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Effect of plant spacing and training methods on growth and yield of guava cv. Arka Mridula under high density planting system

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Abstract
An experiment was carried out to know the effect of plant spacing and training methods on growth and yield attributes of guava cv. Arka Mridula under high density planting system at Horticultural Research Station, Aswaraopet, Khammam, Telangana, India during the year 2013-2016. Among different plant spacing systems wider plant spacing system (1.5 X 2.0 m) significantly increased the plant spread (1.71 m), number of fruits per plant (42.66) and fruit weight (160.91 g) compared to other spacing systems, whereas maximum yield per unit area was recorded in closer spacing system (1 X1 m) (19.34t/ha). Among training methods, vertical single stem with 3-4 branches has recorded the maximum number of fruits per plant (40.48) and yield per unit area (13.64 t/ha) whereas, tatoora with 2 primary branches training method has recorded maximum fruit weight (147.24 g) compare to other treatments. However, training methods did not significantly influence the vegetative growth parameters *viz*., plant height, and plant spread. Among interactions plants spaced with 1.5X 2.0 m along with vertical stem training method (3-4 primary branches) heading back done at 1.0 m of plant height recorded maximum number of fruits per plant (45.16) and fruit weight (161.85 g). Maximum yield was recorded in plants spaced with 1.0X 1.0 m along with tatoora training method (2 primary branches) heading back done at 1.0 m of plant height (20.07 t/ac) compare to other interaction treatments.

Keywords: Plant spacing, high density planting, training methods, heading back and Arka Mridula

Introduction
Guava (*Psidium guajava* L.) is one of the most popular tropical and sub-tropical fruit crops grown in India and belongs to the family Myrtaceae. Guava fruit is rich in vitamin C with fair amount of Calcium, Phosphorus, pantothenic acid, riboflavin, thiamin and niacin. The fruits are used for making juice, jam jellies, and various culinary products. Guava fruit also have certain antioxidant properties and is known to control systolic blood pressure. It is the fourth largest fruit crop grown after mango, banana, and citrus in India. In India it occupies an area of 276 Mha with a production of 4236 MT (NHB, 2019) [9]. In India, guava is cultivated mainly through the traditional system where the production is less because of large trees with low productivity. Large trees take several years to come into bearing and the cost of production per unit area is further increased because of long juvenile period.

Hence, there are certain strategies have to be adopted to intensify the guava production per unit area. Among them high density planting or meadow orchard system is one of the recent technique to boost the guava production where more number of plants per unit area is accommodated compared to traditional planting system. High density planting in guava has been achieved through closer spacing. Under high density planting system where fruiting starts from first year, a precise level of pruning is required to make the balance between the vegetative and reproductive growth. Factors like improper training method adoption, competition for natural resources *i.e*., space, water, sun light and nutrients *etc*., influencing the productivity and quality of fruits in high density orchards of guava. However, appropriate canopy management or training method strongly mitigates the overall orchard yield reductions in plants adopted with high density planting system (Mishra and Goswami, 2016) [8]. Keeping the above information in view, the present investigation was conducted to standardize the effect of plant spacing and training methods on growth and yield of guava cv. Arka Mridula under high density planting system.

Materials and Methods

Present investigation was carried out during 2011-2016 at Horticultural research station, Aswaraopet, Telangana. The soil of the experimental site is sandy clay loam (deep red to brown soils) and is endowed with good drainage. Guava cultivar Arka Mridula was planted during 2011 with different levels of spacing. The experiment was laid out in randomized block design with factorial concept (FRBD) having three factors and with three replications. Under three factorial randomized block design, Spacing factor consists different levels of spacing treatments *viz*., 1X1 m spacing (S_1), 1X1.5 m spacing (S_2), 1X2 m spacing (S_3), 1.5X1.5 m spacing (S_4), and 1.5X2.0 m spacing (S_5), training method factor consists of different levels of training methods *viz*., Vertical single stem with 3-4 branches (T_1) and Tatoora with 2 primary branches (T_2) and heading back height factor consists of different levels of heading back done at plant height levels *viz*., 1 m plant height (H_1) and 1.5 m plant height (H_2). All cultural practices like fertilizers application, spraying of pesticides, fungicides, and irrigation were uniformly practiced as per recommendation. Data was recorded on vegetative parameters *viz*., plant height (m) and plant spread (m) and yield parameters *viz*., number of fruits per plant, fruit weight (g) and yield (t/ac). The data was subjected to statistical analysis as per the procedure out lined by Panse and Sukhatme (1985) [10].

