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PLANT GROWTH CURVES AND FIBRE QUALITY CHANGES OF JUTE (*CORCHORUS* SPP.) GROWN IN BANGLADESH

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ABSTRACT

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Growth curves for *Corchorus capsularis* cv. D-154 and *C. olitorius* cv. O-4 have been determined as a preliminary step in identifying and quantifying growth limitations of commonly grown jute genotypes.

Dry matter accumulation of both genotypes was exponential for 40—50 days from sowing, with relative growth rates (RGR) of 0.14—0.20 g g^{-1} day^{-1} for 'D-154' and about 0.20 g g^{-1} day^{-1} for 'O-4'. Thereafter, RGR declined markedly and continued at low a rate until final harvest, at up to 174 days. The decline in RGR coincided with the onset of the monsoon period.

Harvest index, the proportion of fibre in the above-ground material, reached 18—20% in both 'D-154' and 'O-4' after 75 and 65 days from sowing, respectively. Visually assessed fibre quality was at a maximum between 75 and 105 days for 'D-154' and 50 and 70 days for 'O-4'. After these periods quality progressively declined.

These data suggest that there is considerable scope for genetic improvement of both total dry matter production and harvest index of jute, and thus total fibre yield. The key to such improvement appears to be prolonging the period of high RGR beyond 50 days, so as to maximise fibre production when its quality is highest.

INTRODUCTION

In order to guide plant breeders on appropriate characters to select for in developing improved genotypes of jute it is necessary to identify and quantify growth limitations of existing genotypes at all growth stages. A first step in this regard is to establish models of existing genotypes to provide a baseline from which possible improvements may be proposed. For most plants of economic importance such models usually take the form of growth curves, plotting some measure of plant growth, usually weight of dry matter, against time (Erickson, 1976).

For jute, there are several possible parameters that could be used to

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measure growth over time, such as dry weight, plant height and base diameter. Where sequential measurements of dry matter have been made they are usually too infrequent to permit mathematical analysis of curve shape (e.g. Ghosal and Chattopadhyay, 1977). More detailed curves are available for such non-destructive parameters as plant height (e.g. Rao, 1980). In order to evaluate the most convenient method of measuring jute growth rate it is necessary to determine the relationships between these parameters over time.

In addition to total dry matter production over time it is also necessary to know how dry matter is partitioned between the various components of the plant. Of particular interest is the harvest index, the economically important fraction of the plant. In the case of jute this is retted fibre. We could not find any published information on harvest index of jute on an oven-dried basis. In a related bast fibre crop, kenaf (*Hibiscus cannabinus*), bark constitutes 35—45% of the total oven-dried stem material at harvest (Wood, 1978; Muchow, 1979).

It is generally considered that fibre quality of jute declines after flowering, as estimated by the market value of fibre samples harvested from crops of different age. However, the manner in which quality changes over time, especially in periods prior to flowering, has not been adequately documented. This knowledge is necessary in order to assist economic evaluation of optimum harvest time.

In this paper we report data on frequent measurements of total dry matter and how this is partitioned between the various components of above-ground plant material. These data are compared with non-destructive growth parameters and changes in fibre quality over time. Representatives of the two cultivated species of fibre jute are compared in order to assess the extent of genetic difference in the parameters measured.

MATERIALS AND METHODS

Field experiments were conducted in 1979 and 1981 on a dark grey, poorly drained silty clay soil (Soil No. 50, Naraibag—Jalkundi Association, Brammer, 1967; a Eutric Gleysol according to FAO—UNESCO, 1977) at the Tarabo substation of the Bangladesh Jute Research Institute, located about 13 km southeast of Dhaka, Bangladesh (24°N 90°E).

In 1979, three contrasting jute genotypes, *Corchorus capsularis* cv. D-154, *C. capsularis* cv. Lal Naris (a vegetable type for comparison with the fibre types) and *C. olitorius* cv. O-4, were grown at two plant spacings, 7.5 × 30 cm (the currently recommended spacing) and 30 × 30 cm. Treatments were randomized in four blocks in a split plot design, with genotypes as main plots and spacings as sub-plots. Individual plot size was 6.9 × 6.9 m (i.e. 24 rows with an inter-row spacing of 30 cm in all treatments).

