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Effect of Mulching on *In-situ* Moisture Conservation and Productivity in Vegetable Crops under Rainfed Condition

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ABSTRACT: Water use efficiency in agriculture can be enhanced by several strategies mainly by reducing evaporation from the soil surface. The mulching techniques were being used widely in rainfed crop production worldwide. The mulching techniques can also be implemented in *kharif* vegetables production under rainfed conditions. The current study aimed at evaluating the effect of both plastic mulch and organic mulch on growth and yield of vegetable crops such as radish, cauliflower, yambean and okra during the *kharif* season of 2011 and 2012. The field experiment was designed by taking four vegetable crops such as radish, cauliflower, yambean and okra and three mulching methods such as plastic mulching, organic mulching and no mulching. The results indicated that the mulched plots had higher soil moisture content than bare soil plots, which has positively reflected on vegetative and yield parameters. It is also concluded from this study that mulching has a very beneficial effect for vegetable crops in rainfed conditions including increase in soil moisture, reduces weed growth, maintain soil temperature, increase in yield and promotes early harvest of the crops. It was found that plastic mulching increased the soil temperature by 1.6 – 2.5 °C as compared to no mulching conditions in all the vegetable crops. In case of organic mulching, the soil temperature increased by 1.4 – 2.2 °C as compared to no mulching conditions in all the vegetable crops. Weed density of no mulching treatment were found to 21-25 whereas weed density in case organic mulching and plastic mulching were found to be 7-9 and 3-5 respectively in all the vegetable crops. In addition, organic mulch also adds organic matter, stimulates soil microflora and increases the biological activity of soil. Both the mulching has beneficial effect but the cost of cultivation in plastic mulching is higher than the organic mulching because organic mulch is freely available to the farmers and also plastic mulching requires more technical guidance for maintaining mulch in the field. Therefore, the organic mulching will be very much beneficial and easily adoptable by the farmers in the rainfed conditions of the North Eastern Ghat Zone of Odisha.

Key words: *In-situ* moisture conservation, organic mulching, plastic mulching, productivity, rainfed conditions

Introduction

In the rainfed condition of the North Eastern Ghat Zone of Odisha, the mean annual precipitation ranges between 1400 and 1500 mm. The light textured well drained upland soils coupled with low night temperature provide scope for cultivation of vegetable crops during rainy season (15th June – 15th October). The intermittent dry spells and terminal droughts affect the performance of those high value crops in most of the years. About 40% of the rainfall is lost as surface runoff due to steep topography. In upland situation, there is a need to apply different kinds of mulch material in the vegetable fields preferably over furrows and ridges to arrest soil erosion, conserve soil moisture, intercept surface runoff and suppress weed growth. Due to application of mulch material, surface roughness increases which ultimately helps in increasing the time of detention (opportunity time) of runoff water over land surface. As a result of this the root zone of the crop is replenished with adequate amount of soil moisture and the ground water reservoir is also augmented due to recharge of runoff water (Bhardwaj, 2013; Patil *et al.,* 2013; Sarolia *et al.,* 2012).

The main objectives of the use of different types of mulching in vegetable crops are *in-situ* moisture conservation, weed control, soil temperature modification, soil conservation and after decomposition of organic mulch add plant nutrients, improvement in soil structure and ultimately increases the crop quality and yield. Further, it is reported that mulching boosts the yield by 50-60 per cent over no mulching under rainfed situations (Yadahali *et al.,* 2011; Parmar *et al.,* 2013; Kumar *et al.,* 1998; Ei-shaikh *et al.,* 2008). Organic mulch are efficient in reduction of nitrates leaching, improve soil physical properties, prevent erosion, supply organic matter, regulate temperature and water retention, improve nitrogen balance, take part in nutrient cycle as well as increase the biological activity. To achieve optimum advantage from the organic mulch, the mulch should be applied immediately after germination of crop or transplanting of vegetable seedling @ 5 t ha^{-1}. Paddy straws and dry leaves are most common mulching materials used for fruit and vegetable production in North Eastern Ghat Zone of Odisha. Though straw is poor in nutrient value but after decomposition, it makes soil more fertile. Among organic mulching materials,

straw has a long life in comparison to other mulches. Leaves, an easily available material, are also good for mulching. Though leaves are good for protecting dormant plants during winter by keeping them warm and dry but due to lightweight they may be blown away even by light wind. To counter this problem, it requires anchoring which can be done with stones, chipped bark and covering with net or some form of sheet (Jalota *et al.,* 2007; Kolota *et al.,* 2013; Mareno *et al.,* 2009; Shashidhar *et al.,* 2009).

