Assessment of genotypic variation for dry matter production Under decreasing water supply in dual purpose sorghum

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INTRODUCTION

There is much detailed information on the response of sorghum to drought conditions. Most of the literature focuses attention on grain production and as a result little attention has been paid to the distrubution of the dry matter yield in the vegetative parts of the plant which affects the value of the crop as feed for ruminants.

This program deals with dual purpose sorghum where grain is produced for human consumption either as a source of carbohydrate or as a substrate for fermentation in the brewing industry, and the remaining canopy (stover) is used as animal feed. We presume that stover yield and quality of a dual purpose crop is as important as the grain. Selection of drought resistant sorghum cultivars is a crucial issue in this crop which is widely grown under drought stress conditions. Sorghum genotypes differ in yield under drought stress or in the rate of reduction in yield from non-stress to stress condition (e.g. Seetharama et al. 1982, 1983). Furthermore, the genetic variation for drought resistance depend on the mechanism involved (Blum et al. 1989). Decision on the proper selection criteria is not simple, and it is probably even more complicated to select sorghum with dual purpose triats than to select for either single purpose crop such as grain or forage sorghum

In this report we present results of the first field trial in the research program. This report covers the period from June to December 1989 and includes results of agronomical relevance. Other results, especially those concerning the quality of the stover will be presented in future reports.

MATERIALS AND METHODS

A field experiment is being conducted on the central farm of the Agricultural Research Organization at Bet Dagan. the previous crop was wheat, grown under irrigation in the summer, followed by winter fallow. The soil type is a deep and fertile Vertisol.

The field was fertilized with 500, 400 and 400 kg ha^{-1} of ammonioum sulphate, superphosphate and potassiun chloride respectively. Atrazin was applied twice at a rate of 700 and 900 g ha^{-1} in winter and spring respectively.

Sorghum was sown into wet soil on April 6, 1989. Gravimetric soil water measurements on the day of planting showed that the available soil water to a depth of 180 cm. amounted to 240 mm. No rainfall occurred from planting date onward, and the field was supplied with two light irrigations to assist germination. Fifteen cultivars were included in the experiment. Twelve of them were received from SADCC ICRISAT and they are thought to be among the best cultivars adapted to the region of South Africa. Two cultivars were received from Pioneer Hi-Breed, in Texas, U.S.A. and one was a dwarf drought resistant Israeli grain sorghum cultivar.

The African cultivars were: SDS 1513, SDS 1594-1, SDS 1710-1, SDS 2293-1,SDS 2293-6, SDS 2298, SDS 3168-3, Framida, Ntulired, Red Swazi, SDBP and Town. The American cultivars were P 8319 and P 8320. The Israeli cultivar was Hazerah 226.

The response to soil moisture content was studied with a line-source irrigation system. The seed was sown perpendicular to the line source in rows, 1 meter apart. Seedlings were thinned to 15 per meter. The experimental plots consists of two rows, 12 meter long, replicated three times. Each plot was divided into six, two meter long subplots. Irrigation commenced 45 days after sowing and the amount of water received by the subplots was measured by sets of rain gages installed every two meters in two of the plots. Water was applied late at night when wind velocity was low. Water was sprinkled above the canopy six

times at weekly intervals , and the amount of water applied was calculated so that the rain gages closest to the line source would receive 100% of the evaporation from a class A pan situated in vicinity.

The African and American cultivars appeared to be sensitive to bird damage. To prevent loss of grain yield, heads were covered with paper bags. An attempt was made to bag as many heads as possible, but this could not be accomplished with all cultivars. When bagging was possible all heads in a plot were bagged. Heads in one row of each cultivar were left unprotected in order to evaluate bird damage.

Seven cultivars were selected for complete harvest and analyses. They were selected according the development of the canopy and the appearance of the heads, and included both white and red grain cultivars. In the remaining eight cultivars bagging was performed on sample plants in each subplot so that distribution of the dry matter in the canopy could be measured and their quality traits could be analysed.

All the plants in each subplot were cut and weighed. Three plants in each subplot were sampled for canopy structure measurements. The sample plants were divided into 4 fractions: green leaf blade (GL), yellow leaf blade, (YL) stem+leaf sheath (ST) and heads (HD). A sample of all above ground canopy was used for dry matter determination. The samples were oven dried at 60C.

RESULTS AND DISCUSSION

Water availability

The amount and monthly distribution of rainfall in Lowveld and Middleveld regions of Swaziland are presented in Fig. 1. The growing season depends on water availability. It may generally start in November and finishes in late March. In the middleveld average fainfall during the growing season amounts to 550mm, whereas in the Lowveld it is 300mm. The growth of sorghum in the Lowveld seems to be under continuous-mild drought stress. If one assumes that the potential evapotranspiration for optimal growth of sorghum is approximately, 500mm, the distribution of rainfall over the season in the Lowveld indicates that it is unlikely that severe water stress will develop at critical stage for grain production.

The distribution and the amounts of the irrigation water supplied through the Line Source (LS) sprinkler system are presented in Figs 2 and 3. During the first five irrigations, water distribution was nearly equal in plots on both sides of the line. High wind velocity during the last irrigation impaired water distribution and this is evident in the total amount of water supplied. Of the water applied, maximum amounts were measured by the rain gages, placed two meters from the line. At this position, 660mm were available for plant growth, 420 mm of this, were supplied by irrigation and 240 mm were available as stored soil water. The distribution figures indicate that the plants in subplots at a distance of 10-12 m from the LS were grown solely on stored soil water. It should be noted that the amout of water available for sorghum growth in the Middleveld and Lowveld in Swaziland ccorrespond well to the range of water availability in our field trial.

Agronomical aspects and dry matter yield

Some of the agronomic traits of five African, one American and one Israeli cultivar are presented in Table 1. Water gradient did not affect the number of days to heading and therefore data for different

cultivars are presented as the mean for all subplots. SDBP was the earliest among the African cultivars. this might be an advantage under conditions of water shortage, provided that number of heads produced under stress, relative to the number produced under non stress conditions is not lower than that of a drought resistant cultivar like Hazerah 226. SDBP surpassed all the African varieties in the number of heads produced under non stress conditions. Furthermore, in this cultivar head numbers showed greatest stability over all water levels. In comparision, P 8320 also showed excellent stability but produced fewer heads. Under non stress conditions the number of heads exserted by Ntulired was only slightly smaller than that of SDBP, however it was the most sensitive to progressive water stress.

Plant height of all cultivars was affected by water availability. In most of them height reduction was obvious only 6 m and further from the LS. There is considerable variability amongst the cultivars with regard to bird damage. Ntulired, SDBP and P 8320 suffered least damage.

Data for total dry matter production and for stover and heads yield under extreme water level treatments is presented in Table 2. No significant differences between cultivars were found in total DM yield at 2 m from the LS because of a large experimental error. At 12 m from the LS, the drought resistant Hazerah 226 yielded significantly more DM than most of the tall cultivars. The Israeli and the American cultivars were less sensitive to progressive water stress than african cultivars. At 12 m from the LS yields of Hazerah 226 and P 8320 were 8.7 and 31.4% lower than at 2 m. The reduction in total yield of African cultivars was considerably greater. Since the water gradient in the LS experimental design is not randomly distributed, the data for relative yield reduction cannot be analyzed statistically.

