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Economic Appraisal of Kinnow Mandarin (*Citrus reticulate* Blanco) using Drip Trickle Irrigation and Hydrogel with Mulch in Rainfed Condition

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ABSTRACT

The profitability of drip trickle irrigation and hydrogel with mulch strategies with compared to that with 3 and 6 days drip trickle irrigation intervals and hydrogel viz. 30, 60, 90 and 120 g with black polyethylene mulch of Kinnow mandarin in rainfed condition of shiwaliks foothills Himalayas India. The highest fruit yield was recorded with T_{12} was statistically significant ($p<0.05$). Economics based comparison shows that all treatments were economically viable since their profitability (net income INR 53445.50-243641.98 ha^{-1} and benefit cost ratio 1.61–2.78) were feasible. The net return obtained with T_{12} was statistically ($p < 0.05$) at par with that observed with T_{14}. However, the benefit cost ratio and economic water productivity calculated with T_{12} were found to be significantly higher 39.7 % than that with T_1. These results lead us to conclude that the T_{12} strategy could be used to improve drip trickle irrigation and hydrogel with black polyethylene mulch of water productivity substantially in commercial Kinnow mandarin orchards in sandy loam soil.

Keywords Drip trickle irrigation, Hydrogel, Black polyethylene, Citrus, Economics.

INTRODUCTION

Water is one of the major limiting factors in fruit production and quality attributes. The demand of water from fast industrialization and high population growth, the share of water for horticulture is going to be condensed in the coming decades. The further scarcity of water for fruit production, therefore, should be checked to sustain the food supply through effective water conservation and management practices even in high-rainfall areas (Panda *et al.* 2004). Furthermore, the harvest per every drop of irrigation water should be enhanced while considering the best economic water use efficiency associated with any crop. The beginning of drip trickle irrigation (DTI) is a significant technological improvement in irrigation systems, which helps to combat water scarcity in horticulture. In recent years, the adoption of DTI has gained momentum due to its positive impact on water saving, productivity and produce quality in many crops, including citrus (Fereres *et al.* 2003). Irrigation scheduling is vital for improving the efficiency of drip irrigation systems, as an excessive or sub-optimum water supply has detrimental effects on the yield and fruit quality of citrus (Panigrahi *et al.* 2013). Moreover, the lack of water is developing as

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the major abiotic restraint limiting the productivity potential of citrus orchards in many arid and semi-arid regions (Abu-Awwad 2001). In these regions, DTI has been observed to be effective in combating such irrigation water shortage.

The potential benefits of DTI, hydrogel and black polyethylene mulch, therefore, are expected from: (i) increased water use efficiency (WUE) and (ii) reduced irrigation and production costs, which results in boosting the economics of production. In these regions it can be more profitable for a farmer to maximize crop water productivity than to maximize the harvest per unit land. The water saved can be used for other purposes or to irrigate extra units of land. When the water supply cannot be certain or its on-site availability depends on external factors such as droughts or political decisions taken at local or national level, as occurs in many arid zones of the planet, the drip trickle irrigation is referred to as 'uncontrolled'. The favorable response of pusa hydrogel is a soil conditioner able to retain water and plant nutrients, composite releases water and nutrients to the plants when surrounding soil near root zone of plants starts to dry up. These materials have more efficient water consumption, decrease in irrigation costs and intervals by 50% increase soil water holding capacity up to 2 to 4 times and soil porosity, providing plants with eventual moisture and nutrients as well as improving plant viability and ventilation and root development (Abobatta and Khalifa 2019). The black polyethylene mulch has demonstrated its efficiency in conserving soil moisture and increasing vegetative growth, yield, quality and economics of Kinnow mandarin (Kumar *et al.* 2014).

