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Hydraulic performance of existing drip irrigation system and effect of used plastic based mulching system on Rabi onion (*Allium cepa*)

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Abstract
Polythene mulches have been practiced for soil solarisation during winter months in various vegetable crops and have been found superior over other types of mulches, but plastics is create environmental problems. With this in view the present study has be undertaken on clay loam soil at Raipur, Chhattisgarh for Rabi onion. The aim of the experiment was to study the hydraulic performance of existing drip irrigation system under different operating pressure and prepare used plastic based mulching sheet to evaluate their performance in terms of change in micro-climate. In this study eight different types of mulching conditions were considered *viz*. black plastic mulch (BPM), silver plastic mulch (SPM), used reddish rice bag mulch (RBM), used whitish wheat flour bag mulch (WFBM), used yellowish cement bag mulch (CBM), Paddy straw mulch (PSM), soil mulch (SM) and without mulch (WM) (control) and comparison was done among them in micro-climatic condition. The main micro-climatic parameters like soil temperature, soil moisture content, soil moisture depletion were studied with randomized block designed in three replications. In Hydraulic performances of drip irrigation system were studied for 2.4 l h^{-1} inline emitters at 1, 1.2 and 1.5 kg cm^{-2} pressures, discharges from drippers were found to be 1.99 l h^{-1}, 2.22 l h^{-1} and 2.33 l h^{-1}, coefficient of variation 0.061, 0.044 and 0.029 were found and emission uniformity 95.59%, 96.54% and 96.69% were found, respectively. Also, from this study, it was found that during forenoon soil temperature increases with increasing soil depth but in afternoon the trend was vice-versa. The maximum soil moisture content (27.89%) was found under BPM and minimum soil moisture content (21.52%) was found under used WM. Similarly soil moisture depletion was found minimum in BPM (0.31 mm) and maximum under WM (3.08 mm) under all eight types of mulches. The study concludes that the hydraulic performance of drip irrigation system was found good and needs to be operated at 1.2-1.5 kg cm^{-2} pressure for 2.4 lh^{-1} inline emitter. At a particular spacing, the emission uniformity, uniformity coefficient and irrigation efficiencies increases when operating pressure is increased but coefficient of variation and emitter flow variation decreases when operating pressure is increased. Mulching roll can be prepared from used plastic bags which are available with the farmers in plenty and can be reused as mulching material satisfactorily by small and marginal farmers.

Keywords: Black plastic mulch, drip irrigation, emission uniformity, mulching, Rabi onion, used plastic bags

Introduction
Water is the precision source for agriculture growth and quality of agricultural products. In the methods of providing water to crop, the drip system is the first in techniques that provide a high quality yielding and reduce water wastage. Drip irrigation technique has a better efficiency of water use (Basso *et al.*, 2008) [2], minimizing the negative environmental factors and becoming viable alternative for sustainable irrigated agriculture (Valipour, 2012; Bhattarai *et al.*, 2008) [21, 3] and have the advantage of fitting difficult topography (Wei *et al.*, 2003) [23]. Its field application efficiency can be as high as 90% compared to 60–80% for sprinkler and 50–60% for surface irrigation (Dasberg and Or 1999) [7]. Adoption of micro-irrigation systems may help to increase the irrigated area, productivity of crops and water use efficiency.
Mulching is the addition of inorganic or organic or synthetic material such as plastic sheets, paddy straw, stones, pebbles cover crop residue etc. to the soil surface to provide one or several ecosystem services. Cover crop mulch that remains on the soil surface can be used to add soil organic matter (Dabney *et al*., 2001) [6], prevent soil erosion (Saxton *et al*., 2000) [18], increase soil water retention (McIntyre, 1958; Dabney, 1998) [13, 5], improve soil health

(Wang *et al*., 2011a) [22], and suppress arthropod and weed pests as well as diseases (Altieri 1999; Creamer *et al*., 1996; Gonzalez-Martin *et al*., 2014) [1, 4, 9]. The mulching techniques can be also implemented in summer vegetables production under rain-fed conditions. Mulching with drip irrigation system is an effective method of manipulating crop growing environment to increase yield, minimizes water requirement and improve micro-climate of soil.

