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Productivity and water use efficiency of kinnow mandarin (*citrus reticulate* blanco) as influenced by drip trickle irrigation and hydrogel

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ABSTRACT

An experiment was conducted to find out the effect of drip trickle irrigation and hydrogel with black polyethylene mulch on productivity and water use efficiencyof Kinnow mandarin. The two years pooled data revealed that highest available nitrogen, phosphorus and potassium (244, 20 and 164 kgha^{-1}), porosity and maximum water holding capacity (34.5 and 40.9 %) and percent increase height, spread and canopy volume (13.6, 14.8 and 44.5 %), respectively, were obtained with the application of 3 days drip trickle irrigation and 90 g hydrogel with black polyethylene mulch materials of tree. The drip trickle irrigation and hydrogel with black polyethylene mulch produced a significantly (p=0.05) maximum improve in soil moisture content over control treatment. The 3 days drip trickle irrigation and 90 g hydrogel with mulch showed highest fruit yield (9404.7 kg ha^{-1}), length (6.5 cm), weight (116.5 g) and quality of fruit volume (113.9 cc), Juice content (54.1 %) and TSS (13.3 ^{0}Brix). The specific gravity and titratable acidity showed reverse trend. The water use efficiency and benefit cost ratiowere better in 3 days drip trickle irrigation and 90 g hydrogel with mulchmaterials of tree.

Key words: Soil moisture, available nutrients, yield, fruit quality and benefit cost ratio

INTRODUCTION

Kinnow mandarin (*Citrus reticulata* Blanco) belongs to family Rutaceae and it is one of the most popular fruit crop of citrus species. Kinnow mandarin the most important commercial cultivar of Citrus in Northern India. Citrus (*citrus species*) plant normally require good amount of water compared to other subtropical fruits because sap circulation never entirely finishes and transpiration take place throughout the year as it is evergreen. In the union territory of Jammu and Kashmir, citrus is positively grown in sub-tropical areas of Jammu division. In rainfed areas of *kandi* belt of the soils is the major constraints are soil moisture stress and inherently poor soil fertility. The conservation soil moisture and retain of nutrients by the application of drip trickle irrigation (DTI) and hydrogel with black polyethylene mulch becomes essential for portable cultivation under rainfed condition of semi -arid ecosystem. In-spite of no assured irrigation facilities in this region, the moisture conservation and water storage technique are not in practice has declined alarmingly creating soil water storage in summer season for sustaining the crop. The affirmative 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 reason 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 hydrogel were claimed to decrease fertilizer (N, P and K) leaching and its increase irrigation water level is causing a significant reduce in the available nutrients due to increase leachability (Ekebafe *et al.*, 2011). The black polyethylene mulch has ascertained its effectiveness in conserving the soil moisture and increasing vegetative growth, yield and quality in Kinnow mandarin (Kumar *et al.*, 2014). The DTI is a new concept it is also increasing plant growth, fruit production and fruit quality in citrus cultivars pera orange. Keeping in view of the above facts the present investigation is under taken to assess the influence of drip trickle irrigation and hydrogel with black polyethylene mulch of kinnow mandarin in subtropical climate in rainfed condition.

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MATERIALS AND METHODS

A field experiment was conducted during 2017-18 to 2019-20 at Rainfed Research Substation for Subtropical fruits Raya, Sher-e-Kashmir University of Agricultural Sciences and Technology of Jammu situated at latitude of 32^0 39" North and longitude of 74^0 53" Eastat an elevation of 332 m above mean sea level in the subtropical zone.The experiment was laid out in randomized block design with 15 treatments and 3 replications considering one plant as unit to represent one treatment. The treatment details were T_1 –Control, T_2- 3 days drip trickle irrigation, T_3- 6 days drip trickle irrigation, T_4- 30 g hydrogelwith mulch, T_5- 60 g hydrogelwith mulch, T_6- 90 g hydrogelwith mulch, T_7- 120 g hydrogelwith mulch, T_8- 3 days drip trickle irrigation and 30 g hydrogel with mulch, T_9- 6 days drip trickle irrigation and 30 g hydrogel with mulch, T_{10}- 3 days drip trickle irrigation and 60 g hydrogel with mulch, T_{11}- 6 days drip trickle irrigation and 60 g hydrogel with mulch, T_{12}- 3 days drip trickle irrigation and 90 g hydrogel with mulch, T_{13}- 6 days drip trickle irrigation and 90 g hydrogel with mulch, T_{14}- 3 days drip trickle irrigation and 120 g hydrogel with mulch and T_{15}- 6 days drip trickle irrigation and 120 g hydrogel with mulch. The ten years old plants of kinnow mandarin which were planted in 2007 at distance of 6m x 6m was treated through drip trickle irrigation intervals and different doses of hydrogel with black polyethylene mulch. The 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 litre bottle filled in the tap water and has adjust the drip in minimum rate of 2 litre water per 4 hours was imposed in the root zone of the plant. The soil was analyzed for pH, EC, organic carbon and available nitrogen, phosphorus and potassium by adopting standard procedures (Jackson 1973), bulk density and maximum water holding capacity after harvest of the fruit crop. The NPK doses were applied @ 1600 g, 345 g and 250 g/tree during both the years, now mandarin fruits were harvested in the first week of December. The uniform cultural practices were applied to the experimental trees, which were grown purely under rainfed condition. The soil moisture content was recorded at 0-20 cm soil layer. Fruit quality parameters viz., fruit volume, juice content, specific gravity, titratable acidity and total soluble solids were determine as per standard procedures of Ranganna (2001).

