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Effect of raised bed, mulching and fertigation on productivity and quality of guava (*Psidium guajava* L.) under high density planting system

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Abstract

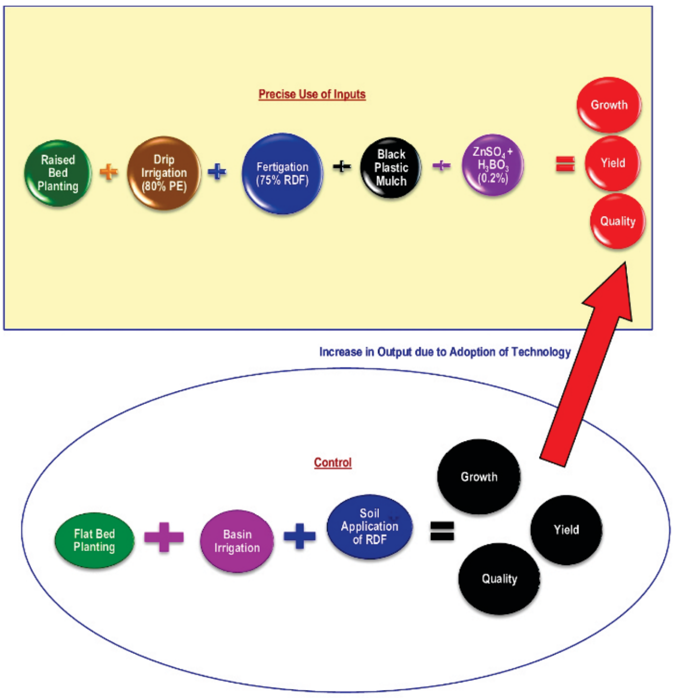
Aim: Increasing the input use efficiency by planting of guava on raised bed, mulched with black polythene sheet along with fertilizer application through drip and foliar spray of micro-nutrients (zinc and boron).

Methodology: Experiment was carried out during 2015-2019 for mrig bahar crop in Lalit guava planted at 3 × 3 m spacing in ICAR-CISH, Lucknow with 5 different treatments (T_1 = Raised bed +drip irrigation @ 80% PE + fertigation @ 75% RDF + mulching with 100μ black polythene + micro-nutrient spray in July and August @ 0.2% each of zinc sulphate and boric acid, T_2 = Raised bed + drip irrigation + fertigation + mulching, T_3 = Raised bed + drip irrigation + fertigation + micronutrient sprays, T_4 = Raised bed + drip irrigation +micro-nutrient sprays + soil application of RDF @ 50:25:50 g N:P:K, T_5 / control = Flat bed + soil application of RDF + basin irrigation).

Results: Canopy volume, trunk-cross sectional area and yield were significantly increased in T_1, which could be attributed to better microclimate in root zone, resulting in improved growth and yield.

Interpretation: The findings of this research have generated the technique of improving space, water and nutrient use efficiency under high density planting system of guava cv. Lalit in subtropical climate which will help the guava growers for sustaining quality production.

Key words: Fertigation, High density planting, Mulching, Raised bed, Yield efficiency.



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Introduction

Guava (*Psidium guajava* L.) belongs to family Myrtaceae, is one of the important fruit crops of alluvial plains of India. It has great market potential due to its delicious taste, aroma, sweet flavour and a fine balance of acid, sugar and pectin and high nutritional value, it gives good economic returns. Usually farmers cultivate guava through traditional spacing (6-8 m apart, 278-156 plants ha^{-1}), due to which full potential of natural resources *i.e.* spacing, soil, sun light and plant nutrient could not be harnessed. However, under intensive orcharding system, available natural resources can be utilized at full potential. High density planting system is possible by control of tree vigour (Das *et al*., 2018), since guava tree flowers and fruits on the current season's shoots either from lateral buds on older wood or shoot terminals (Thakre *et al*., 2013). Under subtropical climate of Northern India, guava tree usually produces fruits twice a year, *viz*. as major crop during rainy season and minor crop during winter season (Adhikari and Kandel, 2015). Fruits produced during rainy season are rough, insipid and poor in quality, while winter fruits are superior in quality with high market demand (Prakash *et al*., 2012), hence, crop regulation for manipulating winter crop is required for making guava cultivation profitable (Singh *et al*., 2001). Thakre *et al*. (2016) also reported that, high density planting management and crop regulation are two important aspects in guava cultivation. Hence, it is imperative to standardize the technology for precise use of available natural resources under high density planting of guava to attain sustainable productivity. The competition between plants for light, water and nutrition under closer spacing significantly affects dry matter partitioning from source to sink (Kumawat *et al*., 2014), further, high production of quality fruits can only be achieved by judicious application of water and plant nutrients (Singh and Singh, 2007).

