5: THE INFLUENCE OF TEMPERATURE ON FIBRE PRODUCTION AND FIBRE PHYSICAL PROPERTIES.

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5.1 Introduction

Within the Belgian Cotton Research Group, the laboratory at Gembloux is responsible for the genetic and ecological aspects of the programmes.

This paper describes an investigation into the effects of temperatures within the range 20°C to 32°C on the yield and characteristics of cotton fibres. Later papers will report the influences of relative humidity, the photo-period and the difference between day and night temperatures. The experimental work was carried out in the growth chambers of the Faculty of Tropical Crop Husbandry in the University of Gembloux.

The weight of lint produced per seed depends on two variables:

— the number of fibres on each seed,
— the weight of cellulose in each fibre.

The influence of temperature on the deposition of cellulose in the fibre has been studied by several workers but little or no attention has been paid to the number of fibres produced per seed.

The weight of cellulose in each fibre can be estimated from one or more of the following measurements; the fineness derived from Arealometer or micronaire readings, the linear density, the percentage of mature fibres, or by direct weighing. Whatever parameters are used, all the results found by the various research workers who have studied the subject (Grant et al., 1966; Hesketh and Low, 1968; Gibson and Joham, 1968; Gibson and Ray, 1969; Grant et al., 1970; Antony, 1977) conclude that a high temperature is favourable to the thickening of the fibre.

However, the influence of temperature on the number of fibres produced per seed does not seem to have been studied.

The total number of fibres produced is the product of the number of fibres per unit area of the seed and the surface area of the seed. This surface area can be related to the volume of the seed by a formula devised by Hodson (1920). The number of fibres per seed is, of course, also related to the weight of cellulose produced per seed, the fibre length and the weight per unit length of the fibre.

An important commercial parameter is the so-called ginning percentage. This is the weight of lint produced by ginning, expressed as a percentage of the original weight of seed cotton.

Hesketh and Low (1968) studied the influence of temperature on ginning percentage and their results indicated that the lower the average temperature during the development of the boll, the higher the weight of fibres produced per seed.

This inverse relationship was not emphasized by Gibson (1966) and Gibson and Ray (1970) who only examined the influence of night temperatures. These results are also in contradiction with those of Quinsenberry (1975); he found that the higher the number of accumulated degree-days during the development of the boll, the higher the lint index.

From the results of Hesketh and Low (1968), it is possible to formulate the hypothesis that the lower the temperature, the higher the number of fibres per seed, assuming that the weight of cellulose produced per seed in such conditions decreases while the amount of cellulose produced per fibre increases.

As far as the physical properties of the fibre are concerned, the results differ from one work to another. According to Hesketh and Low (1968), the higher the temperature during the development of the fibre, the shorter, thicker and stronger are the fibres. These results were confirmed by Grant et al. (1970) and Antony et al. (1975).

On the contrary, Gibson and Ray (1970) did not emphasize the same relation concerning length and tenacity. According to them, the greatest strength at rupture is obtained when night temperature is low and the higher the night temperatures, the longer the fibres.

5.2 Experimental procedure

The experimental conditions were as follows:

— cultivated material : cultivar B 49 originating from Zaire;
— growth substrate : pots with standard earth mixture, water saturated;
— nutrient solution : CERA 2a(i.e. in g/1: KNO_3 x 0.46; $Ca(NO_3).4\ H_2O$ x 1.07; $MgSO_4.7\ H_2O$ x 0.84; KH_2PO_4 x 0.31; at the rate of 0.5 1/week);
— light : 24 TL tubes of 120 watts each, giving 40,000 Lux directly under the glass pane separating the light source from the growth chamber;
— photoperiodism : 12 h/day, 12 h/night;
— relative air humidity : 60% r.h.;
— temperature : 20°C, 24°C, 28°C, 32°C.

All the blooms were tagged daily and the mature bolls were harvested as they opened. Each boll was analysed independently and placed in an envelope. The seed cotton from each boll was ginned and the following characteristic fibre production parameters were measured: the lint index, the fuzz index and the volume of each seed. From these measurements, the lint and fuzz density indices and the ginning percentages were calculated*.

