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Effect of Deficit Irrigation Regimes and Mulching on VNR Bihi Guava Agronomical and Fruit Quality Performance

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ABSTRACT: The scarcity of irrigation water is one of the major causes of low productivity of guava orchards. Deficit Irrigation (DI) is a recently proposed water saving technique in irrigated agriculture. The impact of deficit irrigation regimes and mulching on VNR Bihi guava agronomical and quality performance was studied during the year 2019-20 and 2020-21. The experiment was carried out in two factorial randomized block design with 12 different treatment combinations consisted of three deficit irrigation levels *i.e.*, DI at 50% ETc (DI_{50}), DI at 75% ETc, and FI at 100% ETc. with four types of mulches (silver-black, black-black, organic mulch and without mulch) which are replicated thrice. Results revealed that fully irrigated trees had the highest vegetative growth in terms of plant height, plants spread and stem girth. However, DI_{50} along with silver-black mulch produced maximum total soluble solids, TSS: acid with minimum titratable acidity during both the years of experimentation.

Keywords: Deficit irrigation, mulching, fruit quality and guava

INTRODUCTION

Water scarcity is a major constraint in crop production. Efficient water supply through precise irrigation scheduling is one of the pathways to sustain crop production with higher water productivity. The advent of drip irrigation (DI) is a significant technological improvement in irrigation system, which helps to combat water scarcity in agriculture. In recent years, the adoption of deficit irrigation gains momentum owing to its positive impact on water saving, productivity and quality of produces in many fruit crops. DI is an irrigation strategy where the amount of water applied is less than the full water requirement of a crop to develop desirable stress that has minimal effects on crop yield (English, 1990). The correct application of DI requires the thorough understanding of the yield response of crops to water supply. In water scarce regions, DI can be more profitable for a farmer to maximize crop water productivity instead of maximizing the harvest per unit land (English, 1990). The higher vegetative growth in bearing trees reduces the productivity of guava. Moreover, the water stress during certain crop growth stages enhances the yield and fruit quality of various fruit crops. However, the plants undergo severe stress when soil-water is very low and the water uptake by the roots fails to compensate the optimal evpotranspiration of the tree. Hence, the accurate and precise water application, creating a desirable stress is important for guava production in water scarce regions.

Guava (*Psidium guajava* L.) is one of the most important fruit crops cultivated widely in tropical and sub-tropical regions of the world. It is fifth most important fruit crop of India occupying 2.65 per cent of total area under fruit cultivation. VNR bihi is a leading guava variety in India as a commercial point of view and as bigger size fruits fetches good price in national as well as international markets. The cultivation of this variety mainly confined from central to northern India where around 90 % of annual rainfall is concentrated in 3-4 month (June-September). Irrigation is mainly practised during fruit growth period (September-January) to improve water productivity as well as maximize yield with larger size fruits. For last few years, shortage of irrigation water has become a major threat to production. Farmers are also more concerned with the sustainable production of this variety especially to get more economic benefits. Optimal scheduling of deficit irrigation with mulching can be one of the major alternative for sustaining VNR bihi production in this regions.

Mulching is application of mulched (covered) soil with loose extraneous organic and inorganic materials. Mulches considerably slow the loss of moisture from the soil, resulting in a more stable and consistent soil moisture regime and reduced irrigation frequency (Ramakrishna *et al*., 2006). Mulch can help to reduce water evaporation from the soil surface by a significant amount. This means better water utilization by plants. Mulching increases soil moisture 1.7 times (Shumova *et al*., 2002). Mulch is frequently used with drip irrigation, and it serves an important role in water conservation, notably in controlling soil evaporation, as well as contributing to crop productivity.

Moreover, the information comparing the impact of deficit irrigation along with mulching on guava, in relation to its growth characteristics and fruit quality are not found in any literature. Keeping this in view, a study was undertaken to evaluate the impact of deficit irrigation regimes and mulching on VNR Bihi guava agronomical and quality performance.

