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Impact of Various Types of Mulch Materials on Plant Growth, Yield and Quality Attributes of Kinnow Mandarin

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ABSTRACT

Background: Among Citrus fruits, Kinnow mandarin is one of the significantly important fruit crops commercially grown in North-Western parts of India. However, due to climate change scarcity of water and soil degradation are the challenging problems, which can cause economic loss to growers. Thus, use of mulching is the one of the appropriate practice for sustainable fruit production.

Methods: The experiment consisted of six different types of mulch materials including inorganic and organic mulches like polyethylene (bicolour), bio-mulch (dried local weeds/grasses), mustard straw mulch, sugarcane trash mulch, control (no mulching+no weeding) and hand weeding were applied under Kinnow mandarin trees. The experiment was laid out in randomized block design with three replications.

Result: The findings of the study revealed that maximum canopy volume (5.62 m^3), number of fruits (485.30 $tree^{-1}$), fruit yield (95.44 kg $tree^{-1}$) fruit length, fruit width, fruit weight, total soluble solids, ascorbic acid and juice content (6.51 cm, 8.07 cm, 196.74 g, 12.47°Brix, 46.89 mg/100 ml and 51.37%, respectively) with minimum peel thickness (2.10 mm) and acidity (1.03%) were recorded with bicolour polyethylene mulch followed by sugarcane trash mulch and were the lowest in control. The highest B:C ratio of 2.49 was obtained from the bicolour polyethylene mulch followed by sugarcane trash mulch (2.45) as compared to control (1.96).

Key words: Fruit quality, Kinnow mandarin, Mulching, Yield.

INTRODUCTION

Kinnow mandarin is a hydrid between 'King' (*Citrus nobilis* Lour.) and 'Willow Leaf' (*Citrus deliciosa* Tan.) of family *Rutaceae* developed at the University of California Research Centre, Riverside, USA by Dr. H.B. Frost in 1935 and introduced in India in 1959. Among citrus group, it is one of the important fruit crops commercially grown in North-Western parts of India (Arora *et al*., 2018). Kinnow mandarin has become the most popular among citrus growers of North Western parts of India because of higher yield potential and is adapted under arid and semi-arid climatic conditions of Punjab, Rajasthan, Haryana and Himachal Pradesh (Kumar *et al*., 2015). Consumers prefer Kinnow mandarin due to its attractive colour, high juice content, distinctive flavour and rich in vitamin C, vitamin B and β-carotene (Mahajan *et al*., 2018). Canal water is the major source of irrigation in majority of Kinnow mandarin growing areas. In most of these areas, available ground water has poor quality (brackish to saline) which is detrimental to the plant growth. In present climate change scenario, water scarcity poses greater risk of yield reduction and economic losses to Kinnow growers. Therefore, cost effective techniques are needed to improve water use efficacy in these regions.

Mulching is a promising agronomic practice in which covering the soil surface with a thin layer of either organic (crop residues, dried weeds *etc*.) or inorganic (polyethylene) materials is practiced to conserve soil moisture and soil health thereby, plant growth and yield (Jordán *et al*., 2011). Several researchers studied the effect of various mulching materials such as dead organic mulch (Hammermeister, 2016), crop residue mulch (Budianta *et al*., 2018), horticultural fabric and corn straw mulches (Liao *et al*., 2021), plastic film, biodegradable paper and bio-based film mulches (Zhang *et al*., 2019), polyethylene, paddy straw and rice husk mulches (Lalruatsangi and Hazarika, 2018 polyethylene mulch (Bhandari *et al*., 2017; Wang *et al*., 2019) under fruit tree canopy. Mulching plays significant role in suppression of weeds (Hammermeister, 2016; Sharma and Sharma, 2019), enhanced water use efficiency (El-Naggar *et al*., 2018, Singh *et al*., 2017; Suo *et al*., 2019), improved soil health (Budianta *et al*., 2018), reduce soil erosion and maintain soil temperature (Sarkar *et al*., 2019). It is an effective practice that enhance fruit yield and improve fruit quality in acid lime (Lalruatsangi and Hazarika, 2018) and citrus (Kuniga *et al*., 2018; Wang *et al*., 2019; Xuemei *et al*.,

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2017). Therefore, this study was conducted with the objective to assess the impact of various mulch materials on plant growth, yield and fruit quality of Kinnow mandarin under drip irrigated condition.