In contrast to total DM yield, significant differences in stover and head DM yield were found between the cultivars. SDS 1594-1 and SDS 2293-1 were harvested without heads due to very severe bird damage caused by insufficient bagging. SDS 2293-1 surpassed all other varieties in its stover yield, but is was also the most sensitive to

drought. The genetic variability between cultivars is expressed in the relative sensitivity of stover and head production to drought. Under moisture stress conditions relative yield reduction in Hazerah 226 is due to decreased head production, whereas in P 8320 it is low stover yields rather than diminished head yields that contribute to total yield reduction. Relative reduction of total yield is around 50% in both Framida and SDBP. However in Framida, head production is more sensitive and stover production is less sensitive to moisture stress than in SDBP. The advantage of SDBP explained by its higher head yield in both stress and non stress conditions.

Comparable agronomic attributes and stover DM yield of the other eight African cultivars appear in Table 3. Two of the cultivars deserve further attention. They are: a) Red Swazi for its high head number and stability (except at 12 m from LS), its high stover yield and its earliness. b) SDS 1513 for its head number stability over all water levels.

Water production functions

The linear regressions fitted to head and stover DM yield data as a function of total water are presented in fig 4 and 5. Total water applied and not evapotranspiration was taken as the basis for the water production function. Soil water content for each cultivar over all the water gradient subplots could not be measured on the day of harvest. Consequently we are unable to calculate the actual water requirement. Based on a number of gravimetric measurements of soil water content it seems likely that the difference between total water applied and total evapotranspiration varies in the range of 0-120 mm.

Analysis of water production function for head DM yield indicates that differences between the intercepts of the regressions are responsible more than differences in the slopes or the overall response of the cultivars to a reduction in water supply. Among the African cultivars, highest stability in head yield overall water levels was found in SDBP. In contrast, there were significant differences between the slopes of the stover production functions (fig. 5). Two cultivars,

SDS 2293-1 and Ntulired were highly sensitive to drought where as SDBP was less sensitive in stover production by a factor of approximately 2.

Water use efficiency

The water use efficiency (WUE), i,e, D.M. production of heads and stover as a function of total water applied is illustrated in Fig. 6. The values given for stover production are higher than is known for many forage crops. In most cases there was an increase in WUE with the decrease of water availability to the plants. This indicates that the water stress which gradually developed, especially at distances of 10-12 m from the LS, was only light, and the amount of stored soil water (240 mm) was not low enough to bring about severe stress which could adversely affect stomatal apperture, photosynthesis, growth and thus WUE. Fig. 6 distinguishes between distinct WUE for head production from that of the stover. Except for the dwarf grain type Hazerah 226, the WUE of the stover was higher than that of the heads. Head WUE in Framida and Ntulired was very low, and decreased slightly with decreasing water availability. Among the non dwarf cultivars the highest increase in head WUE as a function of the distance from the LS was found in SDBP. Furthermore, it was the most stable cultivar as the difference between WUE of the stover and the heads remained constant whereas in all other cultivars this difference increased along the water gradient.

Stability and adaptability in sorghum to decreasing water supply

To assess the performance of sorghum cultivars over a range of available water content a technique suggested by Finlay and Wilkinson (1963), Eberhard and Russel (1966) and Samuel at al., 1970 was used. For each cultivar a linear regression of the individual yield (y-axis) on the mean yields of all cultivars for each available water content (x-axis) is computed. The mean yields provides a numerical grading and was suggested a useful evaluation of the environment. This will be referred hereafter as the "environmental index". In fig. 7 the regressions for 7 sorghum cultivars are presented together with a line which represents the population mean (mean of all cultivar yields and

available water contents). cultivars characterized by a regression coefficient (b) of the order of 1 have an average stability over all conditions of water availability tested. Cultivars with regression coefficient lower than 1 have above average stability whereas varieties with coefficients higher than 1 are very sensitive to changes in the environment (water availability). Hazerah 226 (b= 0.159) is the most stable cultivar and SDS 2293-1 (b= 2.164) is the most sesitive one. SDBP with a regression coefficient of 0.953 represent nearly average stability over all conditions of water supply. The regression line of SDS 2293-1 intersect the population mean line at an environmental index of 2.1 kg/m. This indicate that the cultivar is specifically adapted to high yielding environment i.e. high levels of water supply at which mean DM yields higher than 2.1 kg/m can be achieved. On the other hand it performs very poor at low levels of water supply. Hazerah 226 represent the opposite characteristics. It posseses very good stability over a range of water supply while producing above average yields, indicating good adaption to low yielding environment.

A further analysis of the behaviour of all the cultivars tested in this trial is illustrated in Fig. 8. The regression coefficients calculated for each cultivar and shown in Fig. 7 were plotted against the environmental index (mean DM yields of all cultivars obtained under the various levels of water supply). Each plot is represented by a single point which indicate the association between the level of stability and the average yield performance of each cultivar. The vertical and horizontal broken lines in Fig. 8 represent the population mean yield and the average stability respectively. Hazerah 226, Ntulired and SDS 2293-1 have above average DM yield, but the two african cultivars have greater sensitivity to environmental change and are adapted only to growing conditions with high level of water supply. Hazerah 226 is a typical drought resistant grain sorghum. It produces relatively high yields and shows greatest stability over the range of water conditions, however, it cannot be considered good dual purpose cultivar because of its relatively low stover yield (Table 2). Although P 8320 and SDS 1594-1 posseses above average stability their average yields were the lowest. Framida and SDBP are the two cultivars falling closet to the average stability and population mean yield (the intersection of the

broken lines). Framida is superior to SDBP in total yield and stability but it produces fewer heads under both favorable and unfavorable water supply (tables 1,2). An important result is that the variability between cultivars in yield stability is inversely proportional to their mean yield over all the water supply levels. Except for Hazerah 226, the tall cultivars which give the highest mean yields also possess below average stability, i.e. they can be regarded as drought susceptible cultivars and vise versa. It should be noted that early varieties (based on days to heading) tend to be adapted to unfavorable soil water conditions whereas the late varieties tend to be specifically adapted to non stress water regime as they only yield well under those growing conditions.

Canopy Structure

Fig. 9 shows the relative distribution of dry matter in the canopy. Assuming that grain production is the primary objective or at least of equal importance as stover production, then a cultivar with a mean harvest index (based on head weight) of 50% is superior to a more vegetative cultivar. Among the dual purpose entries, P8320 and SDBP possess the highest mean harvest index, of the two, SDBP is less sensitive to changes in water supply. Another important feature of a dual purpose type of sorghum is the "stay green ability". Fig. 10 shows the relative yields of green leaves and heads as a function of change in water supply. In general the relative weight of green leaves was found to be inversely proportional to the relative weight of heads. This was particularly evident at distances of 6 to 12 m from the LS. and amongst cultivars which were highly sensitive to unfavorable water conditions in the number of heads produced and head weights. Canopy structure should have a significant affect on the quality of the stover, and this will be taken into consideration in later stages of the research. At this stage, SDBP appears to be promising cultivar for the environmental conditions in Swaziland.