The plastic materials used as mulch are poly vinyl chloride or polyethylene films. Owing to its greater permeability to long wave radiation it can increase temperature around the plants during night in winter. Hence, polyethylene film mulch is preferred as mulching material for production of horticultural crops. Now a day's application of black plastic mulch film is becoming popular and very good results have been achieved particularly in arid and semi-arid regions (Bhardwaj, 2013). Black polyethylene mulches are used for weed control in a range of crops under the organic system of crop production. In plastic mulch, black polyethylene sheet of 200-micron thickness was used for mulching. It not only reduced the frequency of irrigation but also helped in avoiding short critical dry spells (≤5 days). It also helped in increasing the production potentiality of vegetable crops. The effective life span of plastic mulch is 10 – 15 years. So, it is replaced once in every 10 – 15 years. It is more costly than organic mulch. But, the cost is compensated due its long-term use and multiple benefits (Diaz-Prez *et al.,* 2007; Mahadeen, 2014; Singh *et al.,* 2012).

Therefore, considering the importance of different mulching in various vegetable crops, the present investigation was carried out to study the effect of different mulching material on soil moisture storage, weed density and soil temperature of the different vegetable crops and to study the effect of different mulching material on productivity, profitability and rainwater use efficiency of the different vegetable crops such as radish, cauliflower, yambean and okra under rainfed conditions.

Materials and Methods

The experiment was conducted in the experimental farm of the All India Coordinated Research Project for Dryland Agriculture (AICRPDA), Odisha University of Agriculture and Technology (OUAT), Phulbani, Odisha, India. It is located in North Eastern Ghat Zone of Odisha of latitude of 19^0 34' to 20^0 34' North, longitude of 80^0 30' to 84^0 35' East and an elevation of 518.0 m with respect to the mean sea level. The soil at the experimental site was sandy loam and slightly acidic (pH - 5.3 to 6.5). The detail soil texture and physico-chemical properties in different soil layers of research farm are given in Table 1. The soil of the experimental site is having filed capacity of 13.2%, wilting point of 5.0% on weight basis and bulk density of 1.5 g cm^{-3}. The experimental site falls under the sub-humid subtropical region with average annual rainfall of 1407 mm, concentrated mostly in the months of June to October.

Table 1: Soil texture and physico-chemical properties in different soil layers of the experimental site

Depth (cm)	Sand (%)	Silt (%)	Clay (%)	Textural Class	pH	EC (dS/m)	OC (%)
0-15	68.2	14.5	17.3	Sandy loam	5.3	0.07	0.25
15-30	65.2	13.2	21.6	Sandy clay loam	5.2	0.03	0.17
30-45	63.8	11.8	24.4	Sandy clay loam	6.0	0.02	0.18
45-60	51.2	10.5	38.3	Sandy clay	6.3	0.02	0.12
60-90	48.8	10.8	40.4	Sandy clay	6.5	0.02	0.08

The experiment was conducted during the *kharif* season of the year 2011 and 2012. The normal rainfall in the Research farm is 1407.3 mm which includes 65 rainy days. The total rainfall during 2011 and 2012 were 1317 mm (72 rainy days) and 1695.6 mm (76 rainy days) respectively which were 6.4% less and 20.5% more rainfall than the normal rainfall respectively. The experimental site received rainfall of 1045 mm (59 rainy days) and 1365.8 mm (59 rainy days) during *kharif* season (June to September) of 2011 and 2012 respectively. The normal date of onset of monsoon is 10th June whereas normal date of cessation of monsoon is 6th October. During 2011, the date of onset of monsoon occurred on 4th June whereas the date of cessation of monsoon occurred on 26th September whereas during 2012, the date of onset of monsoon occurred on 7th June whereas the date of cessation of monsoon occurred on 15th October (Table 2). The monthly rainfall distribution of the experimental site during the crop growth period (June to October) during 2011 and 2012 is given in Figure 1. The monsoon scenario of the experimental site during 2011 and 2012 is given in the Table 1. Total four and two numbers of dry spells occurred during the crop growing seasons in 2011 and 2012, respectively.