The seed bed was prepared according to existing recommendations. Cowdung was applied at a rate of about 4.5 t ha^{-1} and the field bullockploughed six times to about 20 cm and then levelled (laddered). Just prior to sowing, 80 kg ha^{-1} urea (about 50% N), 10 kg ha^{-1} potassium chloride (about 50% K) and 50 kg ha^{-1} triple superphosphate (about 20% P) were broadcast onto each plot. The fertilizer was incorporated into the top 5 cm of soil with hand cultivators. A further 80 kg ha^{-1} urea was broadcast on all plots 31 days after sowing of *C. capsularis* cvs. and a further 217 kg ha^{-1} urea, 200 kg ha^{-1} potassium chloride and 120 kg ha^{-1} triple superphosphate at 101 days.

'D-154' and 'Lal Naris' were sown in rows at 2 cm depth on 11 April 1979 and 'O-4' was sown on 16 April 1979. Plots were hand weeded as necessary and gradually thinned. Final thinning to the required spacings was at 40 days for 'D-154' and 'Lal Naris' and 38 days for 'O-4'. The crop was sprayed for mite (*Hemitarsonemus latus* and *Tetranychus bioculatus*) control as necessary. All plots were flood irrigated with about 5 cm of water 1 day prior to sowing and 48 days after *C. capsularis* sowing.

Plants were sequentially harvested at about 4—5-day intervals from 10 days after sowing until the final harvest at 124 days after *C. capsularis* sowing. Sampling was begun at least 30 cm from one randomly selected end of each plot and confined to the inner 20 rows (i.e. two guard rows). At successive harvests, plants were sampled in lines across rows, moving sequentially down rows when all suitable plants in the line had been taken. For the 7.5 × 30 cm spacing, three plants were left as guards between lines across rows and for the 30 × 30 cm spacing no plants were left. Until 61 days after *C. capsularis* sowing, five plants were taken from each plot at each harvest; however, sampling of the 30 × 30 cm spacing did not begin until 39 days. After 61 days, five plants per plot were taken from only one block and two plants per plot from each of the other blocks. Plants were only selected for sampling if they were within 10% of the eye-estimated average height of all plants in a plot.

After each sampling the following measurements were made on each plant sampled: plant height, base diameter and oven dry (80—90°C) weight of main stem leaves, stem and branches (with leaves). At the final harvest, 20 rows each 2.4 m long were cut from the as yet unsampled area of each plot and plant numbers recorded. After leaf fall, stems were retted for 14 days and the fibre separated. Air-dried weights of fibre and stick were measured.

The experiment conducted in 1981 differed from that in 1979 as follows. 'D-154' and 'O-4' were grown in four blocks. Plot size was 4.25 × 9.6 m, with 33 rows each 4.25 m long and 30 cm apart. Intra-row spacing after final thinning was 7.5 cm. Fertilizer application prior to sowing was 200 kg ha^{-1} urea, 100 kg ha^{-1} potassium chloride and 125 kg ha^{-1} triple superphosphate. The same dose of urea was broadcast 40 days from sowing of 'D-154' and at 43 days for 'O-4'. All fertilizers at the initial rates were added at 62, 92 and 124 days for 'D-154' and at 64 and 90 days for 'O-4'. 'D-154' was sown on 19 March and 'O-4' on 22 April. Final thinning was at 39 days for 'D-154' and 28 days for 'O-4'. Plots were flood irrigated with about 5 cm of water 1 week prior to sowing of 'D-154' and 53 days later.

In the 1981 experiment, plants were sequentially harvested at about weekly intervals from 20 days for 'D-154' and 14 days for 'O-4'. Plants were sampled from randomly allocated 1.5 m sections of rows, starting 20—30 cm in from each end of a row. Two guard rows were kept at plot borders and alternate rows were sampled. At each sampling, ten plants were selected from the allocated position in each plot, provided they appeared to be within 10% of average crop height. Each sample of ten plants was then divided into two equal subsamples, on the basis of visually estimated plant height and base diameter.

Individual plant height and base diameter were measured and then fresh weight of main stem leaves, branches (with leaves), bark and stick were measured for each subsample at 20—30 min after cutting from the field. All material except bark of one subsample was oven dried at 75—80°C and the dry weight determined. Fresh bark samples were retted for 15—19 days in about 40 l of tap water to which about 2 l of pond water (inoculant) and 30 g urea were added. Oven-dried bark samples were retted for 20—25 days. Retted fibre samples were thoroughly washed in running tap water and oven dry weights determined. However, weights of air-dried fibre were also determined for the samplings on 10 and 17 June.

