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Response of trickle irrigation and some antitranspirants on fruit yield and quality of Kinnow mandarin (*Citrus reticulate* Blanco) under rainfed condition

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Abstract
Inadequate precipitation of scattering and unproductive rainwater managing producing severe limitations on fruit production in rainfed area. Diverse kinds of drip/trickle irrigation intervals and some antitranspirants are real approaches for refiningfarmingoutput and water feeding. Yet, the impacts of these drip/trickle irrigation intervals and some antitranspirants practices on root zone water supply and antitranspirants related with crop yield are not well agreed. The effectiveness of drip/trickle irrigation and some antitranspirants strategies with compared to that with 3 and 6 days drip/trickle irrigation intervals and antitranspirants (Kaolin 2%, Kaolin 4% and $MgCO_3$ 2%, $MgCO_3$ 4%) of Kinnow mandarin under rainfed condition. The drip/trickle irrigation and antitranspirants produced a significantly (p=0.05) maximum improve in fruit yield over control treatment. The 3 days drip/ trickle irrigation and antitranspirants showed highest fruit yield (5615.60 -5935.30 kg ha^{-1}), total sugar (8.04-8.07) Juice content (49.72-50.65%) and TSS (11.08-11.12^{0}Brix). Usually, these results reveal that three days drip/trickle irrigation intervals with Kaolin (4%) might recommend the necessary water pressure on 'Kinnow' mandarin plants of rainfed condition of subtropical ecosystem informative their fruit yield and quality parameters in water infrequent condition.

Keywords: Kinnow mandarin, kaolin, magnesium carbonate, rainfed condition

Introduction
Kinnow mandarin (*Citrus reticulate* Blanco) is hybrid of 'King' mandarin (*Citrus nobilis* Loureiro) and 'Willow leaf' mandarin (*Citrus deliciosa* Tenore) is the main *citrus* cultivars in India, and it becomes a greatest popular fruit cultivar all over the world. It has developed the imperative fruit crop in the rainfed condition of arid and semi-arid environments of northern India and its nature in brightness, thornlessness and dense bearing. Water availability is the actuality prime problems in fruit production in approximately all the regions of the world. Water is one of the main restraining factors in agriculture and horticulture crops. The demand of water from fast industrialization and far above the ground population growth, the portion of water for horticulture is going to be summarized in the coming decades. The further scarcity of water for fruit production (Panda *et al*., 2004) [1], therefore, should be checked to sustain the food supply through effective water conservation and management practices even in high-rainfall areas.

The beginning of drip/trickle irrigation intervals is a substantial technological improvement in irrigation systems, which helps to combat water scarcity in horticulture. Furthermore, the harvest per every drop of irrigation water should be enhanced while considering the best economic water use efficiency connected with any crop In recent years, the adoption drip/trickle irrigation has gained momentum due to its positive impact on water saving, productivity, and produce quality in many crops, including citrus (Fereres *et al*., 2003) [2]. Irrigation scheduling is crucial for improving the efficiency of drip irrigation systems, as an excessive or sub-optimum water supply has harmful possessions on the yield and quality of citrus (Panigrahi *et al*., 2013) [3]. In addition, the need of water is developing as the major abiotic self-control limiting the efficiency potential of citrus orchards in many arid and semi-arid regions (Abu-Awwad, 2001; Kumar *et al*., 2022) [4, 5].

In these regions, drip irrigation has been observed to be efficient in combating such irrigation water scarcity.

The part of antitranspirants improvement in rainfed horticulture anywhere accessibility of water is very fewer and the temperature is very high which promotes the rate of transpiration. The antitranspirant is also known as transpiration suppressant agents. The antitranspirants were grouped into three categories, namely film-forming types; which coat leaf surface with films that are impervious to water vapour (Mobileaf, hexadeconol and silicon), reflecting materials; which reflect back a portion of the incident radiation falling on the upper surface of the leaves (Kaolin, calcium bicarbonate and China clay) and stomatal closing types; which affect the metabolic processes in leaf tissues (Phenyl mercuric acetate and ABA. Based on the mode of their action, they are categorized into: stomatal closing type (Phenyl mercuric acetate and ABA), film forming type (Mobileaf, hexadeconol and silicon), reflectant type (Kaolin, calcium bicarbonate and China clay) and growth retardants (cycocel).

