The Pharma Innovation Journal 2021; 10(10): 1989-1991

www.ThePharmaJournal.com

The Pharma Innovation

ISSN (E): 2277- 7695
ISSN (P): 2349-8242
NAAS Rating: 5.23
TPI 2021; 10(10): 1989-1991

www.thepharmajournal.com
Received: 11-06-2021
Accepted: 23-07-2021

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Effect of mulching on weed biomass, root growth, yield and economics of tomato (*Lycopersicon esculentum* 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 *viz*., Black plastic mulch: BPM, Rice straw mulch: RSM & Unmulched: UM) on weed biomass, root growth, yield and economics of tomato. Results revealed that black plastic mulch and straw mulch significantly reduced the weed population at first and second interval to the tune of 0-0 and 45.7-68.2 kg ha^{-1}, respectively as compared to unmulched (UM) *i.e.*, 137.5-215.6 kg ha^{-1}. The enhancement in root growth of tomato *i.e.*, dry weight of roots and root volume by 68.1 and 112.9% under BPM and 33.3 and 45.2% under RSM, respectively over UM. The yield of tomato was significantly the highest (374.5 q ha^{-1}) under black plastic mulching (BPM) followed by RSM and UM. The seasonal income in terms of net benefit cost (net B: C ratio) ratio was the highest with the application of black plastic mulch which was followed by rice straw mulch.

Keywords: Tomato, mulching, weed biomass, root growth, yield, economics

Introduction
Tomato (*Lycopersicon esculentum* L.) is one of the popularly grown and highly valuable vegetable crop worldwide. It is second most consumed vegetable in the world after potato (Suresh *et al.* 2014) [1]. The similar picture was found in Indian context also. In the year 2017-2018, the production (19696.9 MT) of tomato in India increased upto 2% from the acreage 808.5 ha along with the productivity 24.4 MT ha^{-1} (Kundu *et al.* 2019) [2]. The major tomato producing states are Bihar, Karnataka, Uttar Pradesh, Orissa, Andhra Pradesh, Maharashtra, Madhya Pradesh and West Bengal (Rao *et al.* 2016) [3].

For successful tomato production about 285 mm water is required during crop establishment, flowering, fruit setting and fruit development stage (Annonymous, 1995) [4]. But irrigation facilities in all the regions are not available. Sometimes, many of the farmers can't afford the expenses of irrigation. Under this situation mulching could be a good substitute means for irrigation to make availability of soil moisture. Mulching has been reported to be increased yield by creating favorable soil hydrothermal regimes (Ma and Han, 1995) [5]. It is an effective practice of manipulating crop growing environment to increase yield and improve product quality by controlling weed growth, ameliorating soil temperature, conserving soil moisture, reducing soil erosion, improving soil structure and enhancing organic matter content (Opara, 1993) [6].

Mulching also enhancing availability of applied and native nutrients, and ultimately increased the crop growth, yield and net return. Different types of materials such as wheat straw, rice straw or husk, plastic film, grass, wood, sand, etc. are used as mulch (Uwah and Iwo, 2011) [7]. The plastic mulch is used widely in many countries for conserving soil moisture and to decrease the cost of weeding and ultimately to lower the cost of crop production. Therefore, the aim of the study was to compare the effect of different types of mulching on the performance of tomato production.

Materials and Methods
Study site characteristics
The experiment was carried out by Krishi Vigyan Kendra, Saran, Bihar during December-April (2018-19) which is being conducted in association with National Innovations in Climate

Resilient Agriculture (NICRA) project since 2011 in sub-tropical humid climate at the investigation site of Affaur, Saran, Bihar. The areas are located at 25° 46' N latitude and 85° 09' E longitude and elevation of 52 m above mean sea level. The site has hot and humid summers and too cold winters with average rainfall of 800-1100 mm of which 80% is received during the monsoon period (June-September). The soil of the experimental site belongs to order Entisols, sandy loam in texture with alkaline pH and low in organic carbon.

Treatments and experimental design

The experiment was laid out with three treatments replicated eight in randomized block design during 11th December 2018-15th April 2019 (one season). The treatments comprised three types of mulching, *viz.*, black plastic mulch (BPM), rice straw mulch (RSM), unmulched (UM). 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. A total of twenty four plots were established, with each plot sized at 180.0 m × 22.2 m.

Nutrients application

Irrespective of treatments, the recommended doses (100%) of farm yard manures (FYM), nitrogen (N), phosphorus (P_2O_5) and potassium (K_2O) were used as 200 quintal, 120 kg and 80 kg per hectare, respectively. N, P, K were applied in the form of urea, di-ammonium phosphate and muriate of potash. Entire dose of FYM and P fertilizers was applied at the time of field preparation. The N and K 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 tomato var. *Pusa Rohini* were transplanted on 11th November 2018 in plots having dimension of 180.0 m × 22.2 m at spacing of 90 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 (UM) plots.

