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Soil mulches able to mitigate soil water deficiency impacts on Eureka lemon (*Citrus limon* Burm) production in rainfed environments in the Shivaliks of Jammu

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Abstract
Irregular rainfall distribution and inefficient rainwater management generate rigorous constraints on crop production in rainfed areas. Different types of mulches are effective methods for improving agricultural productivity and water consumption. However, the effects of these mulching practices on soil water supply and plant water use associated with crop yield are not well understood. A two years study was conducted to analyze the occurrence and distribution of dry spells in a rainfed region of *kandi* belt in Jammu and to evaluate the effects of non-mulching (CK), bajra straw (BS), maize straw (MS), grasses (G), branker (B) (*Adhotada vassica*), farmyard manure (FYM) and black polyethylene (BP) on the soil water supply, plant water use and fruit yield in Eureka lemon (*Citrus limon* Burm). Various organic and inorganic mulches significantly increased the soil moisture status in surface and sub-surface soil layer. The BP mulch recorded the maximum moisture content followed by FYM and B. The BP and FYM were found to be more successful in producing maximum growth extension than rest of the treatments although the differences were non-significant among the treatments. As a result, the fruit yield significantly increased by 15.5, 12.0, 10.5, 9.3, 8.2 and 7.1% for the BP, FYM, B, MS, BS and G treatment compared with the CK treatment. It is concluded that both BP and FYM are effective strategies for mitigating the impacts of water deficit and improving Eureka lemon production in rainfed areas. However, BP is more effective than FYM and B. The poor aeration, non-decomposable nature and lofty cost are the constraints of utilize BP as mulch material. Among the organic mulches, the cost of B was less as the material is easily available in local areas followed by BS and MS.

Keywords: Eureka lemon, growth parameters, quality attributes, mulches, rainfed condition Shivaliks

1. Introduction
Citrus (*Citrus* sp.) tree commonly need good amount of water compared to the other subtropical fruits for the reason that sap circulation never entirely ceases and transpiration take place all over the year as it is evergreen. Eureka lemon (*Citrus limon Burm)* is one of the most important fruit crop of rainfed condition of arid, semi arid region of the country because of its precocity, thornlessness and grave bearing nature. The Eureka lemon grows year-round and lavishly. In rainfed areas, soils moisture and naturally poor fertility are the major constraints. Water and its resourceful use are as growing main concern for agricultural production worldwide is particularly in dryland regions [1]. The semiarid land surface is approximately 18 % that is essential for global food production [2]. The limited groundwater, low rainfall and high water losses combine to make water scarcity is the chief limiting factor for primary production in rainfed semiarid areas [3]. Though, some studies have indicated that an irregular temporal dissemination and inefficient management of precipitation, rather than total rainfall, are the primary constraints on crop production [4]. Studies have reported that adopting augmented water and soil management strategies to bridge water limitations during dry spells can markedly promote crop growth and increase yields [5]. The population continuously increasing, improving rainwater management to mitigate the negative impacts of water deficiency and increase water productivity in rainfed/semiarid areas is crucial to ensuring future food security. Soil surface mulching is a common and real practice for offsetting water limitations in agricultural and horticultural production. Organic and inorganic mulching, an important traditional technique, has been used for many years in the India [6].

The conservation of soil moisture by use of mulches suits essential for moveable cultivation under rainfed condition of semi- arid ecosystem. In spite no assured irrigation in these regions, the moisture conservation technique is not in practice. Mulches is not only conserve soil moisture but also impart manifold beneficial effect, like suppression of thrilling fluctuation of soil temperature, water loss is reduce through evaporation, subsequent more stored soil moisture [7], conservation of soil fertility [8], improvement growth and yield [9]. Several studies have designated that in fruit crops like apple, sapota, and acid lime, eureka lemon mulching improves soil moisture status, growth, yield and quality of these fruits, besides reducing weed growth [8, 9]. Unceasing use of organic mulches are supportive in educating the soil properties and available nutrients in soil, which finally occasioned into better growth and yield of plant [7]. Mulching by plastic polyethylene has evidenced its helpfulness in conserving the soil moisture and increasing the growth, yield and quality in different citrus cultivars [7]. Keeping in view this present study was conducted in this was undertake to assess the effect of different mulches on soil properties, soil moisture, nutrient in soil and quality parameters of Eureka lemon in rainfed condition of Jammu, India.