Furthermore, the relative presentation of drip/ trickle irrigation and several antitranspirants in next of kin to yield and fruit quality attributes of citrus species of Kinnow mandarin grown in rainfed region has not yet been studied. The present experiment was accompanied to study the effects of drip/ trickle irrigation and some antitranspirants on fruit yield and quality attributes and its relation in amongst of Kinnow mandarin under sandy loam soil of the rainfed surroundings of northern India.

Materials and Methods

The experiment was conducted on farmer field with 10 years old plants of kinnow mandarin plants which were planted in rainfed Research Substation for Subtropical fruits Raya, SKUAST- 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. The trial of the experimental soil from sandy loam textural classes. The rainfall distribution patterns are erratic in time, spatial, frequency and high intensity sharing to moisture stress condition. The study consisted of drip/trickle irrigation intervals and different dose of antitranspirants *viz*. Kaolin 2%, Kaolin 4% and $MgCO_3$ 2%, $MgCO_3$ 4% treatments. The sole and combination treatments of drip/trickle irrigation intervals and several doses of antitranspirants in Kinnow mandarin under rainfed condition. The treatments details and water applied are presented in table 1. The water supplied through drip /trickle irrigation water gave during 15th march to 15th July in summer season as well as winter season was provided on 15th September to 15th October in the water stress period. Two litre bottle filed in the tap water and has adjust the drip in minimum rate of two litre water per four hours was executed in the root zone of the Kinnow mandarin plant. The water supplied through drip/trickle irrigation in litre was converting in mm. The efficient rainfall was approximate as the rundown of change in soil water content (mm) in the root zone of trees between, drip/trickle irrigation and potential rainfall. Fruit were harvested from each plant of the experiment and the mean yields were determined by weighing the total fruits for different treatments.

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

Treatment	details	Water applied through drip trickle irrigation litre/year	
		2019	2020
T1	Control	No irrigation	No irrigation
T2	3 days drip irrigation intervals	98.00	98.00
T3	6 days drip irrigation intervals	52.00	46.00
T4	Kaolin (2%)	No irrigation	No irrigation
T5	Kaolin (4%)	No irrigation	No irrigation
T6	Mg CO3 (2%)	No irrigation	No irrigation
T7	Mg CO3 (2%)	No irrigation	No irrigation
T8	3 days drip irrigation intervals + Kaolin (2%)	98.00	98.00
T9	6 days drip irrigation intervals + Kaolin (2%)	52.00	46.00
T10	3 days drip irrigation intervals + Kaolin (4%)	98.00	98.00
T11	6 days drip irrigation intervals + Kaolin (4%)	52.00	46.00
T12	3 days drip irrigation intervals + Mg CO3 (2%)	98.00	98.00
T13	6 days drip irrigation intervals + Mg CO3 (2%)	52.00	46.00
T14	3 days drip irrigation intervals + Mg CO3 (4%)	98.00	98.00
T15	3 days drip irrigation intervals + Mg CO3 (4%)	52.00	46.00

The observation regarding total soluble solid (TSS) of fruits were approximate based on random four fruit samples. The fruit quality attributes of total sugars, reducing sugars, ascorbic acid and acidity were estimated by the standard procedure (Ranganna, 1986) [6]. The significance of fruit yield and fruit quality parameters was calculated by randomized block design (RBD). Coefficient of correlation was worked out between various fruit yield and quality parameters with help of SPSS 16.0.

Result and Discussion

The impact of drip/trickle irrigation intervals and some antitranspirants on fruit yield of kinnow mandarin are presented in figure 1. The fruit yield was highest in T10 followed by T14, T11 and T15 and was lowest in T1. The difference among the treatment was the application of drip/trickle irrigation intervals and antitranspirants *viz*. kaolin and magnesium carbonate in Kinnow mandarin. These finding are agreement with the Kumar *et al*., 2016 [7]; Kumar *et al*., 2022 [8].

