American Tamcot had the longest internodes, while the MAR varieties had the shortest. This may indicate that farmers preferred shorter internodes than present in the Ugandan varieties.

However, in the case of the variety SATU 1995, farmers observed that it had many bolls in spite of long internodes, showing that this trait does not necessarily determine yield.

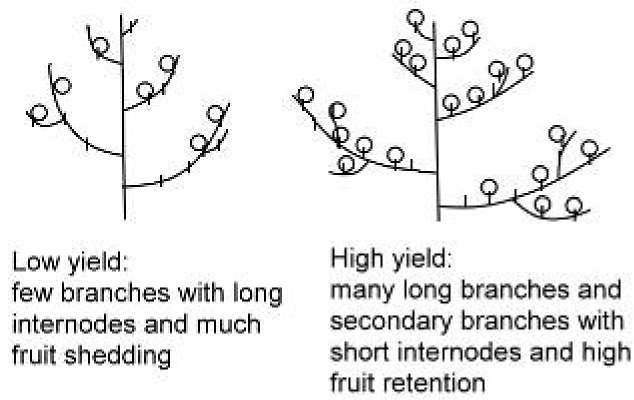

Figure 18. Schemes of typically low-yielding and high-yielding plant habits as distinguished by farmers.

A special character to increase boll number was the so-called twin-trait, which the participants named SSALONGO (the name given to the father of twins) and gave high priority. In this trait, one node carries two fruiting points. Some plants were considered to “almost” have the twin trait, which means that a node carries a fruiting point and a short secondary branch with another fruiting point (see Figure 19). Seven of the selected varieties had or almost had the twin trait.

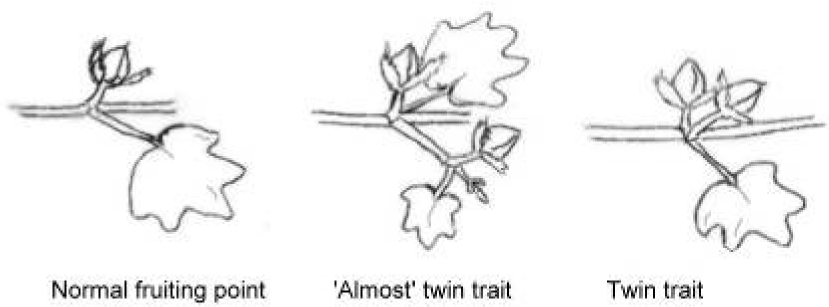

Figure 19. The twinning or twin trait

Monopodial branches are vegetative branches with few fruiting points and many leaves. Plants with a high number of monopodial branches were criticised for having less bolls and being too compact, but a low proportion of monopodia was given lowest priority.

Vigorous growth and a good nutrition of the fruits was concluded from thick stems and branches, but not from height and leafiness (see following section).

The farmers’ ability to quickly judge yield potential was demonstrated in the case of variety BPA 2008. Breeders had expected this about-to-release variety to give a very high yield, but trials with producers in Kasese had proven that its yield was lower than that of the previous variety, BPA 2002. Farmers selected BPA 2008 as interesting for its low branches and large bolls, but predicted that it would yield low. They observed that it had too many monopodial branches and very long internodes, as well as a high proportion of shed bolls. The latter may be due to high physiological boll-shed by this variety, or by higher pest attack, probably caused by environmental factors.

4.4.3 Plant Habit

An open shape means that light penetrates through the plant and air circulates within; this trait was given high priority. The shape depends on the length of the internodes (especially a long first internode on the branch), the distribution of the branches (spaced), their relatively erect position, less monopodial branches (which carry more leaves), and less and smaller leaves. The light penetration is seen to improve photosynthesis and the size and maturity of bolls. Light penetration and air circulation reduce pest pressure, and an open plant is more thoroughly protected by insecticides. However, an openly shaped plant covers the soil less densely and cannot suppress weeds. This might be the reason why farmers did not consider weed suppression although weeding had been rated as the most serious production constraint. Indian varieties have a more compact habit while the BPA 2002 is more open in growth.

Height and determinate habit appeared to play an important role, since plants with a good height were selected in some cases, in spite of several negative characters that were observed. E.g., BPA 1995 was selected because of its height, but the number of branches and bolls was found insufficient. The selected varieties were on average 95 cm high (range 75-116 cm). The eight varieties farmers indicated as having a good height measured on average 90.5 cm (range 75-102 cm). Interestingly, the tallest selected varieties were those belonging to the Ugandan BPA and SATU variety groups. The shortest was the US-American MAR group. Moreover, the five plants marked by the breeder were somewhat taller, measuring on average 105 cm (range 95-133). It thus seems that farmers select for shorter varieties than Ugandan breeders do.

A more determinate type stays shorter, branches more widely, covers the soil early, and needs wider spacing. This fits the farmers' preference for long fruiting branches and their practice to space cotton more widely than recommended. Farmers and scientists agree that the highest quality cotton is produced on the lower branches.

However, short and determinate habit received low and lowest prioritization, respectively, by the mixed farmer-researcher groups. This may be due to its less direct link to yield and quality and the disregard of the participating researchers for these traits. The farmers' preference for short plants confused scientists. Varieties with an indeterminate growth habit, such as BPA 2002, are able to compensate early crop losses caused by delayed weeding or pest pressure by continuous and taller growth. The about-to-release variety BPA 2008 is considered of more determinate habit due to the introgression of wilt-resistant genes from the US genetic resources, and this trait is made responsible for the observed lower yield.

Farmers argued that children could harvest short plants (waist height), which saved labour costs and work time for the adults. If the fruits are difficult to reach for the person harvesting, branches may be broken and the fibre contaminated with dry leaves and dust. In contrast, bending down was not considered a problem for adults that involved in harvesting. Scientists argued that picking by children lead to lower lint quality. Conventional farmers found that the insecticide application on shorter plants was easier and safer, because there was less likelihood for changing winds to blow the insecticide in one's face. A few conventional farmers reported to suffer respiratory problems due to exposure to insecticides. The determinate habit furthermore could facilitate earlier and uniform ripening, while it could negatively affect the plant's ability to compensate early lygus and bollworm damage.

Researchers furthermore argued that the participants who selected for short and determinate plants had very fertile fields. The farmers however consented that in all the represented locations, the soils were fertile enough for excessive growth to occur, even in Bala where soil fertility is slightly problematic (compare Chapter 3). Only in Aromo, farmers considered that their plants grew to a medium, satisfactory height. In the workshop, Aromo farmers therefore dismissed one variety selected by a female farmer from Pingire for being too short (below 90 cm). In the farmers' field, Aromo farmers selected plants of the same height as in other areas, but those plants were taller than the average, while in other locations the plants were shorter than the average.

4.4.4 Quality

High seed quality was very important to farmers and received highest priority in the participatory prioritizations. A hard seed coat verifies that seed are properly matured and dry. If the white endosperm, by squeezing it between the fingers, produces oil, it verifies the viability of the seed. Seeds should be taken from the first picking from early maturing plants, which will yield large and surely matured seed. Farmers considered the observed germination as very important. However, the breeders stressed that differences in germination are most likely due to the different storage time of the seed and not genetic. In the farmers' fields, most farmers selected plants with better growing conditions (wider space, fertile and moist appearance of soil) because they considered their seeds would be rich in nutrients and vital.

High fibre quality was also given highest priority in the participatory prioritization exercises. Farmers considered a white fibre colour and fluffy appearance at plant maturity. However, breeders emphasized that one cannot select for fibre length and fineness by naked eye.

Traits that avoid contamination during harvest and facilitate quick harvesting can also improve fibre quality, but were given a low priority. When leaves were well shed and bolls opened widely, one could more easily pick the fibre without contaminating it with dust and dry tissue from leaves. This was further supported by a short habit, as described earlier, although this may also favour a less careful harvesting by children. Widely opening bolls may have the disadvantage of low storm resistance.

In some cases, farmers selected varieties with fewer leaf hairs and argued that these would not itch during picking and not contaminate the fibres. However, when breeders explained that the leaf-hairs conferred resistance to jassids, the farmers quickly reversed their decision in agreement, although they had no experience with jassid damage due to the hairiness of all former varieties. In addition, in one exercise in a farmers' field, farmers were aware of the importance of hairs for pest resistance.

Early and uniform maturity was frequently mentioned during the selection exercises but given a low prioritization. If the first branch on the plant started low and carried many fruits, farmers took this as a sign that a large proportion of the yield could be picked early. Researchers argued that rain or rat damage could affect such very low fruits. However, the farmers found that if branches were sufficiently erect, rain would not affect the fruits, and that rats can also reach high bolls by climbing the plants. Fast maturity was furthermore evaluated by checking the maturity of the bolls themselves during their formation. Near harvesting time, farmers selected against the plants whose bolls opened first, as this would lead to less uniformity in maturity and might be result of stress that impeded boll development. At harvesting time, farmers selected those plants of which many bolls had opened and leaves had been shed early. The maturity periods experienced by producers are very likely later and the harvesting period is more extended than in the breeding station. The producers' wider spacing causes the plants to form more bolls per plant; and less intensive pest control causes more compensatory fruiting, both stimulating a prolonged fruiting period. For example, most producers stated to harvest in four consecutive pickings, one even in six, while scientists normally consider three as sufficient.

4.4.5 Stress Resistance

Plant health received the highest prioritization although the selection for it was not very prominent in the exercises. This might have been due to plant health being a breeding target that was more important compared to trait indicators, but it may still not have been the most important breeding target. Farmers were only partly aware of the effect of pubescence on pest resistance (see quality) and not aware of the effect of anthocyanin pigmentation, which is considered to confer stress and pest resistance. Farmers did consider the incidence of and damage by aphids, lygus, and bollworms by comparing among varieties and plants. Pest incidence could become an important selection criterion in future work, but for the fields on which the exercises took place, many environmental factors probably caused differences in pest pressure. Namely, shade, strong erosion, different planting dates, and patchy pest attacks differentially affected the field.

In some of the exercises in farmers' fields, the groups or individual participants preferred to select plants from areas with less supportive growing conditions, in order to select for tolerance to drought and low-fertility stress, here termed robustness. Low-fertility stress referes to shallow, stony and sandy patches in the fields. This trait was given highest priority by one group and lowest by the other. The contrasting opinions about this breeding target will be discussed further in Section 4.6. Storm resistance conferred by thick and equally distributed branches was another trait occasionally reported in the selection exercises, but received lowest priority.

4.5 Breeding Targets of Farmers

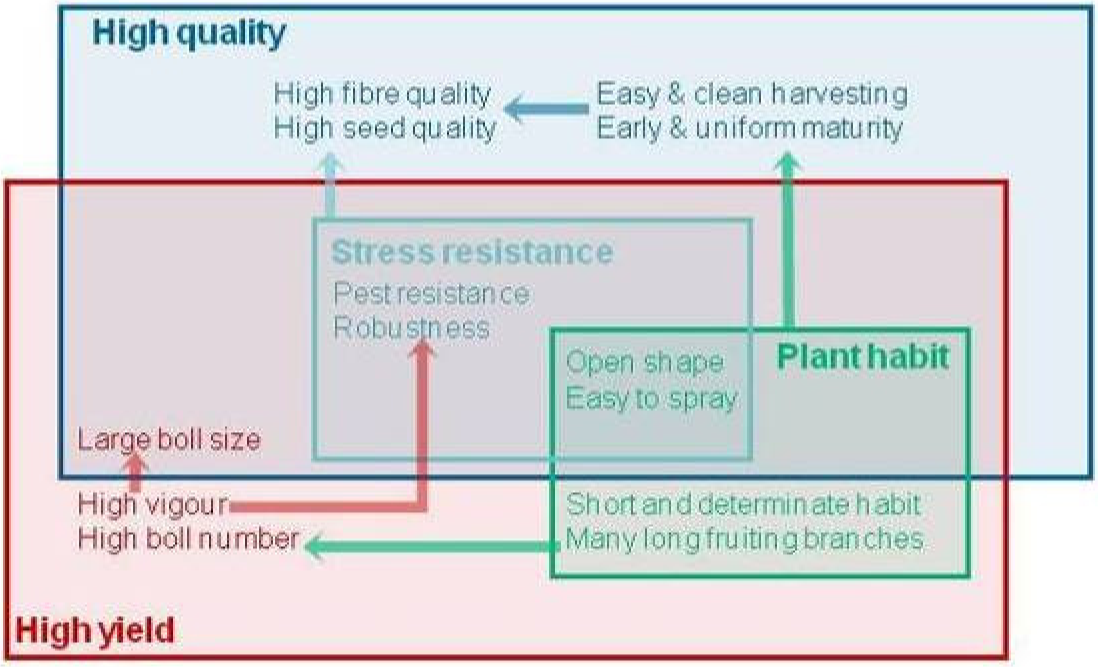

Figure 20. Relation of selected traits and breeding targets (in boxes) pursued by farmers in single-plant and variety selection exercises in cotton. Each trait or breeding target contributes to the breeding target surrounding it. Arrows indicate a trait's or breeding target's contribution to specific traits.