Tree vigour is influenced by the volume of soil accessible to the root system. Zhang *et al*. (2012) stated that planting of guava on elevated beds, 15-20 cm height above ground (preferably called as raised beds), could improve soil organic matter and physical properties such as bulk density, in the root zone. Ground covers are known to prevent weed growth, limit soil temperature variability, improve soil fertility and health, root growth, and water use efficiency (Tarara, 2000). The surface irrigation system is most common in India; however the irrigation efficiency is just 40 per cent (Mandal *et al*., 2007). The low irrigation efficiency is due to conveyance losses by seepage, evaporation and non-beneficial use of phreatophytes. According to Sharma *et al*. (2012), drip irrigation at 80 per cent pan evaporation given to the guava has maximum water use efficiency. Fertigation enables the application of soluble fertilizers along with irrigation water, uniformly and more efficiently, which is considered eco-friendly as it avoids leaching of fertilizers. Kumawat *et al*. (2017) reported that application of 75% irrigation of pan evaporation along with fertigation at 60% of RDF of NPK gave maximum net returns per hectare under ultra high density planting in guava cv. Lalit. Foliar application of micro nutrients like zinc and boron has positive effect on vegetative and reproductive growth, yield and quality of guava due to their stimulatory effect on plant metabolism and production of auxins (Sachin *et al*., 2019).

However, limited information is available on input use efficiency under high density planting (HDP) system of guava. Hence, to examine the response of guava to drip irrigation along with fertigation, mulching and micronutrient spray under HDP system, an experiment was planned with an objective to increase input use efficiency.

Materials and Methods

Experimental site, design and treatments: The investigation was carried out at the research farm of ICAR-Central Institute for Subtropical Horticulture, Rehmankhera, Lucknow, India during 2015-2020. The experiment was conducted in a randomised block design in guava cv. Lalit, planted in July, 2015 at 3 × 3 m spacing. The treatment comprised of drip irrigation at 80% pan evaporation, fertigation with 75% recommended doses of fertiliser (RDF), mulching with 100 micron UV stabilised black polyethylene and spray of micro-nutrients (zinc sulphate and boric acid @ 0.2% each) in July and August under raised bed (T_1), drip irrigation along with 75% RDF and black polyethylene mulch under raised bed (T_2), drip irrigation along with 75% RDF and micronutrient sprays under raised bed (T_3), drip irrigation along micro-nutrient sprays and soil application of RDF (50:25:50 g N:P:K, half N, full P and K in July and remaining N in November) under raised bed (T_4) and soil application of RDF along with basin irrigation under flat bed condition as control (T_5). Each treatment was replicated four times having four plants per replication. The raised bed of 2.5 m wide and 15-20 cm height was prepared by pulling soil between the rows after planting. Seventy five per cent of RDF was applied in 3 split doses, *viz*. after fruit set during July-August (40% each of N and P_2O_5 and 20% of K_2O), during fruit growth stage (20 and 60% of N and K_2O, respectively) and after fruit harvest during October-December (40,60 and 20% of N, P_2O_5 and K_2O, respectively). For comparing the impact of different treatments with control, flat bed planting without mulch was done along with basin irrigation and full RDF, applied in two split doses, ½ N, full P and K during November, while remaining ½ N during September. The basin was made to the extent of canopy spread for basin irrigation in control. Experimental plants were irrigated by drip system installed with 4 drippers per plants of 4 l hr^{-1} capacity. Irrigation was applied at 80% evapo-transpiration. Fertilisers at 75% RDF were provided in July-August (post fruit set stage), September-October (fruit growth stage) and November-December (after fruit harvest) in 7-8 doses through fertigation. Micronutrients (zinc sulphate and boric acid @ 0.2% each) were sprayed after fruit set and again during fruit development. Annual pruning was carried out in May, leaving 25 per cent of old growth. For flower regulation (mrig bahar), irrigation and fertilizer application were withhold from March to June and tree basins were dug 6-8 inches deep to create water stress. Flowering occurred in July - August and fruits were harvested at colour break stage from last week of October to first week of December as guava fruits had staggered maturity.

