Effects of Meteorological Parameters and Irrigation on Micronaire Index of Cotton in Greece

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ABSTRACT

The influence of temperature, rainfall, relative humidity and irrigation on the micronaire value of cotton grown in Greece during the period 1986-1994 was studied. Micronaire was positively affected by temperature, mainly by daily maximum and mean temperature. Within the temperature range encountered, depending on developmental stage, an increase of $1.5 – 2.0^{o}C$ increased micronaire by 0.5. The micronaire value was most influenced during stages that include the period of boll maturation and boll opening, with R^2 values over 0.5 in many cases, reaching 0.9 for the boll opening and harvesting phases. The effects of rainfall and relative humidity were negative and significantly stronger during the stages from boll opening to harvesting with R^2 ranging up to 0.8 for rainfall and R^2 up to 0.6 for relative humidity. Addition of irrigation water to rain weakened regressions and restricted the number of stages with significant water effects. Use of multiple regression analysis, taking account of all parameters studied, resulted in higher R^2 values. Micronaire values could be predicted using the models developed. The applicability of management techniques to decrease adverse or increase favourable effects of weather is discussed.

Introduction

Cotton growth and development are strongly affected by meteorological and other external environmental factors such as water and nutrients availability. Extension of cotton cultivation to temperate areas where low or sub-optimum temperatures are common and strongly influences the crop biological cycle, often results in low yields and quality. Stress due to low temperature at certain developmental stages may not be counteracted by higher temperature during later stages or by a higher radiation level.

Temperatures lower than $11^{o}C$ at the beginning of the growing period (Constable, 1976) may affect growth of the later stages as well as yield and quality (Cristiansen and Thomas, 1969; Sabinina, 1971; Gipson, 1972). Vegetative growth, reproductive development (e.g. flowering initiation and fruiting), boll and fiber development and maturation, are significantly but variously affected by temperature. Generally growth rates increase with temperature (Christiensen and Thomas, 1969; Constable, 1976; Roussopoulos *et al.*, 1978). but floral initiation and flowering are promoted by relatively low temperature (Mauney, 1966; Powell, 1969; Hesketh and Low, 1968). The importance of temperature for boll and fiber development and maturation was observed very early by many investigators (Howkins and Serviss, 1930; Kerr, 1937; Anderson and Kerr, 1938). In many areas, the limiting factor is not mean daily but sub-optimum night temperatures. The significance of night temperature in boll and fiber development has often been stressed (Gipson and Joham, 1968, 1969; Gipson and Ray, 1970, 1973, 1976; Yfoulis and Fassoulas, 1978 ; Roussopoulos *et al.*, 1978).

Low temperature generally increases the maturation period and decreases sugar accumulation in bolls, cellulose synthesis and secondary wall thickening thus fiber maturity (micronaire) and strength. However, fiber length and lint percentage could be adversely affected by high temperatures (Hessler *et al.*, 1959; Nacamura and Sato, 1961; Morris, 1964; Saunt, 1967; Bilbro and Ray, 1973; Hesketh and Low, 1968; Powell, 1969; Gipson and Johan, 1968, 1969 ; Gipson and Ray, 1970; Conner *et al.*, 1972; Schubert, 1975; Constable and Rawson, 1980; Wall *et al.*, 1994). High maximum temperature could act as a higher daily mean temperature and low minimum temperature as a lower mean temperature, as observed for fiber strength and micronaire (Liakatas *et al.*, 1998). Different low and upper temperature limits for cotton growth and development, dependent on research conditions and genotypes were reported by various authors (Hesketh and Low, 1968; Gipson and Johan, 1968; Powell, 1969; Gipson, 1972; Conner *et al.*, 1972; Gipson and Ray, 1973, 1974; Krieg, 1973; Bhatt, 1977).

In Greece, the cotton-growing season is rather short. Unfavourable weather conditions, such as low temperature and untimely rainfalls, particularly during the beginning or the end of the season, often cause serious problems, resulting in lateness and lower yields and quality. Mid season high temperatures combined with water stress could adversely affect cotton boll formation and development. Fiber maturity, commonly expressed by the micronaire value, has great importance for industry and is one of the fiber properties most affected by environmental factors. Thus the study of the specific effects of temperature, relative humidity, rainfall and irrigation on this value in the Greek cotton cultivation is described.

