SHORT SEASON COTTON: HOW FAR CAN IT GO?

Papers Presented at a Technical Seminar at the 55th Plenary Meeting of the

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CONTENTS

Introduction

The Committee on Cotton Production Research of the ICAC had its meeting and Technical Seminar on October 10, 1996. The meeting was chaired by Mr. Abdulkhamit Adylov, Vice Minister, Ministry of Foreign Economic Relations, Republic of Uzbekistan. The Technical Seminar was held on the topic of "Short Season Cotton: How Far Can It Go?" Seven papers were presented in the Seminar on various aspects of short season cottons including availability and utilization of germplasm resources, impact of short season cottons on insect pests control, physiological implications of reducing crop duration, problems faced in breeding for short duration cottons and cost of production comparisons between short and long duration varieties. The presenters were from India, Pakistan, South Africa, Sudan, Uganda, United Kingdom and Uzbekistan. Two papers on the prospects of introducing short season cottons of upland and barbadense types for commercial scale cultivation in Egypt and the role of early maturing varieties in Egyptian agriculture which were not presented in the Seminar are also included in this report.

According to a paper presented by Dr. Mursal of Sudan, the Gossypium germpool has been extensively and successfully utilized in breeding to accomplish a number of objectives and still there is an immense potential to use it in the future. In Sudan, for developing short duration varieties, emphasis has been on reducing the time taken from planting to square formation and from boll formation to opening. Utilization of some early maturing extra-fine genotypes in hybridization programs has reduced the growth period of Barakat by 4-5 weeks. In the case of upland varieties, the aime is to reduce the growing period to below 140 days, and a number of such new varieties have been developed recently.

Dr. M. S. Kairon from India concentrated on morphological characters which affect plant behavior. Reduction in monopodia length, profuse flowering, high early boll setting, short internode length and closer-to-the-main-stem bearing are some of the important criteria used to develop short duration varieties. In India, short duration varieties have enhanced cropping intensity and extended cotton cultivation to new areas. The crop duration period has been reduced by 80-95 days in hirsutum, 25-50 days in arboreum, 55-60 days in herbaceum, 45 days in barbadense and by 50-55 days in commercial cotton hybrids. There is a possibility of reducing the growing period from over 145 days to 125 days in upland cotton.

In Uzbekistan, the Uzbek Scientific Research Institute of Breeding and Seed Production of Cotton has contributed greatly in developing short duration varieties of cotton suitable for local conditions. According to Dr. Ibrahim Egamberdiev, in addition to earliness, resistance to bacterial blight and verticillium wilt, suitability for machine picking and industry requirements are important considerations for selecting desirable plants among segregating genotypes. Lately, varieties having a lint percentage of 41-42% have been developed. Uzbekistan has the typical climatic conditions suitable for growing extra-fine cottons but reduced margin over upland prices has affected the area under extra-fine varieties.

A paper by Dr. Serunjogi of Uganda was limited to problems in breeding for earliness. The four major problems are effect of genetic x environment interaction, limitation of breeding tools and resources, frequent variations in growing conditions and resource management. A number of suggestions were made in the paper to overcome these difficulties. A proposal was also made to develop networks for breeding tools and germplasm resources.

A paper from Pakistan by Dr. Malik referred to the long full season production system which utilizes the primary and secondary fruiting cycles and a short season system which utilizes only the primary fruiting cycle. Short duration cottons intercept solar radiation at a higher rate and the rate of conversion of energy photosynthesis to usable products is also higher but they are not suitable for subsistence agriculture as they have little capacity to recuperate from biotic and abiotic stresses. According to the growing conditions in Pakistan, the cotton season can be reduced to 105, 110 and 115 days and cotton yields of over 1,200-1,500 kg/ha can still be obtained without affecting fiber quality.

A paper by Dr. Russell of the United Kingdom addressed the impact of short season cotton systems on the control of insect pests and diseases. The short season cotton system provides better insect management but the advantages of short season systems are not necessarily carried over to rainfed and small farmer conditions of low input applications. The insect by insect situation for major cotton insects is discussed in the paper.

The only paper on cost of producing short duration and long duration varieties was contributed by Dr. Steenkamp, considering the South African cotton growing conditions. South African conditions require at least 160 degree days for producing optimum yield and reduction in the growing period by 6, 12 and 18 days resulted in significant losses in yield. A savings of $250/ha in inputs, which is 7% of the total cost, resulted in a more than ten times higher loss in actual return.

All papers referred to savings on input applications in the case of short duration varieties but the financial implications for specific growing conditions like those in South Africa do not recommend development of short duration varieties. Most papers emphasized the importance of suitable short duration germplasm not readily available to breeders. Breeders will have to develop a readily usable germplasm supply to prevent wasting much time in avoiding undesirable linkages. A germplasm bank along the lines of multi adversity resistance stocks has been proposed. Though short duration is a relative term, there is a great potential to reduce further the growing period in most countries without affecting yield and quality.

The 1997 Technical Seminar will be held on the topic of Common Fund for Commodities Funded ICAC Projects. Since the recognition of the ICAC as an International Commodity Body with the CFC, five projects have been approved. The Secretariat presented an overview of the four projects currently underway, while a report on the first project, which has been completed, was presented by Dr. Fred Gillham of Australia.

Following the Seminar, the Committee on Cotton Production Research was informed about the progress of the World Cotton Research Conference—2 to be held from September 6-12, 1998 in Greece. The ICAC Secretariat has already contacted the FAO inviting them to join the ICAC and the Hellenic Cotton Board of Greece in sponsoring and organizing the World Cotton Research Conference—2. The Secretariat will make the first formal announcement in the form of a brochure shortly.

The Committee on Cotton Production Research was notified of two more conferences. The Technical Information Section of the ICAC is helping the Central Institute for Cotton Research, Nagpur, India, to attract international participation in a two day group discussion on the "Role of Biotechnology Towards Increasing and Sustaining Productivity in Cotton." The group discussion will be held on November 25-26, 1996, following the Crop Science Congress hosted by the Indian Agricultural Research Council. The other notice was about the All African Crop Science Congress to be held in South Africa from January 13-17, 1997. The Technical Information Section, in collaboration with the African Cotton Research Network (East, Central and South) and the organizers at the Tobacco and Cotton Research Institute of South Africa, plans to organize a separate program on cotton during the congress. This opportunity will be utilized to strengthen the African Cotton Research Network which emerged from informal discussions held during the World Cotton Research Conference—1 in Australia in 1994.

Germpool Utilization in Breeding Short Duration Cotton

Ibrahim El Jack Mursal, Agricultural Research Corporation, Gezira Research Station, Wad, Medani, Sudan

Introduction

Breeding new and improved varieties of cotton proceeds from basic material in which adequate genetic variability is available. Commercial varieties often continue to respond to selection for many years but in time the breeder must create new variability, usually through hybridization.

In most cases breeding work has relied upon variability within a single species and the classic cotton breeding techniques are ideal for the maintenance of existing varieties and for their improvement by judicious cross breeding between varieties. However, characteristics are not expected to appear. The exploitation of genetic variability in a diverse cotton germpool offers opportunities of transferring useful characters to domesticated species. It is the purpose of this note to highlight the potential sources of gene material and to illustrate where the Gossypium germpool has been successfully used to introduce agriculturally useful characters such as earliness in the primary breeding stocks and commercially acceptable cultivars.

The genus Gossypium encompasses an immense variation for breeding extending from the highly improved cultivars of intensive agriculture to the wild species. All except two of the wild forms that exist in certain parts of the tropics are diploid and most are lintless. They have been divided into groups or genomes distinguished by the letters A to G. Two species of genome A (*G. herbaceum* and *G. arboreum*) carry true lint and are widely cultivated in India and other parts of Asia. The most generally cultivated varieties belong to the tetraploid species (*G. hirsutum* and *G. barbadense*) which were shown to be amphidiploids, with two basic sets of 13 chromosomes corresponding closely to A and D genomes.

Gene Transfer

There are three sources of new gene material for crop improvement and the ease with which gene transfers are effected depends on how distantly related is the source of the desirable gene. Utilization of the genetic variability in the biotype of race latifolium, punctatum and mariegalante is not faced with serious genetic obstacles in making gene transfers for the improvement of upland cottons compared to the difficulties encountered when making gene transfers from such closely related species as *G. barbadense*. In fact, race punctatum has achieved some measure of success in improving the bacterial blight resistance level of the uplands and the breeding of better cottons for the dry regions south of the Sahara.

The third potential source of gene material for the improvement of cottons is the range of the diploid species. Their potential contributions are of different kinds but the problems involved in incorporating their gene material are similar. Two techniques have been used: One involving the use of hexaploid made by doubling a triploid from a cross of a diploid by a new world cotton and the other using synthetic allopolyploids in which representatives of two of the diploid groups are brought in together.

Short Duration Cotton

Short duration cultivars are desirable since they have lower requirements of fertilizer, irrigation water and labor. They are exposed to pest attack for a shorter period and therefore need fewer sprays. They can possibly be planted late to escape Heliothis attack. Further, they may prove useful for cultivation in areas where soil moisture/irrigation water becomes a limiting factor during boll maturation.

In Sudan, under normal production conditions and with a July/August planting date, the medium count cottons mature in 150-180 days, the extra fine count cottons in 230-240 days and the coarse count cottons in 130-150 days. The stages of the crop development range (in days) are given in the table below.

In breeding for earliness the emphasis has been on shortening the first and the last stages to produce cultivars that mature in less than 140 days. Cases where the Gossypium germpool has been used to introduce an earliness character into primary breeding stocks or commercially acceptable cultivars will be illustrated.

Wild Species

In the wild species work in Sudan emphasis has been on isolation and identification of bacterial blight resistant genes where five out of sixteen genes were derived from diploid species *G. arboreum* L., *G. herbaceum* L., and *G. anomalum* Wawer and Peyr. However, the germpool has been used for other purposes than a source of resistance. It has been realized that to limit the objective to the transference of a single diploid character such as hairiness or smooth stem is to miss the great potential of these wide crosses which is absent in hybridization within a species or a variety. The importance is emphasized of searching for the unexpected characters which sometimes occur in wide crosses, with a view to use the potentially useful ones in breeding programs. An example concerns plant pubescence where hairy varieties of *G. hirsutum* that effectively resist jassids were developed. However, of significant importance was the material involving the B genome *G. anomalum*. In the early generations hairiness was poorly expressed but there was great variability in most characters.

Three back crosses to the Hexaploid 2 (Bar 14/25 x *G. anomalum*) restored the fertility and the gene controlling hairiness was isolated. But other families both glabrescent and hairy in about the ninth generation attracted interest. Certain vigorous, uniform and fruitful lines were observed to be considerably earlier in the production of first flowers than the sakel parent. An unpredictable character had appeared; the hybridization of the late-flowering sakel and the wild perennial *G. anomalum* was not expected to give rise to exceptionally early varieties. Some plants produced flowers 45 days after planting, compared to 75 days for sakel. The first sympodial node was the 6^{th} or 7^{th} in the hybrid compared with the 11^{th} or 13^{th} for the barbadense.

G. hirsutum

	Days		
	Coarse	Medium	Extra-fine
Planting to squaring	45	45	75
Squaring to flowering	21	21	21
Flowering to boll formation	21	21	21
Boll formation to opening	49	63	63
Total	**136**	**150**	**180**

Some introduced *G. hirsutum* cultivars have been found to be early maturing with acceptable yield and quality and resistance to the pre-barakat race of the bacterial blight disease. These are

Normal leaf: Camd-E, Sp 37-H, Sp 21-s, Gp 3774, Gp 3755, Sp 37, Des 24 N
Okra-leaf: Orsbo, Ors-13 , Tx Orsc-6-79,Tx Orslebo-1-79

G. barbadense

As compared with the local *G. barbadense* cultivars the following introduced Pima cottons were found to be very early, short duration and dwarf. These are Pima okra, Pima 73-106 and Pima 73-109.

The introduced okra leaf hirsutums were compared with two local okra leaf lines and the normal leaf commercial variety Barac (67)B. Sowing date was late (August 21) and plant population was high (150,000/ha). Spraying was done once against jassids.

All the entries had started flowering in 58 days from planting and boll opening in 88 days. Four months after planting (120 days) open bolls comprised 57% and 44% of the total fruiting bodies in Orsbo and Ors-13 respectively against a mere 29% in Barac (67)B and 17% in Sudac-K. Further, considering the proportion of the first picking (140 days after sowing) to the total of the two pickings, Orsbo (84.9%) was earliest, being closely followed by Ors-13 (81.8%).

The introduced normal leaf hirsutum cultivars were tested against Sudac-K, Achillea 82 and Barac (67)B. Owing to being short-duration they were planted late (August 30) in a population of 125,000 plants/ha.

The introductions gave results comparable to those of the Okra-leaf cultivars with higher percentage of the first pick to the total yield (87.4-97.7%). All the introduced cultivars were earlier in maturity than the local commercial varieties Barac (67)B (87.1%) and Achillea 82 (82.8%). The Okra-leaf check Sudac-K gave the lowest value (76.6%) contrary to the belief that the okra-leaf character imparts earliness. Closer examination showed that the boll maturation period of Sudac-K was longer than that of the early maturing normal leaf introductions.

In the *G. barbadense* group crosses between the local barbadense cultivar (Barakat) and the introduced Pima okra, Pima 73-106 and Pima 73-109 resulted in valuable material. The dwarf character of Pima 73-109 shortened the growth period of the late-maturing Barakat by 4-5 weeks saving two irrigations resulting in the new variety S-pima.

Conclusion

The available germplasm in Sudan consists of over 40 members of the diploid species belonging to all genomes, 500 entries in the type collection of the hirsutum and barbadense species and 57 introduced advanced lines. The Gossypium germpool which is very broad has been successfully used to accomplish a variety of objectives and it remains of immense value for the future.

In many countries, including Sudan, the availability of agricultural inputs such as irrigation water, soil moisture, fertilizers and chemical pesticides is limiting the expansion of cotton production. The development of short-duration cotton is a safeguard against these constraining factors and the germpool in Gossypium is adequate to provide the genetic variability needed to introduce agriculturally valuable characters such as earliness.

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Genetic Diversity for Short Duration Cottons

M. S. Kairon and V.V. Singh, Central Institute for Cotton Research, Nagpur, India

Abstract

The concern for short season cottons is important for advantages such as avoidance/escape from unpredictable epidemics of diseases and insect pests and the possibility of a double/triple cropping system, which compensate for reductions in yield associated with short-season cottons. An overview of progress in reduction of crop maturity duration is presented, with examples from the various agro-climatic zones of India, where there is a wide diversity of maturity groups. The role of climatic and geographic factors is fairly well known. It is desirable to adjust or manipulate crop maturity, especially where practices such as excess manuring, irrigation and multiple picking tend to favor prolonging of the duration of the crop. While it is true that despite wide diversity existing for specific plant traits, efforts to introduce short-branching, dwarf stature and cluster fruiting traits have not yielded spectacular results, there is still an apparent scope for further exploitation of several other diverse plant traits and genetic resources, within limits.

Introduction

Short duration cottons are required for location specific niches, especially irrigated or with certain assured rainfall areas, for increasing crop intensity, extending area under cotton and increasing cotton production with pest escape mechanism of earliness, for high per day productivity and for reduced pest and crop management costs. Cottons grown traditionally in India were Asiatic cottons even until the 1920s, but today the upland American cottons and hybrids have significantly altered the species composition contributing highly to total production. Irrigated cotton area has increased to 40% of the total cotton area and the remaining 60% is grown in assured, moderate and low rainfall conditions. In the last 50 years, the crop duration of various varieties in all the four species and hybrid cottons has been reduced considerably, but there is a need to optimize fiber quality and maximize yield potential in short duration varieties. There is good scope in Asiatic cottons also.