Figure 20 shows what breeding targets farmers pursued when selecting for the specific traits. According to the farmers' perception, all traits contributed to a higher yield or higher quality of the variety. The variety's actual yield and quality are supported by the plant habit and stress resistance, which alone are also breeding targets.

An open shape contributes to a beneficial plant habit and pest resistance, and both targets support high yield and high quality. The plant habit supports the harvesting and maturity quality, while the harvesting and maturity quality, plus stress resistance, contribute to seed and fibre quality. Although large boll size is primarily a yield indicator, large bolls are also considered to yield a better seed and fibre quality. The short and determinate habit and the branching traits selected for support the high yield potential. Specifically, the branching habit contributes to higher boll numbers. High vigour is considered to contribute to stress resistance (e.g. storm resistance) and a large boll size.

Thus, all the traits selected for support high yield and quality in a more or less direct way. In that respect, the final breeding goals of farmers do not differ much from those of the researchers. However, the difference is that farmers not only aim at a high quality and yield but in addition look for a rich repertoire of mostly morphological traits in order to estimate yield and quality indirectly, while researchers measure yield directly at harvest. The traits considered by farmers often interact with environmental factors to support high actual yield or quality, such as the open shape that facilitates light penetration to the bolls and thereby qualitative maturing and allows air circulation that reduces pest pressure. The plant habit, harvesting and maturity quality interact with the farmers' practices in that they enable a more quality harvesting. Those traits improve the genotype's ability to utilize environmental and management factors positively. Thereby, indirect traits may have an additional effect on the (directly measured) genetic yield and quality potential of a genotype.

Breeders considered resistance to diseases (wilts and bacterial blight), and pubescence and anthocyanin pigmentations as possible pest resistance traits which farmers were not aware of. Farmers indicated uniform maturity and traits supporting easy and clean harvesting as additional quality traits to those considered by breeders, and placed a larger emphasis on seed quality.

4.6 Observations on the Process

4.6.1 Farmers' Perceptions of Heritability

Farmers were aware of the heritability of most traits. They considered the partitioning of the bolls into four or five carpels non-heritable that is mainly caused by soil fertility. Anthocyanin pigmentation, plant height and pest resistance was seen as partly heritable but mostly caused by environmental factors. Pubescence was seen as highly heritable. The only confusion arose about seed quality, which became apparent during the workshop at the breeding station and when discussing most suitable selection conditions in the farmers' fields.

In the breeding station, the farmers' strong emphasis on the observed germination was seen as a sign of confusing heritable and environmental effects. When discussing the optimal selection conditions, farmers often disagreed with one another and made seemingly contradictory statements. The discussions then revealed that they considered two aspects; On the one hand, plants selected under optimal growing conditions would produce high quality seed. This seed would grow into stronger plants in the next generation, although this would be less heritable in the long term. On the other hand, some farmers argued that the offspring of plants performing well under adverse conditions would be more robust and have higher genetic potential.

4.6.2 Cooperation between Farmers and Scientists

During the workshop, farmers and scientists communicated relatively freely and scientists showed interest in and respect for the farmers' opinions. Female participants participated as actively as males. However, one has to make sure that facilitating field officers do not dominate the discussions among farmers.

The participating scientists (breeders and other cotton researchers) later on expressed their appreciation for the interaction with the farmers, for which they feel to have the chance too seldom. They expressed to have great interest in the farmers' views. Prior to the workshop, the author discussed the traits identified through the exercises in farmers' fields with the breeders and they were positively surprised about the amount of knowledge collected. The participating farmers also expressed to have gained knowledge and insights through the exercises and interaction. They appreciated most the interaction with cotton producers from other regions and involved in other production systems (organic and in conventional). Furthermore, it was demonstrated to the farmers how a cotton flower is self- and cross-pollinated by hand, and several individuals were enthusiastic about trying these methods with different crops.

A number of points fostered the good communication between farmers and scientists. First of all, it was the participants' (farmers, facilitators and scientists) knowledge, argumentation skills, and the ability to foster a respectful dialogue and create a relaxed atmosphere with humour. The farmers were selected for the exercise with consideration of their knowledge or interesting perceptions, argumentation skills and self-confidence during the group discussions and individual interviews (Chapter 3). Before the exercises, the farmers were made aware of these reasons for inviting them, to support their self-confidence further. By having the chance to first explore and discuss the germplasm field without the presence of researchers, farmers freely developed arguments and convinced the other group members about them. Afterwards, in the presence of researchers, the more outspoken farmers narrated the collected arguments, while others were encouraged to join and add. Furthermore, the author, who was aware of some of the farmers' arguments from the previous field meetings and overhearing part of the early discussions, brought up issues when farmers ceased to mention them.

The interaction during the prioritization exercise was much more difficult, because the exercise was more abstract. Also, the participants' preference for mixing groups with different mother languages made the participation difficult for those who were less confident in English. For such an exercise, it would be helpful to have smaller groups and one facilitator for each group.

The large number of accessions to be evaluated (N=121) did not suit the selection methods of farmers. Although participants were encouraged to screen the field roughly and pick out eye-catching ones for in-depth discussion, they preferred to discuss each accession in detail. Therefore, participants became less concentrated after discussing about 60 accessions. Furthermore, the task of selecting only twelve accessions per group was meant to simplify the exercise, but participants initially marked many entries with the pegs. After no more pegs were left, they let one group member note down the numbers of the preferred entries and so increased the number of selections. One participant noted that she got "overly excited" when seeing so many varieties.

4.7 Discussion

Formal cotton breeding in Uganda has been successful in the past, creating varieties with improved disease resistance, fibre qualities and yield potential. That farmers involved in the project workshop selected a large proportion of Ugandan varieties compared to other variety groups shows that the past breeding activities have also been successful in developing farmer-accepted varieties.

However, this chapter has also shown that farmers have complementary knowledge that might help to improve Ugandan cotton varieties further. Farmers and scientists have different and partly complementary abilities for selection. Breeders have special technical abilities in selecting for fibre qualities, potential yield components, disease resistance and specific pest and stress resistance traits (pubescence, anthocyanin). Farmers, on the other hand, emphasize especially morphological traits that breeders do not systematically select for so far, namely open, short and rather determinate habit and morphological traits supporting early and uniform maturity and quality harvesting. Farmers showed that they can quickly evaluate plants with respect to multiple characters at once, faster than they can be measured and documented by breeders. These include many criteria that may have an additional effect on the plant's ability to utilize environmental resources and facilitate harvesting to improve yield and quality beyond the genetic potential. The observed selection goals of farmers and breeders fit the description of Vernooy et al. (2009), who state that science takes a reductionist approach towards breeding, i.e. reduce the number of variables considered, but study them in detail. Farmers on the other hand consider more variables and analyse a plant holistically. The potential of the farmer selection approach merits further evaluation. Participatory cotton breeding research should not aim to compare the farmers' and the breeders' selections in a way of competition, but rather build on the cooperation and complementation of the knowledge of both groups to optimise crop improvement.

However, the chapter has also shown differences in the breeding targets and preferences of breeders and farmers. Seed quality, harvesting and maturity properties, and plant habit are breeding targets of farmers that breeders do not breed for. Breeders introduce West African and Zimbabwean germplasm, which is not preferred by farmers, into the Ugandan varieties. The farmers' selections were on average shorter and more determinate than Ugandan varieties, and probably differed in many other, not measured characters.

From the findings of this project, there was no evidence to indicate differences in the requirements between conventional cotton producers from Teso region and organic producers from Lango regions. Rather, the participating farmers were interested in sharing experiences and often supported each other with arguments. E.g., organic farmers stated that an open plant habit would harbour less pests and conventional farmers added that it would also be more thoroughly protected by insecticides.

Farmers were aware of the heritability of specific traits and the importance of selecting under low-fertility conditions for selecting plants tolerant to those conditions, this conforms with findings of Soleri and Cleveland (2009). However, many farmers preferred beneficial growing conditions to select for seed vigour. This can be termed selection for intra-generational phenotypic differences, which is the most common goal of farmer selection (ibid). Such selection can also lead to genetic responses. Furthermore, the farmers' selection followed a negative selection against unhealthy, overly vegetative of badly germinating plants. The farmers' emphasis on these selection goals does not negate their ability to select for stable genetic responses (ibid).

A participatory breeding approach needs to take into consideration the farmers' different concept of traits to be selected for. The farmers' practical approach may lead to a conflict between selecting for breeding goals expressed in stress condition on the one hand and seed quality requirements on the other. Opinions about the most suitable selection environment also differ among farmers and among breeders. Different perceptions need to be communicated openly to avoid misunderstandings and frustrations, certainly in case selection under stress conditions is planned. More efforts for mutual learning may help to deal with this contrast in perceptions.

The workshop showed that fruitful interaction between cotton farmers and scientists in Uganda has good prospects, especially when the process is carefully designed and participants carefully selected. Farmers from different regions should be given the chance to interact, but for important and more difficult or abstract exercises, separating groups according to their mother language could improve communication. For scientists to take serious conclusions from the discussions, some arguments need to be verified objectively. E.g., whether farmers from all production areas agree on a constraint or selection trait or what actual advantages a trait would give (such as the yield of a determinate plant under average pest pressure). This means that farmers from different regions should be included in exercises or surveys, and that farmers should be given a chance to select for their preferred traits and test preferred varieties under average production conditions.

Besides involving farmers in target setting and selection, it is important to consider the selection environment if yield increases are to be achieved under farmer conditions. In general, selection is more efficient when the correlation between the selection- and the target environment is high (Atlin et al. 2001). However, the selection conditions in the breeding station do not represent the practices of average farmers. The low correlation of selection- and target environment reduces the selection efficiency, both now and when farmers would be involved. Moreover, the current selection conditions do not allow selecting for pest resistance, since insecticide applications mask the susceptibility of the genotypes. Both farmers and breeders do not consider pest resistance to a satisfactory degree, given the high priority of pest constraints (Chapter 3) and the interest of scientists in such research. Thus, the selection environment needs to be adapted to the target environment for the success of the breeding program, to make the benefits of farmer involvement and selection for pest resistance noticeable.

There are three options for adapting the selection- to the target environment. The decentralized option would concern transferring selection from the research station to local, farmer managed selection plots. The centralized option would be to adjust the practices in the selection plot at the research station to a representative spacing, no fertilization and reduced or no spraying. The latter may be more acceptable to breeders if it is introduced as an additional selection plot, which would also enable interesting comparisons to the intensively managed site. Both options can be combined or applied during specific selection stages.

5 Overall Discussion and Conclusion

5.1 Summary of Findings

The presented study explored the feasibility and underlying assumptions for a participatory breeding project, which aims to create a cotton variety specifically adapted to Uganda's organic growing conditions, with special emphasis on increased resistance to lygus damage.

Chapter 2 showed that from an institutional perspective, a breeding project that benefits small-scale cotton producers, including both organic and conventional producers, would be preferable to a project that specifically addresses the needs of organic producers only. Comparisons of the production system and the producers' perceptions of major constraints in two regions with organic and conventional production (Lango and Teso region) did not reveal major systematic differences between the two regions or systems (Chapter 3). Neither did the exploration of breeding targets (Chapter 4). In addition, lygus bugs, which had been initially assumed a major yield-reducing factor in organic production, were not found a more prominent constraint in organic production than in conventional production. Furthermore, there is reasonable doubt whether this pest actually affects cotton yields significantly, or is only perceived as devastating because of its eye-catching leaf damage (Appendix I).

The stakeholder analysis concluded that the introduction of additional cotton varieties next to the one standard variety would require significant institutional changes and be difficult to realize, because it would create stakeholder blocks with opposing interests and a history of conflict (Chapter 2). The CDO, who organizes the seed delivery and oversees the marketing system, does not perceive the extra resources as justified, which are required for introducing additional varieties and a separated seed-delivery and produce-buying system. Although Uganda is one of very few countries growing only one variety of cotton, the fact that cotton is a raw material for industrial processing and faces uniform market requirements raises further doubts about the advantages of greater variety diversity.