MATERIALS AND METHODS

A. Experimental site

The field experiment was carried out during the year 2019-20 and 2020-21 on five year old guava trees cv. VNR Bihi at the Horticulture Research Centre, Patharchatta of GBPUAT, Pantnagar, Uttarakhand (latitude 29°N, longitude 79.3°E and at an average elevation of 243.84 m above mean sea level), India. Trees were spaced at 5m × 3m under medium high density planting system. The experimental site's climate has been classified as humid subtropical, with dry, hot summers and cool winters. The temperature during summer is between 32-45°C while in winter, it ranges between 0-9°C. The average annual rainfall is 1200 mm.

B. Treatments and layout

The experiment was carried out in two factorial randomized block design with 12 different treatment combinations consisted of three deficit irrigation levels *i.e.*, Deficit Irrigation at 50% ETc (DI_{50}), Deficit Irrigation at 75% ETc (DI_{75}), and Full Irrigation at 100% ETc (FI_{100}). with four types of mulches (silver-black, black-black, organic mulch and without mulch) which are replicated thrice. Irrigation was scheduled every other day. The irrigation was given during fruit growth period from September to February in each year of the experiment. Bicolour polyethylene mulches of silver-black and black-black colour of 100 micron thickness, 1.2 m width with black on lower side and silver color on upper side of the sheet were applied to the base of trees and edges were buried in the soil. Organic mulch (paddy straw) was collected from crop research centre, Pantnagar and applied uniformly in each replication to a thickness of 15 cm used in the experiment. Mulches were applied after pruning and recommended package of practices was performed accordingly. Standard recommended dose of fertilizer *i.e.* $N:P_2O_5:K_2O$ @ 750:650:500 g per tree per year was applied during the both years of experiment.

C. Irrigation scheduling

Irrigation was imposed every other day through four on-line 6 l h^{-1} pressure compensated drip emitters per plant fitted on two 16 mm diameter lateral pipes. The emitters were placed at 1.0 m away from plant stem. The daily USDA class A open Pan evaporation readings were obtained from meteorological observatory agrometeorology farm of the university and calculated irrigation water requirement provided on the daily basis. The volume of water applied under FI was computed following the formula (Mane *et al*., 2006):

$$V = Ep \times Kp \times Kc \times Sc \times Wp$$

where, V = volume of water (liters per day per plant), Ep =open pan evaporation (mm per day), Kp = pan coefficient (0.7), Kc =crop coefficient (0.8), Sc = crop spacing (plant to plant x row to row in meter) and Wp = wetting factor (0.3). Irrigation efficiency of drip was considered as 90%.Theeffective rainfall was calculated by FAO to estimate the fraction of the total rainfall which is effectively used by the pants (Brouwer and Heibloem, 1986). The formulae to calculate effective rainfall (Pe) from total rainfall (P):

Pe = 0.8P – 25, when P is more than 75 mm;

Pe = 0.6P – 10, when P is less than 75 mm

Pe is always equal to or larger than zero, never negative.

D. Measurement and analysis

The plant height (distance from ground surface to top of plant crown), plant spread in East-West and North-South directions, stem girth diameter (stem diameter measured at 0.1 m above soil surface) were recorded annually.

Five fruits per plant were chosen at random for the purpose of determining fruit quality criteria (total soluble solids, titratable acidity and TSS: acid ratio). The selected fruits were taken for juice extraction using muslin cloth and TSS of the guava juice was determined by using Erma Hand Refractometer and expressed in °B. The values of TSS were corrected at 20 °C with temperature correction chart as per AOAC (2000). The titratable acidity was determined by diluting the juice extracted from 5 g of sample and filtered through muslin cloth and made up to known volume with distilled water (25 ml), then titrating the same against standard NaOH using Phenolphthalein as an indicator. The appearance of light pink colour was recorded as the end point. The result was expressed in terms of per cent acidity of the fruit (Anon., 1970).

$$\text{TA}(\%) = \frac{\text{Titre value} \times \text{Normality} \times \text{Eq. Wt. of acid} \times \text{Vol. made} \times 100}{\text{Wt. or vol. of sample} \times \text{Vol. of aliquot taken} \times 1000}$$

The TSS: Acid was calculated by dividing the value of total soluble solids with that of titratable acidity value.

