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Performance of Okra (*Abelmoschus esculentus* L. Moench) under Different Spatial Arrangements of *Melia composita* Based Agroforestry System

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A B S T R A C T

Okra (*Abelmoschus esculentus* L. Moench) is an important vegetable crop and *Melia composita* (Malabar Neem or Nimabaro) is emerging industrial agroforestry plantations in southern Gujarat. To maximize the land utilization an agroforestry trial was laid to investigate the performance of okra varieties under different spatial arrangements of 2 year old *Melia composita* plantation with three spacing of S_1 (2x2 m), S_2 (2x3 m) and S_3 (4x2 m) while S_0 as open field at College of Forestry, ACHF, Navsari Agricultural University, Navsari, Gujarat, India, during winter season of 2015-16 and 2016-17. Okra crop (OV_{1-} GAO-5 and OV_2- GJO-3) was intercropped with *M. composita* reported lower growth parameters as well lower yield as compared to open condition. The results of pooled analysis of two years shown that treatment T_2-S_0OV_2 recorded maximum plant height- 106.38 cm, number of branches per plants- 4.68, number of leaves per plants- 36.68, number of flower per plant -26.07, average number of fruits per plant- 22.75, fresh fruit yield per plant- 302.71g and per hectare- 13.62 tonnes in open condition followed by OV_1variety. Similarly in intercropping the growth and yield attributes of Okra were minimum height - 85.74 cm, number of branches per plants - 3.59, number f leaves per plant- 25.06, number of flower per plant - 13.27, average number of pod per plant - 16.02, fresh fruit yield per plant- 268.89g and per hectare- 12.10 tonnes were reported in T_3 (S_1OV_1) i.e. in 2x2 m closer spacing while under wider spacing of S_2 and S_3 okra responded significantly better respectively. Hence wider spacing of S_3 (4x2 m) can be suggested for intercropping under *M. composita* plantations in initial 2-4 years.

Introduction

Agroforestry is a dynamic, ecologically based natural resource management system, through which the integration of trees/woody perennials in farm and rangelands, diversifies and sustains production for increased social, economic and environmental benefits (Leakey, 1996; Bhusara *et al.,* 2017a and b; Kumar *et al.,* 2017b; Panchal *et al.,* 2017). Intercropping of vegetable with commercial tree species in initial stages is desirable for economic gain and additional income to the farmers (Bhusara *et al.,* 2016a; Thakur *et al.,* 2016; Mohanty *et al.,* 2017). Spatial arrangement of trees in plantation plays an important role in growth and yield of agricultural intercrops as well as trees. In order to utilize the interspaces in early stages in closer spacing and wider spacing even in later stages of plantation development the selection of the crops for intercropping is important (Verma *et al.,* 2010; Thakur *et al.,* 2011; Thakur and Verma, 2012; Thakur *et al.,* 2014; Jilariya *et al.,* 2017; Thakur *et al.,* 2018).

Okra or lady finger (*Abelmoschus esculentus* L. Moench) belongs to Malvaceae family is an economically important vegetable crop grown in tropical and sub-tropical parts of the world. In the world, India ranks second in the production of vegetables, next to China with 403.2 lakh tonnes from 43.1 lakh hectares of land. Okra is popular in India because of easy cultivation, dependable yield and adaptability to varying moisture conditions. It has tremendous export potential as fresh vegetable.

Okra is one of the important vegetable crops of Gujarat, covering an area of 41,500 hectares with a production of 3, 65,200 tonnes with average productivity of 8.82 tonnes ha^{-1} reg. okra requires warm and moist season for higher yield. *Melia composita* Wild. (Malabar Neem or Nimabaro) belongs to the meliaceae family is an indigenous species which also distributed to South East Asia and Australia. *M. composita is* very large and fast growing deciduous tree with a straight cylindrical trunk attaining a height of 20-25 m with a spreading crown and a straight bole of 9 m length and l.2-1.5 m girth. It is a short rotation multipurpose tree species which yield useful termite proof timber and also used for packing cases, cigar boxes, tea box, ceiling planks, agricultural implements, pencils, match boxes and splints musical instruments *M. composita* is being advocated as amenable tree species for agroforestry without any deleterious effect on under-storye crops (Kumar *et al.,* 2017a; Thakur *et al.,* 2017a,b,c, Parmar *et al.,* 2018). Okra is an important vegetable crop and *M. composita* is emerging industrial agroforestry plantations in southern Gujarat. Recently in agricultural land a large scale plantations are done for the pulpwood and paper industry which necessitated the intercropping of agricultural crops under the *M. composita*. Many medicinal and aromatic crops have been found to perform well under *M. dubia* plantations (Jilariya *et al.,* 2017; Mohanty *et al.,* 2017; Thakur *et al.,* 2018) and other vegetable and pulse crops are yet be examined. To maximize the land utilization an agroforestry trial was laid to investigate the performance of okra varieties under different spatial arrangements of 2 year old *M. composita* plantation.

