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Polyethylene mulching for enhancing crop productivity and water use efficiency in cotton (*Gossypium hirsutum*) and maize (*Zea mays*) cropping system

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ABSTRACT

Field experiments were conducted consecutively for 2 years at Coimbatore between 2002-03 and 2003-04 crop seasons during winter (August – February). Cotton (*Gossypium hirsutum* L.) followed by summer (March – May), maize (*Zea mays L.*) crops using different thickness black polyethylene mulch film of 30, 50, 75 and 100 micron were evaluated against conventionally planted (no mulch) cotton – maize cropping system for moisture conservation and enhanced crop production efficiency. Higher uptake of nutrients due to higher temperature coupled with higher available soil moisture caused significant increase in root cation exchange capacity, nutrient uptake, dry matter accumulation and partitioning of assimilates under polyethylene mulching with an average yield enhancement of 1.83 to 1.90 fold in cotton and 1.95 to 2.10 fold in maize crops besides saving water. The water requirement of mulched cotton was 58.63 ha-cm whereas conventionally grown cotton was 84.19 ha-cm. The water use efficiency of mulched cotton was 43.2 kg/ha-cm as against 16.6 kg/ha-cm for conventionally planted no mulch cotton crop. The poly-mulched cotton-maize system recorded the highest net return (Rs 74,178/ha) and benefit cost ratio (1.68) as against the conventional system (Rs 29,863 and 1.04).

Key words: Cotton, Fibres, Maize, Mulching, Polyethylene, Water use, Yield

The practice of mulching in agriculture has been widely used as a management tool for centuries. Mulching improves the soil physical condition by enhancing aggregation and conserving soil moisture by increasing infiltration, checking losses by evaporation and run off. It also favourably modifies the soil thermal regime, retards soil erosion and improves soil health. The advantages of using plastic mulches for the production of high value vegetable crops have been recognized in the United States and the European countries. Due to mulching the beneficial effects of plastic mulch for enhanced water and fertilizer utilization and weed control (Fortnum *et al.*, 2000), weeds and pests (Lakshmanan *et al.*, 1995) have been reported. The use of polyethylene mulch though very common in high value vegetable crops, its usage has not been explored in the cotton based cropping system. This study was conducted with the objectives of using polyethylene mulching for water saving, weed control, nutrient management and other beneficial effects like increased crop production efficiency in cotton–maize system.

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MATERIALS AND METHODS

Field experiments were conducted in sandy clay loam soil with low (145 and 160 kg/ha), medium (8.6 and 7.5 kg/ha, and high (466.7 and 533.3 kg/ha) available N, P and K during first and second year of experimentation, respectively between 2002-03 and 2003-04 cropping seasons with cotton (August- February) and maize (March-May) at Regional Station of this Institute to evaluate various thickness (30, 50, 75 and 100 micron) black polyethylene mulching for cotton-maize cropping system than no mulching. The raised bed of the size 13.5 m × 1.2 m were formed leaving 30 cm on all around the raised bed for irrigation. The basal fertilizers (50% N, 50% K and full P) of the recommended 60:13.2:25 kg N,P and K was applied as basal before spreading the polyfilm .The polyethylene sheet was spread on the raised bed and the ends were sealed with soil . The sowing lines were marked on the polyethylene sheets using a sowing rope with markings at required spacing (45 cm plant to plant). Holes were made at required spacing using a 2 inch (5.08 cm) GI pipe and cotton seeds sown in the holes. In each bed, two rows of cotton 'LRA 5166' were sown at 60 cm apart in a paired row of 90/60 cm × 45 cm so as to maintain the recommended population for cotton. The statistical design used was randomized block design with 4 replications. The gross plot size was 13.8 m x 3 m (41.4 m^2). Irrigation was given immediately after the sowing. The remaining dose of fertilizers was given in 2 equal splits at monthly interval. Apart from soil applied fertilizers, two foliar sprays of 1.5% N along with 0.5% K was made during boll formation and boll development stages. The irrigation was given through the irrigation channel on all around the raised bed. The irrigation water was measured through 'V' notch and a total quantity of 28 ha-cm in 5 irrigaitons to poly-mulched cotton and 54 ha-cm in 9 irrigations were applied to conventionally planted cotton. The rainfall received during 2002-03 cropping season was 569.1 mm and during 2003-04 was 545.9 mm. The soil temperature was measured using soil thermometer. The polythene sheets were intact without much damage even after the cotton harvest (cotton stalks were cut close to ground level and a novel approach of sowing succeeding crop of maize was attempted under zero-tilled condition without disturbing the layout. Cotton is a perennial crop and care is to be taken to cut the plant below cotyledon leaves to avoid regrowth. Fresh punchings were made in the polyethylene mulch film, 5 cm away from cotton holes (60 cm x 22.5 cm spacing was adopted for maize crop). Maize hybrid 'CORHM 4' was sown and irrigation was given. Biometric observations were recorded at 90 days after sowing. The CEC of roots was estimated as per Crooks (1964) and expressed in milli equivalent/100 g of roots. For measuring the root volume, entire root portion of the plant was cut and put inside the measuring cylinder with a known quantity of water and the difference in volume of water after the addition of roots was the root volume and expressed in cc. Enumeration of *Azospirillum* was carried out in N-free semi-solid malic acid medium using most probable number (MPN) of, Dobereiner *et al.* (1976). Diazotrophs, facultative methlylotrophs, pink pigmented facultative methylotrophs and PSB were enumerated through standard dilution plate technique in ammonimum mineral salts medium, Pikovskaya's medium. The root system of cotton was cleared and stained and the colonization percentage of arbuscular mycorrhizal fungus was calculated (Mcgonigle *et al.*, 1990). The results of both the years of experimentation showed the same trend and hence the data of 2 years were pooled and analysed using standard analysis of variance.

