Fibre sorghum: effect of the harvesting date on six hybrids with different cycle in Central Italy

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Non-food crops provide raw material for various production chains: fibre or cellulose, biomass, oils for energy, dyes, starch, etc.
Among these crops, sorghum is one of the most interesting since its biomass can be transformed into paper, fibre, ethanol and electricity.

The first studies on fibre sorghum for paper pulping were carried out in France on broomcorn varieties. More recently there has been an increasing interest on the hybrids "grain x broomcorn". A large number of these hybrids have been tested for production under various environmental conditions and cultivation methods both in Italy and elsewhere (Quaranta *et al*., 1994; Hevin, 1996; Duarte *et al*., 1998; Jacquin and Labalette, 1998; Monotti *et al*., 1998; Belocchi *et al*., 1999; Gherbin *et al*., 2001). Interesting results have been also reported on fibre quality (Recchia *et al*., 1998).
According to French studies, the optimal condition for harvesting sorghum hybrids for fibre is 14 days after flowering, when the plants are supposed to reach the maximum yield in dry matter and cellulose content (Peyre, 1979).
In order to establish the optimal harvesting period in the environmental conditions of Central Italy, we investigated the effect of three different harvest date (14, 21 and 28 days after flowering) on the production of six fibre sorghum hybrids characterized by different maturity classes.

MATERIALS AND METHODS

The field experiments were carried out in 1998 and 1999 at the Inviolatella Farm of Cereal Research Institute of Rome (41°58' N, 12°28' E) on deep soils having a clayey texture. Six different fibre sorghum hybrids (H 128, H 133, H 130, H 16, H 132 and H 202) were sowing adopting a complete factorial experimental design with three replications. Plot size was 18 m^2 with 50 cm spacing between rows.

Table 1 - Rome, Inviolatella farm,1998 and 1999: trials management.

	1998	1999
Preceding crop	triticale	durum wheat
Fertilization		
N (kg ha^{-1})	150	150
P_2O_5 (kg ha^{-1})	80	80
Sowing	12 May	12 May
Emergence	20 May	21 May
Thinning	3 June	9 June
Weeds control	-	terbuthylazine
Water supplies		
date	30 July	7 July
m^3 ha^{-2}	800	800

Table 1 shows some information on trials management. In 1998 the irrigation was carried out later than planned because of irrigator failure. The plots were harvested by hand 14, 21 and 28 days after flowering of each genotype on a representative sample of at least 1.5 m^2 per plot. For each year and plot, emergence and flowering dates were recorded, stem height at last blade joint and stem diameter were measured on a sample of 15-30 plants per plot. At harvest, the yield of aboveground fresh biomass, stems and sheaths together (reported below as "stems + sheaths"), leaves and panicles were recorded. For stems + sheaths and panicles, dry weight measure was performed after a treatment at 105° for at least 36 hours.
For each year the results were subjected to variance analysis using MSTAT-C software package; a combined analysis over the years was also performed and the means separated using the Duncan test at a P=0.05 significance level.

WEATHER CONDITIONS

Figure 1 shows decadal maximum and minimum temperatures and rainfall from April to October, for the two-year trial (1998 and 1999) and for the 24-year averages (1974-1997).