Results and Discussion

Vegetative parameters

The data presented in table 1 revealed that, there was no significant difference among plant spacing, training method and plant height (at which heading back was done) treatments with respect to plant height.

The results on plant spread (N-S & E-W) after adopting different plant spacing, training methods and plant height (at which heading back was done) were presented in table 2. The data revealed that there was significant difference among plant spacing with respect to plant spread (Table 2). Maximum plant spread was recorded in plants spaced with 1.5X1.5m (S_4) (1.72m) which was at par with plants spaced with 1.0X1.5m (S_5) (1.71m). However minimum plant spread was recorded in plants spaced with 1.0X1.0m (S_1) (1.52m).

Training methods and plant height (at which heading back was done) were not significantly influenced with respect to the plant spread (Table 2). Among interactions maximum plant spread was recorded in plants spaced with 1.5X1.5m along with tatoora training method (2 primary branches) heading back done at 1.0 m of plant height ($S_4T_2H_1$) (1.79m) which was at par with plants spaced with 1.5X2.0m along with tatoora training method (2 primary branches) heading back done at 1.0 m of plant height ($S_5T_2H_1$) (1.74m), plants spaced with 1.5X2.0m along with vertical stem training method (3-4 primary branches) heading back done at 1.5 m of plant height ($S_5T_1H_2$) (1.73m), plants spaced with 1.5X 2.0m along with tatoora training method (2 primary branches) heading back done at 1.5m of plant height ($S_5T_2H_2$) (1.73m), plants spaced with 1.5X1.5m along with vertical stem training method (3-4 primary branches) heading back done at 1.5m of plant height ($S_4T_1H_2$) (1.70m) and plants spaced with 1.0X2.0m along with tatoora training method (2 primary branches) heading back done at 1.5m of plant height ($S_3T_2H_2$) (1.69m). However minimum plant spread was recorded in plants spaced with 1.0X1.0m along with vertical stem training method (3-4 primary branches) heading back done at 1.5m of plant height ($S_1T_1H_2$) (1.50m).

Table 1: Effect of planting densities and training systems on plant height (m) of guava cv. Arka Mridula

Plant height (m)								
Spacing								
T/H		**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**Mean (H)**	**Mean (T)**
T_1	H_1	2.73	2.64	2.58	2.65	2.74	H_1 Mean	2.84
	H_2	2.88	3.00	3.01	3.08	3.08	2.66	
T_2	H_1	2.63	2.66	2.59	2.70	2.67	H_2 Mean	2.81
	H_2	2.94	2.92	2.94	3.01	3.07	2.99	
Mean (S)		2.80	2.80	2.77	2.86	2.89		
		S		T		H		S X T X H
F test		*		*		*		*
CD (5%)		NS		NS		NS		NS

Figures with same alphabets did not differ significantly.
**Significant at (p= 0.01 LOS).
*Significant at (p= 0.05 LOS), NS- Non Significant.
Values were compared with respective C.D values.
S_1-1X1 m spacing, S_2-1X1.5 m spacing, S_3-1X2 m spacing, S_4-1.5X1.5 m spacing, and S_5-1.5X2.0 m spacing
T_1-Vertical single stem with 3-4 branches
T_2-Tatoora with 2 primary branches.
H_1-1 m plant height and H_2-1.5 m plant height.

