Physiological Effects on Cotton Plant Sown under Plastic Mulch

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ABSTRACT

The physiology of the cotton plant was studied in cotton sown under plastic. This practice is widespread among cotton growers in the Guadalquivir River Valley (SW Spain). Field experiments were conducted in 1993, 1994 and 1995 at Alcalá del Rio (Seville). In one experiment, cotton was sown on two dates in March. This is very early and is not possible without plastic mulch because of low temperatures but it conforms to the usual custom of the growers. A second experiment was sown during the normal planting time for Spain in May, with and without plastic mulch. The first experiment used a split-split plot design with three splits, date of sowing followed by cultivars and then the number of days that the plant remained under plastic mulch (15-45 and 60 days). A similar design was used in the second experiment except that the date of sowing was replaced by the factor with or without plastic mulch. Physiological measurements on vigour, biomass accumulation (root and shoot biomass), LAI (leaf area index), horizontal and vertical flowering rates and boll setting and fruiting sites (plant mapping) were taken at several dates. Results showed that cotton growing under plastic mulch has a fast, luxurious vegetative growth at the beginning of season, with a rapid increment in LAI and a faster vertical flowering rate and an increase in the number of bolls on secondary sympodia than plants without plastic mulch. The root system was completely transformed, the main root being thicker and shorter. A remarkable increase in earliness and yield were shown with a serious propensity to suffer water stress. The increment in potential yield can only be realized with frequent, shallow.

Introduction

The agronomic technique of planting under plastic mulch was introduced in the Guadalquivir Valley (SW Spain) at the beginning of the 1980s. Its principal objective was to improve the thermal conditions in which the cotton plant developed during its initial stages, eliminating germination problems due to low temperatures (Márquez, 1993). The chamber of air formed between the layer of transparent polythene and the ground assures optimum conditions of humidity and temperature and in this way produces rapid germination (Fereres and Goldhamer, 1991) and the spectacular development of the plantlets compared to conventional planting without plastic mulch (Wendt, 1973). In addition, the greenhouse effect leads to an intensive crop development with a noticeably reduced growing season. The most important consequence is the bringing forward of the date of harvest by one month ahead of cotton grown without plastic, thus avoiding the adverse effects of rain on fiber quality. (Lombardo *et al.*, 1992; Márquez, 1990).

Fundamentally, the planting of cotton under plastic mulch quickly spread to become common practice among Spanish cotton growers. Currently, 90% of irrigated cotton in the south of Spain is grown in its early stages under plastic (Robledo de Pedro, 1995). The objective of this study was to find possible physiological modifications that may result from the application of this technique.

Material and Methods

Two different field experiments were conducted in 1993, 1994 and 1995 at Alcalá del Río (province of Seville, SW Spain) on a sandy loam soil (Typic Xerofluvent). Experiment type A was to study the effects of different time periods under plastic with different March sowing dates on the cotton plant. Low temperatures would preclude sowing without plastic mulch in March. Experiment type B had a single sowing date in May when the temperature was over 15.5°C, with various periods under plastic mulch and a control sown without plastic. This experiment was to verify the effects of the accumulation of heat on the cotton plant and to compare the effects of the sowing of cotton with and without plastic mulch.

Pre planting fertilization consisted of 90 Kg N ha^{-1} and 230 Kg P ha^{-1}. Post planting, additional nitrogen was applied at a rate of 200 Kg N ha^{-1}. Insecticides were applied as needed. Furrow irrigation was applied equally to all the plots in 1993 and on different dates depending on the sowing dates in 1994 and 1995.

The first experiment used a split-split plot design with four replications and three splits: date of sowing, (two dates in March), cultivars (Coker-310 and Deltapine Acala 90), and number of days under plastic mulch (15-45-60 days after sowing). Individual plots were 2 m wide by 15 m long, with row spacing of 0.95 m and 150,000 plants ha^{-1}. The second experiment had a similar design with the date of sowing factor replaced by the factor with or without plastic mulch.

