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EVALUATION OF PLASTIC MULCH FOR CHANGES IN MECHANICAL PROPERTIES DURING ONION CULTIVATION

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Abstract: The use of plastic materials for mulching is a very common practice for horticultural crops. Black polyethylene is widely used due to its excellent properties and low cost. An experiment was conducted to ascertain the effect of different types of black polyethylene mulches of varying thickness for its mechanical properties during crop growing period under onion. Changes in tensile strength, elongation at break and tear resistance varied from 24.17 % to 74.82 %, 30.18% to 78.21 % and 19.45 to 60.68 % respectively within different thickness of plastic mulch during the entire duration of the crop. Poly-mulch made of recycled material (50 µm) underwent early deterioration which ultimately affected yield and growth of the crop. Other mulches remained functional during use, although its impact on soil compaction, soil temperature and soil moisture availability differed in narrow range but was certainly more conducive for crop development compared to non mulched plots.

Keywords: Poly ethylene mulch, drip irrigation, tensile properties, water use efficiency.

Introduction

Onion, *Allium cepa* L, is a biennial herb with a characteristic smell. The leaves are tubular and the bulbs are formed by the attachment of swollen leaf bases to underground part of stem which is small and rudimentary. The area under onion has increased in Rajasthan in last few years from 49,000 ha in 2010-11 to 1,39,050 ha in 2012-13 (NHB, 2013). It is a predominantly a rabi season crop. Most of the onion sown in southern part of Rajasthan is sown as rabi crop. Onions are naturally packaged vegetables consisting of fleshy, concentric scales which are enclosed in paper like wrapping leaves, connected at the base by a flattened stem disc. Onions are used as spices, condiments and vegetables almost daily in every kitchen as a seasoning for wide varieties of dishes.

Mulching is the process or practice of covering the soil to make more favorable condition for plant growth, development and efficient crop production. When compared to other mulches, plastic mulches are impermeable to water, it therefore prevents direct evaporation of moisture

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from the soil and thus limits the water loss and soil erosion over the surface. Wide ranges of plastic film based on different types of polymers have all been tried since 1960s. Owing to its greater permeability to long wave radiation, which can increase the temperature around plants during the night times, polyethylene is preferred. Today, the vast majority of plastic mulch is based on low density polyethylene. It is of paramount interest to have the right specification of mulch in terms of thickness and colour. The lifetime of plastic mulching films is reduced owing to their prolonged exposure to climatic agents such as solar radiation, high air temperature and high relative humidity and by chemical products used during crop cycle. As a consequence, plastic mulch can be used only for one or two cultivation periods and with varying degree of mechanical strength due to degradation. Agricultural films should meet a set of minimum design requirements, including adequate strength and elongation at break for mechanical installation. (Briassoulis, 2004).

The soil temperature under plastic mulch depends on the thermal properties of a particular material in relation to the incoming solar radiation (Schales and Sheldrakes, 1963). The degree of contact between the mulch and the soil also affects soil warming. The better contact the mulch has with the soil, the more effective the warming properties of the mulch (Lamont, 1996). There are three primary non degradable mulch types used commercially in the production of vegetable crops black, clear and the group of white on black and silver/aluminum reflective mulch. Black, silver on black polyethylene is the most popular because of benefit of moderating the temperature according to climatic condition, in addition to its low cost. This can be used in all the crops in general.

Materials and Method

Site Description

A field experiment was conducted during 2014-15 at Plasticulture farm, College of Technology and Engineering, Maharana Pratap University of Agriculture and Technology, Udaipur. Geographically, Udaipur is located at 24° 35 N latitude and 73° 44 E longitude. The altitude of the site is 582.17 m above mean sea level. The area has a sub-humid climate.

Experimental details

Six treatments comprising five poly-mulches (black) of different thickness (M_1-20µm, M_2-25µm, M_3-30µm, M_4-35µm and M_5-50µm-recycled) was compared with control (M_0-no mulch) in a randomized block design with four replications for understanding the changes attained in its mechanical properties with the duration in the field.