A further constraint to introducing varietal diversity are the location-specific production conditions. The initial explorations in Chapter 3 have shown that the perceived production constraints differ more between localities within one region than they do between the two studied regions with their different production systems. If this would be true across the whole country, the introduction of specifically adapted varieties would mean introducing numerous, location-specific varieties. These could not be separated regionally and thus harbour the risk of mixing up produce and planting seed under the current distribution and purchasing system.

Instead, the exploration of breeding targets revealed a large potential for improving the current, broadly adapted BPA varieties to better meet the needs of small-scale farmers across the country. Producers identified new breeding targets, such as high seed quality and a plant habit facilitating clean harvesting, and assessed the potential of plants quickly and holistically.

Whether the regional differences in production environments, or those between different groups of farmers, are large enough to justify the extra efforts for creating a specifically adapted variety is still largely a matter of speculation. The benefits of regional adaptation could be estimated better if the production systems were surveyed in all regions of Uganda. Only variety trials in different target regions and an analysis of the genotype by environment interaction could prove the need for more varieties with certainty. Farmer-managed advanced line trials are especially helpful to define clusters of target environments based on differences in environmental parameters, the production systems, and farmer preferences (Ceccarelli 2009a).

Thus, the results of this study call for a participatory cotton breeding project in which the currently grown BPA varieties are improved and maintained as broadly adapted varieties (i.e. adapted to all production regions of Uganda) to the benefit of small-scale cotton producers. In such a project, the public cotton breeders and the central breeding station have to play a prominent role. It calls for a participatory model in which the responsibilities are distributed between farmers and breeders, and there is intense interaction between the two parties. Chapter 4 showed that such interaction can be very fruitful and is met with high interest on both sides. Furthermore, it may facilitate more mutual learning than a merely farmer-based, decentralised approach. In a situation where the perceptions of farmers and scientists about the optimal production methods and main constraints differ greatly (Chapter 3), such mutual exchange and learning may have a great impact on breeding as well as other agricultural research. Furthermore, the intensive interaction of farmers, scientists and the organizations involved in a breeding project (NGO's, universities) could help to create alliances that benefit the social structure of the stakeholders.

5.2 Discussion

5.2.1 An Unusual Participatory Breeding Project

Participatory breeding approaches often go along with calls for decentralization, maintenance of old varieties and creation of greater variety diversity (e.g. Ceccarelli et al. 2000). Participatory plant breeding has proven successful for marginal and highly diverse environments or producer groups and neglected crops. I.e. it has proven successful for situations that are not easily served by centralized research, and where modern varieties have not been adopted, indicating and justifying the need for a specific breeding effort. High potential areas and widely grown crops of public interest were assumed to be served well enough by centralized research, which would be the more cost-efficient alternative.

In contrast, this study is concerned with a participatory approach to breeding such a widely grown crop of public interest. Witcombe (1999) claimed that participatory plant breeding can also be suitable for commercial crops grown in medium-potential areas under semi-intensive management. Positive experiences with participatory breeding of commercially marketed crops are few but exist, such as reported by Virk et al. (1999) for marketed rice for high potential areas, and by Lançon et al. (2004) for cotton breeding in Benin. Furthermore, participatory potato breeding in the Netherlands is successful in spite of its focus on a bulk-marketed crop grown in highly intensive systems (Lammerts van Bueren 2010).

In Ugandan cotton, a central research system serves the average farmer successfully, and one new variety is widely adopted, especially since farmers have no alternative to adoption due to the state-controlled seed distribution. The environment and producer groups are, as far as the results of this study can show, not very diverse. The study has not shown sufficient evidence for differences between regions or production systems that would justify an exploitation of genotype by environment interaction through the more expensive participatory approach. Ceccarelli (2009b) doubts in principle that participatory breeding can be centralized, because a central system cannot create a sense of ownership among the producers. However, decentralization and a participatory approach can also be seen as two independent aspects of a breeding program, even when they often go together. Formal decentralized breeding programs exist (e.g. Stiller et al. 2005 for decentralized cotton breeding), and centralized participatory programs can involve producers through specific participatory models (Morris & Bellon 2004). The recommended activities involve farmers in all main stages of the centralized cotton breeding activities (compare Ceccarelli 2009a, Lançon 2004): setting goals by articulating traits of importance, generating variability (parent selection, farmers provide own selection from commercial crop as germplasm), selection, and evaluation (farmers test advanced lines). The latter means introducing a decentralized element into the present system.

The farmers' traditional varieties and seed systems formed the basis for many participatory breeding projects. Although there is not no history of cotton landraces or a farmer-led seed system in Uganda and the producers involved in this study had no experience with selecting cotton, they were able to define and select for preferred traits in a cotton variety. Djaboutou et al. (2007) stated "The cotton grower can evaluate his plant just as well as the food crop plant grower can do". The potential of farmer knowledge to increase cotton yields has been demonstrated by Lançon et al. (2004). The study has shown that cotton producers have some selection criteria and breeding targets that differ from those of breeders. These different criteria and targets may have a complementary effect on improving the yield and quality of a cotton variety grown under their average conditions. It is difficult for a breeder to anticipate farmers' preferences, so the participation of farmers is necessary for a high breeding efficiency (Courtois et al. 2001). Chapter 3 has shown that scientists have a very different perception of the production constraints than farmers, therefore more dialogue between farmers and scientists is urgently needed. The actual effects of their selection criteria on yields deserve to be tested.

Participatory breeding is usually defined not just as involving producers into breeding, but along with a certain intangible purpose, such as summarized, although not exhaustively, in Figure 21. Decentralization, breeding for specific adaptation and creating farmer ownership are for example emphasized by Ceccarelli (2000, 2009a, 2009b). Weltzien and Christinck (2009) for example emphasize Agrobiodiversity and the importance of landraces. Witcombe and Virk (2009) and Vernooy et al. (2009) consider tapping farmers' environmental knowledge and creating opportunities for farmers and scientists to learn from each other. Compared to these goals, the situation in Ugandan cotton calls for an unusual participatory breeding approach, one that remains rather centralized and focuses on certain traits of interest with wide adaptation rather than regional diversification, maintaining the current one-variety system. It cannot follow all of those goals, but it taps farmer knowledge, enables mutual learning, and has the potential to result into a client/oriented breeding program.

Since participatory breeding is a social product that emerges from interaction in practice and depends largely on the intent of the people involved (Vernooy et al. 2009), it is common for participatory breeding projects to develop and gain in participatory focus over time (Ceccarelli 2009b). Thus, further goals may be pursued in the future.

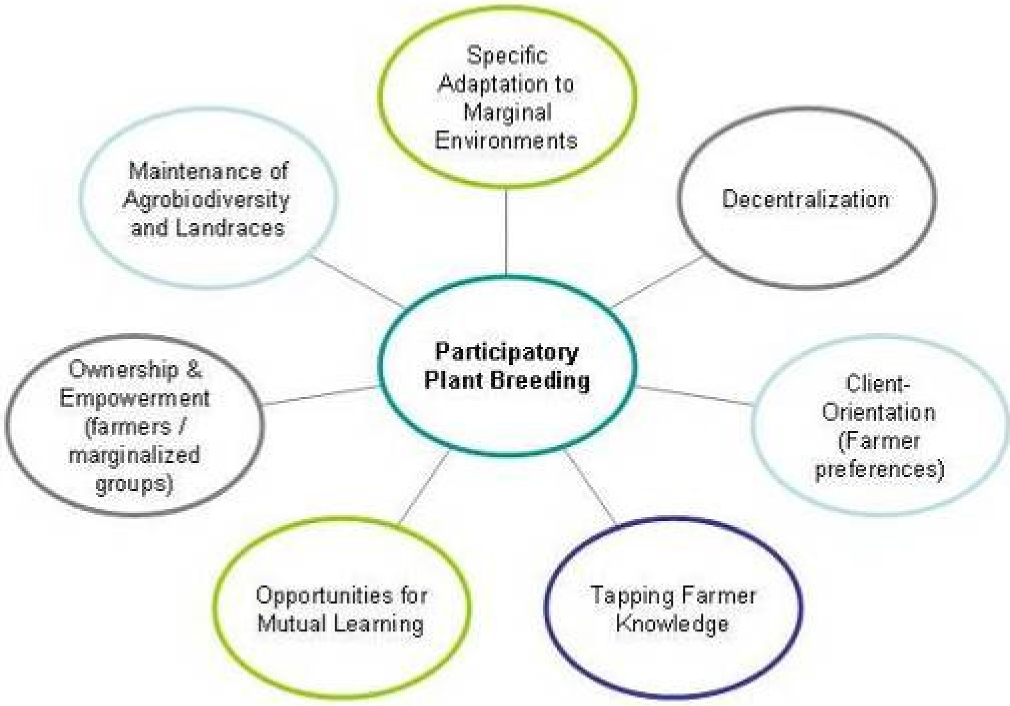

Figure 21. Intangible goals followed by participatory plant breeding according to different authors (Ceccarelli 2000, 2009a, 2009b, Weltzien and Christinck 2009, Witcombe and Virk 2009, Vernooy et al. 2009).

5.2.2 Different Selection Criteria than in West Africa

It should be remarked that the selection criteria of farmers described in his study differ greatly from those of farmer-breeders in Benin (Lançon et al. 2004). Two Beninese farmer breeders selected for taller plants and thereby unconsciously increased the maturity period, while for farmers in this study, early and uniform maturity and short and determinate habit were of importance. The Beninese farmers also preferred plants with smaller bolls, which correlated with higher ginning out-turn and fibre yields (ibid). In contrast, Ugandan farmers, just as the breeders, prefer plants with large bolls in spite of the side effect on lint percentage. The most successful Beninese farmer breeder selected for more pubescent germplasm, while farmers in this study were hardly aware of any effect of pubescence on pest resistance (Djaboutou et al. 2007). Similarly to the Ugandan farmers, Beninese farmers selected against plants that still had green leaves at harvesting. While the reason was not clear for Ugandan farmers, the Beninese ones stated that they harboured aphids and white flies. Germination was an important aspect for the Ugandan farmers and experience in Benin showed that farmers were able to improve this character, resulting in higher population densities. The Beninese successfully selected for a higher seed weight, which was also preferred in this study. In all cases, the seed cotton and lint yield was higher than the local control, the initial population, and the researchers selection, an experience that justifies optimism for a successful project in Uganda.

The differences between the Beninese selections and those in this study fit the disregard of the participating farmers for West-African varieties. Probably, the drier climate, longer day-length, and higher radiation in Benin (caused by the higher latitude compared to equatorial Uganda) contribute to the different variety requirements compared to Ugandan cotton producers.

5.2.3 Importance of a Diagnostic Study

The study is laid out as a diagnostic study as described by Röling et al. (2004). The outcomes of this study prove the need for diagnostic studies as a means to make relevant pre-analytical choices. The study recommends a very different approach to a participatory breeding program that can benefit organic cotton producers in Uganda than was previously assumed. It lead to large changes in the problem definition, especially the importance of lygus pests and the differences between the production constraints under organic and conventional management turned out to be much less significant than assumed in the beginning. Conducting this study also helped to create partnerships with relevant stakeholders and interaction between producers and researchers through conducting this study. The diagnostic study goes along with investigating a broad range of themes to attain an overview of the constraints and opportunities for an in-depth research. Many of the issues covered deserve a more thorough investigation. The open questions remaining are one of the results of this study.

Lastly, it needs to be acknowledged that breeding was the subject of this study, but breeding and agronomic research are not the only possible means to support (organic and conventional small-scale) cotton production in Uganda. There is considerable room for improving agricultural extension by grounding it in the farmers' actual practices and problem perceptions, i.e. focusing on weed control and alternatives to current pest control. E.g., past research has shown a high potential for integrated pest management, and the most effective recommendations and available substances for organic farmers need to be identified. Furthermore, on the institutional side, seed and pesticide delivery were major constraints to farmers and the policies are based on the assumption that inputs need to be subsidized to become affordable, although labour costs are actually the main production costs.