RESULTS AND DISCUSSION

Root characters of cotton

Root CEC is a very important characters in influencing the plant growth which has been significantly enhanced due to polyethylene mulching (19.80 to 27.05 m.e /100 g roots) as against 15.35 m.e/100 g roots under control. Thus, on an average the enhancement in root CEC was about 62.3% due to polyethylene mulching in cotton. Among the various thickness polyethylene mulching, 100 micron recorded significant reduction in the root CEC than other thickness. However, all the polymulched plants were significantly superior to conventional method. This might be due to higher temperature and high moisture regime (Table 2) under polymulching which might have enhanced the mineralization of nutrients in the soil.

Root length was improved under polyethylene mulching as could be seen from 26.8 to 28.3 cm as against 21.8 cm recorded under conventional method. All the polymulched treatments were on par with each other and superior to the no mulch control (Table 1).

Root weight also followed a similar trend when compared with root length .The enhancement in root length, secondary roots and root weight has been reflected in enhanced root volume. The root volume ranged from 11.9

Tablel. Biometric characters of cotton on 90 days after sowing as influenced by polyethylene mulching (Mean of 2 years).

Treatment	Root CEC	Root length (cm)	Root weight. (g/plant)	Secondary roots (nos.)	Root volume (cc)	Leaf area index	Leaf dry weight (g/plant)	DMP (tonne/ha)
100 micron	19.8	26.8	4.45	22.3	13.8	3.51	1.02	4.69
75 micron	27.1	27.7	4.61	21.2	14.4	3.37	0.89	5.04
50 micron	25.9	27.0	4.36	24.4	13.1	3.77	0.95	4.47
30 micron	26.9	28.3	4.12	27.2	11.9	3.29	0.98	4.22
Mean for mulch	24.9	27.4	4.39	23.5	13.3	3.48	0.96	4.61
Control	15.4	21.8	1.65	13.1	5.2	1.55	0.61	2.37
SEm±	0.83	1.74	0.31	2.95	2.0	0.26	0.10	0.20
CD (P=0.05)	1.91	4.0	0.71	6.8	4.6	0.59	0.22	0.46

to 14.4 cc under polyethylene mulching while it was only 5.2 cc under no mulching. The enhanced root growth under mulching might be due to enhanced root proliferation due to higher moisture and temperature.

Shoot growth

The leaf production rate was faster under polyethylene mulching due to better growth environment and higher nutrient mobilization and better partitioning to shoot system as evidenced from 1.49 to 1.63 fold enhancement in leaf numbers under polymulching over conventional method. The favourable growing condition under mulching produced broader and healthy leaves of 84.1 to 95.1 cm^2/leaf as against smaller leaf of (63.3 cm^2/leaf) under control (data not reported). The bigger leaf under mulching produced significant enhancement in leaf weight ranging from 0.89 to 1.02 g/leaf as compared to 0.61g /leaf under control (Table 1).

Dry matter accumulation

The favorable microclimate under poly-mulching facilitated the cotton crop to mobilize more nutrients and resulted in higher accumulation of photosynthates. The higher CO_2 gas produced under poly-mulching due to enhanced microbial activity could not escape easily and hence localized availability of higher CO_2 for enhanced fixation in photosynthesis thereby enhancing the dry matter accumulation to the tune of 1.8 to 2.12 fold enhancement over conventionally grown cotton. Similar findings of impervious nature of mulch film for CO_2 resulting in availability of abundant CO_2 for the actively growing leaves with ultimate increase in plant growth has been reported by Balraj Singh *et al.* (2004).