2. Materials and Methods

2.1 Study site description

This experiment was conducted at Rainfed Research Sub-Station for Sub-tropical fruits Raya, Jammu, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu. The experimental field is situated at an elevation of 332 m above mean sea level and lies between 32º39" North latitude and 0 74 53" East longitude. The climate of experimental site is sub-tropical with hot and dry in summer season, hot and humid in rainy season and cold in the winter months. The maximum temperature rises up to 45ºC during summer and minimum temperature falls to 3.16ºC during winter. Rainfall of 1100 mm occurs annually but about 70 to 80 per cent from July to September and with a very high intensity and frequency distribution. The rainfall distribution patterns are particularly erratic in time and space leads to moisture stress condition during the major part of the year.

2.2 Experimental design and treatments

A study was carried out on 2 years old plants of air layered Eureka lemon which were planted in 2007 at a spacing of 5 m x 5 m these plants were treated with different mulches at Rainfed Research Sub-station for sub-tropical fruits Raya, Sher-e- Kashmir University of Agricultural Sciences and Technology Jammu during 2009-10 to 2010-11. The experiment was laid out in a randomized block design with seven treatments and four replications. Different organic mulches viz non-mulching (CK), bajra straw (BS), maize straw (MS), grasses (G), branker (B) (*Adhotada vassica*), farmyard manure (FYM) and black polyethylene (BP) were imposed uniformly on the basin (10 cm thickness) during the beginning in April. The grasses which are applied in Bermuda grass+ Johnson grass (*Cynodon dactylon* + *Sorghum halepense*). For inorganic mulching, 400 gauge black polyethylene was spread on plant basin. No mulch was applied in control plots. Other cultural practices adopted were similar for all treatments. Nutrient management and other horticultural operations were carried out as per standard practices under rainfed conditions. The fruits were harvested in the month of August by three hand pickings.

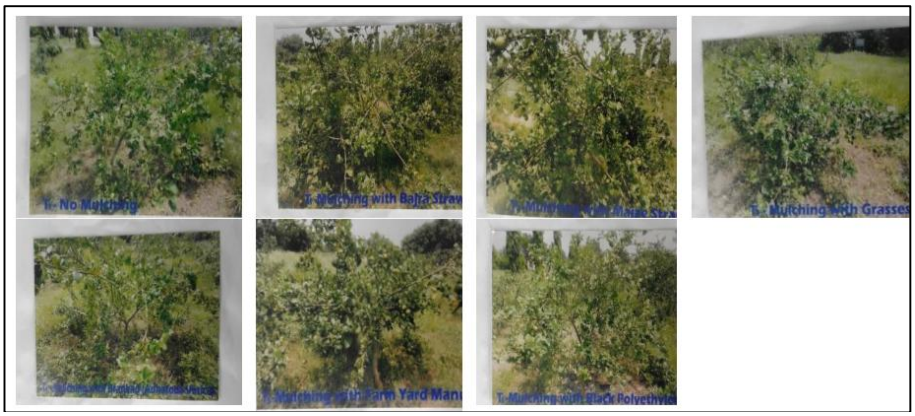


Fig 1: Photographs showing plots under non-mulching (CK), bajra straw (BS), maize straw (MS), grasses (G), branker (B) (*Adhotada vassica*), and farmyard manure (FYM) and black polyethylene (BP) different treatments.

