Effect of microclimatic parameters on the floral physiology and yield of seed cotton*[1/]

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COMPENDIO

Se estudió durante la estación de invierno de 1974-1975, la influencia que sobre la producción de flores, caída de flores y rendimiento de algodón en rama, tienen los parámetros microclimáticos del ambiente, los que fueron modificados mediante el uso de caucho negro, caucho blanco y paja de mijo perlado (Pennisetum glaucum) *como coberturas en el algodón 'MCU 5', bajo riego, en la Universidad Agrícola Tamil Nadu, Coimbatore, India Se calcularon correlaciones simples y múltiples, incluyendo también la edad como un factor fisiológico. El análisis indicó que además de la temperatura, la presión de vapor prevalente en la mañana tuvo una correlación alta, de 0,89, con la producción de flores La presión de vapor también tuvo influencia en la caída de flores pero en menor grado La temperatura del suelo en la tarde tuvo una correlación negativa con el rendimiento La humedad relativa temprano en la mañana tuvo una correlación negativa mientras que la de la tarde tuvo una correlación positiva, lo que indica el papel de la humedad relativa del ambiente en decidir el rendimiento Estos estudios de correlación han indicado también la posibilidad de predecir el rendimiento basándose en las condiciones microclimáticas.*

Introduction

COTTON has been studied in India largely from the breeding point of view being an important cash crop. Very little attention has been paid to the study of its physiological aspects in relation to climatic conditions (6). The yield of a crop is governed by several factors Even for the same variety grown under adequate moisture, nutrition and plant protection, the yield is found to vary considerably and this is attributed to the environmental conditions (11). The cotton crop is no exception to this The number of flowers produced by the plant, the shedding of floral parts and the number of bolls that ultimately mature to give yield are reported to be determined by the environmental factors Environment in its broadest sense includes both soil factors and climatic factors (15) One method to modify the environment would be the application of mulches on the soil in the vicinity of the plant. The potentiality of the mulches in effecting a change in the environment depends on the colour, texture and nature of the mulches. The waste black and white material of the rubber factory and the easily available pearl millet straw were used to study the response of plant to such modifications of the environment as manifested in flower production, flower shedding and yield of seed cotton at the Tamil Nadu Agricultural University, Coimbatore, India, on 'MCU 5' cotton

Materials and methods

Coimbatore is situated at 11°N, 77°E and at altitude of 498 m above mean sea level with an annual average rainfall of 645 mm. The experiment was conducted in the fields of Department of Agronomy, Tamil Nadu Agricultural University, Coimbatore on

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clay loam soil of medium fertility during the winter season of 1974-1975 on MCU 5 cotton under irrigation.

The treatments adopted were (I) control (no mulch), (II) black rubber waste, (III) white rubber waste and (IV) pearl millet straw as mulches. The rubber wastes are factory rejects of the tyre industry. The black material was in the form of 5 mm x 30 cm long and 15 to 30 cm broad. The white rubber waste was in the form of flats of 5 mm thickness, 30 cm long and 15 to 30 cm broad. The pearl millet straw was made into small bundles of 5 to 6 plants so that they could not be disturbed by wind. The experiment was laid out in a randomised block design with seven replications. The crop was sown on 13/8/1974 at the rate of two seeds per hole adopting a spacing of 75 × 22.5 cm. Thinning was done on the 15th day of sowing thus leaving only one seedling per hill. The mulches were applied on 22/9/1974 i.e. 41 days after sowing. White and black rubber wastes were spread at the rate of 31.0 t/ha while 7.1 t/ha alone was used in the cases of pearl millet straw. The picking of seed cotton commenced on 11/12/1974 and ended on 15/1/1975 with six weekly picking. The following climatic parameters were recorded in one replication only.

I) *Soil temperature*:—This was measured in centigrade at 5 cm depth daily at 0630 a.m. and 1430 p.m. from 7th to 23rd week after sowing.

II) *Mulch temperature*:—The temperature within the mulch was recorded in centigrade from 7th to 23rd weeks after sowing daily at 0630 and 1430 hours.

III) *Temperature above mulch*:—The microclimatic temperature of the crop environment was recorded by using Assmann's Psychrometer at the top surface of the mulch and 30 cm above the mulch in centigrade from 64th to 126th day (10th to 18th week) daily at 0640 and 1440 hours.

IV) *Relative humidity and vapour pressure*:—From the wet and dry bulb temperature values recorded by the Assman's Psychrometer the relative humidity and vapour pressure were computed by referring to the Tables prepared (1).

