An appraisal of genotypes performance in cotton (*Gossypium* sp.) breeding experiments in Kivu, Eastern Democratic Republic of the Congo

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ABSTRACT

The ultimate aim of a crop improvement program is the development of improved crop varieties and their release for production. Before lines are released as superior performing types, they are tested in multilocational and macroplot experiments for several years. Such zonal trials identify which line is best for what environment. The identification of superior line is based on an assessment of differences among line means and their statistical significance. The importance of genotype x environment interactions reflects the necessity of evaluating genotypes in more than a single environment. The plant breeder selects superior genotypes for eventual release as commercial varieties based on a rating of these genotypes across varied environments for stability/adaptability. This paper, describes the performance of several advanced cotton genotypes from Nigeria and Egypt (SAMCOT-10, SAMCOT8, RSA(79)4A, ACSA(79)5B, ACSA(79)5F, ASA(74)80C, RASA(78)11A, 1ACSA(78)8C from Egypt (Giza 76, Giza 75, Giza 89, Giza 70, Giza 86) along aside local varieties Turumbi, Ruzizi I, CotonCongo 1, Luvungi 1-2. These lines were evaluated in experiments repeated over two years and six locations in Kivu, Eastern DRCongo. A rating of these genotypes across various environments was also attempted using the performance index approach. The genotypes SAMCOT-10, Giza 70, Ruzizi I and CotonCongo 1 were the most outstanding in yield performance and its component across years and locations. The use of the performance index approach in the rating cultivars across various environments is recommended in DRCongo because of ease of computation and interpretation when the number of entities and test environments are large and because of the gains farmers can get from them.

Introduction

Cotton is mainly cultivated world widely even in DRCongo for its fiber properties and as source of food for both livestock and humans. Cotton seeds contain 35-38% of edible oil, 35-38% of proteins as for soya bean oil. However, the popularization of the consumption of cotton-seed oils or proteins is limited by the level of terpenoid gossypol that is toxic to monogastric animals. Gossypol is however a substance that play an important role in defense mechanisms of the plant (Echekwu,2001; Vandeput,1981).

Cotton together with coffee and tea have been important economic and industrial crops since colonial time. They continue to generate important income to farmer in DRCongo, through exportation and sales of the products at the local and regional markets. In 1994, it was estimated by DRCongo government that more than 2.7% of annual income of farmers in Kivu, Kasai and Oriental provinces, was from cotton cultivation.(Fisher,1917; Jurion,1941; Neirink,1948; Kanff,1946; Vrijdagh,1936). Cotton is very important and had played a valuable role in the development of animal industries (cattle and poultry industry) in the DRCongo; especially by providing foodstuffs (cotton seeds, cattle cakes) necessary to elaborate rations of livestock breeds.

In 1995, cotton covered around 254,476 ha and the annual national production was averagely of 242,356 tonnes (DRCongo Ministry of Agriculture, Annual report, 1995). The production of cotton fiber was estimated to be 9000 tonnes, the cotton fiber exported being of 679 tonnes (Anonymous,1983; Querton,1925; Tandeur,1947; Vandenput,1981). That national annual production could not meet the local need in cotton fiber, estimated to be of 21,000 tonnes yearly. The total annual production of cattle cakes and of cotton oils, were of 804 tonnes and 134 tonnes respectively. This production was facilitated by the existence of several cotton industrial equipments: 102 factories of cotton gin, 12 oil mills, 43 cotton mills (cloth mills) spread in the North, Central and Eastern parts of the country. However, the cattle cakes produced annually at that time was enough to meet the needs of livestock in eastern and Southern part of the country, where it was estimated, in 1996, that the total amount of cattle cakes and cotton-seed meal consumed by cattle and small ruminants under zero grazing system, was of 600 tonnes. With the war disturbance since more than 6 years, the status is unknown. Surely, cotton production has stopped in some provinces due to the outside ongoing rebels war and due to several abiotic and biotic constraints.

