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Assessment of best performing genotypes of *Ailanthus excelsa* under arid climatic conditions

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Abstract

The present study was conducted to screen 19 genotypes of Mahaneem (*Ailanthus excelsa* Roxb.) and to identify the best performing genotypes under arid ecosystem of Haryana, India. Among the genotypes, 'S-9' and 'S-18' performed consistently with higher growth and carbon sequester as compared to other genotypes. The maximum plant height and girth at breast height was 9.91m and 65cm respectively, in 'S-9' after 8 years of planting, which was at par with 04 genotypes ('S-4, S-6, S-11 and S-18') over other selections. At 4 and 8 year after planting of *A. excelsa*, 'S-9' produced the highest biomass production i.e., 0.66 tones per tree over all the genotypes. The maximum mean values of dry matter accumulation/ plant were 0.52 tones/ tree recorded after 8 year of planting in S-9 genotypes. Similar results for CO₂ equivalent, which was significantly higher in S-9 i.e., 0.96 tonnes per tree after 8 years of planting over other genotypes of *A. excelsa*. The overall results revealed that the genotypes 'S- 9' and 'S- 18' were identified as the best genotypes for multiplication in the field to increase the biomass production and CO₂ equivalent for the arid regions.

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Introduction

Ailanthus excelsa Roxb. (Mahaneem) is an important fast growing agroforestry tree species for arid and semi-arid regions. It is one of the promising fast growing multipurpose trees of dry areas due to its ability to grow well with less rainfall and in strong light conditions (Bhimaya et al. 1963). The role of *A. excelsa* in soil organic carbon improvement along with catering diverse needs of farmer viz. fodder, fuel and timber under agri-silvi systems have been recorded (Patel et al. 2008; Jaimini et al. 2006). Moreover, its suitability for low input conditions and fragile

environment is an additional merit (Gupta 1980). The roots of *A. excelsa* tree binds over an area of 3.10 m² (Jat et al. 2011) and can be used to check soil erosion (Lavhale & Mishra 2007). The tree has been extensively used for soil conservation purposes to check the spread of sand dunes and along the road sides to prevent and slow down the dusty winds (Jhorar et al. 2003; Jat et al. 2011; Sharma et al. 2018).

A. excelsa leaves are used as a green fodder to small ruminants because of its high nutritive value, palatability and digestibility.

The green leaves contains 19.87% crude protein, 12.72% crude fibre, 3.53% ether extract, 11.97% total ash, 2.11% calcium and 0.24% phosphorus (Singh & Patnayak 1977). *A. excelsa* is also recognized as a valuable tree in sustainable development and enhancing livelihoods of resource-poor farmers in semi-arid regions because of its wider adaptability, fast growth and higher tolerance to biotic and abiotic stresses, supplying green leaf fodder and timber for plywood (Gupta 1980). Further, wood quality such as microstructure, physical and mechanical properties of any timber species are pre-requisite for efficient utilization (Tripathi & Poonia 2015), *A. excelsa* wood have the properties for utilization as core veneer for manufacturing plywood (Divya et al. 2022). It is very imperative and/or demands of time to identify the fast-growing multipurpose tree which is highly suited for agroforestry systems on sandy loam soils of semi-arid agro-ecosystem to meet out the demand of farmers and forest based industries without degradation of land and forest resources by growing Mahaneem on degraded lands. *A. excelsa* being cross pollinated crop offers tremendous scope for selection of high-yielding genotypes to increase the productivity. Hence, identification of appropriate genotypes suitable for specific region is an important factor. In

some of the region's the *A. excelsa* performing better and in some regions not up to the potential because of location-specific characteristics. Looking to the importance of *A. excelsa* as a nutritious and palatable multi-purpose fodder tree in the semi-arid regions, the present study was conducted to identify the best performing genotypes of *A. excelsa* on the basis of growth and biomass production.