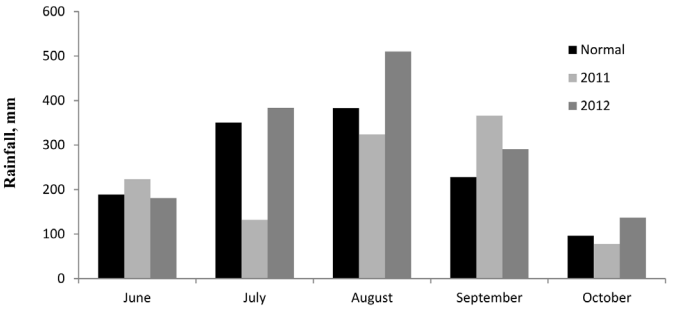


Fig. 1: Monthly rainfall distribution of the experimental site during the crop growth period (June to October) during 2011 and 2012

Table 2: The monsoon scenario of the experimental site during 2011 and 2012

Monsoon parameters	Normal	2011	2012
Onset of monsoon	10th June	4th June	7th June
Cessation of monsoon	6th Oct	26th Sept	15th Oct
Pre monsoon (January - May) (mm)	132.1	194.0	164.0
Monsoon (June - September) (mm)	1150.5	1045.0	1365.8
Post monsoon (Oct - Dec) (mm)	124.7	78.0	124.73
Total rainfall (mm)	1407.3	1317.0	1695.6
Rainy days (No.)	65	72	76
Dry spells during crop season (June-October)	-	4 Nos [7 days (21st to 26th June; 7 days (9th to 15th July); 13 days (26th Sept to 7th Oct); 12 days (9th to 20th Oct)]	2 Nos [9 days (24th Sept to 1st Oct; 15 days (15th to 30th Oct)]

Improved varieties of crops such as radish (Var. Pusa Chetki), cauliflower (Var. Pearl White), yambean (Var. Rajendra Mishri Kanda-1) and Okra (Var. Supriya) have been taken for the experiment. The experiment was conducted in factorial design in which different mulching practices were taken in Factor - A and different vegetable crops were taken in Factor - B. Three mulching practices such as (i) plastic mulch, (ii) organic mulch and (iii) no mulch were taken in Factor-A. The different vegetable crops such as radish, cauliflower, yambean and okra are taken in Factor – B. In organic mulch, *sal* leaves@5 t ha^{-1} were used as organic mulch. It also performed similar functions as that of the plastic mulch but with less efficiency. One of the major advantages of organic mulch is that it is gradually decomposed in soil which ultimately helps in increasing the soil fertility and hence productivity of the crop. In plastic mulch, black polyethylene sheet of 200-micron thickness was used for mulching. It not only reduced the frequency of irrigation but also helped in avoiding short critical dry spells (≤5 days). It also helped in increasing the production potentiality of vegetable crops. The effective life span of plastic mulch is 5-6 years. So, it is replaced once in every 5-6 years. All the vegetable crops were sown during 1st week of July and harvested during 1st week of October but the of radish crop were harvested during 4th week of August.

Soil moisture content up to 30 cm soil depth in the different intervals was measured by gravimetric method (Black, 1965). The soil from 0-30 cm depth was taken by a manual coring. Gravimetric moisture content (g g^{-1}) of the soil samples was calculated on oven dry weight basis, then converted into volumetric moisture content (cm^3 cm^{-3}) and hereafter expressed as profile water content in 0-30 cm soil depth. Soil temperature of the top soil was measured by the soil thermometer at regular interval at different growth stage of the crop. Weed density of the vegetable crops was measured as no of weeds per m^2 at different growth stages of the crop (Seran and Brintha, 2010; Mishra, 2014).