RESULTS AND DISCUSSION

Soil moisture variation

The higher soil moisture content was observed at 170 days as well as 3 days drip trickle irrigation and 90 g hydrogel with black polyethylene mulch at 0-20 cm soil surface after mulching (DAM) (Fig.1). The maximum soil moisture content due to black polyethylene mulch could be due to lessening of water erosion, decrease in soil surface evaporation in (Kumar *et al.*, 2014). Drip trickle irrigation and plastic mulch also increased soil moisture content in Nagpur mandarin (Panigrahi *et al.*, 2008) and hydrogel was able to retain available water and nutrients to the (Pattanaaik *et al.*, 2015).

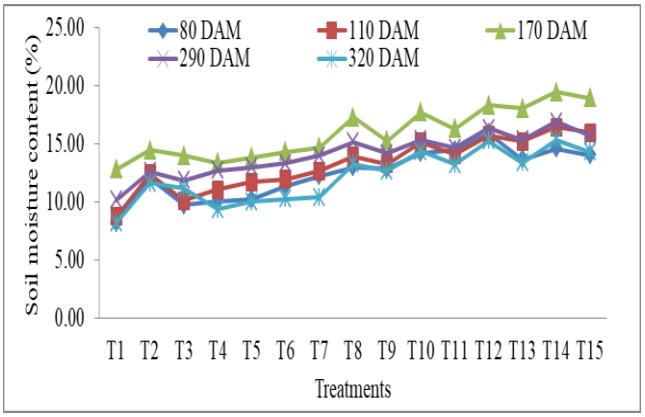
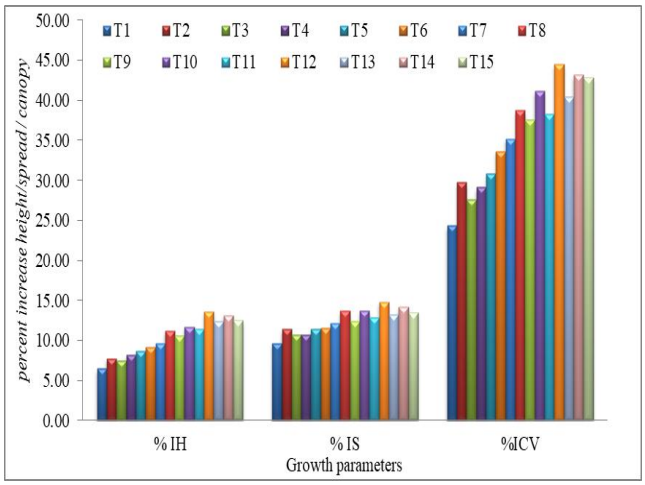


Fig.1: Soil moisture content (%) during different growth stages of Kinnow mandarin at 0-20 cm soil layer (mean of two years)

Growth parameters

The crop vegetative growth was significantly influenced by various treatments of drip trickle irrigation intervals and hydrogen with mulch treatments over control (Fig. 2). The per cent increase in plant height, plant spread and canopy volume was observed highest in 3 days drip trickle irrigation and 90 g hydrogel with mulch closely followed 3 days drip trickle irrigation and 120 g hydrogel with mulch treatment. The better increase in vegetative growth parameters were observed in combination treatment than sole treatment. The

hydrogel increased growth of plant due to soil was wet for lengthier time and upsurge the soil moisture content in Khasi mandarin (Pattanaaik *et al.*, 2015).Black polyethylene mulch prevented the evaporation of water from soil surface weed reduction in kinnow mandarin (Kumar *et al.*, 2014). The valuable effect of drip irrigation with mulch on increase vegetative growth of Nagpur mandarin was reported by Panigrahi *et al.*, 2008.