Materials and Methods

Study site

The studies were conducted at CCS Haryana Agricultural University Regional Research Station, Bawal (28.1° N, 76.5° E and 266 m above mean sea level), Rewari, Haryana, India. The maximum temperature during the experimentation was recorded as high as 45-46°C during May-June, while minimum as low as 0°C during December-January. The site is characterized by high wind velocity, inadequate and erratic precipitation (479-998 mm) during monsoon (July-September) (Table-1). The soil of the experimental site was sandy loam in texture, low in organic carbon, medium in available phosphorus and high in available potassium. The initial soil samples were analyzed and pH ranged from 7.72 to 7.70, EC 0.19 dSm⁻¹, OC -0.20-0.22 %, available P -10.24- 12.50 kg ha⁻¹ and available K 178.10 -179.00 kg ha⁻¹ at surface layer.

Table1. Weather data for the experimental site of *A. excelsa* genotypes

Year	Rainfall (mm)	Maximum Temp	Minimum temp
2013	967.3	45.3°C (May 2013)	0.7°C (Jan 2013)
2014	977.1	45.1°C (May 2014)	2.0°C (Jan 2014)
2015	671.1	44.3°C (May 2015)	2.4°C (Dec 2015)
2016	704.4	44.9°C (May 2016)	4.5°C (Jan 2016)
2017	693.2	42.3°C (May 2017)	2.9°C (Jan 2017)
2018	547.4	43.5°C (May 2018)	2.3°C (Dec 2018)
2019	583.2	45.0°C (May 2019)	3.2°C (Dec 2019)
2020	479.4	44.0°C (May 2020)	2.6°C (Dec 2020)
2021	998.1	41.6°C (June 2021)	2.4°C (Dec 2021)

Survey and genotypes collection

To assess the best performing genotypes, a survey was carried out during 2012–13. The

biometrical observations, viz age, plant height and stem diameter/girth were recorded in September–October 2012 when plant attains

full bloom stage. The phenotypic superior trees were selected on the basis of biometrical characteristics and tagged for seed collection at different locations (*i.e.*, 19 different sites of Rajasthan). The seeds from the different genotypes were collected in April and sown in the nursery in June. In nursery, complete package of practices were followed to save the plants from hot winds, insect, pests and diseases. Timely watering (once in 15 days during summer and winter were applied) as per requirement of the plants as suggested by Jat et al. (2006). The transplanting was done in August 2013 in the main experimental field. The experimental material/ genotypes were collected from the 19 arid and semi-arid sites of Rajasthan, viz Gopalpura ('S-1'), Paragpura1 ('S-2'), Paragpura2 ('S-3'), Paragpura3 ('S-4'), Nathwala ('S-5'), Mundru

('S-6'), Bhinda Stand ('S-7'), DadiaRampura1 ('S-8'), DadiaRampura2 ('S-9'), Bawari1 ('S-10'), Bawari2 ('S-11'), Bawari3 ('S-12'), Khattoomor ('S-13'), Chelasi ('S-14'), Sunwali1 ('S-15'), Sunwali2 ('S-16'), Baleram ('S-17'), Churi ('S-18'), and Jhunjhunu ('S-19') (Table 2). All the 19 genotypes were planted during 2013 in a randomized block design with 3 replications at spacing of 6m×6 m. Three plants from the each genotype were planted in the field. Recommended package of practices were followed and observations were recorded at time of planting and 4 year interval during 2017 (after 4 year of plantation) and 2021(after 8 year of plantation) on various growth-attributing characters, viz plant height (m), girth at breast height (cm), biomass, dry weight and carbon stock.

Table 2. Locations of seed collections of *A. excelsa* genotypes

Genotypes	Location	Latitude (N)	Longitude (E)
S-1	Gopalpura (Jaipur)	26.87	75.81
S-2	Paragpura1 (Jaipur)	27.59	76.09
S-3	Paragpura2 (Jaipur)	27.60	76.09
S-4	Paragpura3 (Jaipur)	27.60	76.09
S-5	Nathwala (Jaipur)	26.55	75.52
S-6	Mundru (Jaipur)	26.91	75.78
S-7	Bhinda stand (Sikar)	27.27	75.61
S-8	DadiaRampura1 (Sikar)	27.34	75.59
S-9	DadiaRampura 2 (Sikar)	27.34	75.59
S-10	Bawari1 (Sikar)	27.57	75.12
S-11	Bawari2 (Sikar)	27.60	75.15
S-12	Bawari 3(Sikar)	27.80	75.50
S-13	Khattoomor (Sikar)	27.36	75.40
S-14	Chelasi (Sikar)	27.85	75.27
S-15	Sunwali1 (Sikar)	27.57	75.15
S-16	Sunwali2 (Sikar)	27.58	75.14
S-17	Baleran (Sikar)	27.91	75.13
S-18	Churi (Jhunjhunu)	27.85	75.08
S-19	Jhujhunu (Jhunjhunu)	28.10	75.37