Statistical analysis: The experimental data obtained during the course of study were subjected to statistical analysis by applying the techniques of analysis of variance (ANOVA) prescribed for the factorial randomized block design to test significance of the overall differences among treatments by the 'F' test and conclusions were drawn at 5 percent probability levels (Gomez and Gomez, 1984).

RESULTS AND DISCUSSION

A. Plant growth response

Plant height (m). The perusal of data presented in Table 1 reveal that the plant height was significantly affected by irrigation treatments during both the years. During the year 2019-20, significantly maximum plant height (4.06 m) was recorded in FI (full irrigation at 100% ETc) followed by DI_{75} however, minimum (3.76 m) was noted in DI_{50} (deficit irrigation at 50% ETc). Similar trend was also observed during 2020-21, being highest (4.21 m) in FI (full irrigation at 100% ETc) followed by DI_{75} (4.07 m) and lowest (3.88 m) in DI_{50} (deficit irrigation at 50% ETc). The higher plant height under higher irrigation regime was probably due to higher photosynthesis rate and its proportionate partioning towards vegetative growth under this treatment. These results are corroborated with the findings of Ramniwas *et al.,* (2012); Preet *et al.,* (2019) in guava who reported that plant height in guava was significantly higher in plants received full irrigation regime as compared to water deficit plants.

The different mulch types *i.e.* silver-black, black and organic mulch (paddy straw) considerably influenced guava plant height during both the years. In 2019-20, maximum plant height (4.02 m) was observed in M_{SB} (silver-black) followed by 3.93 m under M_B (black mulch) and minimum was observed under without mulch condition (3.83 m). Similar trend was also noted in 2020-21; values were 4.14, 4.07, 4.03 and 3.96 in M_{SB}, M_B, M_{OM} and M_{WM} respectively. Mulching influences the microclimate around the rhizosphere by providing optimum conditions for plant growth (Liakatas *et al*., 1986). It enhances the growth of the plants because mulch reduces leaching of nutrients, weed problems, evaporation of soil water and soil compaction (Anikwe *et al*., 2007). Similar findings were also reported by Khan *et al*. (2013**);** Preet *et al.,* (2019) in guava as they also reported positive impact of mulching on plant height of guava. Sakariya *et al*., (2018) also recorded maximum plant height in plants mulched with silver-black plastic mulch in papaya cv. Madhubindu and Taiwan. Interactive effects between deficit irrigation and mulching with respect to plant height were found non-significant during both the years of experimentation

Plant spread (East-West). The different deficit irrigation regime considerably affected plant spread (E-W) in 'VNR' guava cultivar during both the years of experimentation (Table 1). In 2019-20, the highest (4.14 m) plant spread (E-W) was recorded in the plants irrigated at 100% ETc through drip irrigation followed by DI_{75} (deficit irrigation at 75% ETc) whereas, lowest (3.29 m) was observed in DI_{50} (deficit irrigation at 50% ETc). Similarly in 2020-21, the maximum plant spread (E-W) of 4.62 m was observed in the plants irrigated at 100% ETc through drip irrigation followed by DI_{75} (4.26 m) and minimum was observed under DI_{50} (3.76 m). Availability of sufficient quantity of moisture in fully irrigated plants might have helped in promoting the production of growth regulators such as auxins and cytokinins which in turn enhanced the action of cell division and cell elongation eventually increasing plant spread (Fanish *et al*., 2011). Drip irrigation in combination with mulch might have provided consistent soil moisture regime which in turn increased availability and translocation of nutrients and vegetative growth of plants. Similar findings were also reported by Pathak *et al.,* (2002); Ramniwas *et al.,* (2012); Preet *et al.,* (2019) in guava who reported that maximum plant spread was recorded with plants irrigated at 100% ETc through drip irrigation.