Materials and Methods

Melia composita (Malabar Neem or Nimabaro) is an emerging industrial agroforestry plantations in southern Gujarat. To maximize the land utilization an agroforestry trial was laid to investigate the performance of okra varieties under different spatial arrangements of 2 year old *M. composita* plantation at College of Forestry, ACHF, Navsari Agricultural University, Navsari, Gujarat, India, during winter season of 2015-16 and 2016-17. The experiments designed for intercropping of two Okra varieties (OV_1- GAO-5 and OV_2-GJO-3) in winter season with *M. composita,* which was planted in 2014 with three spacing of S_1 (2x2 m), S_2 (2x3 m) and S_3 (4x2 m) while S_0 as open field. Experiment is designed in Randomized Block Design (RBD) with eight treatments and three replications. The treatments for okra crop includes- T_1- (S_0OV_1), T_2- (S_0OV_2), T_3- (S_1OV_1), T_4- (S_1OV_2), T_5- (S_2OV_1), (T_6- (S_2OV_2), T_7- (S_3OV_1) and T_8- (S_3OV_2). Okra height, number of branches, number of leaves and number of flowers was recorded before final harvest by randomly selecting 5 plants in each replication and treatment. Number of fruit in individual selected plant was counted at every picking and finally these were added to obtain the mean number of pods per plant. Yield per plot (4 sq.m) was worked out by multiplying okra yield per plant with total number of plants in respective plots and expressed in kg**.** Yield was calculated by plot value for hectare.

Results and Discussion

The data of growth and yield parameters of Okra as sole crop and under different spatial arrangements for both the year of study (2015-16 and 2016-17) and pooled analysis (Table 1 and 2; Fig. 1 and 2) shown that the okra maximum plant height-106.85 cm, 105.91cm and 106.38 cm; number of branches per plants - 4.68, 4.69 and 4.68; number of leaves per plant 36.54, 36.81 and 36.68; number of flower per plant- 24.91, 27.23 and 26.06 respectively for the first year, second year and pooled analysis under treatment T_2-S_0OV_2 in open condition as compare to other treatment combination. Similarly pooled analysis of two years data for intercropping shown the growth attributes of Okra were minimum height - 85.74 cm, number of branches per plants - 3.59, number of leaves per plant- 25.06, number of flower per plant - 13.27, in treatment T_3 (S_1OV_1) i.e. in 2x2 m closer spacing while under wider spacing of S_2 and S_3 okra responded significantly better respectively. It seems due to less availability of light under closer spacing of as *M. composita* compared to open condition resulted lower growth attributes similar trend was in past also recorded by the Rani *et al.*, (2015) under poplar based agroforestry, Hasan *et al.*, (2012) evaluated the performance of Indian spinach (*Basella alba*) and okra (*Abelmoschus esculentus*) in association with Lombu (*Swietenia hybrid*) and Rajalingam *et al.,* (2016) in *Ailanthus excelsa* with vegetable, Osman *et al.*, (2011) and beans crops, Hanif *et al.,* (2010) in okra with litchi based agroforestry.

The yield attributes like number of fruit per plant 22.51, 22.98 and 22.75; Fresh fruit yield – 203.64g/plant, 296.78 g/plant and 302.71 g/ plant ; yield per hectare- 13.89 tonne/ha, 13.36 and 13.62 tonne/ha were recorded maximum in first year, second year and pooled analysis respectively with the treatment T_2-S_0OV_2 in open condition.