Kinnow is a commercially important citrus cultivar grown in arid, semi-arid and rainfed conditions in northern India. The major constraint to Kinnow production in this rainfed region is the scarcity of irrigation water during its critical period of growth. Drip trickle irrigation has been found to be a potential water-saving technique in Kinnow cultivation (Kumar *et al.* 2014). In India, total area under citrus production is 1055 thousand hectare with an annual production of 12746 thousand metric tonnes (Anonymous 2017). In the union territory of Jammu and Kashmir, citrus is positively grown in sub-tropical areas of Jammu division covering an area of about 14542 hectares with production of about 34191 MT (Anonymous 2017). Kinnow mandarin fruit cultivation in Jammu is achievement motion among the fruit growers due to its profitability and good market value.

On the other hand, the area under Kinnow production is enhancing exponentially due to the higher economic return from this crop compared with others (Bhat *et al.* 2011). Farmers are more concerned with sustaining the yield of Kinnow mandarin using less water, which could be achieved through adoption of drip trickle irrigation, hydrogel and black polyethylene mulch techniques using for this crop. However, suggesting any technique to farmers for adoption requires an impact analysis on crop yield, as well as the economic evaluation of these techniques with the crop in relation to the farmer's perception. Moreover, the comparative performance of drip trickle irrigation, hydrogel and black polyethylene mulch in relation to fruit yield and production economics in citrus grown in rainfed regions has not yet been studied. The present experiment was accompanied to study the effects of drip trickle irrigation, hydrogel and black polyethylene mulch on fruit yield and production economics of Kinnow mandarin in a sandy loam soil of the rainfed conditions of northern India.

MATERIALS AND METHODS

The field experiment was carried out with 10 years old plants of Kinnow mandarin plants which were planted in rainfed research substation for sub-tropical fruits Raya, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu. The climate of the study region is sub-tropical with hot and dry in summer season, hot and humid in rainy season and cold in the winter with mean annual rainfall of 1100 mm, of which approximately about 70 to 80 % is received during the monsoon (July to September) and the rest in winter. Soil of the experimental site from sandy loam textural classes.The rainfall distribution patterns are erratic in time, spatial, frequency and high intensity distribution to moisture stress condition. The study consisted of drip trickle irrigation intervals and different dose of hydrogel with black polyethylene mulch treatments. The performance of sole and combination treatments of drip trickle

Table 1. Water applied through drip trickle irrigation intervals treatments imposed on Kinnow mandarin.

Treatments	details	Water applied through drip trickle irrigation liter/year 2018	2019
T_1	Control	No irrigation	No irrigation
T_2	3 days drip trickle irrigation	98.00	98.00
T_3	6 days drip trickle irrigation	52.00	46.00
T_4	30 g hydrogel with mulch	No irrigation	No irrigation
T_5	60 g hydrogel with mulch	No irrigation	No irrigation
T_6	90 g hydrogel with mulch	No irrigation	No irrigation
T_7	120 g hydrogel with mulch	No irrigation	No irrigation
T_8	3 days drip trickle irrigation and 30 g hydrogel with mulch	98.00	98.00
T_9	6 days drip trickle irrigation and 30 g hydrogel with mulch	52.00	46.00
T_{10}	3 days drip trickle irrigation and 60 g hydrogel with mulch,	98.00	98.00
T_{11}	6 days drip trickle irrigation and 60 g hydrogel with mulch	52.00	46.00
T_{12}	3 days drip trickle irrigation and 90 g hydrogel with mulch	98.00	98.00
T_{13}	6 days drip trickle irrigation and 90 g hydrogel with mulch	52.00	46.00
T_{14}	3 days drip trickle irrigation and 120 g hydrogel with mulch	98.00	98.00
T_{15}	6 days drip trickle irrigation and 120 g hydrogel with mulch	52.00	46.00

