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Biodegradable mulching for moisture conservation, weed control and enhanced productivity of winter irrigated cotton maize system

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ABSTRACT : Field experiment was conducted during 2008-2009 and 2009-2010 cropping season under winter irrigated (August – February) cotton followed by maize (March-May) at Regional Station, Central Institute for Cotton Research, Coimbatore. Eight mulch treatments including polyethylene mulching, biodegradable polyethylene, sugarcane trash, maize stover, gunny sheet, coir waste (subsoil) ,surface coir waste application were compared with no mulch control under three moisture regimes , 0.4 ETc (Crop Evapo Transpiration) through drip, 0.8 ETc through drip and conventional irrigation system. The results revealed that the extra long staple (ELS) cotton hybrid 'RCHB 708 *Bt* responded significantly to moisture regimes and mulches. The crop responded up to 0.8 ETc under no mulch condition while under mulched conditions, the seed cotton yield (SCY) started declining beyond 0.4 ETc. Polyethylene mulching along with drip irrigation at 0.4 ETc recorded 5641 kg SCY/ha and was *on par* with biodegradable polyethylene (5241 kg/ha) at the same moisture level. The water requirement for ELS cotton RCHB 708 *Bt* was 46.4, 63.0 and 80.0 ha cm at 0.4 ETc, 0.8 ETc and conventional irrigation respectively. The zero tilled rotation maize grown after cotton harvest was also significantly influenced by moisture regime and mulch treatments.

Key words : Biodegradable polyethylene mulching, crop residue mulching, nutrient uptake, seed cotton yield, zero tilled rotation maize

Use of polyethylene mulching in agriculture is gaining global significance as it is widely used for soil moisture conservation, weed control, coupled with enhancement in productivity of agricultural crops. Through polyethylene mulching, a yield enhancement of around 1.90 and 2.10 fold was reported respectively in cotton and zero tilled rotation maize compared to conventional method. (Nalayini *et al.,* 2009). *Bt* cotton is reported to perform better under irrigation than the non *Bt* cotton which calls for standardization of irrigation schedules grounded on scientific approaches. Drip irrigation used in combination with plastic mulch typically need water to meet the crop water requirement as the other losses of water are kept minimum thereby increasing the water use efficiency. Polyethylene film by nature is non biodegradable, but it can be made up biodegradable (oxo degradation) by addition of little quantity (4%) of prodegradant additive (d2w, a patented product from UK). The polyethylene film which was prepared with addition of prodegradant not only biodegradable after the intended use, but also utilized by soil microbes as carbon source (Michael Stephenson, 2009). The use of additives to ensure the shelf life of plastics has been earlier reported by Gilead and Scott (1982) wherein, some metal complexes are efficient photo pro oxidants for polyethylene which when photo oxidized, not only fragment but the oxidation products biodegrade in any biologically active medium. Oxobiodegradable plastics sheets can be programmed at manufacturing stage to degrade soon after the harvest or until the mission is accomplished. The remaining bits in the field after harvest can be collected and buried into the soil to hasten the biodegradability. The small unnoticed left over bits in the field may not pose environmental problem due to its biodegradable nature. Australian field trial using biodegradable mulch film on capsicum crops has shown that biodegradable plastic performs just as well as polyethylene film but also has the advantage of being able to be ploughed into the ground after harvest which can reduce the disposal costs while enriching the soil with carbon on degradation (Anonymous, 2004). The use of biodegradable mulch films seems to be a promising alternative because the films can degrade right in the field and the amount of waste ending up in landfills can be avoided (Kijchavengkul *et al.,* 2008). Though the polyethylene mulch (30 - 50 micron) which we have earlier standardized for cotton falls under the recyclable class without causing any environmental pollution, if the polyethylene mulch is not properly removed from the field it may pose problem in long run. Hence the objective of the study is to find alternative suitable biodegradable mulch to the polyethylene mulch.