Specific plant characters are associated with short duration in cotton, but fully determinate types are rare in India. Efforts to introduce short branch, dwarf, cluster fruiting traits in Indian cotton varieties did not yield significant outcomes. There is wide diversity for duration groups, special plant characters associated with early crop maturity and various components of early flowering and boll maturity in the National Gene Bank of Cotton maintained at the Central Institute for Cotton Research, Nagpur. A number of short duration germplasm accessions in the gene bank, in all the four cultivated species, have been identified and documented in the national cotton genetic resources catalogue and some are mentioned in this paper.

The cotton growing environment namely latitude-longitude, altitude, soil types, temperature variations, falling winter temperatures, rainfall pattern etc., also affects crop duration significantly due to alterations in growth phases, photoperiodic differences and flowering pattern etc. Certain plant and varietal characters like bigger boll size, longer staple and leafy types also affect duration.

Agricultural practices related to faulty and unbalanced manuring and excessive and untimely irrigations, multiple picking and tendency to retain the crop for longer periods with expectations to get more income or compensate early stage crop losses due to pests and untimely rains and other practices affect crop duration. Crop termination not at anappropriate time, intentionally to get more produce due to seasonal and price advantages, also prolongs the duration. This is possible because the cotton plant is of a continuous flowering nature. But where there is a sequence of the next crop to succeed cotton, the duration is more or less maintained unlike in locations growing a single crop per year.

A number of selection criteria that determine earliness are used by cotton breeders. Reduction in monopodia, short profuse flowering and high early boll setting types with less leaf, short internode and close fruiting types are given preference in selection. Breeding for early maturity has been successful in releasing a large number of cotton varieties/hybrids for double and triple cropping areas and extending cotton to new areas. Adoption of the pedigree method, transgressive breeding for earliness of flowering, complex crosses and selection, induced mutations, heterosis breeding and introgressive hybridization have helped to develop a number of short duration medium staple varieties and hybrids. There are several choices, limitations, constraints and considerations in developing early maturing cottons as imposed by location specific requirements, environmental variations, agricultural practices, crop physiology and genotype characteristics. In China, USA, Egypt, etc., also short season cottons have been developed, despite differences of opinion on their feasibility. There is a need for augmenting the genepool for early maturing genotypes and specific plant characters from other countries to enrich the National Cotton Gene Bank for enabling continued development of short duration varieties in India.

Role of Short Duration Cotton

Short duration cottons are required for location specific needs to fit into double and triple cropping annual rotations in irrigated areas to increase crop intensity and increase cotton production as well as that of others, especially food crops. Short duration varieties are also required where earliness can be useful as an escape mechanism against severe bollworm attack. It is also useful to escape the dry period after cessation of major rains in assured rainfall areas and to reduce the cost of plant protection as well as total production expenses. Short duration cottons also help to increase the per-day productivity of land.

Indian Cotton Crop Composition

The cottons grown traditionally in India from time immemorial were Asiatic cottons namely *Gossypium arboreum* L. and *G. herbaceum* L. and until the year 1920, their area was 98 percent. As a result of introductions from the USA and other sources and acclimatization efforts since mid of the last century and improvement work in the current century, *G. hirsutum* L. cottons covered 20 percent area by 1950 and gradually increased to nearly 70 percent of area by the late sixties leaving the Asiatic cottons in less than 30 percent of the total cotton area.

By the start of seventies, *G. barbadense* cotton also went into cultivation after locally developed varieties were made available. The late sixties and early seventies saw the pioneering development of hybrid cottons of both intra-hirsutum and hirsutum x barbadense, which went into commercial cultivation on a large area. Subsequently, between the seventies and nineties, quite a large number of hybrids, both public bred and private company bred, became popular in cultivation leading to nearly 40 percent area under hybrid cottons at present. The present composition of Indian cotton crop is estimated approximately as follows:

There is a need for developing short duration cottons in most of the above groups for meeting the requirements for specific niches in India.

Species	**Approximate Area As % of Total 8.5 million ha under cotton**	**Approximate Production As % of Total 15.7 million bales**
G. herbaceum	8	4
G. arboreum	16	8
G. hirsutum	36	40
G. barbadense	0.03	Low
Hybrid Cottons (F1)		
Hirsutum x Hirsutum	35	40
Hirsutum x Barbadense	5	8
Asiatic Cotton Hybrids	Low	Low

Rainfed and Irrigated Cotton

The real impetus for the development of early maturing varieties of cotton was given after independence for increasing total cotton production by increasing the area under cotton in new irrigation projects in North-western India, Andhra Pradesh, Karnataka and Tamil Nadu and as a new crop in the short and medium duration fallow periods in deltaic and tankfed areas after harvest of rice especially in Tamil Nadu, Andhra Pradesh, Orissa, etc. and in rainfed areas without affecting food crop production. Today cotton is grown as an irrigated crop in nearly 40 percent of the area and the remaining as a rainfed crop in assured, moderate and low rainfall areas. Short duration cottons are more important in irrigated areas than in purely rainfed areas except in certain specific niches. With increased area under irrigation and hybrid cottons, pest problems have become severe and early maturing varieties are therefore essential.

Reduction of Crop Duration

The traditionally grown Asiatic (desi or native) cottons and earlier introduced hirsutum and barbadense cottons were of long duration remaining in the field for over 250-270 days. As a result of breeding efforts, the crop duration was gradually reduced in successive commercial cultivars and hybrid cottons as follows:

Still there is a need to optimize fiber quality and maximize yield potential in short duration varieties.

Reduction in Crop Duration (Days)

	From	**To**
Hirsutum varieties	240-270	145-180
Arboreum varieties	210-240	165-190
Herbaceum varieties	230-250	175-190
Barbadense varieties	240	195
Hybrid Cottons	220-240	165-190

Specific Plant Characters and Earliness

Fully determinate types are rare in India, but evolution of semi determinate types has helped to release short duration cottons. Some plant characters are associated with earliness of flowering, synchronous flowering and fruiting. Absence of monopodia, low sympodial node number, short internodes of main stem, moderate boll size (as against big boll size by 7-10 grains), etc., contribute to earliness. Short sympodial branch types and cluster fruiting types which bear fruits close to the mainstem as in some introduced Uzbekistan germplasm also show reduced crop duration. Okra leaf, particularly semi-okra type, is correlated with early maturity compared to normal leaf types by about 10-12 days in hirsutum cottons. Dwarf stature coupled with low sympodial node number also show earliness of crop maturity in hirsutum cottons.

Short Duration Cottons in Gene Bank

Accessions of germplasm maintained in the National Gene Bank particularly breeder's active working genepool and special types are being evaluated continuously to classify them for duration groups into short duration (125-145 days), medium duration (145-165 days), long duration (170-190 days) and extra long duration (200 days and above) based on at least 90 percent of bolls harvested. In addition, the presence of special plant characters correlated with early crop maturity was also looked for and identified in such early maturing germplasm. Based on a study of over 5,000 germplasm accessions in all the four cultivated species, a number of relatively early maturing accessions of 135 to 150 days duration under rainfed (Nagpur, Central India) conditions have been recorded, some of which are listed below:

***G. hirsutum*:** H14, AC738, BN, Okra leaf, Tashkent 1, 70G, 70E, MCU11, J276-1, Pusa 595B, CP 1998F, 76IH 20, Sharada, Sima 1, TxORSC2-78, TxORSC801-79, Acala 8-1, Tamcot SP 21, Acala 69/5, D244/10, Riverina Poplar, U. Ark, D203-5, D238-13-5, USSR NAC 83, MCU7, AKHO81, NHS 1412, LRA 5166, USSR 6228, Anjali, PKV 442, NCSD 3, CNH 36, LH 900, PRS 72, PRS 74, MCU 10, SVPR 1, Krishna, LH 372, NA 247, SH 131, etc.

***G. barbadense**:* SB 289E, SB 1085-6, IARI Pusa types about 200 selections, etc.

***G. arboreum**:* AK 14, K 41, AC 13, AC 18, AC 30, AC 48, AC 60, AC 63, AC 65, AC 543, AC 733, C 420, DC 92, K 10, DS 5, LD 327, NAS 2, NAS 3, NAS 4.

***G. herbaceum**:* LS Early, Baluchistan, G. cot 11, G. cot 13, DB3-12, R.51, Raghavendra (AP), etc.

Environmental Influence

Cotton is grown in India in areas ranging from latitude 9 - 30°N and longitude E in tropical and sub-tropical situations, widely varying soil types and atmospheric temperatures at germination, growth and boll development periods, failing temperatures with onset of winter in north and central India, continuous cloudy days during flowering and boll setting, altitudes (1,000 meters m.s.l.) and photoperiodic differences all of which affect flowering and maturity, thereby influencing total crop duration. Summer grown cottons in Tamil Nadu complete crop maturity earlier than winter crops of upland cottons. About 160 frost fee days and optimum temperatures at crop growth and boll development phases ensure a successful crop of cotton.

Excessive rainfall in certain areas promote growth of more vegetative branches. Compared to deep soils, shallow soils also influence rapid bursting immediately after cessation of rains. Highly monopodial and bushy spreading plant types require longer period for maturity and are associated with lateness, and these are affected further by adverse environments prolonging the duration. Long staple cottons require a longer growing season than short staple cottons. Bigger boll types and end-season bolls require more time for maturity than smaller and also early formed bolls. Advanced sowing in anticipation of rains, raising seedlings and transplanting soon after rains and limited ratoon crops have been found useful to cope with environmental aspects and achieve early crop arrival.

Agronomic Practices

Agricultural practices like excessive application of irrigation water and excessive nitrogenous fertilizer applications at early and vegetative growth stage prolong the vegetative phase considerably, while too late season irrigations, inadequate phosphorous and potash application without balanced 4:2:1 NPK application dose also affect crop maturity and increase duration. Ratoon crops of hybrid cottons mature earlier than planted crop, but are discouraged on account of pest problems. Soil fertility also determines the amount of flowering and extent of earliness. Some chemical treatments like KAOLIN, PIX, Cycocel, NAA, etc. were studied for mitigating certain ill effects arising from adverse environments and genotype traits, but not widely practiced. Use of acid delinted seeds give early germination.

Crop Duration and Crop Termination

Because cotton is a cash crop of a continuous flowering nature, farmers are reluctant to remove the crop by willful termination, especially in India where multiple hand pickings are done, unlike forced chemical termination and once over mechanical harvesting in certain advanced countries. This is especially so when untimely rainfall damages the crop at first bursting stage and also when loss of a significant part of the early formed flowers and bolls occurs due to severe bollworm damage and farmers retain the crop for longer periods to get yield compensation. Sometimes end-season rainfall that helps to induce continued flowering also tempts and enthuses the farmers to reap the benefit of extra yields by prolonged retention of the crop without much extra efforts and cost, especially in years of remunerative prices. Hence even when short duration varieties are made available, farmers tend to retain the crop for longer periods, unless these are grown in lands where a succeeding crop has to be planted within a specific period.

Selection Criteria

Monopodial contribution to yield in Asiatic cottons is about 20 to 30 percent and about 15-20 percent in hirsutum cottons, but they contribute to late maturity. The lowest node of the main stem at which first sympodia occurs indicates early maturity. Other criteria of selection for early maturity used by breeders are 50 percent plants flowering days, 50 percent plants boll bursting days, mean date of maturity, Bartlette's rate index, proportion of first picking to total, etc. Selection for compact plant type, lack of monopodia, short internodes, medium boll size (3.5 to 4.0 g), semi okra leaf type, genotypes with short but profuse peak flowering period, etc. are useful. These selection practices should be judiciously combined with genetic potential for yield and desirable fiber quality traits. More basic studies are required to improve the chances for developing superior short season cottons.

Breeding for Early Maturity

Several relatively short duration cottons have been developed in India for specific situations. Some important achievements include:

- For cotton-wheat rotation in Punjab, Haryana, Rajasthan
  Bikaneri Nerma was the first early maturing genotype identified in Rajasthan which became the forerunner for development of cotton-wheat rotation in a big way in the Bakra Nangal project area in Punjab, Haryana and north Rajasthan followed by release of several high yielding upland cotton varieties and hybrids of about 170 days duration, namely F 414, H 777, F 505, LH 900, G.N. Ageti, Dhanlaxmi, Fateh, Raj HH16, etc., and DS5, LD 327, RG8 in desi cotton.

- For irrigated areas of South India especially Tamil Nadu, Andhra Pradesh, Gujurat, etc.
  MCU 5, LRA 5166, MCU 9, JK 119, LK 861, L 389, H 8

- For rice fallow areas (deltatic and tankfed)
  P 216F, PRS 72, MCU 7, LRA 5166, SIMA 1, VPR 1, MCU 8, Krishna, MCU 11, etc.

- For rainfed areas
  MCU 10, K 10, LRA 5166, LRK 516, CNH 36, NHH 44, CICR HH1, PKV Hy2, AKH 081, Rajat, Vikram, G. cot.11, G. cot.13, etc. in South and Central India.

Most of these are medium staple cottons.

Breeding Methods Adopted

While early maturity as such is a genetic trait influenced by several plant characters, it is also affected by soil, environment and cultural practices and preferred for multiple cropping systems with compulsions not to retain the crop beyond a certain period for planting the next crop. In pedigree breeding, appropriate choice of parents for hybridization and selection criteria for early maturity attributes and identifying transgressive segregants for earliness have paid good dividends. Heterosis breeding through mating of suitable parents like SB 289E, SB 1085-6 or P 4 in *G. barbadense* and G. cot. 100, K 3400, Bikaneri Narma, LRA 5166, AC 122, LRK 516, MCU 5, MCU 10, SVPR 1, NA 247, Suman, Arogya (NISD 3), MCU 7, etc. in *G. hirsutum* have proved to be a better choice for developing short duration hybrids. Through induced mutations 145 days duration variety MCU 7 and 160 days duration MCU 10 have been released in Tamil Nadu. Some complex crosses and three way crosses followed through several generations of selection have resulted in MCU 5, LRA 5166, LRK 516 and CNH 36 which are of 150 to 165 days duration under optimum growing conditions. Arogya (NISD 3) was obtained after several generations of selection from hirsutum x anomalum cross.

The quantitative characters influencing flowering and boll period duration have shown to be mostly additive and in some cases non-additive components of gene action. Hence, pedigree breeding and reciprocal recurrent selection coupled with effective progeny testing are useful.

Limits for Early Maturity-—Some Considerations

In cotton, flowers appear about 8-9 weeks after planting and bolls open about 17-18 weeks after planting. Young squares appear 5-6 weeks after sowing (vegetative period), flowers (anthesis) open about 21 days after square appearance (blooming period) and thus in *G. hirsutum* flowers appear 60-70 days after planting and fruit ripens within 50-70 days after fertilization. A minimum 45 days are required for transition of flower to open into boll, while late season blooms require 10-20 days longer. Cotton fibers to mature in unopened bolls require 45-65 days (boll development period) depending on variety and environment. The variations in fiber properties are more affected in the boll period than in any other period of plant growth. A study of germplasm revealed the range of variability for various developmental phases to be as follows: Days to squaring 35-55 days, squaring to flowering 18-25 days, flowering (anthesis) to boll development 45 to 70 days and flowering interval 40 to 90 days with peak flowering around 30-45 days. Based on this, suitable varieties can be developed with 125-135 days duration as the shortest duration variety.

Monopodial (vegetative) branches produce squares, but the process is much slower and inefficient. From sympodial types, 80-85 percent of total bolls are formed from squares set in 4-5 weeks of squaring. The first three positions on each reproductive (sympodial) branch represent the key sites for fruiting and highly contribute to total yield. The lower its node number, the better for early maturity. Short duration cottons comparable to short season cottons of Texas, USA, set fruiting branches at the 4th or 5th node, while long duration varieties in raingrown situations set them at the 8th or 9th node. Higher fruit retention of early bloom is an important asset. The fruiting "cut out" phase occurring node number is also important as a measure of earliness and nearing of crop maturity.