The similar findings *viz*., plant spacing and pruning factors' not influencing the plant height was earlier reported by Bharad *et al*., (2012) [1] in guava, Kumawat *et al*., (2014) [5] in L-49 guava and Singh *et al*., (2019) [14] in guava cv. L-49. Plant spread was increased with wider spacing or lesser populated planting system under present study (Table 2), the similar increase in plant spread with decreased plant population was earlier confirmed with Singh *et al*., (2007) [13] in guava cv. Allahabad Safeda, Bharad *et al*., (2012) [1] in guava and Kumawath *et al*., (2014) [5] in guava cv. L-49. Competition for water and soil nutrients is a possible factor (Policarpo *et al*., 2006) [11] and also competition for light is the one of the strong factor (Kumawath *et al*., 2014) [5] associated with closed spacing planting systems, under such circumstances plant canopy overlap into the rows, reducing the light incidence on leaves. Consequently, great part of the canopy contributes little or nothing to synthesis of carbohydrates necessary for growth. Thus, the competition between plants for light, water and nutrition under closer spacing resulted to less increase in gain of shoots and spread of the canopy. These factors might be resulted plant spread in closer spacing treatment or higher plant spread in wider spaced treatment (Table 2) under present investigation.

Table 2: Effect of planting densities and training systems on plant spread (m) of guava cv. Arka Mridula

Plant spread (m)								
Spacing								
T/H		**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**Mean (H)**	**Mean (T)**
T_1	H_1	1.53^c	1.64^b	1.63^b	1.68^b	1.64^b	H_1 Mean	1.63
	H_2	1.50^c	1.60^b	1.61^b	1.70^a	1.73^a	1.63	
T_2	H_1	1.52^c	1.60^b	1.54^c	1.79^a	1.74^a	H_2 Mean	1.65
	H_2	1.53^c	1.66^b	1.69^a	1.72^a	1.73^a	1.65	
Mean (S)		1.52^c	1.63^b	1.62^b	1.72^a	1.71^a		
		S		**T**		**H**		**S X T X H**
F test		*		*		*		*
CD (5%)		0.052		NS		NS		0.103

Figures with same alphabets did not differ significantly.
**Significant at (p= 0.01 LOS).
*Significant at (p= 0.05 LOS), NS-Non Significant.
Values were compared with respective C.D values.
S_1-1X1m spacing, S_2-1X1.5m spacing, S_3-1X2m spacing, S_4-1.5X1.5m spacing and S_5-1.5X2.0m spacing
T_1-Vertical single stem with 3-4 branches and T_2-Tatoora with 2 primary branches.
H_1-1m plant height and H_2-1.5 m plant height.

Yield parameters

The results on number of fruits per plant after adopting different plant spacing, training methods and plant height (at which heading back was done) were presented in table 3.The data (Table 3) revealed that there is significant difference among plant spacing with respect to number of fruits per plant. Maximum number of fruits per plant was recorded in plants spaced with 1.0X2.0m (S_3) (42.68), which was on par with 1.5X2.0m plant spacing (S_5) (42.66). However, minimum number of fruits per plant was recorded in 1.0X1.0m plant spacing (S_1) (34.33). Among training methods maximum number of fruits per plant was recorded in vertical stem training method (3-4 primary branches) (T_1) (40.48) where as minimum number of fruits per plant was recorded in tatoora method (2 primary branches) (T_2) (40.06). There was no significant difference observed in plant height at which heading back was done with respect to number of fruits per plant (Table. 3). Among interactions maximum number of fruits per plant was recorded in plants spaced with 1.5X2.0m along with vertical stem training method (3-4 primary branches) heading back done at 1.0 m of plant height ($S_5T_1H_1$) (45.16) whereas minimum number of fruits per plant was recorded in plants spaced with 1.0X1.0m along with tatoora training method (2 primary branches) heading back done at 1.5 m of plant height ($S_1T_2H_2$) (32.83).