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Table 1. Effect of water availability (distance from LS) on agronomic variables of sorghum cultivars.

DISTANCE (m) *	HEAD EXSERTION (d.a.e.) #	HARVEST (d.a.e.)	HEAD No. (per m)	HEIGHT (cm)	GRAIN MOISTURE (%) &	BIRD DAMAGE (%) &
			CV: HAZERAH 226			
2	56	115	18.1±0.7	122.5±2.5	11.8	0
4	"	"	15.9±1.4	120.0±5.0	"	"
6	"	"	18.1±1.2	115.0±0.0	"	"
8	"	"	16.3±1.3	107.5±2.5	"	"
10	"	"	15.5±0.4	100.0±0.0	"	"
12	"	"	15.5±0.7	90.0±0.0	"	"
			CV: SDS 1594-1			
2	99	134	9.8±1.3	270.0±0.0	16.0	100
4	"	"	9.1±1.9	265.0±5.0	"	"
6	"	"	8.2±1.2	220.0±0.0	"	"
8	"	"	7.0±0.9	175.0±5.0	"	"
10	"	"	6.3±1.1	150.0±0.0	"	"
12	"	"	5.4±0.6	150.0±0.0	"	"
			CV: P 8320			
2	84	128	9.2±0.7	237.5±2.5	15.0	35
4	"	"	8.9±1.1	235.0±5.0	"	35
6	"	"	9.1±0.7	225.0±5.0	"	30
8	"	"	9.8±0.2	187.5±7.5	"	30
10	"	"	11.±0.5	150.0±10.0	"	25
12	"	"	7.5±0.4	150.0±40.0	"	20
			CV: NTULIRED			
2	95	130	12.8±1.3	410.0±0.0	15.0	25
4	"	"	10.4±2.4	415.0±5.0	"	"
6	"	"	9.1±0.2	360.0±20.0	"	"
8	"	"	4.2±1.2	252.5±22.5	"	"
10	"	"	0.8±0.3	195.0±15.0	"	"
12	"	"	0.0±0.0	170.0±7.5	"	"

* distance from line source
\# days after emergence to 50 % head exsertion
$ days after emergence
& cultivar mean on the day of harvest

Table 1. (continued)

DISTANCE (m)	HEAD EXSERTION (d.a.e.)	HARVEST (d.a.e.)	HEAD No. (per m)	HEIGHT (cm)	GRAIN MOISTURE (%)	BIRD DAMAGE (%)
			CV: FRAMIDA			
2	77	120	5.3±0.3	275.0±5.0	16.0	70
4	"	"	6.3±0.3	270.0±10.0	"	"
6	"	"	6.5±0.0	230.0±10.0	"	"
8	"	"	7.6±3.1	197.5±22.5	"	"
10	"	"	8.2±0.6	170.0±10.0	"	"
12	"	"	4.5±0.5	160.0±0.0	"	"
			CV: SDBP			
2	63	120	14.8±0.8	315.0±5.0	9.7	35
4	"	"	12.5±0.5	285.0±5.0	"	"
6	"	"	13.3±1.3	280.0±0.0	"	"
8	"	"	13.4±1.1	270.0±0.0	"	"
10	"	"	13.1±0.1	250.0±0.0	"	"
12	"	"	13.5±0.5	160.0±0.0	"	"
			CV: SDS 2293-1			
2	84	130	8.7±0.7	300.0±0.0	11.0	100
4	"	"	8.2±1.2	300.0±0.0	"	"
6	"	"	7.5±0.5	255.0±15.0	"	"
8	"	"	6.7±1.3	175.0±5.0	"	"
10	"	"	4.3±0.4	165.0±5.0	"	"
12	"	"	5.5±1.5	160.0±0.0	"	"

Table 2. Yield components (kg. D.M/m) of sorghum cultivars under non stress and maximum stres conditions.

YIELD VARIABLE	DISTANCE FROM LINE (m)	HAZERAH 226	SDS 1594-1	CULTIVAR P 8320	NTULIRED	FRAMIDA	SDBP	SDS 2293-1	CV (%)
stover	2	0.91 d $	2.44 bc	2.06 cd	3.55 ab	3.04 abc	2.58abc	4.36 a	22.9
stover	12	0.95 b	1.65 a	1.39 ab	1.43 ab	1.71 a	1.13 b	1.27 ab	16.4
yield reduction (%)	&	-4.3	32.4	46.5	59.7	43.7	56.2	70.9	
head	2	1.84 a		0.55 c	0.32 d	0.44 cd	0.97 b		11.6
head	12	1.56 a		0.4 0 bc	0.00 d	0.19 cd	0.52 b		21.1
yield reduction (%)		15.2		27.3	100	56.8	46.4		
total	2	2.75 a	2.44 a	2.61 a	3.87 a	3.48 a	3.55 a	4.36 a	20.5
total	12	2.51 a	1.65 b	1.79 b	1.43 b	1.90 ab	1.65 b	1.27 b	17
yield reduction (%)		8.7	32.4	31.4	63.1	45.4	53.5	70.9	

$ Yields within a row followed by the same letter are not significantly different at 5% level of probability by Duncan's Multiple Range Test.

& Yield reduction % = 1-(Y12/Y2)x100.

Table 3. Effect of water availability (distance from LS) on agronomic variables of sorghum cultivars.

