EFFECT OF SOWING TIME ON SEED PRODUCTION OF KENAF (HIBISCUS CANNABINUS L.) IN SICILY*

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ABSTRACT: Kenaf is an interesting crop for fibre production and a good source of biomass for cellulose. Its high sensitivity to photoperiod limits seed production to the semi-arid environments of Southern Europe. With the aim of studying the effects of sowing time on seed yield, as an additional product of biomass, in a cultivar of kenaf cultivated in Sicily, ten sowings in total, ranging from late May to late July, were carried out in the two-year 2000-01. Irrespective of sowing time, flowering occurred in a rather restricted period (late September - early October). In the average of the first sowing dates (late May) the crop produced almost 27 t ha⁻¹ of total biomass and 3.2 t ha⁻¹ of seeds. The delay of sowing time negatively affected dry biomass accumulation and decreased the pod percentage on total dry biomass. Sowings beyond half June significantly compromised seed yield that, in all cases, did not reach 1.8 t ha⁻¹. Among components, number of total pods per plant affected seed yield, significantly varying with sowing date. A close correlation was found between the length of the interval 'plant emergence-flowering' and seed yield; in particular, the longest the interval, the highest the yield. The duration of the interval "plant emergence-flowering" decreases from 109 to 77 days with the reduction of the average photoperiod from 13.3 to 12.4 h. Keywords: kenaf, grain, biomass production

1 INTRODUCTION

Kenaf (*Hibiscus cannabinus* L.) represents an interesting crop for the fibre production, which recently has been proved to be a good source of biomass for cellulose pulp, to be used in the paper industry in mediterranean countries [1]. In this last case the economic product of kenaf is the stem material, consisting of the outer bark (bast) which produces a high quality pulp.

After the new rules of CAP which does not indicate any crop to cultivate, kenaf may be a possible alternative to the traditional crops. Indeed, the improvement of its agronomic management allows its cultivation in many areas different than the native one, at least for biomass production.

Constraints to the cultivation of this warm season species, originating from tropical areas near equator, were found in the high temperature requirements, which impose the sowing of the crop when minimum temperature goes beyond 12°C [2]. However, in semiarid areas of Southern Europe, the most suitable for seed production of kenaf, the irrigation during summertime is needed.

The high sensitivity of this species to daylength as a short-day species [3] makes quite difficult to produce seed in Europe, and limits its cultivation to this purpose to semi-arid environments of Southern Europe, where light and temperature conditions are the most favourable for seed maturation. In Northern Europe, in fact, the photoperiod reduction coincides with the air thermal lowering, making difficult the seed production. Of course, the sensitivity to photoperiod affects the choice of the most suitable cultivar and sowing time and, as a consequence, harvest time as well.

Seed production of kenaf is also economically important since it is a good source of oil (16-22%) [4] and is necessary for the widespreading of the crop in the European countries for biomass production.

Ministry for Agriculture Policy.

The 'Sezione Scienze Agronomiche' of DACPA of the University of Catania (Italy), in the framework of projects supported by either the Italian Ministry of Agriculture Policy or by the UE, since long time is involved in researches on kenaf for both biomass and seed production in Sicily (South Italy), as related to different agronomic practices [5, 6, 7].

In this paper, the results of a field experiment concerning the effects of the sowing time upon seed yield, as an additional product of biomass, in a cultivar of kenaf cultivated in a typically Mediterranean area, are reported.

2 MATERIALS AND METHODS

The research was conducted in the two-year 2000-01 in a site of the eastern coast of Sicily (10 m a.s.l., $36^{\circ}44'$ N Lat). Ten sowings in total were carried out, from late May to late July, and the cv. Tainung 2 of kenaf was adopted (Table I).

Table I: Sowing dates in the two years of experiment.

Year		Sowing dates					
2000	28/5	8/6	19/6	30/6			
2001	24/5	13/6	23/6	5/7	16/7	26/7	

A randomised blocks experimental design with four replicates was adopted and a plant density of 10 p m⁻² (50 cm between rows and 20 cm between plants along the row) was planned. Before sowing, 50 kg ha⁻¹ of N as ammonium sulphate and 100 kg ha⁻¹ of P₂O₅ as perphosphate were distributed; as top dressing, further 50 kg ha⁻¹ of N as ammonium nitrate were added. The crop was irrigated restoring the 100% of ETm throughout the whole growing season. Water was distributed when the sum of daily ETm, calculated as follows, corresponded to the irrigation volume V: ETm= E₀ x Kp x Kc, where E₀=

^{*}The reported research was supported by the Italian

evaporation of class "A" pan, Kp= pan coefficient, equal to 0.80 in semi-arid environment, Kc= crop coefficient, ranging between 0.4 and 1.1 from plant emergence to beginning of flowering, between 1.1 and 0.7 from bloom up to end of October. The total volume of water distributed ranged from 3000 to 1500 m^3ha^{-1} , for the earliest and latest sowings, respectively.