Periodical observation of growth and yield parameter was recorded during *kharif* season of 2011 and 2012. The yield data were necessary for economic analysis and estimation of water use efficiency. In order to compute the profitability of different crops under different treatments, the net returns and benefit-cost (B:C) ratio were calculated. The net returns (₹ ha^{-1}) were computed as a difference of gross returns and cost of cultivation (₹ ha^{-1}) for each treatment. The B:C ratio was derived as a ratio of gross returns and cost of cultivation for each treatment. The data were subjected to paired "t" test analysis for determining the significance of difference between the treatments and to draw valid conclusions. The level of significance used was p=0.05. Data were analyzed as per factorial design (Gomez and Gomez, 1984). Rain water use efficiency (RWUE) was computed by dividing crop yield by rainfall received during crop growth period and was expressed as kg ha-mm^{-1}. RWUE is a measure of crop's capacity to utilize rainwater into crop yield. The values of Radish Equivalent Yield (REY) (kg ha^{-1}) were computed by using the formula (Behera *et al.,* 2012).

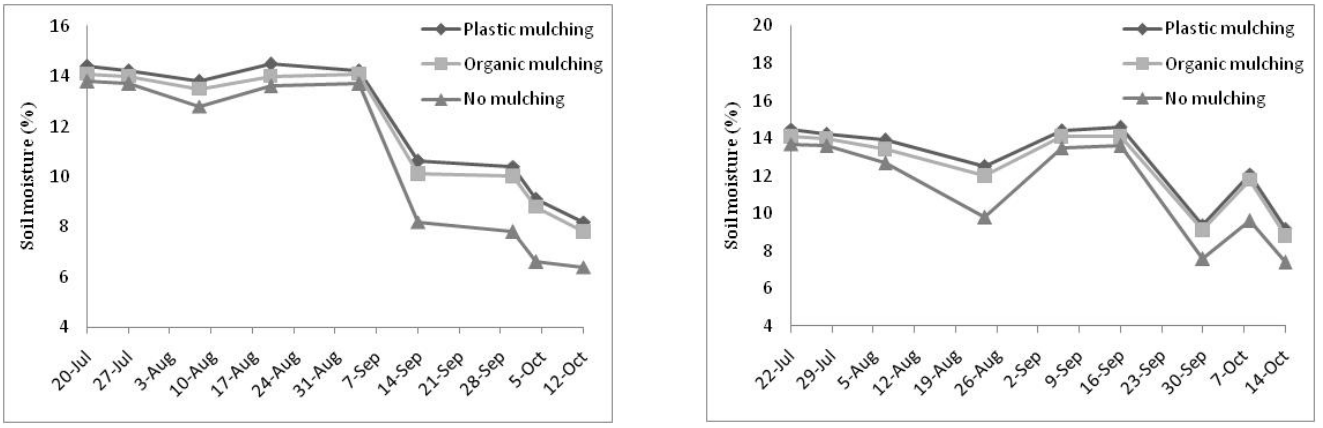
$$REY = \frac{(Y_r \, x \, P_i)}{P_m} \quad (1)$$

where, Y_r is yield of replace crop (kg ha^{-1}), P_r is price of replace crop (₹ kg^{-1}) and P_m is price of radish (₹ kg^{-1})

Results and Discussion

Effect of mulching on soil moisture content

The use of mulching in vegetable crops helps to conserve soil moisture due to modification of favourable micro-climatic conditions in soil. When soil surface is covered with organic mulch, it helps to prevent weed growth, reduce evaporation and increase infiltration of rain water during growing season. In addition, plastic mulch helps in shedding excessive water



(a) (b)

Fig. 2: Effect of mulching on average soil moisture variations (%) in top layer (0-30 cm) of all the vegetable crops in different time interval during (a) 2011 (b) 2012

away from the crop root zone during periods of excessive rain fall. This can reduce irrigation frequency and amount of water used. In the Figure 2, it is clearly visible the impact of mulching on soil moisture storage in the top soil during the year 2011 and 2012. There is no much difference in soil moisture storage in top layer of soil in both the organic mulching and plastic mulching as well as in case no mulching conditions. However, there is decrease in soil moisture storage in all the vegetable crops with no mulching conditions than the mulching condition during the dry spell in both the years. From these results, it is concluded that mulching in vegetable crops helps to conserve soil moisture in the root zone. It was also noticed that the presence of crop residue mulch at the soil atmosphere interface has a direct influence on infiltration of rainwater and evaporation. Mulch cover also reduces surface runoff and holds rainwater at the soil surface thereby giving it more time to infiltrate into the soil.