Footnote:* (Col.2)
Seed index *is the weight of 100 seeds after the lint (but not the fuzz) has been removed.*
Lint index *is the weight of the lint from 100 seeds.*
Fuzz index *is the weight of the fuzz from 100 seeds.*
Lint density index *is the lint index divided by the surface area of the seed.*
Ginning percentage *is the lint index divided by the lint index + fuzz index + weight of 100 bare seeds, expressed as a percentage.*

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The average number of fibres produced per seed (N_{th}) was calculated from the lint index, the average fibre length and the average linear mass by the formula:

$$N_{th} = \frac{\text{lint index}}{\text{fibre length x linear mass}}$$

The fibre properties were evaluated by standard physical measurements made by the Laboratorium De Meulemeester, Rijksuniversiteit Gent, Belgium.

Concerning the primary-wall development, three parameters were considered: the length of the fibre (L), the ribbon width (W), and the fibre perimeter (P). The length was measured on 500 individual fibres and the ribbon width by means of a projection microscope with a magnification of 500 X. The perimeter P was calculated by means of the mathematical formula:

$P = 2W + 2e (\pi - 2)$ where e is the wall thickness.

To characterise the secondary wall development three parameters were also used: the thickness (T), the cross sectional

TABLE 5.1 The ginning percentage and its components.

Parameters / Temperatures	20°C	24°C	28°C	32°C	F.obs
Ginning percentage	38,88(1) 3,08(2)	36,56 1,64	33,01 0,8	26,17 6,43	16,62***
Lint index	6,67 0,53	6,21 0,31	6,00 0,21	4,30 1,46	11,06***
Fuzz Index	1,91 0,50	1,45 0,17	1,96 0,19	1,52 0,32	5,89***
Lint + Fuzz Index	8,58 0,79	7,66 0,32	7,96 0,27	5,82 1,79	9,84***
Weight of 100 delinted seed	9,61 1,76	9,31 0,44	10,24 0,35	9,9 0,13	1,96
Volume of one seed	0,102 0,0093	0,098 0,0063	0,112 0,0042	0,136 0,085	34,53***
Surface of one seed	1,146 0,06	1,115 0,049	1,217 0,029	1,39 0,053	38,96***
Lint density index	59,28 4,42	55,17 2,92	49,33 1,69	30,50 10,73	30,94***
Fuzz density index	16,99 5,29	13,17 1,69	16,12 1,31	10,91 2,49	5,87**
Lint + Fuzz density index	76,27 8,38	68,35 2,9	65,45 1,78	41,49 12,70	25,60***
Percentage of lint in the lint + fuzz density index	78 4,8	80,90 2,38	75,30 1,95	73,50 5,62	6,78**

(1) average
(2) standard deviation

*,**,*** = significant, respectively, for P = 0,95; P = 0,99; P = 0,999

TABLE 5.2 Data concerning the calculation of the theoretical amount of fibres produced per seed and per seed surface unit.

Temperature	Linear density mg/Km	Mean length of the fibres in mm	Weight of lint in mg per seed	Lint density index in mg	Amount of fibres produced per seed	Amount of fibres produced per cm²
20	110	26.7	66.7	59.3	22,150	20,150
24	155	26.6	62.1	55.5	15,062	13,154
28	185	25.9	60	49.3	12,300	10,281
32	80	25.5	43	30.5	21,078	14,950

TABLE 5.3 Secondary wall development: weight of cellulose produced per seed.

t°	mg of lint/seed	mg of fuzz/seed	mg of cellulose/seed
20°	66,7	19,1	85,8
24°	62,1	14,5	76,6
28°	60,0	19,6	79,6
32°	43,0	15,2	58,2

area (S) and the volume (V). The wall thickness was measured on a projection microscope at the magnification of 500 X. The surface of the wall section of a fibre that is not collapsed is calculated by the formula: $S = \pi.e. (D - e)$, e being the wall thickness and D the diameter derived from the perimeter. The volume is the product of the length and section.

Measurements were also made of the tensile strengths of individual fibres, the specific strength and the elongation at break.

5.3 Results and discussions

The results concerning the fibre production characteristics are presented in Tables 5.1, 5.2 and 5.3.

Temperature has a clear influence on all the fibre production parameters. These results confirm those of Hesketh and Low (1968) as far as ginning percentage is concerned. The weight of the seeds has not been affected by the temperature level but the weight of fibres produced per seed or per seed surface decreases with increasing temperature.

The influence of temperature on the other parameters can be summarised as follows:

— extremes of temperature (20°C and 32°C) lead to great variability in the fibre production characteristics around their average values indicating important perturbations in the development processes at these temperatures.

— low temperatures (20°C) bring about a considerable increase in the total quantity of cellulose produced per seed and high temperatures (32°C) lead to a marked decrease.

