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Comparative Effect of Different Mulches on Structural and Hydraulic Properties of Soil under Nectarine

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Abstract

A field study was conducted at the research farm of the Department of Soil Science and Water Management, Nauni, Solan to study the effect of different mulches on structural and hydraulic properties of soil under Nectarine cv. Silver King". Application of different mulch treatments viz. No Mulch (UM), Grass Mulch (GM), Black polythene Mulch (BP), Pine Needle Mulch (PM), Transparent polythene Mulch (TM), Silver polythene Mulch (SM) and Mulch Mat (MM) resulted in significant changes in soil properties at 0-7.5 and 7.5- 15 cm depths. The bulk density (ρ_b) was lowest (1.27 and 1.29 Mg m^{-3}) and total porosity (*f*) was highest (51.96 and 50.57 %) under GM at 0-7.5 and 7.5-15 cm soil depth, respectively. The highest proportion of WSA >0.25 mm (67.20 and 63.90 %) was recorded under T_2 -GM and the lowest (60.77 and 58.83%) was observed under T_3 –BP, in 0-7.5 and 7.5-15.0 cm soil depth, respectively. The highest mean weight diameter (MWD) of soil aggregates (2.25 mm and 2.23 mm) was found in T_3 (BP) at both 0-7.5 cm and 7.5-15 cm soil depth, respectively. Highest saturated hydraulic conductivity (*Ks*) was recorded under T_2 -GM (4.45 cm hr^{-1}), and lowest *Ks* was observed under T_3 -BP (3.50 cm hr^{-1}). Among all the different mulch treatments, black polythene mulch (BP) mulch was found superior in conserving soil moisture as compared to all other treatments at both the soil depths. The highest soil moisture content, *w* during the cropping season under treatment T_3 (BP) at 0-7.5 and 7.5-15 cm ranged between 16.7-19.7 and 18.0-20.8% with mean values of 18.0 and 19.1%, respectively, followed by treatment T_7 (MM) with *w* ranging from 16.4-19.7 and 17.7-20.8% with mean values of 17.8 and 18.9%, respectively. The lowest *w* was recorded under the T_1 (UM), which ranged between 13.7-16.1 and 16.0-18.6% with average value of 15.4 and 17.5% at 0-7.5 and 7.5-15 cm soil depth, respectively. Highest values for maximum water holding capacity (MWHC), field capacity (FC) and permanent wilting point (PWP) were recorded under T_2 (GM).

Keywords: MWD, plant available water, soil bulk density, total porosity, water stable aggregates

1. Introduction

Nectarine (*Prunus persica* L. Batsch var. *nucipersica* cv. Silver King), a mutant of peach with a smooth skin (fuzz-less peach), has become popular stone fruit over the last few years. Warm temperate zones of Europe, North America, South Africa, Asia and Australia are principal nectarine producing regions in world. Separate data for area and production of nectarine is not available. In India, peaches and nectarines are grown commercially in Uttrakhand, Punjab, Himachal Pradesh, Jammu and Kashmir, and hills of North East and South India. Area and production of the crop in the country is 38.3 thousand hectare and 270.5 thousand MT, respectively (FAO, 2020). In Himachal Pradesh, peach and nectarine occupies an area of 5.08 thousand hectare with annual production of 8.05 thousand tones (Department of Horticulture, 2016). Over the last decade, the cultivation of nectarine has gained popularity in mid hills of Himachal Pradesh, particularly in the districts of Solan, Kullu and Sirmour due to its attractive appearance and better remuneration in comparison to peaches.

However, the crop has been mostly established under rainfed ecosystem, which is characterized by undulating hill slopes, undulating agriculture fields, gravely coarse textured soils with poor moisture and nutrient retention capacity, and erratic rainfall pattern. Water stress during the pre and post monsoon periods is of common occurrence. The uneven distribution of rains with common dry spells in winter season, occurrence of sub-optimal soil temperature and poor retentively of hill soils for water and nutrients are the major constraints affecting the yield and quality of the crop. Further, the changing rainfall patterns and rise in temperatures in the recent past are causing soil degradation and increased crop water stress.

Soil temperature and moisture are two major components of soil hydrothermal regimes, which control various root functions such as nutrient uptake and water absorption.