Data Collection

Weed biomass, root growth and crop yield

The weed biomass was estimated twice at one month interval after the application of mulching. Three quadrants of 1.0 m × 1.0 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 (Harrington *et al.* 1994) [8]. 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, mulching materials and weeding. The cost of human labour used for field preparation, nursery raising, irrigations, fertilizers and pesticides 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. Net benefit cost (B: C) ratio was calculated by dividing the net return by total cost of production.

Statistical analysis

The data generated from the present investigation were subjected to statistical analysis using the statistical package SPSS 13.0. The least significant difference (LSD) at 5% for testing the significant difference among the treatment means (Gomez and Gomez, 1984) [9].

Results and Discussion

Weed growth

Practices of mulching significantly ($P \leq 0.05$) reduced the weed infestation compared to unmulched control (Table 1). There was no weed growth under black plastic mulch (BPM) but mulching with rice straw also found to be effective for controlling weeds. Among mulch treatments, decrease in weed dry weight at first and second intervals under BPM and RSM was found to the tune of 0-0 and 45.7-68.2 kg ha^{-1}, respectively compared to unmulched (UM) *i.e.,* 137.5-215.6 kg ha-1. The highest reduction in incidence of weeds under black plastic mulch might be attributed to the suppression of weed growth due to lack of sun light. Straw mulch also reduced the weed population

Table 1: Effect of mulching on weed biomass, and root growth of tomato.

Mulches	Weed biomass (kg ha^{-1})	Root dry weight (kg ha^{-1})	Root volume (cm^{-3})
BPM	0.0a (0.0a)*	11.6a	6.6a
RSM	45.7b (68.2b)	9.2b	4.5b
UM	137.5c (215.6c)	6.9c	3.1c

*Values in parentheses are weed biomass at 2nd interval

BPM: Black plastic mulch, RSM: Rice straw mulch, UM: Unmulched. Different letters in a column indicate significant difference (at 5% level) between the means according to Tukey's HSD test.

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 of Kumar *et al.* 2018 [10], and Sharma & Kathiravan (2009) [11].

Root growth

Mulching produced significant ($P \leq 0.05$) effect on root growth parameters *i.e.*, root dry weight and root volume (Table 1) of tomato in 0-15 cm depth. Dry weight of roots and root volume increased respectively by 68.1 and 112.9% under BPM and 33.3 and 45.2% under RSM, over unmulched control. 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 (Kumar *et al.* 2018) [10]. The poor root growth under unmulched treatment might be due to poor moisture levels in the soil and sub-optimal thermal regimes.

Yield and economics

The yield of tomato was significantly affected by mulching (Table 2) and black plastic mulch (BPM) registered the highest yield (374.5 q ha^{-1}) followed by rice straw mulch (RSM) treatment (305.4 q ha^{-1}) as compared to unmulched (211.9 q ha^{-1}). 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 Kundu *et al.* 2019[2]. The cost involved for tomato production (Table 2) under BPM treatment was the highest followed by RSM because extra expenditure *i.e.*, mulching material cost. The net return of tomato was increased by 131.8% and 80.3% under BPM and RSM, respectively as compared to UM (Rs. 162170.0 ha^{-1}). The seasonal income in term of net benefit cost (Net B: C ratio) ratio was the highest with the application of black plastic mulch which was followed by rice straw mulch. The benefit came mainly due to higher and better quality of crop produce and efficient weed control.

Table 2: Effect of mulching on Yield and economics of tomato.

Mulches	Yield (q ha^{-1})	Cost of cultivation (Rs. ha^{-1})	Gross return (Rs. ha^{-1})	Net return (Rs. ha^{-1})	Net B: C ratio
BPM	374.5a	185855.0a	561750.0a	375895.0a	2.02a
RSM	305.4b	165654.0b	458100.0b	292446.0b	1.77b
UM	211.9c	155680.0c	317850.0c	162170.0c	1.04c

BPM: Black plastic mulch, RSM: Rice straw mulch, UM: Unmulched. Different letters in a column indicate significant difference (at 5% level) between the means according to Tukey's HSD test.

Conclusion

Application of mulching proved the better means for providing favorable soil environmental conditions for tomato production in Bihar. Among the mulching, black plastic mulch (BPM) and rice straw mulch (RSM) conserved the higher moisture contents as compared to unmulched (UM). Reduction in weed competition with crop and enhancement in root growth were well reflected in maximizing the yield of tomato in semi-arid region of Bihar. Based on net benefit cost ratio, the treatment of black plastic mulching was most economical which closely followed by rice straw mulching.

Acknowledgement

The support of Central Research Institute for Dry Land Agriculture, Hyderabad for provided financial support. Also, the Directorate of Extension Education, Dr. Rajendra Prasad Central Agricultural University Pusa, Bihar for providing basic infrastructure for this study is duly acknowledged.

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