Cotton growth and physiological development were assessed throughout the season using measurements of height, nodes (Kerby, 1992), flowering intervals, biomass accumulation (root and shoot dried at 50°C), and leaf area (Sunfleck Ceptometer SF-80), Delta T Devices Ltd.). Plant mapping data using the PMAP programme (Landívar, 1992) were collected on two different dates, middle flowering and at the end of the season. Cotton lint yield was determined by hand harvesting twice from mid-September to mid-October. Samples were collected from each plot at harvest to determine lint percentage and fiber quality parameters, using High Volume Instrument assessments (SpinLab, SL-900).

Results and Discussion

Figures 1, 2 and 3 show that the vigour curves manifest a similar tendency in the early stages of development during the three years of trials with some very fast growth rates in length and node number. These curves are very much higher than the standard curves for Acala SJ-2 (Kerby, 1992) and are maintained until vegetative growth makes way for reproductive development. At this stage, when plants reach the 8-9th node, the tendency becomes inverse and the curves become lower than those of Kerby. Fig.1 shows that at the end of the growing season in the 1993 trials, the plants were affected by premature cutout, especially accentuated in the treatment that remained longest under plastic mulch. The differences from sowing with or without plastic became so notable that the final height of DPL Acala 90 was only 50 cm with 45 days under plastic compared to 115 cm for the same variety sown without plastic or with 15 days under plastic.

In the 1994 trials (Fig. 2) and 1995 (Fig. 3) the tendency was repeated. With longer under plastic, greater vegetative growth is achieved until the 8-9th node, after which the growth rates slow although treatments without plastic gave similar growth curves to the control plants. The premature cutout of the first year was prevented earlier, more frequent irrigation. The study of the flowering intervals and the LAI confirms this rapid initial vegetative development. Fig.4 shows that the plants that remained longer under plastic had shorter vertical flowering intervals, that is to say, faster emission of fruiting branches while the period between consecutive flowers on the same sympodium increased compared to the other treatments. Longer under plastic also promoted higher values in the LAI, with very rapid initial growth (Fig. 5), while in late sowing without plastic, the growth in LAI was slow and progressive, reaching final values similar to treatments with plastic mulch. Slight varietal differences were noted.

Plant mapping was undertaken corroborate the studies on aerial biomass. With longer under plastic, the plants are initially taller (Table 1), have a greater number of well-developed vegetative branches (Table 3), greater biomass in stalk and leaf (Tables 6 and 7) and shorter internodes (Table 2) (Lombardo, 1993). Towards the end of the growing season, these differences between treatments become more marked, with plots that had plastic mulch for a short period (15 days) showing a greater number of reproductive points (Table 5) and open capsules (Table 4).

The study of underground biomass showed important modifications in the root system of plants grown under plastic mulch (Tables 6 and 7). The main root is shorter and thicker, with the majority of the secondary roots close to the surface. These morphological features would favour the harnessing of water in the upper layers of the soil profile, where the root density is greater (Carmi and Shalhevet, 1993; Burke and Upchurch, 1996).

The yields obtained in these trial years does not clearly show that plastic mulch leads to higher yields if the crop is managed in traditional ways. In 1993, heavy rains prevent crop harvesting. In 1994 and 1995 (Table 8), there were no significant differences between the plastic mulch treatments (Trials 1994A and 1995B) but treatments with plastic mulch were significantly superior to those without plastic mulch

The only fiber parameter with significant differences was the micronaire value, but only in 1994 when treatments with plastic mulch were superior to those without (Table 9).

Conclusions

This study verified that the standard vigour curve proposed by Kerby for Alcala SJ-2 in California does not apply to cotton sown under plastic in the Guadalquivir Valley. Cotton plants exhibit rapid early vegetative growth, accompanied by speedy development of the LAI. The increase in vertical flowering rate, the shortening of the internodes and higher number of bolls on secondary sympodia increase the productive capacity of the plant. The greenhouse effect caused by the plastic transforms cotton into an intensive crop, shortening the growing season and thus giving greater earliness, bringing the harvest date forward by approximately one month.

The modifications in the root system that remains very near the soil surface, combined with increased aerial biomass, increase the risk of water stress and may lead to premature cut-out if not remedied through frequent irrigation. Drip irrigation or, in its absence, any system that allows low and frequent doses of water, seems to be the most advisable way of achieving high yield (Gutiérrez, 1997).