Estimation of biomass and carbon stock

Height and diameter of all trees was measured by using Ravi altimeter and tree caliper, respectively (Khanna & Chaturvedi 1994). To estimate biomass of different trees,

non-destructive method was used. Girth diameter was measured at breast height i.e., 1.37m. The biomass and carbon stock of tree was estimated by using following formulas (Poonia et al. 2020). These are:

Parameters studied	Formula
Basal area	$g^2 / 4\pi$ (where, g = girth)
Volume (m^3)	Basal area (m^2) x Height (m)
Above Ground Biomass (ton)	Volume (m^3) x 1.56 (i.e., Basal area expansion factor)
Below Ground Biomass (ton)	0.26 X Above Ground Biomass (ton)
Total biomass (ton)	Above Ground Biomass (AGB)+ Below Ground Biomass (BGB)
Total Dry weight (ton/ tree)	Biomass x 80%
Carbon Stock (ton/ tree)	Dry weight x 50% (Chavan & Rasal 2011)
Co ₂ Equivalent (ton/ tree)	Carbon x 3.67 (Jindal et al. 2007)

The weight of CO₂ equivalent in the tree was measured from the ratio CO₂ to C which is 3.67. Thus, CO₂ equivalent in the tree was measured multiplying weight of carbon in the tree by 3.67 (Jindal et al. 2007).

Statistical analysis

Analysis of variance was carried out using randomized design as per the method suggested by Panse & Sukhatme (1978). Differences between genotypes for all variables studied were tested using ANOVA. Treatment means were compared at $P \leq 0.05$.

Results and Discussion

Plant height is one of the most important characteristics for improved plant development and vitality. Increased plant height can lead to more biomass output; high-ranking genotypes in terms of height can be utilized for tree improvement or selection. In present study, the plant height ranged from 5.00 to 6.51m after 4 year of planting, 8.37 to 9.91m after 8 year of planting, in different genotypes. The variation was significant

among different genotypes (Table 3). Maximum plant height was observed in 'S- 9' (9.91m) which was at par with 4 genotypes (S-4, S-6, S-11 and S-18) after 8 year of planting than rest of the Selections. However, the plant height was also at par in 'S- 18' after planting over the other genotypes. 'S- 9' genotypes from Dadia rampura2 (Sikar) was superior over all the genotypes. The girth at breast height (gbh) of the tree was significantly affected under different genotypes of Mahaneem. Maximum gbh was observed in 'S- 9' (65 cm) which was significantly different ($P \leq 0.05$) with 13 genotypes ('S- 1-3, 5, 7,8,10 and 12-17') after 8 year of planting over the other selections (Table 1). The genotypes selection from Dadia rampura2 (Sikar) ('S- 9) was performing better than the others with respect to girth (gbh). Further, there was no significant differences were observed between 'S-4, S-6, S-9, S- 11 and 18 genotypes of Mahaneem (Table 3).

Table 3. Average of growth performance, biomass production and CO₂ equivalent efficiency of different genotypes of *A. excelsa* after 4 and 8 year of planting

