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The influence of environment and season on stalk yield in kenaf

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ABSTRACT

Kenaf is an important fiber crop worldwide. It was recently introduced to South Africa as a commercial fiber crop. The aim of this study was to determine how different environments and seasons influence stalk yield. Nine kenaf cultivars from various countries were analysed in two environments, over two consecutive seasons, where one location was irrigated and the other not. Data were recorded for total fresh yield, defoliated stalk yield and dry stalk yield. Yield stability was analysed with four different statistical models. The dry stalk yield varied from 15.33 to 17.78 ton/ha. El Salvador and Tainung 2 had high dry stalk yields in the favourable environments, but Tainung 2 did not have stable yield across all trials. Everglades 41 and El Salvador were the most stable of the varieties across both environments and seasons. El Salvador was the cultivar that had the highest and most stable dry stalk yield in the two seasons and two locations in South Africa, and should perform well in commercial production.

1. Introduction

Kenaf (*Hibiscus cannabinus* L.) is a fiber plant native to east-central Africa where it has been grown for several thousand years for food and fiber. Kenaf is a short-day, annual herbaceous plant cultivated for the soft bast fiber in its stem (Dempsey, 1975). It has been cultivated and used as cordage crop to produce twine, rope, gunny-bag and sackcloth for over six millennia (Charles et al., 2002). Kenaf grows in tropical and temperate climates and thrives with abundant solar radiation and high rainfall. Under good conditions kenaf will grow to a height of 5–6 m in 6–8 months and produce up to 30 ton/ha of dry stem material (Wood, 2003). Kenaf was introduced into South Africa recently as a new fiber crop, therefore data on adaptability and yield of introduced cultivars are not available. The first kenaf processing factory in the country went into production in 2006, just outside of Winterton, in Kwazulu-Natal, with 30 farmers contracted to plant the crop. Kenaf fiber bales are mostly exported to the automotive industry in Europe.

In the past, most plant breeding programmes focused primarily on developing high yielding cultivars. Recently, stable and sustainable yields under various environmental conditions have gained importance over only increased yield. The development of cultivars, which are adapted to a wide range of diversified environments, is the ultimate aim of plant breeders in a crop improvement programme (Mohammad Subhan, 2003). Cultivar by environment interactions is an important issue to agronomists who transfer a new variety from one to another environment. The adaptability of a variety over diverse environments is commonly evaluated by the degree of its interaction with different environments in which it is planted. A variety should have a high mean yield but a low degree of fluctuation in yield when planted over diverse environments (Purchase, 1997). The concept of stability has been defined in several ways and several biometrical methods,

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Table 1 – Cultivars used and their countries of origin

Cultivar	Origin
El Salvador	Java, Indonesia
Dowling	Texas, USA
Gregg	Texas, USA
Cuba 108	Cuba
SF 459	Texas, USA
Tainung	Taiwan
Everglades 41	Florida, USA
Endora	Spain

including univariate and multivariate ones, have been developed to assess stability (Becker and Leon, 1988; Crossa, 1990; Mevlut et al., 2005).

The aim of this study was to assess how yield was influenced by location and season, and how stable the yield of nine imported kenaf cultivars were in these environments and seasons.

2. Materials and methods

Cuba 108, Dowling, El Salvador, Endora, Everglades 41, Everglades 71, Gregg, SF 459, and Tainung 2 were used in this study (Table 1). Two trials were planted in different locations close to Winterton. One is next to the Tugela river about 20 km north from Winterton in a reddish brown clay (nitosol) and the second trial in the Drakensberg mountains about 30 km south from Winterton in sandy soil. The Tugela farm has an annual rainfall of 666–745 mm and in the Drakensburg farm area, rainfall can exceed 1000 mm. The long-term average rainfall is the highest in January and February in the Winterton area at 241 and 232 mm respectively (Camp, 1997). The rainfall for December and March is lower at 195 and 172 mm respectively. By April the rainfall tapers off to 68 mm. The long-term maximum temperatures in Winterton vary between 23 and 26 °C and the minimum between 9 and 15 °C from November to April, with April being the coolest month. The first season trials were planted early in November 2003 and were harvested in April 2004, and the second season trials were planted late in November 2004 and were harvested in April 2005. At the Tugela farm no-till was practiced and in the first year the seed was planted in canola residues and in the second year in maize residues. The Tugela trials were irrigated in both seasons as required. At the Drakensberg location the trials were planted in prepared seed beds, but the trials were grown under rain-fed conditions in both seasons. These two locations were chosen as this is the designated area for future production, and this is also the area where a factory was recently built to produce pulp. Fertilization was done according to soil analysis. A randomised complete block design with four replicates was used. Each plot was 1.5 × 9 m with six rows of plants. The interrow spacing was 25 cm and the seed was sown every 10 cm in the row by hand. The final population was 400,000 plants per hectare.

