Characterization of cotton germplasm and its utilization in breeding for major production constraints in Sudan

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ABSTRACT

Bacterial blight, insect pests, lint contamination with honeydew and water shortage are the major constraints to cotton production in Sudan. During the course of germplasm enrichment and characterization, a wide genetic variability, which is expected to provide solutions for these constraints, were identified. Six accessions of diploid cotton consistently showed resistance to bacterial blight under both field and controlled environments. Molecular markers are explored to aid in the transfer and pyramiding of the resistance genes in the commercial cultivars. Six accessions of cultivated cotton were significantly earlier than the commercial cultivars with 56 to 70% of their total yields obtained in the first pick. These genotypes have the potential of reducing production cost, improving lint quality and avoiding drought stress in rainfed areas. Twelve of 68 accessions, containing wild introgressions into commercial cultivars, were selected on the bases of their yield and lint quality to provide wide gradient of leaf-shape and canopy architecture that could be useful in an integrated pest management. Advanced purification and agronomic evaluation confirmed the potential use of these genotypes in breeding program This research emphasizes the importance of enrichment, characterization and maintenance of cotton germplasm as a valuable bio-resource that secure continuous supply of useful variability to overcome the challenge of the complex and variable production constraints.

Introduction

Cotton is a perennial woody shrub adapted to a variety of mostly arid habitats. It is grown as an herbaceous annual crop under both arid and humid conditions (Fryxel, 1986). In Sudan, cotton is the main cash crop occupying an area of over 400,000 ha in irrigated and rainfed agriculture (Mursal, 1988). Sudan produces a wide range of cotton fiber length, including the extra-long fine and the short staple. Long and medium staple cotton are produced under irrigation, whereas short staple cotton is produced under rainfed conditions. Sudan is the world's second largest producer of extra long staple cotton after Egypt (Mursal, 1988; Fadalla, 1990). In the last 10 years (1988-1997), the area under production was 110-282 thousand ha, yielded 364-476 kg/ha of lint (Cotton World Statistics, 1997). Bacterial blight, insect pests (bollworms (*Helicoverpa armigera*), whitefly (*Bemisia tabaci*), jassids (*Impoasca lybica*) and aphids (*Aphis gossypii*), lint contamination with honeydew and water shortage in both irrigated and rainfed areas are the major biotic and abiotic constraints to cotton production in Sudan.

Diverse cotton germplasm was collected and is presently maintained at Shambat research station, this collection includes wild, semi-wild and cultivated introductions of diploid and tetraploid cotton. The collection has contributed significantly to the breeding of the commercial cultivars, particularly in the development of resistance to bacterial bight disease (Innes, 1970). However, detailed information about this collection is lacking and its utilization was limited to the early attempts. The expansion in cotton production and diversification in the production system have pressed hard for germplasm enhancement and characterization to tackle modern breeding strategies and facilitate efficient utilization and maintenance of such a valuable bioresource. A long-term project was launched to enrich and characterize the Shambat collection and establish a database. This paper highlights the progress of this work and emphasizes the useful examples of utilization in breeding for biotic and abiotic stresses.

Germplasm enhancement and characterization

Each season 50-100 accessions (selected from the total collection of approximately 1000 accessions) are planted in the field. These accessions were characterized for their phenological, morphological, yield components and fiber characteristics. Reaction to major diseases, bacterial blight and Fusarium wilt, and morphological characters related to insect pests resistance as pubescence, glandiness and leaf-shape were recorded for each accession. Variability in the traits is extensive for the 400 accessions characterized. Resistant to bacterial bight (post-Barakat race) was identified in four *G. arboreum* and two *G. herbaceum* accessions. Phenological characterization revealed 12 *G. hirsutum* accessions with potential for breeding for early maturity. Wide variability was observed for traits related to integrated pest management such as hairiness, frego bracts, leaf-shape and plant density cover. Genotypes with useful traits were transferred to crossing plots and advanced evaluation to assess their potential utilization in the breeding program.

Genotypes for integrated pest management

Insect pests constitute a major constraint to cotton production in Sudan. In addition to yield losses, insect pests (aphids and whiteflies) cause lint contamination with honeydew (stickiness). Stickiness creates many difficulties in cotton ginning and spinning industry and causes a great loss in the cotton market value. Insect pest control in Sudan has concentrated on integrated management through the use of tolerant cultivars, beneficial insects and insecticides. However, insect control remains to have the greater share in the cost of production and still insect pests inflict the greatest damage. Hairiness and glandiness were the only morphological traits utilized for insect tolerance in the released cultivars. Although hairiness reduces Jassid attack on plants, it increases whitefly population.