2.3 Soil analysis and fruit quality parameters

The soil samples were analyzed for the properties and available nutrients. Soil reaction measured by pH metre, EC by EC metre, organic carbon in soil by standard methods [10]. Available Nitrogen (N) was estimated as per the procedure by [11] and available Phosphorus (P) by [12]. The available potassium (K) was determined in the neutral normal ammonium acetate extract of soil through Flame photometer. The fruits were harvested in the last week of August. The observation regarding fruit size (length and diameter) weight, total soluble solid (TSS) of fruits was estimated based on random four fruit samples. Total sugars, reducing sugars, ascorbic acid and acidity were estimated by adopting the standard procedure [13]. Moisture was determined by using gravimetric method. Agronomic meteorological data including monthly mean daily temperature, relative humidity, evaporation and rainfall distribution during the experimental period collected from Advance Centre for Rainfed Agriculture, Dhiansar station.

$$\text{Soil moisture content (\%)} = \frac{\text{Fresh soil weight (g)} - \text{Soil dry weight (g)}}{\text{Soil dry weight (g)}} \times 100$$

2.4 Statistical analysis

The significance of soil properties and fruit quality parameters was calculated by randomized block design (RBD). Coefficient of correlation was worked out between various soil properties, vegetative extension and fruit quality parameters with help of SPSS 16.0.

3. Results and discussion

3.1 Weather parameters

The table-1 showed that the temperature, relative humidity and evaporation. The mean maximum temperature in summer season 2009-10 of 32.55 ^{0}C and was lowest in winter season of 11.11^{0}C during 2009-10. In the year 2010-11, the maximum temperature in the month May and minimum temperature in January. The relative humidity was maximum in August 74.42 % and minimum in June 21.27 % during 2009-10. The relative humidity was maximum in August 75.44 % and was minimum in May 33.87 % during 2010-11. The evaporation was maximum in 6.30 mm and was minimum in 1.42 January during 2009-10. In the 2010-11, the maximum was recorded in 8.70 mm June and minimum in 0.99 mm December.

Table 1: Average monthly climatic parameters (April-2009 to March-2011)

Months	Air temperature (°C)						Relative humidity (%)		Evaporation (mm)	
	2009-10			2010-11			2009-10	2010-11	2009-10	2010-11
	Min.	Max.	Mean	Min.	Max	Mean				
April	17.37	33.07	25.22	22.43	38.81	30.62	40.27	43.27	3.48	5.88
May	22.44	38.68	30.56	25.01	40.06	32.54	28.97	33.87	4.91	8.13
June	24.10	41.00	32.55	24.75	38.90	31.83	21.27	35.17	6.30	8.70
July	24.41	36.73	30.57	25.45	34.24	29.85	47.87	61.35	3.13	5.36
August	23.65	33.47	28.56	25.17	32.86	29.01	74.42	75.74	3.50	3.37
September	23.34	33.22	28.28	22.78	32.57	27.68	65.60	70.33	4.16	4.14
October	16.76	32.11	24.43	18.62	30.55	24.58	44.42	53.58	5.53	4.35
November	11.27	26.16	18.71	12.15	26.17	19.16	46.37	41.77	3.46	2.66
December	7.46	21.39	14.42	6.75	20.40	13.58	48.26	52.39	2.01	0.99
January	5.61	16.61	11.11	5.56	15.19	10.38	62.52	68.45	1.42	1.21
February	9.73	23.28	16.50	9.84	20.10	14.97	41.61	59.00	2.71	2.81
March	16.28	31.48	23.88	14.00	27.05	20.52	37.68	48.71	4.02	4.80

The figure 1 precipitation was maximum in rainy season in month of August 368.10 mm and minimum in winter season was zero recorded in December month and total annual rainfall was 705.70 mm during 2009-10. The maximum rainfall in rainy season in the month of August 421.90 mm and was minimum in winter season 1.60 mm in the November month and total annual rainfall in 1338.40 mm during 2010-11. The 52.7 % total annual rainfall was higher in 2010-11 as compared to 2009-10 during the experimental period from April to May.