These also affect other physical, chemical and biological reactions involved in the growth and development of plant. Moderation of soil hydrothermal regimes through mulches could enhance the plant growth and crop yields. In-situ soil moisture conservation through mulches can thus be very helpful in increasing crop productivity, arresting the soil degradation, sustaining soil health, mitigating the effects climate change and improving the socio-economic status of the farmers. Bhardwaj (2013) studied the effect of mulches on crop production in rainfed conditions and observed that mulching played an important role in moisture conservation and maintaining soil temperature. Organic mulches are efficient in improving soil physical properties, prevent erosion, supply organic matter, moderate the hydrothermal regimes, enhance water productivity, take part in nutrient cycle as well as increase the biological activity (Pervaiz et al., 2009; Bhardwaj, 2013). Plastic mulches have been reported to moderate soil temperature, conserve moisture and weed control in a range of crops (Sharma and Kathiravan, 2009; Bhardwaj, 2013; Negi, 2015; Wang et al., 2015). Mulching also play an important role in weed control and thus conserve the soil nutrients that are otherwise taken up by the weeds.

Studies have been carried out on the effect of mulching under stone fruits like plum and apricot in Himachal (Singh et al., 2004; Sharma and Kathiravan, 2009; Bindra, 2010). However, not much has been documented on the effect of different mulches on soil physical properties under nectarine. Thus, the present study was conducted to evaluate the effect of different mulches on the structural and hydraulic properties of soil.

2. Materials and Methods

2.1. Study site

The study was conducted during 2017 at the experimental farm (30˚08'50" latitude and 70˚08'50'' longitude) of the Department of Soil Science and Water Management, Dr. Y.S Parmar University of Horticulture and Forestry, Nauni, Solan (HP). The site is located at an elevation of 1175 m above mean sea level, and lies in sub-temperate, sub humid agro-climatic zone of Himachal Pradesh. The area receives average annual rainfall of about 1100 mm, and 75% of this occurs during the monsoon period (mid June- mid September). Winter rains are meager and received during the months of January and February. The rainfall, evaporation and relative humidity during the cropping season is given in Figure 1.

The soils of the experimental site are loam in texture and neutral in reaction (pH 6.7). Organic carbon, available N, P and K in surface layer were 18.4 g kg^{-1}, 303, 43 and 312 kg ha^{-1}, respectively. The values of bulk density, porosity and water stable aggregates (WSA) >0.25 mm were 1.25 Mg m^{-3}, 49.8% and 60.8%, respectively.

2.2. Experimental details

Healthy plants (6 year old) of Nectarine (*Prunus persica* L. Batsch var *nucipersica* cv. Silver king) were selected for the

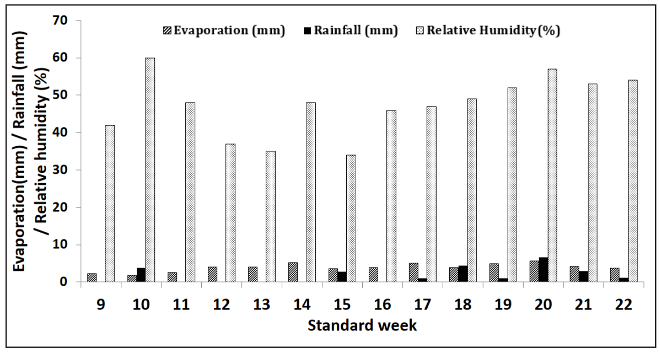

Figure 1: Rainfall, evaporation and relative humidity during the cropping season

study. The experiment was laid out in a completely randomized block design (CRBD) with seven treatments (each replicated thrice) viz. T_1- no mulch (UM), T_2- grass mulch (10-12 cm) (GM), T_3- black polythene mulch (100 µ) (BP), T_4- pine needle mulch (10-12 cm) (PM), T_5- transparent polythene mulch (TM), T_6- silver polythene mulch (SM), and T_7- nylon mulch mat (90 GSM) (MM).

Representative soil samples from 0-7.5 cm and 7.5-15 cm depths were collected as per standard procedures at the end of experiment and soil properties viz. bulk density (ρ_b) - core sampler method (Grossman and Reinsch, 2002), total porosity (*f*) (Flint and Flint, 2002), water stable aggregates (WSA>0.25 mm) and mean weight diameter (MWD) - wet sieving method (Yoder, 1936), saturated hydraulic conductivity (K_s) - Constant head method (Singh, 1980), maximum water holding capacity (MWHC) – Keen Raczkowski box method (Singh, 1980), soil moisture retention - pressure plate apparatus (Richards, 1947) were determined. Soil moisture was also determined at fortnightly intervals during the cropping season.