Cotton was introduced earlier in DRCongo (1912) colonial scientists. Cotton research has been conducted since that time, at several research stations and centres spread in the country: Gandajika, Lodja, Sankuru Katakombe, Lusambo, Lomela–loto, Bene-dibele, Fwamba, Niama, Kabeya, Buama, Yakoma, Doromo (Kasai province), Bambesa (Equator province), Baraka, Bukavu , Uvira-Fizi, Kabinda, Lubarika, Kindu, Maniema, Kiliba, Ruzizi plain, (Kivu province), Bas-Uélé, Haut-Uélé (oriental province), (Anonymous,1983; Fisher,1917; Knaff,1946; Vandeput,1981; Stenr,1927). Cotton breeding program started earlier and included / targeted several aims: Resistance to pests and diseases, yield per hectare and the environmental adaptation of various genotypes, production of pure lines and new genotypes, earlier maturing and transfer to flowers genes of resistance to insect attacks and seed-yield and commercial quality of the fiber (Anonymous,1983). Several varieties were used in that program: Triumph 270D64, GAR, Stoneville, Morogoro, Clevewilt, Simpkins, farm relief, Trice, Nyasland-Allen, Triumph Big Boll.

Around 1940-1950, new adapted varieties were developed: U.4, Barbeton, U.4. hybrids, Gandajika (S.M), Bambesa, U.4 Barbetton, U.4. hybrids, Triumph Gandajika,. The main research centres involved were Gandajika (Kasai province, Central part of the Country) and Bambesa (Orientale province, North-Eastern part of the Country). With these varieties put on the market during independence time, the cotton seed-yield could vary between 200-800 Kg/ha in Northern part of the country to1-1.7t /ha in the Eastern part of the country (Kivu, Maniema), (Anonymous,1983). Towards 1978, the cotton breeding program developed and marketed some other varieties such as, Reba B50 (at Bambesa), NC8, Z407-800-1382-1157, Z407-800-1832-1155, 7G1 (at Gandajika, Kasai province) (Anonymous,1983).

The ultimate aim of a crop improvement program is the development of improved crop varieties and their release for production. Thus is the current goal of the cotton improvement program in the DRCongo, and this since 1986 (Munyuli, 2002). Before genotypes are released as superior performing types, they are tested in miltilocational and macroplot experiments for several years. Such zonal trials identify which genotype/line is best for what environment. The identification of superior genotypes is based on an assessment of differences among genotype means and their statistical significance; whenever a significant test is used to discriminate between genotypes, the usual way of presenting data is arranged the genotype means in order of descending magnitude. Any two means not differing significantly are either underscored by the same genotype or signed by the same letter. Likewise, any two means differing significantly are not underscored by the same genotype or are signed by different small letters. This presentation of data although universally established, lacks simplicity and as the number of genotypes increase, discrimination by eye becomes problematic. (Fasulas,1983; Finley and Wikinson,1963; Lin,1982).

This paper presents the use of an alternative approach, the performance index (Fasulas,1983; Finley and Wikinson,1963; Lin,1982) to evaluate the performance of genotypes in cotton variety trials in the Eastern DRCongo.

Experimental procedure

The study was conducted in areas located between Bukavu and Goma towns, around Kivu and Tanganyika lakes, during the dry and rainy consecutive seasons of 2001-2002 in main zones of the crop production of Kivu province (average population density: 300 inhab/Km^2), (28°-29° E, 11°-31° S), (See Kivu province and the study area on Figure 1 below). The climate of Kivu area is tropical humid, type Aw3. Two main seasons, the long rainy season (September-May) followed by the dry season (June-August) are experienced (Munyuli, 2000; Munyuli and Balezi, 2000). The rainfall pattern is bimodal, and receives an annual average rainfall, which varies between 800, and 2200 mm, with average temperatures of 15°-28 °C and a relative humidity of 65-76% (Munyuli, 2003; Munyuli and Balezi, 2001). The tropical humid climate of the study area is temperate owing to its high altitude, which varies between 800 and 3200 m. Permanent settlements are to be found up to an altitude of 2500 m. Subalpine meadows cover the entire region and abundant mosaic vegetation, from typical savannah to mountain forest via plains, grows on the volcanic and ferraltic soils (ferrisoils) (Munyuli, 2001; Munyuli, 2002).