DISTANCE (m) *	HEAD EXSERTION (d.a.e.) #	HARVEST (d.a.e.) $	HEADS NO. (per m)	HIGHT (cm)	GRAIN MOISTURE (%)	BIRD DAMAGE (%)	PDM (%) &	STOVER DM. YIELD (kg/m)
				CV: SDS 1513				
2	77	126	10.0±0.8	330.0±11.0	11	25	28.9±1.2	3.7±0.2
4	"	"	13.5±1.2	295.0±8.6	"	25	31.9±1.4	2.6±0.2
6	"	"	11.5±1.0	270.0±8.2	"	0	32.2±0.9	2.0±0.1
8	"	"	12.0±0.9	240.0±3.8	"	0	33.4±0.8	1.8±0.1
10	"	"	11.0±0.9	200.0±10.6	"	0	35.0±2.0	1.3±0.2
12	"	"	9.8±0.6	170.0±5.2	"	0	34.6±1.6	1.0±0.1
				CV: RED SWAZI				
2	71	115	14.3±1.4	188.3±7.3	13	50	47.1±1.2	3.7±0.1
4	"	"	13.5±1.7	188.3±8.8	"	"	43.5±1.2	3.1±0.3
6	"	"	8.2±4.0	185.0±2.9	"	"	49.0±5.0	2.8±0.1
8	"	"	10.2±5.1	155.0±16.1	"	"	52.0±2.1	3.2±0.1
10	"	"	13.4±1.3	136.7±8.8	"	"	50.2±0.9	3.1±0.1
12	"	"	5.5±2.8	115.0±15.0	"	"	51.0±1.0	2.1±0.2
				CV:SDS 2298				
2	80	126	10.5±1.4	292.5±2.5	11	40	35.5±0.9	2.9±0.8
4	"	"	4.8±0.3	275.0±0.0	"	"	34.0±0.9	2.2±0.2
6	"	"	6.8±1.3	255.0±15.0	"	"	29.8±4.9	1.7±0.1
8	"	"	7.8±0.8	220.0±20.0	"	"	32.1±1.3	1.9±0.1
10	"	"	7.5±1.0	185.0±15.0	"	"	34.1±0.9	1.2±0.2
12	"	"	5.9±0.4	170.0±12.5	"	"	35.4±2.2	1.1±0.0
				CV: P 8319				
2	80	128	11.7±0.7	205.0±5.0	16	15	27.5±1.0	1.9±0.1
4	"	"	12.2±0.6	200.0±10.0	"	"	31.0±0.3	1.4±0.1
6	"	"	11.3±0.9	187.5±2.5	"	"	37.2±2.7	1.5±0.1
8	"	"	11.9±0.8	155.0±15.0	"	"	39.8±3.8	1.5±0.2
10	"	"	11.3±1.3	130.0±0.0	"	"	36.3±2.6	1.0±0.1
12	"	"	7.3±1.5	120.0±0.0	"	"	33.9±1.2	1.2±0.1

* distance from line source
\# days after emergence to 50 % head exsertion
$ days after emergence
& D.M percentage

Table 3. (continued)

DISTANCE (m)	HEAD EXSERTION (d.a.e.)	HARVEST (d.a.e.)	HEADS NO. (per m)	HIGHT (cm)	GRAIN MOISTURE (%)	BIRD DAMAGE (%)	PDM (%)	STOVER DM. YIELD (kg/m)
				CV: 2293-6				
2	84	126	5.5±1.2	325.0±25.0	19	50	32.9±1.4	3.8±0.8
4	"	"	4.8±0.8	330.0±0.0	"	"	33.4±1.6	2.7±0.7
6	"	"	5.0±1.5	255.0±5.0	"	"	36.5±0.4	2.3±0.0
8	"	"	8.6±1.4	197.5±7.5	"	"	32.1±0.1	2.1±0.5
10	"	"	6.6±2.9	175.0±5.0	"	"	33.3±1.2	1.7±0.1
12	"	"	3.0±0.6	160.0±9.5	"	"	37.4±2.0	1.5±0.0
				CV: 1710-1				
2	95	130	9.0±1.0	270.0±0.0	15	100	25.3±0.3	2.7±0.2
4	"	"	8.4±0.7	260.0±0.0	"	"	27.4±1.1	2.2±0.4
6	"	"	6.±1.9	210.0±0.0	"	"	28.5±0.7	1.8±0.6
8	"	"	5.4±1.9	180.0±0.0	"	"	30.4±2.3	1.8±0.7
10	"	"	2.5±1.5	145.0±5.0	"	"	29.3±0.3	1.3±0.2
12	"	"	1.7±0.3	130.0±6.2	"	"	29.9±1.3	0.8±0.1
				CV: SDS 3168-3				
2	80	126	7.1±1.7	232.5±7.5	18	50	27.1±0.5	2.2±0.2
4	"	"	7.8±1.2	230.0±0.0	"	"	29.4±3.2	1.7±0.2
6	"	"	5.2±0.2	225.0±5.0	"	"	31.8±1.4	2.0±0.6
8	"	"	8.9±0.4	175.0±15.0	"	"	31.9±0.9	1.4±0.3
10	"	"	8.7±0.0	157.5±2.5	"	"	32.6±1.5	1.3±0.0
12	"	"	9.0±0.3	150.0±6.3	"	"	31.4±0.8	1.1±0.2
				CV: TOWN				
2	99	130	8.2±0.8	400.0±0.0	15	100	31.9±1.1	3.3±0.3
4	"	"	5.6±0.9	370.0±5.0	"	"	38.1±2.4	2.6±0.5
6	"	"	3.3±0.3	300.0±0.0	"	"	35.2±0.4	2.0±0.3
8	"	"	3.0±1.5	290.0±0.0	"	"	31.6±1.7	1.6±0.2
10	"	"	1.5±0.1	240.0±0.0	"	"	30.9±0.8	1.4±0.1
12	"	"	2.0±0.2	187.5±2.5	"	"	31.9±1.1	1.7±0.1

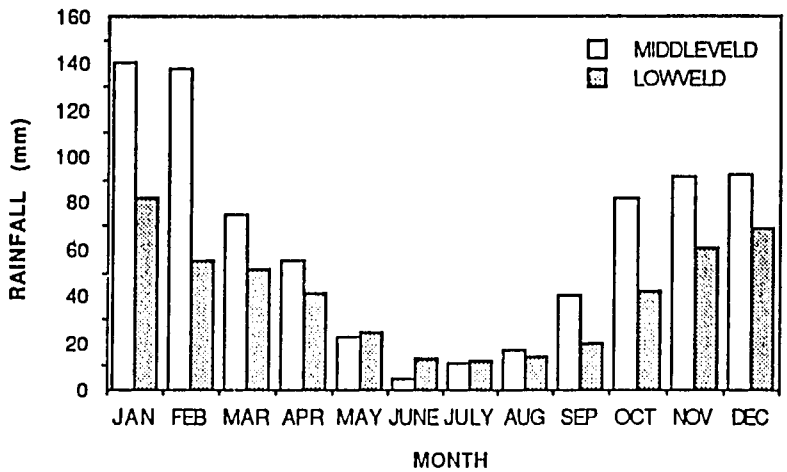

Fig. 1. Mean monthly rainfall for Manzini (Middleveld) over 21 years and for Lavumisa (Lowveld) over 31 years (Mkhatshwa 1988).