The productive potential of cotton sown under plastic mulch is greater than traditional sowing. Nevertheless, the results do not confirm substantial improvements in performance with traditional crop management practices. Although the plant is prepared for a bigger, earlier crop, success ultimately depends on the growing practices used (frequent irrigation with appropriate, timely fertilization to balance the vegetative and reproductive growth through early use of growth regulators) and environmental conditions that convert the high fruit load into real yield.

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References

Burke, J.J. and D.R. Upchurch. (1995): Cotton Rooting Patterns in Relation to Soil Temperatures and the Thermal Kinetic Window. Agron. J. 87:1210-1216.

Carmi, A. and J. Shalhevet. (1983): Root Effects on Cotton Growth and Yield. Crop Sci. 23:875-878.

Fereres, E. and D.A. Goldhamer. (1991): Plastic mulch increases cotton yield, reduces need for preseason irrigation. Cal. Agric. 45(3):25-28.

Gutiérrez, J.C. (1997): Nuevas Técnicas de Manejo del Cultivo del Algodón. I Jornadas Técnicas, Córdoba. Ed. Semanario La Calle.

Kerby, T. (1992): Management by Monitoring. California Cotton Review. 25:1-3.

Landívar, J.A. (1992): PMAP, A Plant Map Analysis Program for Cotton (Prelim. version 3,0). TAES Computer Software Doc.Ser., MP 1740. 32 pp.

Lombardo, V., A. Davi and P. Miceli. (1992): Problemi Agronomici e di gestione di risorse idriche limitate. Nota II: La pacciamatura temporanea del cotone *(Gossypium hirsutum L.)*. Riv. di Agron., 26 (4 Suppl.):772-776.

Lombardo, V., R. Sarno, A. Davi and C. Princivalli. (1993): Risultati di pacciamatura ottenuti nella Sicilia sud occidentale. Agricoltura Ricerca, 143:103-112.

Márquez, F. (1990): Algodón bajo plástico. Un camino para inducir precocidad y aumentar la producción en climas mediterráneos. XI International Congress on the Use of Plastics in Agriculture, E. Pp.47-52.

Márquez, F. (1993): Growing cotton under plastics films. Plasticulture, 98:11-18.

Reddy, V.R. (1993): Temperature Effects on Cotton. Mississippi Agricultural & Forestry Experiment Station. Bulletin 990. 15 págs.

Robledo de Pedro, F. (1995): La Plasticultura española en la década de los noventa. Actas del I Simposium Iberoamericano sobre Aplicación de los Plásticos en las Tecnologías Agrarias. Almería: 81-92.

Wendt, C.W. (1973): Apply degradable plastic to cotton, onions and carrots in the High Plains, 1971. In: Degradable plastic mulch studies in West Texas. Cons. PR-3168-3172. T.A.E.S., College Station, Texas, US.

Table 1. Final plant height (cm) in 1993, 1994 and 1995 experiments.

Days Plastic mulch	1993 A	1994 A	1995 A	Days Plastic mulch	1993 B	1994 B	1995 B
15	120.3 c	91.08 b	114.6 b	15	139.8 a	100.7 a	117.0 ns
45	127.0 b	94.05 a	---	45	143.3 a	103.3 a	---
60	138.0 a	94.93 a	121.0 a	60	131.0 b	98.96 b	121.5 ns
				No plastic	126.3 b	94.42 c	116.7 ns

Table 2. Internode lenght (cm) in 1993, 1994 and 1995 experiments.

Days Plastic mulch	1993 A	1994 A	1995 A	Days Plastic mulch	1993 B	1994 B	1995 B
15	5.170 a	4.020 ns	4.974 a	15	5.379 ns	4.176 ab	5.115 a
45	4.980 b	4.001 ns	---	45	5.401 ns	4.066 bc	---
60	4.976 c	4.065 ns	4.697 b	60	5.194 ns	3.880 c	4.925 b
				No plastic	5.646 ns	4.337 a	5.101 a

Table 3. Number of vegetative branches in 1993, 1994 and 1995 experiments.