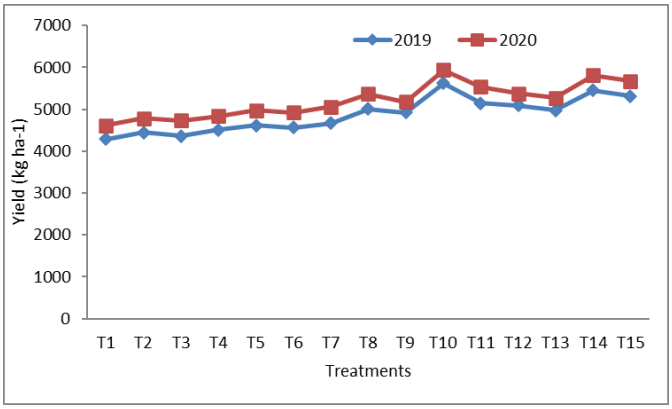

Fig 1: Fruit yield of kinnow mandarin under different treatments

The specific gravity was highest in control treatment and was lowest in T15 treatment (figure-2). The specific gravity was decreasing trend in the application of application of drip/trickle irrigation intervals and some antitranspirants.

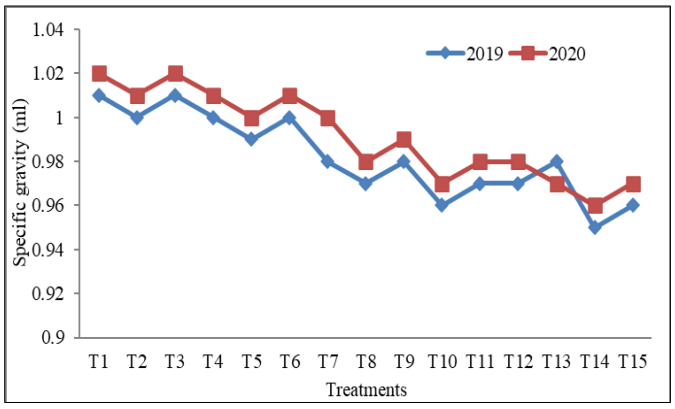

Fig 2: Specific gravity of kinnow mandarin under different treatments

The total soluble solid was rising trend of the application drip/trickle irrigation intervals and some antitranspirants (figure-3). The TSS was highest in T14 followed by T15, T10 and T11 and was minimum in T1. The maximum fruit yield and TSS might be due to dilution of soluble solids concentration in fruit with the drip /trickle irrigation intervals and some antitranspirants.

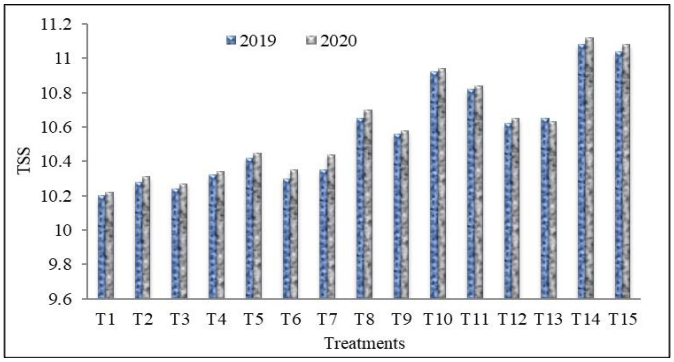

Fig 3: Total soluble solids (TSS) of kinnow mandarin under different treatments

The result shown that the juice content, titratable acidity and ascorbic acid were presented in Table -2 during the year 2019 and 2020. The dissimilarity among the various treatments was statistically significant $p<0.05$). The juice content was highest in T10 followed by T14, T11, T15 whereas lowest in T1 treatments. The titratable acidity was highest in T1 followed by T2, T3 and was lowest in T14. The TA was decreasing trends. The ascorbic acid was increasing trends. The ascorbic acid was highest in T10 followed by T14, T11, T15 whereas lowest in T1 treatments. The improving fruit quality was the application of different treatment was the application of drip/trickle irrigation intervals and antitranspirants *viz*. kaolin and magnesium carbonate in Kinnow mandarin (Kumar *et al*. 2022; Kumar *et al*., 2023) [8, 9].