In early varieties of cotton, physiological problems occur particularly in Russian short branched cluster fruiting hirsutum and barbadense cottons. In such genotypes like PRS 72, K 3400, C 1412 of hirsutum and SB 289 E and SB 1085-6 of barbadense, a number of young bolls dry up remaining firmly on the plant. Similar drying has been reported in an early variety "Oltan" of Iran also to the extent of 30-35 percent. These short sympodial cluster-genotypes could not be effectively used in developing locally adaptable cultivars but have been used as male parents of certain prominent hybrids. Such boll drying contributes to higher trash content in cluster boll cottons.

In China (PRC), short duration varieties Zhong Mian Suo 10 with 115-120 days duration and Heishan Mian 1 of 117-122 days duration are under cultivation. Yugoslav Kekchi Acala is also early with short maturity and early boll formation. Del Cerro and certain storm proof cottons of USA are also reported to be early besides some super okra types having reduced stature and earliness.

In India, Sundaramurthy et al (1994) reported the development of short duration cultures 70E and 7OG with 150 days duration, besides hybrid cottons CDHB 1 and CDHB 2 (in hirsutum x barbadense F1) with 150 days duration. The authors have claimed that these genotypes fit well into the IPM concept as they are semi dwarf, early and require less plant protection chemicals. The USA classification and Indian situation indicate 135-160 days to be considered as short duration, 165-190 days as medium and 200 days and above as long duration. Use of cernuum types from N. E. Hill region of India contribute to early maturity and moderately increased boll size with short staple in *G. arboreum* cottons.

Conclusion

Short duration varieties are desirable only for specific locations, since medium duration varieties of 165-190 days are adequate for many other situations particularly major rainfed areas with only one crop in a year. Short duration varieties suffer from somewhat reduced yield potential, lower staple and lower maturity of fiber compared to medium duration cottons. Besides genetic factors, other environmental and cultivation factors also affect total crop duration in practical agriculture. Yields in short duration varieties are also more likely to be affected by adversities like heavy rains at picking and severe attack by bollworms resulting in loss of the valuable first flush and without any rejuvenation potential. However, there is a need for augmenting the genepool at the National Cotton Gene Bank of India at CICR, Nagpur, for the lowest crop duration ranges and various special plant characters contributing to reduction in crop duration so as to develop short duration cottons of 125 to 140 days with high yield potential and desirable fiber properties for specific areas. Some of the germplasm to be imported into India should include Chinese cottons No. 1, 3, 8, 10, ZHS 10, HM 1, short season barbadense cottons from Egypt, Mexican Queen, Acala clean seed, African hairy, Deltapine early, E 10, 21, E4433, Yugoslav cottons, Bulgarian dwarf, Astigo 4 and USSR types Turfansha Guza (arboreum), dwarf hirsutum mutant No.1 and several short branch or zero branch type and some recent Pima, Supima selections from USA and Israel. More basic studies of earliness characteristics need to be undertaken.

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Breeding for Early-maturing Varieties of Cotton

A.E. Egamberdiev, Uzbek Scientific Institute of Breeding and Seed Production of Cotton, Tashkent, Uzbekistan

The G.S. Zaitsev Uzbek Scientific Research Institute of Breeding and Seed Production of Cotton is Uzbekistan's oldest cotton breeding and seed production research center.

In order to improve breeding effectiveness, the Institute's researchers are engaged in improving theoretical understanding and new methods of breeding. Their primary objective is to develop early-maturing, medium-and long-staple cotton varieties combined, with high yield and improved fiber processibility with host-plant resistance to diseases, particularly verticillium wilt, and pests that would readily lend themselves to modern methods of cotton cultivation and harvesting. The Zaitsev Institute tries to make its contribution to the cause of raising productivity in their country's agricultural sector by genetically improving plants and using them in effective ways. In order to breed early-maturing, high-yielding cotton varieties efforts have been made simultaneously to accumulate genes conferring resistance to many pathogens of *Verticillium dahliae* fungus. The breeding material is assessed for resistance to verticillium wilt, bacterial blight and root rot by developing special infectious environments.

In recent years, Uzbekistan has been expanding areas under grain crops at the expense of cotton. Thus, by the year 2000 the irrigated areas planted to cotton and grain crops will respectively amount to 1.5 million hectares and about 1 million hectares. But all such structural changes notwithstanding, cotton is destined to retain its position as the preeminent national crop, the principal factor determining the economic future of the Republic.

As Uzbekistan has emerged on the world market as an independent cotton power and as the relationship between cotton consumers and suppliers is being increasingly put on a market footing, fiber quality is rapidly gaining importance. As a result, Uzbek cotton breeders are faced with a major task of developing early-maturing varieties capable of giving stable high yields of fiber and seed.

At present, there are 19 cotton varieties cultivated in Uzbekistan, including 17 medium and 2 long-staple ones. Decisions as to which varieties to use where are made on the basis of plan targets and the requirements of the textile industry in terms of various fiber types. These requirements are outlined as follows: Type I-0.4%; Type II-0.4%; Type III-5.0%; Type IV-24.0%; Type V-69.0%; and Type VI-0.4%.

Let's talk first about long-staple cotton. Southern Uzbekistan is known to possess soil and climatic conditions as well as sufficient heat resources uniquely favorable for growing long-staple cotton. Long-staple cotton has been cultivated in the Surkhan-Darya, Kashka-Darya and Bokhara regions for ages, but particularly in the 1980s the area planted to these types was expanded. From 1970 to 1986, the area planted to long-staple cotton increased from 70,000 hectares to 204,000 hectares; seed cotton production reached 587,000 metric tons. Uzbek breeders developed the world's earliest-maturing, high-yield and high-quality cultivars highly adapted to local conditions and suitable for mechanical picking (C-6037, Termez-14, Termez-16, Termez-24, Karshin-8 etc.), yielding Type II and Type III fiber. Recently, new cultivars yielding Type I fiber have been developed (Surkhan-8 and Termez-34).

Long-staple cotton cultivation had an economic boon for Uzbekistan's growers. Starting in 1989, however, the area planted to long-staple varieties began declining; by 1996, it has shrunk to less than 20,000 hectares.

Cotton farmers have a rather vague idea of market conditions and hence see no point in producing long-staple cotton. Thus, in 1995, the purchase prices for a metric ton of seed cotton were 34% higher than for Type I; 19% than for Type II cotton; and merely 10% than for Type III cotton. In other words, the purchase price differential was not large enough to make the extra cultivation expenditure worthwhile. So the price list for the 1995 season provided little incentive to boost the production of long-staple cotton. The situation in the long-staple cotton sector demands, we believe, urgent remedial action, above all, to meet the Uzbek textile industry's demand for valuable fiber. According to A/O Uzlegprom estimates, the 1996 fiber demand (Grades I and II) amounts to some 17,000 metric tons, which translates to a planted area of at least 40,000 hectares. Given certain conditions, long-staple cotton can be highly competitive on the export market, bringing extra hard currency earnings into the country's coffers. Besides, it should be borne in mind that in terms of quality, Uzbek cotton is every bit as good as any foreign cotton.

Breeding of Early-maturing Cultivars of *G. hirsutum*

Earliness is an important trait providing for timely harvesting of high-quality cotton. It is a complex and polygenic trait, a result of interaction of a large number of genes. For this reason, breeding for earliness depends largely on the exploration, replenishment and utilization of the world genepool.

It is well known that cotton originally came from the equatorial areas of Asia, Africa and America where its wild varieties are represented by perennial trees with a small boll and short, usually colored fiber. As the cotton plant migrated to northern areas with their colder climate and longer days, natural and artificial selection, hybridization and mutation pressures resulted in the emergence of numerous early, high-yielding, big-boll forms and varieties with a long, white fiber and sympodial type of branching, adapted to the longer days. This process is still going on in all cotton growing countries of the world. The *G. hirsutum* varieties are the most widespread in the world, accounting for over 90 percent of the entire global area planted to cotton. Another 8-9 percent constitute the share of the *G. barbadense* varieties.

In Uzbekistan, the *G. hirsutum* and *G. barbadense* varieties account, respectively, for 96 percent and about 3-4 percent of the entire area planted to cotton. Since the Uzbek cotton industry is the northernmost in the world, with longest days, its need for early-maturing varieties is particularly acute. The importance of earliness even increases, in particular, during unfavorable years with a rainy and cold spring necessitating replantings, as well as early frosts in the fall; under such conditions, the fate of the crop is almost entirely dependent on the earliness factor. A special group of researchers at the Zaitsev Institute works exclusively on developing early-maturing cultivars. They have immense help in their endeavors from the Institute's world cotton collection which contains in excess of 10,000 varieties, including over 200 perennial forms of cultivars and wild varieties from 107 countries of the world.

Besides annually replenishing, renewing and reproducing this collection, our researchers also seek to find or create new germplasm by crossing wild and ruderal forms with cultivated types. The overwhelming majority of cotton cultivars introduced to Uzbekistan are of a late-season and low-yielding varieties, while early-maturing cultivars are highly susceptible to verticillium wilt. Hence they cannot be directly utilized for commercial cultivation and can only serve as raw material for breeding purposes.

The onslaught of grain crops has ignited an interest in ultra early-maturing cultivars which allow replanting.

Bearing in mind the importance for the country of early and ultra early-maturing varieties, in 1995 the world collection underwent a review and about 500 strains whose growing period does not exceed 105 to 110 days were isolated. However, many of them are susceptible to verticillium wilt. So far 15 strains meeting all breeding requirements in terms of earliness and other economic traits have been isolated and subjected to thorough examination. But distant hybridization by way of crossing wild and ruderal forms has been proven to be the most effective method of breeding for earliness. Thus, the subspecies punctatum and yukatanense have been revealed to possess donor properties in terms of earliness.

The Institute has been the first to demonstrate the high effectiveness of utilizing the wild forms of the *G. hirsutum* punctatum and mexicanum races for the purposes of breeding and genetic research aimed at developing and commercializing early-maturing cultivars exhibiting comprehensive resistance to verticillium wilt and an improved yield of high-quality fiber. The Institute has proven the feasibility of developing varieties combining earliness with resistance to verticillium wilt; developed methods of selecting ecologically distant hybrids; and conducted genetic analysis of the way economically valuable traits are inherited in a system of diallel crossings. Thanks to theoretical advances in developing early-maturing, wilt-resistant forms and a new method of selecting parent lines, our researchers have bred and passed on for testing dozens of new, early-maturing cultivars. Some of them have already been accepted for cultivation, planted over most of the area under cotton (see table), and found to fully meet the requirements of the farming and textile sectors in terms of economically valuable traits. More recently, new early-maturing and wilt-resistant varieties have been developed (C-6532, C-5620, etc.) with a fiber turnout of 40-41 percent.

The new cultivars bred and commercialized over the last decade (C-6524, C-6530, Namangan-77, Fergana-3, C-9070, Bokhara-6, 175-F, Kzyl-Ravat and Yulduz) have been instrumental in enhancing by a considerable margin the quality of the cotton fiber and of the derivative products. Namangan-77 has become a standard whenever Type V fiber is required, while C-6524 for Type IV fiber. Further expansion of the area under these cultivars will be an important factor in improving the economics of cotton farms, cotton processing and textile industries. According to HVI studies of fiber quality performed by Sifat Company, the cotton varieties cultivated in Uzbekistan in their totality are in no way inferior to the cultivars used in other countries and are eminently capable of competing in the world market.

Breeding and genetic research into medium-staple cotton varieties marches on relying on the world collection and the newly synthesized genepool.

The genepool used in the breeding process is constantly augmented with new gene sources, particularly from among wild varieties. Thus, the species *G. aridum* has yielded fiber strength,

Characteristics of Commercial Varieties of Cotton
(G.S. Zaitsev Uzbek Scientific Research Institute of Breeding and Seed Production of Cotton)

Varieties	Year of Introd.	Planting Area Thousand Hectares				Growing Period Days	Yield Centners Per ha	Boll Weight g	GOT %	Fiber Length mm	Breaking Load g/cm	Metric Numb	Relative Break. Load g/tex	Fiber Type
		1993	1994	1995	1996									
C-4727	1961	128.0	109.1	112.0	100.7	130	40.0	6.3	36.0	33.2	4.7	5600	26.2	Y
Kzyl-Ravat	1976	18.3	14.9	11.3	10.2	135	44.0	5.7	35.0	34.0	5.0	5860	26.4	Y
C-6524	1983	217.0	171.0	157.0	73.4	125	46.5	5.9	33.0	35.2	4.5	6350	28.5	IY
C-9070	1990	68.5	67.5	35.5	28.7	120	43.2	6.5	32.0	34.6	4.6	6000	28.8	Y
Fergana-3	1992	60.0	128.0	165.0	282.7	125	45.5	6.5	35.5	33.6	4.6	5650	26.0	Y

donors *G. thurberi*—fineness and length donors; *G. aridum* and *G. thurberi*—wilt resistance, donors *G. sturtianum*, *G. aridum* and *G. triphyllum*—donors of resistance to sucking pests; *G. morilli* and *G. punctatum*—fiber turnout donors. The hybrids with the subspecies from Yucatan (Mexico) are distinguished by virtue of earliness and resistance to verticillium wilt. Interspecific hybridization and colchiploidy of *G. hirsutum* with the wild diploid species *G. trilobum* yielded a wilt-resistant, early-maturing Dier variety and a number of promising lines.

Thus over the years our researchers have created a rich cotton genepool widely used in breeding programs to continuously develop new cotton varieties possessing desired traits on a new genetic basis.

Problems in Breeding for Short Duration Cottons

Lastus K. Serunjogi, Agricultural and Animal Production Research Institute, Serere, Uganda

Introduction

Short season or short duration cotton is desired for a number of reasons which vary with the production farming systems under consideration. Short duration cotton, however, is desired for, *inter alia*:

- Fitting both food and cash (cotton) crops in subsistence agriculture. This is where competition for labor could adversely affect the yield and quality performance of either crop type if long season cottons were used in the system.
- Avoiding drought in short production seasons especially with short rainfall periods with no supplementary irrigation.
- Successive production of cotton after other crops or vice versa in rotations aimed at diversified crop enterprises. This may even be in ecosystems where long seasons are potentially available but land available may not be adequate to permit concurrent cropping of various crops in large scale farming.
- Supplementing other methods for the control of or escape from late season cotton pests.
- Increased economic returns accruing from reduced costs on material input and on crop management activities in a shortened cotton season and in some cases from higher crop prices early in the marketing season.

In Uganda where 100% of cotton production area is rainfed, the labor, land shortage and short season constraints to cotton (*Gossypium hirsutum* L.) production are addressed by taking selection for earliness as one of the major criteria in the variety improvement program. This is supplemented further by the search for appropriate systems of multiple or intercropping cotton with legume or cereal crops to ensure food security and increased incomes for farming families (Elobu et al., 1994). Jenkins (1994) discussed the use of short season cotton as a supplement to host resistance in the management of pests. Ramalho (1994) reported the contribution of short season cultivars to the control of boll weevils (*Anthonomus grandis*) and pink bollworms (*Pectinophora gossypiella* Saunders) in Brazil where they are major cotton pests. Anderson et al. (1976) found an increase in economic returns in analyses on the use of early season cotton strains in the Mississippi Delta. Bridge and McDonald (1987) reported on a major shift between 1978 and 1987 with extensive adoption of short season cultivars to 100% in the states of Mississippi, Arkansas and Tennessee. The switch to short season cultivars was complete in the USA by 1993 basically for their contribution towards pest management (Jenkins, 1994).

There are, however, reports on situations where desired use of short season cotton has been hindered by unfavourable climatic conditions. Ngigi (1994) discussed the rationale for preference of late maturing cotton cultivars in Eastern and Central Kenya to the early types. This was due to the late cultivars' intrinsic attribute of better utilization of the poorly distributed rainfall. The late maturing cultivars through longer gestation periods exhibited higher yields of better quality cotton than the short season types.

