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ORIGINAL ARTICLE **OPEN ACCESS**

Effect of Straw and Plastic Mulching on Soil Environment, Crop Performances and Profitability of Brinjal (*solanum melongena* l.) in Semi Arid Region of Bihar

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ABSTRACT
A field experiment was established at semi arid region of Bihar to evaluate the effect of mulching (i.e., Black plastic mulch: M_1, Rice straw mulch: M_2 & Unmulched control: M_0) on soil environment and crop performances. Results revealed that black plastic and straw mulch conserved higher soil moisture as compared to without mulch in 0-7.5 & 7.5-15 cm soil depths. The maximum reduction in bulk density (BD, improvement in air filled porosity (AFP) and water holding capacity (WHC) was observed in straw mulch followed by black plastic mulch and unmulched control in 0-7.5 cm soil depth. Black plastic mulch and straw mulch reduced the weed population, promoted plant root growth and improved the yield of brinjal. Based on benefit cost ratio, the treatment of straw mulch was most economical which closely followed by black plastic mulch as compared to unmulched control.
Key Words: *Brinjal, Economics, Moisture, Mulching, Root growth, Weed growth, Yield*

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INTRODUCTION

Over the past three decades or so, internationally, rapid strides have been made to evolve and spread resource conservation technologies which enhance conservation of water and nutrients. Conservation technologies which have its roots in universal principles of providing permanent soil cover (through crop residues, cover crops etc.) is now considered the principal road to sustainable agriculture, is a major step toward transition to sustainable agriculture. Thus, a conservation technology like mulching practices is the most suitable and important in this regard especially in the rainfed / dry land agro ecosystem. Mulching is one of the simplest and most beneficial conservation practices that can be used as a protective layer of a material that is spread on top of the soil. Mulches can either be organic-such as vermicompost, grass clippings, straw, saw dust and similar materials or inorganic plastic [14]. The main functions that mulches provide including: weed suppression, soil water conservation, moderation of soil temperature fluctuations (daily and seasonal), increased infiltration of water droplets from precipitation or irrigation, soil protection from traffic compaction, improved soil structure for organic mulches and the slow release of nutrients [6].

Since the late 1930s, mulching has been used for the environmental modification of agriculture lands, forests and urban landscapes [2]. It is a crop production and soil protection technique that involves placement of organic or inorganic materials on the soil surface so as to provide a more favorable environment for plant growth and development [5]. The application of different types of mulch to soil is one of the corner stones of agriculture. Mulch may be organic or inorganic/synthetic in nature. Mulches are well-known for modifying the heat/energy, water balance and also improve the physico-chemical condition of the soil at the surface of soils and creating more favorable conditions for plant growth. Organic mulch decompose slowly, they provide organic matter which has great source of plant nutrients and thereby improve plant growth and yield [11]. While, inorganic mulches have their place in certain field, they lack the soil improving properties of organic mulches. The aim of this study was to evaluate the effects of mulching on soil environment and crop performances.

MATERIAL AND METHODS

Study site characteristics

Field experiments were established during March to July 2018 at the Krishi Vigyan Kendra, Manjhi, Saran, Dr. Rajendra Prasad Central Agricultural University, Pusa, Samastipur, Bihar. It is located at 25° 84" N latitude and 84° 58" E longitude and at an elevation of 36 m above mean sea level. The area falls in sub-tropical, humid agro-climatic zone of Bihar. The average annual rainfall of the area is about 800-1100 mm. Total rainfall received during experimentation was 105 mm. The soils are sandy loam in texture and alkaline in reaction (pH 8.42). The bulk density, air filled porosity, water holding capacity and organic carbon were 1.54 g cm^{-3}, 41.1%, 40.9%, and 3.90 g kg^{-1}, respectively.

Treatments and experimental design

The experiment was laid out with 3 treatments replicated five in randomized block design during 1st March to 15th August 2018 (one season). The treatments comprised three types of mulches, *viz*., black plastic mulch (M_1), rice straw mulch (M_2), unmulched control (M_0).

Field preparation

Before the execution of experiment, the field was well ploughed by tractor followed by planking 15 days prior to actual date of transplanting of seedlings. Weeds, stones, pebbles, etc. were removed from the field. Fifteen raised plots of dimension of 3.0 × 3.0 m were made.

Nutrient application

Recommended doses (100%) of farm yard manures, nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) were used as 200 quintal, 120 kg, 80 kg and 80 kg per hectare, respectively. N, P, K were applied in the form of calcium ammonium nitrate, single super-phosphate and muriate of potash. Entire dose of P and K fertilizers was applied at the time of field preparation. The N fertilizer was applied in two equal split doses, first dose at the time of transplanting and second dose one month after transplanting.