Black plastic mulch is used for moderating the micro climate around the plants but its decomposition is difficult and thus it is environmentally unfriendly. Due to extensive and widespread applications of plastic in all walks of life, every day tons of plastic waste is produced. Almost every day we heard/read news of suffering of poor animals from being fed of plastic waste as it is thrown with eatables. There is an urgent need to arrest expansion of plastic by means of Refuse or Reduce or Reuse or Recycle. What every individual can do is refuse, reduce and reuse. With refuse and reduce, the technology will be overlooked so the benefits will also be reduced. Hence, one of the solutions is reuse. With this in view the present studies has be undertaken to hydraulic performance of existing drip irrigation system and prepare mulch sheet from used plastic materials and its performance evaluation under drip irrigation for rabi onion.

Materials and Methods

Experimental site

Field experiment was carried out during the year 2017-18 in winter season at Department of Soil and Water Engineering, Indira Gandhi Krishi Vishwavidyalaya, Raipur, Chhattisgarh at Latitude 21^{0}14“9” N and Longitude 81^{0}42“10” E and at an Altitude of 302 meters above the mean sea level.

Treatments and experimental design

The experiment were laid out in RBD (Randomised Block Design) having three replications and same level of irrigation (100% ET_c) which consists 8 types of treatment. In Drip Irrigation System, laterals are placed between two rows of plants. The treatment and experimental details are given below:

Treatments details

M_1	=	Black plastic mulch (27 μ)
M_2	=	Silver plastic mulch (27 μ)
M_3	=	used Wheat flour bag mulch (226 μ)
M_4	=	used Rice bag mulch (240 μ)
M_5	=	used Cement bag mulch (306 μ)
M_6	=	Paddy straw mulch (226 μ)
M_7	=	Soil mulch
M_8	=	Without mulch (Control)

experimental details

Crop	:	Onion
Scientific name	:	*Allium cepa* L.
Variety	:	Nasik Red (N-53)
Experiment Gross area	:	160 m^2
Experiment Net area	:	144 m^2
Crop spacing	:	10*15 cm
Fertilizer dose	:	100:50:50: kg NPK ha^{-1}
$ZnSO_4$	:	30 kg ha^{-1}

Measurement of discharge from emitters

Drip irrigation system having a lateral size of 16 mm of 20 m length with 2.4 l h^{-1} emitters (inline) at 40 cm spacing (50 number of emitter per lateral) was used for the study of hydraulic performance. Twelve laterals from the sub main line were erected and 4 emitters in each lateral line were selected randomly from the starting, middle and tail portion for the study and irrigation water was supplied for 15 minutes from a bore well. The flow rate or discharge of emitter at different operating pressure i.e. 1, 1.2 and 1.5 kg cm^{-2} collected in plastic container directly and then measured in measuring cylinder. Discharge of emitters with respect to test time was converted into discharge per hour.

Coefficient of manufacturer’s variation

Coefficient of variation defines as the ratio of the standard deviation of flow to the mean flow for a sample number of emitters. Coefficient of variation (C_v) is a statistical parameter expressed as:

$$C_v = \frac{s}{q_{avg}}$$

Where,

s = standard deviation of flow

q_{avg} = mean flow for a sampled number of emitters of the same type tested at a fixed pressure.

Methods of emission uniformity estimation

Merriam and Keller (1978) [14] presented a rationale to evaluate uniformity of water application from drip irrigation systems in the field and classified the systems on the bases of system uniformity. They expressed field emission uniformity as follows:

$$EU_f = \frac{q_n}{q_{avg}} \times 100$$

Where

EU_f = field emission uniformity expressed as a percentage

q_n = average of the lowest 1/4th of the field data emitter discharge, l h^{-1}

q_{avg} = average of all the field data emitter discharge, l h^{-1}

Emitter flow variation

It consists of finding the minimum and maximum pressure in the sub-units and calculating the emitter flow variation (Q_{var}) as follows.

$$Q_{var} = 100[1- \frac{Q_{min}}{Q_{max}}]$$

Where,

Q_{var}	=	emitter flow variation in percentage
Q_{min}	=	minimum emitter discharge rate in the system, l h^{-1}
Q_{max}	=	design emitter discharge rate, l h^{-1}

Process flow chart of mulch roll preparation from used plastic bags

Collection

(Collection of used plastic bags such as rice bag, fertilizer bag, wheat flour bag, cement bag)

⇩

Cleaning

(Done manually and dried in sun)

⇩

Sorting

⇩

Resizing

(Cut the bag in required size i.e. 50cm*180cm)