5.3 Recommendations for the Envisioned Project: Adapted Aim and Set-up

In conclusion of the findings, the study recommends to adjust the aim of the participatory breeding project. The project should aim at improving the broadly adapted Ugandan BPA cotton variety to better suit the needs of both organic and conventional, small-scale cotton producers. This can be achieved by the following activities:

Workshops in which cotton producers visit the central breeding stations, discuss suitable germplasm, and involve in the on-station selection would enable farmers and scientists to learn from each other, and to both apply their complementary knowledge to develop a superior variety. The two cotton breeders both expressed most interest in this approach. Farmers may introduce additional selection criteria and narrow down selections of breeders (or breeders those of farmers). Witcombe and Virk (2009) argue that special attention to the selection of parents can allow breeders to conduct less crosses but evaluate larger numbers of progeny per cross, which will increase the chance to find the desired allele combinations. They find crosses between a farmer- and a breeder chosen parent a promising approach. A low-input selection environment has to be included in the station, to allow the farmers to select according to their environmental knowledge, enable selection for pest resistance, and maintain a higher correlation to the target environment.

Such workshops should include farmers representing all major production areas of the country to ensure that the selections are not too regionally biased. Breeders furthermore highlighted that a baseline survey of production conditions in different regions would help to judge the arguments expressed by farmers. The workshops should take place twice per season, at late flowering and at the time for the first picking, such that all identified driteria can be selected for (Chapter 4). Farmers should be selected based on their specific knowledge and communication skills, especially self-confidence. The workshops need to be designed carefully to support a fruitful interaction and should be guided by sufficient facilitators.

Advanced lines should be tested in farmer-managed plots in different production regions, and the farmers' opinions considered in the selection of the lines. For this, the mother-baby trial design (Witcombe 2002) could be used. The current testing of advanced lines in few research stations does not sufficiently represent the target conditions nor generate sufficient insight into genotype by environment interactions. Testing in farmers' fields would increase the number of environments and their correlation to the target environment, which helps to increase the estimation of the heritability. An analysis of the genotype by environment interaction would help to identify the broadly adapted lines and evaluate the need for locally adapted varieties more reliably. The farmers expressed high interest in this approach, if the number of entries to be tested is manageable. The breeders stated that it would help their research on the adaptation of their lines, but gave it a somewhat lower priority because of some organizational constraints: The provisions would have to be made that the tested germplasm does not end up in the normal marketing chain and create unwanted diversity in the seeds and fibres available across the country.

Lastly, farmers could select superior plants out of their cultivated fields and self them. The selected seed could be assessed in the breeding station and used as additional source germplasm. Such selections could help to further understand the less explicit selection targets of farmers and explore possible differences between individual farmers or villages, which would again provide insights into the benefit of local adaptation. Furthermore, the high selection intensity and the high phenotypic variance within the variety can lead to good selection responses. Thus, the selections may provide more promising source germplasm than the BPA 2002 stocks maintained at the research station.

Table 15 summarizes the roles of farmers and scientists in the proposed activities. Consultative cooperation takes place when scientists and farmers communicate, but breeders take decisions. Collaborative cooperation requires decisions to be taken jointly, while collegial cooperation means that farmers decide after communication with breeders. Which form of communication or cooperation will actually take place cannot be foreseen, especially since the power to involve farmers into their decisions ultimately lies with the breeders and probably needs to develop over time. However, Table 15 shows the recommended aim.

Table 15. Roles of farmers and scientists and location in different stages of the recommended participatory breeding project.

Stage	Farmers	Scientists	Location
Creating source germplasm	X (collegial)	(evaluation, comparison)	Commercial fields
Selecting parent materials	X (collaborative)	X	Research station, germplasm field
Crossing, first generation selfing		X	Research station, breeding field
Evaluation and single plant/ line selection	X (collaborative, consultative)	X	Research station, breeding field
Advanced line testing	X (consultative)	X (combine data from different sites)	Farmer fields and regional research stations

The results of the recommended activities should be used to evaluate whether introducing greater variety diversity in Uganda could bring benefits that justify dealing with the connected institutional constraints and costs. The evaluation should consider the specific needs of organic producers along with regional differences.

In the meantime, the research on the production systems of this study should be scaled up, by covering more regions (probably through a more quantitative survey) and exploring further issues. These include the reasons behind farmers' practices that consistently differ from recommendations, and the link between farmers' perceptions of a constraint and its measurable extent and yield effect (e.g. with respect to lygus bugs). A better understanding of the production system will help to ground breeding- and other agricultural research in the situation and problem perceptions of the intended beneficiaries.

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Appendix I: Lygus Resistance

I. Introduction

Lygus, a capsid bug (family miridae) feeding on cotton in Uganda, is most frequently referred to as *Lygus vosseleri* Popp., but *L. simonyi* Reut. and the genus name *Taylorilygus* Taylor are used synonymously (Taylor 1946, Hancock 1935, Tingey & Pillemer 1977). This report will refer to *lygus* spp. when referring to a number of *Lygus* or *Taylorilygus* species, and to lygus as the Ugandan species with the before mentioned scientific names. Plant-sucking bugs refers to a group of sap-sucking cotton pests including lygus.

Lygus is mentioned as serious cotton pests in Uganda since 1935 (China 1935). Since 1966, insecticides, especially DDT and later Endosulfan, are applied for their control (Arnold 1976, Horna et al. 2009). Lygus is furthermore reported as a cotton pest in India, Pakistan, Arabia and many African cotton producing countries (Mali, Ivory Coast, Nigeria, Ethiopia, Congo, Madagascar), and a subject of interest as pest on sorghum, hibiscus, and pigeon-pea (Linnavuori & van Harten 2001, Reed et al. 1989, 23-26, 28). However, research on this pest is rare due to its localized importance. Related species affect cotton in the USA and Australia.

Ecology and Control

Lygus bugs multiply on wild plants (*Cissus adenocaulis, Pseudarthria* spec.) as well as sorghum, finger millet, and black gram (*Phaseolus mungo*) which are widely grown in northern and eastern Uganda (McKinlay & Geering 1957). The occurrence is also related to soil and climatic factors (Hancock 1935, Arnold 1976). Towards the maturity of the seed, i.e. mainly during the summer drought, the adults migrate to other possible hosts such as cotton, to multiply there. At this time, early-planted cotton is already in the most susceptible bud-formation stage, while second-crop cotton is still young and suffers early leaf damage. Sorghum, wild sorghum and sorghum residues next to or following cotton increase lygus attack.

For cultural control measures, intercropping with *Cissus adenocaulis* and millet as trap crops was tried but with little success (Arnold 1976, Stride 1969). Natural enemies are a predatory Capsid (*Dercoceris)* and two species of parasitic wasps (*Braconidae*), one of which was considered for biological control of American Lygus species (Snodgrass et al. 1990). For a sap-sucking insect, only insecticides with a systemic or trans-laminar activity are effective, i.e. few organic pesticides. Neem has a trans-laminar activity, also oils and soaps can complicate lygus feeding. Contact insecticides like pyrethrum and spinosad would need to be applied in large quantities and endanger natural enemies. In conventional agriculture, Bt-cotton is not an option to reduce lygus damage, as the Bt-toxin is only effective against lepidopteran pests.

Lygus Feeding and Damage

Lygus bugs feed on young leaves, squares, bolls, and apical buds (Hancock 1935). They penetrate the tissue repeatedly with their stylets (inter- and intra-cellular), causing mechanical damage, and insert saliva containing pectinase, which dissolves the cell's middle lamella, and amylases and proteases to aid digestion (Tingey and Pillemer 1977). Following the maceration of the tissue, the bugs take up large amounts of plant juice (adults of *L. disponsi* 7-13 mg plant juice per day) (ibid). The plant reacts with a wound-response, releasing phenolic compounds. The sucking spots develop brown necrotic spots, which later on fall of, leaving an unevenly developed, perforated leaf tissue. The combination of mechanical damage and pectinase destroys meristematic tissue, affecting the plant's hormone balance and leading to malformations and fruit abscissions (ibid).

Possibly, the combination of amino-acids, injury, oxidative enzymes and phenolic compounds reduce growth promotion locally, while at the same time growth-promoting factors (like tryptophan or auxins) are active in a larger area (ibid). The result is a typically habited, very tall plant with truncated sympodia, few fruiting points and tattered leaves. While the cotton plant is not particularly sensitive to leaf damage, the shedding of fruiting bodies may contribute to significant yield damage.

Assessing the damage caused by lygus bugs is problematic because there is a variety of plant-sucking bugs that feed on cotton (see Figure 22), such as the mosquito bug (*Helopeltis schoutedeni* Reuter) and the green vegetable bug (*Nezara viridula* L.). The former causes leaf tattering, malformation and calluses on the stems, the latter causes malformation and staining of young bolls (Serunjogi et al. 2001). Lygus is a very mobile species that flies mostly at night and is easily scared away by persons in the cotton field, and therefore difficult to observe. Observations in the daytime assess only symptoms and cannot clearly attribute these symptoms to lygus, therefore it is wise to refer to the plant-sucking bug complex instead of lygus alone. Furthermore, the symptoms of aphids and *Earias*-bollworms can resemble the leaf tattering caused by lygus (Bowden & Thomas 1970).

Figure 22. Plant-sucking bugs on cotton in Uganda. From left up to right down: Mosquito bug (*Helopeltis schoutedeni* Reuter), Cotton Harlequin Bug (*Tectocoris diophthalmus*), Green Vegetable Bug (*Nezara viridula* L.), Broken Back Bug (*Taylorilygus pallidulus* Blanchard). The Broken Back Bug occurs only in Australia but was included because of its similarity to the Ugandan Lygus bug.

Effect on Yields

Although lygus had been considered the principal cotton pest in Uganda, in the 1950's and 1960's evidence accumulated to show that this was a misconception, probably due to its eye-catching damage. The arguments and research results are comprehensively described by Bowden & Thomas (1970) and shall be summarized below.

Shedding of fruiting points occurs also as a physiological response to balance the number of fruit with the amount the plant can nurture. At the same time, vigorous and productive plants set more fruits that are later shed. Therefore, the fruiting points shed due to lygus attack may have been shed anyway, and a higher shedding associated with lygus attack may be caused by lygus' positive effect on plant vigour, or preference for more vigorous plants, as indicated in observations quoted in Bowden & Thomas (1970).

In experiments over four years, the presence of plant-sucking bugs, leaf damage or bug-caused sheds of fruiting points was not consistently and sometimes even negatively correlated to yield losses, while bollworm-caused sheds of fruiting points were positively correlated to yield loss in all years. In another experiment comparing different types of insecticides, the insecticide's level of lygus control was again not reflected in final yield, while the level of bollworm control was (Davies 1963 in Bowden & Thomas 1970). When insecticide spraying with DDT was introduced in Uganda on a large scale, the yields in regions known to be little to unaffected by lygus damage responded with the same increments as in areas where lygus caused severe damage (ibid).

McKinlay & Geering (1957) furthermore summarize that early June planted cotton produces the highest yields in spite of suffering the worst lygus damage. They conducted insecticide spraying trials in which they compared cotton sprayed during the main time of lygus attack with that sprayed during the main time of bollworm attack. They concluded that early season spraying, protecting the crop from lygus attack, did not increase the overall yield, but resulted in an earlier formed yield, indicating that loss of fruiting points due to lygus was compensated by a longer fruiting period. When rainfall was normal or the crop was planted early, the plants could fully compensate unchecked lygus damage or the (artificial) removal of fruiting points for up to six weeks, while under below normal rainfall conditions encountered in Tanzania or in late planted cotton, any loss of fruiting points reduced yields and spraying over any period was beneficial.

Lei et al. (2004) studied the effects of artificial damage mimicking mirid feeding and found that damage to bolls younger than ten days caused shedding, while older bolls remain on the plant because only some locules may not develop and get secondary fungal infections. Only when seeds were directly pierced did the fibre development terminate. Under natural infestation of green vegetable bugs, red-banded shield bug and harlequin bug, low mirid densities (about 10% of bolls damaged) still produced high yield and plants compensated the damage by increasing the size, but not the number of undamaged bolls. Under high mirid infestation (up to 54% of bolls damaged), yields were almost halved, but the fibre quality after ginning remained stable.