Various indicators are in use while expressing magnitudes of earliness in cotton. Among these are developmental traits associated with periods towards physiological maturity. They include, *inter alia*, days to first flower, days to flowering or to maturity which is when 50% of the plants are in bloom or are with burst bolls respectively for a given genotype. Another indirect parameter in common use is the percentage by weight (wt) of seed cotton (SC) from the first pick. This is expressed as:

$$\frac{\text{Wt of SC from first pick}}{\text{Total SC wt from all picks}} \times 100$$

This index was referred to as 'Maturity Coefficient' in studies by Hu et al (1993).

Factors affecting phenotypic expression of earliness in cotton are tetrapartite *viz.*

- The genetic constitution of the variety
- The natural environment which is critical in a sense that we may have no control over it and in essence determines suitability of a given location for cotton production.
- The management or farmer input environment over which we have most control.

- The interaction between the plant genetic component and the two types of environments.

Schulze (1993) outlined components of the natural and management environments while discussing limitations to cotton yields. The genetic and genetic x environment interaction factors are the major areas of concern in the breeders' endeavors for improving crop variety in desired agronomic traits including earliness to maturity and in quality aspects. There are, however, problems encountered in attempts to achieve genetic advances for earliness in cotton. This paper outlines these problems with emphasis to the 'New World' amphidiploid tetraploid cultivars *Gossypium hirsutum* L. and *Gossypium barbadense* L.

Problems in Breeding for Earliness in Cotton

Efforts for incorporation of the earliness trait in cotton could be pursued through development of appropriate line varieties or line mixture varieties (composites) or through propagation of hybrid varieties. The problems listed below as those encountered while breeding for earliness in cotton may not necessarily be critical. This is in a sense that with proper planning of research programs within available resources (genetic, physical and financial), plant selections with other desired traits in combination with earliness can be derived. It is the ease and rate of this derivation that is affected by the problems under discussion. The problems are categorized under

- Genetic and genetic x environment interactions
- Breeding tools and available resources
- Environment associated problems
- Planning, resource management, policy and dissemination of technology

Genetic and Genetic X Environment Interactions

Availability and Acquisition of Germplasm and Genetic Diversity

A starting point for a breeder is at the acquisition of or accessibility to germplasm pool for sources of genes. When such genes are introgressed into the existing breeder's populations or cohort, genetic variability for earliness upon which selection can be imposed is generated. The state of germplasm resources for earliness is discussed in other papers in this session. However, it would suffice to state that a breeder aiming for earliness is today faced with the need to 'create' or modify natural germplasm resources into more readily usable forms to serve this particular requirement for earliness. Examples of such newly created pools for multipurpose utilization, including breeding for earliness in cotton, is the germplasm from the Multi Adversity Resistance (MAR) program for pest resistance in cotton (Bird, 1982 and Thaxton and El-Zik,1994). The use of hierarchical open-ended (HOPE) breeding system reported for maize (*Zea mays* L.) by Crammer and Kannenberg (1992) is another example of new types of germplasm formulations extendable to cotton in breeding for earliness. Active participation by breeders in germplasm networks would enable accessibility to such new pools.

Costs for Elucidation of Genetic Basis of Earliness in Cotton Populations

Earliness in cotton is a metrical or quantitative trait governed by many genes which underlie cotton development physiological processes. There is therefore a need to study the genetic basis, inheritance modes and magnitudes of heritability involved in the expression of earliness in the cotton populations. Derivation of components of genetic variances for the traits using mating designs for example, Diallel design, NC Design I or II leads to identification of suitable parent stocks and breeding methods in the breeding program. The methods are time and resource consuming as discussed by Hauller and Miranda (1988).

Genetic Linkages and Association with Earliness

In the tetraploid cottons *G. hirsutum* and *G. barbadense*, the genetic linkage groups comprise 52 chromosomes. The genes contributing to earliness may be in unfavorable associations with genes underlying other traits and thus exhibiting cases of repulsion linkages. Studies for elucidating genetic association of earliness to other traits are therefore necessary in breeding programs. Presence of antagonistic genetic associations between say earliness and fiber quality traits would make concurrent improvement in both aspects futile. The breeding approach is to break linkage groups for favourable genetic recombination through recurrent selection cycles. Recurrent selection processes can lead to genetic recombination and increased frequency of favorable alleles in a population. The procedures were reviewed by Hauller (1985). The procedures though may require several gradual cycles or years and thus reduce on realized genetic advance. Further limitations on genetic gain for earliness may accrue from cases of tight linkages between traits or in cases of adverse pleiotropic gene effects.

Positive associations with earliness though have been reported for traits in cotton. These include cotton mutaits for leaf and bract traits for resistance to pests (Thaxton et al. 1985). Such associations are further useful for indirect selection for earliness by selecting for the easily recognized morphological traits, for example frego bracts.

Difficulties in Effecting Hybridization for Heterosis in Earliness

Heterosis for earliness in cotton has been reported in hybrid varieties. Singh et al., (1993) reported the development of intra - hirsutum hybrid 'Kirti' exhibiting crop duration periods shorter than that of other varieties by 35 days. Further the hybrid was more tolerant to bollworms than 'Hybrid 4' due to its early maturity. Basu, (1994) stressed that for hybrids to be successful, they should be early maturing in addition to other attributes of yield and quality. The problem in propagation of hybrids for earliness, however, lies in the lack of perfect male sterility and fertility restorer genotypic systems in cotton. This is coupled by the need for maintaining apiaries to effect pollination and fertilization of ovules into F1 seeds by bees. India, the leading producer of hybrid cotton, relies on abundant hand labor in rural areas for (Basu, 1994) emasculation and pollination. Such labor may not be easily available elsewhere and hybrid seed production would be expensive.

The Need for Identification of Suitable Selection Indicators for Earliness and Establishing Maturity Groups in Cotton

There is a need to identify utilizable selection indicators or parameters for recognizing earliness in cotton for uniform reference by cotton scientists. Different workers using different selection criteria for earliness may not be referring to the same problems or achievements. This is in reference to the use of days to first flowering versus the days to full bloom or to boll burst and the first pick seed cotton ratio in use in relation to physiological maturity. Further a question arises, is there away of establishing "Maturity Groups" in cotton for uniform references as in soybean (Glycine Max L.). If feasible the group should be handy in requisition for germplasm.

Presence of Genotype Environment Interactions (gxe)

Presence of gxe is a major concern in breeding for earliness in cotton. Large magnitudes of gxe reduce gains from selection for the trait. The (gxe) in addition complicate identification of superior cultivars for this trait. Estimation of the magnitudes of gxe call for increasing testing sites making the testing costly. Numerous methods for assessing stability are available. They enable breeders to rank cultivars by their levels of adaptability. However, their shortcoming is in the inability of these parameters to incorporate the mean yields and the stability in single index. Eskridge (1990) advanced a concept of safety-first rule to meet this requirement. The utilization of the resultant index though calls for excellent mathematical competence on the side of the user.

Tools for Ease of Accessing Genes and Effecting New Genetic Recombination

Conventional breeding methods discussed above for increasing frequency of alleles for earliness are tedious, time consuming and depend on a chance for attaining new useful gene recombination. There are, however, at hand new tools for easing identification of required chromosomal segments (genomic regions) associated with the expression of quantitative traits and even for their transfer to the genotypes under improvement through biotechnology (Stewart, 1991). Molecular markers, for example, "isozymes", "Restricted Fragment Length Polymorphisms" (RFLP), *inter alia*, are useful in identifying "Quantitative Trait Loci" (QTLS). Identification of QTLS for earliness in cotton would go a long way in reducing time for cycles of selection and for improving realized heritability. Beavis et al., (1994) discussed use of QTLS in maize breeding. Biotechnology on the other hand is a new tool capable of transferring genetic material from any form of life, a case which Stewart (1994) coined as 'Alpha and Omega" genetic resources. Stewart (1991) discussed in detail the advances in the application of biotechnology to cotton.

The problem at hand, however, is that not all cotton breeding programs have the capacity or access to such tools. International collaboration at the laboratory level would be an answer to the needy programs.

Unpredictable Changes on the Environment

Unfavorable and drastic changes in the environment, for example in climatic factors of excessive rains, drought or cloudiness, pose problems to breeding for earliness. They alter the testing environment required for identifying the suitable genotypes. Further, if such changes prevailed for long, it would be a blow to cotton production if all cultivars at hand were of the early types.

Proper Planning, Resource Management, Policy and Dissemination of Technology

There is a need to plan and make decisions on whether development of either one or both early and late maturing types is required. This would arise if wide variations in environmental conditions existed in the production areas. If development of both types is required, would it require separate breeding programs? Answers to this may call for special studies on correlations of traits and advances for the trait through selection across different production ecosystems and on existence of genotype x production system interactions. Decisions should be also tied to available resources (genetic, physical and financial) and the economic returns expected from the venture. A need for decisions on this issue was encountered by May and Bridges Jr. (1995) when faced with the need to replace soybean crop after wheat with late planted cotton.

- The decision on developments in a breeding program may be greatly influenced by the government policies on cotton production, especially on private varieties, in a given country.
- The mode of disseminating the resultant improved cultivars for earliness (technology) to the end-user clients (farmers) may also influence the planning and execution of breeding efforts for earliness. In Uganda, a centralized cotton seed scheme where farmers rely entirely on public varieties is in operation. Seed propagation goes through successive waves of production where a small production area supplies seed to a larger zone in the next cotton cropping season. In such circumstances only one type of either early or late type can be developed.
- Industrial preference for particular quality may dictate on whether early types would be developed, if earliness was correlated, say, to desired fiber quality traits.

Conclusion

Problems while breeding for earliness in cotton may not be critical as they could be handled through rationalized visualization of varietal requirements for a given production area. There is also a need for proper planning of the breeding programs and management of resources at hand and for decisions on how the resources could be shared between efforts for early versus late maturing types.

Further suggested areas of exploration by cotton breeders for reduction of time and costs of developing early cotton varieties are

- Seek accessibility to new genetic resources through participation in germplasm networks.
- Seek accessibility to breeding tools through regional and international collaborative research.
- Use of modern information networks and publications.
- Cotton scientists reaching a "universal" agreement on indicators for earliness in cotton and/or establishing "maturity groups" in cotton.

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How A Short Season Changes Physiological Needs of the Cotton Plant

Zahoor Ahmad and Muhammad Nawaz Malik, Central Cotton Research Institute, Multan, Pakistan

@HEAD, MAIN = Introduction

Cotton is perennial by nature and has been domesticated as an annual to overcome crop production and protection problems. Earliness efforts started two centuries ago but real gain was made after the second world war. The boll weevil invasion and bollworm damage to late season bolls, besides development of stripper harvesting, led to short season cotton in the USA. Breeders responded with the development of new varietal types adapted to the crowded environment. These varieties have small plant size, rapidity of fruiting and storm resistance. These varieties set and matured a crop of cotton in a shorter span of time than did long season indeterminate types, a paramount quality for escaping pink bollworm damage and Heliothis threat and avoiding boll weevil damage. Rapid maturity and attendant senescence of the determinate genotypes countered the Heliothis and pink bollworm threat which the early researchers recognized as a potential hazard of long season cotton. A broader, more descriptive terminology gaining acceptance for determinate cottons and the manner in which they were farmed came to be known as "short season." These short cottons were structured to ease pest problems and reduce the amount of insecticides, nitrogen and irrigation. The cotton harvest could be effected in ≤120 days after planting in short season cotton, compared with long season cotton ≥ 180 days. The sweetpotato whitefly (*Bemisia tabaci*) threat in recent years has made short season cotton a nucleus of modern crop production strategy. The linchpin for success in the short season system is earliness and achievement of respectable yield.

Long Season Versus Short Season

Indeterminate cotton varieties are commonly used in a long, full season production system. Growers produce excellent yield of high quality lint by utilizing both the primary and secondary fruiting cycles (Fig. 1) available with the full season production scheme. This system works excellently where input costs are very low and the insect problem is minimal. In a typical full season system, the crop is planted in April, begins flowering in June, attains peak bloom in mid-July and moves into cut-out in mid-August. The secondary fruiting cycle or top crop would begin in late August and continue to early October.

Lint yield produced from the top crop is the primary incentive for pursuing a full season production approach. The amount of lint produced by a top crop appears to be a function of the fruit retention level during the primary fruiting cycle. Under normal conditions when the fruit retention is high, the top crop adds about 50 to 100 kg of lint/ha to the overall yield. However, when the fruit retention level during the primary fruiting cycle is low, the top crop can add up to 300 to 400 kg/ha of lint yield. The top crop is used to compensate for loss of early season fruit set resulting from poor management, bad weather and poor insect control. The downside of the full season production system includes continuing production inputs and insect control.

A cotton crop which could be matured by mid-September and which does not utilize the secondary flowering cycle has been named short season system. The primary objective of short cotton season system is to make best use of the available growing season to produce high yields of quality cotton at reduced cost compared to long season cotton. The major components of the system are rapid fruiting, early maturing determinate varieties, narrow row spacing and high plant population. This system of cotton production increases the amount of solar radiation intercepted by leaves and conversion of that intercepted energy-photosynthesis into usable products. The short season system is not suitable in subsistence agriculture. The short stature and early maturing cotton varieties have little capacity to recuperate from biotic and abiotic stresses experienced during the season. The main features of the two systems are enumerated in Table 1.

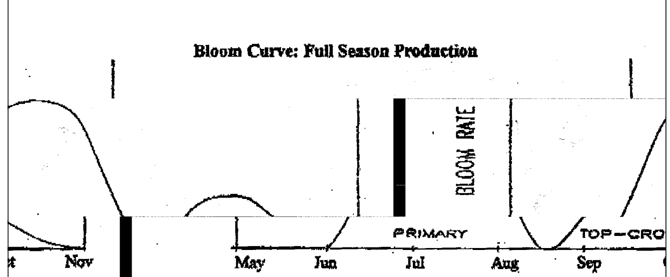

Figure 1: Typical Bloom Curve for a Full Season Upland Cotton Showing Secondary (top crop) Flowering Cycles.

Physiological Considerations for Short Season Cotton

The short season cotton production system compared with the full season cotton production approach offers several potential benefits to cotton growers. In an effort to capitalize upon the potential benefits derived from a short season production system, one must understand some physiological factors and manage them toward a short season production objective in a premeditated manner. Some of these factors include selection of a cotton genotype, earliness, irrigation management, soil fertility, insect pest management, defoliation, lint quality and ultimately yield potential.

Cotton Genotypes

Cotton being perennial in nature and having an indeterminate growth habit would continue to produce fruit in a favorable environment. Notwithstanding this inbuilt habit, the strong pressure placed by breeders to push the crop to produce earlier (Niles, 1970, Bridge and McDonald, 1978) led to the classification of some cultivars as determinate and others as indeterminate (Eaton, 1955). Determinate cultivars are generally classed as early or short season while the indeterminates are referred to as late or full season cultivars. Genetic variation for earliness and for plant interaction with its environment certainly exist in the Gossypium germplasm base (Table 2, Fig. 2)

The data show that breeders have developed cotton cultivars that produce higher yield in a short time than the standard traditional cotton cultivars.

On the other hand, there are several management practices which lead to cotton earliness and ensure success of the short season cotton system without any loss in yield. For better cotton management, the knowledge of developmental events, phenology, is essential to make the short season cotton system successful. Plant mapping is a practical and efficient tool to understand growth behavior and a plant' s responses to its environment, anticipating the current limiting factors and providing the growers with the information they need to make the best possible decision about the crop. Timing to take decision about application of inputs such as fertilizers, insecticides, irrigation, growth regulators and harvest aids is absolutely critical in the short season cotton system.

Table-1 Comparative Features of Long Season Versus Short Season Cotton.