irrigation and different dose of hydrogel with mulch in Kinnow mandarin cultivation. The treatments details and water applied are presented in Table 1. The water supplied through drip trickle irrigation water supplied during 15th march to 15th July in summer season as well as winter season was supplied on 15th September to 15th October in the water stress period. Two liter bottle filed in the tap water and has adjust the drip in minimum rate of two liter water per four hours was executed in the root zone of the Kinnow mandarin plant. The water supplied through drip trickle irrigation in liter was converting in mm. The effective rainfall was estimated as the rundown of change in soil water content (mm) in the root zone of trees between, drip trickle irrigation and potential rainfall in mm. Fruits were harvested from each plant of the experiment and the mean yields were determined by weighing the total fruits for different treatments. The benefit cost ratio (BCR) analysis of any treatments generally indicates its commercial helpfulness. In this study, BCR was calculated to analyze the return of the production system of Kinnow mandarin fruits with every of the drip trickle irrigation intervals and different dose of hydrogel with black polyethylene mulch strategies. The annual operating cost of the drip trickle irrigation intervals systems includes the cost of filling of bottles and regulates the drip in rate. The following assumptions were made in estimating the components of BCR, which include the cost of drip trickle irrigation, hydrogel and black polyethylene mulch system and the gross and net return of each of the different treatments. The cost of application of manure and fertilizer, hydrogel, black polyethylene mulch, drip, bottles plant protection measures, harvesting were calculated in this crop. The gross income from the production system includes the market return from the Kinnow crop. The wholesale price of Kinnow fruit for the Jammu region was taken as INR 25.0 kg^{-1} to INR 40.0 kg^{-1} in December 2019 and December 2020, respectively. The BCR was calculated following the formula (Reddy and Ram 1996) as :

BCR= Gross income/Total cost

RESULTS AND DISCUSSION

The actual costs were worked out for all the treatments, which includes, cost of hydrogel, black polyethylene mulch, basin of preparation, farmyard manure, cost of urea, diammonium phosphate (DAP), muriate of potash (MOP) and miscellaneous (drip, filling of bottles, protection measures, harvesting of fruits). Gross income with the application of drip trickle irrigation and hydrogel with black polyethylene mulch in all treatments were obtained by sale of value of Kinnow mandarin. Cost analysis

Table 2. Average cost of fertilizer and cultivation of Kinnow mandarin with the application of drip trickle irrigation and hydrogel with mulch materials. Miscellaneous: Drip, filling of bottles, protection measures, harvesting of fruits; INR: Indian rupee.

Treatments	Cost of hydrogel per plant (INR)		Cost of black polyethylene per plant (INR)		Cost of basin preparation per plant (INR)		Cost of FYM per plant (INR)		Cost of urea per plant (INR)		Cost of DAP per plant (INR)		Cost of MOP per plant (INR)		Miscellaneous (INR)	
	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019	2018	2019
T_1	0.00	0.00	0.00	0.00	40.00	40.00	60.00	60.00	9.40	9.60	10.00	8.62	3.35	4.75	190.00	190.00
T_2	0.00	0.00	0.00	0.00	40.00	40.00	60.00	60.00	9.40	9.60	10.00	8.62	3.35	4.75	205.00	205.00
T_3	0.00	0.00	0.00	0.00	40.00	40.00	60.00	60.00	9.40	9.60	10.00	8.62	3.35	4.75	200.00	200.00
T_4	48.48	48.48	0.00	0.00	40.00	40.00	60.00	60.00	9.40	9.60	10.00	8.62	3.35	4.75	190.00	190.00
T_5	96.96	96.96	0.00	0.00	40.00	40.00	60.00	60.00	9.40	9.60	10.00	8.62	3.35	4.75	190.00	190.00
T_6	145.44	145.44	0.00	0.00	40.00	40.00	60.00	60.00	9.40	9.60	10.00	8.62	3.35	4.75	190.00	190.00
T_7	193.92	193.92	0.00	0.00	40.00	40.00	60.00	60.00	9.40	9.60	10.00	8.62	3.35	4.75	190.00	190.00
T_8	48.48	48.48	20.00	20.00	40.00	40.00	60.00	60.00	9.40	9.60	10.00	8.62	3.35	4.75	205.00	205.00
T_9	48.48	48.48	20.00	20.00	40.00	40.00	60.00	60.00	9.40	9.60	10.00	8.62	3.35	4.75	200.00	200.00
T_{10}	96.96	96.96	20.00	20.00	40.00	40.00	60.00	60.00	9.40	9.60	10.00	8.62	3.35	4.75	205.00	205.00
T_{11}	96.96	96.96	20.00	20.00	40.00	40.00	60.00	60.00	9.40	9.60	10.00	8.62	3.35	4.75	200.00	200.00
T_{12}	145.44	145.44	20.00	20.00	40.00	40.00	60.00	60.00	9.40	9.60	10.00	8.62	3.35	4.75	205.00	205.00
T_{13}	145.44	145.44	20.00	20.00	40.00	40.00	60.00	60.00	9.40	9.60	10.00	8.62	3.35	4.75	200.00	200.00
T_{14}	193.92	193.92	20.00	20.00	40.00	40.00	60.00	60.00	9.40	9.60	10.00	8.62	3.35	4.75	205.00	205.00
T_{15}	193.92	193.92	20.00	20.00	40.00	40.00	60.00	60.00	9.40	9.60	10.00	8.62	3.35	4.75	200.00	200.00