All this evidence showed that bollworms are the principal pests in Uganda with a "superimposed complex of bugs", including lygus. The losses of partly matured bolls incurred by bollworms cannot be fully compensated and reduce yields. The loss of young fruiting points caused by lygus may only reduce the excess of fruiting points which the plant produces and may be compensated through the further growing season. Only the rare damage to older bolls (which are not shed and therefore not compensated) or damage to late young fruiting points produced as compensation for bollworm-caused losses, will have a significant effect on yield. Since the yield effect of Lygus damage depends on the relation to other pests and climatic factors, a study of the correlation between Lygus infestation and yield in farmers' fields would be helpful to shed light on their importance today and under farmers' conditions.

Previous Breeding Attempts

Selection for lygus resistance had been tried in Uganda in from the 1940's up to 1970. Observations on the leaf tattering symptoms demonstrated variation between species, showing that *G. hirsutum* was more susceptible than *G. barbadense* (Egyptian long-fibre species) and *G. arboretum*; and there is variation between varieties and even sister strains of varieties as well (Serunjogi et al. 2001). Hairiness, tissue thickness, and red pigmentation were considered resistance criteria. However, environmental effects could not be completely controlled and a reliable criterion for resistance or tolerance was not found (ibid). Two seemingly successful attempts resulted in a selection against vigour and yield (Arnold 1976).

The following traits are presumed to confer resistance to different cotton-attacking lygus spp., including e.g. *L. hesperus* and *L. lineaolaris* in the US (reviewed by Tingey & Pillemer 1977, Javaid 1993, Smith 2005). The terms used are explained in Section 4.1.5 of this thesis.

Pubescent cotton varieties were stated to suffer less attack and damage by lygus (Meredith & Schuster 1979, Benedict et. al. 1983), as well as several other cotton pests (jassid, pink bollworm, boll weevil, leaf-worm, bemisia, cotton flea-hopper (Pseudatomoscelis seriatus), and empoasca attack). Cotton has simple trichomes that increase resistance with respect to feeding injury, yield reduction, growth rates, square abscission, but increases susceptibility to leaf ragging. However, high trichome densities may increase susceptibility to secondary pests, such as tobacco budworms, cotton leafhopper, and white fly (Tingey & Pillemer 1977, Javaid 1993, Smith 2005). Knowledge of the quantitative relation of pubescence and infestation may help to identify compromise pubescence level to have good resistance against all pests. Next to trichomes, waxy leaves and thick or lignified tissue may affect thigmoreception and thus confer insect resistance.

Gossypol-containing glands were found to reduce lygus damage up to 57% (e.g. Bottger et al. 1964, Tingey et al. 1975, Paxton 1983) and increase resistance to bollworms, earias, helopeltis, and red spider mites. Variation in leaf gland density has been proven by Zeng et al. (2007) and ranged from 29.2 – 175 per cm^2 in a highly variable species multicross. Most commercial cotton cultivars have a gossypol content of about 0.5% in squares, but higher levels of approximately 1.2% are needed to inhibit growth and development of different cotton pests (Parott 1990). The square gossypol content can be estimated by the calyx gland size and density (Parott 1990). Next to gossypol, the glands contained cyaniding-3-glucoside, which was also effective against lygus (Paxton 1983).

Lygus prefer growing tips of branches or stems of the cotton plant in preference to buds or young bolls (Dale 1958). However, when they attack bolls they severely reduce the quality of the fibres. Therefore, the resistance factors gossypol content and pubescence need to be increased in young tissue of buds, bolls, and vegetative tips.

The nectariless trait reduces lygus populations up to 60% (Meredith et al. 1973, Wilson 1980) and those of heliothis and diapropsis. The nectariless trait has negative side-effects on natural predator populations such as lacewings and parasitoid wasps (Brettell 1983). However, there may be possibilities for quantitative improvements as there is variation for nectary size, ranging from 0.75 to 4mm (and none) in a species multicross (Zeng et al. 2007).

The frego bract increases susceptibility to lygus spp. (Tingey et al. 1974, Lincoln et al. 1971, Leigh et al. 1972) and cotton leaf rollers, although it increases resistance to the spotted bollworm and earias. Furthermore, other properties of cotton that confer resistance to other insect pests might have a positive effect on lygus resistance as well, such as compounds affecting olfaction (deterrents quercitin, rutin and procyanidin or attractants), visual properties (leaf and bud-colour and –shape) antibiotic substances and tolerance mechanisms such as the potential for compensatory growth (compare Smith 2005).

Bt cotton is only effective against Lepidopteran pests, but Monsanto reports that it is trying out a new principle to include lygus and aphid resistance into its Bt variety (Monsanto 2011).

As a conclusion, cotton breeding for resistance to lygus attack should consider pubescence, gossypol pigments and glands, and nectariless cotton varieties or those with less or small nectaries, but the effect of these traits on the different key pests needs to be assessed in the target area of cotton production, to avoid shifting the pest problem to other pests.

Specific reference to the above-described resistance factors has been made in the USA, Pakistan, Benin, and Burkina Faso (Poehlman 1987, Tariq and Rashid 2000, Lançon 2004, van Elzakker 2010, personal communication). Germplasm from these regions should be searched for promising varieties for trials in Uganda. Moreover, the related cotton species *G. barbadense, G. arboretum, G. thurberi, G. harknesii, G. herbaceum*, and *G. longicalyx* can be sources of resistance.

Based on the availability of germplasm at NaSARRI breeding station, pubescence was considered an opportunity for possible lygus resistance breeding. It was assumed that in older research a lesser range of degree of hairiness was available in germplasm and hairiness assessments had been too general, distinguishing only low, medium, and high hairiness. Furthermore, there was interest in exploring the variability of gossypol pigmentation and anthocyanin pigmentation, both easily observable traits with a high potential for application in a breeding program. For nectaries, it was known that there were insufficient differences between accessions to study it. Therefore, an experiment to explore the relationship between hairiness and lygus resistance was desired, but not possible due to practical reasons. Consequently, observations on hairiness and lygus damage were superimposed on two trials in NaSARRI research station, Serere.

II. Materials and Methods

Observations on morphology and lygus damage were superimposed on two existing trials.

Screening all germplasm of NaSARRI (121 entries) grown as germplasm collection was mostly aimed at assessing the available diversity of morphological traits, and narrow down the number of entries to be tested for lygus resistance in a later trial. The germplasm was grown without replication and under a strict spray regime (weekly application of cypercol). However, it was considered that lygus damage might occur earlier in the season before spraying is started, and some damage might occur in spite of spraying. Varieties or lines belonging to the same variety group or origin were considered as groups.

More detailed observations on lygus damage were carried out for eight varieties tested in three replications under organic management. These observations were meant to test whether the morphological traits and lygus damage were linked, and to study how consistent differences in lygus damage are across replications. An organic insecticide was applied (Oxymatrine) but too late in the season and at too large intervals to control lygus completely.

Measurements

To assess the hairiness of the varieties, different methods were tried on two sample leaves and bracts per entry, from different plants. The hairiness was assessed tactually and scored on a scale of 0 to 4 (Table 4, Appendix II for assessment scale). The hair length of average hairs was measured. The hair number was counted on a circular area, or the hair density of the leaf was assessed on a scale of 0 to 4, both with the aid of a binocular microscope. The assessment scale considered the presence of trichomes on different morphological structures (Table 5, Appendix II). The tactual measurements were taken on the upper and lower side of the leaf, the hair numbers were counted on the lower side of the leaf, and the hair density was scored on the upper and lower side of the leaf plus the bracts.

Gossypol gland density was assessed visually on a scale of 0-4 both in the field (for stems, bracts and leaves) and by looking at two sample bracts from each plant on a light box. Anthocyanin pigmentation was scored in the field on a scale of 1-3 for the stem, the leaves, and the bracts.

Lygus damage was scored in the form of leaf shotholes. Because of the uneven, patchy distribution of lygus infestation, at least 20 plants per entry were sampled at each date. Each plant was scored for damage with a weighted score of 0, 0.5, 1 or 2, the average score forming the lygus index.

III. Evaluation of the Methods

After a few entries, the different measurements were evaluated and the less reliable ones stopped. Tactual assessments in the lab appeared more reliable than those in the field, because leaf samples could be compared directly to one another, while those from the field gave inconsistent figures that were insufficiently correlated with the more accurate lab assessments (data not shown).

For hair density, the scoring method appeared more reliable (while faster) than counting hair numbers, because the distribution of the hairs across the leaf is not random. Counted hair numbers were not correlated at all to rated or felt densities on the upper nor the lower leaf. Rather, the hairs concentrate on veins such that counted hair numbers fluctuated greatly depending on how many veins were included in the sample area, but counting on larger areas was impractical. Moreover, the counted hair numbers differed between younger and older leaves, because with the growth of the leaf the non-hairy area between the veins expanded.

Consequently, only the lab-felt hairiness, the scored hair density, and the hair length measurements were continued for the whole germplasm. The correlation between the assessments on different plant parts are shown in Table 16. It shows that correlations between all measures for the upper and lower leaf size were present, but the correlations of the leaf parameters to the bract values were very weak. The measured values for the upper leaf side showed much larger deviations than for the lower leaf. Thus, one could simplify the assessment by measuring only the lower leaf side and the bracts.

Table 16. Correlation for the hairiness parameters between different plant parts.

Correlation	HFL		HD		HL	
	Equation	R^2	Equation	R^2	Equation	R^2
Upper to lower leaf	y = 0.82x + 0.77	0.50	y = 0.68x + 1.34	0.36	y = 1.01x + 0.22	0.28
Upper leaf to bract			y = 0.62x + 0.34	0.15	y = 0.30x + 0.15	0.07
Lower leaf to bract			y = 0.72x – 0.50	0.26	y = 0.27x + 0.11	0.14

HFL – Hairiness felt in the lab, HD – Hair Density, H – Hair Length

The correlations between the different measurements are shown in Table 17. The hair length was not well correlated to the hair density and tactile assessment, but the latter two were correlated, explaining 53 and 62% of the variation on the upper and lower leaf, respectively. Consequently, tactile assessments can give a reasonable estimate for the hair density, but if the hair length is of interest, it needs to be assessed separately.

Table 17. Correlation between the different hairiness parameters on different plant parts

Correlation	Upper leaf		Lower leaf		Bract	
	Equation	R^2	Equation	R^2	Equation	R^2
HFL – HL	y = 0.02x + 0.21	0.07	y = 0.08x + 0.29	0.32		
HD - HFL	y = 0.77x + 0.77	0.62	y = 1.19x - 0.34	0.80		
HD – HL	y = 0.04x + 0.21	0.08	y = 0.15x + 0.15	0.45	y = 0.05x + 0.18	0.23

HFL – Hairiness felt in the lab, HD – Hair Density, H – Hair Length

For the gossypol pigmentation, no variation could be found for the leaves by naked eye assessment, and the variation for the stems was larger within varieties than between varieties. The anthocyanin pigmentation was difficult to assess because of the environmental differences within the field, which influence pigmentation. Therefore, only the gossypol pigmentation of the bracts and the anthocyanin pigmentation of the whole plot was continued to be scored. Both parameters would need assessment under more uniform conditions, replication and /or with more accurate methods.