Fibre samples extracted from the fresh bark were submitted to the Microbiology Division of the Bangladesh Jute Research Institute for visual assessment of fibre quality according to the methods of Alam (1979). No reliable quantitative method of fibre quality assessment was available. Samples were submitted in random order for each block and no information was provided to the assessors as to the nature of the experiment.

Population counts were made at fixed points in each plot on 10 June, 8 July and 17 August 1981. The number of harvestable plants (i.e. within 10% of average crop height) and remaining small plants were recorded in 2 m sections of a row.

RESULTS

Growth curves, plotted as the natural logarithm (ln) of dry weight against time (Milthorpe and Moorby, 1979) are presented for the data obtained in 1979 and 1981 in Fig. 1. Reciprocal exponential functions were fitted to the data as these functions gave the best fits of several models tried. However, they could not entirely account for the abrupt change in slope between 40 and 80 days after sowing. The data could alternatively be considered in terms of two distinct growth phases, represented by separate functions for say 0—50 days (e.g. a straight line) and from 50 days to harvest (e.g. a quadratic curve). However, the main purpose of fitting these functions is to find reasonably simple quantitative descriptions of the changes in growth with time rather than to determine the most perfect fit, irrespective of mathematical complexity.

Growth of both 'D-154' and 'O-4' was exponential until about 50 days from sowing in both years. The relative growth rate (RGR), defined as $(1/x)$ (dx/dt) where x is plant dry weight at any particular time t, for this period was about 0.20 g g^{-1} day^{-1} for both cultivars in 1979 and 'O-4' in 1981. However, initial RGR was only about 0.14 g g^{-1} day^{-1} for 'D-154' in 1981. After about 50 days, RGR declined markedly and continued at a low rate until the final harvest.

The weather data during these experiments are shown in Table 1. The decline in RGR during 40 and 60 days coincided with the change from the hotter, drier pre-monsoon period to the slightly cooler, humid monsoon period (Fig. 1, Table 1). However, in 1981 the onset of the monsoon period was not as abrupt as it was in 1979.

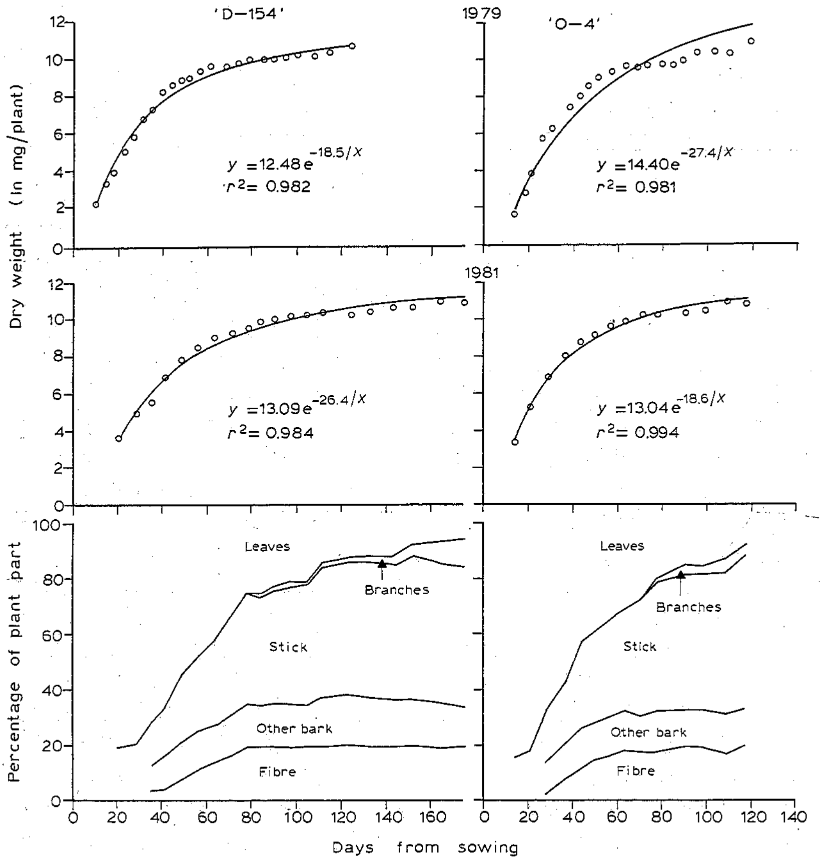

Fig. 1. Changes with time in the natural logarithm of dry matter of total above-ground material of 'D-154' and 'O-4' in 1979 and 1981 and dry matter distribution between main stem leaves, branches, stick, fibre and remainder of bark for 1981 samples. Reciprocal exponential curves ($y = ae^{-c/x}$) were fitted to dry weight data.

