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DEVELOPMENT OF EARLY MATURING FUSARIUM WILT RESISTANT PIGEONPEA CULTIVARS

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ABSTRACT

Most of the East African pigeonpea (*Cajanus cajan* (L.) Millsp) landraces are tall (up to 3.5 m), late maturing (10–12 months), low yielding and susceptible to Fusarium wilt (*Fusarium udum* Butl.), one of the most serious fungal diseases in the region. Breeding populations were created by hybridisation of the local landraces and early maturing, small and brown seeded Indian genotypes in 1984 and 1985. Selection for reduced height, early maturity, grain yield, seed colour and size, and resistance to Fusarium wilt was conducted for seven generations. Selected lines were evaluated at two Fusarium wilt infested plots for two years and also in a wilt infested soil in a glasshouse. Ten lines that were resistant or tolerant to *Fusarium* wilt, early maturing, short in height, high yielding and with large, white/beige seeds were finally selected. High positive significant correlations ($r = 0.87^{**}$ and 0.62^{**}) between glasshouse and two field sick plot disease ratings were observed.

***Key Words*: Fusarium wilt, maturity, screening, seed characteristics, pigeonpea**

RÉSUMÉ

La plupart des variétés locales de pois d'Angole *Cajanus cajan* (L) Millsp, de l'Afrique de l'Est sont hautes (jusqu'à 3.5 m), tardives (10-12 mois), pauvres en rendement et sensibles au flétrissement du *Fusarium udum* Butl.), l'une des mycoses les plus sévères de la région. Des populations de sélection ont été crées entre 1984 et 1985 en croisant des variétés locales avec des génotypes précoces d'origine indienne, de petite taille et à graines brunes. Des sélections pour la réduction de la taille, la précocité, le rendement, la couleur et la grosseur des graines, et la résistance au flétrissement du Fusarium ont été effectuées sur 7 générations. Les lignées sélectionnées ont été évaluées pour le flétrissement du Fusarium en deux parcelles expérimentales infestées et en serre pendant deux ans. Les dix lignées qui se sont montrées résistantes ou tolérantes au flétrissement du Fusarium, précoces, avec une taille réduite, un rendement élevé et de grosses graines blanches ou beiges ont été finalement retenues. Des corrélations hautement significatives et positives de ($r = 0.87^{**}$ et 0.62^{**}) respectivement ont été enregistrées dans les évaluations de la maladie en serre et en parcelles infestées.

***Mots Clés*: Flétrissement du Fusarium, maturité, criblage, caractéristiques des graines, pois d'Angole**

INTRODUCTION

Pigeonpea (*Cajanus cajan* (L.) Millsp.) is one of the most important grain legumes in Eastern Africa. The region is the world's second largest producer after the Indian sub-continent. The crop is valued because it is drought resistant, a cheap protein supplement in the diet for millions of people especially in the semi-arid zones; and a source of fuel and foliage for livestock. However, average yields are low (450–670 kg ha^{-1} purestand, and 300 kg ha^{-1} intercropped). Low yields have been attributed to diseases and pests, low yielding traditional cultivars, moisture stress, labour shortage, poor production practices and socio-economic factors such as pricing, marketing and poor infrastructure.

Fusarium wilt caused by *Fusarium udum* Butl., is probably the most important fungal disease of pigeonpea in the region (Reddy, 1990). Kannaiyan *et al.* (1984) reported high wilt incidence in Kenya (15.9%), Malawi (36.3%) and Tanzania (20.4%). In some fields wilt incidence was as high as 90%. Kannaiyan *et al.* (1984) estimated annual losses caused by this disease in these countries at over US$ 5 million. Although it has been suggested that wilt incidence can be reduced by pigeonpea-cereal rotation (Khan and Ashley, 1975), fallow, green manuring, zinc application, rotation with tobacco, and time of planting (Reddy, 1990), host resistance is probably the most effective and cheapest management practice. Kannaiyan *et al.* (1984) found that perennial pigeonpea in Kenya and Tanzania suffered relatively more from wilt. These landraces are also tall (over 3 m) and late maturing (10–12 months). Little work has been done in Eastern Africa to develop cultivars that mature early, are shorter in height to ease harvesting and spraying operations and are resistant to Fusarium wilt. Introductions of short cultivars from India has not been effective because most are poorly adapted to local conditions, are susceptible to local strains of the wilt pathogen, and have small, brown seeds. This paper reports on efforts made in Kenya to develop early maturing and wilt resistant pigeonpea cultivars.