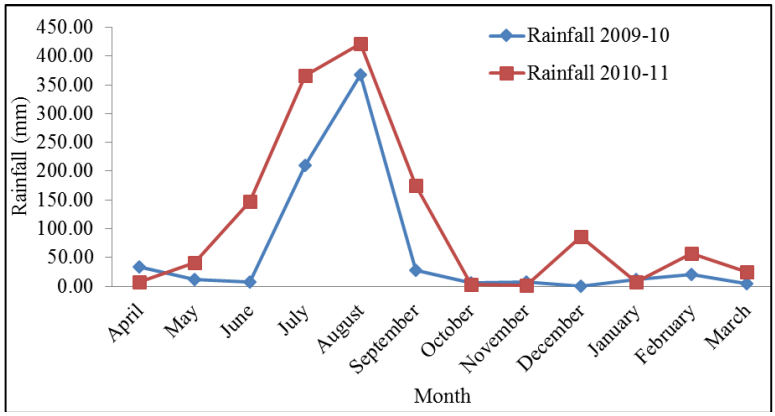


Fig 2: Monthly rainfall distribution from 2009-10 and 2010-11

Soil properties

It is revealed from table 2 that the soil pH was highest in CK and followed by FYM, B, BP, BS, G and MS. Soil pH of the tree basin showed slighter decrease in their values, but the difference was non- significant. The rainfall or irrigation water passed through mulches materials, the layer can affected the lower soil layer by absorption or solving some materials. The decreased could be due to adding up of organic matter after decomposition of mulches; which releases organic acids and dissolve them from their soluble form. These results are similar finding [8]. The electrical conductivity was highest in CK and was lowest in G and MS, respectively. The difference among the mulches was statistically non- significant. Mulches decreased to water evaporation and reducing salt accumulation may be absorbed by mulch layer and lead to reducing of water EC when it reaches to the soil layer. Therefore lead to reducing the accumulation of soluble salts in the soil surface and electrical conductivity of soil can be reduced [8]. The organic carbon was highest in FYM and followed by B, MS, BS, G, CK and lowest in BP. The statistically difference among much was significant. It was observed that the mulches decomposed after rainy season and supplementary lot of humus to the soil. These findings are with the agreement of the results by [7,8]. The significantly (p = 0.05) effect of different type of mulches on available nitrogen was highest in FYM and was lowest in BP. The positive effect of organic mulches on raising the available plant nutrient content in the soil is well documented. The higher potential of nitrate leaching in mulched soil could not be overlooked because nitrate accumulation peak was found at deeper layer of mulched soil compared to no-mulched soil. Soil organic N mineralization is related to the environment [14]. The result revealed that effect of various type of mulches on available phosphorus was significantly affect (p = 0.05).

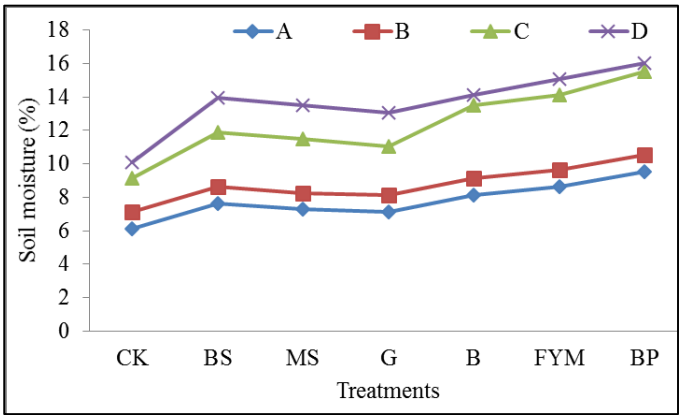
Table 2: Effect of various mulch on soil properties and available nutrients of Eureka lemon under rainfed conditions (pools data 2 years)

