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RESEARCH PAPER

Evaluation of bio and polyethylene mulches on soil moisture, soil temperature, weed biomass and *Kusmi* lac yield on *Flemingia semialata*, a bushy lac host, in eastern India

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Abstract : A field experiment for three consecutive years from 2010 to 2013 was conducted to study the effect of different mulching materials *viz.*, black polyethylene, transparent polyethylene, grass mulch, soil mulch, lac mud and unmulched (control) on soil moisture, soil temperature, weed biomass suppression and *Kusmi* lac yield of *Flemingia semialata* under rainfed conditions in the Research farm of ICAR-Indian Institute of Natural Resins and Gums, Ranchi. Results showed the highest soil moisture conservation in black polyethylene by 31.7, 26.7 and 14.4% over control for the year 2011, 2012 and 2013, respectively. Different mulching materials showed different effects on soil temperature. The maximum mean temperature (21.7^{0}C) was recorded under transparent polyethylene mulch, while, the lowest soil mean temperature (20.8^{0}C) was recorded under grass mulch. Mean soil temperature under grass mulch was lower by 1.1, 0.7 and 1.0^{0}C compared to transparent mulch for three years, respectively. Black polyethylene suppressed the maximum amount of weed (380.22 g m^{-2}), whereas the suppression by transparent mulch was 149.93 g m$^{-2,}$ which was recorded to be the least. Lac yield showed no definite trend in any of the treatments during the study period.

Key Words : *Flemingia semialata*, Lac yield, Mulches, Soil moisture, Soil temperature, Weed suppression

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INTRODUCTION

Most of the lac production in India is based on the commonly cultivated insect *Kerria lacca* (Kerr) (Bahuguna and Shiva, 2002 and Sharma *et al.*, 2006). The insect secretes true lac (Sharma and Ramani, 1999), a resinous compound of great economic importance (Roonwal *et al.*, 1958 and Ramani *et al.*, 2007). Lac derived products are biodegradable, non-toxic, and environment friendly. In addition to this, the lac insect-host association contributes to the conservation of biodiversity, *viz.*, soil flora, fauna, and soil microorganisms (Sharma *et al.*, 2006). The lac insect ecosystem is a complex multi-trophic web of flora and fauna and

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represents a rich biodiversity.

India is the largest producer of lac in the world, followed by Thailand, Indonesia, parts of China, Myanmar, Philippines, Vietnam, and Cambodia etc. At present, production of raw lac in India is approximately 20,000 metric tons per year. The major lac producing states are Jharkhand (56.3%), Chhattisgarh (16.7%), Madhya Pradesh (12.9%), Maharashtra (5.9%) and West Bengal (4%) (Yogi *et al.*, 2014). Lac cultivation is an important source of income for livelihood of the forest and sub-forest dwellers in different states. It is a highly remunerative crop, paying high economic returns to the farmers and also foreign exchange to the country through its export. Total export of lac and its value added products in 2012-13 was 4361.4 tons which was valued Rs. 480.3 crores (Yogi *et al.,* 2014). *Rangeeni* and *Kusmi* are two strains of this insect, each of which produces two crops in a year (bi-voltine). *Kusmi* insect grows mainly on *kusum* and also on a few other hosts like *Flemingia semialata* etc., whereas *rangeeni* strain grows mainly on *palas* and also on a few other trees.

Further, lac host plants can be divided into various categories based on the degree of the preference of the lac insects for the various hosts. *Kusum (Schleichera oleosa)*, *palas (Butea monosperma)* and *ber (Ziziphus mauritiana)* are the traditional lac host plants for culturing the Indian lac insect *Kerria lacca* (Kerr). Use of these hosts have limitations such as difficulty in crop operations on account of its scattered nature and climbing on trees for lac cultivation operations, vulnerability to theft due to relatively higher market price, etc. Gestation period (Time period during which a plant is ready to take lac inoculation load) is also very long for these conventional lac hosts. *Flemingia* spp. is model host plant species proposed for lac cultivation and related research studies in the Indian subcontinent (Yadav *et al.,* 2005). *Flemingia semialata* (Leguminosae: Papilionaceae), a perennial plant species, is a host of commercially important lac insects *Kerria lacca* (Kerr.) This host is fast growing with high coppicing response, bushy in nature and can sustain *kusmi* strain of lac insects, is known for providing world best quality of lac resin.