Soil temperature

Soil temperature was favourably altered due to mulching. The soil temperature across the depth (up to 45 cm) ranged from 28.8 to 29.8 °C under mulching of various thickness. In general, lesser the thickness more was the soil temperature. This might be due to more resistance to in flow as well as escape of heat with thicker mulch material. The temperature increase due to mulching has been reported earlier (Tang and Xu, 1986, Chen and Yin, 1989 and Chakraborty and Sadhu,1994).The conventional method recorded lesser soil temperature of 27.6 °C. The enhancement in temperature of about 2.2 °C under black poly mulching was beneficial for faster mineralization of nutrients in the soil.

Water requirement and available soil moisture

The water requirement of poly-mulched cotton was 58.63 ha-cm (including effective rainfall) and that of conventionally planted cotton was 84.19 ha-cm (Table 2). Mulched cotton consumed lesser water due to lesser evaporative loss of water and weed free environment. Soil moisture conservation due to poly mulching was reported by Channabasavanna *et al.* (1992) and Gupta and Acharya (1993). The mulched area was free from weeds (no weedicide was used to control weeds under mulching) and almost all the weeds were effectively controlled except *Cyperus* spp. which could pierce through the thinner mulch of 30 micron, (data not reported). The effective control of weeds under poly mulching indirectly prevented the loss of water through transpiration by weeds.

Nutrient uptake

Higher temperature and faster mineralization under polyethylene mulching caused increased uptake of nutrients (Table 2) as evidenced from up to 2.1, 2.8 and 2.6 fold higher N,P and K uptake, respectively over conventionally planted cotton.

Beneficial microorganisms

The population of beneficial microorganisms like

Tale 2. Soil temperature, ASM, nutrient uptake, rhizosphere and phyllosphere microorganisms in cotton as influenced by poly-mulching

Treatment	Soil temperature (° C)	ASM (%)	Nutrient uptake (kg/ha) N	P	K
100 micron	28.8	24.75	111.4	13.6	145.2
75 micron	28.8	24.16	125.7	16.0	149.9
50 micron	29.2	22.36	115.6	14.8	152.3
30 micron	29.8	21.52	116.8	14.2	143.4
Mean for mulch	29.2	23.20	117.3	14.8	148.2
Control	27.6	18.26	55.1	5.33	57.5
SEm±			6.84	0.43	4.32
CD (P=0.05)			15.74	0.98	9.94

Microorganisms**	Poly-mulch	No-mulch
A. *Rhizosphere soil* (cotton)/g dry soil		
Diazotrophs	164.2 X 10^4	63.7 X 10^4
Facultative methylotrophs	109.2 X 10^4	26.4 X 10^4
Azospirillum	19.2 X 10^4	6.7 X 10^4
PSB	90.57 X 10^3	42.9 X 10^3
B. *Phyllosphere* (cotton)/g of fresh leaf		
Pink pigmented facultative methylotrophs	134.6 X 10^4	39.3 × 10^4
C. *Root bits (rotation maize)*		
VAM infection (%)	90.0	73.3

**Mean of 6 replications (not statistically analysed)

Diazotrophs, Facultative methylotrophs, *Azospirillum*, phosphorus solubilizing bacteria (PSB) and vesicular arbuscular mycorrhizae (VAM) were higher by 2 to 3 fold (Table 3) due to mulching. The enhanced temperature under mulching coupled with higher available soil moisture regime was highly favourable for the rhizosphere and phyllosphere micro organism since most of the beneficial microorganisms were hemophilic in nature.

Yield attributes

The mulched plots have significantly more sympodial branches than the conventional method. The enhanced sympodial branches might be due to better partitioning of assimilates towards reproductive parts as the source was not limiting under mulching. Better root growth and assimilation of photosynthates under mulching caused higher partitioning of assimilates towards reproductive structure as could be seen from the production of more bolls (31.2 to 33.3 bolls/plant) as against 18.6 bolls/plant under the conventional method. All the mulched treatments were on par and was found significantly superior to control. The poly mulched cotton also had significantly heavier bolls (3.95 to 4.13 g/boll) as against 3.54 g/boll recorded under control. This might be due to better partitioning of assimilates under mulching.

Seed cotton yield and water use efficiency

The favourable micro-climate as discussed earlier under mulching was finally reflected in enhanced seed cotton yield by 1.83 - to 1.90 - fold over conventionally grown cotton. Elias and Goldhamer (1991) has reported 39% enhanced yield due to mulching in cotton crop in California, USA. The polymulched cotton recorded the highest WUE (43.2 kg seed cotton/ha-cm) as against 16.6 kg/ha-cm under conventional method. This might be due to effective control of evaporation and control of weeds under polyethylene mulching.