For better economics return, there should be a trade-off between use of a variety of morphological traits and the realization of an efficient insect pest control. The germplasm characterization showed a rich variability in pubescence, glandiness, bract shape (frego-normal) and leaf-shape. A balance between these traits is expected to contribute to the alleviation of the problem. Over 200 lines of commercial cultivars with wild introgression were originally developed and maintained with residual degree of heterogeneity in the collection under TW serial list. As wild cotton has inferior quality, the TW accessions were first screened via bulk selection and tested for fiber quality. In addition to hairiness gradient, the TW lines contain a wide gradient in leaf-type ranging from super-okra to a broad normal leaf and hairiness combined with frego and normal bracts. Twelve out of 68 of TW lines showed a comparable lint quality and better or similar yields to the commercial cultivars (Table 1). These lines have a potential for reducing the cost of insect pest control through the reduced plant canopy cover and gradient in hairiness and bract shape. This in turn is expected to reduce cost of production and environmental pollution. In addition, the quality of cotton lint is expected to improve as insects (aphids and whiteflies), are the major contributors to the contamination of lint with honeydew.

Early maturing genotypes

In Sudan, cotton is produced mainly under irrigation and only about 10-20% under rainfed (Mursal, 1988). With the increase in cost of production in irrigation schemes and the rise of concern about lint stickiness in the traditional production areas, cotton production is expanding to the rainfed areas. However, this expansion is restricted by the lack of suitable cultivars for rainfed production. Early maturing cultivars are needed to reduce the cost of production and improve cotton quality in the irrigated areas and to reduce the risk of late-season drought stress under rainfed areas through drought escape characteristics.

During the characterization process of the cultivated collection of *Gossypium hirsutum*, several accessions showed early maturity traits. Twelve of these accessions were purified through bulk selection and advanced for field evaluation. Six proved to be significantly earlier than the commercial cultivars with percentages of the seed cotton yields in the first pick ranging between 55 and 70 compared to 27 and 46 in the commercial cultivars (Table 2). The total seed cotton yields of the early maturing genotypes were significantly higher or comparable to those of the commercial cultivars. It should be noted that preliminary stickiness measurements showed that the first pick was free or less contaminated with honeydew. These early maturing genotypes are expected to contribute significantly to the improvement of cotton production in the irrigated as well as in rainfed areas of Sudan.

Resistance to bacterial blight

Bacterial blight, caused by *Xanthomonas campestris* pv. *malvacearum* (E. F. Sm, Dows.) is the most destructive disease of cotton in Sudan. Disease development within cotton fields is generally favored by humid weather and its spread by rainstorms. Crop losses vary considerably with the weather condition, infected part of the plant and the cultivar (Last, 1960). Under severe infection and favorable humid and stormy weather, the disease may cause seedling death, heavy leaf and bud shedding and boll rot. A destructive outbreak occurred during the early stages of the Gezira scheme (1930-1931) that challenged the continuation of cotton production in the Gezira scheme. Resistant genes were identified in Shambat collection and transferred to the commercial cultivars (Innes, 1970; Siddig, 1973). However, a new race (post-Barakat race) has appeared later, which impaired the old resistant genes combinations (Ahmed *et al.* 1997).

In the process of germplasm characterization, six resistant genotypes from the diploid Asiatic cotton, four from *arboreum* and two from herbaceum, were identified out of the 400 accessions screened. These genotypes were subjected to stringent field, plastic and glasshouse evaluations. The bacterium (post Barakat race) was cultured and applied to the plants in the field, plastic and glasshouse by spraying, toothpick scratch and syringe pressure methods, respectively. Disease grades (at the seedling stage) were scored on a 0-10 rating scale in the field or 1-4 scale in the plastic and glasshouse, where lower grades stand for resistant and upper grades stand for susceptible reaction types. In comparisons with the commercial and diploids checks, the identified genotypes consistently showed resistant reaction types under the three experimental conditions (Table 3). Hexaploids resistant plants were produced as an initial step for transferring the resistance to the commercial cultivars. Genetic analysis of the allelic relationship among the different genotypes is going on. Molecular markers linked to the resistance are being explored to facilitate the efficient transfer and pyramiding of the genes in the commercial cultivars.