Effect of mulching on soil temperature, weed growth and nutrient status

Mulching reduces soil temperature in summer, raises it in winter and prevents the extremes of temperatures. In general, the effect of mulching on the temperature regime of the soil varies according to the capacity of the mulching material to reflect and transmit solar energy. It was found that plastic mulching increased the soil temperature by 1.6 – 2.5 ^{0}C as compared to no mulching conditions in all the vegetable crops. In case of organic mulching, the soil temperature increased by 1.4 – 2.2 ^{0}C as compared to no mulching conditions in all the vegetable crops (Table 3). It is also noticed that at night, condensation on the underside of the mulch absorbs the long wave radiation emitted by the soil thereby slowing cooling of the soil.

Table 3: Effect of mulching on soil temperature (^{0}C) and weed density of vegetable crops during the year 2011 and 2012

Crop	Treatment	Average soil temperature (^{0}C)		Weed density (No of weeds/m^2)	
		2011	2012	2011	2012
Radish	Plastic mulch	26.5	26.2	4.2	3.6
	Organic mulch	26.0	25.6	8.3	7.6
	No mulch	24.0	23.7	22.4	21.5
Cauliflower	Plastic mulch	24.5	24.7	5.2	4.4
	Organic mulch	23.8	24.1	9.1	8.4
	No mulch	21.9	22.5	24.2	23.2
Yambean	Plastic mulch	25.1	24.8	4.4	5.6
	Organic mulch	24.8	24.2	7.6	8.4
	No mulch	22.6	22.6	23.2	24.2
Okra	Plastic mulch	24.4	24.2	5.2	4.4
	Organic mulch	23.9	23.6	7.2	8.4
	No mulch	21.8	21.3	24.6	25.8
	SEm±	0.50	0.46	3.6	3.5
	CD at 5%	1.52	1.46	11.4	12.6

By providing a physical barrier, plastic mulching reduces the germination and nourishment of many weeds. The mulching operation favors in the reduction of weed seed germination, weeds growth and keeps the weed under control. In case of organic mulching, loose materials such as leaf or straws also provide effective weed control. The black plastic mulching has a greater effect on weed control than the organic mulching and it was also observed the significant differences in weed control between mulched and un-mulched plots of vegetable crops. Weed density of no mulching treatment were found to 21-25 whereas weed density in case organic mulching and plastic mulching were found to be 7-9 and 3-5 respectively in all the vegetable

crops (Table 3). Organic mulches return organic matter and plant nutrients to the soil and improve the physical, chemical and biological properties of the soil after decomposition, which in turn increases crop yield. Soil under the mulch remains loose, friable and leading to suitable environment for root penetration. The organic mulches not only conserve the soil moisture, but they also increase the soil nutrients through organic matter addition. In case of organic mulching, bulk density of the soil decreased (1.42 g cm^{-3}) as compared to no mulching conditions (1.50 g cm^{-3}). It is also found that the organic matter was significantly higher when organic mulch was applied. It is found from the results that the bulk density of the soil and available potassium decreased in case of organic mulching whereas no differences were found in case of plastic mulching and no mulching treatments. However organic carbon, available nitrogen and phosphorus increased in case of organic mulching whereas no differences were found in case of plastic mulching and no mulching treatments (Table 4).

Effect of mulching on yield and economics of the vegetable crops

Mulching provides a favorable environment for growth which results in more vigorous, healthier plants which may be more resistant to pest injury. Increase in soil temperature and moisture content stimulate root growth which leads to greater plant growth. Therefore, mulched plants usually grow and mature more uniformly than non-mulched plants. Plastic mulch applied to the planting bed prior to planting will warm the soil and promote faster growth in early season, which generally leads to earlier harvest. Organic mulches induced earliness in flowering, less days to fruit set and harvest in vegetable crop over no mulching treatment. The yield, economics and rain water use efficiency data of all the vegetable crops of the year 2011 and 2012 are given in the Table 4. The yield of the vegetable crops from mulched plot was significantly higher than those produced on bare soil. This difference can be attributed to moisture conservation, higher soil temperature, weed control, and increased mineral nutrient uptake in the mulched plot through improved root temperatures.