The practice of mulching has been widely used as a management tool in many parts of the world. The surface mulch favorably influences the soil moisture regime by controlling evaporation from the soil surface, improves infiltration, soil water retention, decreases bulk density and facilitates condensation of soil water at night due to temperature reversals (Yang *et al.,* 2006 and Pawar *et al.,* 2004). Soil mulching with plastic film, which results in reduced water loss and more even regulation of soil temperature, has been widely used in agriculture (Zhang *et al.,* 2005). Plastic mulches directly affect the microclimate around the plant by modifying the radiation budget of the surface and decreasing the soil water loss (Liakatas *et al.,* 1986). Grass/straw mulch showed a significant impact on plant growth and development of ber, a lac host, during establishment stage in studies carried out at Indian Institute of Natural Resins and Gums, Ranchi (Ghosal and Singh, 2012 and Singh *et al.,* 2012). Although much research have been done for understanding the influences of mulch materials on soil moisture, growth, and yield of many fruit and vegetable crops, report on effect of mulch with regard to its efficacy on lac host, *F. semialata,* is missing. Thus, the objectives of the present study were to compare the performance of different mulches with respect to changes in soil moisture regime, soil temperature and weed reduction and also to examine the best mulch option for enhancing *kusmi* lac productivity on *F. semialata* (winter season) under rainfed condition.

MATERIAL AND METHODS

Research site :

The experiment was carried out at the research farm of ICAR- Indian Institute of Natural Resins and Gums Farm, Ranchi ($23^0 23^{|}$ N, $85^0 23^{|}$ E, altitude 650 m) from July 2010 to June 2013. Soil of the experimental plot was of sandy loam texture, soil reaction 4.12, organic carbon content 0.34%, bulk density 1.34 g cm^{-3}, available N 143.9, P 16.2 and K 66.42 kg ha^{-1} with 21.1% field capacity, 11% permanent wilting point and 37.7% water holding capacity (WHC). The average amount of rainfall received during July 2010-June 2013 was 1468.6 mm, about 82.7% of which was received during monsoon period (June-September). The average minimum and maximum temperature were 16.4 and 29.7^{0}C, respectively. The average monthly weather parameter of the study period is presented in Fig. A.

Experimental design :

288 *semialata* plants, at a spacing of 1 m x 1m, were selected for the experiment. The experiment was laid out in Randomized Block Design with plot sizes measuring 4 m x 3 m area replicated four times with six treatments. Each treatment consisted of 12 plants of the

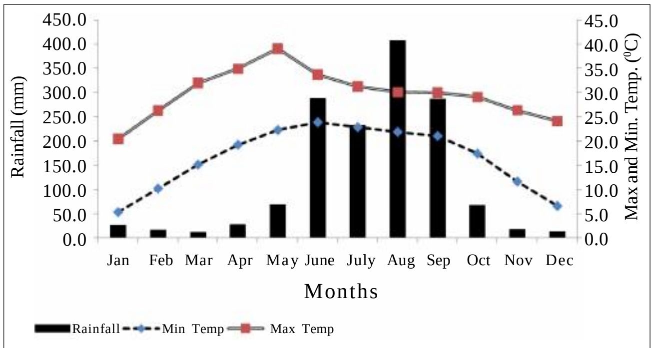

Fig. A : Average monthly weather parameter of Namkum, Ranchi during July 2010- June 2013

same age. The treatments were unmulched control (T_1), black plastic polyethylene film mulch (T_2), transparent polyethylene film mulch (T_3), grass mulch (T_4), soil mulch (T_5) and lac mud mulch (T_6). For polyethylene mulch treatment, black and transparent polyethylene film of 1.10 m diameter with 0.0005 mm (50 µ) thickness was spread uniformly in the basin area of individual plant. Grass mulch was applied on the same area at the rate of 10 t/ha. For soil mulch, upper crust of the soil, upto 10 cm depth, was tilled once during the crop cycle. Lac mud, a waste product of lac, was applied at the rate of 10 t/ha.

Evaluation of soil moisture and soil temperature:

The soil moisture was measured at fortnightly interval (13-15 days interval) throughout the year barring monsoon period (June-September) by gravimetric method (Black, 1965) from 0-30 and 30-60 cm depth of soil profile. The soil from different depths was sampled by manual coring and gravimetric moisture content (g/g) of the soil samples was calculated on oven dry weight basis (%). Soil temperature from each treatment at 30 and 60 cm depth was recorded at the time of collecting the soil sample for moisture analysis by digital thermometer with an accuracy of ± 1.0% range.

Evaluation of weed biomass in the lac host periphery :

The quantity of weeds was recorded at the time of mulch imposition (October-November) and at the removal of mulch material (1st week of June) every year in a 25 cm x 25 cm quadrant from each treatment-replication combination. The above-ground parts were clipped at soil surface, oven dried at 65^0 C for 48 hours and weighed with a digital balance to determine the dry matter (DM) per plot (Okugie and Ossom, 1988; Spandl *et al.*, 1999). The difference in the dry matter weight at the time of imposition and removal of mulch material was considered as the weed suppression for that treatment.