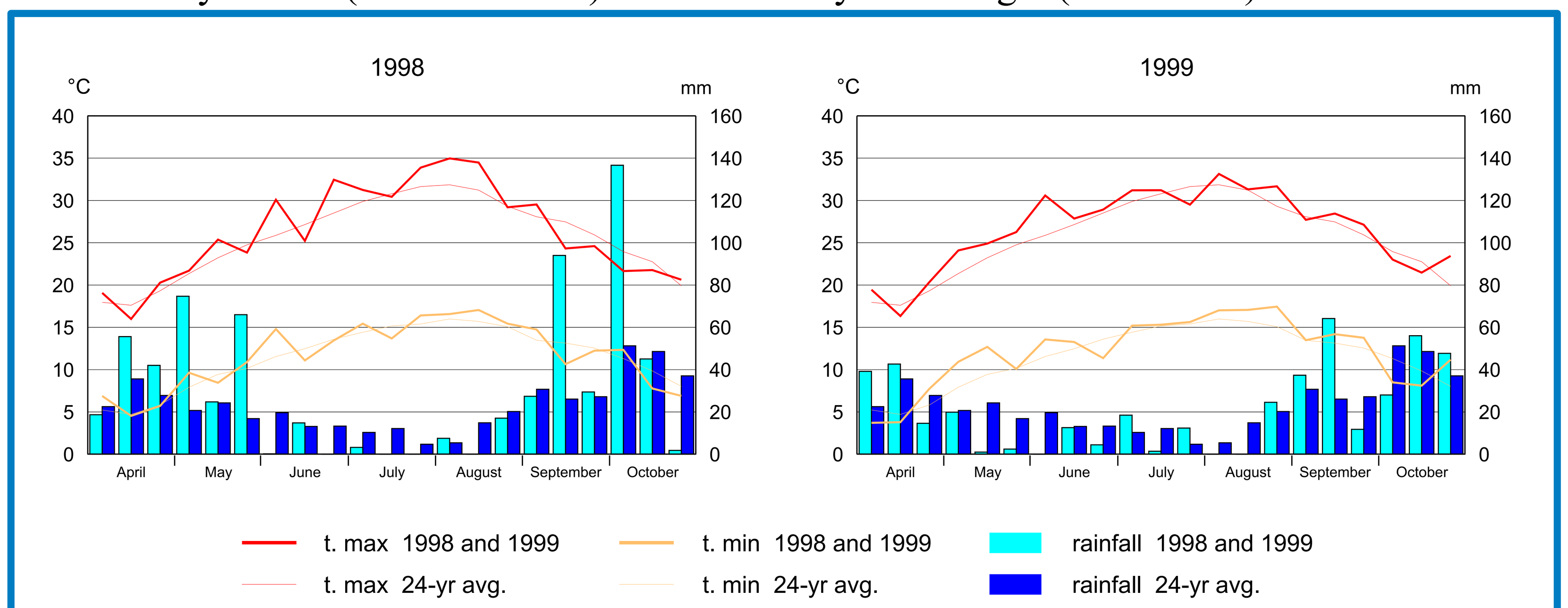


Figure 1 - Rome, Inviolatella Farm. Decadal maximum and minimum temperature (°C) and rainfall (mm) from April to October for 1998, 1999 and 24-yr average (1974-1997).

In 1998 maximum temperature was above the seasonal average during summer months, especially July and August. Rainfall was above seasonal average from second decade of April to third decade of May; rainfall was poor until first decade of September. In the following period temperatures were lower than average and rainfall was abundant.
In 1999 temperatures were above average from May to July with a peak in the first decade of June. Rainfall was below average from the end of April to the end of August except for the first decade of July. In September and October rainfall was substantially on the average.

RESULTS AND DISCUSSION

Table 2 reports the data submitted to the analysis of variance. Stem height, basal diameter and stems + sheaths dry matter shows differences over the two years of trials. In 1998 stems height and dry matter production were lower than those of 1999 (table 3). These differences are likely due to climatic conditions even if we cannot exclude that irrigation delay in 1998 could have played a determining role.

Table 2 - Analysis of variance: statistical significance for plant height, stem diameter, fresh and dry matter (DM) yield.
* significant at the 0.05 level; ** significant at the 0.01 level; n.s. not significant.

Source	d f	Plant height al last blade joint	Bottom stem diameter	Fresh yield: above-ground biomass	Fresh yield: stems + sheaths	DM yield: stems + sheaths
Year (Y)	1	**	**	n.s.	n.s.	*
Replication	4					
Hybrid (Hy)	5	**	**	**	**	**
YxHy	5	**	**	**	**	**
Harvesting (Ha)	2	n.s.	n.s.	n.s.	*	**
YxHa	2	n.s.	*	n.s.	n.s.	n.s.
HyxHa	10	n.s.	**	**	**	n.s.
YxHyxHa	10	n.s.	n.s.	**	n.s.	n.s.

All the traits examined presented statistically significant differences among hybrids; only the early maturing genotypes, H 128 and H 133, were not statistically different (table 3).
The average fresh aboveground biomass yield was 135.1 t/ha whereas the mean value stems + sheaths dry matter was 29.2 t/ha. The harvest treatment had significant effect only on stems + sheaths yield.
The yield increase was 7% from the first to the second harvest, and 3% from the second to the third one.
For each harvest, the correlation between biological cycle and dry matter yield was significantly positive (r=0.91 in the first harvest; r=0.85 in the second and third harvest) confirming that the late-maturing hybrids give the best yield.

Table 3 - Effect of year, hybrid and harvesting date (14, 21, 28 days after flowering of each hybrid) on plant height, stem diameter, fresh and DM yield.

		Plant height al last blade joint (cm)	Bottom stem diameter (mm)	Fresh yield: above-ground biomass stems+sheaths+ panicles+leaves (t ha^{-1})	Fresh yield: stems + sheaths (t ha^{-1})	DM yield: stems + sheaths (t ha^{-1})
Year	1998	294 b	21.5 a	132.2	104.4	27.3 b
	1999	376 a	20.5 b	138.1	110.7	31.2 a
Hybrid	H 128	297 c	18.8 e	104.9 e	81.0 e	23.5 e
	H 133	302 c	19.0 e	107.3 e	83.0 e	24.3 e
	H 130	305 c	19.9 d	122.0 d	96.2 d	26.6 d
	H 16	353 b	21.6 c	141.1 c	111.8 c	29.9 c
	H 132	390 a	22.4 b	155.4 b	126.2 b	34.6 b
	H 202	362 b	24.6 a	180.1 a	147.0 a	36.6 a
Harvesting	+14	334	21.0	133.3	105.6 b	27.6 c
	+21	335	21.2	134.6	107.4 ab	29.6 b
	+28	335	20.9	137.5	109.6 a	30.5 a
	Mean	**335**	**21.0**	**135.1**	**107.6**	**29.2**

Within each column for each treatment, means followed by different letter are significantly different at the 0.05 level of probability by Duncan's Multiple Range Test.