2.3. Statistical analysis

The data on various parameters generated during the study was subjected to standard analysis of variance (ANOVA) of completely randomized block design (Gomez and Gomez, 1984) to test for statistically significant differences among different treatments using a general linear model in the statistical software R (R Core Team, 2013). Post-hoc multiple comparison analysis was done to separate the treatment effects using the *F*-test at the probability level (*P*) of 0.05.

3. Results and Discussion

3.1. Effect of mulches on soil structural properties

Perusal of the data in Table 1 shows significant effect of various mulches on ρ_b, WSA>0.25 mm and MWD at both depths (0-7.5 and 7.5 -15.0 cm). In the 0-7.5 cm soil layer, highest ρ_b (1.30 Mg m^{-3}) was recorded under T_3 (BP), whereas, lowest value (1.27 Mg m^{-3}) was recorded under T_2 (GM). Similarly, at 7.5-15 cm depth, the highest ρ_b (1.32 Mg m^{-3}) was recorded under T_3 (BP) and T_1 (UM) and lowest value (1.29 Mg m^{-3}) was recorded under T_2 (GM) and T_4 (PM). This could be ascribed

Table 1: Effect of different mulches on bulk density (ρb), WSA>0.25 mm and MWD

Treatments	ρ_b (Mg m^{-3})		WSA >0.25 mm (%)		MWD (mm)	
	0-7.5 cm	7.5-15 cm	0-7.5 cm	7.5-15 cm	0-7.5 cm	7.5-15 cm
T_1 (UM)	1.29	1.32	61.83	59.50	2.11	2.11
T_2 (GM)	1.27	1.29	67.20	63.90	2.25	2.23
T_3 (BP)	1.30	1.32	60.77	58.83	2.08	2.07
T_4 (PM)	1.28	1.29	65.10	62.50	2.21	2.19
T_5 (TM)	1.28	1.30	63.63	61.43	2.16	2.15
T_6 (SM)	1.29	1.30	62.30	59.63	2.13	2.12
T_7 (MM)	1.29	1.31	63.17	60.93	2.16	2.14
SEm±	0.01	0.01	0.89	0.69	0.02	0.02
CD (p=0.05)	0.03	0.03	1.94	1.51	0.04	0.05

to enhanced biological activity and addition of organic matter under GM and PM. Decrease in ρ_b under organic mulches has been reported in literature (Lal, 1978; Lal et al., 1980), and a number of scholars have shown a strong correlation between bulk density and organic matter (Sakin, et al., 2011; Chaudhari et al., 2013). Our findings are in line with these studies, and as organic matter increased, bulk density decreased.

The highest proportion of WSA >0.25 mm (67.20 %) in 0-7.5 cm soil depth was recorded under T_2 -GM and the lowest (60.77 %) was observed under T_3 –BP, which was statistically at par with T_1-UM (61.83 %) and T_6 -SM (62.30 %). In 7.5-15 cm depth, the highest value was observed under T_2 -GM (63.90 %), which was statistically at par with T_4-PM (62.50 %). However, significantly lowest value of WSA was found under T_3-BP (58.83%), which was statistically at par with under T_1-UM (59.50 %) and T_6 -SM (59.63 %). The data showed significant effect of mulches on MWD at both soil depths. In 0-7.5 cm soil depth, the highest MWD was recorded under T_2 -GM (2.25 mm), which was statistically at par with T_4-PM (2.21 mm) and significantly lowest MWD was recorded under T_3 -BP (2.08 mm), which was statistically at par with T_1-UM (2.11 mm). The similar results were found at 7.5-15 cm depth. Significantly highest MWD was recorded under T_2 -GM (2.23 mm), which was statistically at par with T_4 (PM) (2.19 mm) and significantly lowest MWD was recorded under T_3 (BP) (2.07 mm), which was statistically at par with T_1 (UM) with value of 2.11 mm.