Days Plastic mulch	1993 A	1994 A	1995 A	Days Plastic mulch	1993 B	1994 B	1995 B
15	7.917 ns	7.014 b	7.062 b	15	7.300 bc	7.832 a	7.457 b
45	8.083 ns	8.389 a	---	45	8.100 ab	7.835 a	---
60	8.250 ns	8.223 a	9.669 a	60	8.150 a	8.041 a	9.376 a
				No plastic	7.250 c	6.792 b	7.874 b

Table 4. Final number of open bolls in 1993, 1994 and 1995 experiments.

Days Plastic mulch	1993 A	1994 A	1995 A	Days Plastic mulch	1993 B	1994 B	1995 B
15	3.667 ns	12.68 a	9.834 a	15	3.050 a	15.96 a	9.042 ns
45	3.650 ns	11.21 b	---	45	2.600 ab	14.29 ab	---
60	2.817 ns	11.10 b	8.083 b	60	1.400 b	12.00 bc	8.500 ns
				No plastic	1.400 b	10.75 c	7.916 ns

Table 5. Final number of fruiting sites in 1993, 1994 and 1995 experiments.

Days Plastic mulch	1993 A	1994 A	1995 A	Days Plastic mulch	1993 B	1994 B	1995 B
15	51.53 a	37.76 a	41.77 ns	15	58.30 a	43.58 a	37.50 ab
45	46.48 b	35.04 ab	---	45	53.80 a	39.12 ab	---
60	47.85 b	34.57 b	40.27 ns	60	52.10 ab	36.58 b	40.21 a
				No plastic	45.45 b	38.00 ab	37.12 b

Table 6. Biomass in experiment 1995A (sowing date 27/03/95), 50 DAP (13/5/95).

Days under plastic mulch	Root length (cm)	Root weight (g)	Main Root Thickness (cm)	Aerial Biomass Weight (g)
15	22.47 a	0.571 b	0.3212 b	5.206 b
60	20.24 b	1.020 a	0.5544 a	7.882 a

Table 7. Biomass in experiment 1994B (Date of sowing 29-04-94), 60 DAP (29-06-94).

Days under plastic mulch	Stem lenght (cm)	Root lenght (cm)	Main Root Thickness (cm)	Leaves weight (g)	Root weight (g)	Stem weight (g)
15	38.06 a	13.75 a	0.491 b	4.140 b	0.500 b	3.974 b
45	46.89 a	11.69 b	0.653 a	4.681 ab	0.985 a	5.030 a
60	42.84 a	11.17 b	0.678 a	5.082 a	1.135 a	5.134 a
No plastic	28.79 b	14.92 a	0.427 c	1.994 c	0.585 b	1.850 c

Table 8. Yield (in kg ha^{-1} seed cotton) in 1994 and 1995 experiments.

1994 A			1994 B		
Treatment	Yield	1st Pick	Treatment	Yield	1st Pick
15 D Plastic Mulch	5212 ns	4489 ns	15 D Plastic Mulch	5657 a	4594 a
45 D Plastic Mulch	4967 ns	4249 ns	45 D Plastic Mulch	5145 b	4144 b
60 D Plastic Mulch	4979 ns	4229 ns	60 D Plastic Mulch	5811 a	4883 a
			No Plastic	3878 c	3238 c
1995 A			1995 B		
Treatment	Yield	1st Pick	Treatment	Yield	1st Pick
15 D Plastic Mulch	3049 ns	3877 ns	15 D Plastic Mulch	3021 a	3645 ns
60 D Plastic Mulch	3082 ms	3743 ns	60 D Plastic Mulch	2767 b	3462 ns
			No plastic	2698 b	3724 ns

Table 9 . Micronaire in experiments 1994 and 1995, A and B .

Days plastic	1994A	1995A	Days plastic	1994B	1995B
15	4,579 b	4,400 ns	15	4,687 ab	4,675 ns
45	4,667 ab	4,444 ns	45	4,787 ab	4,650 ns
60	4,729 a	---	60	4,800 a	---
			No plastic	3,755 b	4,787 ns

Figure 1. Vigour curves in 1993, for Delta Acala 90, sown in May, showing various periods of time under plastic mulch/without plastic.