Mulch type	pH (1:2.5)	EC (dSm^{-1})	Organic carbon (g kg^{-1})	Available Nutrients ($kgha^{-1}$)		
				Nitrogen	Phosphorus	Potassium
CK	7.05	0.25	4.45	255.00	14.14	128.52
BS	6.53	0.18	5.60	266.00	15.12	135.82
MS	6.27	0.19	6.10	270.25	15.45	139.75
G	6.51	0.19	5.40	263.13	14.79	131.89
B	6.64	0.21	6.38	273.75	15.70	142.55
FYM	6.74	0.24	6.90	278.75	16.56	146.20
BP	6.62	0.22	4.23	253.25	13.67	127.68
SE(m)	0.12	0.02	0.30	2.00	0.45	1.04
CD (5%)	NS	NS	0.88	6.00	1.36	3.14

The phosphorus concentration in farmyard manure is higher than its concentration in soil, for that reason irrigation or raining water could transfer phosphorus to soil layer. While other mulches, rising mulch layer caused maintain soil temperature and soil moisture that helped better phosphorus absorption condition in soil [8, 15]. The significantly (p = 0.05) effect of various type of mulches on available potassium was highest in FYM and was lowest in BP. They attributed this to K release during the decomposition of the mulch materials [8, 15].

Soil moisture content

The figure 2 showed that the enlarge in soil moisture content under mulches treatment was statistically significant at both the soil layer of (0-15 cm and 15-30 cm). The superior soil moisture content was observed in BP at both soil layers and the least in CK in the basins of rainfed trees [16]. The advanced soil moisture content under mulches treatments might be due to lessening in water erosion, surface evaporation is reduced, weed suppression, ruling of soil temperature, the outcomes are added in soil moisture [17]. The description of BP prohibited the loss of water in evaporation from the underside surface and condensed it under surface on cooling.



A= 80 DAM (2009-10), B= 80 DAM (2010-11), C= 110 DAM (2009-10) and D= 110 DAM (2010-11)

Fig 3: Soil moisture content (%) at 80 and 110 days after mulch (DAM) during 2009-10 and 2010-11.

The organic mulches was relatively less resourceful in retaining soil moisture due to its early decomposable nature and have favoured the adsorption of evaporated water from the surface of the soil and in turn allowed it to get evaporated from its surface layer into the surrounding atmosphere. The organic and inorganic mulching provided consistently enhanced availability of soil moisture in tree basin due to which the plant roots remained almost certainly active during the irrigation season ensuing in most favourable availability of nutrient and suitable translocation of food materials which accelerated the fruit expansion and progress in Eureka lemon.

Vegetative extension

The data presented in table 3 revealed that the vegetative growth was significantly influenced by various mulching treatments maximum except plant girth. The increase in plant height, spread and girth size was highest (50.75 cm, 32 and 31.62 cm and 2.08 cm) in BP and followed by FYM, B,MS, BS, G and was lowest in CK respectively. The enhance in growth of tree was due to enlarge in availability of soil moisture, nutrients and reasonable evaporation from soil layer [17]. The smallest growth of tree was observed in CK and grasses due to high evaporation and less nutrient availability. The mulches with MS, BS, G were established to be midway in their influence on tree growth. The affirmative reply of mulches on various growth characteristics may be attributed to progress [7]. The various mulches in maximum soil moisture availability, adding up of nutrients and fewer weed growth with organic mulches might be attributed to higher extension of root growth development [9].

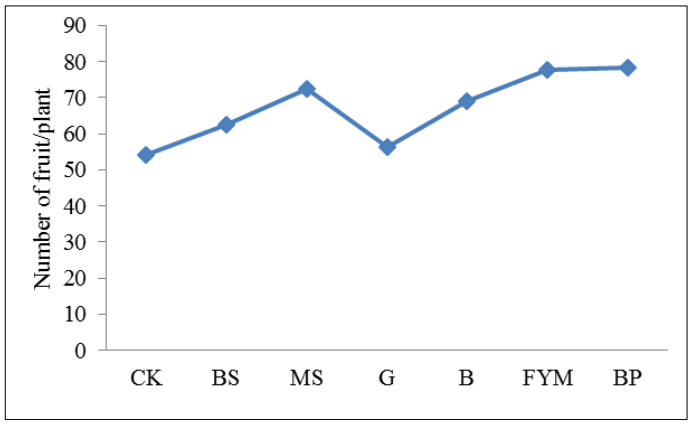
Table 3: Effect of various mulch on vegetative extension of Eureka lemon under rainfed conditions (pools data 2 years)