The plants were manually harvested as soon as 50% of the plants were flowering. Four rows in the middle of each plot were harvested, and 1 m at both sides of these rows was discarded to eliminate side-row effects. Therefore the final plot size was 7 m^2.

The fresh yield was measured per plot after plants were cut. One meter of two stalks from each plot was taken from the middle of the plant. They were weighed immediately after cutting, to determine fresh one meter stalk weight (MSM). They were dried for 5 days at 65 °C, then weighed again to determine dry one meter stalk mass (DMSM). The ratio of MSM and DMSM was percentage dry mass. Analysis of variance and correlation analysis was conducted using Agrobase (2000).

3. Results and discussion

A combined analysis of variance across the two locations and different years showed highly significant differences in the fresh yield between the years, and the two locations, and there was significant year with locality and cultivar with year interaction (Table 2). From the trials and farmer plantings it became clear that the end of October to the beginning of November is the best planting time for kenaf, to avoid early cold spells close to the harvesting time, as kenaf is extremely sensitive to low temperatures.

The interaction of cultivar with year was highly significant. It indicated that the performances of the entries were significantly affected by the seasons, as was reflected in the yield (Table 2). For defoliated and dry yield, the trends were much the same as for the fresh yield, with significant differences between the years, localities, and interactions of cultivar with year, and year with localities. El Salvador significantly out yielded all other cultivars in terms of fresh yield, but when dried, although it still ranked the highest, the weight was close to that of Tainung 2 and Endora. This indicates that it is impor-

Table 2 – Mean squares for yield characteristics of nine kenaf cultivars across localities and years

Source of variation	d.f.	Fresh yield (ton/ha)	Dry yield (ton/ha)
Cultivar (C)	8	405.358	14.931
Location (L)	1	19355.302**	2499.667**
Year (Y)	1	60883.095**	1996.005**
C × L	8	412.500	43.615
C × Y	8	1165.010**	86.897**
Y × L	1	1828.703*	264.984**
C × Y × L	8	146.454	25.449
Bloc × Y × L	12	458.350	37.710

* $P \le 0.05$.
** $P \le 0.01$.

Table 3 – Average yields of kenaf cultivars (over localities and years)

Cultivar	Fresh yield		Defoliated yield		Dry yield	
	ton/ha	Rank	ton/ha	Rank	ton/ha	Rank
Cuba 108	80.36	4	64.16	4	15.27	9
Dowling	76.50	9	63.75	6	15.90	7
El Salvador	92.41	1	73.67	1	17.78	1
Endora	83.82	2	67.98	2	17.42	3
Everglades 41	82.87	3	65.93	3	16.63	4
Everglades 71	79.11	5	63.78	5	16.53	5
Gregg	78.15	6	62.93	7	15.33	8
SF 459	77.56	7	62.44	8	15.96	6
Tainung 2	76.88	8	61.33	9	17.69	2
Mean	80.85		65.11		16.50	
CV (%)	20.75		21.26		28.60	
LSD ($P \leq 0.05$)	4.64		3.83		1.31	

tant to evaluate cultivars specifically for dry stalk production, as a cultivar like El Salvador lost a large amount of weight during drying.

The average dry stalk yield for both years and seasons varied between 15.27 and 17.78 ton/ha. Cuba 108 gave the lowest yield in 2 years, but it was not significantly lower than the other cultivars. El Salvador gave the best dry stalk yield value in a combined 2-year analysis, followed by Tainung 2 and Endora. Cuba 108 gave the lowest yield in 2 years, but it was not significantly lower than that of the other cultivars (Table 3).