Genotypes	Tree height (m)		Tree GBH (cm)		Volume (m ³)		Total Biomass (tones/tree)		Total Dry Weight (tones)		Carbon (tones/tree)		CO ₂ equivalent	
	2017	2021	2017	2021	2017	2021	2017	2021	2017	2021	2017	2021	2017	2021
S-1	6.20	9.19	45.50	57.33	0.10	0.24	0.20	0.47	0.16	0.38	0.08	0.19	0.29	0.69
S-2	6.49	8.66	41.23	58.00	0.09	0.23	0.17	0.46	0.14	0.36	0.07	0.18	0.25	0.67
S-3	5.00	9.16	49.33	54.33	0.10	0.22	0.19	0.42	0.15	0.34	0.08	0.17	0.28	0.62
S-4	5.87	9.75	50.25	61.66	0.12	0.30	0.23	0.58	0.19	0.46	0.09	0.23	0.34	0.85
S-5	5.50	9.21	50.66	59.33	0.11	0.26	0.22	0.51	0.18	0.41	0.09	0.20	0.32	0.74
S-6	5.45	9.72	47.00	64.00	0.10	0.32	0.19	0.62	0.15	0.50	0.08	0.25	0.28	0.91
S-7	6.09	8.69	47.50	59.66	0.11	0.25	0.22	0.48	0.17	0.39	0.09	0.19	0.32	0.71
S-8	6.39	9.14	49.00	55.33	0.12	0.22	0.24	0.44	0.19	0.35	0.10	0.18	0.35	0.64
S-9	5.89	9.91	51.00	65.00	0.12	0.33	0.24	0.66	0.19	0.52	0.10	0.26	0.35	0.96
S-10	6.33	9.10	49.50	57.00	0.12	0.24	0.24	0.46	0.19	0.37	0.10	0.19	0.36	0.68
S-11	6.51	9.67	50.33	62.33	0.13	0.30	0.26	0.59	0.21	0.47	0.10	0.24	0.38	0.86
S-12	6.32	8.70	52.00	59.33	0.14	0.24	0.27	0.48	0.21	0.38	0.11	0.19	0.39	0.70
S-13	6.10	8.83	51.00	59.66	0.13	0.25	0.25	0.49	0.20	0.39	0.10	0.20	0.36	0.72
S-14	6.05	8.72	46.00	51.66	0.10	0.19	0.20	0.36	0.16	0.29	0.08	0.15	0.29	0.53
S-15	5.85	8.69	48.00	57.00	0.11	0.22	0.21	0.44	0.17	0.35	0.08	0.18	0.31	0.65
S-16	5.71	8.37	51.00	53.66	0.12	0.19	0.23	0.38	0.19	0.30	0.09	0.15	0.34	0.55
S-17	5.82	8.87	52.00	56.33	0.13	0.22	0.25	0.44	0.20	0.35	0.10	0.18	0.36	0.65
S-18	6.51	9.88	53.00	62.33	0.15	0.31	0.29	0.60	0.23	0.48	0.11	0.24	0.42	0.88
S-19	6.49	9.12	52.60	61.33	0.14	0.27	0.28	0.54	0.22	0.43	0.11	0.21	0.41	0.79
CD at 5%	0.43	0.58	1.84	2.310	0.024	0.026	0.044	0.052	0.036	0.039	0.018	0.020	0.057	0.071

(2017-4th year after plantation, 2021-8th year after plantation)

The Maximum amount of above and below ground biomass were observed in S-9 (0.52 tones) genotypes after 8 year of plantation and similar amount of biomass

were observed in S-18 (0.48 tones) and S-19 (0.43 tones), which was significantly different ($p \leq 0.05$) with other genotypes (Fig. 1).