Table 4: Effect of mulching on nutrient status of the top soil (0-30 cm) of vegetable crops

Crop	Treatment	BD	OC (g kg^{-1})	Av. N (kg ha^{-1})	Av. P (kg ha^{-1})	Av. K (kg ha^{-1})
	Initial	1.52	4.25	302	29	432
Radish	Plastic mulch	1.51	4.32	305	31	433
	Organic mulch	1.44	5.98	365	42	365
	No mulch	1.52	4.22	308	32	434
Cauliflower	Plastic mulch	1.51	4.30	303	30	431
	Organic mulch	1.43	5.92	360	44	360
	No mulch	1.52	4.23	309	31	432
Yambean	Plastic mulch	1.51	4.23	308	30	431
	Organic mulch	1.42	5.86	372	40	355
	No mulch	1.52	4.20	309	31	432
Okra	Plastic mulch	1.51	4.30	304	32	430
	Organic mulch	1.45	5.94	367	43	352
	No mulch	1.52	4.24	309	33	432

It was found from the results that yields of all the vegetable crops were found to be maximum in case of plastic mulching whereas B:C ratio of organic mulching were found to be maximum in all the vegetable crops. The yield of the plastic mulching plots of radish, cauliflower, yambean and okra were found to be 20514 kg ha^{-1}, 5296 kg ha^{-1}, 11460 kg ha^{-1} and 14008 kg ha^{-1} respectively. The B:C ratio of the organic mulching plots of radish, cauliflower, yambean and okra were found to be 3.68, 2.66, 4.74 and 2.51 respectively (Table 5). This was possible due to the less cost of cultivation in case of organic mulching than the plastic mulching as organic mulches are freely available.

Table 5: Effect of mulching on crop yield, economics and rainwater use efficiency of the vegetable crops (pooled data of 2011 and 2012)

Treatment		Yield (kg ha^{-1})	REY (kg ha^{-1})	Cost of Cultivation (₹)	Gross return (₹ ha^{-1})	Net return (₹ ha^{-1})	B:C ratio	RWUE (kg ha^{-1} mm^{-1})
Crop	Mulching							
Radish	Plastic mulch	20514	20514	42000	143598	101598	3.42	30.39
	Organic mulch	19466	19466	37000	136262	99262	3.68	28.84
	No mulch	14705	14705	34000	102935	68935	3.03	21.79
Cauliflower	Plastic mulch	5296	18914	52000	132400	80400	2.55	5.28
	Organic mulch	4993	17832	47000	124825	77825	2.66	4.98
	No mulch	4156	14843	44000	103900	59900	2.36	4.14
Yambean	Plastic mulch	11460	32743	52000	229200	177200	4.41	10.64
	Organic mulch	11133	31809	47000	222660	175660	4.74	10.34
	No mulch	8322	23777	44000	166440	122440	3.78	7.73
Okra	Plastic mulch	6537	14008	42000	98055	56055	2.33	6.07
	Organic mulch	6184	13251	37000	92760	55760	2.51	5.74
	No mulch	5346	11456	34000	80190	46190	2.36	4.97
	SEm±		505					
	CD at 5%		1540					

Average crop seasonal rainfall (mm): Radish – 675.0; Cauliflower – 1003.2; Yambean – 1073.6; Okra – 1073.6

The rain water use efficiency (RWUE) of all the vegetable crops were found to be maximum in case of plastic mulching. There were significant differences in yield were found in case of no mulch plots and organic mulching as well as plastic mulching plots. However, there were no significant differences in yield were found between the organic mulching plots and plastic mulching plots in all the vegetable crops. Therefore, it is recommended that organic mulching in vegetable crops will be better than the plastic mulching in North eastern Ghat Zone of Odisha because organic mulch such as *sal* leaves are freely and easily available to the farmer.