The similar increase in number of fruits per plant with wider spacing was earlier reported by Kundu (2007) [6] in guava and Kumawat *et al*., (2014) [5] in guava cv. L-49. Higher number of fruits per plant in wider spaced planting system seems to be due to greater photosynthetic activity, because of exposure of more number of leaves to sun light that availability of proper sunlight to the lower branches of the tree at close spacing becomes a limiting factor and it adversely affects the flowering and fruiting. These are the possible reasons for getting more number of fruits per tree in wider spacing trees under present study. Maximum number of fruits per tree was recorded in vertical single stem with 3-4 primary branches allowed training system (Table 3) under present study, which might be due to more lateral primary branches can produce more number of vegetative buds and flower buds, thereby increase in number of fruits per tree. The similar increase in number of fruits with more number of lateral primary branches allowed training system was earlier reported by Vanden Heuvel *et al*., (2004) [15] in grape. Plants spaced with 1.5X2.0m along with vertical stem training method (3-4 primary branches) heading back done at 1.0 m of plant height had recorded the maximum number of fruits per tree under present study (Table 3). More light interception facilitation to leaves by wider spaced planting system and more productive branches production by vertical stem training method (3-4 primary branches) has synergistically enhance the number of fruits per plant when compare to their individual application. The similar synergistic increase in number of fruits per plant was earlier reported by Joshi *et al*., (2016) [3] in guava cv. Pant prabhat adopted with wider spacing plants in combination with half pruned shoots.

Table 3: Effect of planting densities and training systems on number of fruits per plant of guava cv. Arka Mridula

Number of fruits per plant								
Spacing								
T/H		**S_1**	**S_2**	**S_3**	**S_4**	**S_5**	**Mean (H)**	**Mean (T)**
T_1	H_1	34.75	39.41	42.75	41.08	45.16	H_1 Mean	40.48^a
	H_2	35.25	39.75	41.91	42.41	42.33	40.26	
T_2	H_1	34.50	39.66	42.66	41.75	40.91	H_2 Mean	40.06^b
	H_2	32.83	39.58	43.41	43.08	42.25	40.28	
Mean (S)		34.33^d	39.60^c	42.68^a	42.08^b	42.66^a		
		S		**T**		**H**		**S X T X H**
F test		*		*		*		*
CD (5%)		0.056		0.036		NS		0.112

Figures with same alphabets did not differ significantly.
** Significant at (p= 0.01 LOS).
*Significant at (p= 0.05 LOS), NS-Non Significant.
Values were compared with respective C.D values.
S_1-1X1m spacing, S_2-1X1.5m spacing, S_3-1X2m spacing, S_4-1.5X1.5m spacing and S_5-1.5X2.0m spacing.
T_1-Vertical single stem with 3-4 branches and T_2-Tatoora with 2 primary branches.
H_1-1m plant height and H_2-1.5m plant height.

The data depicted in table 4 revealing that there was significant difference among plant spacing, training methods and plant height (at which heading back was done) with respect to fruit weight (g). Among plants spacing, maximum fruit weight was recorded in plants spaced with 1.5X2.0m (S_5) (160.91g) whereas, minimum fruit weight was recorded in plants spaced with 1.0X1.5m (S_2) (138.85g). Among training methods maximum fruit weight was recorded with tatoora training method (2 primary branches) (T_2) (147.24g) and minimum fruit weight was recorded with vertical stem training method (3-4 primary branches) (T_1) (146.45g). Plant height (at which heading back done) was significantly influenced the fruit weight (Table 4), maximum fruit weight was recorded with 1.0m of plant height at which heading back done (H_1) (147.81g) whereas minimum fruit weight was recorded with 1.5 m of plant height at which heading back done (H_1) (145.88g). Among interactions maximum fruit weight was recorded in plants spaced with 1.5X2.0m along with vertical stem training method (3-4 primary branches) heading back done at 1.0m of plant height ($S_5T_1H_1$) (161.85g) whereas, minimum fruit weight was recorded in plants spaced with 1.0X1.5m along with vertical stem training method (3-4 primary branches) heading back done at 1.5m of plant height ($S_2T_1H_2$) (130.45g).