Similarly in intercropping the yield attributes of Okra were lowest with average number of fruit per plant - 16.02, fresh fruit yield per plant- 268.89g and per hectare- 12.10 tonnes in both year pooled analysis in T_3 (S_1OV_1) i.e. in 2x 2 closer spacing while under wider spacing of S_2 and S_3 okra responded significantly better respectively. The probable reason for it might be good availability of light in open condition as compared to *M. composita* based agroforestry system, similar findings are also reported by Babu (2012) for vegetables cultivation under Eucalyptus tree rows; Singh *et al.,* (1997) in Eucalyptus with vegetable crops, Mohammed (2012) in *Poplus deltoids*, Vanlalhluna *et al.*, (2014) in maize under multipurpose tree species and Thakur *et al.,* (2011), Bijalwan (2011) studied agricultural crop in *Melia azaderach* followed by *Grewia optiva*, and *Celtis australis*. Though the wider spacing of S3 (2 x4 m) can be suggested for intercropping under *M. composita* plantations in initial 2-4 years with tree pruning and other plantation management activities. The *M. composita* trees performed better in intercropping than in sole plantations (Fig. 3 and 4). The maximum height increment was in T_4- S_1 OV_1 as 1.20 m in two year while maximum DBH increment was in T_9- S_3 OV_2 as 1.78 cm in two year. It reflect that closer spacing with okra the height was more while with wider spacing DBH was more with intercrops. Thus intercrops favouring the growth of probably due to inputs of nutrients and irrigations provided to crops will have also utilized by the trees.

Table.1 Vegetative growth attributes of okra under different spatial arrangements of *M. composita* and sole cropping

Treatments	Height (cm)			No. of branches/plant			No. of leaves/plant		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T_1 - S_0OV_1	105.48	104.25	104.86	4.53	4.51	4.52	34.98	35.05	35.02
T_2 - S_0OV_2	106.85	105.91	106.38	4.68	4.69	4.68	36.54	36.81	36.68
T_3 - S_1OV_1	87.23	84.25	85.74	3.72	3.47	3.59	25.61	24.51	25.06
T_4 - S_1OV_2	88.60	85.91	87.26	3.85	3.63	3.74	27.17	26.27	26.72
T_5 - S_2OV_1	89.98	87.58	88.78	3.98	3.80	3.89	28.73	28.02	28.38
T_6 - S_2OV_2	91.35	89.25	90.30	4.11	3.97	4.04	30.29	29.78	30.04
T_7 - S_3OV_1	92.73	90.91	91.82	4.25	4.15	4.20	31.86	31.54	31.70
T_8 - S_3OV_2	94.10	92.58	93.34	4.38	4.32	4.35	33.42	33.30	33.36
S. Em ±	**1.29**	**1.26**	**0.90**	**0.20**	**0.26**	**0.16**	**1.58**	**1.75**	**1.18**
C.D. at 5 %	**3.92**	**3.83**	**2.36**	**0.61**	**0.77**	**0.47**	**4.80**	**5.30**	**3.40**
S.Em ± (Y X T)	**-**	**-**	**1.28**	**-**	**-**	**0.23**	**-**	**-**	**1.66**
CD at 5 % (Y X T)	**-**	**-**	**NS**	**-**	**-**	**NS**	**-**	**-**	**NS**
CV %	**9.37**	**9.36**	**9.37**	**8.26**	**10.86**	**9.61**	**8.82**	**9.88**	**9.33**

T_1 - S_0OV_1=Okra variety GAO-5 sole; T_2 - S_0OV_2= Okra variety GJO-3 sole; T_3 - S_1OV_1=*M. composita* (2X2)+ Okra variety GAO-5; T_4 - S_1OV_2=*M. composita* (2X2)+ Okra variety GJO-3; T_5 - S_2OV_1= *M. composita* (3X2)+ Okra variety GAO-5; T_6 - S_2OV_2= *M. composita* (3X2)+ Okra variety GJO-3; T_7 - S_3OV_1= *M. composita* (4X2)+ Okra variety GAO-5; T_8 - S_3OV_2= *M. composita* (4X2)+ Okra variety GJO-3