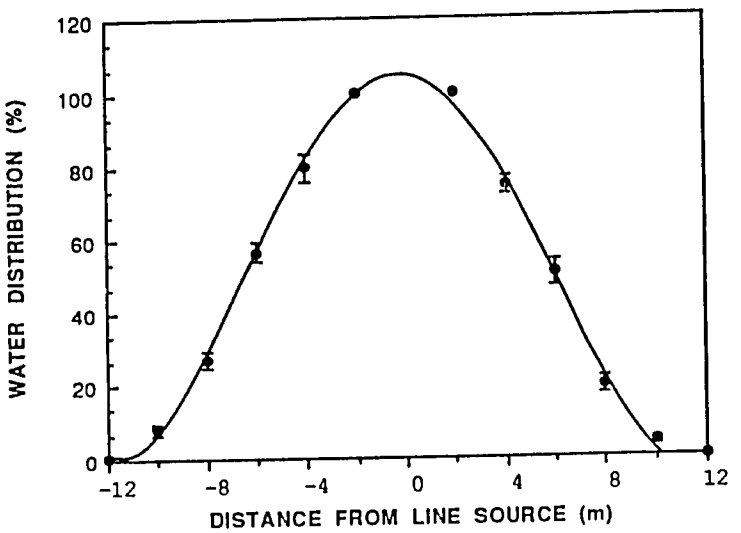

Fig. 2. Water distribution as a function of distance from line source (6 irrigations ±s.e)

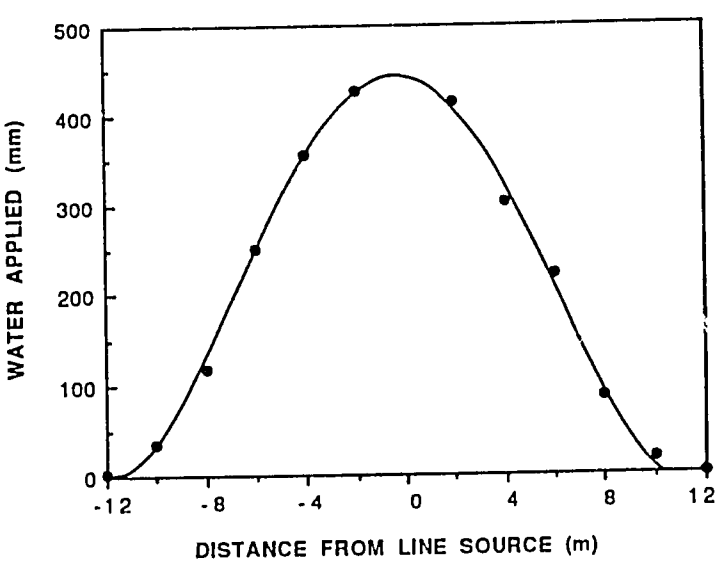

Fig. 3. Amount of water applied as a function of distance from line source

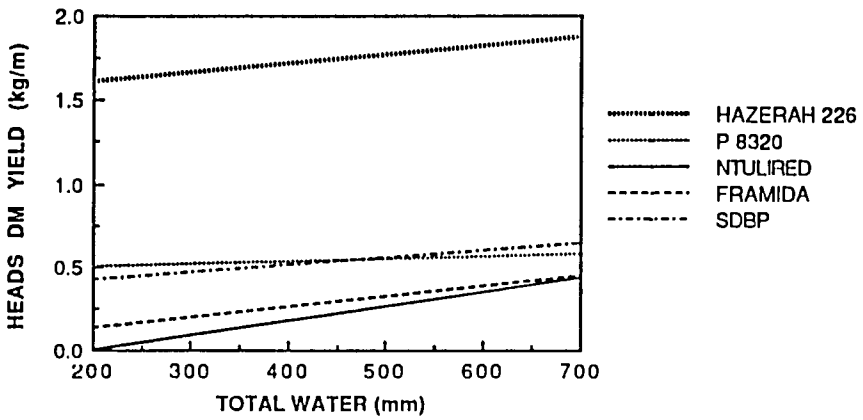

Fig.4. Water production function for head dry matter yield
(total water=soil water content on the day of planting+irrigation water)

Regression equations (n=6)

Hazerah 226	Y= 1.508+0.0005x	R^2=0.614n.s
P 8320	Y= 0.457+0.0002x	R^2=0.223n.s
Ntulired	Y=-0.198+0.0009x	R^2=0.820 *
Framida	Y= 0.003+0.0006x	R^2=0.965 **
SDBP	Y= 0.326+0.0004x	R^2=0.663 *

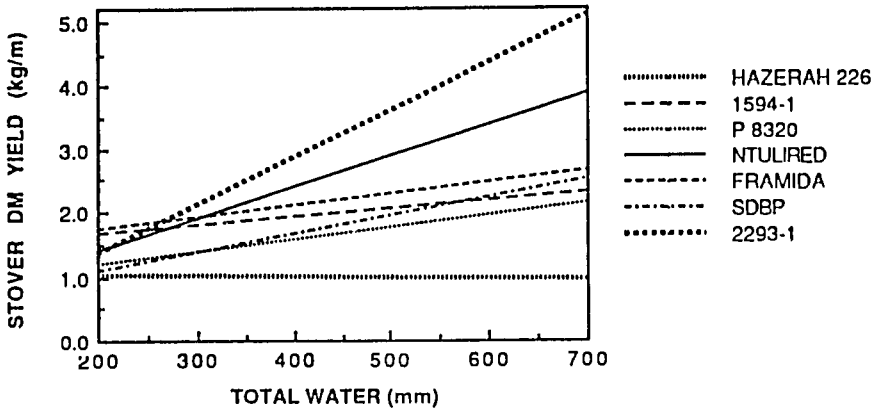

Fig. 5. Water production function for stover dry matter yield
(total water= soil water content on the day of planting+ irrigation water)

Regression equations (n=6)

Hazerah 226	Y= 1.059-0.0002x	R^2=0.157	n.s
1594-1	Y= 1.410+0.0012x	R^2=0.651	n.s
P 8320	Y= 0.831+0.0018x	R^2=0.862	**
Ntulired	Y= 0.391+0.0049x	R^2=0.980	**
Framida	Y= 1.356+0.0018x	R^2=0.419	n.s
SDBP	Y= 0.504+0.0028x	R^2=0.898	**
2293-1	Y= -0.120+0.0074x	R^2=0.929	**