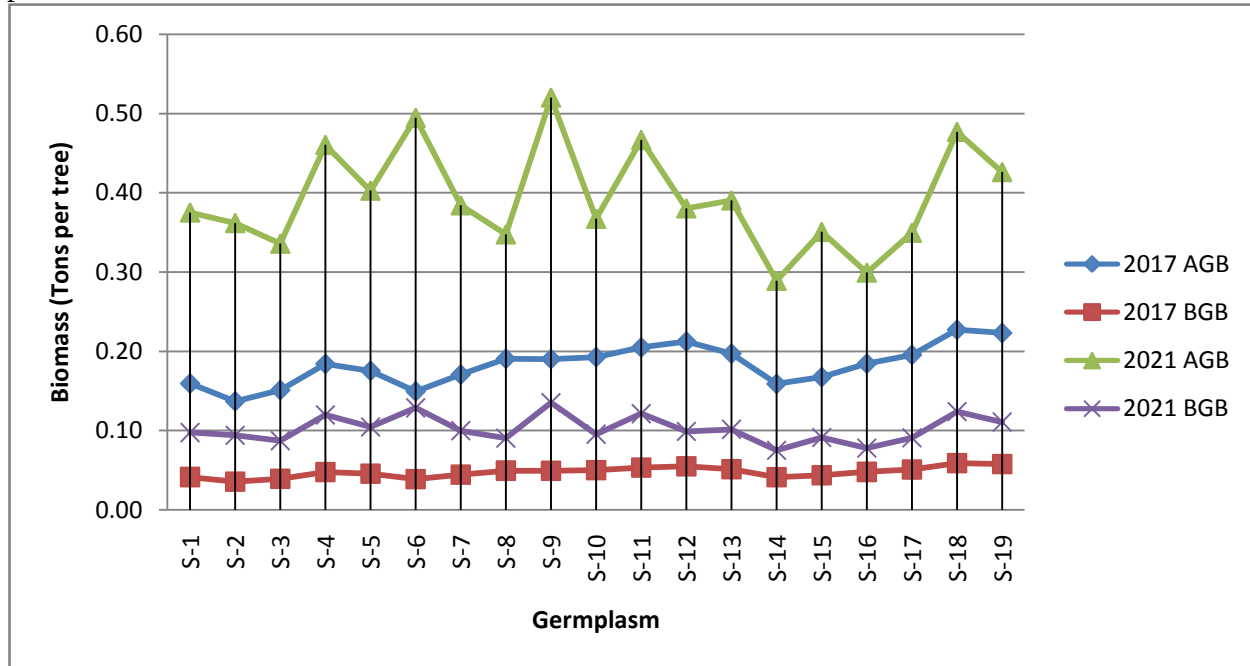


Figure 1. Above and below ground biomass (tones/tree) of different genotypes of *Ailanthus excelsa* after 4 and 8 year of plantation

The results for the total biomass productions per tree, higher were observed in genotypes S-9 (0.66 tones) followed by S-6 (0.62 tones) and S-18 (0.60 tones) after 8 year of plantation whereas minimum were observed in S-14 (0.36 tones) followed by S-3 (0.42 tones) and S-8 (0.44 tones). Further similar results were observed in dry weight production of *Ailanthus excelsa* (Table 3). Carbon storage in different genotypes was varied from 0.15 (S-14) to 0.26 tones (S-9). Total carbon storage within the different genotypes generally increase with increase in girth at breast height. Hence, S-9 and S-18 (0.26 and 0.24 tones, respectively) was found to be superior with respect to carbon

deposition among all planted genotypes. Planting of quality genotypes is one of the options to improve carbon sequestrations of particular sites. In present study, Maximum CO₂ equivalent was recorded i.e., 0.96 tones in S-9 (Dadiarapura2, Sikar) genotypes of *Ailanthus excelsa* after 8 years of plantation whereas, minimum was observed in S-14 (Chelasi, Sikar) i.e., 0.53 tones (Figure 2). Carbon equivalent is more in those genotypes that have higher biomass and high girth at breast height (GBH). Hence, to frame a model for atmospheric CO₂ reduction in specific site, one should have to select the best performing genotypes of tree species for enhance and accurate estimation of carbon sequestration.

