



Research article

## Evaluation of different okra varieties under *Ailanthus excelsa* based silvi-horticulture system

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### Abstract

In order to assess the growth and productivity of okra varieties under *Ailanthus excelsa*-based silvi-horticulture system, a field experiment was carried out at Navsari Agricultural University, Navsari, Gujarat, India. Four okra varieties (Navsari okra, Ajeet, Roshni and Sona-55, denoted as V<sub>1</sub>, V<sub>2</sub>, V<sub>3</sub> and V<sub>4</sub>, respectively) were sown beneath *A. excelsa* and in open conditions. The experiment was designed in a randomized block design with four replications. The experiment's findings revealed that the marketable fruits plant<sup>-1</sup>, marketable fruit yield plant<sup>-1</sup>, marketable fruit production ha<sup>-1</sup>, collar diameter, branches plant<sup>-1</sup>, plant fresh and dry weight plant<sup>-1</sup> and ha<sup>-1</sup> of all okra varieties were maximum under the sole crop (control) except plant height and fruit length. In respect to productivity, the reduction order of marketable fruit yield ha<sup>-1</sup> of different varieties under *A. excelsa* was: Navsari okra (7.59 t) > Ajeet (7.08 t) > Sona-55 (5.35 t) > Roshni (5.21 t). While in open condition was: Ajeet (11.71 t) > Navsari okra (10.53 t) > Roshni (10.30 t) > Sona-55 (9.61 t). Therefore, among the different varieties, Navsari Okra (V<sub>1</sub>) performed better under *A. excelsa* as compared to other okra varieties, but Ajeet variety (V<sub>2</sub>) performed well in open conditions. Consequently, the Navsari okra variety (V<sub>1</sub>) can withstand more shade and aids farmers in increasing their revenue by following the *A. excelsa*-based silvi-horticulture system.

**Keywords:** Agroforestry, *Ailanthus excelsa*, Growth, Okra varieties, yield

### Introduction

In a changing climate, the two greatest dangers to human life are environmental degradation and food insecurity. The environments used for agricultural activity are being significantly affected by climate change; current crop yields may be negatively impacted and reduced. Certain effects, such as the direct impact of heat waves, floods, or other extreme weather events on crop growth, are clearly anticipated (FAO, 2015; Mirzabaev *et al.*, 2023). In light of predictions that the world's population will exceed 11 billion by 2050, the already difficult task of achieving food security while mitigating the effects of climate change has become even more urgent (Karada *et al.*, 2023). Because of this problem, scientists are investigating sustainable farming methods that can both improve agricultural productivity and reduce the negative effects of climate change. Agroforestry is one such sustainable farming method; it involves integrating woody perennials with crops and/or animals on the same piece of land. It offers

an effective solution for sequestering carbon in the soil and mitigating the effects of climate change (Acharya *et al.*, 2018; Rolo *et al.*, 2023). By using agroforestry systems, the strain on natural forests, along with concerns about food security, habitat loss, and climate change mitigation, can be greatly reduced. Since the 1970s, the concept of agroforestry has evolved every decade. It was once considered a separate form of land use. Due to developments in science and technology, it later became undervalued, but today it is viewed as a multifaceted tool capable of transforming the lives of millions of people, as reported by Parthiban *et al.* (2021).

Agroforestry systems provide food, fuel wood, fertilizers, fibers and other essential resources directly to the environment. They can also improve soil fertility, reduce soil erosion, filter air pollutants, and most importantly, help maintain the atmosphere's carbon balance. In light of growing awareness and interest in these benefits, it is important to study the compatibility and interactions

between trees and different crops or varieties to enhance income and ensure long-term sustainability.

Farmers in South Gujarat have shown increasing interest in adopting agroforestry practices on their farmlands. Several studies indicate that farmers in this region have implemented agroforestry systems and generated additional income (Dobriyal *et al.*, 2019; Mevada *et al.*, 2022; Deshmukh *et al.*, 2023). Due to the growing demand from nearby wood-based industries, such as paper mills and plywood factories, along with the prevailing fodder shortage, farmers have increasingly adopted tree-based farming systems (Deshmukh *et al.*, 2025). *Ailanthus excelsa* can effectively meet these demands because it is a fast-growing, multipurpose species valued for its timber, matchwood, medicinal uses, fodder, and packaging material. Its leaves are also nutritious and suitable as supplementary fodder (Musa Tibin *et al.*, 2021). Commonly known as the Tree of Heaven or Maharukh, and widely distributed across Gujarat, including the southern districts. It is economically important, thrives in mixed deciduous forests, and is commonly planted in agroforestry systems as well as along roadsides (Srivastava and Dubey, 2021). Unfortunately, because mature trees take a long time to develop, farmers often prefer to grow suitable intercrops for seasonal income; however, limited data are currently available on such intercropping options. In this context, okra is an important vegetable crop that can grow under varying sunlight conditions. Okra (*Abelmoschus esculentus* (L.) Moench), an annual herb belonging to the family Malvaceae, is a valuable vegetable and oilseed crop with uses in food, paper production, medicine, oil extraction, and various industrial applications (Das *et al.*, 2022).