V) *Air temperature*:—The maximum and minimum temperatures recorded in centigrade at the agrometeorological observatory situated one kilometer away from the experimental site were taken as the macroclimate air temperature due to the crop canopy.

Results and discussion

In the present study, the plants environment was modified by the application of mulches to cover the soil, thus protecting the soil from direct solar radiation, except in control. The effect of mulches was manifested in the changes in the temperature of the soil as well as in the plant environment. In addition, the vapour pressure and relative humidity were also modified by the mulches, providing different environment in the same field. To express more clearly the effect of microclimatic parameters of the environment and the physiological reaction of the plant, expressed in the number of flowers produced, shedding of flowers and yield of seed cotton, in mathematical terms, simple and multiple correlations were worked out, by taking into account, the soil temperature, above mulches, relative humidity and vapour pressure at the surface and 30 cm height as independent variables and the number of flowers produced, number of flowers shed and the yield of seed cotton as dependent variables.

As the effect of the environment may be cumulative the microclimatic parameters prevailing during the previous 2,3 and 4 weeks were considered for working out the correlations and the correlation coefficients. As the response of the plant may vary with its age, the age of the crop was also included in working out the correlations with its responses in respect of the above dependet variables. The significant correlations are discussed below.

Flower production

The data on correlations are presented in Table 1. It may be seen from the Table 1 that the microclimatic temperature at the surface and at 30 cm prevailing in the morning for the period of two weeks preceding flower production had a greater influence than those prevailing during the previous three weeks, in increasing flower production. Soil temperature also had a positive influence, but the coefficient of correlation was slightly lower. This brings out clearly the importance of morning temperature on the production of flowers. Though the physiological processes depend on temperature, in case of flower production the vapour pressure in the morning, prevailing during the previous three weeks also appeared to exercise a greater influence as may be seen by the high coefficient of +0.89. This factor alone could account for 79.52 per cent of the variation in flower production.

Flower production is not always linear. It is said to be related to age of the crop to a certain extent (5). This can also be seen from the negative correlations of 0.57 between age and flower production. In order to study the influence of climatic factors, in relation to the age of the crop, an attempt was made by working out multiple correlation coefficients. Among the various factors that were considered, based on simple correlation coefficients, morning surface temperature and vapour pressure of previous three weeks as well as temperature at surface and 30 cm height for two weeks were found to be effective.

The vapour pressure of the previous three weeks and age of the crop had greater influence as seen from the higher multiple correlation coefficient of +0.82. With these two factors put together 67.75 per cent of flower production could be determined. The relative importance of vapour pressure in the environment have been brought out in this study. The

Table 1.—Relationship between climatic parameters and flower production.

S. Nº	Independent variable	Weeks	n	r	Regression equation	R	Regression equation with age (X_1) as additional independent factor
1.	Soil temp. a.m.	3	24	0.42*	$-1343.45 + 70.88\ X$	0.18	$-1417.09 + 0.93X_1 + 73.33X_2$
2.	Soil temp. a.m.	2	24	0.54*	$-1214.50 + 66.08\ X$	0.30	$-1466.41 + 4.58X_1 + 73.74X_2$
3.	Age in weeks	—	16	-0.57*	$1176.28 - 51.90\ X$	—	—
4.	Temp. above mulch surface a.m.	3	16	0.66**	$-2867.67 + 154.25\ X$	0.48*	$-1651.71 - 25.49X_1 + 116.59X_2$
5.	Temp. above mulch 30 cm a.m.	3	16	0.58*	$-1744.70 + 101.58\ X$	0.42	$-502.02 - 32.40X_1 + 65.38X_2$
6.	V.P. above mulch surface a.m.	3	16	0.89**	$-1945.16 + 139.52\ X$	0.82**	$1474.78 - 16.38X_1 + 125.80X_2$
7.	Temp. above mulch surface a.m.	2	20	0.72**	$-1358.52 + 83.87\ X$	0.51*	$-1345.58 - 0.40X_1 + 83.43X_2$
8.	Temp. above mulch 30 cm a.m.	2	20	0.70**	$-1059.58 + 69.92\ X$	0.48*	$-951.40 - 3.24X_1 + 66.96X_2$
9.	V.P. above mulch surface a.m.	2	20	0.63**	$-1017.93 + 84.54\ X$	0.42	$-677.77 - 10.72X_1 + 73.42X_2$
10.	V.P. above mulch 30 cm a.m.	2	20	0.60**	$-1006.10 + 87.25\ X$	0.41	$-560.53 - 15.67X_1 + 73.47X_2$

** Significant at 1% level * Significant at 5% level Temp. Temperature
V. P. Vapour Pressure

Table 2.—Relationship between climatic parameters and flower drop.