Table.2 Reproductive growth attributes of okra under varying spatial arrangements of *M. composita* and sole cropping

Treatments	No. of flowers/plant			No. of fruits/plant		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T1 - S_0OV_1	23.32	25.15	24.24	21.94	22.20	22.07
T2 - S_0OV_2	24.91	27.23	26.07	22.51	22.98	22.75
T3 - S_1OV_1	13.79	12.74	13.27	16.51	15.52	16.02
T4 - S_1OV_2	15.38	14.81	15.10	17.08	16.30	16.69
T5 - S_2OV_1	16.97	16.88	16.92	17.65	17.08	17.37
T6 - S_2OV_2	18.56	18.95	18.75	18.23	17.86	18.04
T7 - S_3OV_1	20.15	21.02	20.58	18.79	18.64	18.72
T8 - S_3OV_2	21.74	23.09	22.41	19.37	19.42	19.39
S. Em ±	**1.11**	**1.26**	**0.79**	**0.93**	**0.87**	**0.64**
C.D. at 5 %	**3.37**	**3.81**	**2.28**	**2.83**	**2.66**	**1.67**
S.Em ± (Y X T)			**1.18**			**0.90**
CD at 5 % (Y X T)			**NS**			**NS**
CV %	**9.96**	**10.89**	**10.45**	**8.51**	**8.09**	**8.31**

T_1 - S_0OV_1=Okra variety GAO-5 sole; T_2 - S_0OV_2= Okra variety GJO-3 sole; T_3 - S_1OV_1=*M. composita* (2X2)+ Okra variety GAO-5; T_4 - $S_1OV_{2=}$*M. composita* (2X2)+ Okra variety GJO-3; T_5 - S_2OV_1= *M. composita* (3X2)+ Okra variety GAO-5; T_6 - $S_2OV_{2=}$ *M. composita* (3X2)+ Okra variety GJO-3; T_7 - S_3OV_1= *M. composita* (4X2)+ Okra variety GAO-5; T_8 - S_3OV_2= *M. composita* (4X2)+ Okra variety GJO-3

Table.3 Yield attributes of okra under different spatial arrangements of *M. composita* and sole cropping systems

Treatments	Fresh fruit yield (g/plant)			Fresh fruit yield (Kg/plot)			Fresh fruit yield (tonne/ha)		
	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled	2015-16	2016-17	Pooled
T1 - S_0OV_1	303.34	292.42	297.88	5.46	5.26	5.36	13.65	13.16	13.40
T2 - S_0OV_2	308.64	296.78	302.71	5.56	5.34	5.45	13.89	13.36	13.62
T3 - S_1OV_1	271.52	266.25	268.89	4.89	4.79	4.84	12.22	11.98	12.10
T4 - S_1OV_2	276.83	270.61	273.72	4.98	4.87	4.93	12.46	12.18	12.32
T5 - S_2OV_1	282.13	274.97	278.55	5.08	4.95	5.01	12.70	12.37	12.53
T6 - S_2OV_2	287.44	279.34	283.39	5.17	5.03	5.10	12.93	12.57	12.75
T7 - S_3OV_1	292.74	283.70	288.22	5.27	5.11	5.19	13.17	12.77	12.97
T8 - S_3OV_2	298.04	288.06	293.05	5.36	5.19	5.27	13.41	12.96	13.19
S. Em ±	**5.20**	**4.78**	**3.20**	**0.09**	**0.09**	**0.06**	**0.23**	**0.22**	**0.16**
C.D. at 5 %	**15.79**	**14.51**	**10.19**	**0.28**	**0.26**	**0.17**	**0.71**	**0.65**	**0.41**
S.Em ± (Y X T)			**4.99**			**0.09**			**0.22**
CD at 5 % (Y X T)			**NS**			**NS**			**NS**
CV %	**3.11**	**2.94**	**3.03**	**3.11**	**2.94**	**3.02**	**3.11**	**2.94**	**3.02**