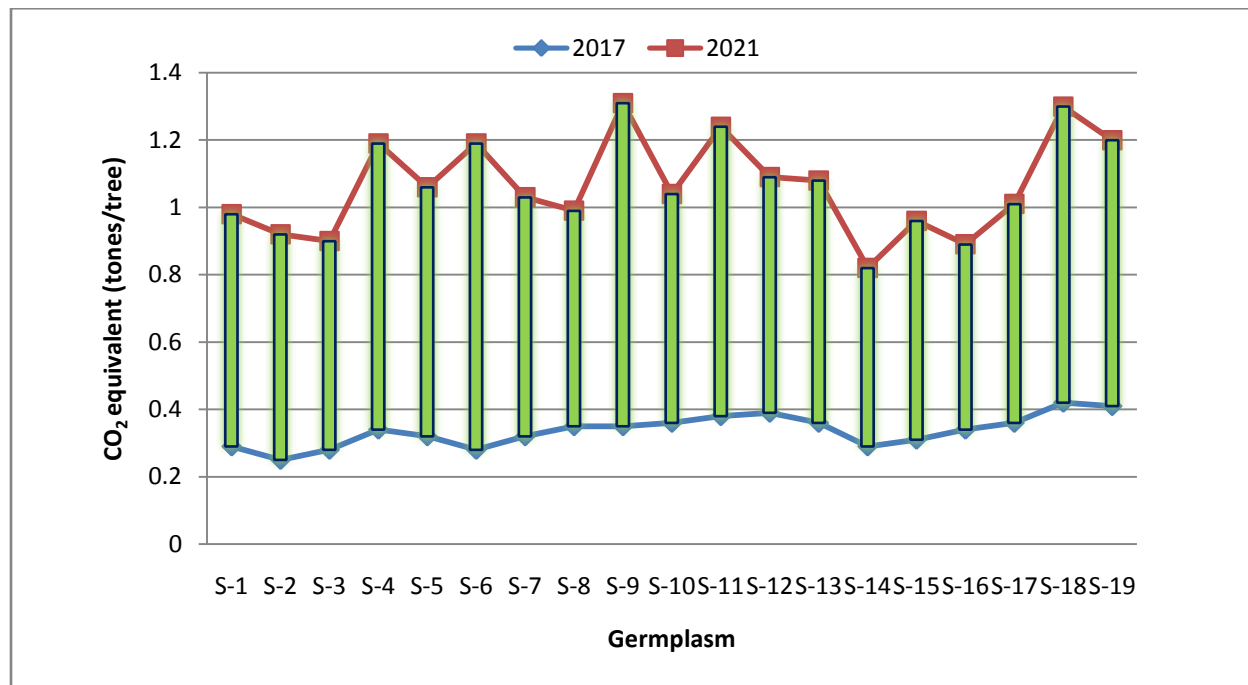


Figure 2. CO₂ equivalent of different genotypes of *Ailanthus excelsa* after 4 and 8 year of plantation.

In forestry, selections of superior genotypes are very important for any tree improvement programme i.e., mainly depends upon the amount of genetic variability in a tree species and it is of significant importance for developing effective tree improvement strategies (Vakshasya et al. 1992). The largest, cheapest and fastest gains in forestry tree improvement programmes will accrue if use of suitable species and seed sources within species is assured (Zobel & Talbert 1984). Against this backdrop the current study has been designed to evaluate and assess 19 genotypes of *Ailanthus excelsa* in order to identify superior genotypes for higher growth and biomass productivity. The present study revealed considerable variability for growth, biomass and carbon stock efficiency among different genotypes of *A. excelsa*. The findings are in agreement with Jat et al. (2010) in which they recorded variability for growth in 18 genotypes of *A. excelsa* collected from Rajasthan. Significant differences or variation in growth after different months of planting

have also been recorded in progenies of *Melia dubia* (Kumar et al. 2013), *Eucalyptus tereticornis* (Kumar et al. 2010) and karanja (Ali et al. 2009; Kaushik et al. 2011, Arya & Lohara 2016). The morphological and genetic variability in seed and seedling among 23 progeny of *Ailanthus excelsa* collected from arid and semi arid region of Haryana and Rajasthan were assessed by Kaushik et al. (2017, 2019). The recorded variability in growth will be valuable for the conservation of genetic variation, prospects of improvement and assessment of the potential of the locally adapted progeny source.

Conclusions

To assess the suitable genotypes based on growth and biomass production under arid conditions of Haryana (India), 19 genotypes of *Ailanthus excelsa* were evaluated during 2013-21. Results indicated that 'S-9' genotypes performed at par with 'S-18' in a similar trend with respect to all the growth characteristics. Among the genotypes, 'S-9' and 'S-18' performed consistently with higher growth

characteristics over the 8 years study. So looking to this trend, it was concluded that *A. excelsa* selection from Dadia rampura2, Sikar ('S-9') was found superior with respect to all the characteristics which was closely followed by the Churi, Jhunjhunu selection ('S-18'). The growth performance of all the genotypes showed positive trend with the age of the plant under arid areas of Haryana, to meet out the demand local community and plywood industries. Hence, the selection of suitable tree species for any specific region is very crucial for sustaining livelihood and rural development.

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