Mulching

The ultra violet (UV) resistant black plastic sheets were cut in rectangular shape, slightly larger than the dimension of plots and holes were made by scissors to fit the plants in the holes. Mulch sheet was laid in the plots before the transplanting of seedlings. The air-dried straw mulch material was spread evenly in the plots to have uniform mulch @ 10 t ha^{-1} just after the establishment of the seedlings. The plastic mulch was removed after the completion of experiment. The partially decomposed straw mulch was allowed to remain in the plot, which was later on mixed with soil.

Transplanting

One month old seedlings of brinjal var. Pusa hybrid-5 were transplanted on 1st March 2018 in plots having dimension of 3.0 m × 3.0 m at spacing of 60 cm × 50 cm.

Irrigation

After transplanting (upto two weeks after transplanting), the crop was irrigated daily with PVC pipe, thereafter the crop was irrigated at 15-20 days interval with 4 cm of irrigation depending upon the prevailing climatic conditions.

Plant protection and weed management

Pesticide was used for the crop protection against major and minor pests. Insecticide (Profenofos @ 1.5 ml l^{-1}) and Fungicide (Carbendazim @ 2 g l^{-1}) were applied at the time of disease and pest infestation. Weed management was done manually only in unmulched control (M_0) plots.

Measurement of soil properties

Soil moisture and temperature

Soil moisture contents were determined gravimetrically in all the plots in 0-7.5 & 7.5-15 cm depth at 15 days interval during the period of experimentation.

Soil sampling and analyses

Soil bulk density (BD) in 0-7.5 & 7.5-15 cm was determined by core method as suggested by Blake and Hartage [1]. In the laboratory, samples were carefully trimmed and dried at 105 ^oC to a constant weight. The air filled porosity (AFP) of both the soil layer was determined after crop harvest from data on BD using the relationship:

$$AFP = 1 - \frac{BD}{PD} \times 100 \quad (1)$$

Where: PD - particle density assumed to be 2.65 g cm^{-3}([8].
The water holding capacity was determined by means of Keen's Raczkowski box method as described by Piper [13].

$$\text{Water holding capacity (\%)} = \frac{\text{Maximum water absorbed by the soil}}{\text{Oven dry weight of the soil}} \times 100 \quad (2)$$

The pH of soil was measured with the help of a pH meter, maintaining the soil-water ratio of 1:2.5 as described by Jackson [4]. The organic carbon content in soil samples was estimated by Walkely and Black [19] method as suggested by Jackson [4].

Yield attributes and yield

The weed biomass was estimated twice at one month interval after the application of mulches. Three quadrants of 0.3 m × 0.3 m were laid randomly in each plot. The samples taken were dried in oven at 65 °C for 48 hr and their weight was taken to determine the weed dry mass. Root growth parameters, *viz*., dry weight (DW) of root and root volume (RV) were determined at the time of crop harvest. Root volume (RV) was determined by water displacement method. The roots were then dried in oven at 65 °C till a constant weight attained and expressed as g $plant^{-1}$. Fruits yield (q ha^{-1}) at marketable maturity was recorded during harvesting.

Economic analysis

The net return was calculated by considering the variable as well as fixed inputs and prevailing market rates. The fixed cost includes tillage, seed, transplanting, irrigation, pesticide, harvesting and transportation. Similarly variable cost included Farm yard manures, fertilizer, mulch materials and weeding. The cost of human labour used for tillage, seeding, irrigation, fertilizer and pesticide application, weeding and harvesting of crops was based on man-days per hectare. Simultaneously, gross returns were worked out for each treatment based on quality and market prices of the produce. The net returns were worked out by deducting the cost incurred from the gross return of the particular treatment. Benefit cost (B: C) ratio was calculated by dividing the net return by total cost of production.

Statistical analysis

The data generated from present investigation were subjected to statistical analysis using the statistical package SPSS 13.0 software (Analyse - General Linear Model-Univariate) (SPSS Inc., Chicago, USA). The same letters with table value represent statistically identical values of the examined combinations of mulching practices according to Tukey's HSD test determining the least significant difference (LSD) at 5% for testing the significant difference among the treatment means [3].

RESULTS AND DISCUSSION

In situ moisture conservation

Comparatively higher moisture conservation was found under M_1 and M_2 mulching treatments (Fig. 1) as compared to unmulched treatment (M_0). The highest in situ moisture conservation was observed with M_1 i.e. black plastic mulch (48.0 & 35.0%) which was at par with M_2 i.e. rice straw mulch (38.0 & 31.0%) in both the depths *i.e*., 0-7.5 cm & 7.5-15 cm, respectively, whereas, the lowest moisture conservation was associated with unmulched control (M_0) in both the depths. An efficient conservation of moisture under mulching may be due to the shading effect, which prevented evaporation of moisture from soil surface and reduced vapour diffusion to the atmosphere [7]. The mechanism involved in the highest moisture conservation in black plastic mulch that water after evaporation condenses on the bottom side of the polythene sheet and drips down again on the soil surface [17].