Material and methods

Standard meteorological data of the Hellenic Cotton Board stations network spread, over the cotton producing area, was used. Area-balanced daily maximum, minimum and mean temperature, rainfall and relative humidity averages were calculated separately for Thessaly (Central Greece) and for the Country as a whole. Region-average irrigation data were also used. The phenological data used refer to observations on the 15%, 50% and 85% of completion for the stages of sowing, emergence, squaring, flowering, beginning of boll opening, boll opening and harvesting, throughout the cotton cultivation zone of the country. Results for 50 % completion stages are presented. Micronaire data were taken from fiber test results of the annual survey of seedcotton quality of the Hellenic Cotton Board. All observations refer to 1986-1994.

Simple linear and multiple regression analyses were applied between independent (weather and irrigation) variables and micronaire.

Results

One - variable models

Temperature. Generally, micronaire value was found to be strongly and positively affected by temperature both in Thessaly and the whole country, as shown by the slope of the corresponding regression lines and the values of the coefficient of variation R_2 (Figs 1-3). Figures 4 and 5 were drawn to better evaluate the magnitude of the effect of temperature at each development stage on micronaire. They show that:

a) In many cases R_2 values exceed 0.5, meaning that over 50% of the micronaire variation could be attributed to temperature.

b) Temperature affects mostly either the later stages (after flowering) or the lengthy stages that include boll development and maturation, like sowing or emergence to boll opening or harvesting, flowering to harvesting, starting of boll opening to harvesting. The last stage, in particular, gave the highest R_2 values (over 0.95) both in Thessaly and the Total Country (Figs 4,5). This is because the stage duration is determined by the 50% of completion. Thus when referring to 50% boll opening, there is another 50% of bolls still developing and so being influenced by temperature. The wicker effect of temperature on micronaire during the earlier stages could be considered as indirect, because of the influence on the total biological cycle of the plant.

c) Daily maximum and mean temperatures were found to influence micronaire more strongly, while the influence of minimum temperature was characteristically lower both in Thessaly and the total Country. This is in agreement with previous investigations, reporting that day time or maximum temperatures have greater influence on fiber maturation and thus micronaire (Liakatas *et al.*, 1998) but contradicts reports on night temperature effects (Gipson and Johan, 1968; 1969). An increase of average temperature by as little as 1.5 to 2.5$_o$C, depending on stage and its duration, increases micronaire by approximately 0.5.

Note that two years, 1988 and 1990, were omitted from the analysis because very irregular micronaire values in the 1988 crop were unexpectedly low for the growing season average temperature. During July 1988 a long wave of hot weather with temperatures of 42 – 45$_o$C prevailed, followed by a very hot August, combined with water shortage caused by a prolonged drought in the previous two years. These extreme weather conditions resulted in incomplete maturation and low micronaire values. The other irregular year, 1990, was fairly normal for cotton cultivation up to August 22 (maturation period) when a sudden weather change took place in the following two days, characterized by a sharp drop in temperature, with rain and minimum temperatures around 5$_o$C. The weather returned to the normal soon afterwards. The unusual, temperature drop, although short, affected fiber maturation, resulting in low micronaire value.

Rainfall and irrigation. Rainfall significantly and negatively affects micronaire value almost exclusively during the end of the growing season i.e. during maturation period up to boll opening, and longer periods including these late stages. In these cases, the linear regression R_2 coefficient values ranged between 0.60 and 0.80 (Figs 6, 8, 9). A total rainfall increase of 100 mm may decrease micronaire index by 0.5. This could be because early autumn rain in Greece coincides with the end of the growing season, usually combined with low temperatures, causing lateness and various quality and yield problems, particularly when following late irrigation. Usually higher rainfall in the latest regions of the North Greece have stronger effects, influencing and differentiating the total country from Thessaly. Supplementary irrigation reduces the number of the stages in which water plays a role in micronaire, weakening correlations (Fig 8, 9). The addition of irrigation reduces the significance of differences only between the beginning of boll opening and harvest. (R_2 = 0.75-0.80).

Relative humidity. Micronaire was little affected by relative humidity and only during the late stages from boll opening to harvesting. R_2 coefficients did not exceeding 0.40-0.50 and only in one case reached 0.60 (Figs 7, 8, 9). Correlations for Thessaly appeared a little better than for the total Country.