TABLE 1

Monthly weather data during growth. All data recorded at Dhaka except rainfall in 1981 which was recorded at Tarabo. Data only given for portions of months after sowing of 'D-154' and prior to final harvest

Month	1979			Total rain-fall (mm)	1981			Total rain-fall (mm)
	Average maximum temper-ature (°C)	Average minimum temper-ature (°C)	Average relative humidity at 09.00 (%)		Average maximum temper-ature (°C)	Average minimum temper-ature (°C)	Average relative humidity at 09.00 (%)	
March					30.3	20.3	74	100
April	34.6	24.2	70	18	30.3	22.0	81	353
May	35.7	25.8	72	96	31.9	23.7	78	347
June	32.9	26.5	82	392	32.6	26.4	82	198
July	31.5	26.2	85	301	30.6	26.0	90	529
August	32.1	26.4	79	98	32.2	26.5	84	269
September					31.1	26.1	91	140

Fig. 1 also shows the distribution of dry matter between upper plant parts in the 1981 experiment. The distribution between leaves, branches and total stem as measured in 1979 for 'D-154' and 'O-4' at the close spacing was similar to that depicted in Fig. 1. In 1979 it was observed that the canopy completely shaded the soil by 40—50 days at the close spacing, with the leaf area index being 3.8 for 'D-154' at 51 days and 1.6 for 'O-4' at 46 days. The proportion of fibre (harvest index) reached a maximum of 18—20% at about 75 days for 'D-154' and 60 days for 'O-4' and stayed at that level for the remainder of the growth period (Fig. 1). The proportion of fibre in total bark, after maximum fibre proportion was obtained, was 53.4% for 'D-154'. This was significantly ($P < 0.001$) less than the 57.4% obtained for 'O-4'. The proportion of stick increased throughout growth to a maximum of about 50% with leaves compensating for this increase.

Retted fibre from the oven-dried bark samples was used for the calculation of dry matter distribution shown in Fig. 1. This may have caused an over-estimation of the proportion of fibre due to inability to remove all debris from the retted fibre. However, it was observed that if the fibre was more rapidly dried at 75°C there was less staining and retention of non-fibre particles. The extent of this over-estimation may be gauged by comparing the ratio of dried fibre to dried stick for samples with oven-dried bark and freshly retted bark. Averaged over all samplings these ratios for oven-dried and fresh bark were, respectively, 0.383 and 0.357 ($P < 0.001$) for 'D-154' and 0.381 and 0.342 ($P < 0.01$) for 'O-4'. This would suggest that the harvest index calculated for fibre from freshly retted bark would be 1—2% less than shown on Fig. 1 for both 'D-154' and 'O-4' over the entire growth period.

Estimated fibre quality reached a maximum between 75 and 105 days for 'D-154' and 50 and 70 days for 'O-4' (Fig. 2). After these periods quality progressively declined.

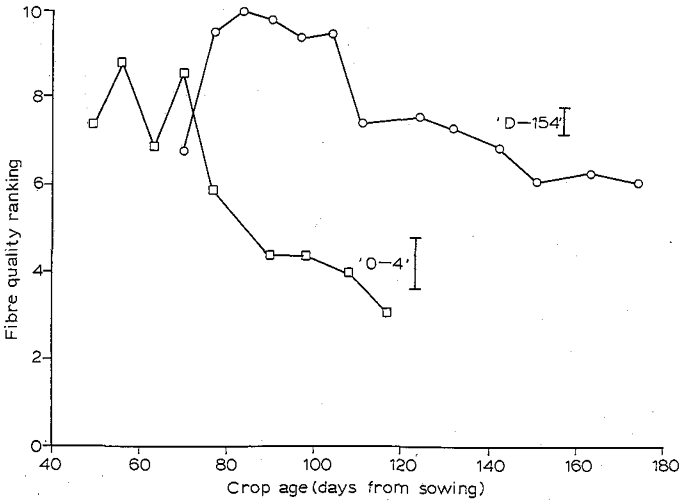

Fig. 2. Changes with time in ranked fibre quality for 'D-154' (○) and 'O-4' (□). Vertical bars are least significant differences between means at $P = 0.05$.

In the 1979 experiment, growth curves for 'Lal Naris' at the close spacing and all cultivars at the wide spacing were essentially similar to those depicted in Fig. 1. However, in these treatments a much greater proportion of dry matter was distributed into branches. In 'Lal Naris' this was caused by prolific flowering at 50 days and subsequent branching, even at the close spacing.