S. Nº	Independent variable	Weeks	n	r	Regression equation	R	Regression equation with age (X_1) as additional independent factor
1.	Temp. above mulch surface a.m.	3	24	0.42*	$1839.26 + 100.19\ X$	0.23	$-4455.97 + 51.86\ X_1 + 187.21\ X_2$
2.	V.P. above mulch surface a.m.	3	24	0.42*	$1558\ 66 + 108.47\ X$	0.20	$-2929.52 + 30.94\ X_1 + 161.97\ X_2$
3.	V.P. above mulch 30 cm a.m.	3	24	0.41*	$-1664.83 + 119.16\ X$	0.18	$-2470.18 + 18.02\ X_1 + 151.91\ X_2$

** Significant at 1% level * Significant at 5% level Temp. Temperature
V. P. Vapour Pressure

increased amount of water vapour would have reduced the transpiration rate and helped the leaves to maintain its turgor for a longer period in the mornings. The rate of transpiration depends on the steepness of the vapour pressure gradient from plant tissue to air and hence the water vapour pressure of the air is the most useful (14). A deeper study under controlled environmet may throw more light on this aspect.

Drop of flowers

The influence of microclimate on flower drops was assessed and presented in Table 2. The mean morning temperature of the previous three weeks as well as the vapour pressure at the surface level and 30 cm above the surface had significant positive correlations with this factor. It is interesting to note that the vapour presure in the morning influenced the production of flowers, and the same factor has influenced the shedding of flowers as may be seen by the coefficients of correlation furnished in the Table 2. However in the latter cases, the coefficients are only 0.42 and 0.41, thus accounting for only less than 18 per cent of the variation.

Joshi *et al.* (13) opined that shedding of buds which appear quite early in the season is due to incongenial quality of the sap and that subsequent shedding of both the buds and bolls which occurred increasingly throughout the period of their formation is the result of food shortage in the plant. Dastur and Mukhtar Singh (8) and Dastur and Gopani (7) in their studies on cotton growth have shown that application of nitrogen increased the production of flowers as well as their retention. It is also possible to have better nurient availability in the soil at higher temperatures due to better microbial activity (3). The temperature in this case showed only a weak correlation accounting only for 17.5 per cent of the variation. It was seen earlier that sudden fluctuations in the environment, caused by major factors like rainfall and sudden decrease in temperature increased flower shedding. Carver (4) stated that there was a general tendency for low yields in rainy years and high yields in dry years. As rainfall is associated with cloudiness, lower sushine and low temperature which might have induced higher rates of shedding.

Yield of seed cotton

The data on simple and multiple correlations worked out between the various microclimatic factors and yield of seed cotton are presented in Table 3.

When the yield was related to age of the crop, it was noticed that during initial stages i.e. up to 19th week there was a positive trend (r=0.88). But when the analysis was extended to later periods, there was a negative correlation (r= −0.40), although it was not significant. This is evident from the yield data presented in Table 4. That the yield increased upto the 3rd picking and declined thereafter in all treatments. Among the various climatic factors, there was a negative trend between the soil temperature in the afternoon and yield (r= −0.41). The high temperature in the afternoon might have increased the respiratory rate and a loss of photosynthesis, thus giving a reduced yield.

The relative humidity appeared to exercise greater influence on yield. As the relative humidity increased in the early morning particularly during the previous two weeks there was reduced yield. On the other hand, an increase in the relative humidity in the afternoon tended to increase the yield as seen by the positive correlation. This indicates that an equitable level of relative humidity appears to be favourable for yield. This applies equally for vapour pressure of the environment. This may probably due to shedding floral parts as too low a temperature in the early morning would increase the relative humidity and vapour pressure near the ground level. Rainfall also increased the moisture of the environment causing increased shedding of flowers. On the other hand the increase in relative humidity and vapour pressure in the afternoon, when temperature would be higher than in the morning, would have reduced the transpiration and maintained the turgidity of the leaves, thus contributing to increased photosynthesis. Gates (10) and Ashton (2) reported that as the cells lose their turgor and begin to wilt, the stomata are closed leading to inhibition of photosynthesis.