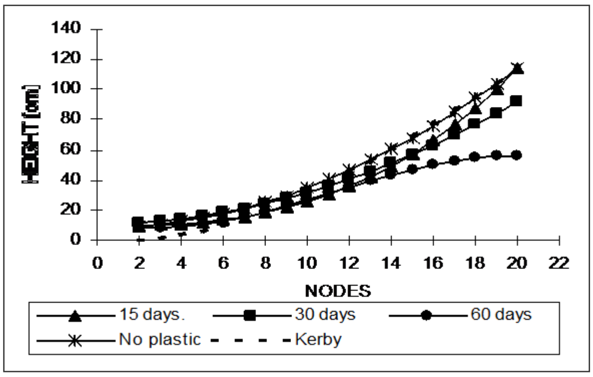

Figure 2. Vigour curves in 1994, for Coker 310, sown in April, showing various periods of time under plastic mulch.

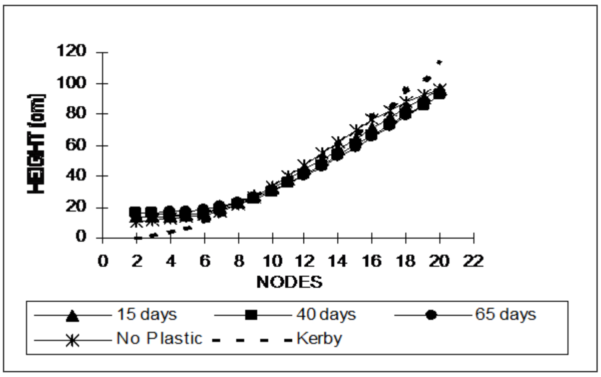

Figure 3. Vigour curves in 1995, for Coker 310, sown in May, showing various periods of time under plastic mulch.

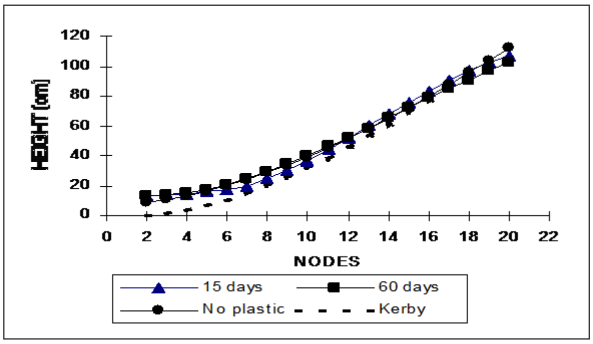

Figure 4. Flowering intervals in 1995 (medium values for both cultivars).

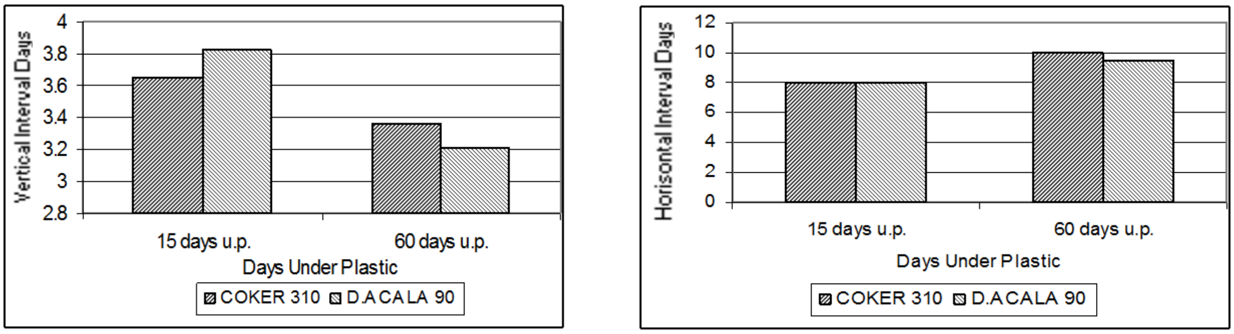

Figure 5. Leaf Area Index (LAI) in 1995, for Coker 310 and D.Acala 90 respectively.