IV. Phenotypic Differences in Morphology

Variability of Hairiness in Total Germplasm

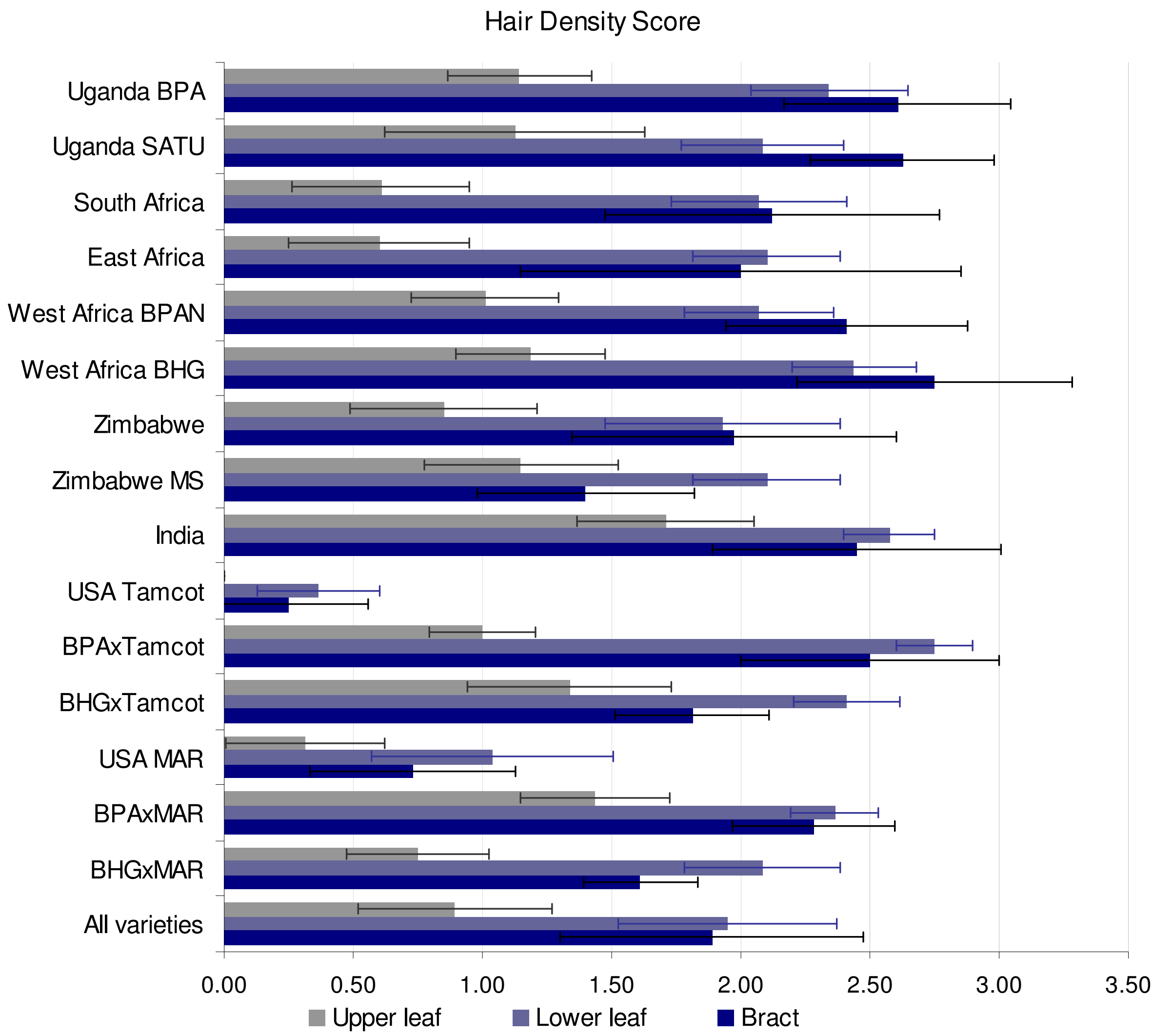

Figure 23. Hair density scores for variety/origin groups on a scale of 0-4.

The mean hair density scores for the upper leaf ranged from 0 to 1.75, i.e. it was not very high for any of the groups (Figure 23). For the lower leaf, the mean hair densities ranged more widely from 0.37 to 3.0, i.e. no variety group was completely smooth on the lower leaves, but also none reached the extreme rating of four. For the bracts, mean hair densities varied from 0.25 to 3.5, but since a different assessment key was used, this does not mean that the variation was higher than on the leaves. The hairiness on the upper leaf always scored lower than that of the lower leaf, and for most varieties, the bract hairs scored higher than the leaf hairs. For the US-American Tamcot and its crosses and MAR and its crosses, and the Zimbabwean MS varieties, the bract hair density is lower in relation to those of the leaves.

The American Tamcot was the least hairy, followed by MAR, which had a medium lower hair density. BHGxMAR crosses were below average on the upper leaf and bract, the Zimbabwean MS varieties on the bracts and the South and East African varieties on the upper leaf. The highest hair density across plant parts had the Ugandan BPA and its crosses, the West African BHG and the Indian varieties. In addition, BPA and SATU had a high bract hair density and the BHGxTamcot crosses a high upper leaf hair density.

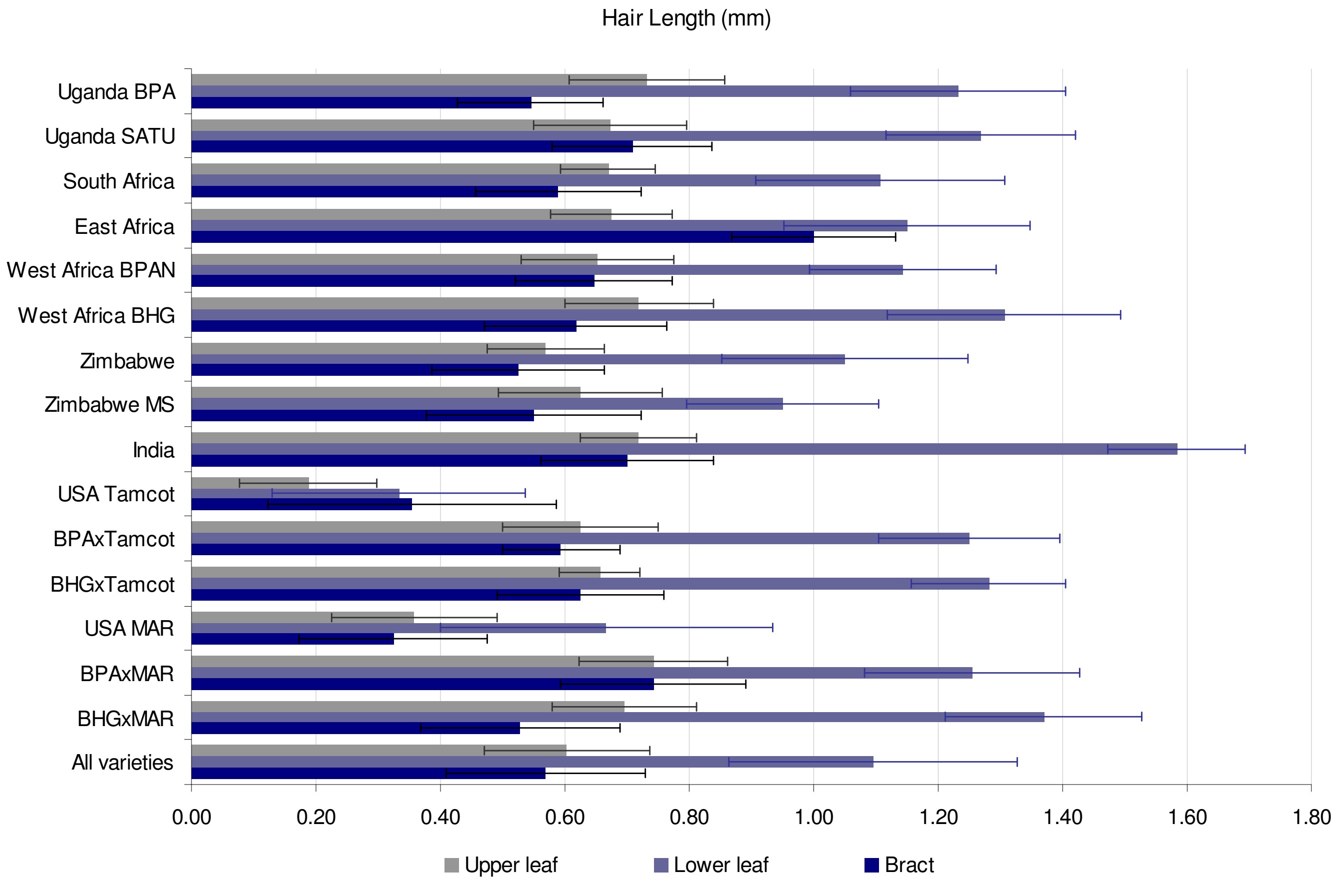

Figure 24. Mean hair length for variety/origin groups in millimetre

The hair length ranged 0.19-0.74 mm on the upper leaf, 0.33-1.58 mm on the lower leaf and 0.32-1.00 mm on the bracts (Figure 24). American Tamcot and MAR varieties had the shortest trichomes, Zimbabwean MS had short trichomes below the leaf and the other Zimbabwean varieties short trichomes on the upper leaf side. The Indian and West African varieties and the BHGxMAR cross had the longest trichomes, the East African varieties and SATU had especially long bract trichomes. The Ugandan BPA variety had above average hair length on the leaves but below average hair length on the bracts.

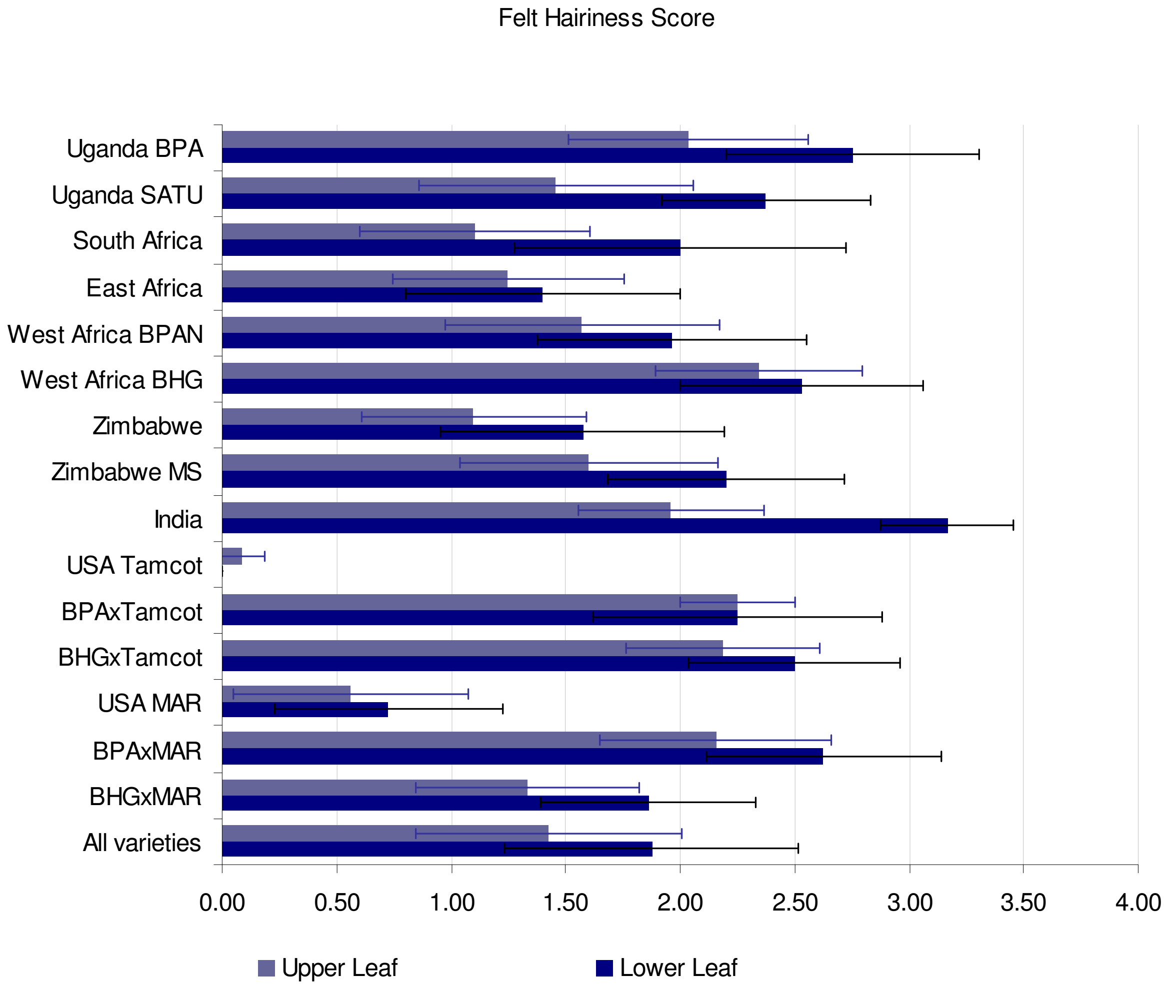

Figure 25. Tactile hairiness scores for variety/origin groups on a scale of 0-4.

The tactile hairiness assessments found the American Tamcot and MAR varieties the least hairy, and the West African and Indian varieties the most hairy (Figure 25). The Indian varieties felt especially hairy on the lower leaf side.

Lygus Damage – Local Distribution and Variety Differences

The lygus damage shows a rather patchy distribution over the germplasm field (Figure 26). Also the damage index per variety also differs substantially between the three replications of the organic variety trial (Figure 27). Thus, the damage index of the entries should be interpreted cautiously.