Table 2: Effect of antitranspirant and drip trickle irrigation intervals on Jice content, Titratable acidity and Ascorbic acid of Kinnow mandarin

Treatment	Jice content (%)		Titratable acidity (%)		Ascorbic acid	
	2019	2020	2019	2020	2019	2020
T1	43.12	43.14	1.10	1.11	21.30	21.33
T2	44.08	44.12	1.06	1.07	22.92	22.95
T3	43.85	43.90	1.08	1.09	22.08	22.12
T4	45.15	46.12	1.05	1.06	23.24	23.27
T5	47.12	47.08	1.02	1.03	24.25	24.30
T6	45.85	46.78	1.04	1.05	23.52	23.55
T7	47.78	48.85	1.01	1.02	24.86	24.90
T8	46.24	46.28	0.97	0.98	24.54	24.55
T9	45.56	45.65	0.98	0.99	24.02	24.08
T10	48.84	49.76	0.89	0.93	26.52	26.55
T11	47.98	49.12	0.93	0.94	25.12	25.15
T12	47.52	48.62	0.94	0.96	25.00	25.04
T13	46.82	47.74	0.92	0.97	24.78	24.81
T14	49.72	50.65	0.87	0.90	26.72	26.78
T15	48.26	49.34	0.90	0.92	25.88	25.92
SEm (±)	0.032	0.036	0.003	0.004	0.252	0.256
CD (P=0.05)	0.103	0.103	0.009	0.011	0.734	0.734

The table-3 showed that the reducing sugar, non-reducing, total Sugar and TSS/acid ratio was significantly influence by various treatments. Plant treated with different treatment were more obvious with appreciate to reducing sugar, non-reducing, total Sugar and TSS/acid compared with control. The reducing sugar was highest in T14 followed by T10, T14 and T11 whereas lowest without the application of treatment T1. The Non-reducing was similar trend in reducing sugar.

The total Sugar was superior in T14 followed by T10, T14 and T11 whereas lowest without the application of treatment T1.

The TSS/acid ratio was maximum in T14 followed by T10, T14 and T11 whereas lowest in control treatment T1. Enhancing the fruit quality attributes was increasing the soil moisture content in the application of drip/trickle irrigation intervals as well as water balance in the application of some antitranspirants of Kinnow mandarin tree. These finding are agreement with (Kumar *et al*. 2022) [8].

Table 3: Effect of antitranspirant and trickle irrigation intervals on reducing sugar, non-reducing sugar, total sugar and TSS/acid ratio of Kinnow mandarin

Treatment	Reducing Sugar (%)		Non-reducing (%)		Total Sugar (%)		TSS/acid ratio	
	2019	2020	2019	2020	2019	2020	2019	2020
T1	3.16	3.18	3.88	3.90	7.25	7.26	9.27	9.21
T2	3.22	3.24	3.94	3.96	7.35	7.37	9.70	9.64
T3	3.19	3.20	3.91	3.92	7.31	7.33	9.48	9.42
T4	3.30	3.32	3.98	4.01	7.42	7.44	9.83	9.75
T5	3.35	3.38	4.04	4.06	7.50	7.53	10.22	10.15
T6	3.42	3.44	4.01	4.02	7.58	7.60	9.90	9.86
T7	3.46	3.48	4.08	4.10	7.63	7.65	10.25	10.24
T8	3.54	3.56	4.18	4.19	7.72	7.75	10.98	10.92
T9	3.52	3.51	4.13	4.14	7.68	7.69	10.78	10.69
T10	3.79	3.82	4.31	4.32	7.92	7.95	12.27	11.76
T11	3.62	3.65	4.26	4.28	7.86	7.88	11.63	11.53
T12	3.60	3.63	4.20	4.21	7.80	7.82	11.30	11.09
T13	3.56	3.58	4.16	4.18	7.76	7.79	11.58	10.96
T14	3.82	3.86	4.38	4.42	8.04	8.07	12.74	12.36
T15	3.75	3.80	4.33	4.35	7.96	7.99	12.27	12.04
SEm (±)	0.045	0.048	0.062	0.065	0.010	0.011	0.168	0.170
CD (P=0.05)	0.130	0.138	0.179	0.187	0.029	0.032	0.490	0.495

Correlation study

It is observed that the table 4 that there is correlation among the fruit yield and quality parameters of Kinnow mandarin tree. The fruit yield and quality parameters was positive and highly significant correlated in TSS (r =0.960**), juice content (r =0.869**), ascorbic acid (r =0.935**), reducing sugar (r=0.977**), non-reducing (r= 0.977**), total sugar(r=0.959**), TSS/AR (r=0.976**) among the various treatments. The highest relationship was observed between total sugar and reducing sugar (r = 0.993**). The fruit yield and quality parameters was negative and highly significant correlated in specific gravity (r = -0.959**), titratable acidity (r= -0.972**) various treatments. These results are conformity with the findings by (Gupta *et al*., 2016; Kumar *et al*., 2018) [10, 11].