The materials used as entry-genotypes were selected from the germplasm pool of the"Institut National pour l'Etude et la Recherche Agronomiques(INERA), Gandajika Agricultural Research Center; and from a cotton company based in Kivu are (Cotonnière du Kivu), (1). Some of these genotypes (Reba B50, NC8,Z407-800-1832-1157) were evaluated alongside, of considered as local varieties from Kivu province (Turumbi, Ruzizi 1, CotonCongo1, Luvungi1-2), from Nigeria (*Gossypium hirsutum*) (SAMCOT-10, SAMCOT-8, RSA(79)4A, ACSA(79)5B, ACSA(79)5F, ASA(74)80C, RASA(78)11A, 1ACSA(78)8C, SAMCOT-6, SAMCOT-9 and from Egypt (*Gossypium barbadense*) (Giza 76, Giza 75, Giza 89, Giza 70, Giza 86). These genotypes were evaluated for two different cropping seasons in two years (2001A & 2002B) at five locations (Kabare-Mubanda, Kiliba-Ruzizi plain, Mugobora, Lweke and Kalonge), using the randomised complete block design with three replications. Plots consisted of two rows 12 m long, spaced 1m apart. Seeds were planted per hole with 45 cm spacing between holes and the seedlings were thinned to two plants per hill at 3-4 weeks after planting. Organic matter mixed to manure (cow dung) was applied at the rate of 25 t/ha, during land preparation. Weeding started earlier and was done regularly. Insect pests were controlled by 3 14-day sprays of Cymbush 10 EC at the rate of 2.5 liters per hectare starting at nine weeks after planting.

Data used for the analysis were taken from mean seed cotton yields per plot. An analysis of variance was done using the Gensat 3.2 (version 6) computer package. For computation of the cultivar performance index, the mean values of seed cotton yield for the genotypes were arranged in descending order of magnitude per site per year. Applying a one-tailed test (Schmitz *et al.*,1951), LSD obtained from the analysis of variance for each site and year was subtracted from the first mean. The number of genotype means smaller than this value depicts the number of genotypes that are significantly inferior, at the chosen level of significance, to the first genotype mean. This number is noted "W". The process is repeated for the second and subsequent genotype entries, and series of "W" values are obtained for each genotype in each year and each site. The cultivar performance index was calculated as follows: P=(100 W) / (V-1) (Finley & Wikinson,1963) where W=number of significantly inferior genotypes and V=number of genotypes tested in the trial.

Results and Discussion

Among all varieties tested, some of them were not viable; we are presenting results for genotypes that could survive during the whole cropping seasons (two years).

The performance of genotypes in two years (two cropping seasons) and five locations are summarized in Tables 2 and 3. The Genotypes, SAMCOT-10, SAMCOT-8, ACSA (79)5B , Ruzizi I, CotonCongo 1 and Giza 70, with cultivar performance indexes varying between 50 and 66%, were the most outstanding in yield performance in 2001 (Season A: September-October) trials at Kiliba, Kalonge and Lweke sites. Their performance indexes denote that these genotypes outyielded significantly 66% (SMCOT-10), 54-56% (SAMCOT-8), 50-51% (ACSA (79)5B, 60% (Ruziz I), 63% (CotonCongo1), 53% (Giza70), of all the genotypes tested at Kiliba, Kalonge and Lweke. The genotypes with P value equal to zero, are denoting that they failed to outyield significantly. There were however no significant differences between genotypes in the trials at Kabare and Mugobora (Table 2). The trend in performance of the genotypes in the 2002B trials (Table 3) was not apparently different from 2001A trials.

At Kiliba, SAMCOT-10, SAMCOT-8, Giza 70, Ruzizi I and CotonCongo 1, with a performance index of 44, 40, 50, 51, 58 respectively, were more superior, outyielding, significantly 40% to 58% of all the genotypes tested (Table 3). At Kalonge, Turumbi, Ruzizi1, CotonCongo and Luvungi outperformed 68%, 61%,61% and 47% of all the other genotypes. All the genotypes in trial at Mugobora in 2002B (season: March-June) failed to perform well. At Kabare, Giza 86, Giza 89, Ruzizi 1, Coton Congo1, Luvungi 1-2, however, are standing out as superior, outyielding significantly 40%, 37%, 44%, 49% and 38% of all the genotypes at the site.

The differential performance of the genotypes in two years and five locations for these trials, brings out very clearly, the existence of genotype x season x environment effect and makes the screening of genotypes for high stability/adaptation under varying environmental conditions an essential step in all any plant breeding program.

This has been adopted in the DRCongo for staple and cash crops that provides to our farmers revenues with low input (intrans) to combat abiotic and biotic productivity constraints.

There is several methods developed by scientists for the rating of genotypes across environments for yield stability/adaptation (Jurion,1941; Lin,1982; Munyuli, 2000; Munyuli, 2002). An alternative method is the cultivar performance index (P). A rating of genotypes tested across years, locations and year x locations using this method is presented in Table 4.