Multivariable models

As meteorological parameters and irrigation may be interrelated or act in combination in affecting micronaire, a multiple regression analysis was attempted for Thessaly and total Country. In many cases the relations were statistically significant at the 99% level. A stepwise regression analysis with a backward selection method was followed. As expected, in most cases the model could be simplified by omitting one or more of the non significant parameters. Finally the model appeared with one to three parameters, usually including one or two expressions of temperature and rain, depending on the stage. For example, the analysis for the stage starting with boll opening and lasting until harvesting gave the equation:

Micronaire = 3.579 + 0.02*Tmean + 0.031*T min – 0.015*T max – 0.0027*Rain – 0.004*Humidity

with: R_2 = 95.92 %, R_2 (adjusted for d.f.) = 75.55 %, Standard Error of Est. = 0.054, Mean absolute error = 0.017 and Durbin – Watson statistic = 1.835

This model can be simplified through stepwise backward analysis providing:

Micronaire = 3.38 + 0.028*T min – 0.003*Rain

with: R_2 = 92.82 %, R_2 (adjusted for d.f.) = 89.23 %, Mean absolute error = 0.0013 and P value = 0.0052

Conclusions

Under normal Greek conditions, the micronaire value is strongly influenced by temperature, less by rainfall and much less by relative humidity. Micronaire was positively related to temperature parameters and negatively to the other parameters studied. Daily maximum and mean temperatures appeared more effective than minimum temperature. The effect of temperature was stage dependent and more pronounced in the later stages because of the direct influence of temperature on fiber maturation. The effects of water (rainfall or rainfall plus irrigation) and relative humidity were obvious almost exclusively during the late stages, due to the lack of significant rains in summer. R_2 values for all parameters were in many cases surprisingly high for the extensive areas of data collection.

These simple or multivariable models could be used for micronaire prediction well before harvesting in seasons with normal weather. This could be of great importance to buyers and manufacturers. The one variable linear models could more easily and probably with a higher accuracy be applied in relatively small areas or for specific genotypes (varieties). There is almost a total lack of model predictability in years with very unusual weather.

Acknowledgement

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Fig 1. Effect of stage average mean daily tempererature on micronaire index during the period 1986-1994 in Total of country (Start of boll opening 50 % - Harvesting 50 %)

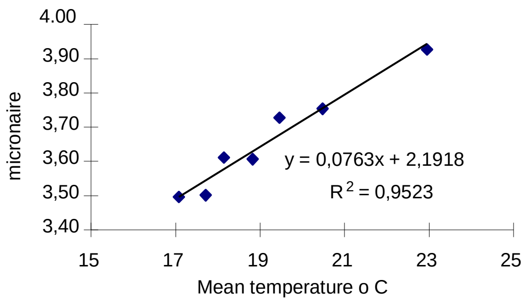


Fig 2. Effect of stage average max tempererature on micronaire index during the period 1986-1994 in Total of country (Start of boll opening 50 % - Harvesting 50 %)

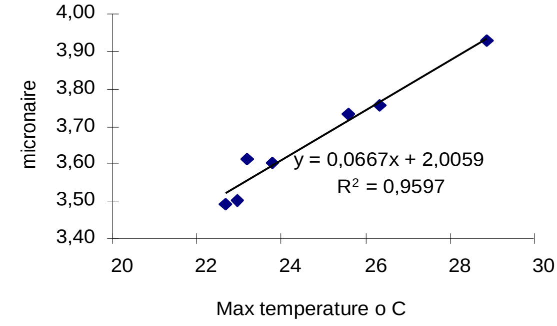


Fig 4. Effect of stage average temperature (mean, max, min) on micronaire index, expressed by R^2 coefficiants values for all stages, in Total Country 50% completion of stages

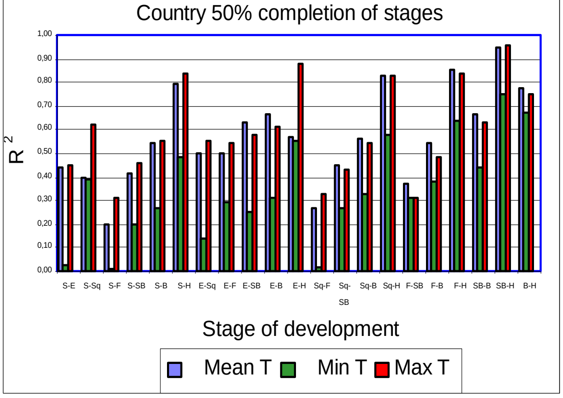


Fig 5. Effect of stage average temperature (mean, max, min) on micronaire index, expressed by R^2 coefficiants values for all stages, in Thessaly 50% completion of stages