MATERIALS AND METHODS

Plant material. Three pigeonpea breeding populations were created by crossing the late maturing, tall, large white seeded local landraces and the early maturing short small brown/dark seeded introductions from India in 1983 and 1984. Three of the parental lines (NPP 725, ICP-7035 and NPP 673/3) were resistant to Fusarium wilt. All other parents were susceptible to the wilt pathogen. The segregating populations were grown in a Fusarium wilt infested plot near Kampi-ya-Mawe Research station in Makueni district in 1985, 1986, 1987, 1988 and 1989. One hundred and eleven F_7 lines were finally selected in 1989 and 19 wilt resistant/tolerant lines evaluated at Katumani and Makueni sick plots and in the glasshouse in 1990 and 1991.

Fusarium wilt infested plots. The field sick plots at Makueni and Katumani were developed by incorporating chopped stems and roots of diseased plants collected from wilt infested farmer's fields in Kitui, Machakos and Makueni districts to build up the inoculum of the wilt pathogen. The susceptible checks (Munaa, NPP 718 and ICP-2376) were grown in these plots to test presence of the pathogen. The dead plants of the susceptible cultivars were chopped and incorporated into the soil. Random samples were taken from diseased plants to confirm the presence of *F. udum* by the laboratory culture of the pathogen. This procedure was repeated throughout the four years of experimentation. The sick plot was considered sufficiently infested after achieving over 60% mortality of susceptible checks. The Makueni sick plot was developed starting 1979 in a farmer's field which had a long history of wilt incidence. Development of Katumani sick plot was initiated in 1990.

In the glass house at Kabete, wooden flats measuring 78 x 60 cm and 45 cm deep were filled with soil from field sick plots. Initially, chopped roots and stems from diseased plants were incorporated. Susceptible checks were then sown and subsequently chopped and incorporated to increase the inoculum load. Conidia from pure cultures of *F. udum* were added. The flats were watered regularly to promote fungal growth. These boxes were ready for use after over 60% of mortality of susceptible checks (Munaa and NPP 718) were realised.

Field experiments. A preliminary evaluation trial of 111 lines was conducted at Makueni in 1989/90 to identify promising lines on the basis of their grain yield, early maturity, plant height, seed colour and size, and reaction to *Fusarium* infestation. Subsequent field experiments were conducted at Makueni and Katumani wilt infested plots in 1990/91 to confirm the performance of the selected lines. The test lines were grown in a randomised complete block design with three replicates in all experiments. A plot consisted of two, 5 m rows. Spacing was 75 cm between rows and 30 cm within rows. Plots were kept weed free by hand weeding. No fertilizers were applied. Pod fly (*Melanogromyza chalcosoma*), pod borer (*Helicoverpa armigera*) and pod sucking bugs (*Maruca testulalis*) were controlled by Ambush (Cypermethrin) and Rogor L-40 (Metasystax) at 1 ha^{-1} sprayed three times at two week intervals starting at flowering.

Glasshouse experiments. The glasshouse experiments were carried out in 1991. Seeds were pre-germinated in incubators maintained at 25–26°C to ensure good plant stand and then transplanted in the wilt sick boxes. A plot consisted of three 60 cm rows replicated three times. Spacing was 7 cm between rows and 5 cm within rows. No fertiliser was added. The plants were watered regularly. Planting for the first experiment was done on 28 March and and on 10 May for the second experiment. Disease onset and progress was monitored and the wilted plants recorded every week for three months. In both field and glasshouse experiments, NPP 718 and Munaa were used as susceptible checks.

In addition to resistance/tolerance to Fusarium wilt, lines were selected for reduced height (about 1.5 m), early maturity (150 days), seed characteristics (large white seeds) and yield as they advanced from one generation to the next.

Data collection and analysis. Data on primary branches, plant height, pods per plant were recorded on ten randomly selected plants in each plot. Days to flowering and maturity was recorded when 50 per cent of plants in each plot had at least one flower and had dry brown pods, respectively. Grain yield was estimated on the basis of whole plot harvest adjusted to 15.5% moisture content. Seeds per pod was based on twenty randomly selected pods in each plot. Seed weight was determined from 100 clean seeds on plot basis. Per cent plant mortality was determined as the proportion of dead and/or wilted plants at maturity divided by the germination count. Disease rating was done using a 1–9 scale (Nene *et al.*, 1981) where those below 3 were considered resistant, 7 tolerant and 9 susceptible.