⇩

Fixing

(Fixed by manually or by sewing machine)

⇩

Mulch frame

(Having uniform holes with spacing15cm*10cm)

⇩

Wrapping

⇩

Punching

(Making uniform holes in mulch sheet)

Observations recorded

Soil moisture measurement

Soil moisture was taken during the experiment with the help of digital Time Domain Reflectometer (TDR) at 5 cm depth and at 7:30 AM and 2:00 PM in the plot covered with different types of mulches as BPM (27µ), SPM (27 µ), WFBM (226 µ), RBM (240 µ) and CBM (306 µ), PSM, SM and WM at same level of irrigation (100% of ET_c).

$$\text{SMD (mm)} = \frac{(\text{F.C.} - \text{M.C.}) \times \text{Root Zone depth} \times \text{B.D.}}{100}$$

Where

F.C. = Field capacity

M.C. = Moisture content

B.D. = Bulk density

Measurement of soil temperature

Soil temperatures were taken daily during the experiment with the help of digital soil thermometer at 7:30 AM and 2:00 PM at 5 and 10 cm depths of the plot covered with different types of mulches as BPM (27 µ), SPM (27 µ), WFBM (226 µ), RBM (240 µ) and CBM (306 µ), PSM, SM and WM (control).

Results and Discussion

Observation of discharge of drip irrigation system under different operating pressure

Drip irrigation discharges were measured at three operating pressures 1, 1.2 kg cm^{-2} and 1.5 kg cm^{-2}, respectively and have been presented in Table 1. The discharge rate increased as the pressure increases from 1 to 1.5 kg cm^{-2}. At maximum pressure of 1.5 kg cm^{-2}, the discharges from 2.4 l h^{-1} drippers were found to be 2.3 l h^{-1}. When pressure decreased from 1.5 kg cm^{-2} to1.2 kg cm^{-2} and 1 kg cm^{-2}, the discharge from 2.4 l h^{-1} drippers were found to be 2.2 l h^{-1}, and 2 l h^{-1} respectively. These discharge variation data at three pressures are presented in the bar diagram in Fig. 1.From the table 1, it is evident that when the pressure is increased then the discharge also increases. The results are in conformity with the findings of Popale *et al.* (2011) [16], Deshmukh *et al.* (2014) [8], Hussain *et al.* (2017) [11], Sinha *et al.* (2018) [19] and Sinha *et al.* (2019) [20].

Table 1: Average emitters flow rate (l h^{-1}) under different operating pressure

S. No.	1	2	3
Emitter (l h^{-1})	2.4	2.4	2.4
Operating pressure (kg cm^{-2})	1	1.2	1.5
Avg. Discharge of drip (l h^{-1})	2.0	2.2	2.3

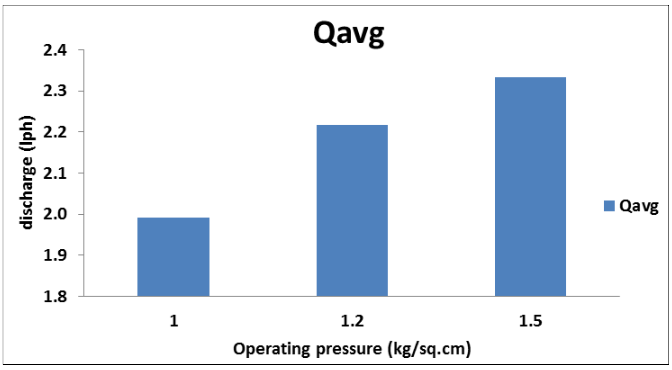

Fig 1: Discharge variation under different operating pressure

Coefficient of manufacture's variation (Cv)

Coefficient of manufacture's variation of 2.4 l h^{-1} emitter at three operating pressures 1 kg cm^{-2}, 1.2 kg cm^{-2} & 1.5 kg cm^{-2}, respectively, and have been presented in Table 2. The coefficient of variation 0.061, 0.044 and 0.029 were found at 1 kg cm^{-2}, 1.2 kg cm^{-2} and 1.5 kg cm^{-2} operating pressure. Thus for a particular spacing, coefficient of variation decreases as the operating pressure is increased for all emission devices. All these coefficient of variation data at different pressure are presented in Fig. 2. The results are in conformity with the findings of Deshmukh *et al.* (2014) [8], Sinha *et al.* (2018) [19] and Sinha *et al.* (2019) [20].