In addition, a high relative humidity acts as a thermo-regulator and consequently can exert an effect on plant growth by way of temperature (16). As in the case of flower counts and the drop of buds and bolls, the yield of cotton crop is a function of the age itself. If, during this period, a better environmental condition is made available for the conversion of photosynthate into a storage material, the lint and seed production in the present case can be increased. This is again indicated by the significant effect of various microclimatic parameters other than soil temperature and the age of the crop. In all cases the coefficients of multiple correlation were found to be of higher order ranging from 0.79 to 0.87. The highest value of coefficient of correlation was found to be in case of vapour pressure at the surface in the morning and at 30 cm height (0.87). In general, these multiple regression analysis indicated the importance of the environmental conditions during the entire period of development of bolls and their bursting period around 4 weeks. Huxley (12) concluded that the yield of cotton is not dependent only upon the vegetative growth made by the crop, but influence of environment upon flowering and fruiting can limit the yield, which ultimately depends not only upon one, but upon a complex interplay of many limiting factors which operate at various times throughout the life of the crop, on processes concerned both with growth and development.

In living organisms the response to these environmental parameters, need not always be linear. Further as suggested by Dorland and Went (9) the optimum requirements of temperature varies with the age. Hence, in order to find out the optimum of environ-

Table 3.—Relationship between climatic parameters, age and yield of seed cotton.

S. Nº (1)	Independent variable (2)	Weeks (3)	n (4)	r (5)	Equation (6)	R (7)	Regression equation (8)	R (9)	Quadratic equation with age (X_1) as additional factor (10)
1.	Age in weeks	—	24	—0.40					
2.	Soil temp. a.m.	4	24	0.40		0.18	$-25.23 - 21.89X_1 + 33.09X_2$	0.36	$-28228.20 - 40.30X_1 + 2559.67X_2 - 55.76X_2^2$
3.	Soil temp. a.m.	2	24	0.40		0.18	$-50.34 - 21.91X_1 + 34.88X_2$	0.28	$-22152.20 - 28.76X_1 + 2021.71X_2 - 44.30X_2^2$
4.	Soil temp. p.m.	4	24	—0.41*	$1572.40 - 42.53X$	0.28	$2011.53 - 31.87X_1 - 36.40X_2$	0.31	$14017.30 - 26.83X_1 - 836.33X_2 + 13.18X_2^2$
5.	Age in weeks	—	12	0.89**	$-2102.68 + 137.55X$	0.86**	$-4530.13 + 190.50X_1 + 73.67X_2$	0.86**	
6.	Temp. above mulch surface a.m.	4	12	—0.54		0.86**	$-4549.26 + 192.67X_1 + 73.49X_2$	0.88**	$-10382.90 + 184.29X_1 + 678.21X_2 - 15.30X_2^2$
7.	Temp. above mulch 30 cm a.m.	4	12	—0.53		0.80**	$-2567.51 + 133.17X_1 + 17.97X_2$	0.81**	$-14922.30 + 181.52X_1 + 1157.10X_2 - 27.72X_2^2$
8.	Temp. above mulch surface p.m.	2	12	0.33				0.79**	$-11286.00 + 135.27X_1 + 593.03X_2 - 9.52X_2^2$
9.	R.H. above mulch surface a.m.	4	12	—0.65*	$15418 - 167.14X$	0.79**	$44.18 + 128.47X_1 - 22.04X_2$	0.81**	$-810.57 + 128.24X_1 - 2.38X_2 - 0.11X_2^2$
10.	R.H. above mulch surface a.m.	2	12	—0.86**	$9175.84 - 98.64X$	0.81**	$2234.02 + 89.82X_1 - 38.97X_2$	0.79**	$-333.75 + 88.87X_1 + 19.56X_2 - 0.33X_2^2$
11.	R.H. above mulch 30 cm a.m.	4	12	—0.35		0.79**	$-1884.04 + 136.89X_1 - 2.34X_2$	0.81**	$-40807.67 + 138.97X_1 + 877.23X_2 - 4.97X_2^2$
12.	R.H. above mulch 30 cm a.m.	2	12	—0.85**	$7901.51 - 85.81X$	0.81**	$1139.81 + 98.34X_1 - 28.91X_2$	0.85**	$-4441.87 + 96.91X_1 + 99.58X_2 - 0.74X_2^2$
13.	R.H. above mulch surface p.m.	4	12	0.79**	$-2145.03 + 38.85X$	0.82**	$-2413.38 + 104.13X_1 + 14.07X_2$	0.80*	$8700.14 + 104.74X_1 - 329.25X_2 + 2.65X_2^2$
14.	R.H. above mulch surface p.m.	2	12	0.15		0.81**	$-2600.60 + 137.13X_1 - 7.5X_2$	0.82**	$-3497.25 + 136.51X_1 + 34.52X_2 - 0.20X_2^2$
15.	R.H. above mulch 30 cm p.m.	4	12	0.72**	$-1677.86 + 32.55X$	0.81**	$-2470.50 + 131.06X_1 + 7.36X_2$	0.81**	$5086.39 + 119.38X_1 - 225.17X_2 - 1.84X_2^2$
16.	R.H. above mulch 30 cm p.m.	2	12	0.39			$-4315.63 + 195.67X_1 + 73.46X_2$	0.87**	$850.99 + 132.60X_1 - 95.27X_2 + 0.79X_2^2$
17.	V.P. above mulch surface a.m.	4	12	—0.58*	$1841.45 - 92.45X$	0.86**	$-4143.91 + 188.07X_1 + 74.18X_2$	0.88**	$-10661.80 + 189.08X_1 + 895.53X_2 + 26.67X_2^2$
18.	V.P. above mulch surface a.m.	2	12	—0.47		0.87**			$-8685.70 + 186.78X_1 + 679.87X_2 - 20.04X_2^2$
19.	V.P. above mulch 30 cm a.m.	4	12	—0.57		0.85**	$-4163.61 + 191.21X_1 + 71.19X_2$	0.87**	$-11181.90 + 183.93X_1 + 1009.48X_2 - 30.71X_2^2$
20.	V.P. above mulch 30 cm a.m.	2	12	—0.48		0.87**	$-4156.49 + 189.79X_1 + 75.32X_2$	0.88**	$-7833.42 + 187.46X_1 + 585.95X_2 - 17.48X_2^2$
21.	V.P. above mulch surface p.m.	4	12	0.67*	$-1575.26 + 92.67X$	0.84**	$-2475.77 + 114.72X_1 + 37.29X_2$	0.89**	$-1659.24 + 110.23X_1 - 42.66X_2 + 2.15X_2^2$
22.	V.P. above mulch surface p.m.	2	12	0.39		0.82**	$-2409.74 + 130.61X_1 + 19.83X_2$	0.82**	$-4727.42 + 131.80X_1 - 230.45X_2 - 4.82X_2^2$
23.	V.P. above mulch 30 cm p.m.	4	12	0.65*	$-1611.16 + 100.57X$	0.82**	$-2444.79 + 118.16X_1 + 35.03X_2$	0.85**	$6543.08 + 118.92X_1 - 864.01X_2 + 22.41X_2^2$
24.	V.P. above mulch 30 cm p.m.	2	12	0.46		0.82**	$-2375.98 + 127.82X_1 + 21.93X_2$	0.82**	$-2654.52 + 127.87X_1 + 48.75X_2 - 0.65X_2^2$