Conclusion

Characterization and maintenance of crop germplasm are of paramount importance for continuous supply of genetic variability for crop improvement. The cotton collection of Sudan constitutes a rich genetic resource that will contribute significantly to the alleviation of the existing environmental production constraints. Incorporation of the molecular marker technology will hasten and increase the efficiency for transferring useful traits to the commercial cultivars. The early maturing and potentially useful TW genotypes will be evaluated at various locations to assess their stability under different environments and proceed with their release as new varieties. These genotypes are currently tested for tolerance to moisture stress at the vegetative stage to evaluate their potential tolerance to early season drought under rainfed conditions.

Acknowledgement

The funding of this research project by the Sudan Cotton Company, Khartoum is gratefully appreciated.

References

- Ahmed, S.F. (1990). Prospects of hybrid cotton production in Sudan. Proceedings of FAO–ICAR Regional Expert Consultation on Hybrid Cotton, 22–25 October 1990. CICR, Nagpur, India
- Ahmed, N. E., A. Mavridis and K. Rudolph (1997). Isolation of new races of *Xanthomonas malvacearum* from a continuous plot at Gezira Research Station. *U.K. J. Agric. Sci*., **5**: 32-39.
- Fryxel, P. A. (1986). Ecological adaptation of *Gossypium* species. In Cotton physiology. J. R. Mauney and J. MD. Stewarts (eds.) pp 1-7. The Cotton Foundation, Publisher, Memphis, USA.
- Innes, N.L. (1970). Breeding for bacterial blight resistance. *In* Cotton production in the Gezira environment. M.A. Siddig and L.S. Hughes (eds.), ARC, Sudan 144-152.
- Jackson, J.E. and Faulkner, R.C. (1962). Studies in the quality of Gezira cotton: 1. The relationship between quality and crop earliness. *Emp. J. Exp. Agric*., **30**: 192.
- Last, F.T. (1960). Effect of *Xanthomonas malvacearum* (E. F. Sm, Dows.) on cotton yields. *Emp. Cotton Grow. Rev*., **37**: 115.
- Mursal, E. I. (1988). Country statement of the Sudan delegation to the 48th plenary meeting of the International Cotton Advisory Committee (ICAC).
- Siddig, M.A. (1973). Barakat, a new long staple cotton variety in the Sudan. *Emp. Cotton Grow. Rev*., **307**: 37-115.

Table 1. *Morphological, seed cotton yield and its components, and fiber characteristics of the TW accessions and the leading commercial cultivars grown at the GRS, season 2000/01.*

Genotype	Leaf shape	Seed cotton yield (kg/ha)	Bolls/plant	Boll weight	GOT	Lint index	Seed index	Fiber length	Micronaire
Acala 93H	Normal	2903	14.9	4.2	33.0	6.0	10.0	29	4.3
Barac (67)B	Normal	2631	9.7	6.0	38.6	7.0	10.8	28	4.1
TW1	Okra	2451	13.9	5.4	36.9	6.0	10.5	29	3.9
TW2	Okra	2658	10.1	5.4	39.5	6.8	11.9	28	4.0
TW3	Okra	3322	11.3	6.1	39.2	7.2	12.1	28	4.5
TW4	Okra	2935	12.0	5.3	39.8	7.7	10.3	27	4.5
TW5	Okra	2663	16.0	4.9	37.7	6.0	11.0	28	4.1
TW6	Normal	3355	14.7	5.8	35.7	6.6	12.3	28	4.3
TW7	Normal	2960	13.5	5.1	36.6	6.3	11.2	29	4.3
TW8	Normal	2725	12.8	4.6	35.4	6.1	11.5	30	4.1
TW9-1	Normal	3222	15.0	5.3	37.1	7.3	10.6	28	4.5
TW10	Okra	3536	13.3	6.0	37.5	6.4	11.1	29	4.4
TW11	Normal	3422	13.5	5.6	37.6	6.6	10.8	28	4.3
TW12	Normal	2873	15.5	5.6	34.3	5.7	11.2	29	3.9
Difference	-	***p=.001	***p=.0003	***p=.003	***p<.0001	*p=.025	ns p=.50	***p=.008	*p=.02
LSD(P=0.05)	-	487	2.6	0.84	1.9	1.3	1.9	1.4	0.44
Coeff. Var.	-	0.132	0.183	0.12	0.057	0.139	0.104	0.039	0.076

*, **, *** indicate that means are significantly different at probability p= .05, .01 and .001, respectively.