Table 2: Coefficient of variation under different operating pressure

S. No.	1	1	2
Emitter (l h^{-1})	2.4	2.4	2.4
Operating pressure (kg cm^{-2})	1	1.2	1.5
Coefficient of variation	0.061	0.044	0.029
Classification	Average	Good	Good

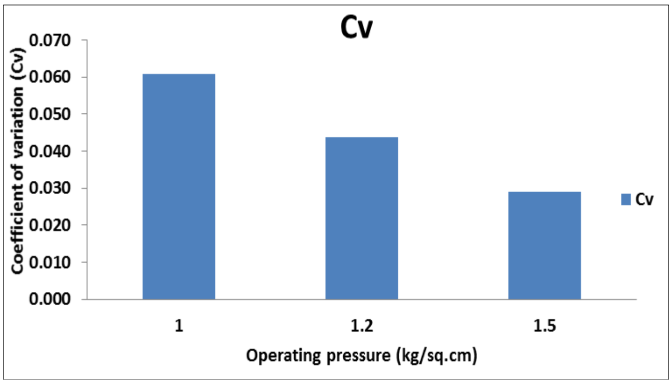

Fig 2: Coefficient of variation under different operating pressure

Emission Uniformity (EU_f)

Emission uniformity of the system decides the uniformity distribution of discharge by each emitter or uniformity distribution of water to each crop. The calculated emission uniformity data at three pressures 1 kg cm^{-2}, 1.2 kg cm^{-2} and 1.5 kg cm^{-2} have been presented in table 3 and Fig. 3. The maximum average emission uniformity 96.69% was observed at operating pressure 1.5 kg cm^{-2} in 2.4 l h^{-1} emitters. Similarly Emission uniformity was 96.54% and 95.59% at 1.2 kg cm^{-2} and 1 kg cm^{-2} operating pressure in 2.4 l h^{-1} emitters, respectively. Thus for a particular spacing, emission uniformity increases as the operating pressure increases for all emission devices. The results are in conformity with the findings of and Deshmukh *et al.* (2014) [8], Hussain *et al.* (2017) [11], Sinha *et al.* (2018) [19] and Sinha *et al.* (2019) [20].

Table 3: Emission uniformity under different operating pressure

S. No.	1	2	3
Emitter (l h^{-1})	2.4	2.4	2.4
Operating pressure (kg cm^{-2})	1	1.2	1.5
Emission uniformity (%)	95.59	96.54	96.69
Classification	Excellent	Excellent	Excellent

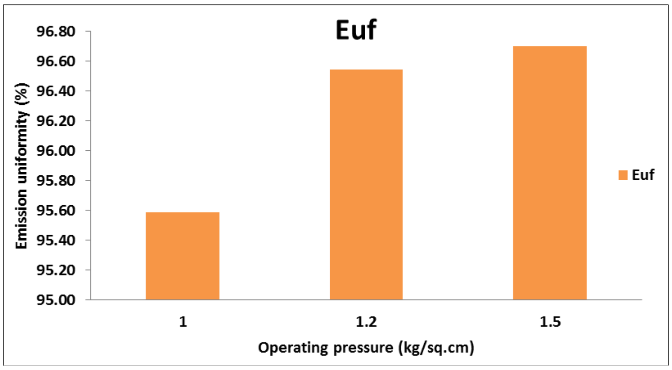

Fig 3: Emission uniformity under different operating pressure

Emitter flow variation (Q_{var})

Emitters flow variation, (Q_{var}) of drip irrigation system at different operating pressures are given in Table 4 and have been presented in Fig. 4. The emitter flow variation 7.8% was found minimum at 1.5 kg cm^{-2} operating pressure and maximum 18.57% at 1 kg cm^{-2} operating pressure and 12.5% at 1.2 kg cm^{-2} operating pressure. From the observed data it is clear that the emitter flow variation mostly depends on the performance of emitter under the field condition, if the ratio between minimum and maximum discharge value is more then it will give low emitter flow variation which will come under non- acceptable range. The results are in conformity with the findings of SAFI *et al.* (2007) [17], Deshmukh *et al.* (2014) [8], Sinha *et al.* (2018) [19] and Sinha *et al.* (2019) [20].