The seeds of onion variety Agri-Found Dark Red (AFDR) were sown directly in nursery beds of size 1m x 3m keeping the seed rate 10 kg /ha. Vermi compost @ 1.5 kg/m^2 was added and mixed with soil media. The seed was sown in lines of 10cm apart in raised beds on 10th October 2014. Light watering was done on alternate day to provide sufficient moisture in raised bed for proper germination and vegetative growth. 49 days old seedlings were transplanted in different treatments on raised bed under gravity fed drip irrigation.

The recommended fertilizer dose of 100:50:100 NPK kg/ha were given to all treatments. The entire quantity of phosphorus and potash was applied as basal dose at the time of final field preparation in the form of di-ammonium phosphate and muriate of potash. Whereas, 50% nitrogen was applied at the time of final field preparation and the rest was administered through drip fertigation in two equal splits at 30 and 45 days after transplanting.

Testing of Mechanical Properties of Plastic mulches

Testing of critical initial physical and mechanical properties of the films were carried out in terms of average thickness, tensile properties, elongation at break and tear resistance. Test procedure followed were IS 2508(1984) for tensile strength measurements and IS 13360-5-23(1996) for tear resistance. Test specimen for tensile property determinations were of dimension 25mm x 150mm and 50 mm radii half circle for tear tests. Tensile strength, elongation at break along Machine Direction (MD) and Transverse Direction (TD) of test specimen were conducted on a Universal Testing Machine (UTM). Tear resistance was tested in Elmendorf (pendulum type) tear tester. Mulch specimen at fixed time interval during the course of field exposure under onion crop were collected. Test specimen of mulch film from the mulch bed was collected following standard procedure for its tensile strength, elongation at break and tear resistance at an interval of 30 days after exposure on the field till harvest of the crop. Testing was done for fresh film, 30 Days After Transplanting (DAT), 60 DAT samples, 90 DAT and 120 DAT.

Irrigation Water Application

The amount of water to be applied through drip irrigation was based on depletion of moisture upto 25% of available moisture content (ASM). Soil moisture status was constantly recorded at 10 cm, 20 cm and 30 cm soil depths through soil moisture probes and gravimetric method.

Determination of Plant physiological Parameters and other parameters

Plant growth parameters were observed at 30 DAT, 60 DAT and 90 DAT and yield data were recorded at the time of harvest. Other data recorded were maximum and minimum soil temperature at 5 and 10 cm depths. Impact of mulch on soil compaction was measured with cone penetrometer at 60 days and 120 days after transplanting.