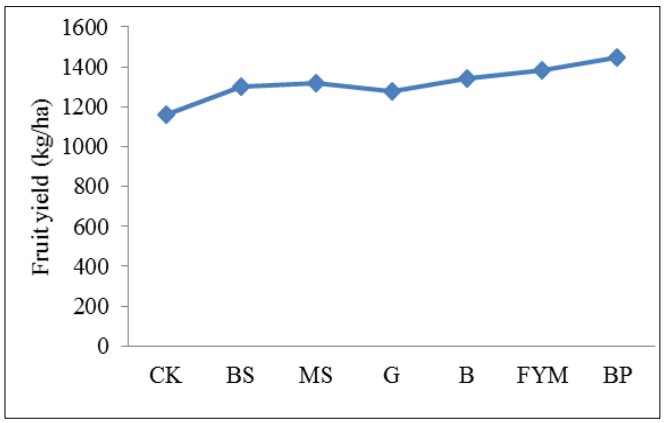
Mulch type	Plant height (cm)	Plant girth (cm)	Plant spread (cm)	
			East-West	North-South
CK	234.75	11.11	157.00	160.88
BS	255.50	12.11	168.00	170.50
MS	265.50	12.21	172.00	175.00
G	250.00	11.75	163.50	166.50
B	272.00	12.13	176.50	180.00
FYM	279.50	12.90	184.50	187.50
BP	285.50	13.19	189.00	192.50
SE(m)	5.03	0.20	3.92	3.67
CD (5%)	15.06	NS	11.73	10.98

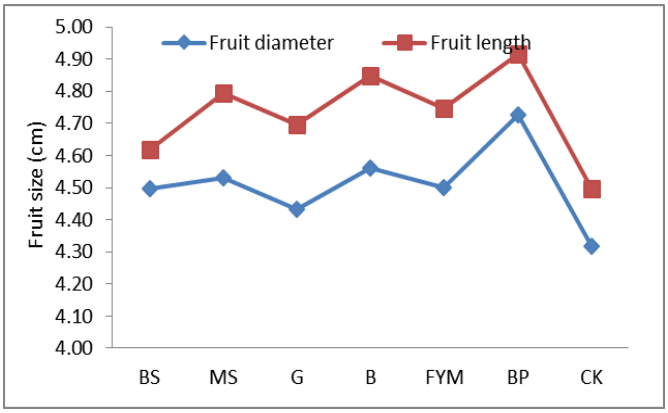
Fruit yield and quality parameters

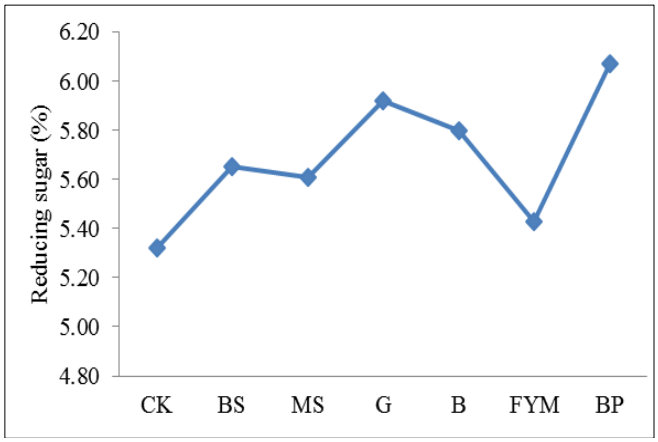
The figure 3 showed that the fruit yield was significantly influence by various mulches. Tree treated with different mulches were more evident with esteem to fruit yield compared with control. The raise in fruit yield was generally attributed to enlarge in availability of organic matter and available nutrients in soils. The highest fruit yield in BP, FYM, B, MS, BS and G were 1.24, 1.18, 1.15, 1.13, 1.12 and 1.10 times higher as compared to those in CK, respectively. Similar results are also reported in citrus and other crops [7, 16]. The fruit weight was statistically significant in various mulches treatments. The highest fruit weight in BP, FYM, B, BS, MS and G were 1.33, 1.21, 1.19, 1.10, 1.09 and 1.08 times higher as compared to those in CK, respectively. The total soluble solids were BP and G were 1.07 and1.05 times higher then CK, respectively. However, MS and BS were 1.03 similar times higher in CK. The differences among the various mulches were statistically significant. The fruit size (length and diameter), reducing sugar, total sugar, ascorbic