T_1 - S_0OV_1=Okra variety GAO-5 sole; T_2 - S_0OV_2= Okra variety GJO-3 sole; T_3 - S_1OV_1=*M. composita* (2X2)+ Okra variety GAO-5; T_4 - $S_1OV_{2=}$*M. composita* (2X2)+ Okra variety GJO-3; T_5 - S_2OV_1= *M. composita* (3X2)+ Okra variety GAO-5; T_6 - $S_2OV_{2=}$ *M. composita* (3X2)+ Okra variety GJO-3; T_7 - S_3OV_1= *M. composita* (4X2)+ Okra variety GAO-5; T_8 - S_3OV_2= *M. composita* (4X2)+ Okra variety GJO-3
(Plot Size: 4 sq.m)

Fig.1 Growth attributes of Okra under different spatial arrangements of *M. composita* and sole cropping systems (Flowers, Branches, Fruits)

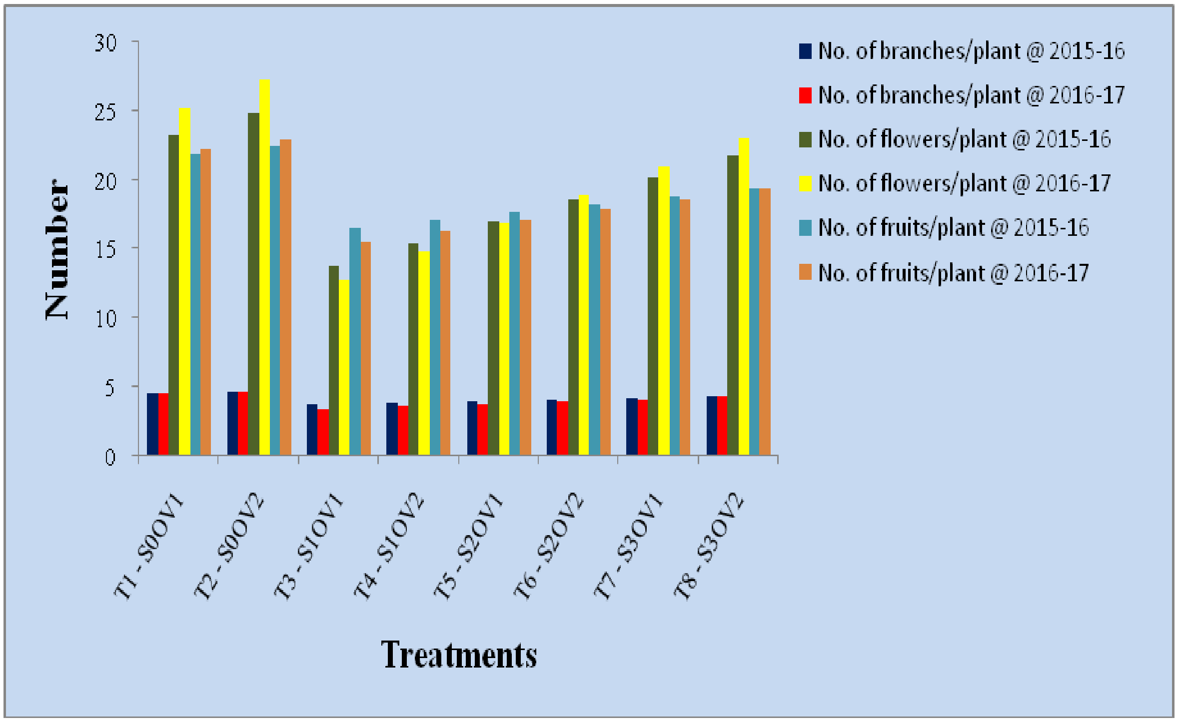


Fig.2 Yield (per plant and per hectare) attributes of okra under different spatial arrangements of *M. composita* and sole cropping systems