"Hybrids x harvest" interaction was not significant for stem + sheaths dry matter yield. This results indicate a similar trend in the yield of hybrid genotypes when the harvest date varies, even if the early and medium-maturing hybrids seem to have a higher yield increase with respect to late-maturing genotypes (figure 2).

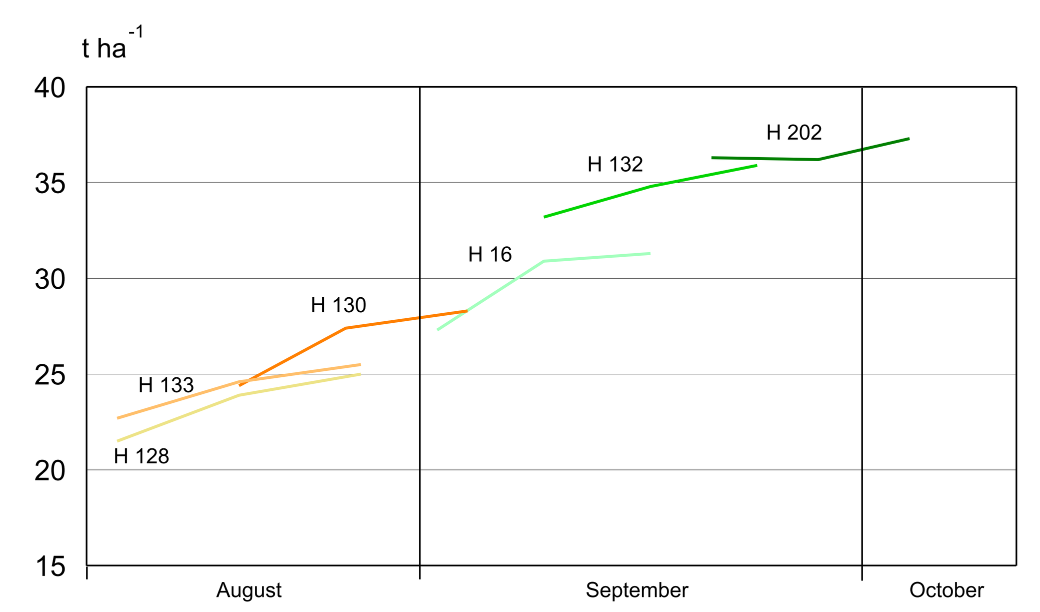


Figure 2 - Stems + sheaths DM yield as a function of three harvesting dates (14, 21 and 28 days after flowering) for six fibre soghum hybrids (mean of 2 yr).

Fibre sorghum biomass at harvest was characterized by a high moisture content, around 73% with slight variations among hybrids and harvest period (figure 3). This moisture rate strongly suggest that the harvested crop has to be dried in field before transportation and storage.