MATERIALS AND METHODS

A field trial was conducted at experimental Kinnow orchard of the ICAR-AICRP on Fruits, Department of Horticulture, Agricultural Research Station (SK Rajasthan Agricultural University), Sriganganagar during 2017 to 2019. Kinnow mandarin trees budded on Rough lemon (*Citrus jambhiri* Lush.) rootstock having uniform vigour and age with spacing of 6 × 6 m were selected. All the experimental trees were maintained under similar agronomical practices and irrigated through drip irrigation on alternate days. The experiment was laid out in randomized block design with three replications and single tree as treatment unit and the data were collected on various parameters. Six different types of mulch materials including inorganic and organic mulches *viz.*, polyethylene (bicolour) 100 µ, bio-mulch (dried local weed grasses) (5 cm thickness), mustard straw mulch (5 cm thickness), sugarcane trash mulch (5 cm thickness), control (no mulching + no weeding) and hand weeding were applied (Fig 1). The mulches were applied after fertilization in month of February. Organic mulches were applied every year and polythene mulch was retained for all three years.

The canopy volume was calculated based on the formulae (Westwood, 1978)

$$\text{Canopy volume} = \left(\frac{4}{3}\right)\left(3.14\right)\left(\frac{H}{2}\right)\left(\frac{W}{2}\right)$$

Where,

H = Height of the tree.

W = Width (width was minor axis while height was major axis).

Fully ripen fruits at golden orange colour stage were harvested during mid-January. Total number of fruits tree^{-1} were counted and yield was recorded by weighing the fruits. 10 fruits tree^{-1} were randomly collected and sent to fruit laboratory for further physico-chemical analysis. In laboratory, the fruits were washed with tap water to remove dirt followed by air drying. Average fruit weight was calculated by weighing ten fruits on digital weighing balance. The transverse diameter (length) and longitudinal diameter (width) and peel thickness of fruits from each experimental tree were measured with the help of vernier caliper. Juice content of fruit was extracted separately for each replication and weighed. The average juice percentage was calculated based on the formulae:

$$\text{Juice content} = \frac{\text{Juice weight per fruit}}{\text{fruit weight}} \times 100$$

The TSS (°Brix) of juice was measured by using hand refractometer. Total titratable acidity and ascorbic acid content were estimated through standard techniques (AOAC, 2000). All the common cost concepts of agricultural economics were used to interpret the results. To analysis of common cost of cultivation the variable and fixed inputs used in cultivation of Kinnow mandarin were included. The additional cost of each treatment was calculated based on the price of mulch material for each tree separately. Then total cost of cultivation was calculated by addition of common cost of cultivation and additional cost of treatment. Gross return was obtained by multiplying the yield per hectare with the prevailing wholesale price of Kinnow mandarin in local market. The field experiment was laid out in randomized block design with three replications and data were analyzed statistically by analysis of variances as one-way ANOVA. Significance was tested using F-test at a 5% level of probability ($P<0.05$). The standard error of the mean (SEm±), the critical difference (CD) at 5% level of probability ($P< 0.05$) were worked out for the study of each parameter by Gomez and Gomez (1984).