		Long Season Cotton System	Short Season Cotton Syste
	1.	Indeterminate cotton varieties	Determinate cotton varieties
	2.	Slow fruiting and late maturity	Rapid fruiting and early maturi
)	3.	Two fruiting cycles (Primary and Secondary)	One fruiting cycle (Primary Onl
	4.	Low plant density	High plant density
d fertilizer	5.	More irrigation and fertilizer	Reduced irrigation a
tion	6.	More soil compaction	Reduced soil compa
	7.	Prune to insect damage	Avoids insect dama
ost	8.	High insecticide cost	Reduced insecticide
ice	9.	Insect resistance	Avoids insect resista
	10.	High energy input	Low energy input
for double cropping	11.	Less time for double cropping	More ti
or progressive and sustainable	12.	Suitable for subsistence farming	Suitable farming
of harvest equipment	13.	Non efficient use of harvest equipment	Effect us
ving and cost effective	14.	Labour intensive and less cost effective	Labour s
ental friendly.	15.	Environmental hazard	Environ

Table 2. First and second harvest and percent first harvest for different cotton genotypes.

pes	First Harvest	Second Harvest	Total Yield	Percent First Harvest	Genoty
		(kg of lint/ha)			
	562	314	876	64	CAB-CS*
	545	381	926	59	C316-91*
397	506	903	44		DPL-50*
560	328	888	63		Niab-78**
492	420	912	54		CIM-240**
314	512	826	38		MNH-147**

on Cultivars
Cotton Cultivars

* USA Cott
** Pakistan (

The ability to be on time determines the success or failure of a short season cotton production system.

Earliness

Earliness is a main feature of a short season cotton system. Several plant features contribute to earliness: Fruiting branches starting at lower nodes, high retention of early fruit and rapid boll maturity and opening. Cultivar, weather and management influence all these parameters of earliness.

Node Number of the First Fruiting Branch

The main component of earliness is the first sympodial main stem node number. The cultivar has a strong influence on first sympodial node number and breeders have used this to move fruiting higher or lower on the plant. Short season cotton varieties begin fruiting at main stem node 5 to 7 but there are varieties which bear the first sympodial at node 9 and above. It has been estimated that one node increase in the sympodial branch number delays crop harvest by approximately 4 to 7 days. Thus a 5 node range in varieties represents a potential 20 to 35 days delay in harvest.

Weather also influences the first sympodial node number of the main stem. If the weather is extremely cool or hot during the early weeks after planting, fruiting will start at higher main stem node number. If the weather is warm and ideal (maximum 32-35°C, minimum 23-25°C), fruiting will start at a lower main stem node number. Adverse weather conditions can make a difference of 1 to 3 nodes compared with ideal weather conditions.

Management also influences the node number of the first sympodial branch. If the plant density is excessively high (60,000

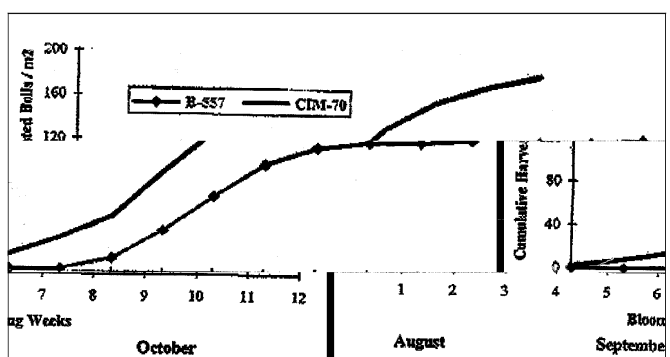

Fig.2 Fruiting Pattern of Cultivar B-55'

plants/acre), the node of the first fruiting branch is raised by one node compared with low density (20,000 plants/acre). High density also lengthens the flowering rule: The time interval between flowers both up the plant and out the sympodial branch increases by approximately 10 percent. High fertility and excessive irrigation also raise the node number of the first fruiting branch.

Flower Bud Shedding during Squaring Phase (High Fruit Retention at Lower Nodes)

The retention of fruit at lower nodes is a key to success in a short season production system. Genotypes differ greatly in physiological shedding during squaring phase (Table 3).

Genotypes susceptible to heat stress shed a large number of fruiting bodies and grow rank. The effective fruit setting starts when temperature becomes favorable (max. temperature >35°C, min. temperature <25°C).

@HEAD, MINOR B = Fruit Retention at Lower Nodes

Genotypes which are tolerant to heat are determinate in character; set fruit at lower portion of the plant; and are suitable for short season cotton systems (Table 4). In contrast, genotypes susceptible to heat stress, set fruit at higher nodes and produce more yield at the top portion of the plant. These genotypes fit in full season cotton production systems.

Rapidity of Fruit Formations

Rapid fruit formation is necessary for the short season cotton system. There are appreciable differences among genotypes (Table 5) in rate of fruit formation (vertical fruiting interval, horizontal fruiting interval). Rapidity of fruit formation seems to be a heritable character and genotypes could be bred for short season cotton systems.

Fertilizer

The largest input world over with respect to fertilizer in most cotton fields is that of nitrogen. The important fact of nitrogen fertilization in cotton, besides the total rate, is that of timing and incremental additions of N fertilizer through the course of the growing season. In general, adequate quantities of N fertilizers are applied to fields with higher yield goals. In the short season production system, the timing of fertilizer applications becomes perhaps even more critical than the total quantity of nitrogen fertilizer prescribed for the whole season. Nitrogen applied too late in the season in a crop intended for early termination could extend growth and delay maturity. Nitrogen deficiency in early growth stages in the short season cotton production system would limit plant structure, leaf area expansion and potential fruiting sites and pose a real threat of possible reduction in yield potential.

Table-3 Ranking of cotton genotypes in flower bud shedding during squaring ase at Multan, Pakistan.

	Cultivars Rating		
ow	Medium	High	L
70 (10)	CIM-240 (22)	SLH-41 (25)	CIM-
78 (12)	CIM-109 (23)	SLS-1 (32)	Niab-
70 (14)	MNH-93 (24)	MNH-147 (36)	DPL-

Table-4 Genotype Variations in Various Physiological Traits having Bearing on Short Season Cotton Production System

Physiological Traits	Cultivars Rating		
	Low	Medium	High

7	≥ 8	≥ 9		
-57 -29 -121 579 79	GH3 CIM-1100 LRA-5166 S-12	AENB-1/85	First sympodial Node Number	CR DN CR BH FH

			NIAB-78 Cyto-10/91		
≥ 25 RA-5166 -12 ENB-1/85		Node Number Bearing first Effective boll	≥ 16 CRIS-5A DNH-29 CRIS-121	≥ 20 FH-679 NIAB-78 Cyto-10/91	

	BH-74	GH-3 CIM-1100		
ht	≥ 16 CRIS-5A DNH-29 CRIS-121 BH-74	≥ 20 FH-679 NIAB-78 Cyto-10/91 GH-3	≥ 25 CIM-1100 LRA-5166 S-12 AENB-1/85	Sympodial He (cm) Bearing First Effective Boll

128 10/91 -78 79 4	≥ 142 CRIS-121 DNH-29 CRIS-5A	Sympodial Height (cm) Bearing last Effective Boll	≥ 96 AENB-1/85 S-12 CIM-1100 GH-3	Cyt NIA FH- BH-

Fertilizer management in short season cotton should attempt to maximize the benefit from the production of early bolls. Early season nitrogen deficiencies can be compensated in full season cotton by taking advantage of the compensatory habit of the cotton plant, if the crop is provided adequate available nitrogen late in the season. In order to develop an efficient management strategy for a short reason cotton production program, this indicates the importance of maintaining an adequate level of available nitrogen early in the growing season to capitalize upon early boll production in the first flowering period. The potential fruiting sites depend upon the development of more fruiting branches early in the season along with sufficient photosynthetic capacity. In short season cotton systems, one should avoid late season build-up of elevated levels of available nitrate nitrogen. Soil and plant tissue analysis should be used to refine N fertilizer application in short season cotton. This includes preseason soil tests to evaluate residual nitrate nitrogen in the top two feet of the soil profile and petiole tests for NO_3-N during the course of the growing season.

Balanced fertilizer in the beginning of the season, including all major nutrients and micro nutrients, is essential for vigorous crop growth and early fruit set to exploit full potential of a cultivar. In determinate cotton varieties, suited for the short season system, the demand for nutrients arises more sharply than in indeterminate cottons. Soils with less than adequate level of nutrient supply are unlikely to fulfill the demand of a growing crop in the short season cotton system. Inadequate nutrient supply would limit plant size in addition to excessive fruit shedding early in the season. This

Table 5. Earliness and rapidity of fruit formation

Cultivars	Flowering Rule (Days)		60 % Harvest (DAP)	
al	Vertical Interval			Horizontal Inter
	2.2	145	NIAB-78	5.2
	2.7	150	CIM-240	5.7
	2.6	155	MNH-93	5.8
	2.9	162	CIM-83	6.2
	2.9	165	SLS-1	6.7

would limit the size of the crop in the first fruiting cycle and cause loss in yield.

Water Management

Water supply (rainfall plus irrigation) is the prime determinant of cotton yield. Scheduling irrigations for short season cotton is difficult because of its non-compensatory growth habit and high risk decisions.

Short season cottons develop plant canopy earlier and require water sooner than long season cotton. Because the narrow row system has a greater leaf surface, it has greater light interception and more evapotranspiration. The timing of first irrigation in short season cotton decides the yield potential as water stress has an impact on early squares retention. The first irrigation cannot be delayed without much sacrifice in yield in short season cotton.

Irrigation decisions become more critical during mid-season, as crop evapotranspiration rates are at their peak and there is a potential for young fruit failure. The mid-season irrigation scheduling should recognize the benefit of allowing a modest amount of crop water stress to accrue as the plant moves from a primarily vegetative growth habit to one that produces fruit. The balance between vegetative and reproductive growth is essential in directing photosynthates to young developing bolls. Crop water stress levels may be elevated gradually after mid-season irrigation to make the crop early.

In unstressed cotton, canopy closed 7 to 10 days following appearance of the first flower. Peak water demand does not occur until cotton rows are closed. At first flower, average crop water use is 0.2 inches per day whereas crop water use increases to more than 0.3 inches per day through plant cut-out. During this period, the water supply should match crop demand.

The timing of the last irrigation is crucial to harvest a uniform and early crop. Early termination of irrigation will result in loss of yield and poor fiber quality. Irrigation termination 3-4 weeks ahead of harvest may help to obtain a respectable yield and desired fiber quality. Short season cotton has a lower delta of water due to early withdrawal of water for crop termination. However, a regular water supply is a prerequisite for success of short season cotton.

In establishing mid and late water management, the focus should be placed on both the plant and the soil together. Cotton plant water status measurements are useful because they integrate root depth, available soil moisture and climate into one single assessment. Soil moisture evaluations, on the other hand, help to assess the quantity of water available at rooting depth and the ability of the plant to successfully mine soil moisture.

Each soil is unique in its ability to supply soil moisture, directly impacting irrigation schedule events. Obtaining information related to the soil water extraction pattern during the growing season is most useful and should be used with plant based monitoring methods like the pressure chamber to help guide irrigation decisions in short season cotton.

Cotton Quality

The long season production system provides a greater potential for high seed cotton yield but there is some evidence that diminished quality of cotton may result from bolls maturing late in the season (Table 6).

The cool weather during the later part of the season and plant aging reduce overall fiber quality. This occurs due to lower carbohydrate supply and low night temperature. High micronaire results from early season bolls due to greater supply of carbohydrates. The top crop resulting from second fruiting cycle in a long season cotton production system is likely to produce lower quality of fiber. The micronaire is likely to be affected seriously in top crop, coming from the second fruiting cycle of long season cotton. The short season cotton production system provides insurance against lower micronaire value.

The quality parameters such as staple length and strength are mainly genotype characteristics. The determinate and indeterminate cotton cultivars may therefore not differ in these parameters of fiber quality. However, micronaire and maturity are mainly an environmental phenomenon. The crop maturing early is likely to have high micronaire and more mature fiber than that maturing late in the season (Table 7).

The fiber strength could decrease from weathering of lint in the field (Table 8).

Research conducted in the USA showed that weathering in the field resulted in reduction of about 1 percent loss per week in fiber quality parameters such as staple length, strength and fineness. The studies conducted at Multan showed that highest quality of lint was obtained from bolls set in the month of September, with a slightly lower value in August-set bolls and progressively lower quality for those set in the month of October. These studies indicate that better lint quality results from short season cotton production.

Table-6 Fibre characteristics in relation to boll setting dates (Cv. CIM-109, Multan, Pakistan)

	ngth tex	Date of Boll Setting	G.O.T. (%)	Staple Length (mm)	U.R. (%)	Micronaire	Maturity Ratio	St
	.40	16.08.92	32.63	25.65	48.00	5.13	0.96	[illegible]
	.07	23.08.92	33.40	26.67	48.77	4.97	0.95	[illegible]
	21.30	30.08.92	33.00	28.19	47.87	4.37	0.9	
	21.17	07.09.92	33.50	26.67	47.17	3.90	0.[illegible]	
	21.37	13.09.92	35.23	25.90	47.37	3.37	0.[illegible]	
	21.217	20.09.92	35.67	25.65	44.57	3.33	0.[illegible]	
	19.47	27.09.92	34.89	24.38	45.30	3.07	0.[illegible]	
0.63	19.27	04.10.92	35.83	23.62	44.67	2.73		
0.53	-	11.10.92	37.44	21.59	44.07	2.30		
0.53	-	18.10.92	37.53	20.57	41.57	2.30		
0.02	0.61	L.S.D.(0.05)	0.72	0.01	1.10	0.09		

Table-7 Effect of Temperature on Micronaire (ug/inch) in Different Cultivars.

	Boll Setting Dates	Temperature(°C) during Boll Maturation Period		Cultivars			
-12		Max.	Min.	MNH-93	NIAB-78	CIM-109	CIM-240
4.90	16/8	32	26	5.40	5.15	5.13	5.83
5.81	[illegible]	23/8	32	24	5.42	5.10	4.97
4.93	5.13	30/8	33	23	5.25	4.92	4.37
4.43	4.43	7/9	33	22	4.72	4.44	3.90
3.63	3.20	13/9	32	21	4.38	4.22	3.57
3.47	3.13	20/9	32	18	2.92	3.25	3.43
3.07	3.23	2.95	27/9	31	18	2.65	2.56
3.73	2.30	2.86	4/10	30	17	2.60	2.50
2.30	2.30	2.80	11/10	29	16	2.60	2.50
2.30	2.30	2.80	18/10	28	14	2.55	2.40

Insect Pest Management

An effective and affordable pest control program is essential to achieve both earliness and optimal yield. Early in the season the focus must be on protection of young squares from insect damage. About 90 percent of yield in determinate cotton cultivars comes from the fruit set within the first four weeks of flowering. The square shed during the first three weeks of squaring is primarily due to insects with only 5-7 percent of squares shed during the first four weeks of squaring being from a physiological or other nature. As flowering starts and boll load begins to develop, fruit loss from physiological shed may increase due to factors inducing carbohydrate stress on the plant. That is not a problem in early season fruit.

The short season cotton system offers no compensation time for early season square loss, making protection of these squares more important than those formed late in the season.

Defoliation

The final production step prior to harvest in cotton is defoliation. In general, the short season production system offers better opportunities for cost effective defoliation because most defoliants are applied when temperatures are warm. Many crop preparation and defoliation chemicals are biologically active and work more quickly and effectively when warmer temperatures prevail.

Physiological Limits for Short Season Cotton

Cotton is perhaps the most complicated plant grown on a large scale in the world. It is a deciduous perennial shrub, grown as an annual and its growth duration is being shortened further to 120 days to overcome vagaries of weather and effectively control insect damage without causing any loss in yield.