MATERIALS AND METHODS

Field experiments were conducted consecutively for two years during winter (August-February) cotton followed by summer (February-April) maize of 2008-2009 and 2009-2010 cropping season. Raised bed of the size 1.5 m width and 9 m long were formed using tractor drawn broad bed furrow maker with 30 cm furrow on all around the raised bed for irrigation. The polyethylene sheet of 30 micron thickness with silver colour top layer and black colour bottom layer was used. The sheet was spread uniformly over the raised bed and the edges were sealed with the soil, leaving 30 cm from both edges of the bed, two sowing lines were fixed using sowing rope with markings at 60 cm apart. The holes were made at 60 cm apart using a 5 cm diameter GI pipe (by gently pressing the GI pipe, holes were made easily as the thickness of the film was very less). Sowing was taken up in the sowing holes followed by irrigation. For the biodegradable poly ethylene mulching treatment, the procedure explained above was repeated. For subsoil coir treatment, the coir waste was applied before sowing using the tractor drawn subsoil coir pith applicator which could open the furrow at the centre of the raised bed and placed the coir wastes and covered it with soil. For sugarcane trash, maize stover and surface coir mulching, 50 per cent of the mulch materials were applied manually at 15 DAS and the remaining 50 per cent were applied on 30 DAS above the entire raised bed. The sugarcane trashes and maize stover were cut into 10-15 cm using chop cutter before application. The gunny sheet mulch was spread in between the two sowing rows. ELS RCHB 708 *Bt* cotton was used as test material in split plot design with eight mulch treatments such as control (no mulch), subsoil coir pith (2 kg/m^2), maize stover (5 kg/m^2), sugarcane trash (5 kg/m^2), surface coir (2 kg/m^2), gunny sheet, biodegradable polymulching and polymulching in the main plots with three moisture regimes namely conventional irrigation , drip irrigation at 0.4 ETc and drip irrigation at 0.8 ETc in the sub plots. The experimental sites was low in available nitrogen (168, 174 kg/ha), high in available P (27.6, 28.6 kg/ha) and high in available K (625, 654 kg/ha) during 2008-2009 and 2009-2010, respectively. The infiltration rate of the experimental field was 1.88cm/hr and the field capacity moisture (%) was 23.4 and the moisture at permanent wilting point was 17.4 on fresh weight basis. A fertilizer dose of 120: 26.4: 50 kg NPK/ha was uniform for all the treatments. Full dose of phosphatic fertilizer and ¼ of nitrogenous and potassic fertilizers were given as basal at sowing and the remaining dose of N and K were given in three equal splits at monthly interval. Drip lines were fitted @ one lateral for two crop rows of cotton and the drippers @ one dripper for two crop hills of cotton.

Calculation of water to be applied through drip system : The volume of water to be given on alternate days through drip was calculated using the following formula.

$$V = E_p \times K_p(0.7) \times K_c \times A \text{———————} (1)$$

Where; V = Volume of water to be given (l/dripper)

E_p = Pan evaporation (mm),K_p = Pan Co efficient (0.7) ,K_c = Crop Co efficient (Which vary for different growth stages of crop, it was 0.45, 0.75, 1.15 and 0.75 for initial (0-25 DAS), development stage (26-70 DAS), boll development (71-120 DAS) and maturity stage (121- harvest), respectively.

A=Area to be wetted

Based on the above equation, a ready reckoner was prepared and the irrigation was scheduled on alternate days based on the open pan evaporimeter reading and the exact quantity of water given was measured using water meter. For control plots, the water to be irrigated was measured through 'V' notch. The rainfall received during the first and second year of experimentation was 41.3 ha cm and 38.1 ha cm contributing to 23.7 ha cm and 26.8 ha cm of effective rainfall which has been accounted while calculating the total water requirement of cotton crop. After the harvest of cotton, the stalks were cut below the cotyledon leaves to avoid re growth of cotton and the holes were made at 5 cm away from the cotton rows at 20 cm (plant to plant) and the maize hybrid , CORH M4 was sown without disturbing the layout.

RESULTS AND DISCUSSION

Effects of mulches and moisture regimes on growth and yield attributes of cotton : Growth attributes namely plant height, leaves/plant and dry matter accumulation were found to be influenced significantly by mulches and moisture regimes. All these growth attributes were higher under drip system at 0.8 ETc and was on par with drip system at 0.4 ETc and found significantly higher than conventional irrigation system. Among the different mulch treatments, except surface coir pith application and mulch control, all other mulch treatments recorded significantly taller plants, more number of leaves and higher dry matter accumulation and were on par with each other (Table1).The ELS cotton RCHB 708 *Bt* responded significantly to the mulches, moisture regimes and their interaction for yield attributes. The results revealed that under no mulch condition, the ELS *Bt* cotton responded up to 0.8 ETc through drip system which recorded 54.3 bolls/plant as against 39.5 bolls/plant under conventional irrigation system and wherever mulches were applied, the response was obtained up to 0.4 ETc and the bolls number started declining beyond 0.4 ETc.Polyethylene mulching and biodegradable polyethylene mulching recorded higher number of bolls/plant and was *on par* and found significantly superior to rest of the treatments. The boll weight was not significantly altered either by mulches or moisture