Ginning per cent, fiber quality parameters, lint index and seed index

The fiber output as measured by the ginning per cent was significantly enhanced due to poly-mulching. The fiber length as measured by the 2.5% span length was significantly altered due to polyethylene mulching (Table 4). The poly-mulched plants produced longer fiber when compared with shorter fibers recorded under conventional method. The accumulation of higher temperature (higher degree days) under polymulching caused earlier harvest of

Table 3. Yield attributes seed cotton yield and water use efficiency of cotton as influenced by poly-mulching (mean of 2 years)

Treatments	Sympodia/ plant	Bolls/ plant	Boll wt (g/boll)	Seed cotton yield (kg/ha)	Water use efficiency (kg of seed cotton/ ha-cm)
100 micron	18.2	32.8	3.95	2586	43.6
75 micron	18.2	33.3	3.99	2606	44.0
50 micron	18.2	30.9	4.13	2542	43.1
30 micron	18.1	31.2	3.98	2502	42.2
Mean for mulch	18.2	32.0	4.01	2559	43.2
Control	15.2	18.6	3.54	1368	16.6
SEm±	0.79	1.91	0.18	131	
CD (P=0.05)	1.82	4.4	0.42	301	

Table 4. Fiber output, fiber quality parameters, lint index and seed index of cotton as influenced by poly mulching

Treatment	Ginning (%)	Fiber length (mm)	Fiber strength (g/tex)	Micronaire (ug/inch)	Fibre quality index	Lint Index (g)	Seed index (g)
100 micron	35.0	29.30	23.29	3.94	346.2	4.39	9.59
75 micron	35.0	29.60	23.52	3.94	349.5	4.33	9.24
50 micron	34.9	29.50	23.27	3.95	339.5	4.19	9.04
30 micron	34.9	29.80	23.94	3.94	364.0	4.27	9.24
Mean for mulch	34.9	29.50	23.50	3.94	349.0	4.30	9.28
Control	32.7	28.40	22.74	3.77	333.2	4.10	8.57
SEm±	0.56	0.34	0.73	0.27	10.1	0.34	1.11
CD (P=0.05)	1.29	0.79	1.67	NS	23.3	NS	2.55

about 3 weeks than conventional method. Also, earlier formed bolls were retained under polyethylene mulching due to stress free growth environment. This might have given more opportunity for the fiber to grow longer. The fiber strength and micronaire were not affected by polymulching.

The fiber quality index (FQI) is an integrated value to combine various fiber parameters like fiber length, fiber strength and micronaire (FQI = fiber length × fiber strength ÷ square root of micronaire). This FQI was significantly better under polymulching. Among the various thickness polyfilm, thinner film of 30 micron recorded the highest FQI of 364.0.

The lint index was not significant under polymulching while seed index was significantly enhanced due to polymulching with the seed index value ranging from 9.04 to 9.59 g as against 8.57 g under conventional method. The significant increase in seed index under poly mulching might be due to better seed filling under the unstressed environment of poly mulching.

Table 5. Economics of cotton cultivation as influenced by poly mulching

Economics (Rs/ha)	Poly-mulch	No-mulch
Cost of cultivation of cotton excluding weeding, cost of poly-mulch film and laying of poly mulching	13, 413	13,413
Cost of poly-mulch film	21,938	
Cost of weeding	2,500	7,500
Total cost of cultivation	37851	20,913
Seed cotton yield (kg/ha)	2,559	1,368
Gross return	63,975	34,200
Net return from cotton	26,124	13,287
Cost of cultivation for maize crop	6,250	10,000
Grain yield (kg/ha)	6,788	3,322
Gross return	54,304	26,576
Net return	48,054	16,576
Gross return from cotton - maize system	1,18,279	60,776
Total cost of cultivation of cotton-maize system	44,101	30,913
Net return of cotton - maize system	74,178	29,863
Net benefit : cost ratio	1.68	1.04

Cost of poly-mulch film : Rs 135/kg, Cost of seed cotton: Rs 25/kg, Cost of maize grain : Rs 8/kg.

Growth, yield attributes and yield of zero-tilled rotation maize

The zero-tilled rotation maize which was grown immediately following the cotton crop was also benefited due to poly-mulching. All the growth and yield attributes like plant height, leaf numbers, dry matter accumulation, cob length, cob diameter, number of grain rows/cob, number of grains/grain row, 1,000-seed weight and grain yield were significantly enhanced under polymulching (Table 5). The enhancement in grain yield was to the tune of 1.95 to 2.10 fold than its conventionally grown maize crop. Ramakrishna *et al.* (2006) reported 94.5% higher yield in groundnut due to polyethylene mulching.