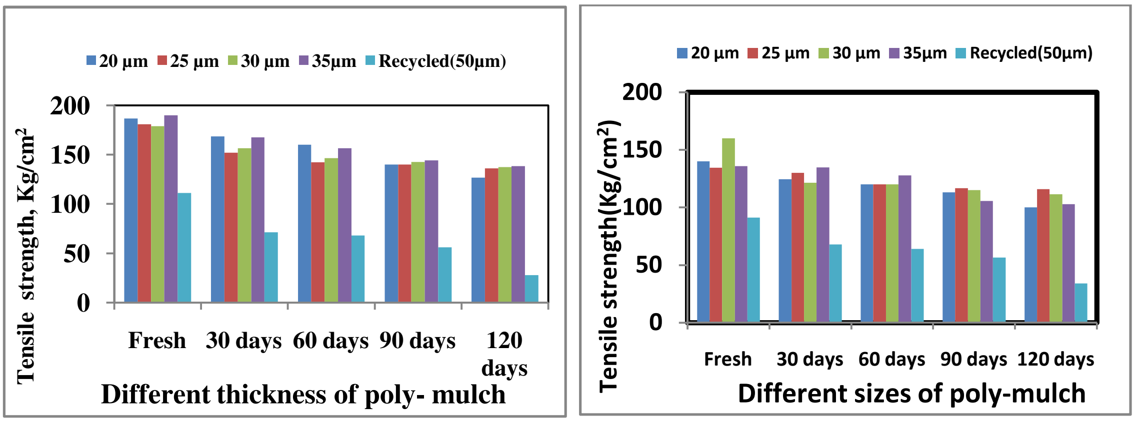
Results and Discussion

Mechanical Properties of Plastic Mulch with duration in field

Tensile properties is one of the main parameters which decides the longevity of a plastic film. These films due to its prolonged exposure to solar radiation, heat, humidity and other factors tend to losen its tensile strength and other mechanical properties like tear resistance, opacity, density and thickness. Global degradation i.e. degradation of the film irrespective of the factors, combinations, conditions and mechanism of degradation can be roughly evaluated from loss of mechanical strength. The mechanical properties those may be measured for ascertaining it are elongation at break, tensile strength, modulus of elasticity and tear resistance (Briassoulis and Aristopoulou, 2001). The values obtained regarding mechanical properties and its changes during the crop cycle can be a measure to understand the right thickness of mulch and it can form the basis for a decision for reuse of the same mulch for using in subsequent season.

Tensile Strength

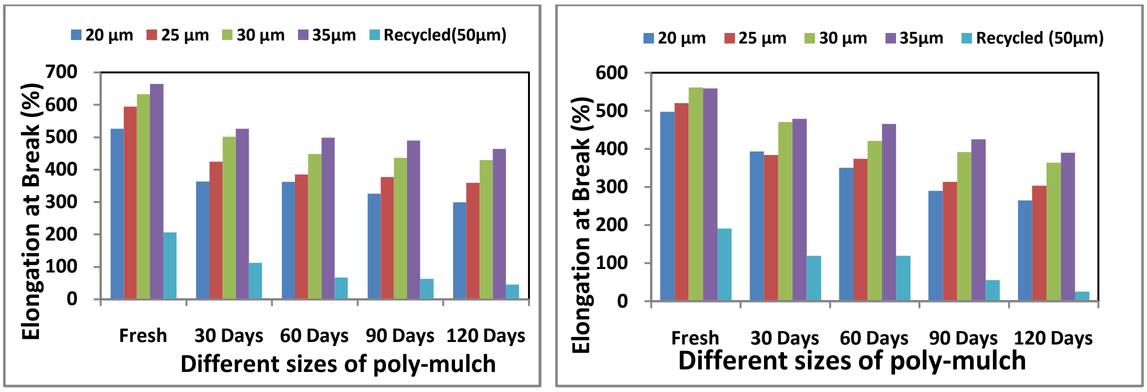
Tensile strength which is the force applied at any given moment to the area of original cross section (expressed in kg/cm^2) initially ranged between 178.9 to 190 kg/cm^2 for treatments M_1, M_2, M_3 and M_4. Tensile strength as prescribed by IS-2508 for Low Density Polyethylene (LDPE) should by more than 120Kg/cm^2 along machine direction. Initial tensile strength value along machine direction of the film for recycled mulch it was 111.2 kg/cm^2. Tensile strength of plastic material had a decreasing trend during duration of its exposure in the field under onion crop. The decrease was seen to be more pronounced in all treatments after first month of exposure. The reason for this can be attributed to the fact that during first month, the film was more exposed to solar radiation as vegetative growth of onion was less.



a) b)

Figure 1: Tensile Strength of poly-mulches of different thickness in a) machine direction and b) Transverse direction under onion crop

In machine direction of the films, tensile strength of M_4 (35 µm mulch), M_3(30 µm mulch), M_2(25 µm mulch), M_1(20 µm mulch) came down to 138.5 Kg/cm^2, 137.4 kg/cm^2, 136.3 kg/cm^2, 126.60 kg/cm^2 respectively after 120 days from 190.0 kg/cm^2, 178.9 kg/cm^2, 180.8 kg/cm^2 and 186.8 kg/cm^2 respectively of the initial value. However, in M_5 (recycled mulch, 50 µm) the evolution of tensile strength was from 111.2 kg/cm^2 (initial value) to 28.0 kg/cm^2 in 120 days. Similar trend was also observed along transverse direction of the film.