South, Trees

0.09	0.10		*	0.26	0.25	0.36	0.18	0.06	0.02	0.24	0.02	0.07	0.04	0.04	0.09	0.12	0.07	0.00	0.06	0.13	0.06	0.11	0.18	0.04	0.07	0.03	0.07	0.07	0.09	0.00	0.03	0.00	0.05	0.11	0.15	0.09					
0.24	0.11	0.07	*	0.16	0.05	0.11	0.13	0.07	*	0.18	0.15	0.13	0.17	0.13	0.10	0.19	0.17	0.20	0.08	0.15	0.19	0.24	0.21	0.08	0.19	0.14	0.33	0.22	0.21	0.04	0.00	0.13	0.05	0.10	0.10	0.08	0.30	0.18	0.00	0.04	
0.40	0.39	0.21	0.19	0.23	0.07	0.05	0.00	0.11	0.21	0.18	0.29	0.27	0.16	*	0.13	0.13	0.22	0.38	0.26	0.57	0.22	*	0.31	0.15	0.04	0.08	*	*	0.09	0.07	*	0.07	0.13	0.17	0.05	0.05	0.21	0.10	0.03	0.06	0.01

Figure 26. Damage index appraised for the plots as laid out in the germplasm field. Shading white: Damage index<0.12, green: 0.12<Damage index<0.25, yellow: 0.25<Damage index<0.38, orange: Damage index>0.38.

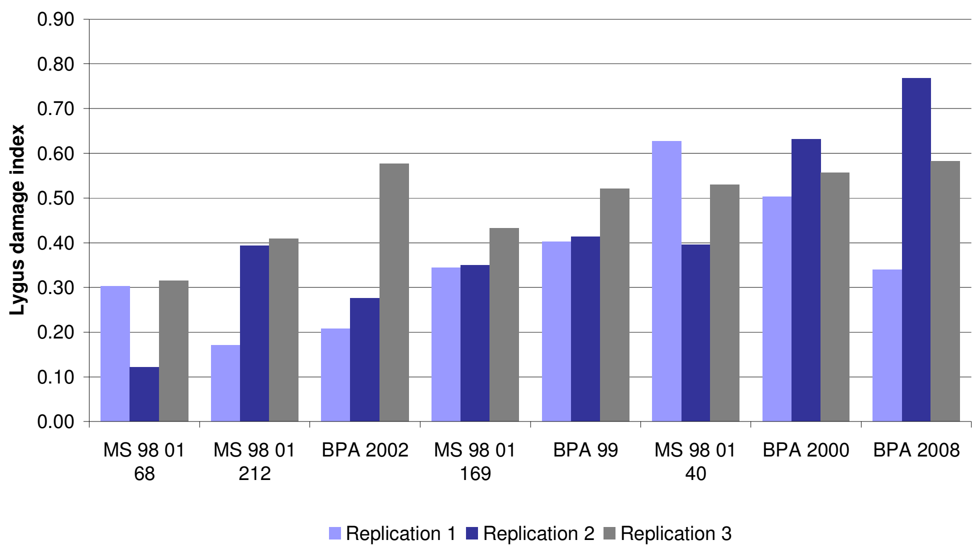

Figure 27. Lygus damage index of eight cotton varieties under organic conditions in three randomized blocks.

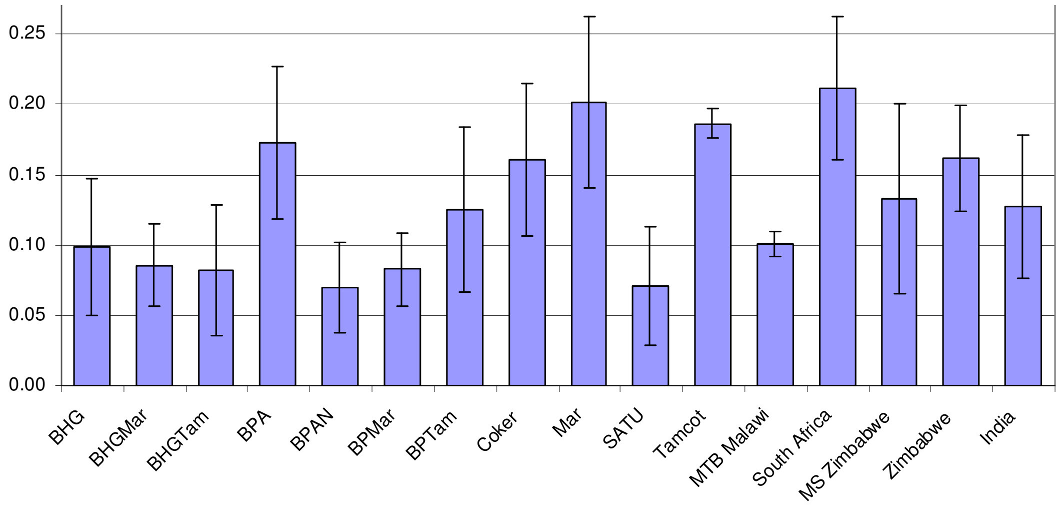

Figure 28. Lygus damage index per variety group of 121 entries.

The lygus damage indizes ranged from 0.1 to almost 0.8 under organic conditions (Figure 27) and from below 0.05 to almost 0.26 under conventional conditions (Figure 28). The difference between the two trials may be explained by the use of insecticides in the latter, as well as a much lower plant density and different soil conditions.

Under organic conditions (Figure 27), the varieties BPA 2000, BPA 99 and MS 98 01 40 had consistently higher damage indizes and variety MS 98 01 68 consistently lower ones than the other BPA and MS varieties. Generally, the BPA varieties seemed to suffer higher damage than the MS varieties, although that trend is not reliable.

Under conventional conditions (Figure 28), a slightly higher damage on BPA varieties than on MS varieties can be observed as well. BPA varieties, as well as Mar and South African varieties, were highly damaged. Ugandan SATU, Malawian MTB and West African BHG and BPAN varieties and some of their crosses suffered lower damage than other varieties.

The described differences indicate tendencies but may as well be artefacts of location effects (spotted lygus attack) or environmental influences such as unchecked differences in insecticide application. To confirm the differences, trials with high numbers of replications are needed, since even three replications in the organic trials showed considerable random errors. Apparently, the higher lygus damage of some varieties did not influence the selection by farmers negatively, since farmers chose many of the more highly damaged BPA, Mar and South African varieties (compare Chapter 4).

Correlation of Morphology and Lygus Damage

There are no correlations between morphology (Hairiness, Anthocyanin, Gossypol) and lygus damage index. Table 18 shows the correlation of lygus damage with few selcted parameters for illustration, all other measurements taken were even less correlated.

Table 18. Correlation of selected morphology parameters with lygus damage index.

Explaining variable	Linear Equation	R^2
Hair density (leaf upper side)	y = -0.038x + 0.163	0.061
Hair density (leaf lower side)	y = -0.015x + 0.159	0.014
Hair length (leaf upper side)	y = -0.143x + 0.163	0.017
Anthocyanin (plot)	y = 0.015x + 0.106	0.010
Gossypol (bracts)	y = -0.004x + 0.154	0.002

V. Discussion

The organic trial and the germplasm characterizations confirmed the difficulties reported in older literature with assessing lygus damage reliably and finding morphological parameters that confer lygus resistance. Although considerable variation for hairiness was present, it did not correlate with lyus damage, which contrasts some rather generalized statements in the literature.

Given the high environmental influence on lygus damage, it will be very difficult to improve lygus resistance through a participatory breeding project which focuses more on the plant as a hole. In addition, a possibly long process of basic research, which is at the same time not very promising considering the experiences in this thesis and older research, would be required.

If lygus resistance should become a breeding goal in future projects, first, varietal differences need to be confirmed and the most susceptible and most resistant varieties identified. To this end, a small number of varieties should be tested with many replications and under no-spray conditions. To distribute lygus attack more evenly, rows of alternative host plants should be planted within the trial field. The contrasting varieties can then be characterized for a large number of characters, which may necessitate elaborated laboratory analyses, since naked-eye observations in the past have not yielded results. When characters conferring lygus resistance should be found, their inheritance and possibly negative correlations with yield need to be analyzed.

Older research highlighted that the effect of lygus damage on yield is mostly over-estimated. Whether that is still true today, after possible changes in the ecological surroundings of the bug, the production regions and systems, new varieties, and the specific case of organic farmers, needs to be confirmed. Only a high effect on yields and income could justify the necessary basic research to breed for lygus resistance. With the current body of knowledge, lygus resistance cannot be recommended as a promising nor worthwhile breeding goal.

Appendix II

Table 1. Cost calculations for model cotton producers in Uganda. (Source this research)

Item	Unit cost	Unit	Conventional high investment		Conventional low investment		Organic	
			Number	Amount	Number	Amount	Number	Amount
Land-hire	247,000	Ha	1	247,000				
Ox-plough	112,000	Ha	2	224,000	-	-	-	-
Planting seed	2,470	Ha	-	-	-	-	-	-
Hand-ploughing	75,000	Ha	-	-	2	150,000	2	150,000
Weeding	20,000	Ha	5	100,000	4	80,000	4	80,000
Organic pesticide (Loro)	14,000	Ha	-	-	-	-	3	42,000
CDO pesticide	7,400	Ha	3	22,200	3	22,200	-	-
Market pesticide	5,000	Ha	2	10,000	-	-	-	-
Defoliator	5,000	Ha	1	5,000	-	-	-	-
Spray pump & labour	7,400	Ha	6	44,400	3	22,200	3	22,200
Picking	150	Kg	2250	337,500	1660	249,000	766	114,900
Sorting	50	Kg	1250	62,500	1000	50,000	461	23,050
TOTAL Costs				**1052,600**		**573,400**		**432,150**

Figure 1. Seasonal Calendar

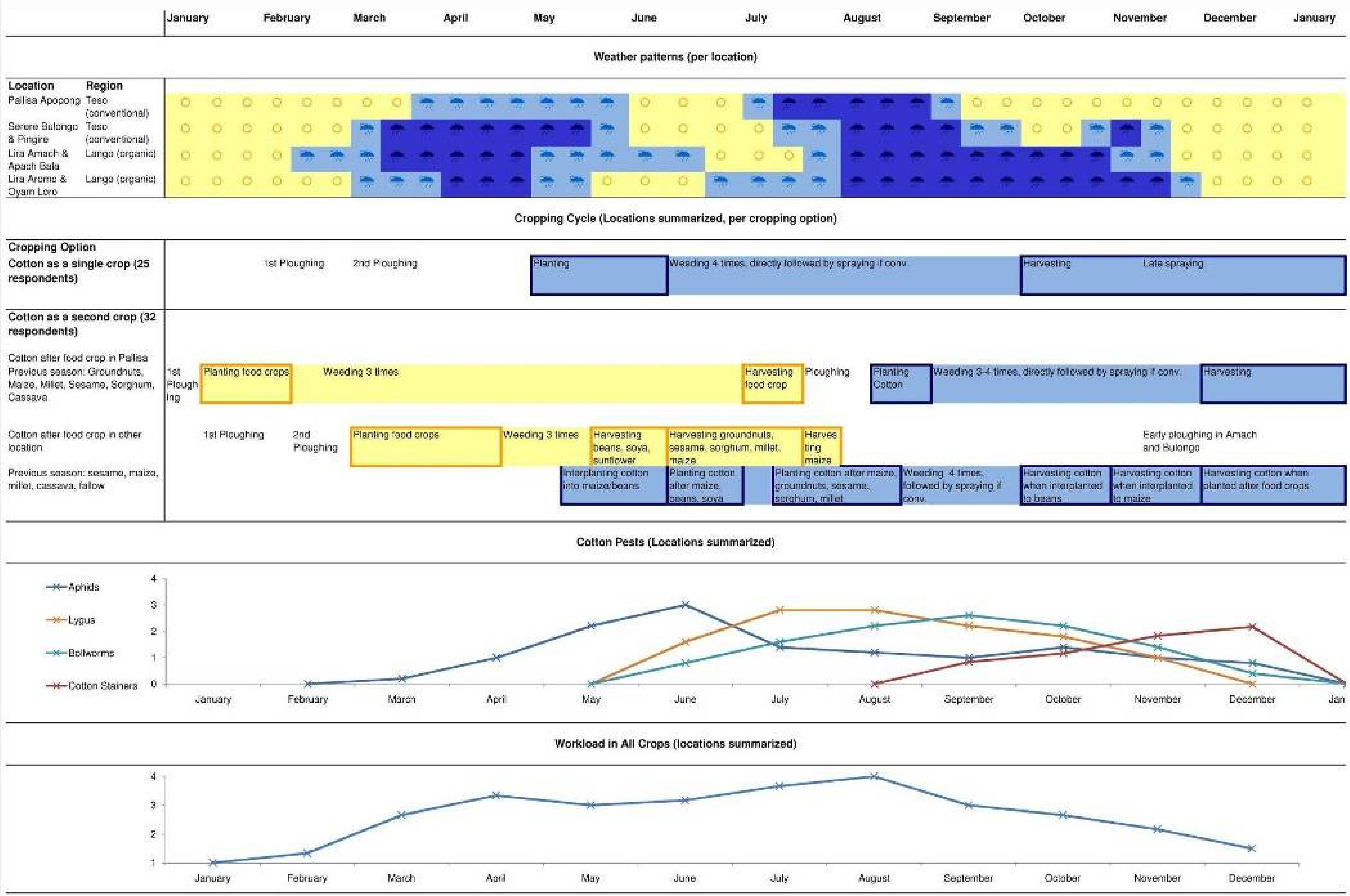

Table 2. Mean, Median, and Standard Deviation of constraints rated for their importance by farmers in six locations in Uganda, in 2010.