Growth parameters like canopy spread (between rows and within row), tree height, trunk diameter, and average diameter of primary branches were recorded during September-October. Tree canopy volume was calculated as the product of canopy height, canopy spread (between rows and within row), which was then multiplied by 0.5238 (Castle, 1983). Trunk cross-sectional area (TCSA) was calculated by the formula (TCSA= Square of trunk girth at 10 cm height from base / 4π) and expressed in cm^2 (Kumar *et al*. 2008). Yield and quality traits (fruit length, breadth and weight, pulp-seed ratio, total soluble solids, titrable acidity and ascorbic acid) were determined after periodical harvesting of fruits. Yield efficiency was worked out by the formula suggested by Castle (1983).

Statistical design and analysis: The experimental data were analyzed using SPSS software version 9.1. The visual indication of data dispersion on bar and line graph was achieved by means along with the standard error of the mean (SEM). Treatment difference was evaluated by Duncan Multiple Range Test (DMRT) at $P<0.05$.

Results and Discussion

The perusal of data shows that (Table 1) significantly highest canopy height was recorded in T_1 treatment over control. Canopy spread between rows was recorded significantly highest in T_1, T_2 and T_3 treatments during 2018-19 compared to control and canopy volume was found significantly higher by 52.83, 36.63 and 26.39 per cent during 2017, 49.45, 30.44 and 26.63 per cent during 2018 and 54.80, 36.05 and 33.92 per cent during 2019 in T_1, T_2 and T_3 treatments, respectively, as compared to control (Table 1). Trunk cross-sectional area was significantly higher in T_1 during 2018, which was at par with that of T_2 during the same year, as compared to control. Primary branch cross-sectional area was significantly higher in T_1 during 2018 and 2019, which was at par with those of T_2 during 2018 and T_2 and T_3 during 2019, as compared to control. Secondary branch cross-sectional area was highest in T_1 during 2018-19, which was at par with those of T_2 and T_3 during 2018-19 (Table 1). Simpson *et al*. (2019) also found that the traditional method of planting (flat bed with no groundcover) resulted in smaller trees as measured by tree height, canopy circumference, and trunk diameter in grapefruit (*Citrus paradisi* Macf. cv. 'Rio Red') whereas adoption of plastic ground covers under raised bed condition could potentially improve water conservation while increasing production. Larco *et al*. (2013) reported greater allocation of biomass to the roots when plants of blueberry (*Vaccinium corymbosum* L.) were grown on raised beds than on flat beds, and plants produced 33 per cent higher yield when grown on raised beds than on flat beds. Thus, loose and aerated soil in raised bed might have created congenial environment for root growth and increasing root volume. The use of black polythene mulch might have facilitated more retention of soil moisture and regulated temperature fluctuations, improved physical, chemical and biological properties of soil, resulting in better root growth compared to unmulched soil and ultimately enhancing plant growth (Sharma and Bhardwaj, 2017). The frequent and continuous application of irrigation water through drip system might have led to uniform distribution of moisture in soil profile, thereby increasing turgidity of cells, leading to cell enlargement and better cell wall development, which promoted better tree growth compared to surface irrigation (Mandal *et al*., 2007). Shirgure (2013) also observed increased tree growth due to drip irrigation equivalent to 80 per cent pan evaporation in Nagpur mandarin (*Citrus reticulata* Blanco). The increase in tree growth due to application of 75 per cent RDF was also observed in other fruit crop like papaya (Sadarunnisa *et al*., 2010). Improvement in growth of guava tree due to application of zinc and boron might be due to the enhanced metabolic activity which leads to increase in various plant metabolites responsible for cell division and elongation resulting in an increased plant growth characteristics (Hatwar *et al*., 2003; Patil *et al*., 2008).