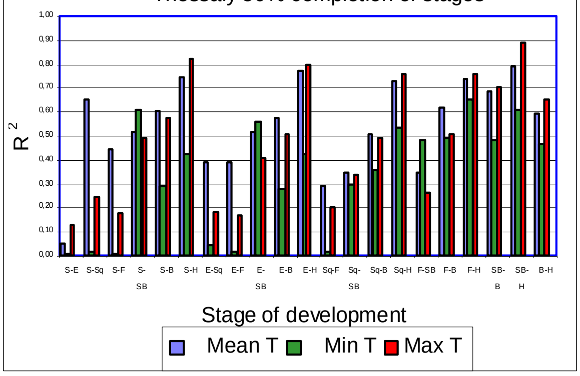


Fig 6. Effect of stage average rainfall water on micronaire index during the period 1986-1994 in Total of country (emergence 50 % - Harvesting 50 %)

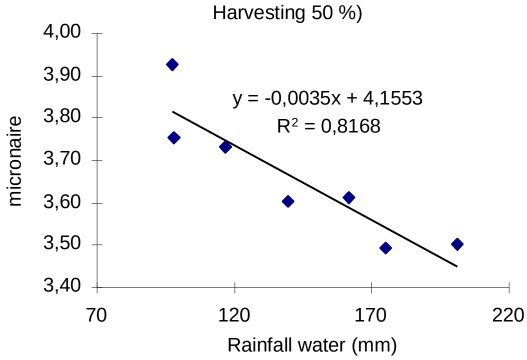
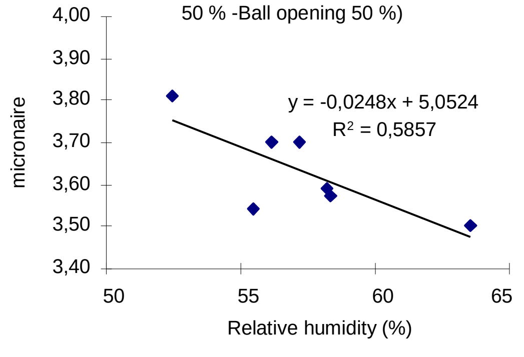


Fig 7. Effect of stage average relative humidity on micronaire index during the period 1986-1994 in Thessaly (Start of boll opening 50 % -Ball opening 50 %)



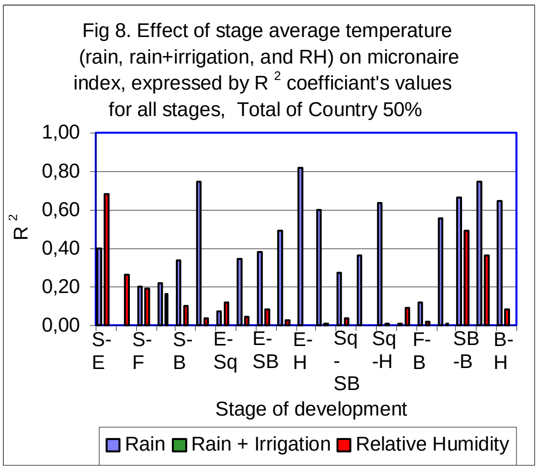


Fig 8. Effect of stage average temperature (rain, rain+irrigation, and RH) on micronaire index, expressed by R 2 coefficiant's values for all stages, Total of Country 50%
1,00
0,80
0,60
0,40
0,20
0,00
R 2
S-E
S-F
S-B
E-Sq
E-SB
E-H
Sq-SB
Sq-H
F-B
SB-B
B-H
Stage of development
Rain
Rain + Irrigation
Relative Humidity

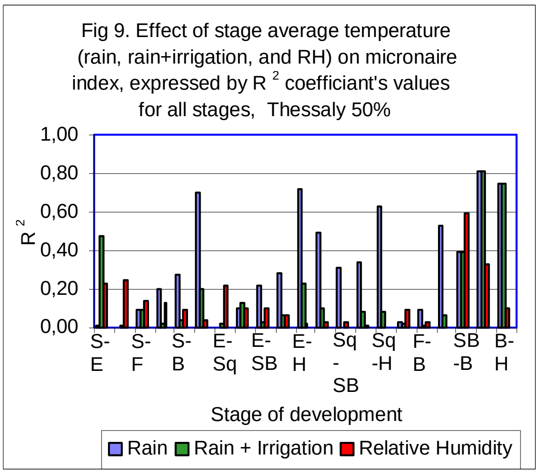


Fig 9. Effect of stage average temperature (rain, rain+irrigation, and RH) on micronaire index, expressed by R 2 coefficiant's values for all stages, Thessaly 50%
1,00
0,80
0,60
0,40
0,20
0,00
R 2
S-E
S-F
S-B
E-Sq
E-SB
E-H
Sq-SB
Sq-H
F-B
SB-B
B-H
Stage of development
Rain
Rain + Irrigation
Relative Humidity