Data for individual sites were also analysed separately to determine the significance of genotype effects and homogeneity of error variances (Steel and Torrie, 1980). Combined analysis for field and glasshouse experiments were also performed as suggested by Gomez and Gomez (1984). Planned least significant differences (PLSD) was used for mean separation.

RESULTS

The 111 lines originated from crosses among three wilt resistant lines (NPP 725, ICP-7035 and NPP 673/3) and seven susceptible parental lines (NPP 670, Munaa, NPP 679, NPP 718, M.S., GPL-3 and NPP 726). Four of the parental lines (NPP 679, Munaa, M.S. and NPP 673/3) were selections from landraces and are tall (1.9–2.5 m), late maturing (250 days), but with desirable white/beige seeds (19 g/100 seeds). Five parental lines (NPP 725, QPL-3, ICP 7035, NPP 726 and NPP 718) were introductions from India and were selected because of their early maturity (120–150 days), short stature (0.5–1.6 m) and wilt resistance (NPP 725 and ICP-705). However seeds of these introductions are small and brown. NPP 670 was selected because of its large white seeds (19 g/100 seeds) and early maturity (150–160 days). As expected, breeding populations from these parental lines showed wide variation for all the characters considered. Phenotype selection for wilt resistance/tolerance, reduced height (1.5 m), early maturity (150 days), seed characteristics and grain yield from this breeding population resulted in 111 lines which were evaluated at Makueni in 1989/90.

Of the 111 lines evaluated at Makueni in 1989/90, 48 were discarded due to high mortality (9 lines) and brown seed colour (39 lines). Brown seed cultivars are not preferred by local farmers and consumers. For the remaining 63 lines, there were significant ($P \leq 0.05$) differences in the number of primary branches, plant height, pods per plant, duration to flowering and maturity, seeds per pod, 100-seed weight and mortality due

TABLE 1. Means and ranges of the base populations and the selected lines

Character	Base population		Selected populations	
	Mean	Range	Mean	Selection differential
Days to flowering	108.3	95–145	109.2	0.9
Days to maturity	160.0	152–196	163.8	3.8
Plant height (cm)	82.8	35.1–105.4	92.5	9.7
Primary branches/plant	9.1	5.2–24.1	7.8	-1.3
Pods/plant	69.5	41–315	78.8	9.3
Seeds/pod	4.9	4–7	5.3	0.4
100-seed weight	14.0	7.5–17.6	15.0	1.0
Yield (kg ha^{-1})	1358.7	320–7249	1461.4	102.7
Per cent mortality	30.6	0–100	11.9	-18.7

to wilt. These 63 lines were considered as the base population for subsequent experiments. The means and range for the various characters of this population are shown in Table 1. There was considerable variability for all the nine characters measured. For example, the mortality due to Fusarium wilt in the base population varied from 0–100 per cent. Wilt infestation was initially noticed within the third month after planting and continued throughout the season until maturity. The disease was evenly distributed in the field as indicated by death of susceptible checks planted after every five test lines. Nine genotypes had 0 per cent mortality (KB 38/1, KO 71/3, KZ 93, KB 38, KZ 77, KO 71/2, KO 101/1, KO 237 and KO 25/2). The mortality rate for the two susceptible checks, Munaa and NPP 718 was 100% and 80.4%, respectively.

From these 63 lines, the most promising 19 lines were selected for combining resistance/ tolerance to wilt with reduced height, seed characteristics, early maturity and yield potential.

Table 2. Mean per cent mortality of 19 pigeonpea lines grown in field sick plots and in *Fusarium* wilt infested soil in the glasshouse, 1989–1991

Line/cultivar	Makueni 1990/91	Katumani 1990/91	Glasshouse 1990	Mean
KO 25/2	16.1	0.0	19.4	11.8
KO 237	15.0	0.0	12.9	11.6
KB 38/1	22.5	16.8	26.8	22.0
KZ 63	16.1	33.3	15.6	21.7
KO 120	45.9	23.5	41.7	37.0
KO 420	38.7	26.0	41.7	35.5
KO 71/2	14.1	51.0	18.0	27.7
KZ 21/2	11.8	61.7	14.3	29.3
TK 21/1	1.6	10.0	10.0	7.2
KZ 56	29.3	0.0	15.0	14.8
KZ 36	20.0	76.7	25.0	40.6
KZ 77	24.7	14.0	41.7	26.8
KO 71/3	45.0	33.4	55.3	44.7
KB 48	36.9	71.5	40.2	49.5
KO 29/1	7.2	16.0	17.0	13.4
KZ 69/2	34.3	56.6	5.0	47.0
KZ 8/1	13.7	39.0	39.0	30.6
KO 101/1	45.0	22.0	23.0	30.0
KO 36/1	54.3	60.9	65.0	60.0
Munaa	90.7	100.0	69.0	86.0
NPP 718	88.3	100.0	69.0	86.0
Mean	32.4	41.6	34.6	36.2
LSD (0.05)	28.2	25.9	24.2	