The rankings for the three characteristics were similar, which was reflected in the highly significant correlation between fresh yield and dry stalk yield ($r = 0.892$), and between defoliated yield and dry stalk yield ($r = 0.893$), which showed that total fresh yield of a plant is a good indication of the dry stalk yield that can be obtained from that plant. The dry fiber yield is 5–6% of the fresh stems, and this equals 18–22% of the dry plant. Commonly the fiber yield is 1–2 ton/ha, but it can reach 3–3.5 ton/ha under ideal conditions (Dempsey, 1975).

3.1. *Stability analysis*

Wricke (1962) defined the concept of ecovalence as the contribution of each cultivar to the cultivar with environment interaction sum of squares. When the ecovalence value is higher, the genotype's contribution to the total genotype with environment interaction sum of the squares is also greater. Shukla (1972) defined the stability variance as an unbiased estimate of the variance of genotype i across environments after the removal of environment main effects. A genotype is called stable if its stability variance (σ_i^2) is equal to environmental variance (σ_0^2), which means that $\sigma_i^2 = 0$. A relatively large value of σ_i^2 will thus indicate greater instability of genotype i. The additive main effects and multiplicative interaction method (AMMI) method integrates analysis of variance and principal component analysis into an unified approach (Gauch, 1988) and is especially useful in estimating multi-location trials (Gauch and Zobel, 1988). A large genotypic interaction principal component axis 1 (IPCA1) value reflects more specific adaptation to environments with IPCA1 values of the same sign. On the contrary, genotypes with IPCA1 values close to zero show wider adaptation to the tested environments (Zobel et al., 1988; Gauch and Zobel, 1988; Crossa et al., 1991).

A comparison of the stability parameters for kenaf genotype traits was done for the different stability measures applied using their rank levels (Table 4). Wricke's (1962) ecovalence and Shukla (1972) gave the same stability ranking of the cultivar. On the overall rank, Everglades 41, El Salvador and Everglades 71 were the most stable cultivars in terms of fresh yield. El Salvador, Everglades 41, Dowling and Everglades 71 were the most stable cultivars for dry yield.

These imported cultivars were therefore quite well adapted to the proposed production area, and good yields should be realised from the best cultivars. The best yielding cultivars also produced well in different bioresource areas, and farmers in

Table 4 – Summary of stability statistics for yield (fresh and dry) of kenaf cultivars

Cultivar	Wi-Ecovalence			Shukla			AMMI			Rank
	Fresh	Dry	R	Fresh	Dry	R	Fresh	Dry	R	R
Cuba 108	517.4	30.75	7	804.9	45.29	7	2.97	−1.32	7	7
Dowling	278.5	11.56	4	395.3	12.39	4	−1.69	0.80	4	4
El Salvador	143.0	1.79	2	163.0	−4.35	2	−1.58	−0.15	3	2
Endora	368.1	18.94	6	549.0	25.04	6	1.81	−0.72	6	6
Everglades 41	59.6	0.20	1	20.1	−7.09	1	−1.07	0.04	1	1
Everglades 71	195.6	18.34	3	253.2	24.02	3	−1.22	−0.21	2	3
Gregg	285.2	18.64	5	406.8	24.53	5	1.75	−0.79	5	5
SF 459	673.7	33.80	8	1072.9	50.51	8	3.25	−1.01	8	8
Tainung 2	926.8	177.9	9	1506.7	297.53	9	−4.23	3.35	9	9

the whole production area can plant a selection of the best cultivars.

4. Conclusions

The dried stalk material (after retting) is what is pulped in the factory, and is therefore the most important yield indicator. High yielding varieties El Salvador and Tainung 2 were well adapted to the irrigated conditions. They are from Indonesia and Taiwan respectively. Everglades 41 (Florida, USA) and El Salvador were the most stable of the varieties across environments and seasons. El Salvador was the cultivar that had the highest dry stalk yield in the two seasons and two locations in South Africa. The farmers who have been contracted to produce kenaf for the factory plant the crop under either irrigated or dry land conditions, depending on their farming system. The small-scale farmers all use a dry land system. It is therefore crucial to use well-adapted cultivars. El Salvador seems to be the safest choice for the farmers, and if farmers are planning to plant exclusively under irrigated conditions, Tainung 2 is also a good choice. The ideal is to get a breeding programme started as soon as possible to breed cultivars specifically for South African conditions.

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