Table 1. Growth and yield attributes of ELS *Bt* cotton cv. RCHB 708 *Bt* as influenced by moisture regimes and mulches

Treatments	Plant height (cm)	Leaves/ plant	Sympodia/ plant	Bolls/ plant	Boll wieght (g/boll)
Mulches					
No mulch (control)	118.7	229.5	22.7	44.7	5.90
Sub soil coir pith (2 kg/ m^2)	145.7	261.5	24.4	49.1	5.90
Maize stover (5 kg / m^2)	146.2	263.0	24.6	51.7	6.13
Sugarcane trash (5 kg / m^2)	147.2	264.0	24.2	50.7	6.00
Surface coir pith (2 kg/ m^2)	120.5	245.0	23.1	45.2	5.83
Gunny sheet mulching	145.0	260.0	24.5	49.8	6.20
Biodegradable poly mulching	152.5	288.2	25.5	72.3	6.10
Polyethylene mulching	154.2	295.4	26.2	79.4	6.30
CD (p= 0.05)	16.8	41.5	1.35	7.92	NS
Moisture regimes					
0.4 ETc (Drip)	152.0	285.2	24.9	59.0	6.25
0.8 ETc (Drip)	156.2	297.0	25.3	56.6	5.93
Conventional irrigation	115.5	207.8	23.0	50.5	5.98
CD(p = 0.05)	7.34	18.12	0.59	3.45	NS
CD (p = 0.05) for interaction	NS	NS	NS	13.30	NS

regimes (Table 2).

Mulches and moisture regimes on seed cotton yield (SCY) : The SCY followed the same trend as that of boll numbers. The interaction effect between mulches and moisture regimes was significant. Under no mulch condition, RCHB 708 *Bt* responded up to 0.8 ETc through drip system with a SCY of 4070 kg/ha as against 3421 kg/ha under conventional irrigation system. Earlier, enhanced SCY up to 44.5 per cent at 0.8 ETc through drip over conventional irrigation has been reported (Nalayini *et al.,* 2006). However, under mulched condition, the response was seen only up to 0.4 ETc and this might be due to avoidance of direct contact of sunlight on the mulched soil keeping the evaporative loss at its minimum. The SCY found to decline at 0.8 ETc under mulched condition. Among the mulches, polyethylene mulching and biodegradable polyethylene mulching recorded 5472 kg/ha and 4853 kg/ha and was *on par* and found significantly superior to other mulches. Among the combinations, irrigation through drip at 0.4 ETc with polyethylene mulching recorded the highest SCY of 5641 kg/ha and was *on par* with biodegradable polyethylene mulching (5234 kg/ha) at the same moisture level and polyethylene mulching under conventional irrigation (5357 kg/ha) and biodegradable polyethylene mulching under conventional irrigation (4679 kg/ha). Thus we could infer that when polyethylene mulching and biodegradable polyethylene mulching are used even the conventional irrigation is sufficient to get the desired yield and however in terms of enhancing moisture conservation, we can combine the polyethylene or biodegradable polyethylene with drip irrigation. Higher yield and better growth under mulched condition at lower moisture regime were due to better moisture conservation and favourable condition for plant growth (Table 4).

Water use efficiency (WUE) : The water use efficiency as measured by the ratio of seed

Table 2. Boll numbers in ELS *Bt* cotton cv. RCHB 708 *Bt* as influenced by interaction between moisture regimes and mulches