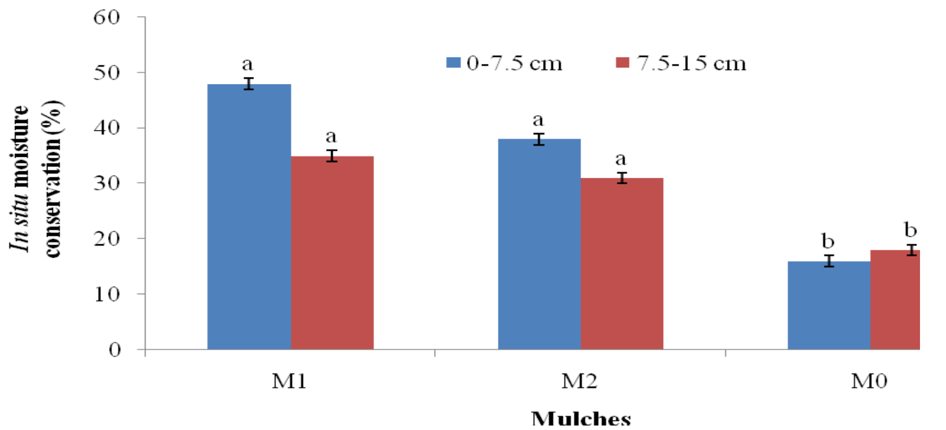

Fig. 1: Effect of mulches on in situ moisture conservation (%) in 0-7.5 & 7.5-15 cm soil depths. Vertical bars indicate ± S.E. of mean of the observed values. Different letters indicate significant difference (at 5% level) between the means.

Soil bulk density, air filled porosity and water holding capacity

Soil physical properties like bulk density (BD), air filled porosity (AFP) and water holding capacity (WHC) had not significantly ($P \leq 0.05$) influenced with mulch treatments (Table 1) in 0-7.5 cm & 7.5-15 cm soil depth but rice straw mulch (M_2) proved to be better performance in respect of reduction in BD and improvement in AFP & WHC in both the depths when compared with unmulched control (M_0) because loosening of soil due to decomposition of organic mulches resulting in top soil becoming more friable. Other possible reason that accumulation of decomposed and partially soil organic carbon enriched materials trigger microbial processes that enhanceed soil resilience as compared to the unmulched treatment (M_0). Bulk density increased under unmulched treatment (M_0) that may be due to compaction of surface soil which had a deleterious effect on crop growth. This effect might have been mitigated under mulch treatments. The results of this experiment are close conformity with Pervaiz *et al*., [12], and Zhang *et al*., [20].

Soil reaction and soil organic carbon

The analysis depicted that soil reaction (pH) was not significantly ($P \leq 0.05$) influenced with the application of mulching (Table 1) in both the depths. The lower pH value was recorded in organic mulch treatment *i.e*., rice straw mulch (M_2) which may be due to production of more carbonaceous material as compared to rest of the treatments. In contrast, soil organic carbon (SOC) was significantly ($P \leq 0.05$) affected by mulching in 0-7.5 cm soil depth & the highest SOC content was obtained in rice straw mulch treatment (M_2) which was at par with black plastic mulch (M_1) as compared to unmulched control (M_0) due to the fact that organic mulches upon decomposition provide carbonaceous material to the soil along with higher crop root biomass. These findings are in accordance with the studies of Muller and Kotschi [10] reported that organic mulch when applied to the soil decomposes; release nutrients and organic matter (humus) hence, increased growth of the plants.

Table 1. Effect of mulching on soil bulk density (BD), air filled porosity (AFP), water holding capacity (WHC), soil reaction and SOC in 0-7.5 & 7.5-15 cm depths.

Mulches	Soil Depth 0-7.5 cm					Soil Depth 7.5-15 cm				
	BD (g cm^{-3})	AFP (%)	WHC (%)	pH (1:2.5)	SOC (g kg^{-1})	BD (g cm^{-3})	AFP (%)	WHC (%)	pH (1:2.5)	SOC (g kg^{-1})
M_1	1.52a	42.6a	46.2a	7.9a	4.8ac	1.56a	41.1a	41.2a	8.2a	3.2a
M_2	1.51a	43.0a	46.8a	7.6a	5.1a	1.56a	41.1a	41.6a	7.9a	3.8a
M_0	1.52a	42.6a	41.8a	7.9a	4.7c	1.56a	41.1a	40.9a	8.2a	3.1a

Black plastic mulch (M_1); Rice straw mulch (M_2); Unmulched control (M_0); Different letters in a column indicate significant difference (at 5% level) between the means according to Tukey's HSD test.