%IH= Percent increase height; %IS= Percent increase spread; %ICV = percent increase canopy volume

Fig. 2: Vegetative growth of Kinnow mandarin as affected by drip trickle irrigation and hydrogel with mulch (mean of two years)

Soil fertility

Application of drip trickle irrigation and hydrogel with black polyethylene mulch material significantly improved in soil properties as compared to control (Table 1). Amongst the combination treatment of water supply through drip trickle irrigation and hydrogel with black polyethylene mulch material showed better response, followed by different dose of hydrogel with mulch and drip trickle irrigations. The bulk density showed reverse trend and as a result minimum was recorded in 3 days drip trickle irrigation and 90 g hydrogel with mulch (1.58 g cm^{-3}) and maximum in control (1.68). The greater porosity and maximum water holding capacity was recorded in 3 days drip trickle irrigation and 90 g hydrogel with mulchfollowed by 3 days drip trickle irrigation and 120 g hydrogel while as minimum in control. The soil pH of the tree basin was reduced whereas EC was increased, but the differences were non-significant. The drip trickle irrigation and hydrogel with mulch covered the soil surface, it was gathered carbon dioxide in soil reacts with soil moisture and found carbonic acid, is marginally reduced under treated plant compared to untreated plants (Tiwari *et al.*, 2014).

Table 1: Soil fertility changes in soil as affected by drip trickle irrigation and hydrogel with mulch in Kinnow mandarin (mean of two years)

Treatment	BD (g/cm^3)	Porosity (%)	MWHC (%)	pH (1:2.5)	EC (dSm^{-1})	OC (gkg^{-1})	Available nutrients		
							N	P	K
T_1	1.68	38.8	26.0	6.9	0.35	4.69	231	17	159
T_2	1.67	39.2	27.7	6.8	0.35	4.71	233	17	159
T_3	1.67	38.9	26.4	6.8	0.35	4.70	232	17	159
T_4	1.66	39.1	27.3	6.7	0.35	4.74	234	17	159
T_5	1.66	39.3	28.0	6.7	0.36	4.83	235	17	159
T_6	1.65	39.4	28.7	6.6	0.36	4.89	237	18	159
T_7	1.63	39.8	29.7	6.6	0.36	4.93	238	18	159
T_8	1.61	40.4	32.0	6.5	0.37	5.02	240	19	161
T_9	1.63	40.1	30.5	6.5	0.36	4.98	239	18	160
T_{10}	1.60	40.6	32.5	6.4	0.37	5.09	242	19	162
T_{11}	1.61	40.1	32.1	6.5	0.36	5.07	241	19	161
T_{12}	1.58	40.9	34.5	6.4	0.37	5.20	244	20	164
T_{13}	1.60	40.5	32.8	6.4	0.37	5.10	240	19	162
T_{14}	1.59	40.7	34.3	6.3	0.37	5.15	243	20	163
T_{15}	1.59	40.4	33.7	6.3	0.37	5.12	241	19	163
SEm±	0.01	0.09	0.12	0.16	0.010	0.006	0.25	0.45	0.23
LSD P=0.05)	0.037	0.26	0.35	NS	NS	0.017	0.72	NS	0.68

The soil organic carbon and available nitrogen, phosphorus and potassium were observed higher in 3 days drip trickle irrigation and 90 g hydrogel followed by 3 days drip trickle irrigation and 120 g hydrogel with mulchand 6 days drip trickle irrigation and 120 g hydrogel while lowest in control. The increase in soil organic and available N, P and K content could be due to greater temperature, prevent leaching of losses and retain the water and nutrient in soil, which in turn changes the soil microbial communities and redox potential, thus affected the soil nutrients status (Tiwari *et al.*, 2014).

Yield and fruit quality

The fruit yield and quality attributes were affected by drip trickle irrigation intervals and different dose of hydrogel with black polyethylene mulch materials (Table 2). Plant treated with soil application of hydrogel cover the soil surface on plant basin and drip trickle irrigation produced more fruit yield than without application. The increase in fruit yield was mainly attributed to increase in soil moisture for longer time and availability of nutrients as well as reducing the fruit drop due to water stress. The higher fruit yield was recorded with treatment 3 days drip trickle irrigation and 90 g hydrogel (9404.7 kg ha^{-1}) followed3 days drip trickle irrigation and 120 g hydrogel (9093.3 kg ha^{-1}) while as lowest in control (5771.2 kg ha^{-1}). These results are in accordance with the finding of Panigrahi *et al.* (2008), Kumar *et al.* (2014) and Pattanaaik*et al.* (2015). The fruit quality attributes were also influenced by drip irrigation, different types of different dose of hydrogel (Table 2).