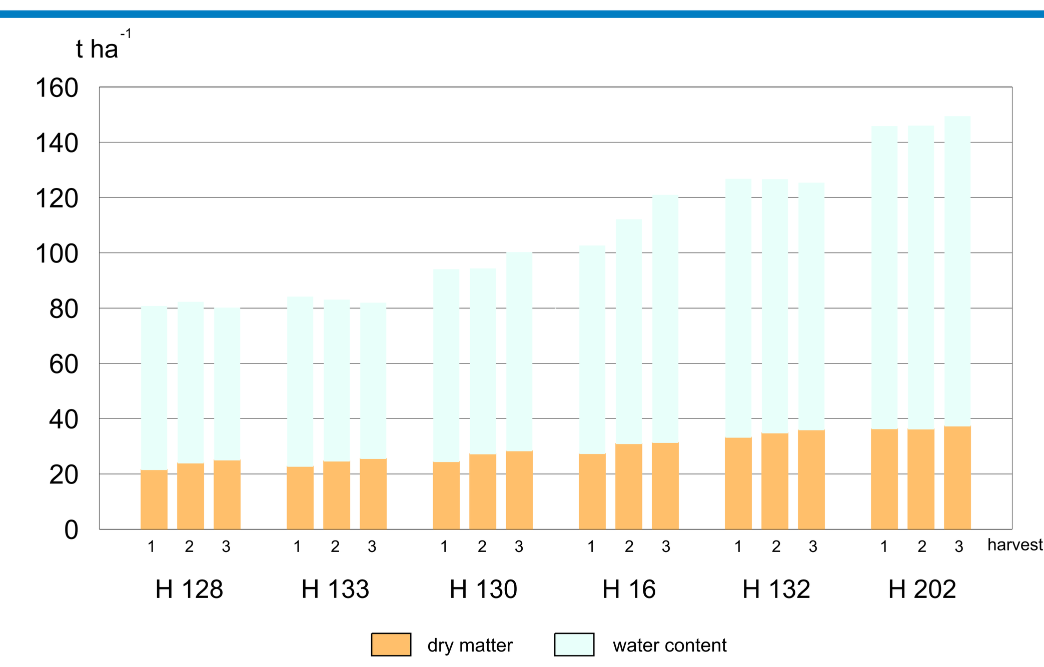
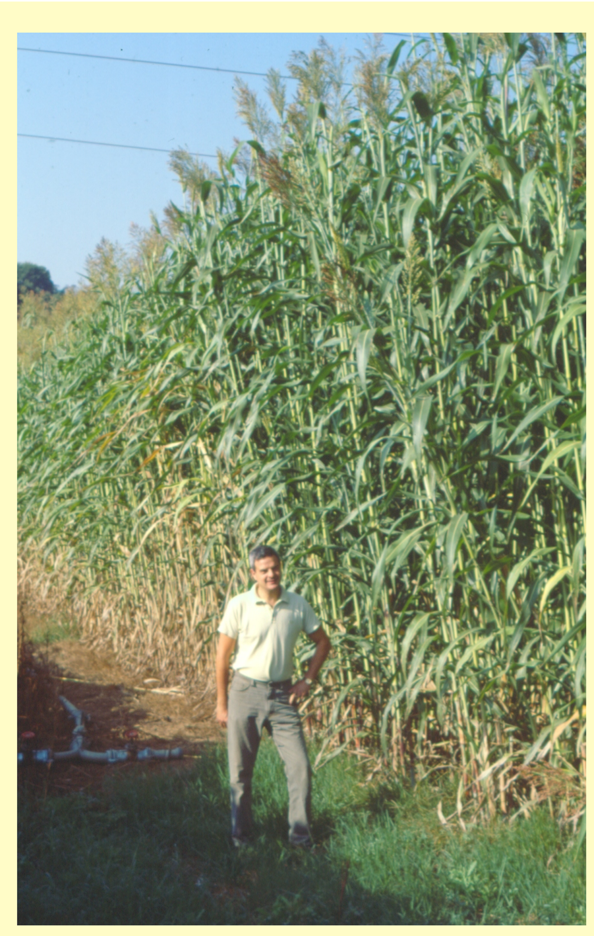


Figure 3 - Stems + sheaths fresh yield, water content and DM yield for six fibre sorghum hybrids in three harvesting dates (14, 21, 28 days after flowering).

Meteorological data, recorded during 1974-1997 period at the weather station of Inviolatella Farm (table 4), show that in August there are ideal climatic conditions to dry biomass (day-length, temperature, rainfall and number of rainy days). During September and October, when the day-length and temperatures gradually decrease and rainfall and number of rainy days increase, the number of days necessary for drying the biomass increases.
Although the maximum yield was obtained by late-maturing hybrids harvested 21-28 days after flowering, for obtaining an adequate drying of biomass in field, the harvest should not carried out later than the first fortnight of September.

Table 4 –Significant climatic data that can influence the field air-drying of biomass, recorded at the weather station of Inviolatella Farm (Rome) during 24-yr (1974-1997).

Month	Decade	Day lenght (h m)	Temperature max (°C)	Temperature min (°C)	Precipitation (mm)	Years with 1 rainy days (n.)	Years with 3 rainy days (n.)	Years with 5 rainy days (n.)
August	I	14.16	31.9	16.0	5.4	12	0	0
	II	13.52	31.2	15.7	14.9	12	3	0
	III	13.25	29.3	15.1	20.2	17	7	1
September	I	12.57	28.1	13.5	30.7	18	5	1
	II	12.29	27.5	13.1	26.1	18	8	2
	III	12.01	25.9	12.6	27.2	16	11	1
October	I	11.33	24.0	11.3	51.3	21	12	3
	II	11.06	22.8	9.9	48.6	21	12	7
	III	10.38	19.9	8.0	37.1	22	13	7



Our data suggest that in Central Italy it is not convenient to use the extreme late- maturing hybrids. As a matter of facts medium and medium-late maturing hybrids enable the obtaining of 25- 30 t ha^{-1} of dry matter in a seasonal period characterized by suitable weather conditions for drying the biomass directly in the field (figure 2) .

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