Constraint	Organic			Conventional			Total	Normality of		P value (ANOVA)	Comments
	Lira - Aromo	Oyam - Loro	Apach - Bala	Serere - Pingire	Serere - Bulongo	Pallisa - Apopong		Values	Residuals		
Aphids Mean	3.6d[1]	3.8d	2.7bc	1.6a	3.4c	2.5b	2.9	-	+	<0.001	
Median	4	4	3	1.5	3	2	3				
StdDev	0.79	0.46	1.11	0.74	0.52	0.93	1.05				
Lygus Mean	3.3b	2.5b	3.3b	2.1a	2.9b	2.2 a	2.8	+/-	+/-	0.064	Bala 3 & Pallisa 1 missing values, Loro 2 & Pallisa 1 outliers removed
Median	3	3	3	2	3	1.5	3				
StdDev	0.76	1.60	0.82	0.83	1.13	1.47	1.14				
Bollworm Mean	3.7b	1.3a	3.0b	3.3b	3.4b	2.1a	2.8	-	+/-	<0.001	
Median	4	1	3	4	3.5	2.5	3				
StdDev	0.49	1.37	1.00	1.16	0.74	0.99	1.22				Loro 2 missing values
Cotton Stainers Mean	3.3b	3.3b	2.3ab	2.0a	2.0a	1.5a	2.4	+/-	+/-	0.029	
Median	4	4	2	2	2	2	2				
StdDev	0.95	1.16	1.25	1.15	1.69	0.76	1.32				Pingire 1 missing value
Disease Mean	0.8	0.4	2.2	0.1	1.4	1.0	1.0	-	+/-	0.011	Aromo, Bala, Pingire, Bulongo & Pallisa each 1 missing value
Median	0	0	2	0	2	1	0				
StdDev	1.33	1.06	1.17	0.38	1.40	0.82	1.20				
Soil fertility Mean	0.6	1.5	2.0	0.6	1.4	1.6	1.3	-	-	0.377	
Median	0	1	2	0	0.5	1	1				
StdDev	1.13	1.69	1.15	1.06	1.69	1.85	1.49				Residuals S-curved
Drought Mean	1.4	1.8	2.0	2.3	2.4	2.6	2.1	+	+	0.496	
Median	1	2	2	2.5	2.5	2.5	2				
StdDev	1.27	1.39	1.41	1.16	1.30	1.06	1.26				
Weeds Mean	2.7	3.4	3.0	3.9	3.5	3.5	3.4	-	-	0.214	
Median	3	4	3	4	4	4	4				
StdDev	1.38	0.79	1.10	0.35	0.93	0.76	0.94				Bala 2 outliers removed
Tall Growth Mean	1.0	1.1	1.7	1.9	1.1	0.8	1.3	-	-	0.626	
Median	0	0	2	2	0.5	0	1				
StdDev	1.41	1.64	1.50	1.55	1.36	1.16	1.42				
Germination (seed) Mean	0.7a	2.5b	2.9c	3.7d	2.0ab	1.6ab	2.2	+/-	+	<0.001	Pallisa 1 & Pingire 1 missing value
Median	1	2.5	3	4	2	1	2				

StdDev	0.76	1.51	1.46	0.49	1.31	1.51	1.50				
Seed availability								-	-	0.107	
(quantity) Mean	3.3	1.6	1.6	0.9	1.3	1.3	1.6				Pingire 1 missing value
Median	4	1	0	0	0.5	1	1				
StdDev	1.50	1.85	1.99	1.46	1.58	1.39	1.72				
Seed availability											
(timing) Mean	4.0d	0.3a	2.3c	2.2bc	1.8bc	1.0ab	1.7	-	-	<0.001	
Median	4	0	2	2.5	5	0	2				Aromo 2 & Pingire 2
StdDev	0.00	0.71	1.50	1.17	1.28	1.41	1.56				missing values
Price Mean	3.4b	3.3b	2.4ab	4.0c	4.0c	1.5a	3.1	-	-	<0.001	
Median	3	4	2	4	4	1	4				
StdDev	0.53	1.16	1.13	0.00	0.00	1.69	1.30				
Flooding											
Mean					0.6	1.4	1.0	-	-	0.256	Pallisa 1 & Bulongo 1
Median					0	1	0.5				missing value, other
StdDev					0.89	1.62	1.38				locations not asked
Monkeys Mean				3.2		0.0	1.6	-	-	<0.001	Pingire 3 missing
Median				4		0	0				values, other locations
StdDev				1.30		0	1.79				not asked
Termites Mean				2.4		0.1	1.2	-	-	0.002	Pingire 3 missing
Median				3		0	0				values, other locations
StdDev				1.82		0.35	1.58				not asked
Germination											
(Weather) Mean	0.6	0.4	1.1	0.6	0	0	0.4	-	-	0.348	Aromo 2, Pingire 1 &
Median	0	0	0	0	0	0	0				Pallisa 2 missing values
StdDev	0.89	1.06	1.68	1.51	0	0	1.10				

[1] Values followed by the same letters within a row do not differ significantly according to a Mann-Whitney-U test.

Table 3. Ranking of production constraints per locality.

Median score	Organic						Conventional					
	Lira - Aromo		**Oyam - Loro**		**Apach - Bala**		**Serere - Pingire**		**Serere - Bulongo**		**Pallisa - Apopong**	
4	Seed availability / timing	4.0	Aphids	3.8			Price	4.0	Price	4.0	Weeds	3.5
	Bollworm	3.7	Weeds	3.4			Weeds	3.9	Weeds	3.5		
	Aphids	3.6	Stainers	3.3			Germination	3.7	Bollworm	3.4		
	Seed availability / quantity	3.3	Price	3.3			Bollworm (median 3.5)	3.3				
	Cotton Stainers	3.3					Monkeys	3.2				
3	Price	3.4	Lygus	2.5	Lygus	3.3	Termites	2.4	Aphids	3.4	Drought	2.6
	Lygus	3.3	Germination	2.5	Bollworm	3.0	Drought (median 2.5)	2.3	Lygus	2.9	Bollworm	2.1
	Weeds	2.7			Weeds	3.0	Seed availability / timing (median 2.5)	2.2	Drought (median 2.5)	2.4		
					Germination	2.9						
					Aphids	2.7						
					Tall growth	1.7						
2			Drought	1.8	Price	2.4	Lygus	2.1	Stainers	2.0	Aphids	2.5
					Seed availability / timing	2.3	Stainers	2.0	Germination	2.0	Stainers	1.5
					Stainers	2.3	Tall growth	1.9	Seed availability / timing	1.8	Lygus (median 1.5)	2.2
					Disease	2.2	Aphids (median 1.5)	1.6	Disease	1.4		
					Soil fertility	2.0						
					Drought	2.0						
1	Drought	1.4	Seed availability / quantity	1.6					Soil fertility (median 0.5)	1.4	Soil fertility	1.6
	Germination	0.7	Soil fertility	1.5					Seed availability / quantity (median 0.5)	1.3	Germination	1.6
			Bollworm	1.3					Tall growth (median 0.5)	1.1	Price	1.5
											Flooding	1.4
											Seed availability / quantity	1.3
											Disease	1.0
0	Tall growth	1.0	Tall growth	1.1	Seed availability / quantity	1.6	Seed availability / quantity	0.9	Flooding	0.6	Seed availability / timing	1.0
	Disease	0.8	Disease	0.4			Soil fertility	0.6	Monkeys	0.0	Tall growth	0.8
	Soil fertility	0.6	Seed availability / timing	0.3			Flooding	0.2	Termites	0.0	Termites	0.1
							Disease	0.1			Monkeys	0.0
							Monkeys	0.0				
							Termites	0.0				

Table 4. Assessment scale for tactile hairiness scores (carried out on two sample leaves from two different plants per entry, in the lab)

Score	Criteria upper leaf	Criteria lower leaf
0	No hairs felt between nor on main veines	No hairs felt between main veines (hairs on veines always present)
0.5	No hairs felt between nor on main veines, but hairs on veines visible	No hairs felt between main veines, but visible
1	No hairs felt between main veines but some on the veines	Hairs between main veines detectable
2	Hairs between main veines barely detectable	Hairs between main veines form a smooth cover
3	Hairs between main veines detectable, but also smooth surface felt	Dense hair cover between main veines, no smooth surface felt
4	Dense hair cover between main veines, no smooth surface felt	Dense hair cover between main veines, no smooth surface felt, hair cover on main veines also very dense

Table 5. Assessment scale for hair density scores (carried out on two sample leaves and bracts from two different plants per entry, with aid of a binocular microscope)

Score	Criteria upper leaf	Criteria lower leaf	Criteria bract
0	No hairs present on 1st order veines[1]	Hairs present on 1st order veines[1]	No or hardly any hairs present on pigmented veines
1	Hairs present on 1st order veines	Hairs present on 1st and 2nd order veines[2]	Hairs present on pigmented veines but noneor hardly any in-between veines
2	Hairs present on 1st and 2nd order veines[2]	Hairs present on 1st, 2nd and 3rd order veines[3]	Few hairs present in-between pigmented veines
3	Hairs present on 1st, 2nd and 3rd order veines[3]	Hairs present on 1st, 2nd, 3rd and 4th order veines[4]	Many hairs present in-between pigmented veines
4	Hairs present on 1st, 2nd, 3rd and 4th order veines[4]	Hairs present on all veines and the tissue between them	In-between pigmented veines are smaller veines completely covered with hairs

[1] 1st order veines are raised and white on the upper and lower leaf side
[2] 2nd order veines are raised and white on the lower leaf side only
[3] 3rd order veines are raised on the lower leaf side but not coulored differently than th surrounding tissue
[4] 4th order veines surround a number of cells with a gossypol pigment in the middle, they are the lowest order of visually distinguishable veines



Figures 2-4. NaSARRI Research Station: Breeders Office, Laboratory Ginnery, Seed Storage



Figures 5-7. NaSARRI Research Station: Germplasm field, Organic variety trial


Figures 8-10. Fieldwork: Lango Organic Farming Promotion, Facilitator Charles Enacu (CDO) and his wife, Facilitator Morish Opio (LOFP) and a participant



Figures 11-13. Fieldwork: Motorcycle transport, Participants

Figures 14-16. Constraint Scoring: Female participants, Facilitator Geoffrey Oloro and participants, Facilitator Morish Opio and participants

Figure 17. Germination problems: Field with cotton in different sizes from numerous replantings and remaining gaps

Figures 18-19. Participatory trait exploration in farmers fields

Figures 20-22. Participatory Workshop, Serere: Demonstration of hand-pollination of flowers, Participants discuss

Figures 23-25. Plants selected by breeders: tall, vegetative growth, long branching, semi-open habit, last picture BPA 2008

Figures 26-27. Plants selected by farmers: short and wide, less vegetative, open habit

Figures 28-30. Gossypol assessment: Comparing bract samples on a light box, gossypol in cotyledons of a seedling

Figures 31-37. Pubescense on bract (left), upper leaf (middle) and lower leaf (right). Upper row pubescent samples, lower row glabrous samples

Figures 38-39. Lygus damage on cotton leaves

Figures 40-41. Bug damage on cotton leaves: probably mosquito bug, leafhoppers