Across the two years, SAMCOT-10, SAMCOT-8, Giza70, Ruzizi1, CotonCongo1, having the highest values of P, were the most superior genotypes at Kiliba and Kalonge. SAMCOT-8, Giza 75, Ruzizi 1, CotonCongo were the most outstanding at Mugobora. SAMCOT-10, ACSA(79)5B and Turumbi, were the most outstanding at Kabare site. When the performance index is taken across the five locations, the best genotypes in 2001A were SAMCOT-10, Giza75, Ruzizi1, CotoCongo1, ACSA(79)5B. Across the two years and five locations, the most outstanding genotypes were CotonCongo1, Ruzizi1, SAMCOT-10, SAMCOT-8, Giza70 and Turumbi.

In general, the performance index brings out the genotypes SAMCOT-10, SMCOT-8, CotonCongo1, Ruziziz1 and Giza 75, as the most outstanding in these trials. Giza 75, SAMCOT-10 and SAMCOT-8, are introduced varieties from Egypt and Nigeria. CotonCongo 1 and Ruzizi1 have been found to be very stable cotton varieties, released as new varieties long time ago by extension services and Cotton companies in collaboration with research institutions.

The attraction of the performance index approach in the rating of cultivars across environments is in relation to its ease of computation and interpretation especially when the number of genotypes (varieties) and test-environments are large, a situation, which makes other conventional methods more cumbersome. This method is also currently in use in Nigeria and several other African countries for that reason.

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Table 1. *Characteristics of trial sites where cotton genotypes were evaluated, in multi-locational trials during two years (2001A & 2002B).*

Characteristics	Kiliba (Ruzizi plain)	Kabare (Mubanda)	Mugobora	Kalonge	Lweke
Altitude (m)	850	1950	2250	1750	1450
Rain, annual mean (mm)	900	1650	1950	1500	1710
Temperature (0°C), annual mean	25.5	20.5	17.5	19.5	22.5
Relative humidity (%)	69	77	78	76	75
Field slope (%)	0	2	3	4	5
Type of habitat	Plain	Hills	Marshland	Mountain	Hills
Type of soils	Sandy-loam	Clays	Shale-clays	Sandy-clay	Clays
Average pH(water)	5.9	6.7	6.2	5.9	7.5
Previous crop farmed	Potatoes	Beans/cassava	Peas/wheat/ soya bean	Sorghum/beans	Maize/groundnut
Neighbouring vegetation	Fallows	Sylvi-culture plantations	Fallows	Mountain forest	Fallows

Table 2. *Performance of cotton genotypes according to mean and performance index (P), Eastern DR Congo, 2001A.*

	Kiliba		Kabare		Mugobora		Kalonge		Lweke	
Genotypes	Mean (kg/ha)	P	Mean (kg/ha)	P	Mean (kg/ha)	P	Mean (kg/ha)	P	Mean (kg/ha)	P
SAMCOT-10	1170	66	1355	11	650	0	1154	51	1179	50
SAMCOT-8	1027	54	1196	11	850	0	1044	56	1127	56
ACSA(79)5B	1077	51	1539	24	452	0	1209	11	1050	50
RSA(79) 4A	849	30	1374	20	750	0	1191	20	950	47
RASA(78)11A	750	20	1292	7	650	0	915	30	850	0
Giza 86	768	11	1209	0	492	0	1036	0	900	0
Giza 70	980	53	1580	0	552	0	1179	0	650	0
Giza 75	646	27	1300	0	450	0	976	0	650	0
Giza 89	555	11	1429	0	375	0	1051	0	780	0
Reba B50	680	24	1379	0	522	0	1097	11	703	1
NC8	603	12	1100	0	375	0	1005	1	676	1
Turumbi	576	22	971	0	540	0	979	1	1150	1
Ruzizi 1	1100	60	1610	11	494	0	1172	64	1150	61
CotonCongo	1210	63	1560	24	500	0	1136	54	970	50
Luvungi1	879	51	1500	2	452	0	1105	0	850	1

Table 3. Performance of cotton genotypes according to mean and performance index (P), Eastern DR Congo, 2002B.