Scenario 1

The structural development of the cotton plant allows its manipulation and shortening of the production season. The cotton plant produces fruit in the axil of each sympodial leaf, and these fruit are separated speciously and temporally along the plant. There is some minimum time required to form a given number of potential

Table-8 Weathering Effects on Fibre Characteristics of CIM-109 Grown at Multan, Pakistan

	Harvest Date	Staple length (mm)	U.R. (%)	Micronaire	Maturity Ratio	Strength g/tex	Dates
	26.16	45.40	3.75	0.84	20.13		01.12.92
	26.16	44.87	3.68	0.84	19.40		09.12.92
	26.16	44.87	3.72	0.84	20.53		15.12.92
	26.16	44.90	3.67	0.85	19.50		22.12.92
	26.16	44.50	3.67	0.78	19.33		29.12.92
	25.90	44.33	3.65	0.83	19.60		05.01.93
.16	44.50	3.72	0.84	19.40	13.01.93	2	
.16	44.53	3.68	0.85	19.13	20.01.93	2	
.90	44.77	3.63	0.82	18.77	26.01.93	2	
.90	44.50	3.62	0.79	18.33	02.02.93	2	
Sig.	N. Sig.	N.Sig.	N.Sig.	0.59	L.S.D.(0.05)	N.	

d for 60 days after full opening.

*Bolls weathered in the fiel

fruiting sites on the plant. In general, during the prime portion of the season, the vertical flowering interval is 3 days and the horizontal flowering interval is 6 days. The minimum time required for the plant to form 10 potential fruiting sites which are required for 1,235 kg/ha of lint at 74 thousand plants per hectare is 15 days. The average heat units required to mature cotton boll ranges between 500-600°C, and in calendar days it often happens in 45-55 days in most cotton regions. This shows that theoretically the cotton production period can be shortened to 105 days. Figure 3a shows the theoretical scenario for this calculation. It is assumed that all fruiting sites will form bolls which mature to harvest and there is no shedding of fruiting bodies during this period.

Scenario 2

Cotton plants do not mature all flower buds to harvestable bolls. Figure 3b shows that if 1/3 of fruiting forms abscise, the length of time needed would be 21 days to produce 10 bolls per plant.

Scenario 3

Cotton plants may shed half of fruiting bodies (Figure 3c) and in this case the length of time needed would be 24 days to set 10 bolls per plant.

These diagrams assume that 80-90% of yield on cotton plant is located on nodes 1 and 2 on the fruiting branches.

Option 1

The potential of achieving 1,235 kg/ha of lint can be achieved even in case of 50% fruit shedding by increasing plant population to 148 thousand plants per hectare.

Option 2

The cotton plant is capable of producing two fruiting sites at each node. The second fruiting site is about one week later than the

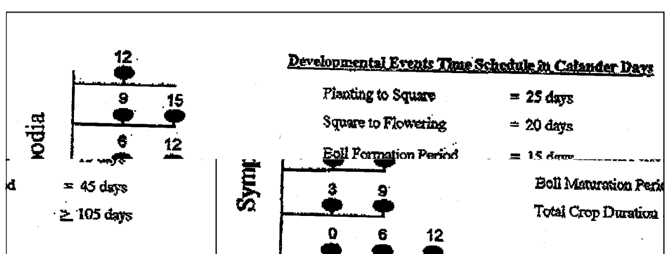

Fig 3a: Time Frame for Production of Ten Fruiting Sites

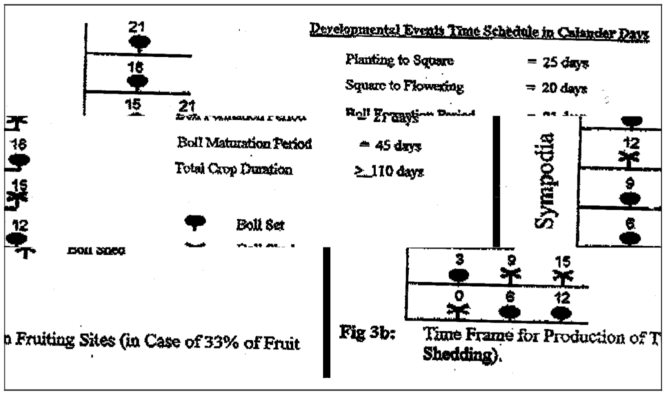

Fig 3b: Time Frame for Production of T… Fruiting Sites (in Case of 33% of Fruit Shedding).

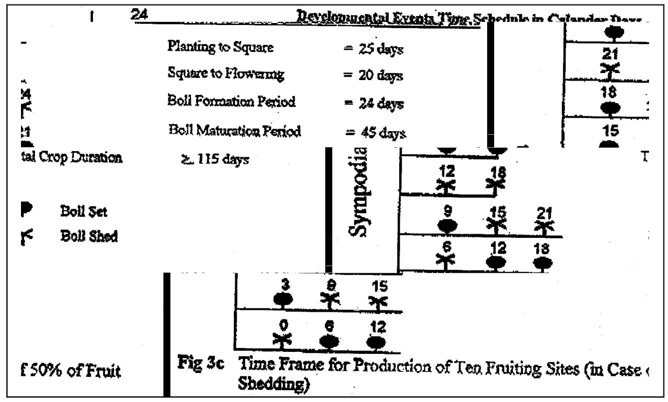

Fig 3c Time Frame for Production of Ten Fruiting Sites (in Case of 50% of Fruit Shedding)

first fruiting site. Use of this position could reduce by one third the time required for a given number of flowers.

These theoretical considerations clearly demonstrate a wide scope for producing an economic cotton yield in a short duration of time.

Conclusion

Short season cotton production is an increasingly attractive and viable option to cotton producers in the world to reduce production costs and avoid excessive use of pesticides. Gossypium germplasms for a short season cotton system are available which can efficiently be grown to harvest as good a yield as in the long season cotton system. A cotton production strategy that stresses earliness is central to profitability with the short season system. Aggressive early season management to ensure early reproductive development and maximum fruit retention is essential, and critical agronomic inputs: fertilizer, water, growth regulators, pesticides and harvest aids must be used carefully to optimize yields while minimizing production costs. Timing is absolutely critical in application of production technology in the short season cotton system. Just as the ability to properly time a response determines the success of a stand-up comic, the ability to "be on time" determines the success or failure of a particular practice in short season cotton systems.

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Impact of Short Season Cotton Systems on the Control of Insect Pests and Diseases

D.A. Russell and R.J. Hillocks, Natural Resources Institute, Kent, United Kingdom

Introduction

Most of the published work on the impact of short season cotton systems has concentrated on insect management in high-input, irrigated cotton of upland (*Gossypium hirsutum*) varieties. The advantages to pest control in these systems do not necessarily carry over to rainfed and especially small-farmer, low-input systems as we shall see.

The advantages of short season systems for boll weevil control had been apparent since the end of the 19th century (Howard 1898) but the impetus for the development of the current short season systems in upland, and later barbadense, cottons was the emergence of extremely damaging levels of a number of pest species, uncontrollable with toxic insecticides in the 1960s and 70s. In Mexico and South Texas, resistance problems with the tobacco budworm *Heliothis virescens* (Fabricius) resulted in decline in the planted area from 295,000 ha in Mexico in 1960 to little more than 500 ha in the early 1970s. The Texas gulf coast and lower Rio Grande Valley cotton area declined from 200,000 ha to 66,000 ha over the same period (Atkisson et al 1982). In large measure, these problems were induced by heavy chemical control of boll weevil (*Anthonomus grandis* Boheman) and pink bollworm (*Pectinophora gossypiella* Saunders), which reached 15-20 applications per season in the late 1960s. In California's Imperial Valley the cost of insect control had reached over $600 per ha by the late eighties (Chu et al 1992) and the cotton area had fallen from 60,000 ha to 5,500 ha in 1989 mainly due to failures in pink bollworm control.

Subsequently, other benefits of short season systems in addition to their pest control impact, such as the reduced period that the crop occupies the ground, avoidance of unfavorable weather conditions late in the season and yield improvements, have emerged and been capitalized on in-breeding and cultural practice developments.

The concept of short season systems is a relative one. A conventional cotton season in California's Imperial Valley covers 230-240 days while in the Missouri Botheel 140-150 days is the norm. A short Imperial Valley season may therefore be longer than the conventional Missouri season. Discussion of the effects of shorter season systems must therefore take account of the separate effects of the reduction in the time available for pest development and the periods of availability of particular (especially fruiting) structures. In general breeding for early crop maturity has frequently enabled damage by fruiting structure feeders (bollworms and budworms and boll weevil) to be avoided, but effects have been much less marked on organisms able to develop on a wider range of tissues (leafworms, thrips, plant bugs, fleahoppers, spider mites, aphids and whiteflies) (Gannaway 1994). Indeed the increased humidity in earlier closing canopies can have detrimental effects on sucking pest control.

The aspects of short season systems, as developed in the USA, having greatest influence on pest numbers have been the use of narrow row widths (increasing the efficacy of sunlight interception), reduction in water use (fewer irrigations and irrigation at higher percentage available water depletion levels), earlier and more compressed fruiting periods in varieties with a more determinate growth habit, shorter time to harvest, the use of plant growth regulating chemicals to terminate fruiting early and dessiccate the crop and the increased length of the cotton-free period. These attributes taken together resulted in the average percentage of the cotton area grown in early maturing varieties in 12 US states to increase from 23% in 1978 to 68% in 1986 (Bridge and McDonald 1987). The use of early maturing varieties and short season systems is increasing in irrigated cotton production worldwide. However, the compact fruit-set period also carries a risk to the crop if adverse conditions occur at that time, and careful protection of the early fruit from pests and diseases is necessary. The following summarizes the demonstrated impact of short season systems on a range of major pest species.

Boll Weevil (*Anthonomus grandis*)

Shorter seasons reduce the period available for insect development and so reduce the levels of overwintering populations. This effect is enhanced by the potential to have the ground free of host plants for more than five months of the year. However, it is the early start and compact flowering period of the short season varieties which allow escape from much of the boll weevil damage by ensuring that the main crop is set during the first post-wintering adult generation, which is generally much lower and less damaging than the second. Bolls older than 12 days are virtually immune from attack and a satisfactory crop can be set in the first 20-30 days of flowering (Atkisson et al 1982). In the Texas system, a single insecticide during early squaring to reduce female populations below 50/ha, with a second if required at 25% square damage, allows a 50 day insecticide free period before a third (and often last), application is required. This is frequently for bollworm control as much as boll weevil control (Heilman et al, 1979). Early termination by irrigation or plant growth regulator applications and harvest in late July/August before weevils enter diapause, helps prevent the build up of damaging overwintering populations. King et al (1993) showed how innoculative releases of boll weevil parasites early in the season can produce further benefits for control of the whole pest complex by removing the need for the early squaring insecticide application.

Pink Bollworm (*Pectinophora gossypiella*)

Pink bollworm shows an extended spring emergence from diapause (March-August in many areas) but a fairly rapid re-entry into diapause (mid-September to the end of October at latitudes around 30 degrees). Consequently, it is possible to use short season systems to ensure that a significant proportion of the spring emergence and the development of most of the potentially overwintering larval population, occurs when fruiting structures are not suitable for oviposition and development. Full season systems with a second fruiting cycle and a second pick in Nov/Dec may have the cotton in the ground for 10-12 months of the year, maximizing pink bollworm problems. Chapman and Cavitt had showed as early as 1937 that stripping all fruit in October reduced overwintering pink bollworm populations in the soil by 75%. The use of defoliants (like Drop = Thidiazuron) and dessiccants (like Prep = Ethephon) in late August was found to reduce overwintering populations still further (Henneberry et al 1992). Narrow row planting, probably through its effect on earliness, could also reduce the overwintering population by as much as 55% (Walhood et al, 1981). The same authors found that early irrigation termination (mid-July in the Imperial Valley) greatly reduced larval numbers in bolls and reduced the spring emergence from the soil, as measured by soil cage traps, without affecting first-pick yields adversely. This was true whether the cottons were short season forms or long season forms terminated early. The conventional cotton second cycle produced only a further 350 kg of seed cotton per ha at considerable extra expense in pink bollworm control and in development of overwintering populations. US experiments on the impact of short season cottons on this species are well summarized in Henneberry (1987).

These results encouraged the testing of a compulsory short season system in the Imperial Valley in 1990 (Nuessly et al, 1994). Irrigation was terminated in the second half of July, harvest aid or defoliant chemicals were used by 1 September and harvests were complete by 1 November (Chu et al, 1992). In the subsequent two years of the mandatory system, pink bollworm numbers, as recorded by pheromone traps and boll examinations, were steadily reduced. This gave great impetus to the spread of short season systems in the USA and beyond.

Other Bollworms and Budworms

In the New World, short season cultivars have been used to partially evade problems with *Helicoverpa zea* (Boddie) and *Heliothis virescens* in Texas (Norman et al, 1987) and elsewhere (Heilman et al 1979). Depending on the diapause cycles and availability of alternative host plants to these highly polyphagous insects, similar effects might be expected in the other species of the group *Heliocoverpa punctigera* (Hubner) in Australia, *H. geletopoeon* (Dyar) in southern South America, *Heliothis peltigera* (Dennis and Schiffermuller) in the Old World and *H. viriplaca* (Hufnagel) in Asia and the Middle East. Control of the biologically rather similar, though oligophagus, *Diparopsis* species (*D. watersii* (Roths) and *D. castanea* Hmps.) on African cottons should also be improved by short season systems but experimental changes in sowing date have not proved useful (Tunstall 1994). The terminal-boring and flower and square attacking propensities of *Earias* species (*E. insulana*, *E. vitella* and *E. biplaga*) make them a particular threat to short season cottons where significant populations are present early in the season (as in India/Pakistan, for example, but not in Egypt/North Africa). Whether the shorter period during which soft cotton tissues are available for attack and the longer cotton-free period in the winter will assist in *Earias* control depends critically on the availability of alternative malvaceous host-plants in these non-diapause insects (Reed 1994).

It should be noted that other factors such as the use of okra-leaf, nectariless and glabrous varieties (Henneberry 1987), fewer irrigations and irrigating at lower available soil moisture levels (Flint et al 1994) can also greatly reduce bollworm numbers.

Leaf Worms

Although a shorter season will provide less time for the build up of damaging populations, especially where desiccants and defoliants are used, there appears to be no clear evidence of important effects of short season systems on control of the main leafworm species: *Spodoptera littoralis* (Biosduval) in the Old World, and *Bucculatrix thurberiella* (Busck) and *Alabama argillacea* (Hubner) in the New World.

Whitefly (*Bemisia* sps)

Whitefly *Bemisia tabacci* (Gennadius) numbers are increased on stressed plants, possibly due to increased movement of phloem in the tissues (Flint et al 1994). There is therefore frequently a build up of infestations on plants after irrigations have ceased before harvest. As generation turnover is so rapid in these insects, bringing the pre-harvest moisture stress earlier in the season generally has the effect of moving the infestation earlier. Nuessly et al (1994) demonstrated that moving irrigation cut-off from 11 September to as early as 14 August had no useful effect on the numbers of adult whitefly per leaf right through to harvest. If the period of boll maturity is moved back to a time when it is hotter and drier there may be some beneficial effect on insect mortality. The extra stress caused by the compact fruiting period of short season varieties generally has the effect of increasing the risk of whitefly problems. Nectariless, smooth leaved and okra-leaved varieties offer a more useful contribution to control (Berlinger 1986). It is worth noting that the optimal water stress conditions (and leaf hairiness factors) for whitefly and bollworm control are diametrically opposed (Flint et al 1994).

Diseases

Provided short season cottons are selected for resistance to bacterial blight (*Xanthomonas malvacearum)* and vascular wilt (*Verticillium dahliae*) and *Fusarium oxysporum* diseases where necessary (e.g. Tamcot SP-21S, SP-37H and TX-CAMD-E, Heilman et al, 1979), they are subject to the same biotic constraints as the indeterminate types. verticillium wilt (*V. dahliae*) control benefits from early harvest by the reduction of late damage (Johnson et al, 1973). Liu et al 1990 gained a 27-50% reduction in the incidence of the vascular wilts from planting a short season variety in China. However, one important exception to the generally encouraging picture is with the leaf spot disease caused by alternaria fungi. This disease becomes a problem in upland cottons when the crop is predisposed to infection by potassium deficiency, when it can cause rapid defoliation of the crop, preventing the lint from maturing fully (Hillocks 1992, Hillocks and Chinodya 1989). The peak period of demand for potassium is during boll maturation. With determinate cottons, with most of the bolls maturing at the same time, potash deficiency can be more acute, resulting in early predisposition to alternaria leaf spot.