Air temperature (°C), global solar radiation (MJ m⁻²), rainfall (mm), class "A" pan evaporation (mm), by means of a CR21 Campbell (USA) data logger, were recorded. Photoperiod was calculated according to Keisling [8]. The date of plant emergence, beginning of flowering, 1st pod ripening, when they occurred in the 50% of plants per plot, were recorded.

Irrespective of sowing date, the crop was harvested the 28 of December 2000, in the 1^{st} year, and the 8 of January 2002, in the 2^{nd} year. Biomass and seed yield were measured on a 2 m² area of each plot. At harvest, on 10 randomly collected plants, morphological (plant height) and productive (total epigeal dry biomass, partitioned in stems and pods), seed production per plant, number and dry weight of pods per plant, number and dry weight of seeds per pod) traits were measured for all the sowing dates, excluding the last two of the second year.

All data were statistically analysed by ANOVA, considering 'year' as a random factor and 'sowing date' as a fixed factor. The 'F' value of sowing date was obtained dividing the mean squares of sowing date by the mean squares attached to 'sowing date x year' interaction. When 'F' ratios were significant, means were separated by the Least Significant Difference (L.S.D.) test.

3 RESULTS

3.1 Meteorological data

Thermal conditions suitable for the sowing of kenaf (minimum temperature >12 °C) occurred from the middle of May(Fig. 1).



Figure 1: Meteorological course with time.

Afterwards, along the growing season, maximum temperatures reached more 35°C and minimum more than 25°C. Average temperature became lower than 20°C from late October onwards.

There was an absence of rainfall from June to September, excluding few events of less than 10 mm. Heavy rainfalls, not exceeding 40 mm each, occurred between October and December, in both years.

Daily photoperiod during the first part of the crop growing season (plant emergence-flowering) declines from 15.5 h to 13.0-12.5 h (earliest sowings), down to 11 h measured when the plants of the very late sowing of 2001, flowered.

3.2 Length of growing season

The length of the whole growing season was affected by the time of sowing, ranging from 199 to 157 days of the 1^{st} and the last sowing date of 2001, respectively (Fig. 2).



Figure 2: Length of growing season and of main phenological stages for all the sowing dates of both years.

The differences recorded may be ascribed to time of flowering, which occurred in a rather restricted period (end of September-early October) irrespective of sowing date. The almost simultaneous flowering shortened the 'plant emergence-beginning of flowering' interval by delaying the sowing time, in both years. The length of the subsequent interval ('beginning of flowering-1st pod ripening) less varied with the date of sowing than the previous period, and maturity of pods was achieved between the 1^{st} and the 2^{nd} ten-day of December. In the last sowing dates of the 2^{nd} year of experiment the crop showed a different behaviour in terms of duration of growing season, since flowering occurred a month later (half November), but pods ripened only few days later, when compared to the other sowing times. These results are supported by the high sensitivity of kenaf to the daylength, which affects the initiation of flowering.

In order to explain the variability of the 'plant emergence-beginning of flowering' period among the different sowing dates, the lengths of the different intervals were related to the average temperature and photoperiod of the twenty days before beginning of flowering. It is possible to observe that the duration of the interval was not related to average temperature, while a strong relation was noted with photoperiod (Fig. 3). The duration, in fact, decreases from 109 to 77 days with the reduction of the average photoperiod from 13.3 to 12.4 h. With a lower average photoperiod (11.1 h) the duration of the interval increased again to 102 days. This latter result may be related to the average temperature before flowering experimented by the crop, which is below 19°C and may lower than thermal requirements of the crop at flowering stage.



Figure 3: Relationships between the 'plant emergencebeginning of flowering' interval duration and average photoperiod (above) and air temperature (below) of the twenty days before flowering.

3.3 Plant height

Plant height ranged between 369.4 cm (1st sowing of 2000) and 300.5 cm (last sowing of 2001) (Fig. 4).



Figure 4: Plant height in relation to sowing date in the two years of experiment.

An overall decrease of plant height with the delay of sowing date was ascertained, but in the 1st year of experiment the decrease was not significant when excluded the 1st sowing (369.4 cm, against 344.0 cm, on average of the following sowings), whereas in the 2nd year it always significantly declined by postponing the sowing from late May-half June (1st and 2nd sowing, 357.3 and 344.6 cm, respectively) onwards, down to

300.5 cm. Thus, at ANOVA this character did not differ significantly among sowing dates, on average of the years, because of the high value of the interaction 'year x sowing time' (LSD_{int}= 16.8 and 22.8 at p \leq 0.05 and 0.01, respectively).