Table 4: Emitter flow variation under different operating pressure

S. No.	1	2	3
Emitter	2.4	2.4	2.4
Operating pressure (kg cm^{-2})	1	1.2	1.5
Emitter flow variation (%)	18.57	12.5	7.8
Classification	Acceptable	Acceptable	Desirable

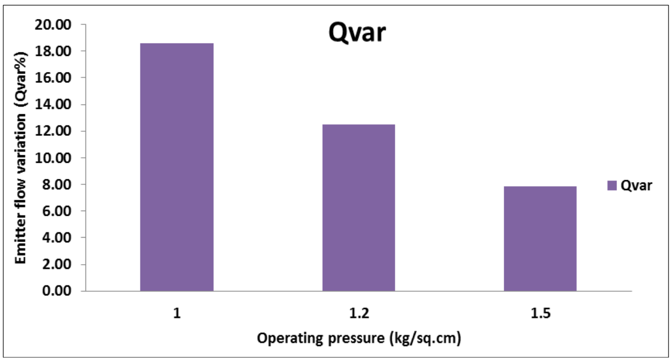

Fig 4: Emitter flow variation under different operating pressure

Effect of mulches on soil moisture content and soil moisture depletion

Average soil moisture content and soil moisture depletion with different types of mulches was measured at 5 cm soil depth and has been presented in Table 5 and fig. 5 in the form of bar diagram. Significantly maximum average soil moisture at 5 cm depth was recorded in BPM (27.89%) followed as SPM (27.38%), WFBM (26.97%), CBM (26.04%), RBM (25.42%), PSM (25.10), SM (22.38%) and WM (21.52%). Similarly soil moisture depletion was found minimum in BPM (0.31 mm) followed as SPM (0.53 mm), WFBM (0.71 mm), CBM (1.11mm), RBM (1.38 mm), PSM (1.52 mm), SM (2.70 mm) and WM (3.08 mm). The result revealed that soil moisture content at 5 cm depth was found maximum under black plastic mulch (BPM) and minimum under without mulch (WM) and soil moisture depletion minimum under black plastic mulch (BPM) and maximum under without mulch (WM). The results are in conformity with the findings of Deshmukh *et al.* (2013), Manisha (2015) [12], Sinha *et al.* (2018) [19] and Sinha *et al.* (2019) [20].

Table 5: Soil moisture content and soil moisture depletion under different types of mulches

S. No.	Treatment	MC at 5 cm Depth (%)	SMD (mm)
1.	BPM	27.89	0.31
2.	SPM	27.38	0.53
3.	WFBM	26.97	0.71
4	RBM	25.42	1.38
5.	CBM	26.04	1.11
6.	PSM	25.10	1.52
7.	SM	22.38	2.70
8.	WM	21.52	3.08