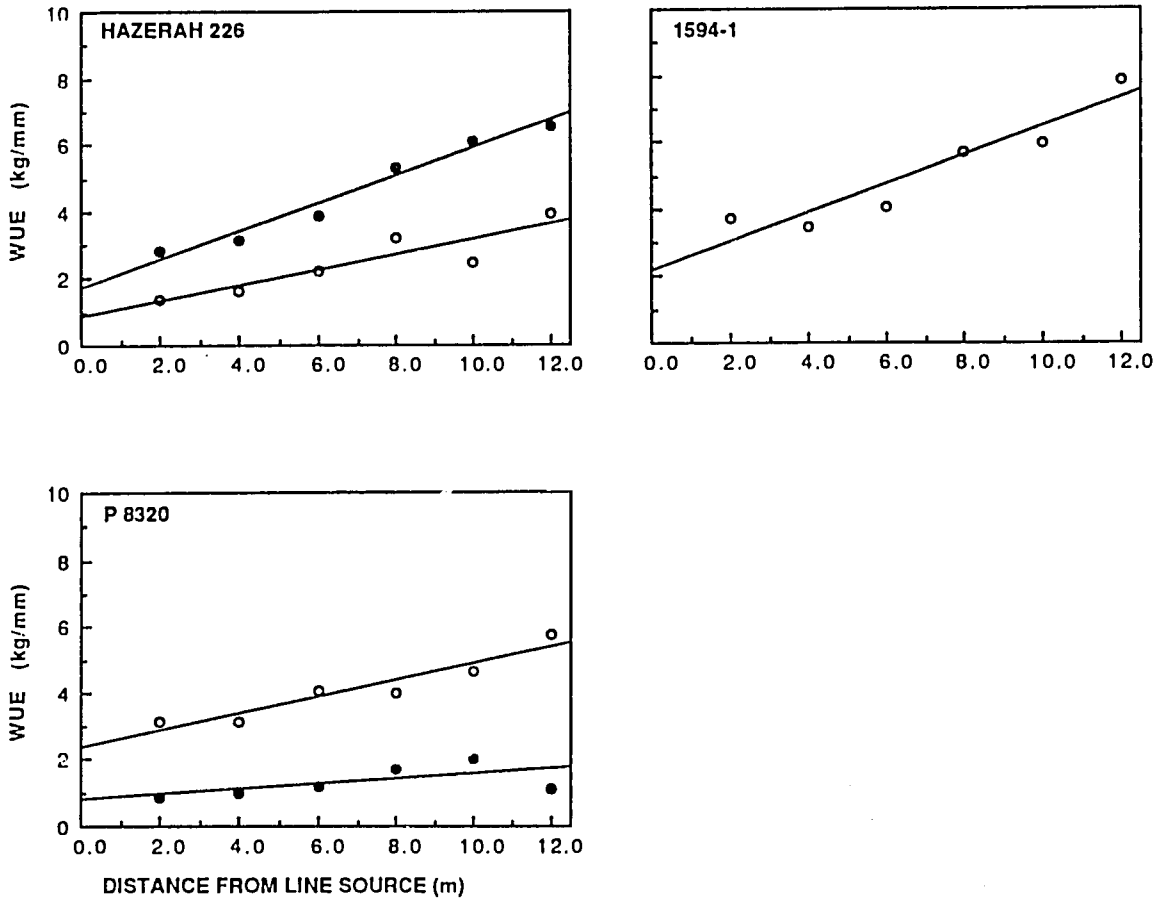

Fig. 6. Water use efficiency (total water basis) as a function of distance from line source

● head, o stover

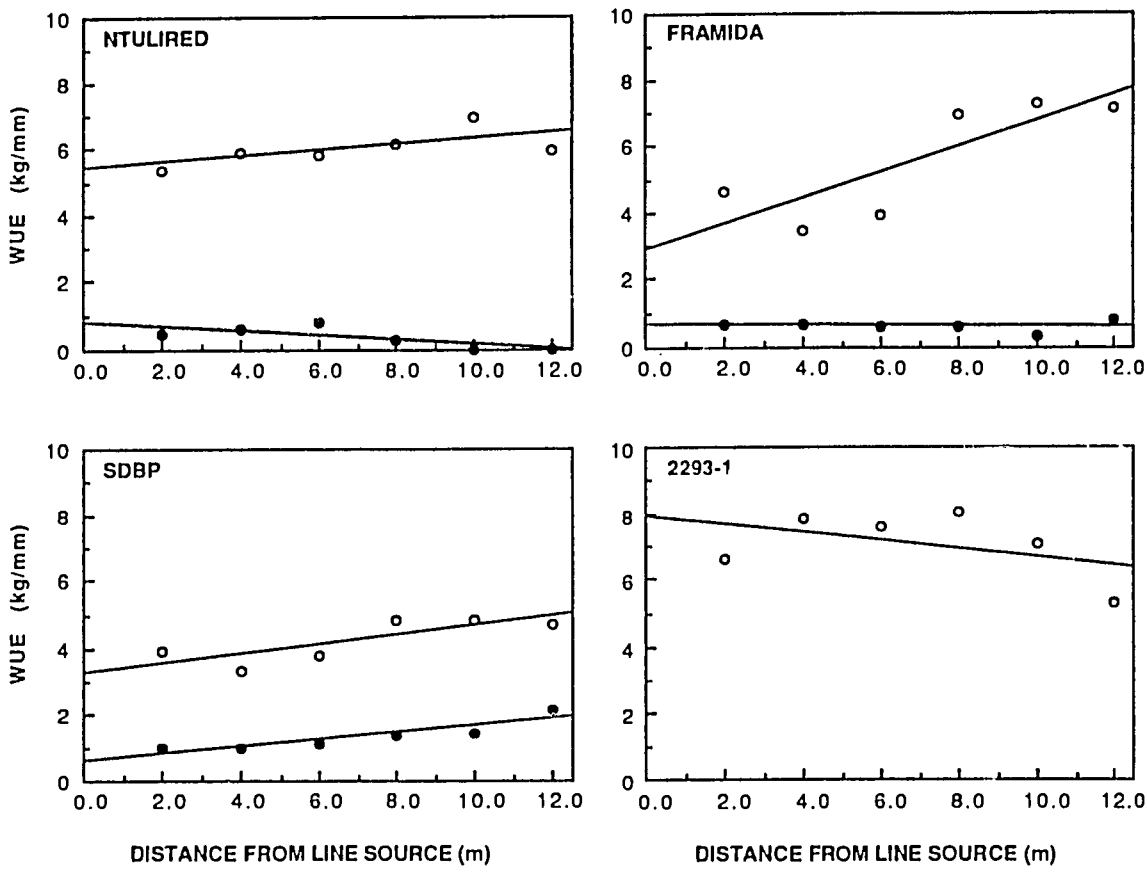

Fig. 6. (continued)

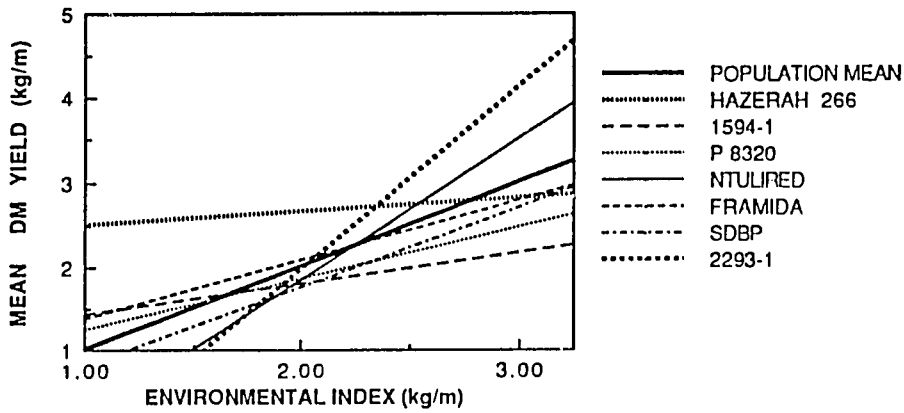

Fig.7. Over all relationship between cultivar performance and environmental index
x axis: mean D.M yield of all cultivars in each of the water regimes.
y axis: D.M yield of individual cultivar in each of the water regimes.
population mean: 1/1 line.