3.4 Aboveground dry biomass

The delay of sowing time negatively affected dry biomass accumulation in both years. In fact, the earliest sowing (late May) ensured a total dry biomass yield (>27 t ha⁻¹) significantly higher than that of following sowings (close or lower than 20 t ha⁻¹) (Fig. 5). Differently than plant height, the high homogeneity between the years determined a high significance within sowing times in terms of dry biomass yield, on average of years.



Figure 5: Aboveground dry biomass and its partitioning in relation to sowing date in the two years of experiment (white bars: year 2000; grey bars: year 2001).

In the sowing of early June the highest incidence of pods on total biomass was achieved (26.1% in both years); by shifting the sowing to end June-early July, the pods contribution to total biomass progressively decreased down to 18% (2000) and 21% (2001). Consequently, the stem percentage on total biomass increased, by delaying the sowing time.

Plotting the 'plant emergence-flowering' interval against total biomass cumulated, a linear regression (r= 0.893^{**}) was observed. Basically, the crop takes advantage of early sowings since it benefits from a longer period for assimilating dry matter.

3.5 Seed yield

The seed yield was significantly affected by the time of sowing that, when delayed from late May to late Juneearly July, determined a significant decrease in seed production (from 3.28 to 1.36 t ha⁻¹, on average of years) (Fig. 6).



Figure 6: Seed yield in relation to sowing date in the two years of experiment.

In particular, sowings beyond half June significantly compromised seed yield that, in all cases, did not reach 2 t ha⁻¹.

Yield was strictly related to the number of pods per plant ($r= 0.848^{**}$). It must be noted how the strong yield difference between the first two sowing dates and the other two is related to the dramatic reduction in the number of pods per plant (from 118.2 to 57.2). This may be explained by the changed conditions of temperature and photoperiod during the fruit-setting period, which probably limited flower development and fruit setting itself, as well as the presence of pollinators. In opposite, the number of seeds per pod and the 100-seed weight were not affected by sowing date (Table II).

Table II: Seed yield components per plant on average of the years (LM= Late May; EJ= Early June; HJ= Half June; LJ= Late June; EJI= Early July).

Sowing time	Plant density (p m ⁻²)	Pod number (n)	Seeds per pod (n)	100 seed weight (g)
LM	7.1 a	118.2 a	22.5 a	2.00 a
EJ	8.0 a	93.0 b	21.3 a	2.20 a
HJ	7.2 a	60.5 c	21.2 a	2.09 a
LJ-EJl	7.5 a	57.2 c	23.4 a	1.78 a

A close correlation ($r= 0.966^{**}$) was ascertained between dry biomass and seed yield, when considering the pool of data of the two years.

Moreover, a significant correlation ($r= 0.809^*$) was found out between the length of the interval 'plant emergence-flowering' and seed yield. In particular, the longest the interval, the highest the yield. This was basically due to the fact that, irrespective of time of sowing, the flowering occurred in a narrow period; thus, with early sowings the crop is able to assimilate a higher total dry matter before flowering, useful for sustaining a higher pod production

4 CONCLUSIONS

The cultivation of kenaf in the semi arid environment of Sicily ensures good levels of seed yield (> 3 t ha⁻¹) with sowings carried out between the end of May and the beginning of June. However, also with late sowings (early July), yield did not decline below 1.2 t ha⁻¹, similar to those obtained in Central Italy in a higher latitude area (43°40' N Lat) [2].

In the climatic conditions of Sicily, final dry biomass (stems), in this case considered as an additional product, achieved almost 24 t ha⁻¹ with the earliest sowings (late May), higher than those obtained in other experiments carried out in the same environment [2], where, however, lower plant densities (5 plant m⁻²) were adopted.

The date of flowering was related to the twenty days average photoperiod before flowering, while temperature seems do not exert any influence unless below a certain threshold (<20°C daily average temperature).

Seed yield was significantly correlated to the number of pods per plant but not to the number of seeds per pod or to their weight.

The research has proven the possibility of producing significant amount of seed of this crop in the most

Southern areas of Europe, whereas in more northern areas the high photoperiod does not allow floral initiation. Moreover it has been ascertained the possibility, in the climatic conditions of Sicily, to sow this crop after the harvest of a winter crop.

5 ACKNOWLEDGEMENTS

The authors wish to thank Mr. S. Scandurra for his technical assistance in field.

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