TABLE 3. Mean performance of ten selected early maturing pigeonpea lines at two locations in Kenya, 1990–1991

Line	Primary branches/ plant	Height (cm)	Days to flowering	Days to maturity	Pods/ plant	Seeds/ pod	100-seed weight	Yield (kg ha^{-1})	Disease rating[a]
Makueni									
KO 25/2	8.4	83.5	11.3	157.7	62.6	4.3	15.2	2333.7	MR
KO 237	13.0	130.0	112.3	160.0	101.0	4.2	14.9	2126.5	MR
KB 38/1	14.0	112.0	110.0	153.0	66.0	4.6	16.7	1707.44	T
KZ 63	7.5	95.5	117.0	167.0	35.3	4.0	14.8	1403.7	MR
KO 120	10.9	109.8	113.7	160.3	47.4	4.5	15.4	1672.2	T
KO 420	10.5	107.3	110.0	160.0	16.8	4.4	13.4	1055.5	T
KO 71/2	8.1	120.6	112.3	162.3	51.8	4.9	16.3	1876.5	MR
KZ 21/2	8.9	104.0	112.3	157.7	62.6	4.3	15.2	2333.7	MR
TK 21/1	10.2	134.4	108.0	156.4	38.2	4.1	14.6	1738.2	R
KZ 56	6.3	113.8	114.4	167.4	18.2	4.2	16.7	2438.4	T
Mean	9.8	111.2	112.2	160.2	50.0	4.4	15.3	1970.6	
Katumani									
KO 25/2	7.1	128.1	108.3	154.0	90.6	4.6	16.0	1310.6	R
KO 237	7.7	87.5	121.3	160.7	76.4	4.6	12.4	2685.8	R
KB 38/1	8.6	122.0	108.3	139.0	177.8	4.5	15.5	2962.6	MR
KZ 63	6.9	117.8	134.0	174.0	86.0	4.5	13.9	1455.7	T
KO 120	10.9	109.8	113.7	160.3	47.4	4.5	15.4	1672.2	T
KO 420	8.0	105.7	116.3	159.0	126.1	4.7	12.5	2868.8	T
KO 71/2	6.8	96.5	119.0	141.7	122.0	4.7	12.7	2338.8	S
KZ 21/2	8.3	93.8	114.0	173.7	98.3	4.,4	12.2	1950.5	S
TK 21/1	10.2	134.4	108.0	156.4	38.2	4.1	14.6	1738.2	R
KZ 56	6.2	112.0	115.0	162.0	35.0	4.2	14.5	2258.0	R
Mean	7.7	108.0	118.7	157.7	94.7	4.5	13.6	2158.1	R
LSD (0.05)	2.58	18.7	19.02	12.92	75.46	0.8	3.45	886.7	

[a]R = resistance, MR = moderately resistant, T = tolerant, and S = susceptible (Nene *et al.*, 1981)

The mean and selection differentials for the 19 lines is shown in Table 1. The selection intensity was 7.5%. These lines had yields over 1000 kg ha^{-1}, a 100-seed weight of 15 g, matured within 180 days and a mortality rate of 11.9%. The 19 lines were evaluated in wilt infested plots and in the greenhouse in 1990/91 to confirm their performance and final selection.