Table 4: Effect of planting densities and training systems on fruit weight (g) of guava cv. Arka Mridula

Fruit weight (g)								
Spacing								
T/H		S_1	S_2	S_3	S_4	S_5	Mean (H)	Mean (T)
T_1	H_1	136.41	142.00	139.54	155.66	161.85	H_1 Mean	146.45[b]
	H_2	140.16	130.45	141.20	156.30	160.91	147.81[a]	
T_2	H_1	142.66	141.12	142.32	156.54	159.97	H_2 Mean	147.24[a]
	H_2	136.62	141.83	145.52	144.91	160.92	145.88[b]	
Mean (S)		138.96[d]	138.85[d]	142.14[c]	153.35[b]	160.91[a]		
		S		T		H		S X T X H
F test		*		*		*		*
CD (5%)		0.161		0.102		0.102		0.321

Figures with same alphabets did not differ significantly.
**Significant at (p=0.01 LOS).
*Significant at (p= 0.05 LOS), NS-Non Significant.
Values were compared with respective C.D values.
S_1-1X1 m spacing, S_2-1X1.5 m spacing, S_3-1X2 m spacing, S_4-1.5X1.5m spacing and S_5-1.5X2.0m spacing.
T_1-Vertical single stem with 3-4 branches and T_2-Tatoora with 2 primary branches.
H_1-1m plant height and H_2-1.5m plant height.

Increase in fruit weight with widely spaced (1.5X2m) (Table 4) plants may be due to the fact that plant leaves intercepted maximum radiation which in turn had more efficient photosynthetic activities resulting in higher availability of net photosynthesis which enabled the plants to produce fruits with higher weight (Kumawat *et al*., 2014) [5]. Among training systems the maximum fruit weight and minimum number of fruits per tree was recorded in tatoora with 2 primary branches under present study (Table 3 and Table 4). Increase in fruit weight with decrease in number of fruits per tree was earlier reported by Rahman *et al*., (2017) [12] in guava cv. Peyara-2. Maximum fruit weight was resulted from tatoora with 2 primary branches training system this might be due to less number of fruits per plant obtained in such training system, which favour each fruit with greater amount of photosynthates, sun light and aeration (Rahman *et al*., 2017) [12]. 1.0 m of plant height at which heading back done treatment was recorded maximum fruit weight compared to heading back done at 1.5m of plant height (Table 4) under present study, similar higher fruit weight with plants headed back at lower height was earlier reported by Gill *et al*., (2011) [2] in pomegranate cv. Kandhari. Which might be due to availability of more canopy area and solar radiation to the entire tree in bush type (lateral primary branches allowed at ground level) training system (Mathew *et al*., 2005) [7]. Plants spaced with 1.5X2.0m along with vertical stem training method (3-4 primary branches) heading back done at 1.0 m of plant height had recorded the maximum fruit weight under present study (Table 4). More light interception facilitation to leaves by wider spaced planting system and more productive branches production by vertical stem training method (3-4 primary branches) has synergistically enhance the fruit weight when compare to their individual application. The similar synergistic increase in fruit weight was earlier reported by Joshi *et al*., (2016) [3] in guava cv. Pant prabhat adopted with wider spacing plants in combination with half pruned shoots.

Table 5: Effect of planting densities and training systems on yield (t/ac) of guava cv. Arka Mridula

Yield (t/ac)								
Spacing								
T/H		S_1	S_2	S_3	S_4	S_5	Mean (H)	Mean (T)
T_1	H_1	19.16	15.13	12.12	11.58	9.97	H_1 Mean	13.64[a]
	H_2	20.03	15.22	12.00	11.97	9.23	13.61	
T_2	H_1	20.07	15.09	12.28	11.83	8.84	H_2 Mean	13.58[b]
	H_2	18.12	15.17	12.83	12.39	9.2	13.62	
Mean (S)		19.34[a]	15.15[b]	12.31[c]	11.94[d]	9.31[e]		
		S		T		H		S X T X H
F test		*		*		*		*
CD (5%)		0.058		0.037		NS		0.117