Table 2: Fruit yield, quality attributes, water use efficiency and economics of Kinnow mandarin as affected by drip trickle irrigation and hydrogel with mulch (mean of two years)

Treatment	Yield (kg ha^{-1})	Fruit length (cm)	Fruit weight (g)	Fruit volume (cc)	Specific gravity (ml)	Jice content (%)	TSS	Titratable acidity (%)	WUE (kg $ha^{-1}mm^{-1}$)	Net return per ha (Rs)	Benefit /cost ratio
T_1	5771.2	6.1	106.4	106.8	1.01	44.0	10.2	1.13	6.97	57337	1.66
T_2	6043.7	6.3	109.2	107.8	1.01	44.5	10.3	1.07	7.30	72065	1.79
T_3	5977.0	6.2	108.3	107.6	1.01	44.2	10.3	1.10	7.22	65677	1.73
T_4	6288.3	6.2	110.0	109.8	1.00	45.0	10.4	1.06	7.60	75652	1.75
T_5	6685.9	6.2	111.8	110.0	1.00	45.2	10.4	1.04	8.08	93363	1.82
T_6	7211.3	6.3	112.8	110.3	1.00	45.5	10.8	1.06	8.71	110596	1.87
T_7	7489.3	6.4	113.0	110.7	1.00	46.0	11.2	0.99	9.05	128761	1.91
T_8	8365.0	6.4	114.4	111.3	1.00	47.1	11.8	0.96	10.10	140798	2.28
T_9	7861.8	6.4	114.5	110.3	1.00	46.8	11.5	0.97	9.50	127093	2.17
T_{10}	8768.1	6.4	114.6	112.0	0.99	51.3	12.4	0.94	10.59	183254	2.48
T_{11}	8473.4	6.4	115.0	111.1	1.00	49.9	12.0	0.93	10.23	174331	2.43
T_{12}	9404.7	6.5	116.5	113.9	0.99	54.1	13.3	0.88	11.36	239082	2.74
T_{13}	8876.5	6.5	115.0	112.8	1.00	52.4	13.0	0.91	10.72	219344	2.62
T_{14}	9093.3	6.5	115.5	112.9	0.99	52.1	13.1	0.86	10.98	213150	2.42
T_{15}	8734.7	6.5	114.0	112.1	0.99	50.9	12.4	0.87	10.55	200196	2.34
SEm±	61.1	0.04	0.34	0.04	0.001	0.04	0.02	0.005	-	-	-
LSD (P=0.05)	177.9	0.12	0.99	0.12	0.004	0.11	0.04	0.013	-	-	-

Highest fruit weight (116.6 g), fruit length (6.5 cm), TSS (13.3), fruit volume (113.9 cc) and juice content (54.1 %) were observed with treatment 3 days drip trickle irrigation and 90 g hydrogel closely followed by 3 days drip trickle irrigation and 120 g hydrogel. The specific gravity and titratable acidity showed reverse trend and as result, 3 days drip trickle irrigation and 120 g hydrogel treatment exhibited minimum value while maximum in control. These findings are in agreement with the results of Pattanaaik *et al.* (2015) in Assam lemon and Kumar *et al.* (2016) in Eureka lemon.

Water use efficiency and economics

The water use efficiency (WUE) was computed to be maximum under 3 days drip trickle irrigation and 90 g hydrogel with mulch (11.36 kg $ha^{-1}mm^{-1}$) followed by (10.98 kg ha^{-}

$^{1}mm^{-1}$). The high WUE of 3 days drip trickle irrigation and 90 g hydrogel may be attributed to the increase in fruit yield production and higher fruit quality. However, the possible reasons for higher fruit yield and available soil moisture in root zone under this treatment towards enhanced the vegetative growth of the plants. Similar results are reported by Panigrahi *et al.* (2014). The highest net return per hectare was recorded with 3 days drip trickle irrigation and 90 g hydrogel with mulch. The maximum benefit cost ratio was observed (2.74) in 3 days drip trickle irrigation and 90 g hydrogel with mulchand closely followed by (2.62) in 6 days drip trickle irrigation and 90 g hydrogel with mulchwhile as minimum (1.66) in control. Higher benefit cost ratio due to higher fruit yield than the related cost of treatments in this case. Similar findings have been reported by Kumar *et al.* (2014).

Hence it may be concluded that 3 days drip irrigation and 90 g hydrogel with black polyethylene mulchwas found to boost the longevity and productivity of the Kinnow mandarin in K*andi* belt of Jammu sub-tropics.

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