The data presented in Table 2 showed significant effect of mulches on *f* (%) of soil at both 0-7.5 and 7.5-15 cm depths. The data revealed that in 0-7.5 cm depth, significantly highest *f* was recorded under T_2 (GM) i.e 51.96% which was statistically at par to T_4 (PM) i.e 51.27% and T_5 (TM) i.e 51.40%, and lowest *f* was recorded under T_3-BP (49.87%), which was found statistically at par with T_1 -UM (50.13%), T_6 -SM (50.19%) and T_7 -MM (50.58%). Similarly, in 7.5-15 cm depth, highest *f* was recorded under T_2 -GM (50.57 %), which was found statistically at par with T_4 -PM (50.13%), T_5 -TM (50.35%) and T_6 -SM (49.28%), and lowest *f* was recorded under T_3-BP (47.90%), which was found statistically at par with T_1 (UM) (48.03%), T_6 (SM) (49.28%) and T_7 (MM) (48.96%). The higher porosity under GM can be attributed to higher organic carbon content, low bulk density and improved soil aggregation (Sharma et al., 1992). The improvement in soil organic matter, structure and porosity could have led to the subsequent improvement in bulk density over time. These results are in line with those of Chaudhari et al. (2013) and Nwokocha et al. (2007) who found that porosity and bulk density depended on soil organic matter, and improved over time due to organic mulches.

Table 2: Effect of different mulches on total porosity (f), and saturated hydraulic conductivity (K_s)

Treatments	f (%)		K_s (cm h^{-1})	
	0-7.5 cm	7.5-15 cm	0-7.5 cm	7.5-15 cm
T_1 (UM)	50.13	48.03	3.91	3.84
T_2 (GM)	51.96	50.57	4.45	4.43
T_3 (BP)	49.87	47.90	3.50	3.63
T_4 (PM)	51.27	50.13	4.33	4.28
T_5 (TM)	51.40	49.35	4.25	4.28
T_6 (SM)	50.19	49.28	4.04	4.00
T_7 (MM)	50.58	48.96	4.15	4.11
SEm±	0.41	0.63	0.14	0.08
CD (p=0.05)	0.90	1.38	0.31	0.17

3.2. *Effect of mulches on hydraulic properties of soil*

The data showed significant effect of mulches on *Ks* at both the soil depths (Table 2). It is evident from data that in 0-7.5 cm soil depth, significantly higher *Ks* was recorded under T_2 -GM (4.45 cm hr^{-1}) which was statistically at par with T_7 -MM (4.15 cm hr^{-1}), T_5 -TM (4.25 cm hr^{-1}) and T_4 -PM (4.33 cm hr^{-1}) whereas, lowest *Ks* was observed under T_3 -BP (3.50 cm hr^{-1}). Similarly at 7.5-15 cm depth, highest *Ks* was observed under T_2-GM (4.43 cm hr^{-1}), which was statistically at par with both T_4-PM and T_5 -TM (4.28 cm hr^{-1}). Lowest *Ks* was found under T_3-BP (3.63 cm hr^{-1}). This indicates favorable effect of organic mulches (GM and PM) and can attributed to improvement in the soil structure and porosity in comparison with UM (Bhagat and Acharya, 1987; Nwokocha et al., 2007). Mulching increased the soil porosity, which in turn led to significant improvement in the *Ks*. The larger the *f* more is the transmission of water through the soils.

The changes in soil moisture content (*w*) (w/w, %) during the cropping season recorded at 15 days interval from March to May at 0-7.5 and 7.5-15 cm soil depths are presented in figure 2. Appraisal of the data revealed that all mulching treatments increased the *w* over the control T_1 (UM). T_3 (BP) maintained the highest *w* throughout the cropping season over other