The weed suppression per cent by weight was calculated by

$$\text{Weed suppression (\%)} = \frac{\text{(Wt. of DM at the time of mulch imposition} - \text{Wt. of DM at the time of removal of mulch material)}}{\text{Wt. of DM at the time of mulch imposition}} \times 100$$

Lac culture operations and yield determinations :

Inoculation of broodlac on *Semialata* plants for winter season *(Aghani)* crop was done as per shoot length available and the mean rate was 20g/ plant during July-August in all the three years 2010-2012 and the crop was harvested during February-March every year. Data on broodlac yield ratio and broodlac thickness was recorded.

The results obtained were subjected to statistical analysis (LSD, programme ANOVA) and consequently compared using the least significant difference test at the probability level of 95% (LSD_{05}, P= 0.05).

RESULTS AND DISCUSSION

The results obtained from the present investigation as well as relevant discussion have been summarized under following heads :

Soil moisture :

Mean soil moisture contents ranged from 9.41 % under control (without mulch) to 11.73% under black polyethylene mulch (Table 1). Maximum moisture contents were found under black polyethylene mulch (T_2) for all the years. The moisture conserved under the treatment was significantly superior over the control and it was greater to the tune of 31.7, 26.7 and 14.4% over control for the year 2011, 2012 and 2013, respectively. Transparent polyethylene and grass mulch also showed superiority over control in all the years. During the year 2012 and 2013 plastic mulch and grass mulch showed significant moisture conserved over control.

Soil temperature :

Analysis of variance showed that soil temperature significantly affected ($P \leq 0.05$) by mulching treatments. The mean soil temperature was highest under transparent polyethylene mulch (T_3) and lowest under the grass mulch (T_4) treatment, but there was no significant difference in soil temperature between T_2 and T_3 treatments (Table

2). The soil temperature under the grass mulch treatment was significantly lower (20.8^0 C) than in the control treatment (21.4^0 C). Mean soil temperature under grass mulch was lower by 1.1, 0.7 and 1.0^0 C compared to transparent polyethylene sheet for three years, respectively (Table 2).

Weed biomass suppression :

Black polyethylene suppressed the most weed infestation, while transparent polyethylene and control suppressed the least (Fig. 1). In fact, transparent mulch showed the highest weed coverage and in the year 2012-13, the weed infestation was 33.3% more under this mulch at the time of removal of the mulch when compared to its imposition, signifying transparent mulch to be highly ineffective in weed suppression. The black polyethylene mulch reduced the highest weight (380.22 g m^{-2}) whereas the transparent mulch reduced the least weight (149.93 g m^{-2}).

Lac yield :

Transparent polyethylene mulch showed the maximum yield ratio (8.8:1), while the maximum thickness (4.7 mm) was found with black polyethylene for the lac crop season 2010-11. The lowest broodlac yield ratio

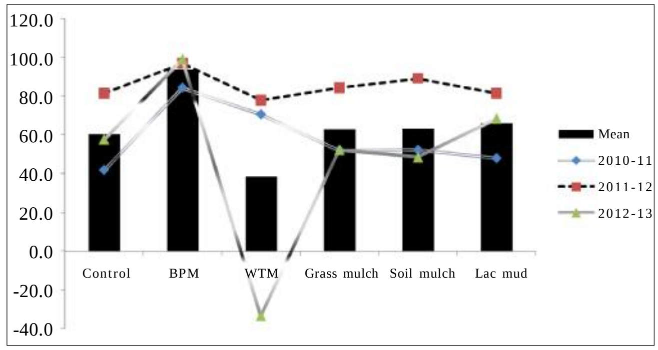

Fig. 1 : Weed suppression (%) under different mulches in different years

was found to be under lac mud (4.7:1) with the lowest broodlac thickness in control (3.6 mm) (Table 3). For 2011-12, analysis of data showed the maximum yield ratio (4.3: 1) with grass mulch, while maximum thickness (6.1 mm) was observed with white transparent polyethylene. Control showed the least yield ratio (1.9:1), while lowest thickness (3.1 mm) was recorded in soil mulch. For 2012-13, the maximum yield ratio (2.5:1) and maximum thickness (9.1 mm) were recorded with transparent mulch. Soil mulch showed the least yield ratio (0.5:1) and thickness (6.5 mm).