The average individual fruit weight was significantly highest in T_1 during 2017-19 (35.21, 38.49 and 34.09% more than control, respectively), which was at par with those of T_2 and T_3 during 2017 (33.27 and 33.07% more than control, respectively) and T_2 during 2018 (18.86% more than control). Fruit yield significantly increased by 49.03, 112.02 and 106.11 per cent over control in T_1 during 2017-19, respectively, which was at par with T_2 (84.95% more than control) during 2019 (Table 2). Fruit length was significantly higher in T_1 compared to control during 2018 and 2019, which was at par with T_2 and T_3 during both the years. Similarly, fruit breadth was higher in T_1 during 2017 and 2018, which was at par with T_2 during 2017, and T_2 and T_3 during 2018. Pulp-seed ratio was found highest in T_1 during 2017-19, and non-significant with that of control (Table 2). The large fruit size and high tree yield in T_1 and T_2 over control might be attributed to warmer temperature in the plastic-covered raised-bed system that enabled higher light use efficiency, thereby promoting healthier plant growth and higher tree yield (Condori *et al*., 2017). Raised bed around tree basin, make the plant rhizosphere pulverized (loose), which favours better soil microbial activities compared to flat bed system (Patino-Zuniga *et al.*, 2009), thereby improved various physiological processes in plant, resulting in better growth, flowering and yield (Zhang *et al*. 2012). Increase in fruit yield on using black plastic mulch might be attributed to its role in reducing soil water evaporation, and exploiting deep soil water so as to support biomass accumulation and optimize dry matter allocation (Sharma and Bhardwaj, 2017). The improved yield with conjunctive use of drip irrigation and fertigation might be due to the fact that drip irrigation and fertigation permits better use

Table 1 : Effect of different inputs on tree growth attributes in guava cv. Lalit under Lucknow condition*

Treatments	Canopy height (m)			Canopy spread between rows (m)			Canopy spread within row (m)			Canopy volume (m^3)			Trunk cross-sectional area (cm^2)			Primary branch cross-sectional area (cm^2)			Secondary branch cross-sectional area (cm^2)		
	2017	2018	2019	2017	2018	2019	2017	2018	2019	2017	2018	2019	2017	2018	2019	2017	2018	2019	2017	2018	2019
T1	2.86 ±0.12^{a}	3.02 ±0.11^{a}	3.18 ±0.11^{a}	2.30 ±0.09^{NS}	2.46 ±0.06^{a}	2.64 ±0.13^{a}	2.20 ±0.05^{a}	2.34 ±0.05^{a}	2.51 ±0.05^{a}	7.62 ±0.53^{a}	9.12 ±0.62^{a}	11.08 ±0.97^{a}	27.15 ±1.27^{NS}	52.85 ±4.96^{a}	59.19 ±5.26^{NS}	7.88 ±1.50^{NS}	16.55 ±1.62^{a}	17.39 ±1.49^{a}	3.14 ±1.04^{NS}	7.93 ±0.61^{a}	9.60 ±0.67^{a}
T2	2.69 ±0.12^{ab}	2.80 ±0.13^{ab}	3.00 ±0.05^{ab}	2.25 ±0.05^{NS}	2.39 ±0.03^{ab}	2.63 ±0.06^{a}	2.14 ±0.08^{ab}	2.25 ±0.10^{ab}	2.35 ±0.10^{ab}	6.81 ±0.56^{a}	7.96 ±0.78^{ab}	9.74 ±0.35^{a}	26.49 ±6.79^{NS}	47.79 ±6.74^{ab}	57.48 ±7.42^{NS}	7.03 ±1.65^{NS}	15.73 ±1.42^{a}	17.06 ±1.64^{a}	3.13 ±1.27^{NS}	7.44 ±1.96^{a}	9.56 ±2.21^{a}
T3	2.51 ±0.06^{bc}	2.68 ±0.04^{bc}	2.79 ±0.04^{bc}	2.10 ±0.05^{NS}	2.29 ±0.13^{abc}	2.54 ±0.03^{ab}	2.28 ±0.15^{a}	2.40 ±0.14^{a}	2.58 ±0.14^{a}	6.30 ±0.40^{ab}	7.73 ±0.47^{ab}	9.59 ±0.54^{a}	18.69 ±2.30^{NS}	36.08 ±5.16^{bc}	56.55 ±5.83^{NS}	5.49 ±0.72^{NS}	10.90 ±2.05^{b}	13.46 ±2.28^{ab}	2.23 ±0.25^{NS}	6.70 ±0.54^{ab}	7.99 ±0.59^{ab}
T4	2.34 ±0.10^{c}	2.47 ±0.12^{c}	2.74 ±0.12^{bc}	1.99 ±0.22^{NS}	2.04 ±0.13^{c}	2.18 ±0.18^{c}	1.86 ±0.11^{b}	1.96 ±0.13^{b}	2.13 ±0.13^{b}	4.61 ±0.68^{c}	5.30 ±0.75^{c}	6.84 ±1.03^{b}	14.40 ±2.91^{NS}	20.91 ±3.47^{c}	43.54 ±7.52^{NS}	4.25 ±0.95^{NS}	6.76 ±1.30^{b}	7.41 ±1.36^{c}	1.29 ±0.10^{NS}	3.15 ±0.85^{c}	3.80 ±0.93^{c}
T5	2.29 ±0.06^{c}	2.46 ±0.06^{c}	2.57 ±0.06^{c}	1.99 ±0.02^{NS}	2.14 ±0.07^{bc}	2.22 ±0.07^{bc}	2.09 ±0.08^{ab}	2.20 ±0.08^{ab}	2.38 ±0.08^{ab}	4.98 ±0.27^{bc}	6.10 ±0.53^{bc}	7.16 ±0.59^{b}	19.17 ±4.49^{NS}	24.01 ±5.42^{c}	43.04 ±5.64^{NS}	4.50 ±0.72^{NS}	7.66 ±1.06^{b}	8.61 ±1.13^{bc}	1.34 ±0.11^{NS}	3.78 ±0.12^{bc}	4.85 ±0.13^{bc}
CV	**11.06**	**10.35**	**9.12**	**11.26**	**10.12**	**11.59**	**10.78**	**11.02**	**10.36**	**24.16**	**24.96**	**23.96**	**41.37**	**43.90**	**26.03**	**43.69**	**42.91**	**40.28**	**70.61**	**46.70**	**44.76**