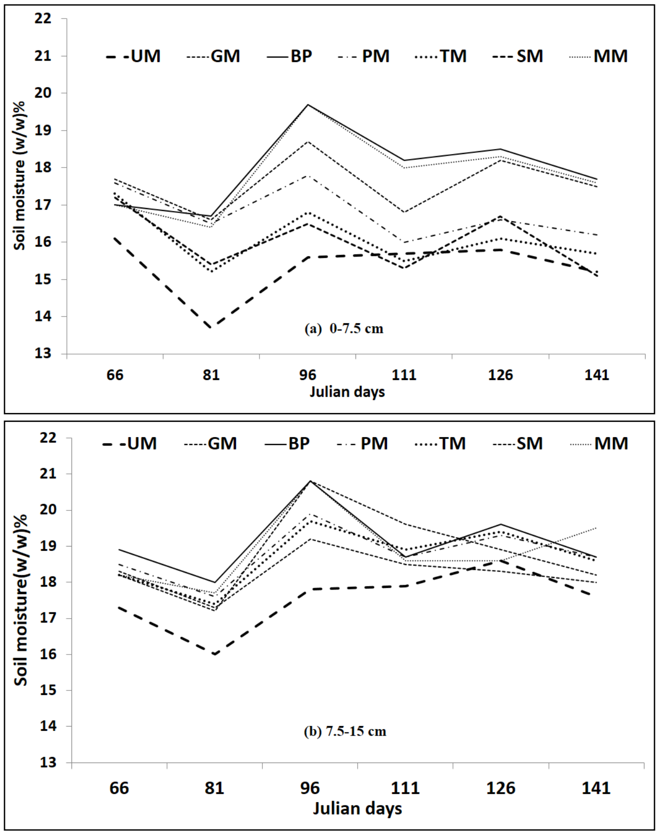

Figure 2: Soil moisture content at (a) 0-7.5 cm and (b) 7.5- 15 cm depths under different mulches

treatments. The highest *w* under treatment T_3 (BP) at 0-7.5 and 7.5-15 cm ranged between 16.7-19.7 and 18.0-20.8% with mean values of 18.0 and 19.1%, respectively, followed by treatment T_7 (MM) with *w* ranging from 16.4-19.7 and 17.7-20.8% with mean values of 17.8 and 18.9%, respectively. Similarly, the *w* under T_2 (GM) ranged between 16.6-18.7 and 17.2-20.8% with mean values of 17.6 and 18.8%, respectively. The lowest *w* was recorded under the T_1 (UM), which ranged between 13.7-16.1 and 16.0-18.6% with average value of 15.4 and 17.5% at 0-7.5 and 7.5-15 cm soil depth, respectively. Conservation of soil moisture is essential for profitable crop production under rainfed crop production. All mulches maintained higher *w* in comparison to no mulch. At 0-7.5 and 7.5-15 cm soil depth, T_3 (BP) maintained 17.0 and 9.0% higher *w* over T_1 (UM). The higher *w* under all mulching treatments was due to shading effect, which prevents evaporation of soil moisture from soil surface and reduce vapor diffusion to the atmosphere. Among, different mulches comparatively higher soil moisture content under T_3 (BP) may be due to efficient weed control and the fact that water after evaporation condense on the bottom side of polythene sheet and drips down again on the soil surface. Similar findings have been reported by several researchers (Sharma and Kathiravan, 2009, Kumar et al., 1990, Chandel et al., 2010, Walsh et al., 1996 and Renquist et al., 1982), who reported comparatively higher soil moisture contents in different mulches over unmulched trees.

Table 3 and 4 shows the effect of mulches on MWHC, field capacity (FC), permanent wilting point (PWP) and plant available water content (PAWC) at both soil depths on gravimetric and volumetric basis, respectively. The data on volumetric basis (v/v, %) (Table 4) is described here due to its more practical significance. A perusal of data showed significant effect of mulches on MWHC at both soil depths. In 0-7.5 cm soil depth, significantly highest MWHC was recorded under T_2 (GM) (57.77%) and lowest was observed under T_1 (UM) (53.40%). While, at 7.5-15 cm depth significantly highest value was observed under T_3 (BP) (56.19%) and lowest was found under T_6 (SM) (53.67 %). The highest value of FC was recorded under T_2 (GM) (30.03%), which was statistically at par with T_5 (TM) (29.07%) and T_4 (PM) (29.66 %) whereas, lowest value of FC was observed under T_3 (BP) (26.74%), which was statistically at par with T_1 (UM) (27.71%) and T_6 (SM) (28.18%). In 7.5-15 cm depth, highest FC was observed under T_2 (GM) (30.14%), which was statistically at par with T_4 (PM) (29.56%), and T_5 (TM) (29.54%). However, lowest value of FC was found under T_3 (BP) (26.76%), which was statistically at par with T_1 (UM) (27.81%) and T_6 (SM) (27.80%). The effect of different treatments was statistically non significant on PWP

Table 3: Effect of different mulches on MWHC, FC, PWP and PAWC (w/w, %)