Table 2. Seed cotton yield and its components and earliness parameters of early maturing genotypes and the leading commercial cultivars (season 2000/01).

Genotype	Seed cotton yield (kg/ha)	% 1st pick	GOT	Plant height	Node to 1st fruiting branch	Days to 1st square	Days to 1st flower	Days to 1st boll	Fiber length (mm)	Micronaire
Acala 93H	3137	27	33.6	113	5.3	33.7	53.7	100.3	31.3	4.5
Barc (67)B	3150	46	37.4	89	5.0	34.3	54.3	101.3	29.6	4.3
TE1	3633	32	37.6	87	4.7	34.3	54.0	98.7	30.0	4.7
TE2	3486	31	38.2	96	4.7	34.0	54.0	99.7	28.4	4.9
TE3	3535	57	36.6	84	5.0	33.7	50.7	95.0	29.4	4.1
TE4	3214	32	33.4	95	5.0	36.7	56.0	99.0	29.3	4.5
TE5	3131	28	39.3	86	5.0	36.0	55.7	103.0	29.2	4.7
TE6	3419	30	38.6	83	5.3	38.7	58.3	101.5	29.2	4.9
TE7	2992	37	37.0	97	4.7	35.0	52.7	99.0	29.3	4.8
TE8	3515	55	36.5	85	5.7	34.0	50.7	97.0	29.9	4.2
TE9	3353	70	36.8	80	4.7	31.3	49.7	96.0	29.3	4.4
TE10	3092	63	39.2	83	5.0	33.3	50.7	94.7	28.2	4.9
TE11	3502	59	37.1	89	5.0	32.3	50.0	97.3	29.2	3.9
TE12	3831	64	36.5	86	4.7	32.3	50.0	97.3	27.8	4.1
Difference	*p=.044	***p<.0001	***p<.0001	***p<.0001	ns p=.221	* p=.021	***p=.0004	***p=.005	*p=.012	***p<.0001
LSD(P=0.05)	497	13	2.3	12	0.85	3.4	3.8	4.3	1.6	0.43
Coef. Var.	0.109	0.334	0.065	0.132	0.132	0.108	0.077	0.065	0.043	0.087

*, **, *** Indicate that means are significantly different at probability p= .05, .01 and .001, respectively.

ns Indicates not significantly different.

Table 3. Reaction of the commercial cultivars (Barakat 90 and Barac (67)B), two susceptible diploids and the six resistant diploids to bacterial blight under field, plastic-house (PH) and glass house (GH).

Genotype	Species	Disease grade[a] (Mean ± SE) Field	PH	GH	Reaction type
Barakat 90	*G. barbadense*	8.0 ± 0.2	3.0 ± 0.0	4.0 ± 0.0	Susceptible
Barac (67)B	*G. hirsutum*	8.7 ± 0.4	3.3 ± 0.3	4.0 ± 0.0	Susceptible
T3-120/99	*G. herbaceum*	8.6 ± 0.4	3.0 ± 0.3	4.0 ± 0.0	Susceptible
T10-111/98	*G. arboreum*	8.8 ± 0.4	4.0 ± 0.0	4.0 ± 0.0	Susceptible
T5-118/98	*G. arboreum*	3.0 ± 0.0	1.3 ± 0.3	1.3 ± 0.3	Resistant
T6-109/98	*G. arboreum*	3.9 ± 0.6	1.0 ± 0.0	1.0 ± 0.0	Resistant
T7-106/98	*G. arboreum*	3.1 ± 0.2	1.3 ± 0.3	1.3 ± 0.3	Resistant
T8-105/98	*G. arboreum*	3.0 ± 0.0	1.0 ± 0.0	1.3 ± 0.3	Resistant
T9-117/98	*G. herbaceum*	3.4 ± 0.0	1.0 ± 0.0	1.3 ± 0.3	Resistant
T4-116/98	*G. herbaceum*	3.8 ± 0.0	1.3 ± 0.3	1.7 ± 0.3	Resistant

[a] Determined on a rating scale of 0-10 in the field and 1-4 scale in the PH and GH, where 0 (field) and 1 (PH and GH) = immune; 1-4 (field) and 2 (PH and GH) = resistant; 5-7 (field) and 3 (PH and GH) = intermediate; 8-10 (field) and 4 (PH and GH) = susceptible.

Data were collected from 5-10 plants in each of the three replications for each genotype.