Genotypes	Kiliba Mean (kg/ha)	Kiliba P	Kabare Mean (kg /ha)	Kabare P	Mugobora Mean (kg /ha)	Mugobora P	Kalonge Mean (kg /ha)	Kalonge P	Lweke Mean (kg /ha)	Lweke P
SAMCOT-10	950	44	567	0	760	0	1172	1	1191	0
SAMCOT-8	1150	40	591	0	492	0	1286	0	750	0
ACSA(79)5B	1280	11	715	0	570	0	1209	0	650	0
RSA(79) 4A	476	24	625	0	503	0	1154	0	550	0
RASA(78)11A	975	11	625	0	557	0	1109	0	656	0
Giza 86	866	1	916	40	562	0	916	0	700	1
Giza 70	850	50	824	0	750	0	1264	0	950	17
Giza 75	681	1	696	0	448	0	1300	1	760	0
Giza 89	757	0	915	37	782	0	1400	17	492	0
Reba B50	568	0	710	0	757	0	1600	0	625	0
NC8	559	0	670	0	857	0	1500	0	916	21
Turumbi	615	0	551	0	804	0	1670	68	824	2
Ruzizi 1	956	51	1150	44	815	0	1400	61	790	4
CotonCongo	900	58	1250	49	750	0	1300	61	1000	33
Luvungi1	886	0	950	38	760	0	1650	47	950	24

Table 4. Rating of cotton genotypes using the performance index (mean of the 2 seasons), eastern DRCongo, 2001-2002.

Genotypes	Across two years (Py) Kiliba	Kabare	Mugobora	Kalonge	Lweke	Across locations (PS) 2001A	2002B	Across two years and five locations (PYS)
SAMCOT-10	30	15	17	36	7	20	16	17
SAMCOT-8	31	6	6	35	4	12	24	16
ACSA(79)5B	0	10	3	31	1	11	6	7
RSA(79) 4A	0	5	1	0	0	3	3	5
RASA(78)11A	0	0	0	6	0	3	0	3
Giza 86	3	0	0	0	0	11	0	4
Giza 70	6	0	12	0	0	6	3	16
Giza 75	28	0	17	36	0	19	6	6
Giza 89	0	0	0	0	0	3	0	7
Reba B50	0	0	0	0	0	0	3	2
NC8	0	0	0	3	0	0	3	1
Turumbi	0	10	0	6	0	4	0	9
Ruzizi 1	33	0	11	29	0	11	21	17
CotonCongo	34	0	12	30	0	7	19	18
Luvungi1	0	0	0	0	0	0	0	1

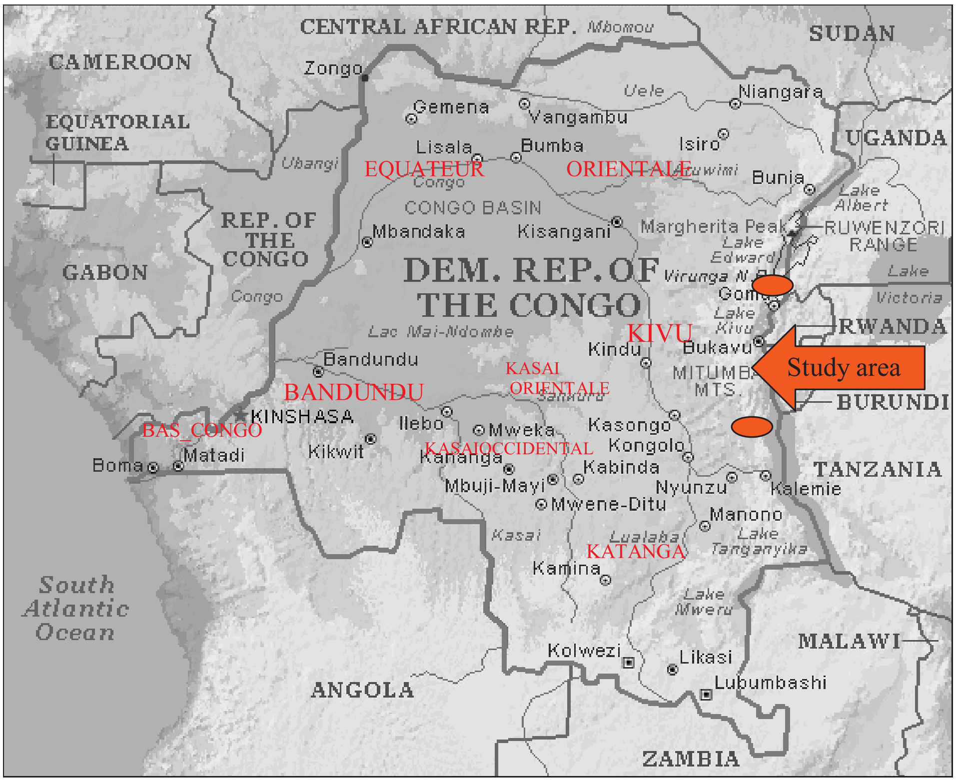

***Figure 1**. Map of Democratic Republic of Congo (Study area is shown between the two points). The study area is indicated by a red arrow, between the two points in Kivu province.*