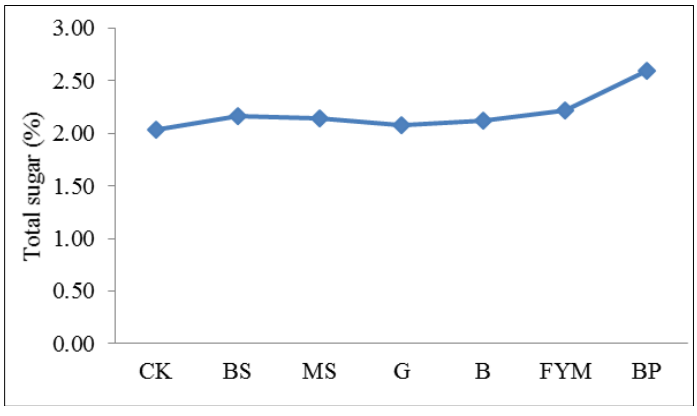
acid were highest in BP followed by FYM and B respectively. The difference among the various mulches was statistically non- significant. The fruit acidity indicating there were no carrying out of mulches were non-significant among different treatment. The high fruit quality is associated to weed free environment, high soil moisture retention and higher nutrient uptake under black polythene mulch treatment [18].











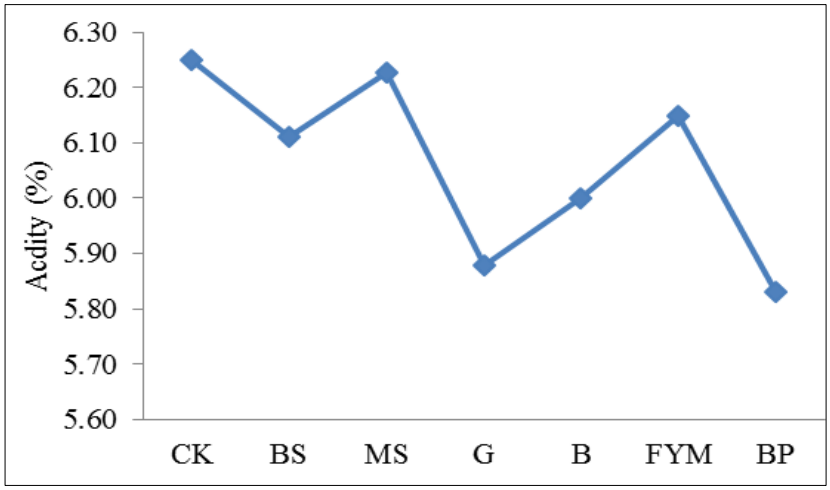


Fig 4: Effect of various mulch on fruit yield and quality attributes of Eureka lemon under rainfed conditions during 2010-11

Correlation Study

It is revealed from table 4 that there is correlation between soil properties with vegetative extension of Eureka lemon tree. The soil pH and EC was positive and significant correlated (r = 0.853*) among various mulches treatments. The organic carbon was positive and highly significant correlated in available nitrogen (r = 0.999**), available phosphorus (r = 0.989**) and available potassium (r = 0.981**). The available nutrients were positive and highly significant correlated among each other. The highest relationship was observed between organic carbon and available nitrogen content. The plant height and girth was positively correlated with organic carbon, available nitrogen, and phosphorus and potassium contents except soil pH. The plant spread (east- west) was positive and highly significant correlated in plant height (r = 0.987**) and plant girth (r = 0.972**). Plant spread of north-south was positive and highly significant correlated in plant height (r = 0.983**) and plant girth (r = 0.964**). The maximum relationship was observed in plant spread of east –west and north south (r = 0.999**) of the plant tree. These results are conformity with the findings by [19].