Inferences can be drawn here that, though, yield ratio and broodlac thickness were numerically higher in

Table 1 : Mean soil moisture (%) under various treatments during different years (2011-13)

Treatments	2011 (Jan-Dec)	2012 (Jan-Dec)	2013 (Jan-May)	Mean
T_1-Control	9.08	10.77	8.38	9.41
T_2- BPS*	11.96	13.65	9.59	11.73
T_3-TS	10.93	12.49	8.85	10.75
T_4-GM	9.38	12.60	9.39	10.45
T_5- SM	9.51	10.56	8.05	9.37
T_6- LM	9.64	11.37	7.90	9.63
S.E. ±	0.27	0.44	0.19	0.32
C.D. (P=0.05)	0.58	0.94	0.41	0.47

*BPS- Black polyethylene sheet; TS- Transparent sheet; GM- Grass mulch; SM- Soil mulch; LM- Lac mud

Table 2 : Mean soil temperature (^{0}C) under various treatments during different years (2011-13)

Treatments	2011 (Feb-Dec)	2012 (Jan-Dec)	2013 (Jan-May)	Mean
T_1-Control	21.3	20.9	22.2	21.4
T_2- BPS*	21.4	21.3	22.1	21.6
T_3-TS	21.5	21.4	22.3	21.7
T_4-GM	20.4	20.7	21.3	20.8
T_5- SM	20.8	21.1	22.0	21.3
T_6- LM	20.6	20.9	22.0	21.2
S.E. ±	0.09	0.08	0.16	0.10
C.D. (P=0.05)	0.19	0.17	0.34	0.22

Table 3 : Lac crop yield parameters for *Semialata* under different kind of mulches (2011-13)

Treatments	Broodlac yield ratio (output: input)			Broodlac thickness (mm)		
	2010-11	2011-12	2012-13	2010-11	2011-12	2012-13
T_1.Control	5.1	1.9	1.6	3.6	4.6	7.2
T_2- BPS*	6.5	4.1	2.4	4.7	5.1	7.7
T_3-TS	8.8	3.9	2.5	4.6	6.1	9.1
T_4-GM	5.7	4.3	1.4	3.4	4.9	7.4
T_5- SM	5.8	3.2	0.5	4.9	3.1	6.5
T_6- LM	4.7	3.3	1.1	3.9	4.50	6.9
S.E. ±	1.45	1.19	0.67	1.53	0.82	1.21
C.D. (P=0.05)	NS	NS	NS	NS	NS	NS

NS=Non-significant

the mulched treatments when compared to control in general; no significant difference was observed among the treatments. There were variations in lac yield between the years, which probably can be partly due to biotic and abiotic factors.

Previous research has indicated that mulching insulates the soil surface and hence increases resistance to heat and vapour transfer (Bussiere and Cellier, 1994; Chung and Horton, 1987). This in turn produces adjustments in energy balance and reduces evaporation, increasing available soil water (Movahedi Naeni and Cook, 2000a; Unger, 1978). In our study, plastic and grass mulch showed the better retention of soil moisture under the *F. semialata* periphery. The mulch prevents evaporation of water from the soil surface. At the same time, water moves from deeper soil layers to the topsoil by capillarity and vapor transfer, thereby keeping the topsoil water content relatively stable (Wang *et al.*, 1998; Li *et al.*, 1999). The result was in conformity with the findings of Ramakrishna *et al.* (2006) who reported that the amount of moisture stored in the profile to a soil depth of 90 cm was significantly greater under polythene and straw mulch over bare and chemically mulched soil.

The prevention of direct contact of solar radiation alongside increased moisture content with the soil by the organic mulches explains the low soil temperature under grass mulch. No significant differences in soil temperature were recorded among lac mud, soil mulch and control treatments. The film mulch prevents water exchange between the soil and air, which in turn reduces the latent heat flux and also reduces the exchange of heat between soil and air (Wang and Deng, 1991). Several investigators have reported that the soil thermal regime under straw mulching was different from that of bare soil, with soil temperatures often being lower under mulched surfaces than in non-mulched soils (Bristow, 1988 and Sarkar *et al.*, 2007). The results are also in conformity with the results of Moreno and Moreno (2008) who found the lowest values of temperature under the biodegradable and the highest under the polyethylene mulches employed for production of tomato crop.

Much sunlight penetration inside transparent sheet facilitated photosynthesis of inside grasses, causing abundance of the weeds. The result is consistent with the findings of Grassbaugh *et al.* (2004) who reported weed reduction to the tune of 80% under black plastic mulch. Ngouajio and Ernest (2004) reported that the highest and lowest weed biomass in white and black plastic mulches, respectively.

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