Conclusion

Based on the two years results, it could be concluded that use of mulches increases the soil temperature in all the vegetable crops compared to no mulching conditions which favours in the reduction of weed seed germination, weeds growth and keeps the weed under control. Among the different mulches studied, it was found that organic mulches improve organic carbon, available nitrogen and phosphorus. Though yields of all the vegetable crops were found to be maximum in case of plastic mulching, B:C ratio of organic mulching were found to be maximum in all the vegetable crops. Therefore, it is recommended that organic mulching in vegetable crops will be better than the plastic mulching in North Eastern Ghat Zone of Odisha.

References

Behera, B., Sankar, G.R.M., Sharma, K.L., Mishra, A., Mohanty, S.K., Mishra, P.K., Rath, B.S., Grace, J.K. (2012). Effects of fertilizers on yield, sustainability and soil fertility under rainfed pigeon pea + rice system in subhumid Oxisol soils. *Communications in Soil Science and Plant Analysis*, 43: 2228-2246.

Bhardwaj RL. 2013. Effect of mulching on crop production under rainfed conditions - A review. *Agricultural Reviews,* 34(3): 188-197.

Black CA. 1965. Methods of soil analysis. 1st Edn., American Society of Agronomy, Madison, pp. 1572.

Diaz-Perez JC, Gitaitis R and Mandal B. 2007. Effect of plastic mulches on root zone temperature and on the manifestation of tomato spotted wilt symptoms and yield of tomato. *Scientia Horticulturae,* 114: 90-95.

Gomez, K. A. and Gomez, A. A. (1984). Statistical procedures for agricultural research. New York: John Wiley.

Ei-Shaikh A and Fouda T. 2008. Effect of different mulching types on soil temperature and cucumber production under libyan conditions. *Misr Journal of Agricultural Engineering,* 25(1): 160- 175.

Jalota SK, Khera R, Arora VK and Beri V. 2007. Benefits of straw mulching in crop production: A Review. *Journal of Research (Punjab Agriculture University),* 44: 104-107.

Kolota E and Adamczewska-Sowinska K. 2013. Living mulches in vegetable crops production: perspective and limitations (A review). *Acta Scientiarum Polonorum Hortorum Cultus,* 12(6): 127-142.

Kumar R, Srivastava BK and Kumar R. 1998. Influence of different mulching materials on yield and quality of winter tomato. *Proceedings of the National Academy of Sciences India Section B - Biological Sciences*, 68(3-4): 279-82.

Mahadeen AY. 2014. Effect of polyethylene black plastic mulch on growth and yield of two summer vegetable crops under rainfed conditions under semi arid region conditions. *American Journal of Agricultural and Biological Sciences,* 9(2): 202-207.

Mishra A. 2014. Effect of winter maize-based intercropping systems on maize yield, associated weeds and economic efficiency, *Comunicata Scientiae,* 5(2): 110-117.

Moreno MM, Moreno A and Mancebo I. 2009. Comparison of different mulch materials in a tomato (*Solanum lycopersicum* L.) crop. *Spanish Journal of Agricultural Research*, 7: 454-464.

Patil SS, Kelkar TS and Bhalerao SA. 2013. Mulching: A soil and water conservation practice. *Research Journal of Agriculture and Forestry Sciences*, 1(3): 26-29.

Parmar HN, Polara ND and Viradiya RR. 2013. Effect of mulching material on growth, yield and quality of watermelon (*Citrullus Lanatus* Thunb) Cv. Kiran. *Universal Journal of Agricultural Research*, 1(2): 30-37.

Sarolia DK and Bhardwaj RL. 2012. Effect of mulching on crop production under rainfed condition: A Review. *International Journal of Research in Chemistry and Environment,* 2: 8-20.

Shashidhar KR, Bhaskar RN, Priyadharshini P and Chandrakumar HL. 2009. Effect of different organic mulches on pH, organic carbon content and microbial status of soil and its influence on leaf yield of M-5 mulberry (*Morus indica* L.) under rainfed condition. *Current Biotica,* 2: 405-412.

Singh AK and Kamal S. 2012. Effect of black plastic mulch on soil temperature and tomato yield in mid hills of Garhwal Himalayas. *Journal of Horticulture and Forestry,* 4: 78-80.

Yadahalli GS, Vidyavathi GY and Srinivasareddy GV. 2011. Mulching, one of the means to mitigate drought. *Agrobios Newsletter*, 9(10): 36-37.