*Means±S.Em with the same superscripted letter in a column are not significantly different by Duncan test at $P \leq 0.05$. T_1 = Raised bed + drip irrigation (80% PE) + fertigation (75% RDF) + black polythene mulching (100μ) + micro-nutrients (0.2% of zinc sulphate and boric acid) spray in July and August; T_2 = Raised bed + drip irrigation + fertigation + mulching; T_3 = Raised bed + drip irrigation + fertigation +micronutrient sprays; T_4 = Raised bed + drip irrigation + micro-nutrient sprays + soil application of RDF (50:25:50 g N:P:K) and T_5 = Flat bed + soil application of RDF + basin irrigation (control).

Table 2 : Effect of different inputs on fruit quality and bio-chemical parameters in guava cv. Lalit under Lucknow condition

Treatments	Fruit length (cm)			Fruit breadth (cm)			Average individual fruit weight (g)			Fruit yield (kg per tree)			Pulp-seed ratio			Fruit TSS (° Brix)			Titrable acidity (%)			Ascorbic acid (mg 100 g^{-1})		
	2017	**2018**	**2019**	**2017**	**2018**	**2019**	**2017**	**2018**	**2019**	**2017**	**2018**	**2019**	**2017**	**2018**	**2019**	**2017**	**2018**	**2019**	**2017**	**2018**	**2019**	**2017**	**2018**	**2019**
T1	65.25 ±2.66^{a}	73.25 ±3.01^{a}	68.00 ±1.78^{a}	69.50 ±1.71^{a}	74.75 ±3.33^{a}	71.00 ±3.00^{NS}	173.75 ±8.20^{a}	224.00 ±15.77^{a}	213.70 ±1.05^{a}	24.83 ±1.08^{a}	40.13 ±2.68^{a}	24.88 ±1.38^{a}	5.13± 0.37^{NS}	5.19± 0.17^{a}	5.08± 0.55^{NS}	11.50± 0.65^{NS}	14.25± 0.48^{NS}	13.58 ±0.51^{a}	0.31 ±0.05^{a}	0.30 ±0.01^{a}	0.32 ±0.04^{a}	169.00 ±1.47^{NS}	167.40 ±2.74^{a}	171.25 ±0.85^{a}
T2	60.50 ±0.65^{ab}	67.50 ±2.06^{ab}	66.50 ±3.30^{ab}	66.50 ±2.10^{ab}	69.25 ±3.45^{ab}	70.50 ±3.18^{NS}	171.25 ±15.88^{a}	192.25 ±13.77^{ab}	204.82 ±0.06^{b}	20.96 ±0.95^{b}	31.25 ±2.25^{b}	22.33 ±1.58^{a}	4.60 ±0.35^{NS}	4.65± 0.29^{ab}	4.02± 0.64^{NS}	11.50± 0.87^{NS}	14.25± 0.48^{NS}	12.45± 0.49^{ab}	0.42 ±0.01^{b}	0.31 ±0.02^{ab}	0.43 ±0.02^{b}	169.00 ±1.22^{NS}	160.18 ±3.81^{ab}	168.00 ±0.41^{b}