Okra is a prominent vegetable crop extensively cultivated in the South Gujarat districts of Surat, Tapi, Navsari, Bharuch and Valsad (Parmar and Leua, 2020). It is an economically important vegetable grown in tropical and subtropical regions of the world. Statistically, Gujarat is the second-largest producer of okra in India, after West Bengal, with 75.27 thousand hectares under cultivation and a production of 921.72 thousand metric tons (MoAFW, 2018; Manikanta and Kumar, 2022). Okra is also a vital crop for intercropping; it can be cultivated under partial shade and is widely available in commercial markets across the country (Kakade *et al.*, 2020; Mevada *et al.*, 2023). Therefore, the objective of the present study was to identify a suitable okra variety for an *Ailanthus*-based silvi-horticulture system in South Gujarat.

## Materials and Methods

**Experimental site and field preparation:** The field experiment was conducted at the Natural Resource Management (NRM) Farm, College of Forestry, Navsari Agricultural University, Navsari, Gujarat, India, during

the *kharif* seasons of 2023 and 2024. The experimental site is situated at 20.95° N latitude and 72.93° E longitude, with an elevation of 11.0 m above mean sea level. The region is characterized by a warm and humid monsoonal climate, receiving an average annual rainfall of 1500–1800 mm. Winters are moderately cold, while summers are typically hot and humid. The mean annual temperature recorded during the study period was 27.1°C.

The soils of the experimental area, popularly known as the 'Deep Black' soils of south Gujarat, have developed from old alluvium derived from basaltic parent material and predominantly contain 2:1 expanding-type montmorillonite clay mineral. These soils are heavy-textured, deep clayey, and moderately drained, with a high water-holding capacity. The major physico-chemical properties of the experimental soil were recorded and the standard methods were employed for analysis (Table 1). A five-year-old, well-established *A. excelsa* plantation spaced at 5.0 × 3.0 m in the farm was selected as the experimental site for evaluating okra as an intercrop in the agroforestry system. Prior to sowing, land preparation was carried out between the rows of the plantation and nearby open field using a tractor-mounted cultivator, operated twice in perpendicular directions to control initial weed growth. This was followed by secondary tillage with a rotavator to further pulverize the air-dried soil and obtain a fine tilth suitable for laying out the field and sowing of the crop.

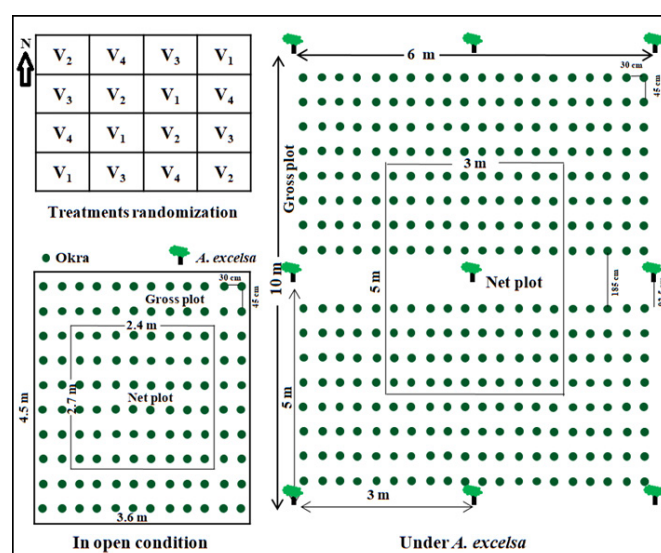
**Experimental design and layout:** The experiment was conducted to evaluate the performance of different okra varieties under an *A. excelsa*-based silvi-horticulture system and in open conditions. Four okra varieties having diverse agronomic traits were used as treatments, *viz.*, V<sub>1</sub>: Navsari okra, V<sub>2</sub>: Ajeet, V<sub>3</sub>: Roshni F1 and V<sub>4</sub>: Sona-55. The varieties were sown between the rows of *A. excelsa* at a spacing of 45 × 30 cm in the East-West direction (Jana *et al.*, 2010). The same set of treatments was also evaluated under open-field conditions. The okra varieties Hybrid Ajeet, Roshni F1 and Hybrid Sona-55 were procured from the Seed Bhandar, Navsari, whereas the Navsari okra variety was obtained from the Regional Horticultural Research Station, NAU, Navsari.

The experiment was laid out in a randomized block design (RBD) along with four replications. Under the *Ailanthus*-based silvi-horticulture system, the gross and net plot sizes were 10.0 × 6.0 m and 5.0 × 3.0 m, whereas, in the open condition, corresponding sizes were 4.5 × 3.6 m and 2.7 × 2.4 m, respectively (Fig 1). The layout ensured uniformity of treatment distribution and minimized environmental variability across the study area.