Economics of cotton-maize system

The economics of poly-mulching (Table 6) revealed that though initial investment is higher owing to higher input cost of poly film, adoption of cotton – maize system under poly-mulching is economically feasible as the net return and benefit cost ratio were higher under poly-mulch based system owing to higher yield enhancement in both cotton and maize system besides additional benefits like saving in weeding cost as well as saving of irrigation water.

Table 6. Growth, yield attributes and yield of maize as influenced by polyethylene mulching

Treatment	Plat height (cm)	Dry matter production (g/plant)	Cob length (cm)	Cob diameter (cm)	Number of grain rows/cob	1,000-seed weight (g)	Maize grain yield (tonnes/ha)
100 micron	257	195	32.00	16.33	29.67	255.0	6.51
75 micron	297	217	32.00	15.33	37.67	234.3	6.72
50 micron	280	210	29.67	16.00	36.33	253.0	6.99
30 micron	270	197	29.67	17.67	36.67	267.3	6.93
Mean for mulch	225	205	30.83	16.33	35.09	252.4	6.79
Control	228	137	22.00	10.67	29.67	192.3	3.32
SEm±	7.5	20.6	1.36	0.94	2.05	1.77	0.38
CD (P=0.05)	17.2	47.3	3.13	2.17	4.71	4.07	0.87

To sum up, use of black polyethylene mulching is a potential and hitherto untapped option for the agricultural crops for conserving the most precious water and efficiently managing weeds without any herbicides and enhancing the crop production efficiency by many fold in bot cotton and maize crops. However, higher initial cost of this material is the only hindrance in advocating this technology to the small and marginal farmers of our country. While appropriate government policy like availability of subsidized polyfilm as in the case of drip system will go a long way in future for improving the productivity and profit of farmers besides saving the precious water and creating lesser pressure on ground water resources.

REFERENCES

Singh, Balraj., Khokhar, K.S. and Kumar, Mahesh 2004. Use of plastic mulching for quality vegetables. *Intensive Agriculture* **42**(1-2): 3–5.

Channabasavanna, A.S., Havanagi, G.V. and Setty, R.A. 1992. Studies on mulching and spacing on yield and quality of tomato under rainfed condition. *Farming Systems* **8**: 109–110.

Chakraborty, R.C. and Sadhu, M.K.1994. Effect of mulch type and colour on growth and yield of tomato (*Lycopersicum esculentum*) *Indian Journal of Agricultural Sciences* **64**: 608–612.

Elias, Fereres. and Goldhamer, David A. 1991. Plastic mulch increases cotton yield, reduces need for pre-season irrigation. *California Agriculture* **45**(1): 25–28

Chen, Q.E. and Yin, J.S.1989. Effects of plastic mulch on soil properties and cotton growth in saline – alkali soils. *Journal of Soil Science* China **20**: 1–3.

Crooks, W.M.1964. Measurement of CEC of plant roots. *Plant Science* **21**: 43–49

Dobereiner, J., Marriel, I.E. and Nery, M. 1976. Ecological distribution of *Spirillum lipoferum* Beijerinck. *Canadian Journal of Microbiology* **22:** 1464–1473.

Fortnum, R.A., Kasperauer, M.J. and Decoteau, D.R. 2000. Effect of mulch surface colour on root knot nematode of tomato grown in simulated planting beds. *Journal of Nematology* **32**(1): 101–109.

Gupta, R. and Acharya, C.L. 1993. Effect of mulch induced hydrothermal regime on root growth, water use efficiency, yield and quality of strawberry. *Journal of Agricultural Sciences* **64**: 608–612.

Lakshmanan, R., Punnoose, K.I., Mathew, M., Mani, J. and Pothen, J. 1995. Polythene mulching in rubber seedling nursery. *Indian Journal Natural Rubber Research* **8**: 13–20.

Mcgonigle, T. P., Miller, M. H., Evans ,S, D. G., Fairchild, G. L. and Swan, J.A. 1990. A new method which gives an objective measure of colonization of roots by vesicular-arbuscular mycorrhizal fungi. *New Phytology* **115**: 495–501.

Ramakrishna, A., Hoang Minh Tam., Suhas P. Wani, Tranh dinh Long.2006. Effect of mulch on soil temperature, moisture, weeds infestation and yield of groundnut in northern Vietnam. *Field Crops Research* **95**: 115–125.