At the close spacing in 1979, good linear correlations between either plant height in cm (y_1) or base diameter in mm (y_2) and dry matter in g per plant (x) were obtained for 'D-154' ($y_1 = 30.3 + 7.0x$, $r^2 = 0.97$; $y_2 = 5.19 + 0.36x$, $r^2 = 0.91$) and 'O-4' ($y_1 = 25.4 + 7.7x$, $r^2 = 0.93$; $y_2 = 4.73 + 0.29x$, $r^2 = 0.88$) until the second last harvest (when branching was minimal).

At the final harvest in 1979, 'D-154' yielded 1.8 t ha^{-1} of air-dried fibre and 'O-4' yielded 1.4 t ha^{-1}. Estimates made in 1981 indicated that these

TABLE 2

Estimates of the reduction in plant population with time in 1981, compared to that at the final thinning; viz., 444 444 plants ha^{-1} at 39 days for 'D-154' and 28 days for 'O-4'. Plants counted were within 10% of estimated average crop height (i.e. harvestable)

'D-154'		'O-4'	
Days from sowing	% original population	Days from sowing	% original population
83	75	49	92
111	72	77	87
151	68	117	73

air-dried samples contained about 12% moisture. In 1979 it was noticed that only about half of the initial plant population at the close spacing (444 444 plants ha^{-1}) actually survived until final harvest. This decline in plant population over time was measured in 1981 (Table 2). With time there was an increasing proportion of smaller, non-harvestable plants which eventually died towards the end of the growth period.

DISCUSSION

It is desirable to maximise fibre yield of jute in the shortest growing period possible, in terms of both producing high quality fibre (Fig. 2) and fitting jute into more flexible cropping systems. The growth curves of Fig. 1 suggest that this may best be attained by arresting the rapid decline in RGR between 40 and 60 days. For example, if RGR could remain constant after 40 days at, say, half the rate prior to 40 days, then maximum dry weights achieved in this study would be reached within 80 days.

Improvement of jute fibre production therefore requires an understanding of why RGR declines as shown in Fig. 1. In 1979, this could have been attributed to inadequate basal fertilizer addition and the unusually hot and dry conditions prior to the break of the monsoon, necessitating irrigation on 29 May 1979. However, with increased fertilizer application and under different climatic conditions (Table 1), growth curves obtained in 1981 remained essentially similar to those in 1979. The only noticeable difference was the slower initial RGR of 'D-154' in 1981, presumably caused by its earlier sowing when temperatures were lower. It can be suggested that the generally low RGR during the monsoon period may be due to a less than optimum canopy structure in jute crops after 50 days. The decline in plant population over time (Table 2), apparently due to shading effects, supports this suggestion. The horizontal arrangement of broad shaped leaves ensures shading of leaves lower in the canopy. This effect would be magnified during the overcast conditions of the monsoon season. Further work is needed to determine optimum canopy structures for jute under monsoon conditions.

Although it appears that 'O-4' had a higher initial RGR than 'D-154', in both 1979 and 1981, this may be a consequence of the later planting of 'O-4', and hence initial growth occurring under higher temperatures, rather than any genetic difference in initial RGR between these cultivars. However, it would seem desirable to screen a wide range of genotypes for RGR to, say, 80 days. It would not be necessary to take sequential measurements of dry matter to do this because of the good linear relationship between plant height and dry matter. Plant height has the advantage of being a non-destructive parameter and more closely related to dry matter than is base diameter.

There seems to be additional scope for increasing yield of jute by increasing harvest index above the presently obtained maxima of 20%. This has been achieved, for example, in grain crops (Davies, 1977). A first step in increasing harvest index would be to assess the extent of genetic variation in this character. There is remarkably little difference in harvest index between 'D-154' and 'O-4' and only a small difference between them in the proportion of fibre in total bark. However, a wide range of genotypes should be compared with the eventual aim of incorporating material with high harvest index into breeding programs.

The present data allow assessment of economic options for optimum harvest time in existing cultivars. After 90 days the rate of increase in fibre yield is slow, and directly proportional to dry matter increase. Thus, for land not subject to deep seasonal flooding these slow gains in amount of fibre, coupled with declining fibre quality, must be weighed against possible gains of earlier planting of a following crop. It should also be realized that the data in Fig. 1 are on a per plant basis so that increases in yield per plant with time will be offset by a decreasing plant population with time.

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