Regression coefficients (b)

Hazerah 226	0.159
1594-1	0.365
P 8320	0.611
Ntulired	1.675
Framida	0.709
SDBP	0.953
2293-1	2.164

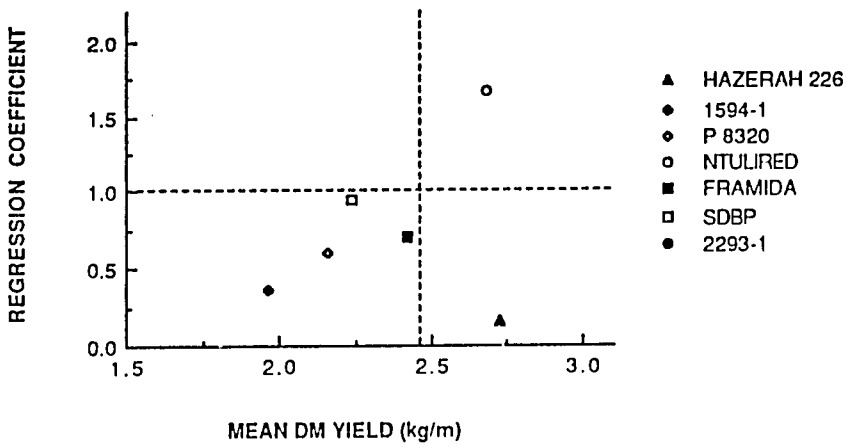

Fig. 8 . The relationship of cultivar adaptation to moisture environment and mean DM yield (the coefficients used are those presented in fig.7.)
Horizontal broken line : average stability
Vertical broken line : population mean yield

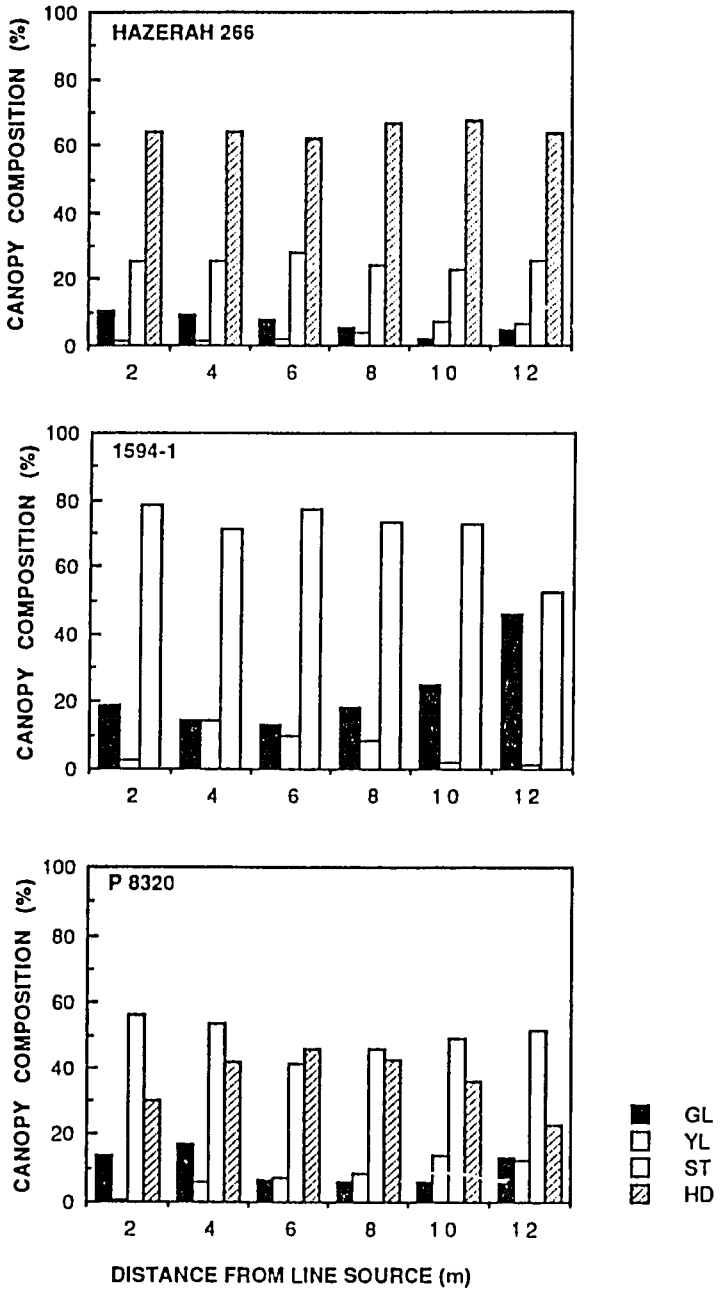

Fig.9. Canopy composition (% of total dry weight) as function of distance from line source.
GL: green leaf, YL: yellow leaf, ST: stem, HD: head