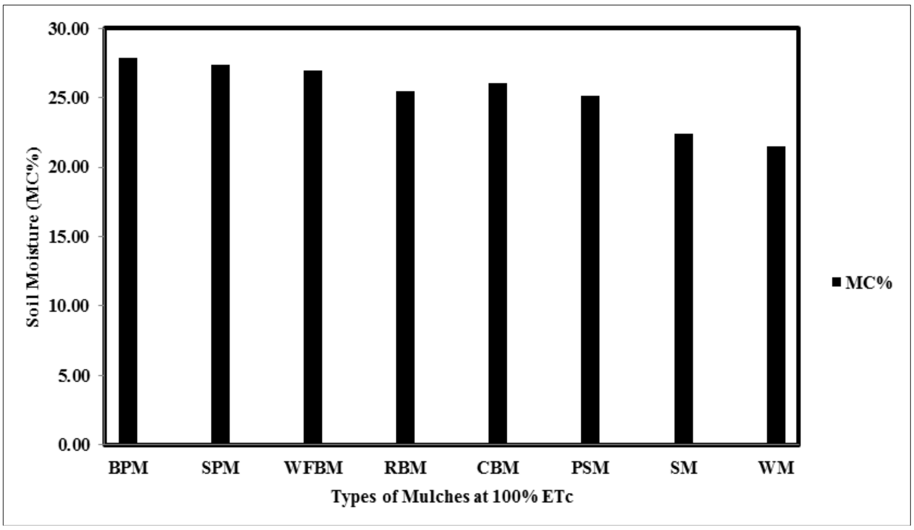

Fig 5: Soil moisture under different type of mulches at 5 cm depth

Effect of different types of mulches on soil temperature

Soil temperature was recorded at 7:30 AM and 2:00 PM from 17 December 2017 to 10 February 2018. The average soil temperature of growth period of onion at 5 and 10 cm depth has been presented in Table 6. From Fig. 6, it can be seen that at 7:30 AM the average soil temperature at 10 cm depth is higher as compared to 5 cm depth under all eight type of mulches. At the same time soil temperature has been found maximum under BPM followed by SPM, WFBM, CBM, RBM, PSM, SM and WM at 5 and 10 cm depth. Result revealed that during forenoon soil temperature decreases with decreasing depth. Increasing and decreasing trend of soil temperature under BPM depends on daily atmospheric temperature. Similar trend follows in the case of SPM, WFBM, CBM, RBM, PSM, SM and WM. Based on the recorded data at 2:00 PM the average soil temperature at 10 cm depth is lower as compared to 5 cm depth under all eight types of mulches. From fig 6, at the same time soil temperature has been found maximum under BPM followed by SPM, WFBM, CBM, RBM, SM, WM and PSM at 5 and 10 cm depth. The result revealed that at afternoon soil temperature decreases with increasing depth at 2:00 PM.

Table 6: Soil temperature under different types of mulches at 7:30AM and 2:00PM at 5 and 10 cm depth

Types of mulches	Soil Temperature (^{0}C)			
	7:30 AM		2:00 PM	
	5 cm	10 cm	5 cm	10 cm
BPM	17.0	17.8	27.5	25.1
SPM	16.8	17.5	26.8	24.6
WFBM	16.5	17.4	26.4	24.4
RBM	16.2	17.0	25.0	23.6
CBM	16.3	17.2	25.8	24.1
PSM	16.0	16.8	23.6	22.4
SM	15.7	16.6	24.6	23.2
WM (Control)	15.5	16.4	24.2	22.9

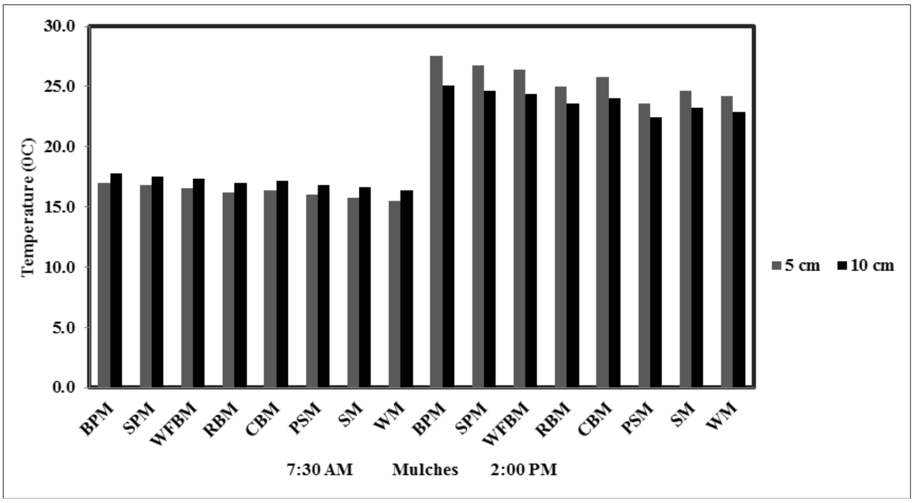

Fig 6: Mean soil temperature under different mulches at 7:30 AM and 2:00 PM at 5 cm and 10 cm depth

Conclusion

The uniformity coefficient and emission uniformity increased while co-efficient of variation decreased as operating pressure increased for drippers. Study of hydraulic performance of drip irrigation system will be helpful for deciding operating pressure, lateral, emitter and plant spacing along with duration of irrigation through an emitter of known discharge. Hydraulic performance of drip irrigation system was found good and needs to be operated at 1.2-1.5 kg cm^{-2} pressure for 2.4 l h^{-1} inline emitter. Wheat flour bag mulch, rice bag mulch and cement bag mulch are cheaper than the other used plastic mulching materials and easy in preparation. The study concludes that mulching roll can be prepared from used rice bags, fertilizer bags, wheat flour bag etc. which are available with the farmers in plenty and can be reused as mulching material satisfactorily by small and marginal farmers.

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