**Crop sowing and management:** After field preparation, the seeds of the okra varieties were sown manually by dibbling at a spacing of 45 × 30 cm, as per the treatment details, during the first week of July in both years. The

**Table 1.** Initial physico-chemical properties of experimental soil

Sr. No.	Soil properties	Under <i>A. excelsa</i>	In open condition	Methods employed	References
1.	Sand (%)	22.42	23.91	Pipette method	Piper (1966)
2.	Silt (%)	26.16	25.33		
3.	Clay (%)	51.42	50.76		
4.	Textural class	Clay	Clay		
5.	Bulk density ( $\text{Mg m}^{-3}$ )	1.34	1.38	Core sampler	Blake and Hartge (1986)
6.	Porosity (%)	52.14	49.04		
7.	Soil pH <sub>1:2.5</sub>	7.12	7.68	Potentiometric	Jackson (1967)
8.	Soil EC <sub>1:2.5</sub> ( $\text{dS m}^{-1}$ )	0.62	0.76	Conductometric	
9.	SOC (%)	0.84	0.72	Wet digestion by Chromic acid	Walkley and Black (1934)
10.	Available N ( $\text{kg ha}^{-1}$ )	279	262	Alkaline $\text{KMnO}_4$	Subbiah and Asija (1956)
11.	Available $\text{P}_2\text{O}_5$ ( $\text{kg ha}^{-1}$ )	115	88	Olsen's method (Spectrophotometer)	Olsen <i>et al.</i> (1954)
12.	Available $\text{K}_2\text{O}$ ( $\text{kg ha}^{-1}$ )	543	554	N, N, $\text{NH}_4\text{OAC}$ (pH 7.0) extractants (Flame photometer)	Jackson (1967)

**Fig 1.** Layout of the experiment

crop was fertilized with the recommended dose of NPK @150:50:50 kg per ha (Aklade *et al.*, 2018). Urea, SSP and MOP were used as sources of N, P and K, respectively. The full doses of P and K were applied as a basal application with the drilling method, whereas N was applied in three equal splits, first at sowing through drilling and the remaining two at 30 and 60 DAS by broadcasting. During both years, adequate rainfall was received; however, in the event of prolonged dry spells, the crop was irrigated using tub-well water. All recommended agronomic practices, including gap filling, weeding, nipping and intercultural operations, were followed as per the regional recommendations (Kumar and Choudhary, 2014).

**Observations recorded:** Observations pertaining to the plant height were recorded at 60 days after sowing (DAS) and at harvest, while the numbers of branches per plant, and collar diameter were assessed only at harvest. The yield attributes, namely, number of fruits per plant, fruit length (cm), and fruit weight (g), were recorded at each alternate picking and averaged. The weight of fruits per plant was measured at every picking until crop maturity from each net plot, and the total fruit yield was calculated by summing the weights from all pickings. The fruit yield obtained from each treatment was then converted into tons per hectare. After the last picking, the fresh biomass of the harvested plants from each plot was weighed and subsequently air-dried to a constant weight. The biomass values were then expressed as fresh and dry biomass (g) per plant and later converted into tons per hectare. In addition to crop observations, growth parameters of *A. excelsa* were also recorded to assess the influence of intercropping on tree growth. Tree height, diameter at breast height (DBH) and crown spread were measured using a clinometer, vernier caliper, and measuring tape, respectively, at the end of the experiment in both years.

**Statistical analysis:** The observations recorded during the experimentation were subjected to analysis of variance (ANOVA). After verifying the assumptions of normality and homogeneity of variances, ANOVA was performed, and the treatment means were compared using Duncan's multiple range test (DMRT) at  $p < 0.05$  (Panse and Sukhatme, 1995). Furthermore, R software was used to generate graphs and analyze the relationships among various okra traits (Core Team, 2017).

## Results and Discussion

Many crops perform better in agroforestry systems due to positive interactions and efficient resource utilization, whereas others struggle because of competition or unfavorable growing conditions. Selecting the right crop that can thrive alongside a tree crop is essential for effective agroforestry. Mevada *et al.* (2023) reported that okra is an important vegetable crop that grows best in partial shade. Therefore, the objective of the present study was to assess the performance of several okra varieties under an *A. excelsa*-based silvi-horticulture system. The mean data of the two-year (pooled) experimental results are presented below.