@HEAD, MAIN = Low Input Systems

These comments have applied particularly to high-input, irrigated systems. Where the crop is grown rainfed and with minimal inputs, as it is for example in much of Africa south of the Sahara, with smallholders rarely having more than 0.5 ha under cultivation, the relative merits of determinate and indeterminate varieties may be reversed. Recently in countries such as Tanzania and Uganda, restructuring under World Bank guidelines has led to the withdrawal of subsidies on fertilizer and pesticides and consequently their use on cotton has declined. Grown under such low-input systems cotton is vulnerable to moisture stress, nutrient deficiency and pest attack.

The cotton varieties grown in many of the main producer countries in eastern and southern Africa are derived from the Albars, (which were originally selections for bacterial blight resistance). The indeterminate habit of these African upland cottons provides a buffer against boll shedding early in the season due to lack of moisture or insect attack, allowing the plants to compensate by producing new fruiting branches later in the season, provided rainfall is adequate. Short season cotton insect control depends critically on the protection of early squares and bolls to protect yield. Where there is no moisture control and the high demand for nutrients over a concentrated fruiting period cannot be met with fertilizers, or where picking creates a period of intense labor demand which would be greatly exacerbated with a determinate cotton and especially where long and extra-long staple cottons requiring a lengthy growing period for optimum development are grown, short season systems are generally inappropriate. In countries such as Zimbabwe, where the small holder sector expanded greatly after independence to almost half the national cotton production, less importance is now placed on the development of short season cottons.

Conclusion

Short season cotton systems have provided clear benefits in terms of control of oligophagus fruit-feeding lepidoptera and boll weevil especially where insecticide resistance is a problem and moisture and nutrient stress are under grower control. In general, disease and insect pest control benefit from the longer period when the crop is not occupying the ground. Short season systems are more neutral with respect to other pests and may have significant disadvantages where high levels of input and mechanical harvesting are not an option.

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Cost of Production: Short Season vs Conventional Cotton

C.J. Steenkamp and H. de Kock, Tobacco and Cotton Research Institute, Rustenberg, South Africa

Introduction

Before we proceed it will be necessary to bring you into the picture of our line of thinking about short season cultivars. The request was to compare the production cost of short- season cultivars with ordinary cultivars. Led by the results, this paper turned out quite differently from what we initially set out to do.

For the production of fiber by the cotton plant a certain input of heat and radiation is necessary. A direct measurement of this is the cumulative day degrees (Figure 1). In the early season the accumulation is slow. As the season proceeds, the accumulation accelerates with a tapering off at the end of the season. Dippenaar (1988) defined the actual growing season as that period in which the mean minimum night temperatures exceed 13°C. The accumulative day degrees are calculated on the area under the temperature curve in excess of 13°C during the day. The cotton plant needs a minimum of 1,600 cumulative day degrees for maximum production. If the minimum night temperatures are plotted against time, a typical curve, as in Figures 2 and 3, will be obtained. The period during which the mean night temperatures are in excess of 13°C is the effective growing period of that specific locality. For growing ordinary cultivars this period should be 160 days long in other words the cumulative day degrees must exceed 1,600.

The cotton production areas in the RSA are projected upon this map (Figure 4) with a cumulative day degrees of 2,944 in the North compared to 1,780 in the South. In between there are areas with even fewer cumulative day degrees. Most of these areas do have enough days or accumulative heat for normal production with a day or two or a few heat units to spare This fit is so tight that if anything goes wrong and replanting is necessary, the remainder of the growing season is too short for the production of ordinary cotton cultivars. This was the motivation for breeding for a short-season cultivar. Looking at production costs only will result in an incomplete picture, therefore we will look at yield and income first.

Initially the fiber quality of short season breeding lines was all but satisfactory. From Table 1 it is clear that the quality of the latest breeding lines is up to standard.

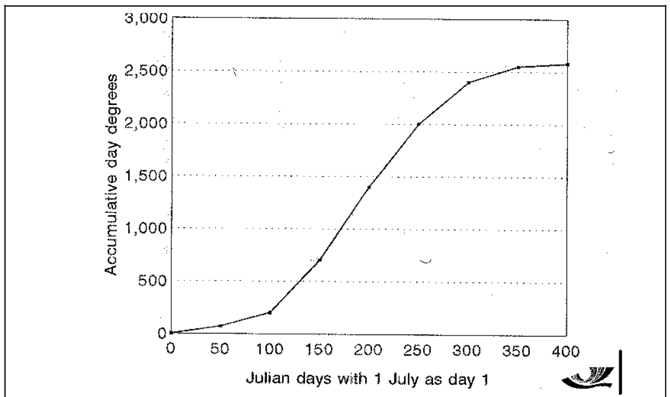

Figure 1 Accumulation of day degrees as the growing season proceeds

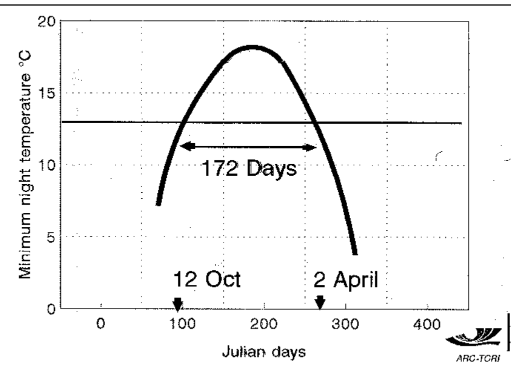

Figure 3 Mean minimum night temperature at Loskop taking July 1 as Julian day 1 for period 1974-87

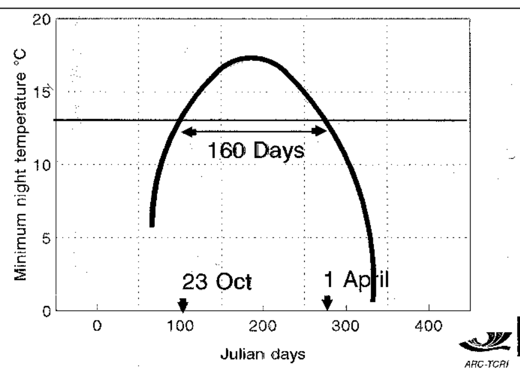

Figure 2 Mean minimum night temperature at Vaalharts taking July 1 as Julian day 1 for period 1972-86

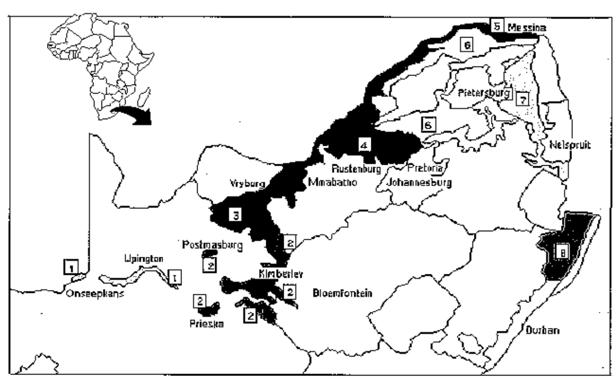

Figure 4 : Cotton Production Areas in the Republic of South Africa

Table 1. Data from early maturity trial at Vaalharts

Length	Unif	Strength	Mic	R/kg	Entry	Yield	Fibre	Income
		kg.ha	%	$/ha	mm.	%	cN/tex	
19/10/95								
7,40[illegible]	1[illegible]	4738	36.8	2933	29.9	48.0	20.4	36.[illegible]
5432	**30.2**	**51.0**	**22.1**	**4.0**	**8,889**	**2**	**6616**	**40.1**
3667	29.4	50.9	22.0	3.9	7.807	3	5743	36.8
6/11/95								
4.0	6,0739	1	2821	38.9	1515	28.0	52.8	16.0
40.8	**2403**	**28.8**	**53.1**	**22.0**	**4.4**	**7,807**	**2**	**332**
37.7	1799	28.9	52.2	22.4	4.3	7,807	3	269
5/12/96								
22.6	3.2	7,326	1	2213	34.8	1282	29.8	48.1
2763	**37.4**	**1833**	**28.7**	**49.1**	**23.3**	**3.7**	**7,807**	**2**
2441	34.5	1466	29.0	48.2	23.5	3.4	7,659	3

Table 2. Season length in days and days from planting to first picking

ason length	Days to picking	Planting date	Se
163	224	19/10/95	
6/11/95	145	206	
5/12/95	116	196	

This location with a long-term growing season of 163 days is one of the marginal cotton producing areas in the Republic of South Africa.

From Table 1, it is evident that entry 2 outperformed the other entries in seed-cotton yield and fiber quality irrespective the planting date (length of the growing season). Furthermore, it is evident that all three entries followed the same pattern. Only entry two will be discussed further. Quality of entry 2 is good even with a growing season of only 116 days.

The production data and fiber quality as affected by planting date are in Table 1 and season length and days from planting to first picking in Table 2. There was a dramatic decrease in the seed-cotton yield as well as income from planting date one to planting date 2 which was 18 days later (Table 1). This dramatic decrease levelled off between planting date 2 and planting date 3 which was 30 days later than planting date 2. Calculating the regression curves with only three planting dates is open to criticism, but because these curves for yield and income forecast plant behavior, it seems to be the only logical step (Figure 5 & 6). Entry No. 3 is Acala 1517/70 or the South African version thereof. It seems that natural selection over the years in the marginal areas resulted in this cultivar doing well in a short season.

From these curves the loss in yield (kg ha^{-1}) income (\$ ha^{-1}) per 6-day period was calculated. The six day interval was selected because it is the common numerator of 18 and 48 nearest to one week.

The loss per 6-day period in seed cotton production (kg ha^{-1}) and income in \$ ha^{-1} is given in Figure 7. A delay of only 6 days in planting led to a dramatic decrease in both parameters. For the next 6-day period the decrease was less dramatic, although it was still high, and for the next 6 days the decrease was even less. From day 18 onwards the decrease levelled off and was constant for the consecutive 6-day periods up to day 48.

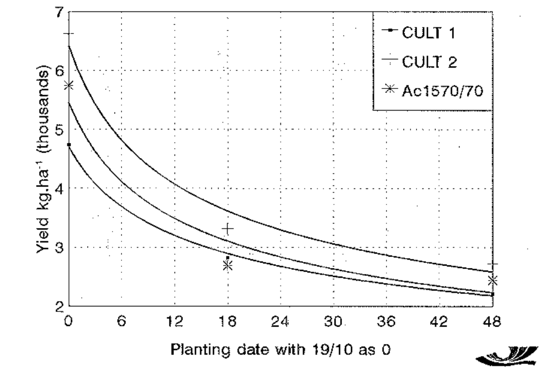

Figure 5. Seed-cotton yield of cultivars as influenced by planting date taking earliest planting date of 19/10 as day 0

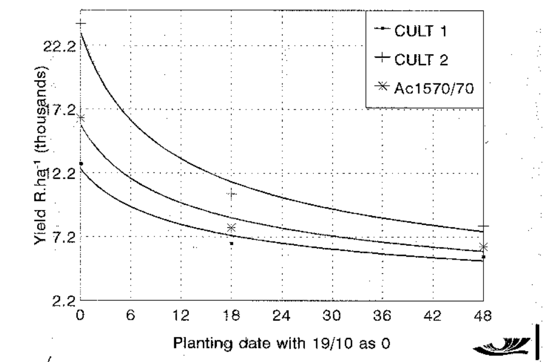

Figure 6. Income R.ha^{-1} from cultivars as influenced by planting date taking earliest planting date of 19/10 as day 0

Figure 8 shows the % loss based upon the yield (kg ha^{-1}) and income (\$ ha^{-1}) at the optimum planting date.

This shows much the same picture as that of the actual yield. The faster decrease in income, namely 45% for the first 12 days, indicates that the loss of quality with later plantings is higher than the loss in yield, which was 32% for the corresponding time.

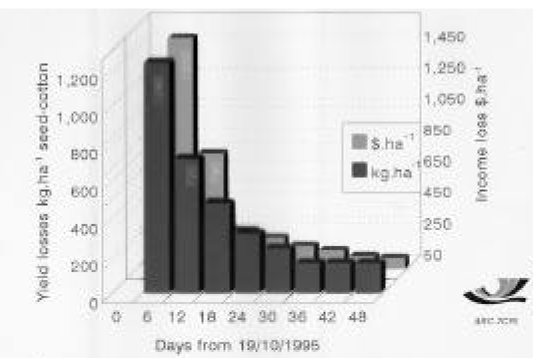

Figure 7. Yield losses per 6-day period planted later than 19/10/1995

Although the net yield of the latest planting (48 days later) was only 41% of the seed cotton (kg ha^{-1}) and 34% of the net income ($ ha^{-1}) produced by the first planting, a yield of 2.76 tons of seed cotton ha^{-1} is still an economical proposition if production costs are kept at bay. This breeding line has the advantage that, with a full growing season, it can produce a high yield of good quality. The steady decrease in yield and income cannot continue indefinitely; the question is, where does the bottom fall out?

The following main items make up the production costs:

Main Element of Production Costs

1. Seedbed and fertilizer
2. Planting
3. Weed control
4. Irrigation and fertilizer
5. Pest control
6. Harvesting

Because the first three items are fixed irrespective of the length of the growing season, the last three will make the difference. The integrated pest management program recommended in the RSA consists of only three sprays. It is unlikely that a short-season cultivar will receive less than this, so we can eliminate this item as well. Because fertilizer applications are based on a realistic target yield, some savings can be scored on this item. With the shorter growing season a few irrigations might not be necessary. Lower yields will result in lower harvesting costs. At most, these savings will amount to $250 compared to a loss of $2,600 in income. So you see, actually there is no comparison.

In planning for the coming season, in a marginal area such as this, the point of departure should be the setting of a realistic target yield. Research showed that corrective treatments can be imposed up to six weeks after planting, thereby raising the initial set target yield. In a high risk area such as this it is recommended that the initial target yield must be set at 2.76 tons of seed-cotton ha^{-1}. As the growing season proceeds, a new target yield can be set. Corrective measures, such as fertilizer applications to ensure that

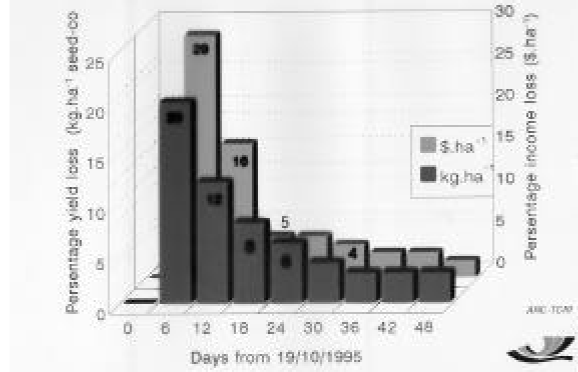

Figure 8 Yield as a percentage of that obtained with the full growth season for each 6-day period from 19/10/1995

the new set goal is reached, must be carried out within the first six weeks after planting.

Conclusions

- In the RSA we have an advanced cotton breeding line that can produce a good yield of acceptable quality with a growing season of 116 days. With a full growing season, this cultivar outperformed all commercial normal growing season cultivars in both yield and fiber quality.
- The lower input costs cannot by far compensate for the loss in yield due to a shorter growing season.

@BULLET1 = As a first option the full growing season must be utilized. The shorter the growing season the lower the yield.

@BULLET1 = If production costs are kept at bay, a profitable yield can be produced with a growing season of 116 days.

- The short-season cultivar is merely there to utilize the remainder of the growing season effectively if something goes wrong and replanting is necessary.
- This is merely the beginning. We have a promising advanced short season cotton breeding line which can produce a good crop with a growing season of only 116 days.