Mulches	Moisture regimes			
	Drip (0.4 ETc)	Drip(0.8 ETc)	Conventional irrigation	**Mean**
No mulch (control)	40.3	54.3	39.5	44.7
Sub soil coir pith (2 kg/ m^2)	53.9	48.1	45.2	49.1
Maize stover (5 kg / m^2)	54.7	52.9	47.5	51.7
Sugarcane trash (5 kg / m^2)	52.2	49.0	50.8	50.7
Surface coir pith (2 kg/ m^2)	49.1	46.0	40.5	45.2
Gunny sheet mulching	54.4	50.6	44.4	49.8
Biodegradable poly mulching	78.2	72.9	65.9	72.3
Polyethylene mulching	89.3	78.7	70.0	79.4
Mean	**59.0**	**56.6**	**50.5**	
CD (p=0.05) for mulches	7.92			
CD (p=0.05) for moisture regimes	7.92			
CD (p=0.05) for interaction	13.30			

cotton produced to the water consumed by the cotton crop ranged from 58.4 to 91.6 kg/ha cm, the highest (91.6 kg/ha cm) under polyethylene mulching followed by biodegradable poly mulching (81.8 kg/ha cm) as against the lowest (58.4 kg/ha cm) under no mulching. Among the moisture regimes, drip at 0.4 ETc recorded the highest WUE of 95.2 kg/ha cm might be due to better moisture conservation due to mulches at lower moisture regime of 0.4 ETc (Table 3).

Uptake of nutrients : Mulches and moisture regimes significantly influenced the nutrient uptake of ELS cotton, RCHB 708. Higher

Table 3. Dry matter production, water use efficiency and nutrients up take of *Bt* cotton cv. RCHB 708 *Bt* as influenced by moisture regimes and mulches

Treatments	DMP(t/ha)	WUE*	Nutrients uptake (kg/ha)		
			N	P	K
Mulches					
No mulch control	4.80	58.4	120.0	25.4	134.4
Sub soil coir pith (2 kg/ m^2)	6.30	70.2	158.1	34.0	217.9
Maize stover (5 kg / m^2)	6.39	68.9	160.4	35.5	215.5
Sugarcane trash (5 kg / m^2)	6.45	68.7	162.5	35.8	216.4
Surface coir pith (2 kg/ m^2)	5.15	63.3	127.2	26.3	164.8
Gunny sheet mulching	6.42	69.2	161.8	34.0	215.4
Biodegradable poly mulching	6.61	81.8	172.4	35.6	218.1
Polyethylene mulching	6.98	91.6	177.3	35.4	230.3
CD(p=0.05)	1.68		19.35	1.41	15.38
Moisture regimes					
0.4 ETc (Drip)	6.59	95.2	165.4	35.9	210.3
0.8 ETc (Drip)	6.75	68.6	170.8	36.4	216.0
Conventional irrigation	5.05	50.7	128.7	25.9	178.5
CD(p=0.05)	0.73		8.44	0.62	6.72
CD (p=0.05) for interaction	NS		NS	NS	24.10

*WUE = water use efficiency (kg of seed cotton/ha cm of water used)

Table 4. Seed cotton yield of ELS *Bt* cotton cv. RCHB 708 *Bt* as influenced by interaction between moisture regimes and mulches

Mulches	Moisture regimes			**Mean**
	Drip (0.4 ETc)	Drip(0.8 ETc)	Conventional Irrigation	
No mulch (control)	3175	4070	3421	**3555**
Sub soil coir pith (2 kg/ m^2)	4314	4067	4092	**4158**
Maize stover (5 kg / m^2)	4254	4215	3979	**4149**
Sugarcane trash (5 kg / m^2)	4208	4077	4002	**4096**
Surface coir pith (2 kg/ m^2)	4111	3809	3442	**3787**
Gunny sheet mulching	4354	4250	3994	**4199**
Biodegradable polymulching	5234	4647	4679	**4853**
Polyethylene mulching	5641	5418	5357	**5472**
Mean	**4411**	**4319**	**4121**	**4284**
CD (p=0.05) for mulches	620.0			
CD (p=0.05) for moisture regimes	270.1			
CD (p=0.05) for interaction	928.5			

temperature and faster mineralization under mulching might have caused increased uptake of nutrients. Mulching was also reported to support (2-3 folds) rhizospheric and phyllospheric microbes (diazotrophs, facultative methylotrophs, *Azospirillum* spp., phosphorus solubilizing bacteria (PSB), and Arbuscular Mycorrhizae) due to its enhanced temperature and higher soil moisture. The higher microbial population in mulch treatments would have played a significant role in nutrient mobilization (Nalayini *et al.,* 2009). All other mulches except no mulching and surface coir treatments recorded significantly higher uptake of NPK. The significant reduction in uptake of these nutrients in surface coir application might be due to initial higher C/N ratio of the coir material when it is applied on the surface of the soil which caused stunted growth and lesser dry matter accumulation by the cotton crop. However when the coir was placed deep using the coir pith applicator, it was as good as application of other plant wastes like sugarcane trash or maize stover mulching. Among the moisture regimes, Drip at 0.4 ETc and 0.8 ETc were *on par* and significantly superior to conventional irrigation.