T3	59.25 ±5.20^{ab}	67.25 ±3.84^{ab}	63.25± 2.66^{abc}	62.00 ±0.71^{bc}	68.50 ±1.85^{ab}	69.25 ±3.84^{NS}	171.00 ±14.20^{a}	180.25± 15.07^{b}	184.98 ±0.01^{c}	18.73± 1.50^{bc}	29.75 ±1.44^{b}	13.87 ±0.60^{b}	4.50± 0.32^{NS}	4.48 ±0.30^{ab}	3.89± 0.59^{NS}	12.13± 0.52^{NS}	13.25± 0.85^{NS}	11.55 ±0.22^{bc}	0.46 ±0.03^{bc}	0.36± 0.02^{bc}	0.45 ±0.03^{b}	169.75 ±1.80^{NS}	164.32 ±1.13^{a}	165.25 ±0.75^{c}
T4	50.50 ±4.84^{b}	51.50 ±1.44^{c}	57.75 ±0.75^{c}	55.73 ±1.42^{c}	53.75 ±1.25^{c}	64.00 ±1.08^{NS}	125.75 ±14.56^{b}	122.25 ±8.19^{c}	151.04 ±3.04^{e}	16.25 ±0.71^{c}	16.75 ±2.10^{c}	10.05 ±0.59^{b}	4.15± 0.34^{NS}	3.85 ±0.35^{b}	3.20± 0.44^{NS}	12.50± 0.65^{NS}	14.75 ±0.48^{NS}	11.13 ±0.43^{c}	0.54 ±0.04^{c}	0.33± 0.02^{abc}	0.53± 0.03^{bc}	170.50 ±1.19^{NS}	160.65 ±2.57^{ab}	164.50 ±1.19^{c}
T5	53.50 ±3.12^{ab}	61.75 ±2.56^{b}	59.75 ±1.11^{bc}	58.00 ±4.14^{c}	65.00 ±2.94^{b}	65.75 ±1.31^{NS}	128.50 ± 11.27^{b}	161.75 ±3.30^{b}	159.37 ±1.25^{d}	16.66 ±1.32^{c}	18.93 ±1.52^{c}	12.07 ±1.62^{b}	4.41± 0.34^{NS}	4.35 ±0.35^{ab}	3.42± 0.71^{NS}	12.75± 0.75^{NS}	13.00± 0.91^{NS}	10.95 ±0.35^{c}	0.52 ±0.02^{c}	0.38 ±0.01^{c}	0.56 ±0.03^{c}	169.50 ±1.85^{NS}	154.02 ±1.92^{b}	161.50 ±0.65^{d}
CV	**14.63**	**13.91**	**8.74**	**10.72**	**13.03**	**8.20**	**21.07**	**23.17**	**13.84**	**19.63**	**34.80**	**38.53**	**15.33**	**15.42**	**31.78**	**11.10**	**9.88**	**10.41**	**22.71**	**13.09**	**22.66**	**1.64**	**4.04**	**2.22**

Means±S.Em with the same superscripted letter in a column are not significantly different by Duncan test at $P \leq 0.05$. T_1 = Raised bed + drip irrigation (80% PE) + fertigation (75% RDF) + black polythene mulching (100µ) + micro-nutrients (0.2% of zinc sulphate and boric acid) spray in July and August; T_2 = Raised bed + drip irrigation + fertigation + mulching; T_3 = Raised bed + drip irrigation + fertigation +micronutrient sprays; T_4 = Raised bed + drip irrigation + micro-nutrient sprays + soil application of RDF (50:25:50 g N:P:K) and T_5 = Flat bed + soil application of RDF + basin irrigation (control).

Table 3 : Pearson correlation analysis between different parameters as influenced by different inputs in guava cv. Lalit under Lucknow condition