Table 4: Correlation among the fruit quality attributes of Kinnow mandarin in various treatments during 2019.

Parameters	Yield	Specific gravity	TSS	Juice content	Titratable acidity	Ascorbic acid	Reducing Sugar	Non-reducing	Total Sugar
Specific gravity	-0.959**								
TSS	0.960**	-0.945**							
Jice content	0.869**	-0.910**	0.843**						
Titratable acidity	-0.972**	0.960**	-0.960**	-0.894**					
Ascorbic acid	0.935**	-0.956**	0.897**	0.973**	-0.947**				
Reducing Sugar	0.977**	-0.967**	0.949**	0.914**	-0.976**	0.958**			
Non-reducing	0.977**	-0.984**	0.977**	0.910**	-0.981**	0.952**	0.987**		
Total Sugar	0.959**	-0.967**	0.947**	0.919**	-0.978**	0.954**	0.993**	0.989**	
TSS/acid ratio	0.976**	-0.958**	0.984**	0.881**	-0.993**	0.933**	0.973**	0.985**	0.971**

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

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

It is obvious from table 5 that the correlation studies the yield and fruit quality parameters among each other. The yield and fruit quality parameters was positive and highly significant correlated in TSS (r =0.968**), juice content (r =0.869**), ascorbic acid (r =0.944**), reducing sugar (r=0.979**), non-reducing (r= 0.977**), total sugar(r=0.965**), TSS/AR (r=0.976**) among the various treatments. The highest relationship was established between TSS/AR and non-reducing (r = 0.997**). The fruit yield and quality parameters was negative and highly significant correlated in specific gravity (r = -0.941**), titratable acidity (r= -0.970**) among the various treatments. The positive and highly significant correlated between TSS and reducing sugar (r= 0.993**). These results are conformity with the findings by (Gupta *et al*., 2016; Kumar *et al*., 2018) [10, 11].

Table 5: Correlation among the fruit quality attributes of Kinnow mandarin in various treatments during 2020**.**

Parameters	Yield	Specific gravity	TSS	Jice content	Titratable acidity	Ascorbic acid	Reducing Sugar	Non-reducing	Total Sugar
Specific gravity	-0.941**								
TSS	0.968**	-0.938**							
Jice content	0.869**	-0.828**	0.836**						
Titratable acidity	-0.970**	0.974**	-0.968**	-0.887**					
Ascorbic acid	0.944**	-0.918**	0.911**	0.954**	-0.952**				
Reducing Sugar	0.979**	-0.948**	0.962**	0.914**	-0.980**	0.961**			
Non-reducing	0.977**	-0.962**	0.985**	0.896**	-0.993**	0.953**	0.986**		
Total Sugar	0.965**	-0.957**	0.955**	0.914**	-0.989**	0.957**	0.993**	0.986**	
TSS/acid ratio	0.976**	-0.965**	0.991**	0.872**	-0.992**	0.938**	0.979**	0.997**	0.981**

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

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

Conclusions

This study found that temporally uneven rainfall distribution, resulting in soil water stress was the major constraint on Kinnow mandarin fruit development and quality in the rainfed sub-tropics of Jammu and Kashmir.Drip/trickle irrigation is founding as a creative and water saving techniques in 'Kinnow' mandarin. The uses of antitranspirants in summer season decrease the water loss through transpiration as the output of partial closer of stomata. The substantial trickle irrigation intervals with Kaolin (4%) followed by $MgCO_3$ resulted in important of higher fruit yield and quality. Based on these results, it can be liable the foliar application of Kaolin (4%) with three days trickle irrigation might better option for 'Kinnow' mandarin cultivation in water scarcity period. These results may provide valuable information for improving fruit production and water utilization particularly in the rainfed areas.

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