The perusal of data in Table 1 indicated that plant spread (E-W) was statistically significant among different mulching treatments. In 2019-20, maximum (3.93 m) plant spread (E-W) was observed in silver-black mulch (M_{SB}) followed by black mulch M_B (3.82 m) and organic mulch M_{OM} (3.68 m). During year 2020-21, similar trend was also observed as recorded in the previous year studies. Highest plant spread (E-W) was observed in silver-black mulch M_{SB} (4.41 m) and lowest (4.00 m) in the plants under without mulch (M_{WM}) condition. The increase in plant spread could be ascribed to higher uptake of nutrients under silver-black and black plastic mulch as it conserves optimum soil moisture and moderates evaporation from soil surface (Joshi *et al*., 2012). In contrast to this, minimum plant spread was recorded in without mulch plants because of lower moisture availability (Shirgure *et al*., 2003), low nutrient availability (Shukla *et al*., 2000) and more weed competition (Yadav *et al*., 2004). Similar, findings were also reported by Singh (2020) that maximum plant spread was observed in VNR Bihi guavas when plants mulched with silver-black mulch as compared to unmulched plants. Moreover, interactive combined effect of deficit irrigation and mulches showed non-significant influence on plant spread (E-W) during both the years of experimentation.

Plant spread (North-South). The data pertaining to plant spread (N-S) revealed that different levels of irrigation considerably affected plant spread (N-S) during the investigation period (Table 1). During 2019-20, maximum plant spread (N-S) of 2.85 m was recorded in the plants irrigated at 100% ETc through drip irrigation followed by 2.65 m in DI_{75} (deficit irrigation at 75% ETc) and minimum (2.27 m) in DI_{50}

(deficit irrigation at 50% ETc). Similarly, during 2020-21, significantly higher (3.55 m) plant spread (N-S)was recorded in the plants irrigated at 100% ETc through drip irrigation as compared with 3.37 m in DI_{75} and 3.03 m in DI_{50}. Similar trend was also observed in terms of plant spread (N-S)as mentioned in pooled data for two years in Table 1. These results are in accordance with Kumar *et al.*(2012) who elucidated that irrigation at 1.0 IW/CPE ratio significantly increased plant spread than other irrigation levels in “Chandler” strawberries.

The different type of mulches *i.e.* silver-black, black and organic mulch (paddy straw) substantially influenced guava plant spread (N-S) for two consecutive years. During 2019-20, maximum plant spread (N-S) of 2.77 m was observed in M_{SB} (silver-black) followed 2.61 m in M_B (black mulch) and minimum was observed under without mulch condition (2.44 m).Similar trend was also observed in second year *i.e.* 2020-21; being significantly maximum (3.47 m) in silver-black mulch (M_{SB}) followed by black mulch (3.33 m) and organic mulch (3.29 m) and minimum (3.18 m) in without mulched plants.

Table 1: Effect of deficit irrigation and mulching treatments on plant height (m) and plant spread E-W (m) in guava cv. VNR Bihi

Treatments	Plant height (m)			Plant spread E-W (m)			Plant spread N-S (m)		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
(A) Deficit irrigation									
DI_{50}	3.76	3.88	3.82	3.29	3.76	3.52	2.27	3.03	2.65
DI_{75}	3.93	4.07	4.00	3.81	4.26	4.03	2.65	3.37	3.01
FI_{100}	4.06	4.21	4.14	4.14	4.62	4.38	2.85	3.55	3.20
SEm±	0.038	0.035	0.028	0.049	0.058	0.031	0.046	0.060	0.039
CD at 5 %	0.112	0.102	0.081	0.142	0.171	0.091	0.136	0.176	0.116
(B) Mulches									
Silver-black	4.02	4.14	4.08	3.93	4.41	4.17	2.77	3.47	3.12
Black	3.93	4.07	4.00	3.82	4.29	4.06	2.61	3.33	2.97
Organic	3.89	4.03	3.96	3.68	4.14	3.91	2.55	3.29	2.92
Without mulch	3.83	3.96	3.90	3.55	4.00	3.78	2.44	3.18	2.81
SEm±	0.044	0.040	0.032	0.056	0.067	0.036	0.053	0.069	0.046
CD at 5 %	0.129	0.118	0.093	0.164	0.197	0.105	0.157	0.204	0.134
Interaction (DI×M)									
SEm±	0.076	0.070	0.055	0.097	0.117	0.062	0.093	0.120	0.079
CD at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