Treatments	MWHC		FC		PWP		PAWC	
	0-7.5 cm	7.5-15 cm	0-7.5 cm	7.5-15 cm	0-7.5 cm	7.5-15 cm	0-7.5 cm	7.5-15 cm
T_1 (UM)	41.39	41.86	21.48	21.07	6.95	6.70	14.53	14.37
T_2 (GM)	45.61	43.23	23.71	23.42	7.47	7.22	16.23	16.20
T_3 (BP)	42.46	42.46	20.57	20.22	6.67	6.42	13.90	13.80
T_4 (PM)	44.45	43.09	23.17	22.92	7.37	7.12	15.80	15.80
T_5 (TM)	44.03	42.91	22.77	22.72	7.24	6.99	15.53	15.73
T_6 (SM)	43.72	41.39	21.79	21.44	6.96	6.71	14.83	14.73
T_7 (MM)	43.49	41.27	21.80	21.61	6.96	6.71	14.83	14.90
SEm±	0.46	0.28	0.44	0.41	0.24	0.24	0.37	0.39
CD (p=0.05)	1.00	0.60	0.97	0.89	NS	NS	0.80	0.84

Table 4: Effect of different mulches on MWHC, FC, PWP and PAWC (v/v, %)

Treatments	MWHC		FC		PWP		PAWC	
	0-7.5 cm	7.5-15 cm	0-7.5 cm	7.5-15 cm	0-7.5 cm	7.5-15 cm	0-7.5 cm	7.5-15 cm
T_1 (UM)	53.40	54.69	27.71	27.81	8.97	8.84	18.75	18.96
T_2 (GM)	57.77	55.63	30.03	30.14	9.47	9.29	20.57	20.85
T_3 (BP)	55.20	56.19	26.74	26.76	8.67	8.49	18.07	18.27
T_4 (PM)	56.89	55.58	29.66	29.46	9.43	9.18	20.23	20.38
T_5 (TM)	56.21	55.78	29.07	29.54	9.24	9.08	19.83	20.45
T_6 (SM)	56.56	53.67	28.18	27.80	9.00	8.69	19.19	19.10
T_7 (MM)	55.95	54.48	28.04	28.25	8.96	8.77	19.08	19.48
SEm±	0.96	0.67	0.67	0.65	0.31	0.31	0.55	0.59
CD (p=0.05)	2.09	1.46	1.45	1.42	NS	NS	1.19	1.28

at both soil depths. Mulching treatments showed significant differences w.r.t. PAWC at both soil depths (Table 4). In 0-7.5 cm soil depth, highest value of PAWC was recorded under T_2 (GM) (20.57%), which was statistically at par with T_4 (PM) (20.23%) and under T_5 (TM) (19.83%), and lowest PAWC was observed under T_3 (BP) (18.07%) which was statistically at par with T_1 (UM) (18.75%) and T_6 (SM) (19.19%). While in 7.5-15 cm depth, highest value was observed under T_2 (GM) (20.85%), which was statistically at par with T_4 (PM) (20.38%) and T_5 (TM) (20.45%), and lowest value of PAWC was found under T_3 (BP) (18.27%). The results are in accordance with the finding of Rasyid et al. (2018), who studied changes in soil water retention under different mulches. They reported that mesh mulch had the highest water retention on lower suction, and control had the lowest water retention on the high suction. Soil water availability was highest in mesh mulch type followed by control and poly mulch type. This study could conclude that continuous incorporation of organic matter was useful in increasing soil water retention.

4. Conclusion

Application of different mulch treatments had significant effect on the structural and hydraulic properties of soil at both 0-7.5 and 7.5- 15 cm depths as compared to no mulch treatment. The organic mulches line GM and PM, showed most favourable effect on the bulk density, aggregate stability, total soil porosity and saturated hydraulic conductivity. The higher porosity (51.96 and 50.57%) was found under GM, which may be due to low bulk density (1.27 and 1.29 Mg m^{-3}) and improved soil aggregation. At lower suction (MWHC and FC), organic mulches recorded higher moisture content, but there was no significant effect on moisture content at higher suction (PWP). Among all the different mulch treatments, black polythene mulch (BP) was found superior in conserving soil moisture as compared to all other treatments. The highest w under treatment BP at 0-7.5 and 7.5-15 cm ranged between 16.7-19.7 and 18.0-20.8% with mean values of 18.0 and 19.1%, respectively, followed by treatment T_7 (MM) with w ranging from 16.4-19.7 and 17.7-20.8% with mean values of 17.8 and 18.9%, respectively.

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