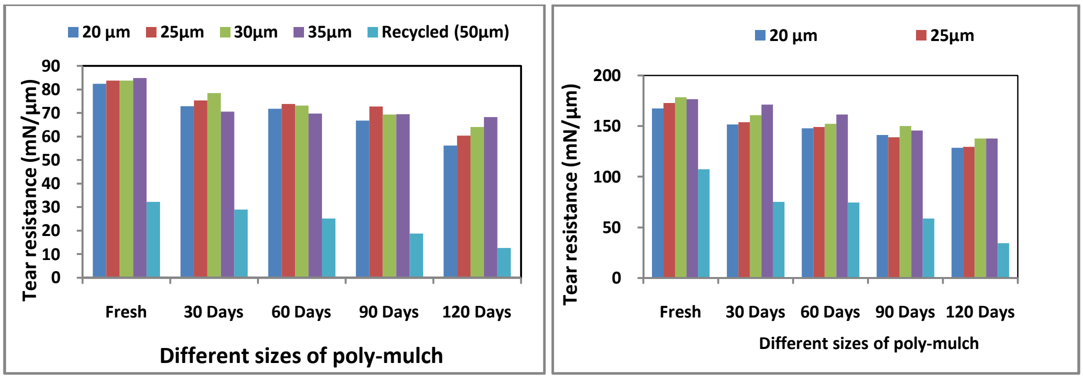


a) **b)**

Fig. 2: Elongation at break of poly-mulches of different thickness in a) machine direction and b) transverse direction under onion crop

Elongation at break

Elongation at break is the strain produced due to the force applied in the test piece expressed usually as a percentage of the original guage length of the test specimen. Reductions in elongation at break values were in the range of 30.18 to 78.21 percent after 120 days of exposure under onion crop in different mulches along machine direction of the film. Highest reduction was seen in mulch M_5 (recycled poly mulch) where reduction was upto the tune of 70.21%. Lowest reduction of this parameter was seen in treatment M_4 (35 µm film) followed by M_3 (30 µm film) and M_2 (25 µm film). Almost similar pattern was also observed along transverse direction of the film where the elongation at break values reduced from 30.25 % (M_4) to 80.89 % (M_5). The reduction was more pronounced after 30 days of exposure across all treatments. The highest value of elongation at break was found in mulch M_4 (664.6%) followed by mulch M_3(632.6%) and the lowest value of elongation at break was found out to be for mulch M_5(206.6%). These values conformed to IS- 2508-84 standards, which prescribes a minimum elongation at break for LDPE of thickness ranging from 12.5 – 75 µm should be more than 200% and 300% along MD and TD respectively.



a) b)

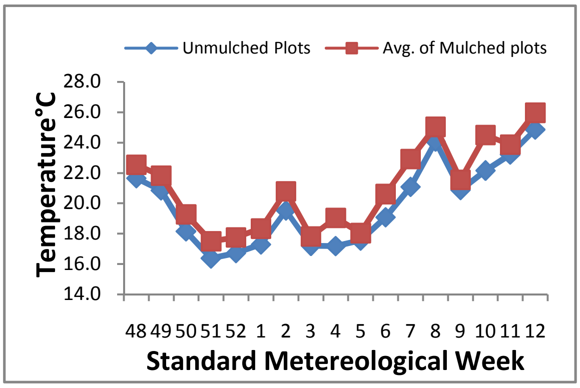
Fig. 3: Tear Resistance of poly-mulches of different thickness in a) machine direction and b) transverse direction under onion crop