B. Fruit quality parameters

Total soluble solids (°B). It is pertinent to mention from Table 2 that different levels of irrigation (DI) exhibited significant effect on total soluble solids (TSS) content of guava during the both years of study. During 2019-20, TSS to the tune of 12.35 °B was recorded in the fruits harvested from the plants irrigated with DI_{50} (deficit irrigation at 50% ETc) followed by 12.00 °B in DI_{75} (deficit irrigation at 75% ETc)and minimum (11.25°B) in FI (full irrigation at 100% ETc). Furthermore in the year 2020-21, the slight increment in TSS was noted when plants were irrigated at DI_{50} (deficit irrigation at 50% ETc) and the value was 12.78 °B whereas the lowest (11.48°B) was found in the plants irrigated at FI (full irrigation at 100% ETc). The increase in soluble solids under deficit irrigation treatments might be due to the fact that water shortage accelerate starch degradation and increase the accumulation of sugars in fruits as a result of reduced irrigation (Ebel *et al.,* 1993). These results are in line with the finding of Garcia-Tejero *et al.* (2010); Navrrao *et al.* (2010); Panigrahi *et al.*, (2014) in citrus and Mellisho *et al.*, (2012); Laribi *et al.*, (2013), and Selahvarzi *et al.*, (2017) in pomegranate as they reported increase in concentration of soluble solids in response to deficit irrigation. The data pertaining to the effect of different type of mulches on TSS content is presented in Table 2. The guava plants mulched with M_{SB} (silver-black) registered higher TSS (12.17°B) followed by 12.00 °B in M_B (black-black) in comparison to 11.53°B in the fruits obtained from M_{WM} (without mulch). During 2020-21, higher TSS of 12.50°B was observed in M_{SB} (silver-black) mulch followed by 12.30°B in M_B (black-black) mulch and these treatments were substantially higher than the fruits obtained from plants having without mulch and values were 11.83 °B. Mulches ensures optimum soil moisture as a result of reduced evaporation from the soil surface eventually leads to increment in soluble solids content of guava fruits (Sagar *et al.*, 2019). Furthermore, application of different combinations of deficit irrigation and mulch had non-significant influence on the TSS content of fruit during both the years of investigation.

Titratable acidity (%). It is evident from Table 2 that individual irrigation treatments exerted a significant influence on titratable acid content wherein titratable acidity (TA) increased with increase in irrigation from 50% ETc to 100% Etc during both the years. During 2019-20, FI (full irrigation at 100% ETc) treatment had maximum (0.60 %) acidity content followed by 0.50 % in DI_{75} (deficit irrigation at 75% ETc) and minimum (0.44 %) in DI_{50} (deficit irrigation at 50% ETc). In 2020-21, significant higher acidity content of 0.58 % was recorded in FI (full irrigation at 100% ETc) and lower (0.42 %) in DI_{50} (deficit irrigation at 50% ETc). The lower titratable acidity in fruits with deficit irrigation at 50% ETc was probably caused by enhanced transformation of acids to sugars in fruits which is required to maintain the osmotic pressure of fruit cells under mild water deficit condition prevailed under this irrigation regime (Huang *et al*., 2000). Parvizi and Seepaskhah (2014) also reported decrease in titratable acidity under deficit irrigation as compared with FI plants.

In the year 2019-20, maximum acidity content of 0.54 % was recorded in the without mulched plants followed by organic mulch (0.50 %) and these were considerably higher than 0.52 % in M_B (black-black) and 0.49 % in M_{SB} (silver-black). Similar trend was also found in following year 2020-21 and the values ranged from 0.46 % in M_{SB} (silver-black)and 0.52% in M_{WM} (without mulch). The reduction in titratable acidity under various mulches over without mulched plants might be due to the fact that polymulches conserves optimum moisture in the root zone that facilitated continuous nutrient supply during entire fruit growth period led to hydrolysis of organic acid by increased enzymatic activity and resulted in reduction in acidity of guava fruit. Prakash *et al.,* (2015); Upreti *et al.,* (2018) in mango and El-Tawell and Farag (2015) in pomegranate also found reduction in acidity under different mulching materials.