** Significant at 1% level * Significant at 5% level

Temp. Temperature
R. H. Relative humidity
V. P. Vapour Pressure

mental conditions for obtaining the highest yield, an attempt was made in the present investigation by extending the multiple regression analysis by taking age as well as the linear and the quadratic terms of the environmetal conditions into account. However, as the number of observations available were limited, this could give only broad indications.

The details of significant multiple correlation coefficients are presented in Table 3. It may be observed from the values of coefficient that the quadratic term fits in better than linear term alone. This may help in finding out the optimum requirement of temperature in relation to age of the crop. The regression analysis has brought out clearly the effect of the microclimaitc vapour pressure, temperature and relative humidity in predicting the yield of cotton. Based on the prediction equation, the expected values of yield for a given temperature, relative humidity and vapour pressure of the surface and crop canopy were worked out for the factors which gave higher coefficients of correlations of about 0.85, and found to fit well.

Thus the multiple regression analysis has broughtout clearly the effect of microclimatic parameters as modified by mulches on the yield of 'MCU 5' cotton to the extent of predicting the yield fairly accurately based on the temperature, vapour pressure and relative humidity prevailing in the crop environment. The study has also brought out clearly the use of mulches as a tool for modifying the environment of the crop to obtain greater yield.

Summary

The influence of microclimatic parameters of the environment on production of flower, flowers shedding and yield of seed cotton as modified by the use of black rubber, white rubber and pearl millet straw as mulches on MCU 5 cotton were studied during 1974-1975 winter season under irrigation at the Tamil Nadu Agricultural University, Coimbatore, India. Simple and multiple correlations were worked including age also as a physiological factor. The analysis indicated that in addition to temperature, vapour pressure prevailing in the morning had a high correlation of 0.89 with flower production. Vapour pressure also influenced flower shedding but to a lesser extent. Soil temperature in the afternoon had a negative correlation with yield. Relative humidity in the early morning has a negative correlations while in the afternoon had a positive correlation, indicating the role of relative humidity of the environment in deciding the yield. These correlation studies have also indicated the possibility of predicting the yield based on microclimatic conditions.

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