1990/91 experiments. The 19 selected lines and two susceptible checks were further evaluated for their reaction to Fusarium wilt in field sick plots at Makueni and Katumani (National Dryland Farming Research Station) during the 1990 short rains and in sick boxes at Kabete in 1990. Table 2 shows the per cent mortality of these lines in the glasshouse and in the field. Analysis of variance showed that there were significant differences among the lines and locations. Average mortality was highest at Katumani sick plot and lowest at Makueni sick plot in 1989/90. However, the mortality rate of the susceptible checks was high in all the field sick plots in all seasons (over 80%) and 69% in the glasshouse. This indicated that the test soils had adequate inocula for testing the materials. Most of the genotypes rated as resistant in the base population showed higher levels of mortality in subsequent field and glasshouse evaluations. In other cases the reverse was true. There was strong positive correlation between glasshouse disease rating and field rating at Makueni ($r = 0.87^{**}$) and Katumani ($r = 0.62^{**}$) and also between the two field test sites ($r = 0.62^{**}$). Three lines (KO 25/2, TK 21/1 and KO 237) showed consistently low mortalities both in field and glasshouse evaluations (Table 2). One line was rated resistant, 13 tolerant and one (KO 36/1) susceptible to Fusarium wilt. KO 36/1 had been selected because of heavy podding among the few surviving plants.

From the 19 lines, the best 10 combining early maturity, reduced height, seed characteristics, high yield potential with tolerance/resistance to Fusarium wilt were selected. One of these lines was consistently rated resistant, three moderately resistant and six tolerant to Fusarium wilt (Table 3). There were significant genotypic differences for primary branches, plant height, days to maturity, and grain yield. Location effects were significant for primary branches, plant height, pods plant^{-1}, days to flower and seed weight. Location x genotype interactions were significant only for primary branches and plant height. These lines had an average of 8.7 ± 1.6 primary branches per plant; average height of 109 ± 10.2 cm, 73.7 ± 29 pods per plant, 3.5 ± 0.3 seeds per pod, 80% flowered within 116 days and 90% matured in 160 days and had large, white seeds (14.5 ± 1.0 g/100 seeds). The average yield of these lines was 2013.7 ± 380 kg ha^{-1} across the test environments.

DISCUSSION

The results of the present study indicate possibility of early maturing wilt resistant cultivars. All the ten lines selected were resistant or tolerant to Fusarium wilt. The variable mortality rates across sites were probably due to presence of different strains of this pathogen and prevailing weather conditions which may affect disease development. Okiror (1986) showed that isolates from 12 pigeonpea growing areas in Kenya including the two test sites used in this study, differed in their virulence and growth characteristics. Of the lines he tested, few showed resistance to more than four isolates. In the present study, diseased materials from diverse sources were incorporated in the test sites to facilitate identification of lines with resistance to more than one strain. The consequently high mortality rate of the susceptible checks (Munaa and NPP 718) indicated adequate inocula and limited possibility of escapes.

Most of the local landraces of pigeonpea grown in Eastern Africa are not only tall but also late maturing. Omanga, P.A., Shakoor, A. and Siambei, M. (Personal communication, 1990) reported average maturing period of improved landraces to be 220–238 days. Such tall plants are difficult to spray and harvest. The selected lines in this study matured early (c.a. 160 days) and were shorter (c.a. 110 cm) indicating that selection for reduced height and early maturity was effective.

Most farmers and consumers in Eastern Africa have a preference for large white/beige seeded types, characteristic of traditional landraces. However, most cultivars from the Indian sub-continent have small brown seeds. This is partly because in Eastern Africa the seeds are eaten whole while in India the seeds are dehulled to remove seed coats and subsequently split (dhal). Consequently in the former case the seed coats affect the physical appearance or attractiveness of the cooked food but not in the latter. Efforts to introduce early maturing, small brown seeded cultivars in 1973 in Kenya were unsuccessful probably due to their undesirable characteristics such as seed colour and size, susceptibility to wilt and poor adaptation (Okiror, 1986). The ten selected lines reported in this paper have large white/beige seeds with an average seed weight of 14.6 g/100 seeds.

Grain yield of pigeonpea in farmers' fields in Eastern Africa is low. Omanga *et al.* (personal communication, 1990) reported average yields of 472 kg ha^{-1} in Kenya while estimated yields in Tanzania were 450–670 kg ha^{-1} (Maingu, Z.E. and Mligo, J.K., 1990: personal communication). The selected lines in the present study have an average yield of 2013 kg ha^{-1} and therefore a higher yield potential than local landraces, and two crops can be harvested each year because of their early maturity.

The results of this study indicates new potential for increasing pigeonpea productivity not only in Kenya but also in other pigeonpea growing areas in the region with similar production constraints. The selected lines combine resistance to Fusarium wilt with early maturity, reduced plant height, desirable seed characteristics and improved yield potential. It is recommended that they should be evaluated to confirm their yield stability.

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