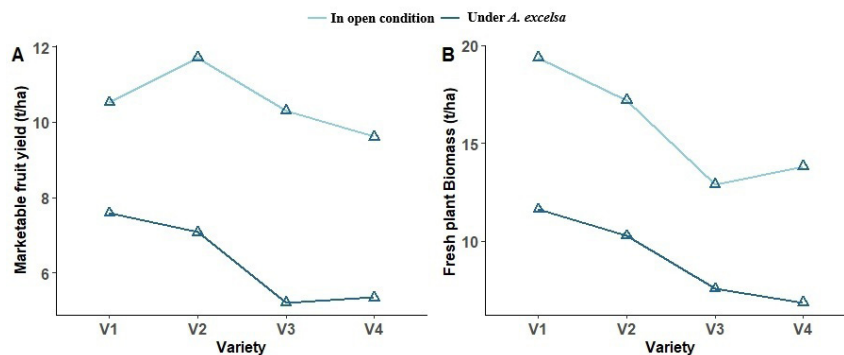
**Growth attributes:** Okra's growth attributes are quantifiable traits that indicate the health and development of the plant throughout its life cycle. Growth attributes

such as plant height, collar diameter, number of branches per plant, and the fresh and dry weight of the plants were recorded (Table 2). The height of okra was measured at 60 days after sowing (DAS) and at final harvest. The pooled analysis indicated that under *A. excelsa*, plant height was significantly different compared to open conditions. All okra varieties exhibited noticeably taller plants under the agroforestry system than in the open crop. The Navsari okra variety ( $V_1$ ) recorded a significantly higher plant height (117.4 cm) at the final harvest stage under the agroforestry system. However, at 60 DAS, the Roshni variety ( $V_3$ ) showed the maximum plant height (76.5 cm) under  $T_3$ , which was at par with  $T_4$ . This might be due to enhanced cell division and expansion of these varieties under shaded conditions (Schoch, 1972). Similar observations were reported in okra grown under *Swietenia hybrida* (Hasan *et al.*, 2012). Conversely, in open

**Table 2.** Performance of growth attributes of okra varieties under *A. excelsa* and in open condition

Treatments	Plant height (cm) at 60 day	Plant height (cm) at harvest	Collar diameter (cm) at harvest	Branches plant <sup>-1</sup> at harvest	Fresh plant weight (g)	Dry plant weight (g)	Fresh plant weight (t) ha <sup>-1</sup>	Dry plant weight (t) ha <sup>-1</sup>
$T_1$ : $V_1$ + <i>A. excelsa</i>	67.8 <sup>bc</sup>	117.4 <sup>a</sup>	1.71 <sup>b</sup>	1.11 <sup>e</sup>	240.9 <sup>b</sup>	57.0 <sup>b</sup>	11.63 <sup>d</sup>	2.75 <sup>d</sup>
$T_2$ : $V_2$ + <i>A. excelsa</i>	61.8 <sup>cd</sup>	104.7 <sup>b</sup>	1.73 <sup>b</sup>	1.81 <sup>cd</sup>	213.3 <sup>c</sup>	49.5 <sup>c</sup>	10.26 <sup>e</sup>	2.38 <sup>e</sup>
$T_3$ : $V_3$ + <i>A. excelsa</i>	76.5 <sup>a</sup>	103.0 <sup>b</sup>	1.69 <sup>b</sup>	1.05 <sup>e</sup>	156.9 <sup>e</sup>	36.8 <sup>e</sup>	7.56 <sup>f</sup>	1.77 <sup>f</sup>
$T_4$ : $V_4$ + <i>A. excelsa</i>	70.0 <sup>ab</sup>	88.3 <sup>c</sup>	1.62 <sup>b</sup>	2.52 <sup>a</sup>	141.9 <sup>e</sup>	34.1 <sup>e</sup>	6.85 <sup>f</sup>	1.64 <sup>f</sup>
$T_5$ : $V_1$ sole	60.0 <sup>d</sup>	101.7 <sup>b</sup>	2.10 <sup>a</sup>	1.48 <sup>de</sup>	286.3 <sup>a</sup>	67.0 <sup>a</sup>	19.38 <sup>a</sup>	4.53 <sup>a</sup>
$T_6$ : $V_2$ sole	53.9 <sup>e</sup>	86.9 <sup>c</sup>	2.05 <sup>a</sup>	2.04 <sup>bc</sup>	253.8 <sup>b</sup>	60.3 <sup>b</sup>	17.21 <sup>b</sup>	4.08 <sup>b</sup>
$T_7$ : $V_3$ sole	53.2 <sup>e</sup>	67.1 <sup>d</sup>	1.67 <sup>b</sup>	2.39 <sup>ab</sup>	191.1 <sup>d</sup>	44.5 <sup>d</sup>	12.90 <sup>c</sup>	3.00 <sup>d</sup>
$T_8$ : $V_4$ sole	66.3 <sup>bcd</sup>	88.1 <sup>c</sup>	1.58 <sup>b</sup>	1.58 <sup>d</sup>	203.1 <sup>cd</sup>	48.7 <sup>c</sup>	13.81 <sup>c</sup>	3.30 <sup>c</sup>
SEM	2.437	3.351	0.063	0.106	7.209	1.686	0.414	0.107
CD	6.956	9.564	0.179	0.303	20.575	4.811	1.183	0.305
SEM (Y X T)	3.447	4.739	0.089	0.150	10.195	2.384	0.586	0.151
CD	NS	NS	NS	NS	NS	NS	1.67	NS
CV	9.37	8.67	8.70	14.86	8.37	8.30	8.15	8.93