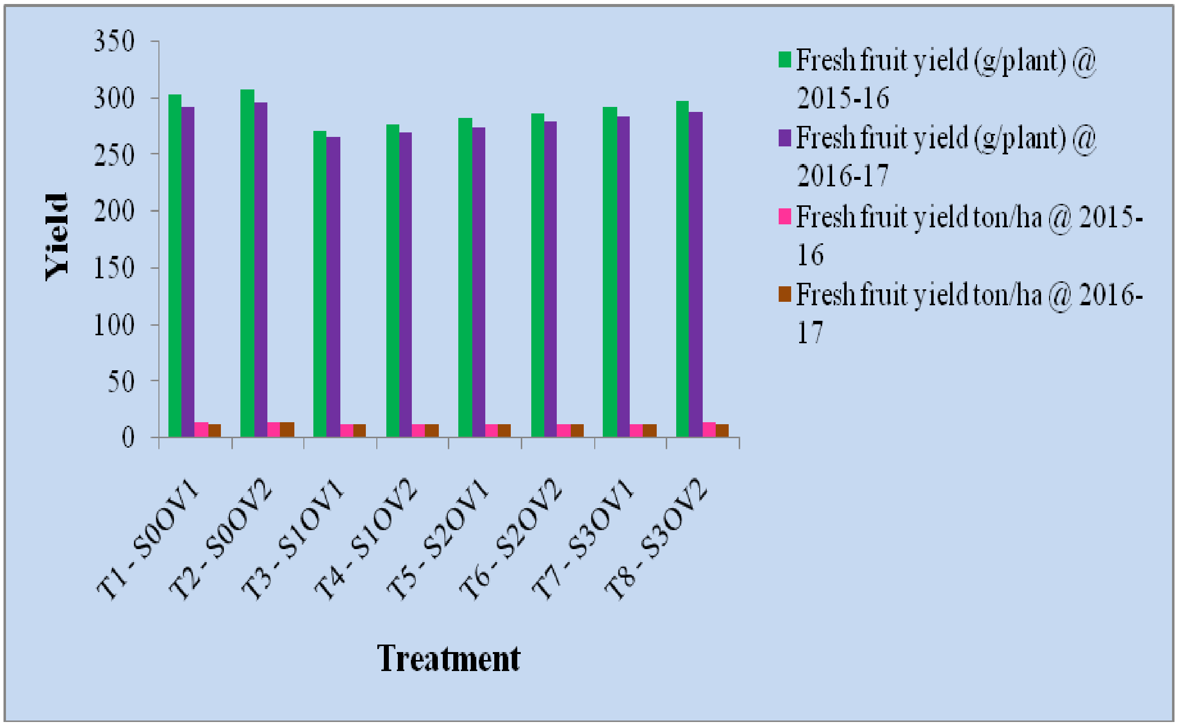


Fig.3 Growth attributes (Height) of *M. composita* in different spatial arrangement under sole plantation and with okra intercrop