of farmyard manure with the different treatments of hydrogel, black polyethylene urea, diammonium phosphate, muriate of potash and miscellaneous charges are presented in Table 2. It is obvious from the data the cost incurred on basin preparation per tree (INR 40.00), farmyard manure (INR 60.00) and black polyethylene mulch (INR 20 per plant). The variation in urea, DAP and MOP rate offered by year wise in 2018 and 2019, urea (INR 9. 4 and 9.60 per plant), DAP (INR 10.0 and 8.6 per plant) and MOP (INR 3.4 and 4.8 per plant) and hydrogel (INR1616 per kg) as well as miscellaneous charges (drip, filling of bottles, protection measures, harvesting of fruits in INR 190 –205 per plant of Kinnow mandarin.

Table 3. Economics of Kinnow production using drip trickle irrigation and hydrogel with mulch materials.

Treatments	Yield ($kgha^{-1}$)		Gross income (INR ha^{-1})		Total cost of cultivation (INR ha^{-1})		Net income (INR ha^{-1})	
	2018	2019	2018	2019	2018	2019	2018	2019
T_1	5615.60	5924.18	140390.00	148104.50	86944.50	86944.50	53445.50	61160.00
T_2	5904.72	6182.72	159427.44	166933.44	91114.50	91114.50	68312.94	75818.94
T_3	5838.00	6116.00	151788.00	159016.00	89724.50	89724.50	62063.50	69291.50
T_4	6188.28	6385.66	173271.84	178798.48	100421.94	100421.94	72849.90	78376.54
T_5	6666.44	6705.36	206659.64	207866.16	113899.38	113899.38	92760.26	93966.78
T_6	6963.90	7455.96	229808.70	246046.68	127376.82	127376.82	102431.88	118669.86
T_7	7269.70	7706.16	261709.20	277421.76	140854.26	140854.26	120854.94	136567.50
T_8	8245.48	8484.56	247364.40	254536.80	110151.94	110151.94	137212.46	144384.86
T_9	7822.92	7900.76	234687.60	237022.80	108761.94	108761.94	125925.66	128260.86
T_{10}	8687.50	8845.96	304062.50	309608.60	123629.38	123629.38	180433.12	185979.22
T_{11}	8373.36	8573.52	293067.60	300073.20	122239.38	122239.38	170828.22	177833.82
T_{12}	9290.76	9518.72	371630.40	380748.80	137106.82	137106.82	234523.58	243641.98
T_{13}	8823.72	8929.36	352948.80	357174.40	135716.82	135716.82	217231.98	221457.58
T_{14}	8973.84	9212.92	358953.60	368516.80	150584.26	150584.26	208369.34	217932.54
T_{15}	8651.36	8818.16	346054.40	352726.40	149194.26	149194.26	196860.14	203532.14