\* $V_1$ : Navsari okra;  $V_2$ : Ajeet;  $V_3$ : Roshni;  $V_4$ : Sona-55



**Fig 2.** Influence of *A. excelsa* and open condition on marketable fruits yield ha<sup>-1</sup> (A) and fresh plant biomass ha<sup>-1</sup> (B) of okra varieties

conditions, the minimum plant height (67.1 cm) was noted in the Roshni variety (V<sub>3</sub>). Crops grown in open conditions received more solar radiation than those under the ailanthus trees, which eventually resulted in shorter plants. Likewise, increased plant height under reduced light levels has also been observed in okra under Litchi by Hanif *et al.* (2010) and in eggplant by Miah (2001). On the other hand, overall maximum collar diameter, branches per plant, and plant fresh and dry weight per plant (g) and per hectare (t) were recorded in open conditions compared to the *Ailanthus*-based silvi-horticulture system (Table 2; Fig 2).

Among the different treatments, significantly higher collar diameter, fresh and dry weight per plant (g) and per hectare (t) were recorded in T<sub>5</sub> (Navsari okra variety, V<sub>1</sub>, in sole crop), with values of 2.10 cm, 286.3 g, 67.0 g, 19.38 t, and 4.53 t, respectively, followed by T<sub>6</sub> in open conditions. These traits were greater in sole crops for all varieties compared to their performance under the silvi-horticulture system. This may be attributed to reduced competition for nutrients, light, and space in open conditions, leading to vigorous growth and higher accumulation of biomass. Similar findings were reported by Muoneke and Udeogalanya (1991), who observed that an increase in components in multi-storeyed cropping systems reduces growth traits.

Additionally, the highest number of leaves per plant in okra was reported by Deswal and Nandal (2008). The lowest collar diameter was observed in the V<sub>4</sub> variety under open conditions (T<sub>8</sub>), while the lowest fresh and dry weight per plant (g) and per hectare (t) was recorded in T<sub>4</sub> (V<sub>4</sub> + *A. excelsa*). In contrast, the highest number of branches per plant (2.52) was recorded in T<sub>4</sub> (V<sub>4</sub> + *A. excelsa*), which was at par with T<sub>7</sub>, whereas the lowest (1.05) was noted in T<sub>3</sub> (V<sub>3</sub> + *A. excelsa*).

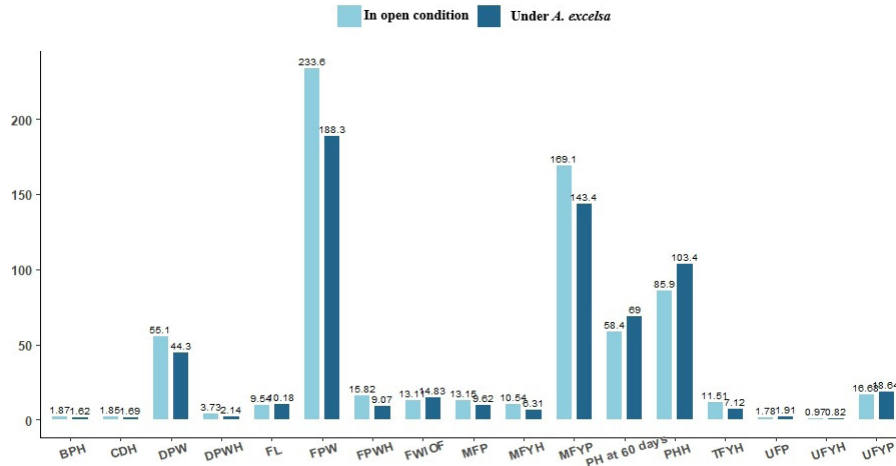
**Yield attributes:** The characteristics of the plant that contribute to yield include marketable fruit yield, marketable fruit length, marketable fruit weight per plant, and the fresh weight of individual okra fruits. These traits were measured, and the pooled data were recorded (Table 3).

The maximum okra fruit length was recorded under the *Ailanthus*-based silvi-horticulture system compared to the open condition. Pooled analysis showed that among the different okra varieties, the T<sub>3</sub> treatment (V<sub>3</sub> + *A. excelsa*) produced the longest fruits (11.24 cm) under the ailanthus canopy, which was statistically at par with T<sub>7</sub> and T<sub>4</sub>. In contrast, the shortest fruit length was reported in the T<sub>5</sub> treatment. The maximum fresh weight of individual okra fruits (15.97 g) was recorded in T<sub>1</sub>, which was in par with T<sub>3</sub>. Additionally, all varieties exhibited higher individual fruit fresh weight under the *Ailanthus*-based silvi-horticulture system compared to the sole cropping condition, possibly due to greater moisture content in

Table 3. Performance of yield attributes of okra varieties under *A. excelsa* and in open condition