RESULTS AND DISCUSSION

Growth and yield

Data presented in Table 1 showed that various mulch materials enhanced the plant growth and yield of Kinnow mandarin as compared to control. A maximum canopy volume (5.62 m^3) was recorded with sugarcane trash mulch followed by bicolour polyethylene mulch (5.48 m^3). Maximum number of fruits (485.30 tree^{-1}) and yield (95.44 kg tree^{-1}) was recorded with bicolour polyethylene mulch followed by sugarcane trash mulch (480.31 tree^{-1} and 91.80 kg tree^{-1}, respectively). These two treatments were at par for all growth and yield parameters but significantly superior over control. The lowest canopy volume (3.91 m^3) and yield (60.90 kg tree^{-1}) was recorded in control. Canopy structure of tree can directly affect light interception and the potency of light energy utilization. Optimum canopy structure is base of perfecting photosynthetic efficiency and achieving higher fruits yield. The increase in canopy volume of the plant was due to increased availability of soil moisture, nutrients and moderate evaporation from soil surface (Lalruatsangi and Hazarika, 2018), enhanced the soil organic carbon contents and its active fractions in the soil (Gu *et al*., 2017) or might be due to better hydrothermal conditions provided by mulch as confirmed by Kaur and Mahal (2017). Improvement in canopy volume and yield of Kinnow mandarin might be due to fact that the bicolour polyethylene mulch and sugarcane trash mulch maximized nutrient uptake, enhanced water use efficiency and improved soil health. Reduced evaporation losses and modified infiltration capacity and optimized soil temperature were responsible for enhanced water availability in mulching treatments. In control, more weed infestation resulted in higher moisture loss from the soil surface and competition for nutrients may be accountable to minimized these parameters. These findings were in agreement with the results of Liao *et al*. (2021) in apple, Bhandari *et al*. (2017) in litchi and Jamir and Dutta (2020), Kumar *et al*. (2015), Kuniga *et al*. (2018), Lalruatsangi and Hazarika (2018), Liu *et al*. (2012), Wang *et al*. (2019), Xuemei *et al*. (2017) in citrus fruits. Further, strong and significant correlation between



Fig 1: Various mulches used under tree canopy of Kinnow mandarin.

canopy volume and yield in Kinnow has been reported by Rattan *et al*. (2020) which confirmed the greater canopy volume and yield due to mulching in present findings.

Physico-chemical characterization of Kinnow mandarin

The data presented in Table 1 and 2 revealed that various mulches significantly increased the fruit quality parameters *viz.*, fruit length, fruit width, fruit weight, total soluble solids (TSS), ascorbic acid and juice content while reduced the peel thickness and acidity of Kinnow mandarin fruits. An average maximum fruit length, fruit width, fruit weight, TSS, ascorbic acid and juice content (6.51 cm, 8.07 cm, 196.74 g, 12.47°Brix, 46.89 mg/100 ml and 51.37%, respectively) and minimum peel thickness and acidity (2.10 mm and 1.03%, respectively) were recorded in the bicolour polyethylene mulch followed by sugarcane trash mulch. In sugarcane trash mulch applied trees, fruit length (6.42 cm), fruit width (7.61 cm), fruit weight (191.36 g), TSS (11.98 °Brix), ascorbic acid (46.52 mg/100 ml) and juice content (49.90%) were recorded with peel thickness and acidity (2.15 mm and 1.05% respectively). Both the above mentioned treatments were at par to each other in all parameters except fruit width. The minimum fruit length, fruit width, fruit weight, TSS, ascorbic acid and juice content (5.28 cm, 6.38 cm, 166.09 g, 8.33 °Brix, 33.45 mg/100 ml and 40.96% respectively) with maximum peel thickness and acidity (3.67 mm and 1.31% respectively) were recorded in control treatment. The changes in physico-chemical quality attributes of Kinnow mandarin fruits might be due to the appropriate availability of nutrients and soil moisture content continuously during the growth and development period of fruits. While in control, severe weed infestation competed for nutrients and soil moisture. The fluctuation in soil moisture and temperature were also the major cause of poor fruit quality.

The superiority of plastic mulch and sugarcane trash over other mulches could be due to these mulches are completely or more efficiently impermeable to water. Thus, these mulches consequently regulate direct evaporation of soil moisture and reduce the water losses soil erosion more significantly over the surface. These findings were in close conformity with the results of Bhandari *et al*. (2017) in litchi, Bhattacharjee *et al*. (2020), Das and Dutta (2018) in mango, Shen *et al*. (2019) in apple, Bhanukar *et al*. (2015) in Kinnow mandarin, Lalruatsangi and Hazarika (2018) in acid lime and Liu *et al*. (2012), Shimazaki and Nesumi (2016), Wang *et al*. (2019) in citrus fruits.

Economics of technology

The economics of various mulching treatments was worked out and presented in Table 3. The cost of each treatment was calculated based on the price of mulch material for each tree separately. The income was calculated according to the saleable market mean price of the fruits. The highest B:C ratio 2.49 with net profit (Rs. 1,58,370.00 ha^{-1}) was

Table 1: Impact of various mulches on growth and yield of Kinnow mandarin (Three years pooled data-2017-19).