	CH	CSBR	CSWR	TCSA	PBCSA	SBCSA	CV	FL	FG	FW	FY	PSR	TSS	TA	FAA
CH	1.000														
CSBR	0.944*	1.000													
CSWR	0.518	0.710	1.000												
TCSA	0.950*	0.998**	0.682	1.000											
PBCSA	0.953*	0.992**	0.636	0.998**	1.000										
SBCSA	0.911*	0.995**	0.743	0.989**	0.982**	1.000									
CV	0.939*	0.984**	0.778	0.978**	0.963**	0.975**	1.000								
FL	0.886*	0.963**	0.828	0.962**	0.946*	0.959**	0.982**	1.000							
FG	0.875	0.960**	0.816	0.962**	0.948*	0.957*	0.972**	0.998**	1.000						
FW	0.914*	0.987**	0.795	0.984**	0.971**	0.984**	0.993**	0.993**	0.990**	1.000					
FY	0.978**	0.973**	0.652	0.980**	0.976**	0.948*	0.978**	0.960**	0.955*	0.970**	1.000				
PSR	0.915*	0.895*	0.696	0.905*	0.891*	0.862	0.941*	0.948*	0.940*	0.929*	0.964**	1.000			
TSS	0.746	0.497	-0.151	0.522	0.551	0.423	0.477	0.369	0.355	0.415	0.613	0.553	1.000		
TA	-0.992**	-0.927*	-0.561	-0.930*	-0.926*	-0.890*	-0.945*	-0.893*	-0.877	-0.912*	-0.975**	-0.942*	-0.731	1.000	
FAA	0.877	0.759	0.407	0.741	0.731	0.721	0.792	0.672	0.633	0.716	0.793	0.738	0.759	-0.899*	1.000

*Correlation is significant at 0.05 level (2-tailed); ** Correlation is significant at 0.01 level (2-tailed). CH = Canopy height; CSBR = Canopy spread between rows; CSWR = Canopy spread within row; TCSA = Trunk cross-sectional area; PBCSA = Primary branch cross-sectional area; SBCSA = Secondary branch cross-sectional area; CV = Canopy volume; FL = Fruit length; FG = Fruit girth; FW = Average individual fruit weight; FY = Fruit yield; PSR = Pulp-seed ratio; TSS = Total soluble solids and TA = Titrable acidity, FAA = Fruit ascorbic acid

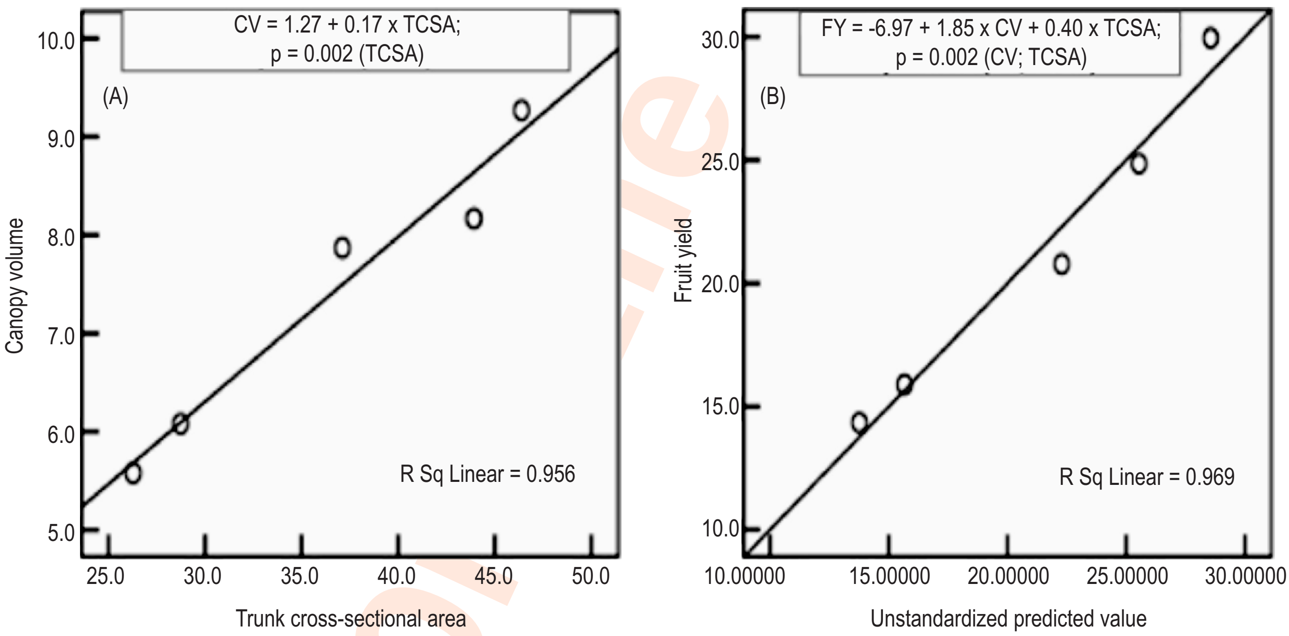

Fig. 1 : Regression analysis of canopy volume with trunk cross-sectional area (A) and fruit yield (FY) with canopy volume (CV) and trunk cross-sectional area (B) as influenced by different inputs in guava cv. Lalit under Lucknow condition.