None of the fibre quality parameters were influenced significantly due to the mulches or moisture regimes (Table 5)

Zero tilled rotation maize : The surface coir application recorded the lowest maize grain yield might be due to wider C/N ratio of the coir waste when applied on the surface. All the mulches except surface coir mulching recorded higher maize grain yield over no mulch control might be due to moisture conservation and also due to supply of nutrients due to degradation of crop waste applied as mulches over a period of six to eight months. Among the moisture regimes, drip at 0.8 ETc recorded the highest maize grain yield followed by drip at 0.4 Etc and conventional method. The efficient moisture conservation achieved at lower moisture regime of 0.4ETc for cotton crop could not be achieved for maize crop as the applied mulches started degradation over a period of time.

The study revealed that the biodegradable polyethylene mulching was as good as polyethylene mulching for use in *Bt* cotton production. There is a great scope for biodegradable polyethylene to be used as mulch

Table 5. Fibre quality parameters of extra long staple *Bt* cotton cv. RCHB 708 *Bt* as influenced by moisture regimes and mulches

Treatments	2.5 per cent span length	Fibre strength (g/tex.)	Micronaire (µ g/inch)	Uniformity ratio (per cent)	Maturity ratio
Mulches					
No mulch (control)	34.7	25.0	3.7	44.4	0.67
Sub soil coir pith (2 kg/ m^2)	35.5	25.1	3.9	44.2	0.7
Maize stover (5 kg / m^2)	35.8	25.8	4	45.1	0.71
Sugarcane trash (5 kg / m^2)	35.7	25.5	4	40.3	0.72
Surface coir pith (2 kg/ m^2)	35.3	24.5	3.9	44.5	0.71
Gunny sheet mulching	35.5	24.9	3.9	44.4	0.69
Biodegradable poly mulching	35.7	24.9	3.8	44.7	0.69
Polyethylene mulching	35.8	24.6	3.8	44.7	0.69
CD(p=0.05) for mulches	NS	NS	NS	N S	NS
Moisture regimes					
Drip (0.4 Etc	34.3	23.3	4.0	44.9	0.70
Drip (0.8 Etc)	36.1	26.2	3.8	44.2	0.68
Conventional Irrigation	35.9	25.6	3.9	43.0	0.70
CD (p=0.05) for moisture regimes	NS	NS	NS	NS	NS
CD (p=0.05) for interaction	NS	NS	NS	NS	NS

Table 6. Grain yield of zero tilled rotation maize after the harvest of cotton as influenced by moisture regimes and mulches

Mulches	Moisture regimes			
	Drip (0.4 ETc)	Drip(0.8 ETc)	Conventional Irrigation	**Mean**
No mulch control	4.00	4.80	4.13	**4.31**
Sub soil coir pith	6.27	6.23	6.20	**6.23**
Maize stover	6.23	6.40	6.23	**6.29**
Sugarcane trash	6.30	6.40	6.27	**6.32**
Surface coir pith	2.70	2.63	2.70	**2.68**
Gunny sheet mulching	6.37	6.40	6.13	**6.30**
Biodegradable polymulching	6.23	6.77	6.27	**6.42**
Polyethylene mulching	6.57	6.40	6.50	**6.49**
Mean	**5.58**	**5.75**	**5.55**	
CD (p=0.05) for mulches	0.19			
CD (p=0.05) for moisture regimes	0.08			
CD (p=0.05) for interaction	0.32			

to enhance crop productivity and to conserve soil moisture. The crop based mulches such as sugarcane trash, maize stover and coir waste were also be considered, but, next only to polyethylene and biodegradable polyethylene mulching. The surface coir application was not found to be useful in our study. Irrigation water requirement can be reduced to 50 per cent by use of mulching. Conventional irrigation system is sufficient to get the desired yield if polyethylene and biodegradable polyethylene mulching is practiced by farmers. .However keeping in terms of further moisture conservation, we can combine these mulches with drip system (Table 6).

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