Treatment	Fruit length (cm)	Fruit width (cm)	Peel thickness (mm)	Fruit weight (g)	Canopy volume (m^3)	Number of fruits $tree^{-1}$	Yield (kg $tree^{-1}$)
T_1: Control	5.28	6.38	3.67	166.09	3.91	367.91	60.90
T_2: Hand weeding	6.00	6.67	3.33	174.56	4.55	417.30	72.79
T_3: Bio- mulch (dried weed or grasses)	5.98	6.98	2.72	180.97	5.21	439.49	79.56
T_4: Mustard straw mulch	6.37	7.39	2.31	184.39	5.30	472.29	87.11
T_5: Sugarcane trash mulch	6.42	7.61	2.15	191.36	5.62	480.31	91.80
T_6: Polyethylene mulch	6.51	8.07	2.10	196.74	5.48	485.30	95.44
SEm	0.08	0.11	0.08	1.93	0.13	13.32	1.52
CD @ 5%	0.24	0.32	0.23	5.46	0.37	37.78	4.30

Table 2: Impact of various mulches on physicochemical attributes of Kinnow mandarin fruits (Three years pooled data - 2017-19).

Treatment	TSS(°B)	Juice content(%)	Acidity(%)	Ascorbic acid (mg/100 ml)
T_1: Control	8.33	40.96	1.31	33.45
T_2: Hand weeding	9.28	44.21	1.22	36.85
T_3: Bio-mulch (dried weed or grasses)	10.18	45.37	1.17	38.30
T_4: Mustard straw mulch	10.55	46.16	1.11	42.37
T_5: Sugarcane trash mulch	11.98	49.90	1.05	46.52
T_6: Polyethylene mulch	12.47	51.37	1.03	46.89
SEm	0.20	0.78	0.02	0.99
CD @ 5%	0.57	2.22	0.06	2.79

Table 3: Impact of various mulches on economics of Kinnow mandarin production.

Treatment	Yield (kg $tree^{-1}$)	Yield (q ha^{-1})	Gross returns (Rs. ha^{-1})*	Cost of cultivation (Rs. ha^{-1})	Net profit (Rs. ha^{-1})	Profit over control (Rs. ha^{-1})	BC ratio
T_1: Control	60.92	168.75	168750	86000	82750	0	1.96
T_2: Hand weeding	72.79	201.63	201630	92300	109330	26580	2.18
T_3: Bio-mulch (dried weed or grasses)	79.56	220.38	220380	98500	121880	39130	2.24
T_4: Mustard straw mulch	87.11	241.29	241290	102000	139290	56540	2.37
T_5: Sugarcane trash mulch	91.80	254.29	254290	104000	150290	67540	2.45
T_6: Polyethylene mulch	95.44	264.37	264370	106000	158370	75620	2.49

*calculated based on market price of fruits Rs. 10 per kg.

obtained from the bicolour polyethylene mulch followed by sugarcane trash mulch (B:C ratio 2.45) as compared to control (BC ratio 1.96). The bicolour polythene mulch gave an additional income of Rs. 75,620.00 as compared to control. More or less similar findings have been reported by Bons *et al*. (2018), Kumar *et al*. (2014) in Kinnow mandarin, Bhattacharjee *et al*. (2020) in guava and Lalruatsangi and Hazarikaand (2018) in acid lime. Although the initial effect of polythene mulching on plant growth and yield is positive, its residual impact needs to be worked for plant growth yield and economics.

CONCLUSION

Based on the findings of this study, either bicolour polyethylene mulch or organic mulch (sugarcane trash) have significant impact on plant growth, yield and physico-chemical attributes of Kinnow mandarin with the higher returns as compared to control treatment. Organic and inorganic mulches showed positive effects on growth and quality attributes due to enhanced water use efficiency and improved soil moisture conservation resulted into improved physico-chemical properties of soil providing congenial environment to the root zone of the tree. While in control, lower soil moisture regimes, more weed infestation resulted in higher moisture loss from the soil surface and competition for nutrients minimized these parameters. The technology (organic sugarcane trash mulch) will also be helpful for crop residue management and organic Kinnow mandarin production.

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Conflict of interest

All authors declare that they have no conflict of interest.

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