of water and nutrients, lower leaching losses and more controllable application of nutrients as compared to conventional nutrient and water supply methods (Singh *et al*., 2017). Increase in guava yield due to foliar spray of zinc sulphate may be due to increase in number of fruits per tree either by improving pollen germination or by helping the growth of pollen tubes, thus facilitating in timely fertilization before stigma loses its receptivity or style becomes non-functional and also helped to increase fruit weight by regulating metabolic activities leading to increased stored food materials in the fruit tissues (Parmar *et al*., 2014), besides, improving retention of fruits on the tree by increasing the internal auxin levels through zinc mediated biosynthesis of tryptophan. The positive effect of boric acid on guava yield may be attributed that boron has role in cell wall structural integrity, cell expansion and transport of minerals, thereby increasing mobilization of photosynthates from all other parts of the plant towards developing fruits which are extremely active metabolic sink (Singh *et al*., 2001).

Total soluble solids significantly increased by 23.97 and 13.70 per cent in T_1 and T_2 over control, respectively, during 2019. The titrable acidity content in fruit significantly decreased by 40.38, 21.85 and 43.30 per cent over control in T_1 during 2017-19, respectively, which was at par with that of T_2 during 2018 (18.54% lower than control) (Table 2). Total ascorbic acid content in fruit increased by 8.69 and 6.04 per cent in T_1, as compared to control, during 2018 and 2019, respectively, which was non-significant with T_2, T_3 and T_4 treatments (4.00, 6.69 and 4.30% more than control) during 2018 (Table 2). Thus trees of T_1 had much better micro-climate in the rhizosphere for tree growth, as compared to control, and thus large tree canopies were able to intercept more solar radiation (Binkley *et al*., 2010) which affected the amount of photosynthates and their distribution to the sinks, subsequently increasing the sugar content and decreasing the acid percentage (Mohsen and Osman, 2015) and also improving ascorbic acid content in fruits (Nemeskéri *et al*., 2019).

The correlation analysis revealed positive and highly significant association between trunk cross-sectional area and canopy spread between rows (r = 0.998 at P<0.01) (Table 3). Fruit yield was highly significant and positive correlated with canopy volume (r = 0.978), trunk cross-sectional area (r = 0.980), fruit length (r = 0.960), fruit girth (r = 0.955) and fruit weight (r = 0.970) while negatively correlated with titrable acidity (r = -0.975) at $P \leq 0.01$. Fruit ascorbic acid content was found negatively correlated with titrable acidity (r = -0.899 at P<0.05). Regression model exhibited 99.50 per cent influence of canopy spread between rows, observed under different inputs in guava cv. Lalit, on variation in trunk cross-sectional area. Further it was observed that with unit change in canopy spread between rows, there was 49.42 times change in trunk cross-sectional area. Similarly, 95.60 per cent variation in canopy volume occurred due to variation in trunk cross-sectional area and change in canopy volume was 0.17 times more than that of trunk cross-sectional area (Fig. 1A). Hence, canopy volume, which could be referred as the estimate of bearing potential for fruit trees, were strongly related to trunk cross-sectional area (Smith, 2008). We also observed in the regression model that canopy volume and trunk cross-sectional area exerted significant influence on fruit yield and 96.90 per cent variation in fruit yield happens due to variation in above two factors (Fig. 1B). Thus, it was observed that unit change in canopy volume and trunk cross-sectional area respectively caused 1.85 and 0.40 times more change in fruit yield. Dogra and Kumar (2018) found a highly significant and positive phenotypic and genotypic correlation of fruit yield with trunk girth in peach genotypes. They also observed maximum positive direct effect of tree volume on fruit yield. Thus, enhancement of tree size is important for commercial fruit production, especially after planting, since tree size generally affects fruit yield.

It can be concluded that water and nutrient use efficiency can be improved under high density planting system by planting guava on raised beds of 15-20 cm height along with drip irrigation at 80% ET, fertigation at 75% RDF, foliar spray of 0.2% zinc sulphate and boric acid each and mulching with UV stabilised black polythene. Thus, adopting technology will help the guava growers in sustaining quality productivity under high density planting system.

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Add-on Information

Author's contribution : K.K. Srivastava: Experiment implementation, Data recording; **P. Barman:** Data analysis, manuscript preparation; **P. Patil:** Financial support (Project Coordinator, AICRP on Fruits); **D. Kumar:** Editing, Result Interpretation; **N.K. Sharma:** Data recording.

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