TSS/acid ratio. The data presented in Table 2 reveals that TSS/acid ratio (28.27 in 2019-20 and 30.90 in 2020-21) was observed maximum under DI_{50} (deficit irrigation at 50% ETc) which was followed by DI_{75} (deficit irrigation at 75% ETc) (23.92 in 2019-20 and 25.49 in 2020-21) and FI (full irrigation at 100% ETc) (18.80 in 2019-20 and 20.01 in 2020-21). The high ratio of TSS/TA in deficit irrigation indicated the role of stress in promoting physiological development and fruit ripening. Moreover, water shortage accelerates starch degradation and results in sugar accumulation (Ebel *et al*., 1993). Mellisho *et al.,* (2012); Pena *et al.,* (2013); Selahvarzi *et al.,* (2017) in pomegranate reported similar trends of higher maturity index under deficit irrigation treatments.

During 2019-20, different type of mulches used in guava, notably influenced TSS/acid ratio as compared to unmulched plants (Table 2). Maximum TSS/acid ratio of 25.34 was recorded in M_{SB} (silver-black) which was appreciably more than 23.99 in M_{OM}, 23.60 in M_B, and 21.73 in M_{WM}. Similar trend was also witnessed in 2020-21and values were varied from 27.62 in M_{SB} to 23.09 in M_{WM}. Application of drip irrigation in association with mulch provides constant moisture supply to the root zone led to active absorption of roots resulted in higher maturity index (TSS/TA) of guava fruits. These results are in accordance with the findings of Iqbal *et al.,* (2015) in aonla, Singh *et al.,* (2015); Preet *et al.,* (2021) in guava. Interactive effect between deficit irrigation and mulches i.e. (DI × M) on TSS/acid ratio in "VNR Bihi"guavas were statistically non-significant.

Table 2: Effect of deficit irrigation and mulching treatments on TSS (°B), acidity (%) and TSS/acid ratio in guava cv. VNR Bihi.

Treatments	TSS (°B)			Titratable acidity (%)			TSS/acid ratio		
	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled	2019-20	2020-21	Pooled
(A) Deficit irrigation									
DI_{50}	12.35	12.78	12.56	0.44	0.42	0.43	28.27	30.90	29.59
DI_{75}	12.00	12.28	12.14	0.50	0.48	0.49	23.92	25.49	24.70
FI_{100}	11.25	11.48	11.36	0.60	0.58	0.59	18.80	20.01	19.41
SEm±	0.120	0.130	0.077	0.006	0.007	0.004	0.264	0.309	0.222
CD at 5 %	0.353	0.380	0.226	0.019	0.020	0.013	0.775	0.905	0.651
(B) Mulches									
Silver-black	12.17	12.50	12.33	0.49	0.46	0.48	25.34	27.62	26.48
Black	12.00	12.30	12.15	0.52	0.50	0.51	23.60	25.22	24.41
Organic	11.77	12.07	11.92	0.50	0.48	0.49	23.99	25.93	24.96
Without mulch	11.53	11.83	11.68	0.54	0.52	0.53	21.73	23.09	22.41
SEm±	0.139	0.150	0.089	0.007	0.008	0.005	0.305	0.356	0.256
CD at 5 %	0.407	0.439	0.261	0.022	0.023	0.015	0.895	1.045	0.752
Interaction (DI × M)									
SEm±	0.240	0.259	0.154	0.013	0.013	0.009	0.529	0.617	0.444
CD at 5 %	NS	NS	NS	NS	NS	NS	NS	NS	NS

CONCLUSIONS

Deficit irrigation is found as a productive and water saving technique in drip-irrigated guava orchard. This study demonstrated that mild water deficit during fruit growth period could impose desirable water stress on the guava plants, resulting improved internal fruit qualities (total soluble solids and acidity) in the crop.

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