Figures with same alphabets did not differ significantly.
**Significant at (p= 0.01 LOS).
*Significant at (p= 0.05 LOS), NS-Non Significant.
Values were compared with respective C.D values.
S_1-1X1 m spacing, S_2-1X1.5 m spacing, S_3-1X2 m spacing, S_4-1.5X1.5 m spacing, and S_5-1.5X2.0 m spacing
T_1-Vertical single stem with 3-4 branches and T_2-Tatoora with 2 primary branches.
H_1-1m plant height and H_2-1.5m plant height.

The data presented in table 5 revealing that there was significant difference among plant spacing, training methods and plant height (at which heading back was done) with respect to yield (t/ac). Among plants spacing maximum yield was recorded in plants spaced with 1.0X1.0m (S_1) (19.34 t/ac) whereas minimum yield was recorded in plants spaced with 1.5X2.0 (S_5) (9.31 t/ac). Among training methods maximum yield was recorded with vertical stem training method (3-4 primary branches) (T_1) 13.64 t/ha) and minimum yield was recorded with tatoora training method (2 primary branches) (T_2) (13.58 t/ha). Plant height (at which heading back done) did not significantly influenced the yield. Among interactions maximum yield was recorded in plants spaced with 1.0X1.0m along with tatoora training method (2 primary branches) heading back done at 1.0 m of plant height ($S_1T_2H_1$) (20.07 t/ac), which was at par with plants spaced with 1.0X1.0m along with vertical single stem training method (3-4 primary branches) heading back done at 1.5 m of plant height ($S_1T_1H_2$) (20.03 t/ac). However, minimum yield was recorded in plants spaced with 1.5X2.0m along with tatoora training method (2 primary branches) heading back done at 1.0 m of plant height ($S_5T_2H_1$) (8.84 t/ac).

The similar maximum yield per unit area with closed spacing

planting system was earlier reported by Kumawat *et al*., (2014) [5] in L-49 guava. Individual plants in closed spacing treatment showed lower number of fruits per tree and lower fruit weight whereas, yield per unit area showed in increasing trend under present study which might be achieved due to higher planting density under closed spacing planting system (Kumar and Singh, 2000) [4]. Among training systems vertical single stem training method (3-4 primary branches) had recorded maximum yield per unit area, which might be due to more number of fruits produced per plants (Table 3) the similar findings were earlier confirmed by Vanden Heuvel *et al*., (2004) [15] in grape with trellis training system. Among interactions closed spacing along with tatoora training method (2 primary branches) heading back done at 1.0 m of plant height had synergistically improves the yield per unit area when compare to their individual application. The similar synergistic increase in yield was earlier reported by Joshi *et al*., (2016) [3] in guava cv. Pant prabhat adopted with wider spacing plants in combination with half pruned shoots.

Conclusion

Based on the major findings of the study it was concluding that, among different plant spacing systems, wider plant spacing system (1.5X2.0m) significantly increased the plant spread, number of fruits per plant and fruit weight compare to other spacing systems, whereas maximum yield per unit area was recorded in closed spacing system (1X1m). Among training methods, vertical single stem with 3-4 branches has recorded the maximum number of fruits per plant and yield per unit area whereas, tatoora with 2 primary branches training method has recorded maximum fruit weight compare to other treatments. However, training methods did not significantly influence the vegetative growth parameters *viz*., plant height, and plant spread. Among interactions plants spaced with 1.5X2.0m along with vertical stem training method (3-4 primary branches) heading back done at 1.0 m of plant height recorded maximum number of fruits per plant and fruit weight. Whereas, maximum yield recorded in plants spaced with 1.0X1.0m along with tatoora training method (2 primary branches) heading back done at 1.0 m of plant height compare to other interaction treatments.

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