The Role of Early Cotton Varieties in Egyptian Agriculture

Ahmed El-Gohary and Mohamed El-Moghazy, Cotton Research Institute, Giza, Egypt

Egypt has had the potential to produce an extra-long staple cotton since 1840. The reputation of the Egyptian cotton was achieved by the experience of the research staff in its various activities such as breeding, varietal maintenance, agronomy, physiology, technology, plant protection and plant pathology, in addition to the fertile soil and the ideal weather.

Cotton is considered to be the milestone of the Egyptian economy due to its numerous derivatives such as lint, feed cakes, edible oils, etc. It also played a vital role in the Egyptian agricultural rotation in the fifties and sixties, when the area assigned to the cotton crop increased to more than two million feddans representing about one third of the total area in Egypt.

The credit goes to the efforts exerted by the Egyptian cotton breeders, who have been able to develop more than ninety different varieties, distinguished in both productivity and quality and which have contributed in saving more than half of the area for food crops and preserving the same quantity with improved quality.

Area, Production and Yield of Cotton in Egypt in the Last Six Years (1991-1996)

Year	Area Feddan[1]	Average Kentar/fed[2]	Production Kentar Lint[3]
1991	852,084	6.84	5,826,504
1992	840,296	8.51	7,147,518
1993	884,310	9.40	8,314,166
1994	721,443	7.10	5,064,608
1995	710,207	8.67	6,156,987
1996	930,000	9.00	8,310,000

[1] Feddan equals 4,200 m^2
[2] Kentar equals 50 kg lint cotton
[3] Estimated

Lint Yield and Fiber Properties of some Early Maturing Varieties and Promising Lines

Varieties & Lines	Lint Yield c/f	Season in Days	Fiber Properties				
			Micron.	Mill	Length 2.5%	Length 50%	Strength
Giza 77	9.01	190	3.6	143	34.6	17.6	34.5
Giza 83	10.50	170	3.9	152	30.7	15.1	28.1
Giza 85	10.30	170	3.8	147	30.0	15.0	30.8
Line[1]	11.40	165	3.8	158	32.4	16.3	33.2
Line[2]	11.35	165	4.0	165	30.1	15.1	30.1
Line[3]	10.58	170	3.4	142	35.4	17.8	35.2

[1] (Bahtim 105 x Giza 67) x (Giza 72 x Del Cerro)
[2] Giza 83 x Dendera
[3] Giza 84 x (Giza 74 x Giza 68)

The main features of the future policy of the Egyptian Ministry of Agriculture are increasing crop area, saving water and minimizing insecticide usage. In order to achieve this policy which is adopted now, many efforts of the cotton breeders are directed at earliness resources utilizing early maturing varieties, variations induced by mutations and introductions, etc.

A comprehensive breeding program was adopted with some modifications especially date of planting including the recommended and late dates after the winter crops had been harvested.

These efforts which were started more than fifteen years ago at two research stations in Upper Egypt and the Delta, have succeeded in developing three early maturing commercial varieties named Giza 77, Giza 85, and Giza 83 which belonged to the Egyptian extra long-staple (over 1⅜ inch) and long staple categories (over 1¼ inch). Three more promising lines are under propagation, two of which belong to the long staple, while the third one belongs to the extra-long-staple (over 1⅜ inch).

The development of early varieties has realized the policy of the Ministry of Agriculture in:

First: Increasing Crop Area

In l996, more than 900,000 feddans were cultivated under cotton and more than 50% of this area was planted after harvesting winter crops such as faba beans, sugar beets, vegetables and to a certain extent, early wheat and more than three cuttings of clover, the main winter forage in Egypt. Most Egyptian cotton varieties share these achievements, but the most successful ones which have responded to a great extent in planting after winter crops, are the early maturing ones Giza 83 and Giza 85 (Mubarak 93).

Many benefits were realized such as increased farmers income, sufficient green and dry feed for livestock and sufficient food crops like wheat and faba beans. More cotton area in the future, due to farmers capability to obtain another crop in addition to cotton the same year, will produce a sufficient quantity of food for local consumption and exportation. These benefits are achieved when cotton is cultivated after harvesting winter crops. Other benefits were also gained when the early varieties were planted early in the season or at the recommended dates, so the harvest dates would be mainly August or early September. The farmers would have a chance to benefit from their land in many ways.

Second: Minimizing Insecticide Usage

As it is well known, pink bollworm is one of the key pests in Egypt as well as *Earias insulana* in some locations, especially Upper Egypt where maize dominates as a summer crop and certain locations in Delta also, where vegetables are preferred as a competing crop in areas close to capitals of governorates. Heavy infestation of the aforementioned pests, beside aphid and whitefly in some areas, especially where vegetables are considered to be the main component in the rotation, is a serious issue in these areas. Infestation usually takes place late in the season, about the second half of July or the beginning of August and later.

Maturity and opening of more than 10% of bolls in early varieties coincide with the time of heavy infestation by the aforementioned pests. In addition to the compactness, the short statured varieties provide an unsuitable micro environment for whitefly build up.

Thanks to the early-maturing varieties, which are the milestone in the integrated pest management program adopted in Egypt including sex pheromone techniques, successful results in two governorates of cotton area have been obtained.

The 1995 season passed with less than one spray of insecticides in an area amounting to about hundred thousand feddans which recorded the highest productivity average of 550 kg lint cotton/feddan with high quality fibers. The estimated figures have ensured a significant increase in yield this season, 1996. These achievements indicate the comprehensive efforts exerted by Egyptian breeders in breaking the negative correlations among earliness, high yield and quality, through many crosses which were subjected to severe selection at different generations, selecting the unique ones and releasing three commercial varieties mentioned above. These fruitful results encourage the breeders to proceed in the short-duration varieties program.

Third: Water Saving

Limited water resources on the one hand and the rapid population growth on the other hand demand higher water use efficiency thus saving water for increasing crop area, adding new cultivated lands and to meet peoples' needs.

It is clear that the early maturing "short duration" varieties have become vital and of great importance. The new early varieties of about 170 days since planting until harvesting, instead of 200/210 days in other varieties, have given us the chance to save one or more irrigations which can be used for other purposes. Earliness is considered to be the milestone for intensification of the field crops program system which was laid out by the Agricultural Research Center and implemented through its research institutions.

Prospects of Short Season Cottons in Egypt

A.A. Abdel Bary, M.A. Bishr and F.I. Rehab, Alexandria University, Alexandria, Egypt

Introduction

The cotton genus *Gossypium* includes some forty species. These species differ in their nature of growth and growing season. Some species are perennial types which live for several years. Others are annual types which complete their lives in one year. However, all cotton species are perennial in nature. In other words, an annual type can survive for several years. Almost all cultivated cottons are treated in commercial production as annual cottons. Annual cultivated cottons differ also in their growing season or from planting date to maturity stage.

The two prevailing cotton species hirsutum and barbadense differ in their growing season. Hirsutum cultivars require 5-6 months to mature while barbadense cultivars take 7-8 months to mature. There has been a general trend in breeding to introduce short season cottons all over the world. Early maturity or short season cottons have several advantages. These include

- Economic use of land
- Less water
- Low cost of pest control
- Potentiality of introducing other crops with cotton

Egyptian cottons are long season type which require 7-8 months while upland cottons are short season with 5-6 months.

The Need for Short Season Cotton

The short season cottons have been a temptation to the Egyptian breeders. However, the high quality of Egyptian cottons hindered the introduction of the upland short season cottons in Egypt. Several Egyptian breeders went to the extreme of warning of the danger of introducing the short season upland type with its medium quality lint. However, the temptation of short season cottons was strong to invite several breeders to work for short season cottons. This paper summarizes the attempts to introduce short season cotton in Egypt. However, two main reasons are now pushing Egypt towards some short season cotton cultivars. These reasons are

- The food shortage and the pressing need to grow wheat or faba bean before short season cotton.
- The need of local textile industry for more medium quality cotton with a competitive price to suit the bulk of the local textile industry in Egypt as coarse fabrics for more local consumption.

Approaches to Short Season Cotton

Several approaches were followed to introduce short season cottons in Egypt. Four approaches were prominent among these trials. These were

- Selection within Egyptian *G. barbadense* cultivars
- Introduction of *G. hirsutum* cultivars
- Interspecific crosses between long season Egyptian cultivars and short season upland cultivars
- Vegetative propagation of cotton by plant cuttings

The following is a brief review of the work along these four approaches during the last twenty years in Egypt.

Selection for Early Maturity in Egyptian Cottons

Early maturity is an attractive property in selection programs of cotton breeding. There has been a general trend towards breeding for early maturity. The recent cultivars are in general early maturing than old cultivars. However, the shortening of the season did not exceed one or two weeks. The only exception was the appearance of Dendera cultivar which is grown in upper Egypt. During the flood irrigation before the Aswan High Dam, the land was flooded during August. Farmers used to pull cotton plants before maturity, leave them on roads until maturity, then harvest the open bolls. Appearance of Dendera in the early 1950s solved the problem since the cultivar completed its maturity before the Nile flood in late August. Dandara, however, suffers from lint immaturity, a large defect in the performance of the cultivar which limits its utilization in textiles. Thus its area has been always limited until the cultivar was replaced recently by other early maturing cultivars such as Giza 80, Giza 83 and Giza 85.

Introduction of Short Season Upland Cultivars

Although there have been several trials to introduce upland cultivars in Egypt, the most extensive trials were in the early 1970s and 1980s. In the early seventies, Rehab et al (1974) introduced a short season upland cultivar from the USSR known as 108F. The cultivar was produced by Russian breeders to suit the short season in USSR. The Russian cultivar was compared with two Egyptian cultivars (Ashmouni and Giza 69), the short medium and long staple cottons in Egypt at that time, together with Deltapine 15, an upland cotton from the USA. Two dates of planting (March and May) at three locations were carried out. May planting was carried out after wheat harvesting. Results indicated several conclusions. First, the short season 108F allowed growing wheat as a winter crop (November-May) and the short season cotton (May-October). Second, late May planting of 108F gave higher yield than all other three cultivars. Third, 108F had the staple length as Ashmouni but with somewhat weaker lint. Fourth, the Russian cultivar gave 97.2% of it's yield after 130 days compared with 92% for the early upland.

Another study was designed (11) to follow a rotation where cotton was grown with wheat on the same land with different winter crops such as wheat, faba bean and full clover crop. The three years study confirmed the previous conclusions although a different upland cultivar, McNair 220, was used. Also in 1971 (3), Abdel Bary proved a big difference in growing season between barbadense and upland cultivars in Somalia.

In 1981 (11), an extensive project was formulated by the Egyptian Ministry of Scientific Research to evaluate the short season cottons of upland cotton in Egyptian agriculture. Six universities, the Ministry of Agriculture, the National Research Center and the committees of textiles cooperated in the extensive project where the introduced cultivars were evaluated for four years over nine locations. The pressing forces behind the project were

- The need for more food crops
- The need for cheap cotton for the local industry
- The increasing import of upland cotton for the local industry in Egypt

Again that extensive project led to the following conclusions. First, in general upland cultivars were about two months earlier in maturity than Egyptian cottons, thus they matured in 4.5-5 months. Second, the upland cultivars grown late in June allowed the production of wheat before cotton, beside the high cotton yield. Third, the low cost of production in case of the short season uplands. Upland cottons grown in early June and harvested late in October exceeded Egyptian cultivars by 100% in yield in all regions for four years. McNair 220 gave an average yield of 13 kentars/acre compared with 5 k/acre for the recommended Egyptian cultivar at each region. Fourth, spinning performance of McNair 220 was satisfactory for medium counts required by the bulk of the Egyptian textile industry. These conclusive results left no doubt of the potentiality of growing upland cottons in a limited area in Egypt to satisfy the need of the local industry and increase food crops in Egypt. By the way, Egypt is the only cotton producing country where only barbadense type is grown. Fear of contamination of Egyptian cottons with introduced upland varieties hindered the introduction of upland cottons in Egypt in spite of all the previous favorable factors. Thus the third approach of interspecific crosses was natural.

Interspecific Crosses

At the same time of evaluating the short season uplands, Alexandria breeders started the difficult and tedious approach of interspecific crosses in 1980. The idea was combining the two major traits of upland with the high lint quality of Egyptian barbadense. The two desirable traits of Upland were short season and high yield. The two traits were proven by several works as stated before.

Several upland cultivars were crossed with several Egyptian cultivars in 1980. However, the most promising cross was between Alexandria 4 and Acala SJ2. Alexandria 4 is a high yielding glandless new strain (4) developed by Alexandria University in 1986. Acala SJ2 is a dominating upland cultivar grown in California, USA. The interspecific cross indicated a great potentiality of desirable combinations of cotton strains (5). However, the short season property was stressed throughout the last fifteen years in the derivatives of the interspecific cross. The work indicated that it was possible to isolate some early maturing or short season strains. However, it was difficult to combine the high yield with high lint quality. The undesirable link between high yield and high lint quality was quite obvious. That linkage was referred to by several authors (Abdel Bray, 1955 and El Enane 1981). Short season strains were isolated from the derivative strains of that cross (4). Both glanded and glandless strains were also isolated (4). Strains showing high yield and short season together with satisfactory level of lint quality were also isolated. At the present time, several short season strains with high yield and average lint quality in F_{15} generation are being evaluated against commercial cultivars.

In general, success of interspecific crosses of Egyptian barbadense x short season upland opened a new era in cotton breeding in Egypt. Several strains tolerating late planting in May and June without negative effect, on their yield were isolated (4, 5, 6 and 7). These strains require some five months to mature and leave a window for wheat crop before cotton.

Vegetative Propagation of Cotton by Plant Cuttings

That is the fourth approach of early maturity. We were studying the vegetative propagation to solve the problem of hybrid cotton. Since early fifties (16), hybrid vigor in cotton was proved. We

Figure 1: A Cutting Plant

were also able to confirm hybrid vigor in interspecific crosses in Egypt (8). However, the problem of maintaining a vigor in later generations and the difficulty of cross pollination to renew F_1 hindered utilization of hybrid vigor in cotton all over the world except in India.

We thought of vegetative propagation of F_1 to solve the problem. Starting 1960 (9), several trials were made. However, extensive work on plant cutting was done recently. Several graduate students completed their thesis work on the problem (15 & 16). To our surprise, the additional advantage of high yield in plant cutting was early maturity or short season. Advantages of cuttings were high yield, early maturity, better lint quality and less attack by bollworms.

The short season property was explained as a result of fast rooting of the cutting while high yield was explained as a result of the well developed root system of the cutting. Low infestation of bollworms was due to early formation of bolls. Several cultivars were compared by normal seed planting and plant cuttings. In all cultivars, cuttings gave high yield and about one month earlier in maturity. Yield increase was on the average about 50% over seed plants, while maturity was 20-30 days earlier on the average (Fig. 1 and 2).

Conclusion

Short season cotton has a great advantage especially in countries with limited resources of land, water and other production inputs. In Egypt, where food crops are badly needed, short season cottons will allow growing more wheat or faba bean on the same land, in addition to savings of irrigation water and pest control chemicals. There are alternatives for short season cottons in Egypt. These are

- Selection of early maturity among the present cultivars
- Introduction of short season cotton (mostly upland)

Figure 2: Cutting Plants Earlier Than Seed Plants

- Interspecific crosses between Egyptian and upland cottons
- Vegetative propagation of cotton by cuttings

Each alternative has its advantages and limitations. However, Egypt must work fast for introducing short season cottons to solve both the food and textile problems. Perhaps an economic evaluation of the four previous approaches may indicate the suitability of one approach over another. There is enough scientific data on each approach accumulated over the last twenty years to support the value of short season cottons.

Perhaps vegetative propagation by cuttings may be the most easy approach with no objection from advocators of "pure Egyptian cotton for Egypt." Promising strains from the interspecific crosses with high yield and satisfactory lint quality may be the second approach and will take more time for propagation to cover a considerable area to produce cotton needed by the local industry for coarse spinning. At any rate, there is a pressing need for short season cottons in Egypt to produce both cotton and food crops at a sound economic base.

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