Treatments	Fresh weight of individual okra fruit (g)	Okra fruit length (cm)	Marketable fruit yield plant <sup>-1</sup> (g)	Marketable fruits plant <sup>-1</sup>	Unmarketable fruits plant <sup>-1</sup>	Unmarketable fruit yield plant <sup>-1</sup> (g)	Unmarketable fruit yield (t)	Unmarketable fruit yield ha <sup>-1</sup>	Marketable fruit yield ha <sup>-1</sup> (t)	Total fruit Yield ha <sup>-1</sup> (t)
T <sub>1</sub> : V <sub>1</sub> + <i>A. excelsa</i>	15.97 <sup>a</sup>	9.44 <sup>bc</sup>	173.4 <sup>ab</sup>	10.97 <sup>c</sup>	1.63 <sup>b</sup>	15.00 <sup>cd</sup>	0.57 <sup>f</sup>	7.59 <sup>d</sup>	7.59 <sup>d</sup>	8.16 <sup>c</sup>
T <sub>2</sub> : V <sub>2</sub> + <i>A. excelsa</i>	13.26 <sup>bc</sup>	9.59 <sup>bc</sup>	159.5 <sup>bc</sup>	9.82 <sup>d</sup>	1.75 <sup>b</sup>	15.69 <sup>c</sup>	0.67 <sup>e</sup>	7.08 <sup>d</sup>	7.08 <sup>d</sup>	7.75 <sup>c</sup>
T <sub>3</sub> : V <sub>3</sub> + <i>A. excelsa</i>	15.83 <sup>a</sup>	11.24 <sup>a</sup>	118.7 <sup>d</sup>	9.04 <sup>e</sup>	2.81 <sup>a</sup>	31.38 <sup>a</sup>	0.71 <sup>e</sup>	5.21 <sup>e</sup>	5.21 <sup>e</sup>	5.92 <sup>d</sup>
T <sub>4</sub> : V <sub>4</sub> + <i>A. excelsa</i>	14.27 <sup>b</sup>	10.47 <sup>ab</sup>	122.2 <sup>d</sup>	8.64 <sup>e</sup>	1.46 <sup>bc</sup>	12.49 <sup>e</sup>	1.32 <sup>b</sup>	5.35 <sup>e</sup>	5.35 <sup>e</sup>	6.67 <sup>e</sup>
T <sub>5</sub> : V <sub>1</sub> sole	13.39 <sup>bc</sup>	8.55 <sup>c</sup>	168.7 <sup>bc</sup>	12.71 <sup>b</sup>	1.63 <sup>b</sup>	16.31 <sup>c</sup>	0.63 <sup>ef</sup>	10.53 <sup>b</sup>	10.53 <sup>b</sup>	11.16 <sup>b</sup>
T <sub>6</sub> : V <sub>2</sub> sole	13.49 <sup>bc</sup>	9.60 <sup>bc</sup>	187.8 <sup>a</sup>	15.11 <sup>a</sup>	1.49 <sup>bc</sup>	13.28 <sup>de</sup>	1.00 <sup>c</sup>	11.71 <sup>a</sup>	11.71 <sup>a</sup>	12.72 <sup>a</sup>
T <sub>7</sub> : V <sub>3</sub> sole	13.15 <sup>bc</sup>	10.97 <sup>a</sup>	165.8 <sup>bc</sup>	12.36 <sup>b</sup>	2.94 <sup>a</sup>	26.88 <sup>b</sup>	0.82 <sup>d</sup>	10.30 <sup>bc</sup>	10.30 <sup>bc</sup>	11.12 <sup>b</sup>
T <sub>8</sub> : V <sub>4</sub> sole	12.44 <sup>c</sup>	9.05 <sup>c</sup>	154.3 <sup>c</sup>	12.44 <sup>b</sup>	1.06 <sup>c</sup>	10.25 <sup>f</sup>	1.42 <sup>a</sup>	9.61 <sup>c</sup>	9.61 <sup>c</sup>	11.03 <sup>b</sup>
SEM	0.567	0.385	6.044	0.306	0.165	0.778	0.035	0.294	0.294	0.316
CD	1.618	1.100	17.250	0.874	0.471	2.219	0.100	0.840	0.840	0.901
SEM (Y X T)	0.802	0.545	8.548	0.433	0.233	1.100	0.049	0.416	0.416	0.447
CD	NS	NS	NS	NS	NS	NS	0.14	NS	NS	NS
CV	9.94	9.57	9.47	6.59	21.91	10.79	9.59	8.56	8.56	8.29