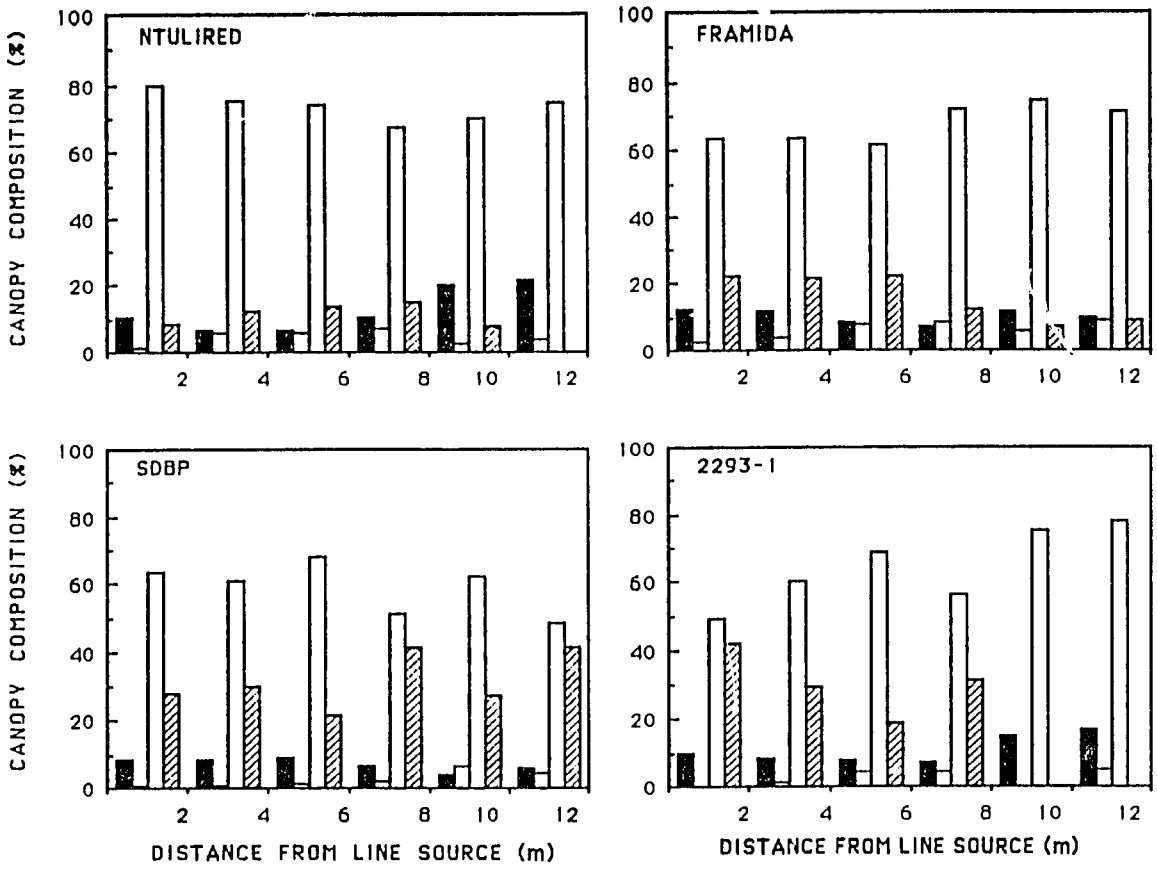

Fig. 9. (continued)

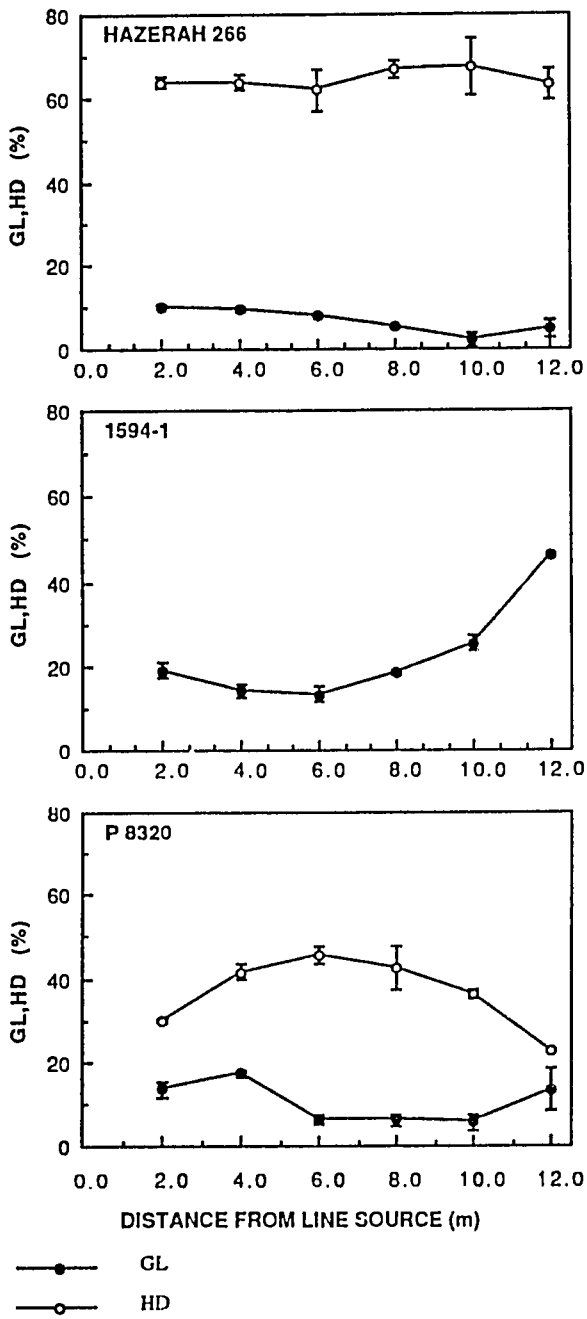

Fig.10. relative yield (%) of green leaves (GL), and head (HD) as a function of distance from line source.

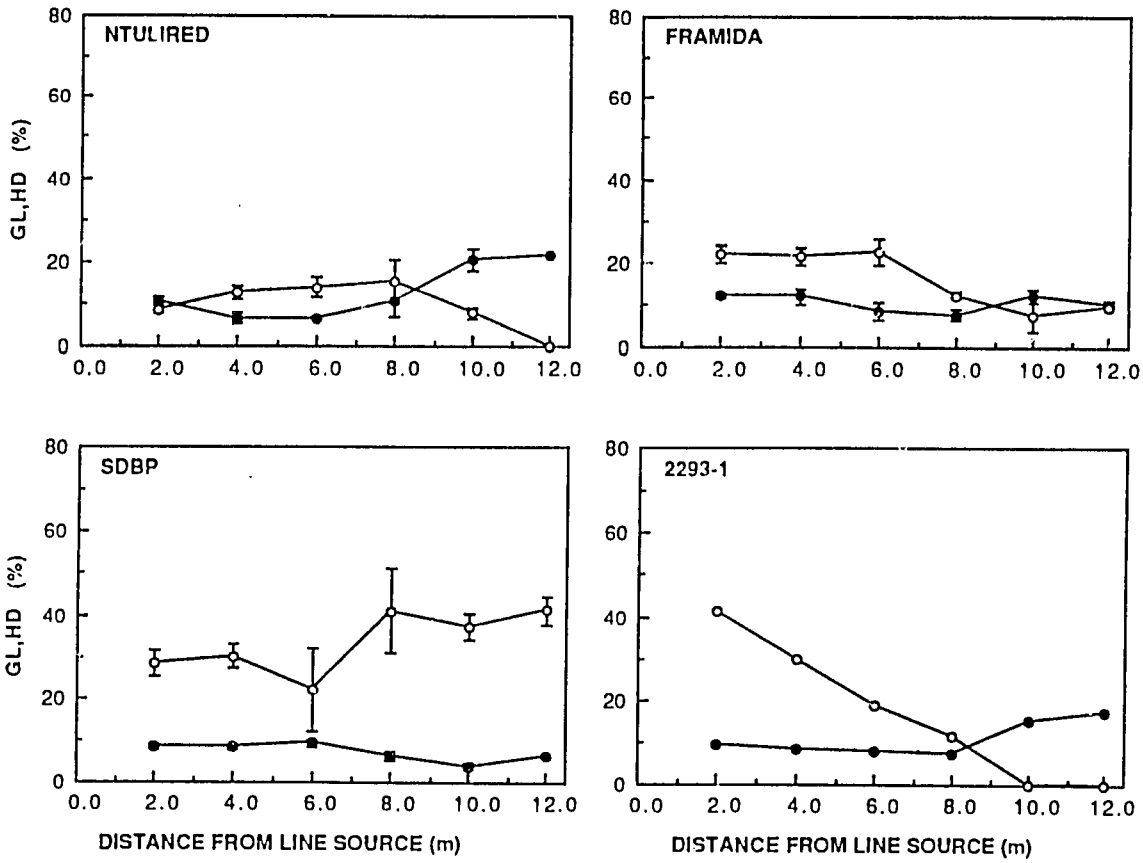

Fig. 10. (continued)

GL
HD