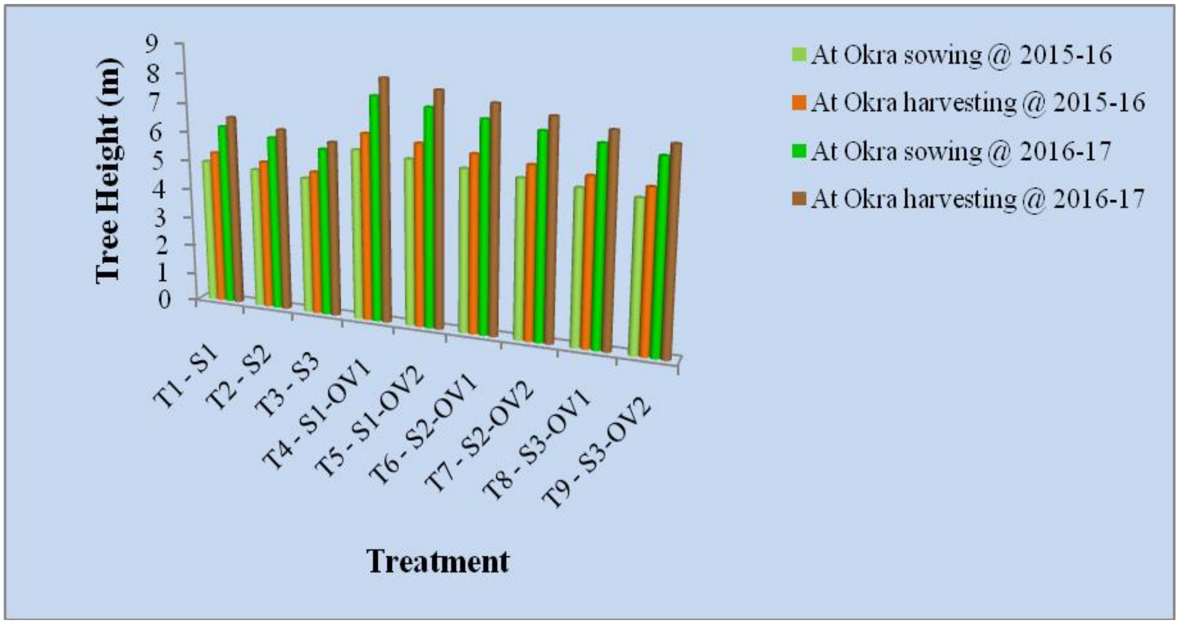
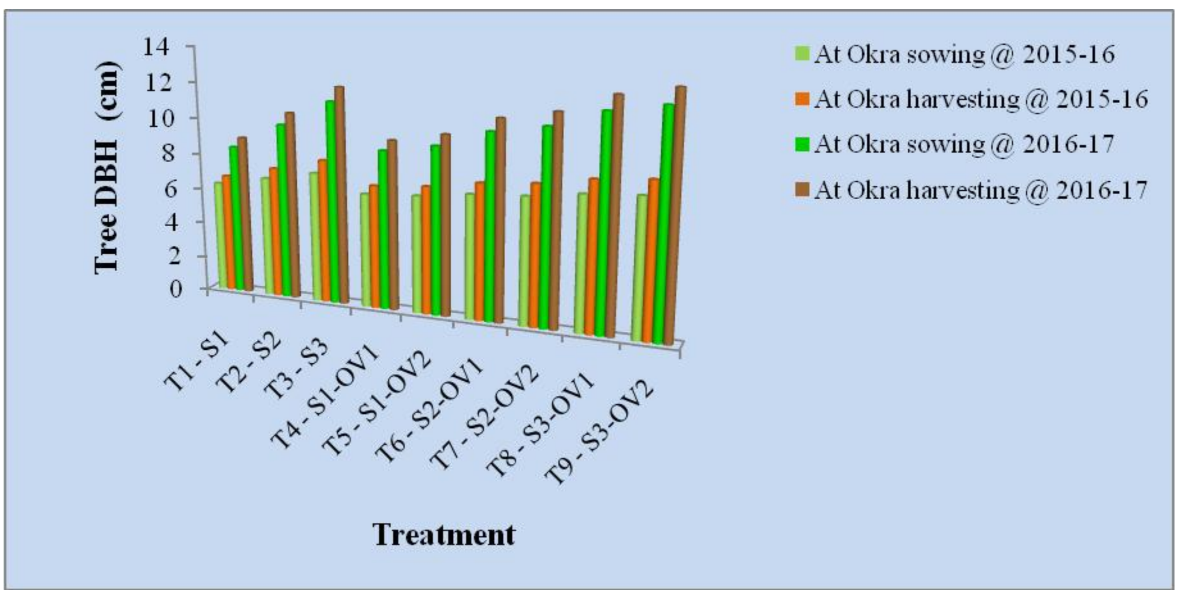


Fig.4 Growth attributes (DBH) of *M. composita* in different spatial arrangement under sole plantation and with okra intercrop



Intercropping of vegetable with fast growing trees provide maximum returns to the farmers as compared to sole plantation or sole cropping. The interaction of trees and crops can be utilized for maximum gain by technological interventions and good agricultural practices. In present study the intercropping of okra varieties with *Melia composita* plantations in different spacing were found highest under sole cropping compared to intercropping. However, contrary the growth and yield parameters of

M. composita were found maximum with intercrops than sole plantation irrespective of spatial arrangement.

The average maximum pod yield of okra reported in T_2-(sole cropping with variety GJO-3) as 302 g/ plant and 13.62 tonnes/ ha while in intercropping maximum yield was recorded with T_8- (variety GJO-3 with *M. composita* at 4x2 m spacing) as 293.05 g/ plant and 13.19 tonnes/ ha which shows marginal reduction of 0.43 tonnes/ ha in yield (Table 3).

Hence wider spacing of (4x2 m) can be suggested for intercropping under *M. composita* plantations in initial 2-4 years.

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