Tear Resistance

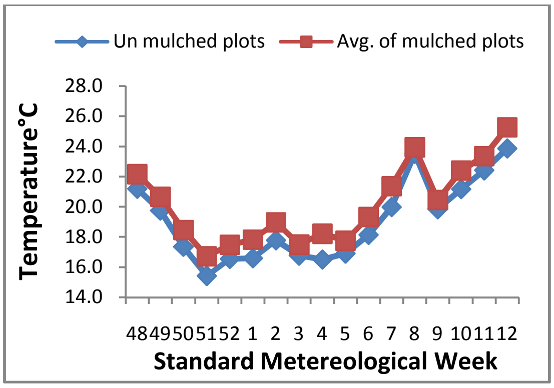
Tear resistance was more along the transverse direction of the film compared to machine direction. Highest tear resistance value (176.6 mN/µm) was recorded in mulch M_4 and the lowest value (107.5 mN/µm) recorded in treatment M_5 along the transverse direction of the film. However, along the machine direction tear resistance value varied narrowly in Treatments M_1, M_2, M_3, and M4 from 84.8 mN/µm (M_4) to 82.4 mN/µm (M_1). Lowest value of tear resistance in machine direction was found in treatment M_5 (32.2). If we observe the trend during the course of exposure of the film, in treatment M_4 the drop in tear resistance was minimum (19.45%) in machine direction and in transverse direction (21.97%). While in treatment M_5, maximum drop in value was observed which was 60.86% and 67.9% in machine direction and transverse direction respectively.

Mulching effect on soil temperature and soil compaction

The influence of mulching with different thickness of black poly-mulch on seasonal maximum, minimum and mean soil temperature at 5cm and 10cm depth varied although in a narrow range. At 10 cm depth, mulch M_4 recorded highest maximum temperature (29.2°C) followed by M_3 (29.0°C) while, the lowest temperature was recorded in M_0 (28.5°C). The highest increments of soil temperature under the different mulches in relation to bare soil occurred during the early crop season, when the plants shaded less and is in agreement with findings of Brault et al. (2002). However, the minimum soil temperature was recorded in mulch M_0 (11.1°C) followed by mulch M_1 (11.9°C), M_2 & M_5 (12.0°C), M_3 (12.4°C) and M_4(12.5°C). In general, presence of mulch altered soil temperature at both depths. The study demonstrated higher soil temperatures in black poly-mulched plots than that of non-mulched plots during the growing period regardless of the weather. Black poly-mulch increased the soil temperature by 1.2 °C and 1.7°C at 5 cm and 10 cm depths respectively. Dvorak *et al.* (2012) reported similar results of rise in soil temperature of about 0.2 to 1.6°C. The color of plastic determines the behavior of radiant energy and its influence on the microclimate, which in turn affect soil temperature. Black plastic mulch tend to absorb and transmit more shortwave radiation thereby resulting in increased temperature in the soil profile. The positive effect of plastic mulch on soil temperature directly impacts the micro-climate around the plant and modifies the balance between the absorbed and reflected radiation transmitted through the plastic mulch.



a)



b)

Fig 4: Mean Soil temperature at a) 5cm depth and at b) 10cm depth during crop duration

Mulches were also able to maintain proper soil condition for cultivation as evidenced by the resistance (force per unit area) offered by soil against deformation and as measured with cone penetrometer (ASAE Standards, 1998). It is also a measure of soil tilth and compaction. Cone penetration value at 0 cm, 2.5 cm, 5 cm, 7.5 cm, 10 cm, 12.5 cm and 15 cm depth recorded after two months and at the end of season of in all treatments reveals that soil conditions in terms of cone penetration in all mulched treatments were better than non mulched soil. The mean soil penetration value as observed from cone penetrometer for M_0, M_1, M_2, M_3, M_4 and M_5 were 1065.8 N/mm^2, 584.0 N/mm^2, 591.3 N/mm^2, 610.3 N/mm^2, 587.8 N/mm^{2}and 878.4 N/mm^2, respectively. It implies that mulched plot favoured a better soil tilth even after the end of crop season. Higher value of cone penetration in M_5 (recycled mulch) could be because of tearing of recycled plastic film after 45 days of its exposure and the mulch behaved more or less as non-mulched plots especially towards the later stage of the crop.