— intermediate temperature regimes (24°C and 28°C) produce similar quantities of cellulose per seed with the higher temperature producing slightly higher yields.

— the two lowest temperature regimes (20°C and 24°C) lead to the formation of small sized seeds, the average surface and volume of which are similar. These latter parameters increase as the temperature level increases above 24°C.

— a higher temperature produces a reduction of the weight of fibre produced per unit surface (lint density index).

— temperature has no consistent influence on the proportion of lint to fuzz within the total amount of cellulose produced per unit area. The percentage of lint is nevertheless higher at 24°C than at 28°C. Similarly, temperature does not seem to have a consistent influence on the production of fuzz per unit surface though this value is slightly higher at 28°C than at 24°C.

— the total weight of cellulose produced per unit surface (lint + fuzz density index) varies with the temperature in roughly the same way as the total weight of cellulose produced per seed (lint + fuzz index), i.e. a high value at 20°C, lower and similar values at 24°C and 28°C and a considerably lower value at 32°C.

— there appears to be a critical threshold between 28°C and 32°C as far as the number of fibres produced per seed and per seed unit surface are concerned. These factors decrease in the order 20°C — 24°C — 28°C but increase at 32°C.

These results confirm the inverse relationship found by Hesketh and Low (1968), i.e. the higher the temperature, the fewer fibres produced per seed but the more secondary wall deposited within each fibre. Between 28°C and 32°C, the pattern seems to break down with marked changes in fibre linear density and perimeter.

The data presented in Table 5.3 is consistent with the hypothesis that in non-extreme temperature conditions, each seed has a given potential for cellulose production which is distributed among all the fibres growing on the seed. If environmental conditions are favourable to the initiation of a large number of fibres, then those fibres are relatively immature and vice versa.

A low level of continuous temperature brings a high increase of the seed cellulose potential production, which come from the marked augmentation of the number of fibres initiated per seed.

The physical properties of the fibres grown under the various temperature regimes are listed in Tables 5.4 and 5.5. These results confirm the tendencies observed by Hesketh and Low (1968), Grant et al. (1970), Antony et al. (1977), i.e. that the fibres are shorter, thicker and stronger at break if the temperature during the development of the bolls is high. This is true until a threshold temperature between 28°C and 32°C is reached. A constant temperature of 32°C results in a considerable disturbance of the thickening and lengthening processes and such fibres have a much smaller perimeter and wall thickness.

5.4 Conclusions

The separate study of the influence of temperature on various components of the ginning percentage has produced a better understanding of the action of temperature on this parameter: the weight of the seed is not affected by the level of temperature but the weight of the fibres produced per seed or per seed unit

TABLE 5.4 Primary-wall development: length and perimeter.

Temperature, T (°C)	Length, l (mm)	Ribbon width, W (μm)	Fibre Perimeter, P (μm)
20	26,7	23,3	57,4
24	26,6	22,3	62,0
28	25,9	22,5	69,4
32	25,5	21,1	48,8

TABLE 5.5 Mechanical characteristics: strength of individual fibre, specific strength and elongation

Temperature, T (°C)	Strength of individual fibre (g)	Specific strength (g/mm²)	Elongation (%)
20	1,76	8,7	11,6
24	3,75	12,9	11,2
28	-	-	8,9
32	1,76	13,1	6,8

surface is low if the temperature is high; the increase of the seed surface at high temperatures cannot compensate this decrease.

A constant extreme temperature regime of 20°C or 32°C leads to important perturbations in the development of seeds and fibres. The total amount of cellulose (lint and fuzz) produced per seed and per seed surface unit, is maximal at 20°C and minimal at 32°C and intermediate and similar at the other two temperatures.

Temperature has a substantial influence on the number of fibres initiated per seed. Below the critical threshold of temperature (which is situated between 28°C and 32°C) the number is high if the temperature regime prevailing during the induction phase is low. On the other hand, the amount of accumulated cellulose per fibre is high if the temperature during the thickening phase of the fibres is high. (This again proves correct until we reach a critical threshold of temperature located between 28°C and 32°C). It thus appears that the seed has a given potentiality of cellulose production which is distributed among the fibres, independent of their number.

As far as the physical properties of the fibre are concerned, the thickness and the strength of the fibres increase and the length decreases if the temperature regime during the development of the bolls decreases. Again, this relationship breaks down at the highest temperature of 32°C.

The similarity of our results with other research workers corroborates our hypothesis concerning the theoretical number of fibres produced per seed and the potential for cellulose production.

5.5 Literature

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