Weed growth

Application of mulches significantly ($P \leq 0.05$) reduced the weed infestation compared to unmulched control (Table 2). There was no weed growth under black plastic mulch (M_1) but mulching with rice straw

(M_2) also found to be effective for controlling weeds. Among mulch treatments, decrease in weed dry weight at first and second intervals under M_1 and M_2 was found to the tune of 0-0, 56.1-84.5, 159.2-256.5 kg ha^{-1}, respectively compared to unmulched control (M_0). The highest reduction in incidence of weeds under black plastic mulch (M_1) might be attributed to the suppression of weed growth due to lack of sun light, their delayed emergence and reduced population. Straw mulch also reduced the weed population because it has smothering effect on weed population by putting a physical barrier by imparting photosynthetic activity and inhibiting the top growth of weeds. These results are in line with the findings Raina *et al*., [15], and Sharma & Kathiravan [16]. Mulching reduced competition occurring between main crop and weeds and created favorable conditions for crop growth.

Root growth

Application of mulches gave a significant ($P \leq 0.05$) effect on root growth parameters *i.e.,* root dry weight and root volume (Table 2) of brinjal in 0-15 cm depth. Dry weight of roots and root volume increased respectively by 87.7 and 64.6 % under M_1 and 89.5 and 50.0 % under M_2, over unmulched control (M_0). The higher root growth under mulching might be primarily due to moderation of hydrothermal regimes leading to favorable soil air-water relations who encouraged proliferation and elongation of roots and adequate moisture under mulches reduced the soil strength for root penetration and proliferation. Earlier reports have also highlighted the beneficial effects of straw mulch on root growth [9]. The poor root growth under unmulched treatment might be due to poor moisture levels in the soil and sub-optimal thermal regimes.

Table 2: Effect of mulching on weed growth, root growth, crop yield and economics.

Mulches	Weed biomass (kg ha^{-1})	Root dry weight (kg ha^{-1})	Root volume (cm^{-3})	Crop yield (q ha^{-1})	Cost of cultivation (Rs ha^{-1})	Gross return (Rs ha^{-1})	Net return (Rs ha^{-1})	(B:C ratio)
M_1	0.0a (0.0a)	12.2a	7.2a	265a	165800a	530000a	364200a	3.20a
M_2	56.1b (84.5b)	10.7a	6.2a	258a	145354b	516000a	370646a	3.55a
M_0	159.2c (256.5c)	6.5b	3.8b	186b	168540a	372000b	203460b	2.21b

Black plastic mulch (M_1); Rice straw mulch (M_2); Unmulched control (M_0); Different letters in a column indicate significant difference (at 5% level) between the means according to Tukey's HSD test.

Crop yield and economics

The yield of brinjal was significantly affected by mulching (Table 2) and black plastic mulch (M_1) registered the highest yield (265 q ha^{-1}) which was at par with rice straw mulch (M_2) treatment (258 q ha^{-1}) as compared to unmulched control. The effective weed control, favorable hydrothermal regimes, better root growth and increased nutrient uptake under mulches might have led to higher yield. These results are in line with the findings of Vazquez *et al*., [18].

The cost involved for brinjal production (Tale 2) under unmulched control (M_0) treatment was higher followed by black plastic mulch (M_1) and straw mulch (M_2) because extra expenditure *i.e*., weeding and irrigation cost involved in unmulched control (M_0) treatment. The net return of brinjal increased by 82.2 and 79.0% under M_2 and M_1, respectively as compared to M_0 (Rs. 203460 ha^{-1}). The seasonal income in term of benefit cost (B: C ratio) ratio was the highest with the application of straw mulch (M_2) which was at par with black plastic mulch (M_1). The benefit came mainly due to higher and better quality of crop produce and efficient weed control.

CONCLUSION

Application of mulches proved the better means for providing favorable soil environmental conditions for brinjal production in Bihar. Among the mulches, black plastic mulch (M_1) and rice straw mulch (M_2) conserved the higher moisture contents as compared to unmulched control (M_0). Reduction in weed competition with crop and improvement in soil organic carbon (SOC) were well reflected in maximizing growth attributes *viz*., root growth and yield of brinjal in semi arid region of Bihar. Based on benefit cost ratio, the treatment of rice straw mulch was most economical favorable which closely followed by black plastic mulch.

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