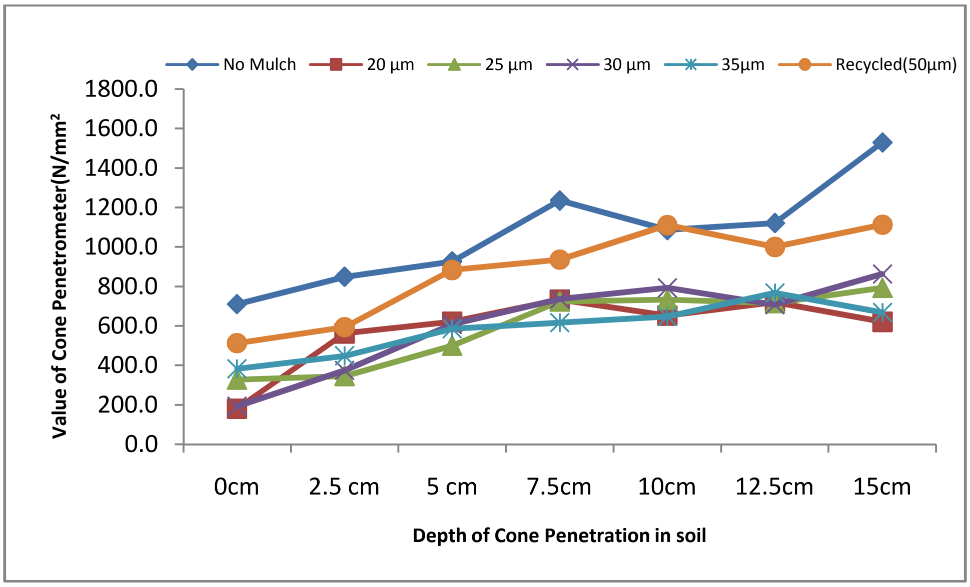


Fig.6: Average measure of soil compaction (Force in N/mm^2) under different treatments as affected by different film thickness of poly-mulches

Onion growth parameters

Significant difference was observed in plant height, during 30 DAT, 60 DAT and 90 DAT in all mulched treatment over non- mulched treatments. However, no. of leaves were non significant. Bulb size and average yield was also significantly superior in M_3, M_4 and M_2 compared M_1, M_5 and M_0. Bulb size (equatorial diameter-7.5cm and polar diameter-5.1cm) and bulb yield (57.60 t/ha) was obtained in M_3 i.e. poly- mulching with 30 µm film. This was closely followed by M_4 (57.33 t/ha) treatment i.e. mulching with 35 µm poly- film. In treatment M_0 (No Mulching) the lowest Bulb size (equatorial diameter-6.7 and polar diameter- 4.7) and bulb yield per square meter area (38.23 t/ha) were observed.

Table 1: Effect of mulching with different thickness on growth and yield characteristics

Treatments	Plant Height (cm)			No. of Leaves			Bulb Size (cm)		Avg. Yield (t/ha)
	60DAT	75DAT	90DAT	60DAT	75DAT	90DAT	Eq.Dia	Pol. Dia	
M_0	17	47.4	60.1	3.9	6.3	8.6	6.7	4.7	38.20
M_1	19.5	52.8	65.6	4.3	6.7	11.2	7.1	5.1	48.27
M_2	20.1	52.6	63.9	4.3	6.8	11	7.2	4.8	51.33
M_3	21.4	53.8	65.6	4.2	7	9.75	7.5	5.1	57.60
M_4	20.6	52.6	65.5	4.1	6.8	9.9	7.3	4.8	57.33
M_5	20.4	53.4	62.6	4.3	6.6	9.9	6.9	4.7	44.53
SEm±	0.820	1.497	1.190	0.188	0.155	0.489	0.167	0.124	2.67
CD at 5%	2.470	4.513	3.587	NS	NS	1.475	0.504	0.375	8.07

Conclusion

The mechanical properties in all mulches except recycled black mulch did not suffer mechanical deterioration due to exposure in the field beyond permissible limit in one crop season. Furthermore, within poly mulching there is an optimum thickness which imparts more favourable condition of soil by moderating soil temperature, soil compaction for good root penetration and proper soil moisture availability. It could be also be concluded from the studies that overall black poly-mulching have a positive impact on yield and growth parameters in onion production.Water use efficiency of the irrigation method can be enhanced by the use of polyethylene mulching and hence, significant water savings can be achieved.

Acknowledgements

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