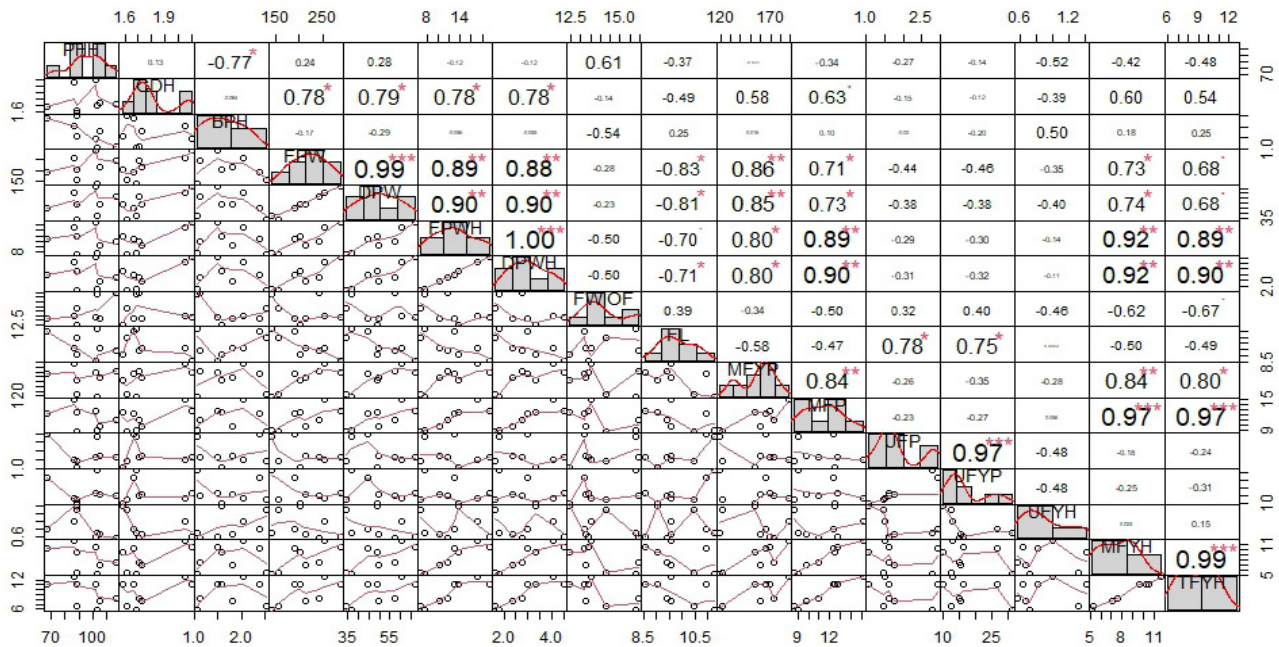
\*V<sub>1</sub>: Navsari okra; V<sub>2</sub>: Ajeet; V<sub>3</sub>: Roshni; V<sub>4</sub>: Sona-55



BPH: Branches plant<sup>-1</sup> at harvest; CDH: Collar diameter (cm) at harvest; DPW: Dry plant weight (g); DPWH: Dry plant weight (t) ha<sup>-1</sup>; FL: Okra fruit length (cm); FPW: Fresh plant weight (g); FPWH: Fresh plant weight (t) ha<sup>-1</sup>; FWIOF: Fresh weight of individual okra fruit (g); MFP: Marketable fruits plant<sup>-1</sup>; MFYH: Marketable fruit Yield ha<sup>-1</sup> (t); MFYP: Marketable fruit yield plant<sup>-1</sup> (g); PH at 60 days: Plant height at 60 days; PHH: Plant height (cm) at harvest; TFYH: Total fruit Yield ha<sup>-1</sup> (t); UFP: Unmarketable fruits plant<sup>-1</sup>; UFYH: Unmarketable fruit Yield ha<sup>-1</sup> (t); UFYP: Unmarketable fruit yield plant<sup>-1</sup> (g)

Fig 3. Influence of *A. excelsa* and open conditions on different parameters of okra

Table 4. Correlation between the several okra variables



\*\*\*Correlation significant at 0.001 level (two tailed); \*\*Correlation significant at 0.01 level (two tailed); \*Correlation significant at 0.05 level (two tailed)

okra fruits grown under shade. Moreover, the number of marketable fruits per plant, marketable fruit yield per plant, unmarketable fruit yield per hectare, marketable fruit production per hectare, and total fruit yield per hectare of all okra varieties were significantly higher in open conditions than under the ailanthus canopy, except for unmarketable fruits per plant and unmarketable yield

per plant, which were higher under the silvi-horticulture system. The maximum number of marketable fruits per plant (15.11), marketable fruit yield per plant (187.4 g), marketable fruit yield per hectare (11.71 t), and total yield per hectare (12.72 t) were recorded in T<sub>6</sub> (V<sub>2</sub> sole), followed by T<sub>5</sub>. However, under the silvi-horticulture system, T<sub>1</sub> (V<sub>1</sub> + *A. excelsa*) outperformed the

**Table 5.** Growth parameters of *A. excelsa* with different varieties

Varieties	Height (m)		Diameter (cm)		Crown spread (m)			
	Yr - I	Yr - II	Yr - I	Yr - II	N-S		E-W	
					Yr - I	Yr - II	Yr - I	Yr - II
V <sub>1</sub>	8.95	10.6	12.97	15.13	3.50	4.31	2.32	2.53
V <sub>2</sub>	7.83	9.5	13.61	15.83	3.38	4.02	2.45	2.57
V <sub>3</sub>	8.32	9.87	13.97	16.23	3.75	4.18	2.40	2.68
V <sub>4</sub>	8.55	10.1	13.27	15.47	3.70	4.19	2.26	2.44

other treatments. The lowest marketable fruit yield per plant (118.7 g), per hectare (5.21 t), and total yield (5.92 t) were observed in T<sub>3</sub> (V<sub>3</sub> + *A. excelsa*) (Table 3; Fig 2).