Table 4: Correlation of soil properties and vegetative extension of eureka lemon under rainfed conditions (pool data 2 years)

	pH	EC	Organic carbon	Avail N	Avail P	Avail K	Plant height	Plant girth	Plant spread (E-W)
EC	0.853*								
Organic carbon	-0.338	-0.168							
Avail N	-0.312	-0.139	0.999**						
Avail P	-0.226	-0.064	0.989**	0.990**					
Avail K	-0.266	-0.056	0.981**	0.989**	0.977**				
Plant height	-0.345	0.008	0.325	0.352	0.283	0.417			
Plant girth	-0.335	-0.011	0.208	0.232	0.186	0.288	0.957**		
Plant spread (E-W)	-0.220	0.124	0.233	0.263	0.209	0.337	0.987**	0.972**	
Plant spread (N-S)	-0.194	0.154	0.214	0.245	0.191	0.322	0.983**	0.964**	0.999**

*. Correlation is significant at the 0.05 level (2 tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

It is evident from table 5 that the correlation studies of fruit quality parameters among each other. The fruit yield and number of fruits was positively and significant correlated. The fruit weight was positive and significantly correlated in number of fruits (r = 0.843*) and fruit yield (r = 0.955**). The fruit diameter and fruit length was positive and highly significantly correlated with number of fruits, fruit yield, fruit weight and fruit diameter. The maximum relationship (r = 0.938**) was observed with the fruit diameter and fruit yield. The total soluble solids (TSS) was positive and significantly correlated with fruit yield (r = 0.801*), number of fruits, fruit weight, fruit length and fruit diameter.

Table 5: Correlation among the fruit quality attributes of Eureka lemon in various mulches under rainfed conditions during 2010-11.

	No. of fruit /plant	Yield	Fruit weight	fruit diameter	Fruit length	TSS	Reducing sugar	Total sugar	Ascorbic acid
Yield	0.893**								
Fruit weight	0.843*	0.955**							
fruit diameter	0.814*	0.938**	0.914**						
Fruit length	0.800*	0.897**	0.853*	0.919**					
TSS	0.584	0.801*	0.721	0.754	0.679				
Reducing sugar	0.232	0.602	0.59	0.713	0.696	0.731			
Total sugar	-0.405	-0.152	-0.265	-0.311	-0.139	0.225	0.245		
Ascorbic acid	0.789*	0.827*	0.794*	0.913**	0.773*	0.787*	0.571	-0.397	
Acidity	0.082	-0.310	-0.414	-0.436	-0.403	0.862*	0.626	-0.269	0.363

*. Correlation is significant at the 0.05 level (2 tailed).
**. Correlation is significant at the 0.01 level (2-tailed).

The ascorbic acid was positive and highly significant correlated with number of fruits, yield, fruit weight, fruit length, fruit diameter, TSS. Total sugar was positively correlated with TSS and reducing sugar. The fruit acidity was positive and highly significant correlated with (r = 0.862*) TSS. The similar findings have also been advocated by [19] in her studied on Guava Crop.

4. Conclusions

This study found that temporally uneven rainfall distribution, resulting in soil water stress was the major constraint on Eureka lemon growth and development in the rainfed sub-tropics of Jammu and Kashmir. BP and FYM evidently increased soil water storage and ensured plant water availability, particularly during the early growth seasons; this mitigated the negative impacts of water deficit and improved water utilization. Consequently, both organic and inorganic mulches treatments significantly increased the Eureka lemon yield. However, BP was more effective than FYM and B in improving fruit yield. These results may provide valuable information for improving horticultural production and water utilization particularly in the rainfed areas.

5. Acknowledgement

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