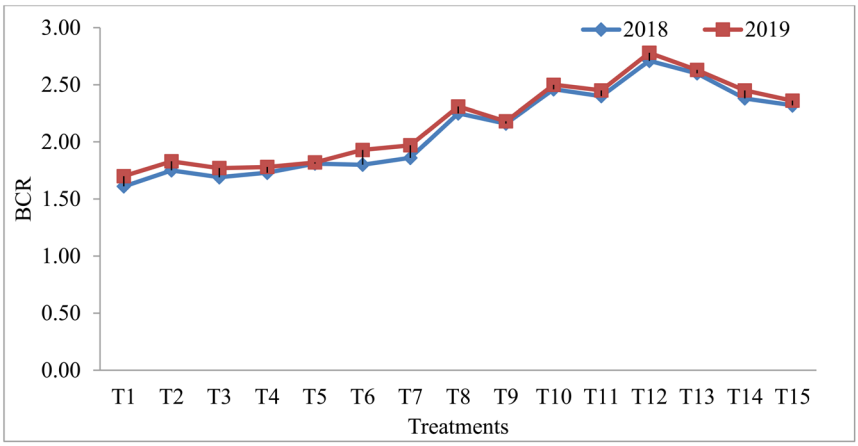

Fig. 1. Comparative analysis of cost-benefit ratio of drip trickle irrigation and hydrogel with mulch in Kinnow mandarin.

Table 3 show that the yield and grass income generated with the drip trickle irrigation and hydrogel with black polyethylene mulch were affected significantly ($p<0.05$). The highest yield was harvested under T_{12}, generally maximum gross income (INR 371630.40–380748.80) among the treatments, followed by (INR 358953.60–368516.80). However, the yield and gross income with T_{14} were statistically ($p<0.05$). The gross income in 2019 was significant higher yield under different treatments in 2018, in unkindness of higher yield under different treatments in 2019. The difference between the years was ascribed to the higher selling of good quality of fruits in this country.

The total cost of cultivation of Kinnow mandarin, which mainly consisted of drip trickle irrigation and hydrogel with black polyethylene mulch system was estimated to be maximum INR 150584.26 for T_{14} followed by T_{15} (INR 149194.26), T_7 (INR 140854.26), T_{12} (INR 137106.82), T_{13} (INR 135716.82) and was lowest in T_1 (INR 86945.50) treatments. However, the cost of cultivation was estimated to be lower for T_3 and T_2 (INR 89725.50 and INR 91115.50) due to reduced cost of different dose of hydrogel and application of black polyethylene mulch material of Kinnow mandarin.

The net income (NI) was observed to be highest with T_{12} (INR 234523.58–243641.98), followed by T_{13} (INR 217231.98–221457.58), T_{14} (INR 208369.34–217932.54) and was lowest in T_1 (INR 53445.50–61160.00), respectively (Fig. 1).

The benefit cost ratio was observed higher in T_{12} (2.71 and 2.78) followed by T_{13} (2.60–2.63) and was lowest in T_1 (1.61–1.70) among the treatments. Based on this analysis, it can be concluded that 3 days drip trickle irrigation and 90 g hydrogel with black polyethylene mulch material is a productive and potential water saving technique for Kinnow mandarin cultivation in northern India. In spite of a marginally higher net return due to high fruit yield, higher BCR was generated under this treatment due to good quality of fruits.

CONCLUSION

The improving fruit yield and high BCR with respect to Kinnow mandarin orchard under rainfed condition of Jammu sub-tropics. Thus, the adopting of 3 days drip trickle irrigation and 90 g hydrogel with black polyethylene mulch is an economically viable option compared with other treatments for Kinnow mandarin cultivation in sandy loam soils.

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