Overall, okra yield decreased when intercropped with *A. excelsa* compared to the open condition. This reduction may be attributed to the interception of photosynthetically active radiation (PAR) by the *A. excelsa* canopy, resulting in limited light availability and reduced photosynthesis, ultimately suppressing crop growth and yield. Similar interpretations have been reported by several researchers (Deswal and Nandal, 2008; Prasad *et al.*, 2011; Chandana *et al.*, 2020; Mevada *et al.*, 2023). Likewise, higher yield components and yield of sunflower have been observed in sole cropping compared to cultivation under neem or melia trees (Panneerselvam and Arthanarib, 2011). Although the fresh weight of individual okra fruits was not significantly affected by different treatments, it was slightly higher under the agroforestry system than in open conditions.

**Comparison of okra growth and yield attributes under ailanthus and in open condition:** From the above findings, the okra varieties performed differently under *A. excelsa* and in open conditions. Among the four okra varieties, the Ajeet variety (V<sub>2</sub>) performed better in the open environment compared to the others, whereas under the *A. excelsa* tree, the Navsari okra variety (V<sub>1</sub>) performed better than the rest. However, the different growth and yield attributes of okra also varied across environmental conditions. In the present study, certain okra characteristics, such as plant height, fruit length, and individual fruit weight, were greater under the ailanthus canopy than in the open. In contrast, attributes such as the number of marketable fruits per plant, marketable fruit yield per plant, number of branches per plant, collar diameter, fresh and dry weight per plant, and fresh and dry weight per hectare were all highest in the open environment (Fig 3). Similarly, studies have shown that growing lettuce under shade improves light interception by increasing both total and specific leaf area, although the overall number of leaves per plant often decreases (Marrou *et al.*, 2013; Valle *et al.*, 2017). In many other

crops, shade improves plant energy conversion efficiency, helping mitigate yield reductions; however, indirect effects of shade, such as reduced transpiration and/or increased water-use efficiency, are often necessary for yield enhancement (Slattery *et al.*, 2013). Shade avoidance syndrome, which includes various morphological and physiological modifications, has been associated with several processes that facilitate tolerance or even positive yield responses when crops are exposed to shade (Evans and Poorter, 2001; Franklin, 2008; Gratani, 2014).

**Correlation of the different traits of okra:** Positive correlations among several quantitative traits were observed in the correlation analysis of okra parameters (Table 4). The fresh and dry biomass of the okra crop was positively associated with collar diameter. Several growth and yield attributes depend on different correlated parameters. Marketable fruit production, marketable fruit yield per plant, and the number of marketable fruits per plant also showed favorable correlations. No additional significant relationships were detected among the other okra characteristics. These findings are consistent with those of Ram *et al.* (2024), who reported that fruit yield per plant, considered the most important trait, showed a highly significant and positive association with average fruit weight (0.62) and number of fruits per plant (0.73). Similarly, Solankey *et al.* (2009) found that single-fruit weight, number of fruits per plant, and number of seeds per fruit were significant factors influencing fruit yield.

**Growth parameters of *A. excelsa*:** Table 5 shows the growth parameters of *A. excelsa*, where different okra varieties were cultivated. The results demonstrated that *A. excelsa*'s growth parameters, including height, diameter and crown spread, were increased in the second year as compared to the first year. However, different okra varieties were planted as an intercrop under *A. excelsa*, which had no effect on the growth parameters of *A. excelsa*. These findings are comparable to Jaisankar *et al.* (2014), who found that arable crops had no effect on *Dalbergia sissoo* growth, and also Moreira *et al.* (2024), who reported that intercrops had no effect on tree growth.

## Conclusion

It is found that the okra can grow beneath the *A. excelsa* tree. But the growth and yield were lower compared to the open condition, except for plant height and fruit length. Among the studied different varieties of okra, the Ajeet variety (T<sub>5</sub>) performed better in an open environment. On the other hand, Navsari okra (T<sub>1</sub>) performed better under an *Ailanthus*-based silvi-horticulture system than other okra varieties. This variety is most suitable and shade-tolerant as compared to other studied varieties under the *A. excelsa*-based silvi-horticulture system. Based on the aforementioned results, farmers in South Gujarat can grow the Navsari okra variety under *A. excelsa* tree for a higher yield and, eventually, higher returns per unit area.

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